British Geological Survey

Technical Report WF/88/1

Mineral Resources Series

Sand and Gravel Resources

NJ 70, 72 and NO 79*

# Inverurie, Dunecht, Banchory and Stonehaven, Grampian Region

## Part 1: Report

Natural Environment Research Council

Mineral Assessment Report 148

British Geological Survey

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Companies Letter

Dear Sir,

SCOTTISH SAND AND GRAVEL RESOURCE ASSESSMENT REPORT

As you may know the British Geological Survey has conducted surveys of sand and gravel resources in various parts of Britain. In Scotland this work is being carried out on behalf of the Scottish Development Department.

You may be interested to learn that the results of the assessment of the Inverurie, Dunecht and Banchory-Stonehaven areas are now available. Further information of our findings which are published as reports accompanied by 1:25 000 resource maps, is given in the attached notes.

Yours faithfully,

D.I.J. MALLICK
Programme Manager,
Highlands & Islands Research Programme

**THE SAND AND GRAVEL RESOURCES OF THE COUNTRY AROUND INVERURIE AND DUNECHT, AND BETWEEN BANCHORY AND STONEHAVEN**

BGS Technical Report No WF/88/1

(Mineral Assessment Report No. 148)

This report (in two volumes) is one of a series on the assessment of sand and gravel resources by the British Geological Survey. The sand and gravel deposits of some 398km$^2$ of country around Aberdeen are described with reference to two accompanying coloured 1:25000 scale resource maps. Fifty-four boreholes, thirty-eight measured sections and eighty-one shallow pits specially sunk to augment earlier records and to quantify the results of the most recent geological survey of the area at the 1:10 000 scale by staff of BGS form the basis of the assessment.

The results and conclusions are set out in Volume 1 which also includes descriptions of the topography and geology supported by detailed information concerning the composition and distribution of the sand and gravel resources. Estimates of the gross amount of material present within sub-areas (resource blocks) are quoted at a stated level of confidence in the tables of results. Grading details, the mean thicknesses of mineral (sand and gravel) and of overburden are also given. Explanations of the statistical methods used in the calculations and the utility of two types of geophysical remote sensing (ground resisivity and electromagnetic conductivity), used in the investigations are discussed.

Volume 2 comprises records of all of the trial pits, measured sections, boreholes and resistivity soundings used in the assessment. It includes details of the sieve grading analysis of each sample of sand and gravel collected.

The Survey was not concerned with the estimation of *reserves* (which can only be assessed in the light of existing economic considerations), but rather with regional and national *resources*, which include deposits which are not currently exploitable but have a foreseeable use. The work may be regarded as the application to large areas of some of the methods used commercially for evaluating reserves on small sites. The report also represents an extension of geological mapping for mineral planning and site investigation purposes, since it provides more information than the geological maps alone about the thickness and quality of the deposits.

Copies of Volume 1 of this report, price £10.00 (postage and packing £1.50 extra) are available through the bookshop of the British Geological Survey at: Murchison House, West Mains Road, Edinburgh EH9 3LA. (031-667-1000)

Copies of Volume 2 (detailed records), price £31.00 (postage and packing £1.50 extra) can also be reproduced on request to Mrs Maureen Edwards (Bookshop).

*Bibliographic reference*

AUTON, C.A., MERRITT, J.W. and ROSS, D.L. 1988. The sand and gravel resources of the country around Inverurie and Dunecht, and between Banchory and Stonehaven, Grampian Region. Description of 1:25 000 sheets NJ 70, 72 and NO. 79 and parts of NO. 88, 89 and 99. *Mineral Assessment Report No. 148; British Geological Survey Technical Report* No. WF/88/1. 2 Vols: 269pp, 11 figures, 24 tables, 2 colour-printed maps.

Results from this study are also incorporated in a summary assessment of sand and gravel resources of northeast Scotland, details of which are shown on an accompanying sheet.

Reports on the sand and gravel resources of sixteen other areas in Scotland have been published previously. Please see attached list for details.

## SUMMARY ASSESSMENT OF THE SAND AND GRAVEL RESOURCES OF NORTHEAST SCOTLAND

by J.W. Merritt, C.A. Auton and D.L. Ross

**BGS Technical Report WF/88/2**

This report is one of the series commissioned by the Department of the Environment on behalf of the Scottish Development Department. The study area, which encompasses the major sand and gravel resources of the Grampian Region, has been identified by the SDD as an area of priority planning interest because of land-use problems around the rapidly expanding city of Aberdeen.

The report is both a synthesis and a development of the published sand and gravel resource assessments covering the areas around Peterhead (Mineral Assessment Report No. 58), Ellon (Mineral Assessment Report 76), Aberdeen (Mineral Assessment Report 146) and Inverurie, Dunecht, Banchory and Stonehaven (Mineral Assessment Report 148). The aim of the report is to summarise the considerable body of data and, at the same time, to present it in a form readily usable in physical planning. Thus the report is a resume, but it introduces the potential end-uses of the resource as a factor, which leads in turn to a ranking of areas as a guide to the development of mineral planning policies.

Data on the sand and gravel have been used as the basis for a rigorous appraisal of the resources, placing particular emphasis on potential end-usage and takes into account the most likely forms of working practice. The deposits of sand and gravel area described briefly and systematically, and are portrayed on a series of 8 summary resource maps at the 1:25 000 scale. The most attractive resources are shown on three target maps at the 1:50 000 scale, but such identification of them does not necessarily indicate deposits which are all economically workable today.

The summary resource maps included with this report are developed from the maps accompanying the Mineral Assessment Reports and incorporate specially designed computer graphics. All available results of in-house mechanical and physical testing of aggregate from the study area have been collated and interpreted.

Copies of this report are available on "Open File" and may be examined at the offices of the Grampian Regional Council (Department of Physical Planning) Aberdeen and the British Geological Survey at:

Murchison House, West Mains Road, Edinburgh, EH9 3LA (031 667 1000)

Keyworth, Nottingham, NG12 5GG (06077 6111)

Copies of this report, price £49.50 (postage and packing £3.00 extra) reproduced on request to:- Mrs Maureen Edwards (Bookshop)
British Geological Survey
Murchison House
West Mains Road
Edinburgh
EH9 3LA

Bibliographic reference

MERRITT, J.W., AUTON, C.A. and ROSS, D.L. 1988.

Summary assessment of the sand and gravel resources of Northeast Scotland. British Geological Survey Technical Report No. WF/88/2. 2 vols: 59pp, 8 Figures, 9 tables. 11 dye-line maps.

Overleaf: copy of Figure 1 from the report, showing location of study area.

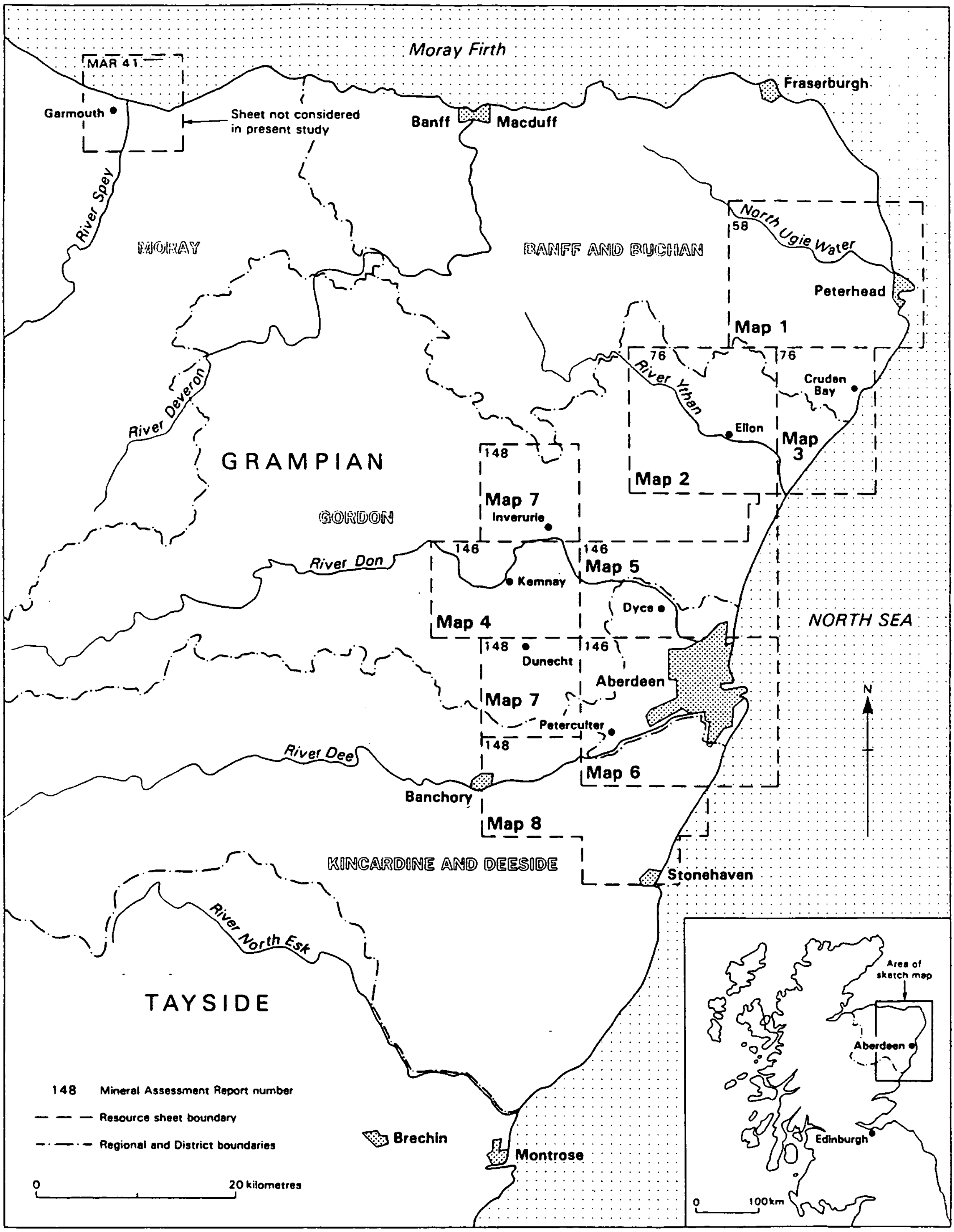



**Figure 1.** Sketch-map showing the location of the published resource sheets in northeast Scotland

PUBLISHED SCOTTISH SAND AND GRAVEL ASSESSMENT REPORTS January 1989

The sand and gravel resources of the country around **Darvel**, Strathclyde. Description of parts of 1:25 000 sheets NS 53, 54, 63 and 64. Nickless, E F P, Aitken, A M and McMillan, A A. 1978. Miner. Assess. Rep. Inst. Geol. Sci., No. 35. ISBN 0 11 844082 7 £7.00.

The sand and gravel resources of the country around **Garmouth**, Grampian Region. Description of 1:25 000 resource sheet NJ 36. Aitken, A M, Merritt, J W and Shaw, A J. 1980. Miner. Assess. Rep. Inst. Geol. Sci., No. 41. ISBN 0 11 884090 £8.75

The sand and gravel resources of the country around **Lanark**, Strathclyde Region. Description of 1:25 000 resource sheet NS 94 and part of NS 84. Laxton, J L and Nickless, E F P. 1980. Miner. Assess. Rep. Inst. Geol. Sci., No. 49. ISBN 0 11 884110 6 £11.00

The sand and gravel resouces of the country around **Dolphinton**, Strathclyde Region and **West Linton**, Borders Region. Description of 1:25 000 resource sheet NT 04 and 14 and parts of NT 05 and 15. McMillan, A A, Laxton, J L and Shaw, A J. 1981. Miner. Assess. Rep. Inst. Geol. Sci., No. 62. ISBN 0 11 884149 1 £8.00

The sand and gravel resources of the country around **Ellon**, Grampian Region. Description of 1:25 000 resource sheets NJ 93 with parts of NJ 82, 83 and 92, and NK 03 with parts of NK 02 and 13. Merritt, J W. 1981. Miner. Assess. Rep. Inst. Geol. Sci., No. 76. ISBN 0 11 884176 9 £15.00

The sand and gravel resources of the country around **Newport-on-Tay**, Fife Region. Description of 1:25 000 resource sheet NO 42 and parts of NO 32 and 52. Laxton, J L and Ross, D L. 1981. Miner. Assess. Rep. Inst. Geol. Sci., No. 89 ISBN 0 11 887413 6 £12.75

The sand and gravel resources of the country west of **Peterhead**, Grampian Region. Description of 1:25 000 resource sheet NK 04 and parts of sheets NJ 94 and 95 and NK 05, 14 and 15. McMillan, A A and Aitken, A M. 1981. Miner. Assess. Rep. Inst. Geol. Sci., No. 58. ISBN 0 11 884145 9 £12.00

The sand and gravel resources of the valley of the **Douglas Water**, Strathclyde Region. Description of 1:25 000 resource sheet NS 83 and parts of NS 82, 92 and 93. Shaw, A J and Nickless, E F P. 1981. Miner. Assess. Rep. Inst. Geol. Sci., No. 63. ISBN 0 11 884150 5 £11.50.

The sand and gravel resources of the country around **Glenrothes**, Fife Region. Description of 1:25 000 resource sheet NO 20 and parts of NO 21, 30 and 31. Aitken, A M and Ross, D L. 1982. Miner. Assess. Rep. Inst. Geol. Sci., No. 101. ISBN 0 11 887415 2 £15.00

The sand and gravel resources of the country around **Biggar**, Strathclyde Region. Description of 1:25 00 resource sheets NS 93 and NT 03 and parts of NS 92 and NT 02. Shaw, A J and Merritt, J W. 1982. Miner. Assess. Rep. Inst. Geol. Sci., No. 95. ISBN 0 11 887414 4 £15.00

The sand and gravel resources of the country around **Callander and Dunblane**,

Central Region. Description of 1:25 000 resource sheet NN 60 and 70. Merritt, J W and Laxton, J L. 1982. Miner. Assess. Rep. Inst. Geol. Sci., No. 121 ISBN 0 11 887417 9 £15.00

The sand and gravel resources of the country west of **Stirling**, Central Region. Description of 1:25 000 resource sheets NS 69 and 79. Laxton, J L and Ross, D L. 1983. Miner. Assess. Rep. Inst. Geol. Sci., No. 131 ISBN 0 11 887421 £14.50

The sand and gravel resources of **Strathallan**, Tayside Region. Description of parts of 1:25 000 sheets NN 80, 81, 90 and 91. Aitken, A M and Shaw, A J. 1983. Miner. Assess. Rep. Inst. Geol. Sci., No.132 ISBN 0 11 887422 5 £15.50

The sand and gravel resources of the country around **Kinross**, Tayside Region. Description of 1:25 000 resource sheet NO 00 and 10 with parts of NT 09 and 19. Merritt, J W and Ross, D L. 1983. Miner. Assess. Rep. Inst. Geol. Sci., No.139 ISBN 0 11 887423 3 £17.50

The sand and gravel resources of the country around **Temple** and **Dalkeith**, Lothian Region. Description of 1:25 000 resource sheets NT 25 and 26, and NT 35 and 36. Aitken, A M, Lovell, J H, Shaw, A J and Thomas, C W. 1984. Miner. Assess. Rep. Br. Geol. Surv., No. 140 ISBN 0 11 887 424 1 £20.00

The sand and gravel resources of the country around **Aberdeen**, Grampian Region. Description of 1:25 000 sheets NJ 71, 80, 81 and 91, parts of NJ 61, 90 and 92, and with parts of NO 89 and 99. Auton, C A, and Crofts, R G. 1986. Miner. Assess. Rep. Brit. Geol. Surv. (internally published), No. 146. ISBN 852720890

The sand and gravel resources of the country around **Inverurie** and **Dunecht**, and between **Banchory** and **Stonehaven**, Grampian Region. Description of 1:25 000 sheets NJ 70, 72 and NO 79, and parts of NO 88, 89 and 99. Auton, C A, Merritt, J W, and Ross, D L. 1988. Miner. Assess. Rep. No. 148; Brit. Geol. Surv. Technical Report No. WF/88/1. 2 vols: 269pp, 11 figures, 24 tables, 2 colour-printed maps.

TECHNICAL REPORT WF/88/1

# The sand and gravel resources of the country around Inverurie and Dunecht, and between Banchory and Stonehaven, Grampian Region

1:25000 sheets NJ 70, 72 , NO 79, and parts NO 88, 89, 99

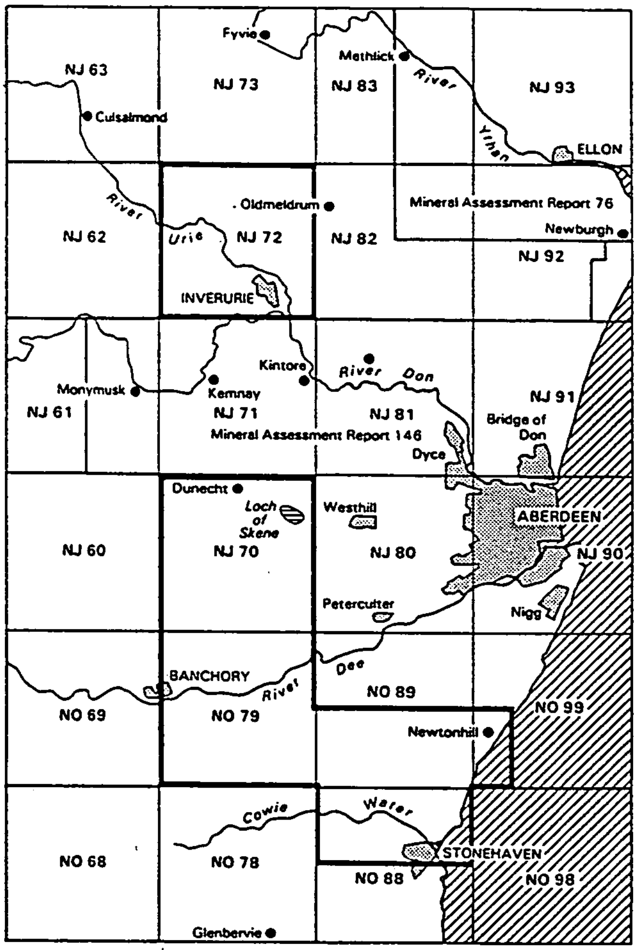
## Part 1: Report

C A Auton, J W Merritt and D L Ross

BRITISH GEOLOGICAL SURVEY

TECHNICAL REPORT WF/88/1

Mineral Resources Series




# The sand and gravel resources of the country around Inverurie and Dunecht, and between Banchory and Stonehaven, Grampian Region

Description of 1:25 000 sheets NJ 70, 72 and NO 79, and parts of NO 88, 89 and 99

## Part 1: Report

C A Auton, J W Merritt and D L Ross

*Contributor*
B Cannell

Mineral Assessment Report 148

*Geographical index*
UK, NE Scotland, Grampian

*Subject index*
Mineral assessment, exploration, geology, geophysics, Quaternary, sand and gravel, boreholes

This report was commissioned by the Department of the Environment

*Bibliographic reference*
**Auton, C A, Merritt, J W, and Ross, D L.** 1988. The sand and gravel resources of the country around Inverurie and Dunecht, and between Banchory and Stonehaven, Grampian Region. *British Geological Survey Technical Report* WF/88/1.



Keyworth, Nottingham British Geological Survey 1988

**BRITISH GEOLOGICAL SURVEY**

The full range of Survey publications is available through the Sales Desks at Keyworth and Murchison House, Edinburgh. Selected items can be bought at the BGS London Information Office, and orders are accepted here for all publications. The adjacent Geological Museum bookshop stocks the more popular books for sale over the counter. Most BGS books and reports are listed in HMSO's Sectional List 45, and can be bought from HMSO and through HMSO agents and retailers. Maps are listed in the BGS Map Catalogue and the Ordnance Survey's Trade Catalogue, and can be bought from Ordnance Survey agents as well as from BGS.

*The British Geological Survey carries out the geological survey of Great Britain and Northern Ireland (the latter as an agency service for the government of Northern Ireland), and of the surrounding continental shelf, as well as its basic research projects. It also undertakes programmes of British technical aid in geology in developing countries as arranged by the Overseas Development Administration.*

*The British Geological Survey is a component body of the Natural Environment Research Council.*

Maps and diagrams in this report use topography based on Ordnance Survey mapping

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This report relates to work carried out by the British Geological Survey on behalf of the Department of Trade and Industry. The information contained herein must not be published without reference to the Director, British Geological Survey.

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## PREFACE

The demand for industrial minerals and for land for all purposes continues at a high level and it remains clear that a national assessment of mineral resources is necessary. As well as providing a stock-taking of resources, regional assessment gives the basis, along with other studies, for sound planning policies and decisions about the use of land.

Sand and gravel was selected in the 1960s as the bulk mineral most needing attention and systematic surveys were initiated under the then Ministry of Land and Natural Resources, beginning in southeast England. Some 147 full resource surveys have been carried out by BGS to a standardised model, providing an assessment to a consistent level of confidence.

The hinterland of Aberdeen was selected as an area of priority planning interest by the Scottish Development Department in discussion with the local authorities. The work was commissioned and financed by the Department of the Environment, with a financial contribution from Grampian Regional Council, Gordon District Council and local aggregate operators.

This report describes the resources of sand and gravel of 398 $km^2$ of country around Inverurie, Dunecht, Banchory and Stonehaven, in Grampian Region, and shown on the accompanying resource maps. The work is based primarily on the revision geological survey at a scale of 1:10 000 of parts of 1:50 000 Sheets 76, 67 and 66 undertaken between 1986 and 1987 by C A Auton and J W Merritt. A programme of drilling, trial pit excavation, sampling and aggregate testing was undertaken in 1986 by C A Auton, J W Merritt, D L Ross and C W Thomas. Geophysical soundings (including the measurement of ground resistivity and electromagnetic conductivity) were taken during the summer of 1986 and the winter of 1987 by C A Auton and B Cannell. The interpretation of the resistivity sounding data was undertaken by B Cannell using a VAX 8600 main-frame computer at BGS Keyworth. The geophysics was undertaken with the aim of evaluating the contribution that geophysical methods could make to the assessment of sand and gravel resources in Scotland. The survey was supervised by D J Fettes and D I J Mallick, Managers, Highland and Islands Research Programme.

J D Burnell, ISO, FRICS (Land Agent), was responsible for negotiating access to land for drilling; the ready cooperation of land owners, tenants and sand and gravel operators is gratefully acknowledged.

The views expressed in this report are not necessarily those of the Department of the Environment or the Scottish Development Department.

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Director

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**The Mineral Assessment Report Series**

The first twelve reports on the assessment of British sand and gravel resources appeared in the Report series of the Institute of Geological Sciences as a subseries. Report 13 and subsequent reports up to number 139 appear as Mineral Assessment Reports of the Institute of Geological Sciences. Reports 140 to 144 were published as Mineral Assessment Reports after IGS had been renamed the British Geological Survey.

The reports up to number 144 are published through Her Majesty's Stationery Office and are available from Government Bookshops, other booksellers or directly from the British Geological Survey. They are listed in HMSO's Sectional List 45.

Report 145 and subsequent Mineral Assessment Reports are published internally by the British Geological Survey. The style of these reports and their accompanying maps vary but all may be purchased from the Bookshops at the Keyworth and Edinburgh offices of the British Geological Survey, or from the Bookshop of the Geological Museum, Exhibition Road, London SW7 2DE.

Details of the reports published through HMSO and BGS appear at the end of this report.

Sand and gravel surveys have been commissioned recently by the Department of the Environment using universities and the private sector. These reports are broadly similar to Mineral Assessment Reports but are not listed here: details of their availability may be obtained from the Department of the Environment, 2 Marsham Street, London, SW1P 3EB.

Any enquiries concerning this report may be addressed to the Programme Manager, Highlands and Islands Research Programme, British Geological Survey, Murchison House, West Mains Road, Edinburgh EH9 3LA.

*Bibliographic reference*

AUTON, C.A., MERRITT, J.W. and ROSS, D.L. 1988. The sand and gravel resources of the country around Inverurie and Dunecht, and between Banchory and Stonehaven, Grampian Region. Description of 1:25 000 sheets NJ 70, 72 and NO 79, and parts of NO 88, 89 and 99. *Mineral Assessment Report No. 148; British Geological Survey Technical Report* No. WF/88/1.

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*Note* National Grid references are given in the form [855 156] throughout. Figures with northings between 000 and 250 relate to places in 100-km square NJ, those with northings between 900 and 999 to places in 100-km square NO.

*A companion study summarising the sand and gravel resources of northeast Scotland will be published shortly (Merritt, Auton and Ross, 1988). This report will consider further the resources identified here, targeting the resources which are likely to prove of most immediate interest to the industry and hence to the planning authorities.*

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**Figures**



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**CONTENTS OF PART 2: BOREHOLE AND GEOPHYSICAL LOGS**

## EXECUTIVE SUMMARY

Detailed geological mapping followed by the drilling of fifty-four boreholes and the excavation of eighty-one shallow pits supervised and recorded on site by the British Geological Survey, together with the inspection and sampling of thirty-eight sand and gravel workings, form the basis of the assessment of sand and gravel resources around Inverurie, Dunecht, and between Banchory and Stonehaven, Grampian Region. Additional data included pre-existing site investigation information and the results of forty-three resistivity soundings made and interpreted by the British Geological Survey.

All known deposits in the area which might be potentially workable for sand and gravel have been investigated and a simple statistical method used to estimate their volume. Some 523 bulk samples of sand and gravel were collected and graded. Representative samples were selected for petrological analysis and for physical and mechanical testing in the laboratory.

A full geological account of the area is given and the sand and gravel resources are described in detail. Results of the laboratory analyses and tests are reported and interpreted. Details of the mineral-bearing area, the mean thickness of overburden and mineral, and the mean gradings of deposits are presented. Detailed logs of boreholes, pits, measured sections and resistivity soundings are appended. The drift geology, the sand and gravel resources and the position of sample points used in the assessment are identified on two colour-printed 1:25 000 scale resource maps. Simplified geological and geophysical logs are displayed on the maps as computer-generated graphic arrays.

By comparison with the spreads of sand and gravel in southeast England the resources of the Aberdeen area are both limited in their distribution, and variable in their character, which makes them difficult to assess. The most laterally extensive and lithologically homogeneous deposits were laid down as terraced spreads within the major valleys in a periglacial environment shortly after the decay of the last ice-sheet to cover the Scottish mainland. Moundy, more heterogeneous deposits, were laid down in close contact with the melting ice and they also form important resources. These two types of deposit, which lie mainly above the water-table, are covered by negligable overburden. Extensive spreads of water-saturated sand and gravel are concealed beneath peat and alluvial overburden in the river valleys and within the ice-scoured topographic depressions that are a feature of the area. Up to now, however, it has been Scottish practice not to work deposits lying below the water-table.

The detailed mapping and sampling undertaken during the present survey have shown that the sand and gravel resources of the assessment areas are, on average, only about 50% of what was previously anticipated from the limited information that was available before the survey.

It is concluded that, on the whole, the gravels of the survey area are sound, durable and are suitable for most applications provided that an appropriate form of processing is used. Granite is the most common constituent of the gravel and sand, but gabbro is more abundant in the valley of the River Urie, and psammite and quartzite are dominant in the deposits around Stonehaven.

In the Inverurie resource sheet area, resources are restricted to fragmentary valley-side terraces and sub-alluvial deposits; they total only about 19 million $m^3$.

In the Dunecht resource sheet area, the most notable resources occur as terraces within the valley of the Corskie Burn and as both moundy and terraced spreads in the valley of the Leuchar Burn around and to the southwest of Leuchar Moss. The total resources of the Dunecht sheet are estimated to be 51 million $m^3$.

The principal resources occur in the Banchory/Stonehaven resource sheet area; they are estimated to be 122 million $m^3$. The most extensive deposits occur in the valley of the River Dee, where they occur both above and below the water-table. Other important resources occur as moundy deposits within the valleys of the Burn of Sheeoch, the Cowie Water and the Carron Water, and beneath an outwash plain immediately inland of Stonehaven.

Two types of geophysical remote sensing were tried on an experimental basis; ground resistivity and electromagnetic conductivity. It is concluded that the Offset Wenner method of ground resistivity sounding gives useful site specific information, but its utility is dependent on having good local borehole control. It is especially useful for estimating the total thickness of sand and gravel at sites where access is difficult or where the ground cannot be disturbed; it is also useful where deposits prove too coarse to drill cost-effectively. It cannot be regarded as an alternative to drilling, except in areas where there is a large amount of pre-existing borehole and

grading data.

Electromagnetic conductivity surveying has been used effectively as an aid to geological mapping in parts of southern Britain where there is often little surface expression to deposits owing to the presence of a thick mantle of periglacially disturbed ground. It was found that this method of remote sensing was not particularly useful or cost-effective in the survey area.

## INTRODUCTION

The survey reported here is concerned with the assessment of sand and gravel *resources*. In other words, it is aimed at the identification of the distribution, character and volume of material that is potentially workable as a source of aggregate and which consequently might prove to be economically exploitable. The work does not attempt to estimate *reserves* of sand and gravel, because this requires detailed site investigation to determine yield, grade and variability in the light of current economic conditions. Clearly, the economic, environmental and other factors influencing whether a deposit may be workable in the future cannot be predicted; they are likely to change with time. Deposits not currently economically workable may be exploited as demand increases, as higher grade or alternative materials become scarce, or as improved processing techniques are applied to them. The improved knowledge of the main physical properties of the resource and their variability, which this survey seeks to provide, will add significantly to the factual background against which planning policies can be decided (Archer, 1969; Thurrell, 1971, 1981; Harris and others, 1974).

The survey provides information at the *indicated* level for which "tonnage and grade are computed partly from specific measurements, samples or production data and partly from projection for a reasonable distance on geologic evidence. The sites available for inspection, measurement, and sampling are too widely or otherwise inappropriately spaced to permit the mineral bodies to be outlined completely or the grade established throughout" (Bureau of Mines and Geological Survey, 1948, p.15).

It follows that the whereabouts of reserves must still be established and their size and quality proved by the customary detailed exploration and evaluation undertaken by the industry. However, the information provided by this survey should assist in the selection of the best targets for such further work; a subject which is considered in more detail in a separate report (Merritt, Auton and Ross, 1988).

The following physical criteria are used to define a *resource* in the context of this assessment survey:

a The deposit should average at least 1m in thickness.

b The ratio of overburden to sand and gravel should be no more than 3:1.

c The proportion of fines, that is, particles passing the No.240 mesh BS sieve, about 0.065mm, should not exceed 40 per cent.

d The deposit must lie within 25m of the surface, this being taken as the likely maximum working depth under most circumstances. It follows from the second criterion that boreholes are drilled no deeper than 18m if no sand and gravel has been proved.

A deposit of sand and gravel that broadly meets these criteria is regarded as *potentially workable* and is described and assessed as *mineral* in this report. Mineral I is potentially workable sand and gravel; Mineral II is potentially workable till (or weathered rock). As the assessment is at the 'indicated' level, parts of such a deposit may not satisfy all the criteria.

For the particular needs of assessing sand and gravel resources, a grain-size classification based on the geometric scale 0.063mm, 0.25mm, 1mm, 4mm, 16mm has been adopted. The boundaries between *fines* (that is, the clay and silt fractions) and *sand*, and between sand and *gravel* material, are placed at 0.063mm and 4mm respectively (see Appendix D).

The volume and other characteristics of the deposits are assessed within *resource blocks*. No account is taken here of any factors, for example, roads, buildings and land of high agricultural or landscape value, which might stand in the way of sand and gravel being exploited, although towns and large villages are excluded. The estimated volumes, therefore, bear no simple relationship to the amount that could be extracted in practice; the data are best used as a basis for comparing one area with another.

*It must be emphasised that an assessment of a resource block applies to the block as a whole. Valid conclusions cannot be drawn about the mineral in parts of a block, except in the immediate vicinity of sample points.*

**Description of the assessment area**

This survey is concerned with the assessment of sand and gravel resources within 398km$^2$ of ground around Inverurie and Dunecht and between Banchory and Stonehaven (Figure 1) in the Grampian region of Northeast Scotland. The area includes the valleys of the Rivers Urie, Don and Dee together with the coastal lowlands around Stonehaven.

The sand and gravel resources of the survey area are identified on three resource sheets, two of which are printed together on one map. Map 1 includes 1:25 000 resource sheets NJ 70 (Dunecht) and NJ 72 (Inverurie). Map 2 includes the Banchory/Stonehaven resource sheet, which covers sheets N0 79 (whole), NO 88 NW and NE, NO 89 SW and SE and NO 99 SW.

Sheet NJ 72 includes the town of Inverurie together with the valleys of the River Urie and its tributaries upstream of the confluence of the River Urie with the River Don (Figure 2). The highest ground in the area (+237m OD) occurs on the interfluve between the Rivers Don and Urie, to the west of Inverurie.

On sheet NJ 70 the ground rises steadily towards the Hill of Fare (+471m OD) beyond the western margin of the survey area. Barmekin Hill (+274m OD) is the highest point on the interfluve between the Corskie Burn and the Gormack Burn, which drain eastwards across the district.

The Banchory/Stonehaven sheet includes the valley of the River Dee and its tributaries between Banchory and Drumoak, as well as the valleys of the Cowie Water and the Carron Water. The ground rises from the coast towards Cairn-mon-earn (+378m OD), which is the highest point in the area. The town of Stonehaven is situated on a coastal plain at the mouth of a deep valley. North and south of the town, the gently rolling coastal lowlands rise to between 100m and 200m above OD.

## GEOLOGY

### Mapping

The ground covered by this survey falls within three 1:50 000 sheets of the Geological Map of Scotland; Sheet 76 (Inverurie), Sheet 67 (Stonehaven) and Sheet 66 (Banchory). Until the present study, the drift geology of these sheets had not been mapped in much detail. The solid geology of Sheets 76 East (Kintore) and 76 West (Alford) also has been revised recently and the solid editions of these maps, are nearing completion.

One-inch Sheet 67 (Stonehaven) was originally published in 1884. Minor revisions were made in 1898 and in 1929 and the latest edition (solid and drift) was published, with minor amendments, in 1967. One-inch Sheet 76 (Inverurie) was published in 1886 and sheet 66 (Banchory) was published in 1897. Only hand-coloured, solid and drift editions of these two maps are currently available.

One-inch Soil Survey maps provide a modern coverage for the Inverurie, Banchory and Stonehaven areas, Sheets 76 and 66/67 respectively. These maps provided the basis for the 'preliminary study' of the sand and gravel deposits around Aberdeen (Merritt and Peacock, 1983). Most of the ground identified in that report as possibly containing deposits of potentially workable sand and gravel was examined by BGS staff during a rapid reconnaissance resurvey undertaken in 1984-85. The results of this survey formed the basis of an environmental geology study centred on Aberdeen (Smith, 1986).

The detailed remapping of the drift by C A Auton and J W Merritt in 1986-87 forms the basis of the assessment survey. The extent of the full revision mapping is shown in survey diagrams at the base of each resource sheet.

### Publications

There are no comprehensive modern accounts of the geology available for most of the assessment area, but an explanatory memoir for the adjoining Aberdeen district (Sheet 77) has been published recently (Munro, 1986). Sheet 76 (Inverurie) is described in the memoir for central Aberdeenshire (Wilson and Hinxman, 1890). No memoirs have been produced to accompany the Stonehaven and Banchory sheets. However, an excursion guide to the geology of the Aberdeen area, edited by Trewin and others (1987), gives detailed geological information for 24 study areas throughout Grampian Region and provides an up-to-date framework for understanding the solid geology of the ground covered in the present study.

The sand and gravel deposits were dealt with specifically by Anderson (1943, 1945) as part of a wartime study of resources in Scotland. More recently, Peacock and others (1977) provided a systematic general account of the sand and gravel resources of Grampian Region. This was followed by the preliminary study of sand and gravel deposits in the Aberdeen area (Merritt and Peacock 1983) which included all of the ground covered by the present survey (except sheets NO 88 NW and NE around Stonehaven). The Stonehaven area was included in a preliminary study of sand and gravel deposits of Strathmore (Aitken, 1983).

Mineral Assessment Report No. 146 (Auton and Crofts, 1986), covers the adjoining area of Aberdeen (Figure 1). Other sand and gravel assessment reports in this series are available for the country around Peterhead (McMillan and Aitken, 1981) and Ellon (Merritt, 1981).

## Solid geology

The geological classification of the principal rock types occurring in the assessment areas is shown in Table 1. A brief description of the most important features of the solid (bedrock) geology is provided here, in order to explain the contribution made by the various types of bedrock to the composition of the sand and gravel deposits in the district. A more detailed account of the solid geology of the area is given in Appendix A. The solid geology of the Inverurie and Dunecht resource sheets is shown in outline in Figure 3; that of the Banchory/Stonehaven resource sheet is outlined in Figure 4.

The oldest rocks of the district are the Dalradian metamorphic rocks that crop out north of the Highland Boundary Fault. They include resistant rock types such as quartzite and psammite (impure quartzite), which form a significant proportion of the durable clasts in the gravels throughout most of the study area. Less resistant metamorphic rocks, such as slate (pelite), schist and gneiss (semipelite), and metamorphosed limestone are also present. These generally form a small proportion of the gravel clasts and are often deeply weathered. The presence of large amounts of these friable metamorphic rock types in sand and gravel can seriously affect the strength of the aggregate.

The metamorphic rocks have been intruded by coarse-grained granitic, basic and ultrabasic igneous rocks, which are categorised as 'Caledonian', both in Table 1 and in the appended borehole logs. Granite forms most of the bedrock in the vicinity of Dunecht and Banchory, and gabbro underlies most of the northern part of the Inverurie resource sheet. Rounded clasts of granite are the predominant component of gravels throughout the area lying to the north of the Highland Boundary Fault. Granitic rocks have been particularly susceptible to deep chemical weathering, with the result that much of the high ground formed of granite is mantled by several metres of decomposed material. This deeply weathered rock has been incorporated into the drift deposits throughout much of the district and is responsible for their very sandy nature. Most of the coarse and medium-grained sand in the potentially workable deposits is composed of quartz and feldspar derived from granite.

Sedimentary rocks of Silurian and Devonian age form the bedrock to the south of the Highland Boundary Fault. These 'Old Red Sandstone' rocks include sandstone, conglomerate and some thin beds of mudstone and siltstone. Durable clasts of quartzite and vein-quartz (derived from the conglomerate) form the predominant gravel components in the Stonehaven area, whereas clasts of sandstone, mudstone and siltstone are usually present only in minor amounts. The reddish brown, fine and medium-grained, quartzose sand that is typical of the sand and gravel deposits in the Stonehaven area is derived mainly from the underlying sandstone bedrock.

## Drift (Quaternary) geology

### *Introduction*

The Quaternary history of the study area and a full description of the drift deposits, is given below. Apart from pockets of deeply weathered granite, which are sources of coarse-grained clayey sand, all other known resources of sand and gravel occurring within the area are of Quaternary age and of ice-related origin. In order to fully understand the nature, form and distribution of the sand and gravel deposits it is therefore important to consider the glacial and post-glacial history in some detail.

The glacial deposits of sand and gravel occurring in the study area are inherently variable in composition, discontinuous in extent, and complex in distribution. They are therefore more difficult and costly to delineate and to assess than, for example, the extensive spreads of terraced gravel in the Thames or Trent valleys of England. In general, the sand and gravel in the survey areas is restricted to the valleys where it occurs as isolated hummocks and ridges, flat-topped mounds and valley-side terraces. These deposits mainly lie above the water-table. Large spreads of sand and gravel underlie the alluvium of river floodplains and are concealed beneath areas of basin peat, but these mineral deposits are predominantly water-saturated and could only be exploited by dredging, a practice that is not favoured in Scotland.

A selective glossary of geological terms, relating particularly to the Quaternary geology of the area has been provided.

*Detailed account*

Northeast Scotland was glaciated several times during the Pleistocene epoch (1.7 million to 10 000 years ago). These glacial episodes modified the pre-Quaternary land surface by widening, straightening and deepening river valleys, breaching watersheds and polishing and striating outcrops of resistant bedrock. Because erosion associated with each ice advance largely removed the evidence of previous glaciations, most of the glacial drift now exposed is thought to be associated with the last (Devensian) glacial period. This certainly appears to be the case in the study area as no deposits could be attributed positively to earlier glaciations, either during this assessment survey, or during previous geological investigations in the district.

The Late Devensian ice sheet reached its maximum extent in northeast Scotland about 18 000 years ago. Most of the district was covered by ice that flowed eastwards from accumulation centres in the Grampian Highlands. The southwestern part of the district, however, was covered by a separate ice-stream (the Strathmore lobe), which flowed northeastwards through Strathmore, along the southern flank of the Grampian Highlands and into the adjacent North Sea basin. The former line of confluence of the main Grampian ice-sheet and the Strathmore lobe can be ascertained quite precisely because there are marked differences in the nature and thickness of the deposits derived from the two ice masses; we have called these two sets of deposits the 'Inland Series' and the 'Red Series'. These contrasts may have partly resulted from differences in the basal thermal regime across the ice sheet: most inland areas were covered with cold-based ice with little associated glacial erosion and thick, warm-based ice flowed out of Strathmore and along the North Sea coast causing significant erosion (Hall, 1986). The former zone of confluence between the two ice masses can be traced southwestwards from the coast at Muchalls towards the vicinity of Torr Wood [NO 836 887] in the valley of the Cowie Water. South of the valley of the Cowie Water, the zone can be followed SSE from near Redcloak [NO 856 872] to the vicinity of Nether Wyndings [NO 817 853] at the southern margin of the Banchory/Stonehaven map.

Clayey lodgement till was deposited beneath the actively moving ice. The Strathmore lobe produced thick deposits of till rich in erratics of Silurian and Devonian rock-types whereas the main Grampian ice-sheet generally yielded thinner deposits of till containing erratics of Dalradian metamorphic rocks and Caledonian igneous rocks.

It is debatable whether the Late Devensian ice-sheet began to thin initially as a result of snowfall becoming inadequate to sustain it or whether deglaciation only began following a general rise in mean annual temperature. However, it is clear that after about 18 000 years ago the higher ground had started to become ice-free. Ice gradually became confined into separate glaciers within valleys, like that of the River Dee, that were orientated parallel with a major direction of flow (and within which most of the glacial erosion had occurred)

Continued ice-wastage led to the deposition of sheets of glacial outwash beyond the margins of the retreating or stagnating ice. Glacial meltwater streams cut complex networks of meltwater channels beneath the ice and across the ground which had become ice-free. Ultimately, a large amount of meltwater was ponded temporarily behind residual ice masses and glacial debris left in the main valleys.

A spectacular group of channels of the sub-glacial type, known as 'The Devil's Kettle' are cut to depths of between 20 and 30m into psammitic and semipelitic bedrock at Cheyneyhill Wood [NO 840 880], northwest of Stonehaven. North and west of Stonehaven, a steep-sided glacial drainage channel up to 20m deep, trends SW-NE from the vicinity or Ury Home Farm [NO 858 883] towards Megray Wood [NO 873 890]; it then swings eastwards to reach the coast near Limpet Mill [NO 889 891]. This 'ice-marginal' channel was cut at an early stage during the deglaciation of the district by meltwater derived from the main Grampian ice sheet and the Strathmore lobe, which were juxtaposed in the area.

A good example of ponding occurred in the vicinity of Inverurie, where the lower reaches of the valleys of the River Urie and the Lochter Burn were occupied by a glacial lake. This temporary, probably ice-dammed lake (Glacial Lake Urie) stood at about 63m above OD; it was rapidly infilled with deltaic sand and gravel and finely interlaminated silt and clay.

During the deglaciation, moundy moraines, formed of poorly sorted glacial debris, were laid down at the margins of glacier-ice in the valleys. As the ice melted, sandy flow-till was deposited on top of previously deposited lodgement till and also on areas of newly exhumed bedrock. The morainic deposits are collectively termed 'morainic drift' and they form irregular hummocks and ridges that stand up to 20m above the surrounding ground surface. They are formed of a complex mixture of clayey diamicton, sandy diamicton and intercalated lenses of poorly stratified, often clay-bound sand and gravel. The material, which was deposited in contact with glacier-ice with minimal water sorting, may form elongate ridges on the flanks of valleys (lateral moraines) or transverse ridges lying across valley-floors (terminal moraines). The latter mark the positions of still-stands during the retreat of a valley glacier.

As the ice-sheet decayed, sediment-laden meltwaters issued from subglacial or englacial tunnels to form moundy spreads of poorly sorted 'glacial' sand and gravel at the ice-margin. Material deposited within the subglacial and englacial tunnels now forms sinuous, steep-sided ridges called eskers. These deposits were often let down onto the exhumed land surface as the ice, in which they were contained, melted. As a result, eskers commonly cut obliquely across the present topography and their internal stratification often shows evidence of post-depositional collapse.

Proglacial meltwaters deposited extensive spreads of 'fluvioglacial' sand and gravel within the principal valleys as they became free of ice. Kame-terraces were laid down by subaerial glacial meltwater streams that flowed between valley glaciers and ice-free ground on the valley-sides. The streams generally deposited coarse outwash material. When the ice that occupied the valleys finally melted, these kame-terrace deposits were left as linear, flat-topped spreads of sand and gravel, standing up to 30m above the floodplains of the present rivers.

The surfaces of kame-terraces and other types of outwash deposit are often deeply pitted (kettled), indicating that large blocks of ice were incorporated in the deposits as they were laid down. These ice blocks were partially insulated by the covering of outwash debris and remained frozen for some time after most of the surrounding land surface had become ice-free. When the buried blocks finally melted, large hollows known as kettle-holes, were formed. It is the presence of kettle-holes within the kame-terrace deposits that is primarily responsible for the moundy nature of many of these deposits at the present-day. Erosion by glacial meltwater and subsequent fluvial activity has also modified the surface of some kame-terrace deposits in the Banchory district, notably on the south side of the valley of the River Dee in the vicinity of Keiths' Hill [NO 799 982].

As explained above, there is clear evidence that during the Devensian glaciation at least two ice-streams were confluent in the Stonehaven district. The deposits of the Strathmore lobe, which are characteristically of a vivid red-brown colour, are thought to be the onshore equivalent of the Wee Bankie Formation described by Stoker, Long and Fyfe (1985) from the adjacent part of the North Sea. They include clayey and sandy diamictons (lodgement till and flow-till), water-sorted silty (fluvioglacial) sand and gravel and poorly-sorted coarse (glacial) sand and gravel. They also include finely-laminated sandy silt and stiff, waxy clay (glaciolacustrine deposits). This suite of deposits, which has been mapped up to 7km inland from the coast at Stonehaven, was formerly termed the 'Red Clay Series' by Jamieson (1906), the 'Strathmore Drift' by Bremner (1934), and the 'Red Series' by Synge (1956). Similar deposits in the Ellon and Aberdeen areas have been termed 'red drift' by Merritt (1981) and Auton and Crofts (1986).

In this report the term 'Red Series' is used (Table 1). Most of the material within the 'Red Series' in the vicinity of Stonehaven itself is thought to have been derived from ice which flowed northeastwards into the area from Strathmore, but similar deposits farther north contain additional clasts derived from the North Sea basin.

The drift deposits derived from the main Grampian ice-sheet are predominantly yellowish-brown or grey in colour and contain a preponderance of locally derived clasts of igneous and metamorphic bedrock. The term 'Inland Series' has been used for similar deposits in the Buchan area (Hall, 1984; Connell and Hall, 1987) and as most of the material derived from the main ice-sheet in the present study area is also of inland provenance, the same term has been used here. Although direct evidence of the direction of ice movement (such as glacial striations on exposed bedrock) is scarce, the overall direction of movement appears to have been from the west, that is, from the Grampian Highlands and towards the coast. The direction of flow was more variable locally and it was largely governed by the local topography.

The 'Inland Series' deposits (Table 1) include stiff, clayey diamictons (lodgement tills) and friable, sandy diamictons (flow-till and ablation till), well-sorted sands and gravels deposited by meltwaters proglacially (fluvioglacial sand and gravel) and poorly-stratified sands and gravels, showing only limited evidence of water-sorting and laid down in contact with ice (glacial sand and gravel). Beds of finely laminated, yellowish brown and olive grey sandy silt and clay (glaciolacustrine deposits) were laid down in temporary lakes that occupied much of the low-lying ground during the deglaciation of the inland area.

Deglaciation appears to have been well advanced in the Banchory area by around 12 000 years ago. For example, radiocarbon dating of organic remains within lacustrine sandy silts and clays gave ages of 11 900 ± 260 BP and 10 280 ± 220 BP (Vasari, 1977). These dates relate to the uppermost part of the lacustrine sequence, which was formed in an extensive lake that occupied a large ice-scoured depression lying between Drumoak and the Hill of Fare. The dated organic deposits formed during the Windermere Interstadial, by the end of which, most, if not all, of Scotland had become ice-free.

Glaciers returned to the mountainous areas of Scotland during the subsequent cold period (the Loch Lomond Stade), between 11 000 and 10 000 years ago. The study area experienced periglacial conditions during this period. It is debatable whether any remnants of the ice-sheet still blocked drainage in some of the larger valleys during this return to a cold climate, but solifluxion and mass-wasting certainly caused considerable downslope redistribution of unconsolidated material at this time. These periglacial processes are responsible, at least in part, for the subdued relief of much of the low lying ground in the district.

The present warm, interglacial climate began at the beginning of the Flandrian Stage (Recent), around 10 000 BP. Reduction in annual snow melt in the catchments of both the River Don and River Dee, led to decreased fluvial activity in the valleys that had formerly been filled by glacier-ice. The braided, multi-channel river regime typical of the periglacial climate of the Loch Lomond Stade changed to the single-channel, sinuous river regime typical of the present day.

During the Devensian glaciation in Scotland the world-wide eustatic lowering of sea level, resulting from the abstraction of sea water during the formation of the ice-sheets, was more than offset by the concommitant depression of the land surface caused by the weight of the overlying ice masses. In Late-Glacial and Post-Glacial times, the isostatic recovery of the land lagged behind the eustatic rise in sea level for a while as water from the melting ice returned to the sea. As a result, relative sea level rose and raised beaches were formed along the present coastline.

Along the coast between Muchalls and Stonehaven, for example, the glacial drift is overlain by raised beach deposits of Late-Glacial age (about 12 000 to 10 500 years old) and also by Post-Glacial (Flandrian) raised beach deposits, formed between 6,500 and 6 000 years ago (Cullingford and Smith, 1980; Smith and others, 1980). The Late-Glacial raised beach deposits, which vary in composition from well-rounded cobble-gravel to sandy silt, rest on benches cut in drift deposits at heights of between 25 to 30m above present sea level. Post-Glacial raised beach deposits, which are composed of beach-shingle and sand, are generally present on the landward side of the present-day beaches, and stand up to 8m above the mean high water mark.

The youngest superficial deposits (apart from the present-day beaches) include alluvium and peat, most of which is associated with the present drainage. Spreads of lacustrine alluvium and peat also flank many of the small lochs, such as the Loch of Skene. The floodplain alluvium of the main river valleys conceals thick fluvioglacial sequences that were deposited by braided-rivers. Hill peat is still accumulating in many of the upland areas where it forms extensive peat mosses, notably Blackburn Moss [NO 792 909] on the Banchory/Stonehaven resource sheet and Red Moss [NJ 748 015] on the Dunecht resource sheet.

## COMPOSITION OF THE MINERAL DEPOSITS

Potentially workable sand and gravel is found mainly in deposits classified as fluvioglacial sand and gravel, glacial sand and gravel and alluvium. It also is found in glaciolacustrine deposits and raised beach deposits (of both Late-Glacial and Post-Glacial age). In addition, some occurrences of morainic drift, till and weathered bedrock form potential sources of poor grade aggregate.

Details of the particle size distributions of the mineral-bearing deposits in the survey area are given in Tables 2 and 3 and they are shown graphically in Figures 5 and 6. Each curve represents the cumulative mean grading of all the bulk samples of potentially workable sand and gravel taken from each type of deposit; the envelope within which the mean gradings from individual sample points fall, is also shown. The mean gradings are also represented in graphical form as histograms.

The mean particle size distributions of the four principal mineral-bearing deposits of the Inverurie and Dunecht sheet areas are given in Table 2 and Figure 5. The mean grading of potentially workable till and morainic drift is also included; these two types of deposit (Mineral II) have been considered together for the purposes of assessing these sheets.

Mean grading data for six mineral-bearing deposits in the Banchory/Stonehaven sheet area are given in Table 3 and Figure 6. Mean grading data is included separately for potentially workable till (Mineral II) and morainic drift (which is classed as Mineral I on this resource sheet because the deposits are thought to be generally more attractive sources of aggregate than similarly classified deposits in the Inverurie and Dunecht sheet areas).

Petrological analyses (pebble-counts) were conducted on 16 composite samples taken from assessment boreholes, pits and working quarries in the district. In order to have sufficient material for these analyses, as well as for mechanical and physical testing, samples from more than one sample point were amalgamated. The source of each composite sample is shown in Table 4; material from the same 16 samples was also subjected to the mechanical and physical tests (described in the next chapter). In general, each composite sample represents a group of deposits that are regarded as being geologically or geomorphologically similar. The pebble-counts were made on the 10 to 14 mm size fraction of the aggregate in order that a comparison could be made with the mechanical and physical tests, which were also carried out on this size range.

The rock classification scheme used for the pebble-counts is shown in Table 5; it is like that used in Mineral Assessment Report 146 for the adjoining Aberdeen assessment area. This enables a direct comparison to be made between the clast lithologies of similar mineral deposits from both assessment areas. The scheme is based partly on the parameters used to establish the British Standard Groups *(trade groups)* of rock identified in BS 812.1:1975, and partly on the classification scheme proposed by Knill (1963, Table 4). Not all of the rock groups listed in Table 5 are present in the study area.

Some of the rock groups broadly coincide with the British Standard Groups but others do not. For example, the *granite group* in this scheme combines the 'granite', 'quartzite' and part of the 'gritstone' groups of the British Standard. A more comprehensive geological subdivision of the pebble lithologies is used in the logs for individual boreholes, pits and sections given in Appendix G.

The results of the petrological analyses are given in Table 6. It is quite clear that rocks of the *granite* group predominate in every composite sample analysed. However, variations in the proportions of clasts of different rock types within the *granite* rock group may affect the strength and durability of the aggregate. In order to investigate this possibility, a three-fold subdivision of the *granite* rock group was made (see Table 6).

The main accessory rock types are generally from the *porphyry, schist, basalt* and *gabbro* rock groups. Slate and cryptocrystalline siliceous rocks are rare.

**Inverurie sheet**

Apart from the valley of the River Don, where there are thick deposits of alluvial gravel, most of the potentially workable sand and gravel in this sheet area underlies terraces in the main valleys and is classified as fluvioglacial sand and gravel.

In the valley of the River Urie, the fluvioglacial material becomes progressively finer downstream; this is reflected in the relative proportions of gravel and sand and in the grading of the sand fraction alone (see Table 10). Gravel taken from sample points in this valley were grouped into composite sample 8 (Table 4). The pebble-count of this sample (Table 6) is quite distinctive as it is the only one dominated by gabbro, diorite and amphibolite. These rock-types have been derived from the basic igneous intrusions in the north of the resource sheet area (see Figure 3). The sand fraction also contains a conspicuously large amount of dark-coloured minerals derived from these basic rocks. Platy-shaped clasts of slate are common, especially in the very fine gravel and coarse sand fractions, but they are probably not sufficiently abundant to be a problem in commercial end-use.

The grading characteristics of the fluvioglacial and alluvial gravels in the valley of the River Don are similar (see Table 11), although the alluvial gravels seem to be coarser, especially in the uppermost metre or so. Both types of deposit are generally much coarser than those in the valley of the River Urie, mainly because the River Don is the larger river and it has a much steeper gradient locally.

Composite sample 9, taken from sample points in the valley of the River Don, is markedly different in composition to sample 8 representing the Urie valley. In sample 9, granite and psammite predominate and there is very little gabbro and amphibolite. As the catchment area of the River Don immediately upstream of Inverurie is mostly underlain by mixed metamorphic rocks, it is not surprising that the gravel includes a relatively large amount of mica-schist and quartz-mica schist.

The mechanical and physical properties of the two composite samples derived from the Inverurie sheet are dealt with in the next chapter.

**Dunecht sheet**

Fluvioglacial and glacial sand and gravel form resources of equal importance on this sheet, the distinction between the two categories of deposit being based primarily on geomorphology rather than composition or grading. Much of the alluvium is sandy and also constitutes a large resource, but it lies mainly below the water-table.

*Fluvioglacial sand and gravel*

Important resources of fluvioglacial sand and gravel occur in the valley of the Corskie Burn (block A) and in the vicinity of Leuchar Moss [NJ 790 047], in block C, where they underlie an extensive outwash fan.

The grading characteristics of the terraced fluvioglacial deposits in the valley of the Corskie Burn (Table 12) are broadly comparable with those of fluvioglacial sand and gravel in the valley of the River Urie on sheet NJ 72. Coarse gravel predominates over fine, but there are relatively few cobbles. The sand is medium to coarse-grained with a little fine. Gravel taken from five sample points in block A were amalgamated into composite sample 10 (see Table 4). Most of the Dunecht sheet area is underlain by granite and predictably, the pebble-count of sample 10 (Table 6) revealed an abundance of granite with subsidiary amounts of psammite, pegmatite and porphyry. The sand fraction is dominated by quartz and feldspar.

Mean grading data from sample points positioned on the outwash fan in the vicinity of Leuchar Moss are given in Table 14. The material is much sandier and the sand is much finer-grained than most of the exposed fluvioglacial deposits elsewhere on the sheet. The material fines progressively from the proximal to the distal end of the fan; it also thins and oversteps a concommitantly greater thickness of fine-grained glaciolacustrine silt and clay in this direction. Gravel taken from boreholes sited on the fan was amalgamated to form composite sample 11 (Table 4). The pebble-count on this sample (Table 6) revealed it to be dominated by granite (72%) with minor amounts of psammite, porphyry, vein-quartz and diorite. The sand is quartzo-feldspathic and, when fine-grained, it is slightly micaceous.

*Glacial sand and gravel*

Moundy deposits of glacial sand and gravel form important resources in the northeastern part of block D and in block C. They also form a small resource in block F. Glacial sand and gravel is intrinsically more heterogeneous and less well sorted than the fluvioglacial type. In general, steep-sided eskers and hummocks are formed of coarser material than more rounded eskers and hummocks, but it is not possible to generalise further.

The mean grading of the glacial sand and gravel of block D is given in Table 15. Gravel taken from four sample points in these deposits was amalgamated into composite sample 12 (Table 4). The pebble-count undertaken on this sample (Table 6) shows a preponderance of granite, which is typical of gravels within the Dunecht resource sheet area, but it also indicates a relatively large amount (12%) of schist. The sand is typically quartzo-feldspathic.

The mean grading of the glacial sand and gravel of block C is given in Table 14. Composite sample (11) was derived from both glacial and fluvioglacial deposits in this block.

The mean grading of the glacial sand and gravel of block F is given in Table 17. These deposits are represented by composite sample 13. The pebble-count on this sample predictably showed granite to predominate, but there was also a relatively large amount of pegmatite and psammite.

*Alluvium*

Alluvial sand and gravel underlies the flat-lying, poorly-drained areas of the resource sheet. The thickest known deposits occur in the vicinity of the Loch of Skene, in block A, and beneath the extensive alluvial flat lying at the centre of block D. The resources, however, are almost wholly water-saturated. As it is usually difficult to distinguish Post-Glacial alluvial sand and gravel from underlying fluvioglacial deposits in boreholes, the two are generally grouped together as 'valley-floor' deposits for the purposes of assessment. Mean grading data for the valley-floor deposits of blocks A, D and F are given in Tables 12, 15 and 17 respectively. The material is relatively well sorted and tends to grade as a pebbly sand or sandy gravel.

No composite samples were prepared specifically to represent the valley-floor deposits, but some material was included in the samples taken from the glacial and fluvioglacial sand and gravel. The gravel fraction is predominantly composed of granite and the sand is mainly comminuted granite, that is, quartz and feldspar with traces of mica.

The mechanical and physical properties of the aggregate from this resource sheet area are dealt with in the next chapter.

**Banchory/Stonehaven sheet**

*Fluvioglacial sand and gravel*

The bulk of the potentially workable sand and gravel in the Banchory/Stonehaven area occurs within the flat-topped mounds and terraced spreads of fluvioglacial sand and gravel that flank the larger valleys. The fluvioglacial deposits, which commonly underlie floodplain alluvium, have a mean grading of 4 per cent fines, 56 per cent sand and 40 per cent gravel (sandy gravel). There is, however, a relatively wide range of values between individual sample points, as is shown by the broad envelope in Figure 6a, which indicates that there is considerable variation in the grading of the deposits locally.

The fluvioglacial deposits characteristically occur in multiple fining-downward sequences. Individual units are generally moderately well sorted and often well bedded (low angle cross-stratification is often evident). The deposit, as a whole, is medium to coarse-grained, with a poorly developed mode in the medium sand fraction. In the samples graded, coarse and fine gravel are present in almost equal amounts and cobbles account for 7 per cent (by weight) of the material.

The most extensive gravelly fluvioglacial deposits in the Banchory area have been proved in sample points sited on the terraces in the valley of the River Dee (composite samples 2 and 3; Table 6). The gravel is mainly composed of angular to subrounded clasts of granodiorite, psammite and quartzite; vein-quartz, diorite, pegmatite, fine-grained acid igneous rocks together with pelitic and semipelitic schist are also present.

Gravel from sample points sited on fluvioglacial deposits in the valleys of the Burn of Sheeoch and Garrol Burn (composite sample 15 and part of composite sample 7), and the Burn of Knock (composite sample 1) is mainly composed of angular to subangular clasts. It is of broadly similar composition to that of the valley of the River Dee described above. It does, however, contain a higher proportion of granitic clasts, mostly derived from the Kincardine granite, which crops out in the southern and eastern parts of sheet NO 79 (see Figure 4).

In the Stonehaven district, thick fluvioglacial deposits containing a significant proportion of material of 'inland' provenance occur in the valley of the Cowie Water (composite sample 6) and within an extensive outwash terrace (composite sample 14), close to the town itself. The gravel from the upper part of the valley of the Cowie Water is of similar composition to material from the valley of the River Dee, but the terraced outwash gravel at Stonehaven contains a much higher proportion of quartzite and coarse-grained sandstone derived from Silurian and Devonian rocks (which crop out in the vicinity) as well as clasts of granite and schist.

The fluvioglacial sand and gravel of the 'Red Series' (composite sample 5; Figure 6b) has been looked at separately. Samples taken from the deposit have a mean grading of fines 7 per cent, sand 70 per cent and gravel 23 per cent (pebbly sand). Compared to the other fluvioglacial deposits, the 'Red Series' material is more clayey and slightly better sorted; it has a much higher proportion of fine and medium-grained sand, and a lower proportion of coarse gravel. The gravel (composite sample 5) is composed predominantly of vein-quartz, psammite, quartzite, fine and coarse-grained sandstone, together with weathered pelitic and semi-pelitic schist; granitic clasts account for only 8 per cent (by number) of the composite sample.

*Glacial sand and gravel*

Deposits classed as glacial sand and gravel are much less extensive than the fluvioglacial deposits on the Banchory/Stonehaven sheet. They are generally restricted to mounds of very coarse gravel and to esker ridges composed of complex coarsening-downwards sand and gravel sequences. An undulating spread of silty cobble-gravel lying to the north of Stonehaven is also classed as glacial sand and gravel. This deposit (composite sample 16) is poorly stratified, shows little evidence of water-sorting and contains a high proportion of angular clasts, features that tend to characterise many glacial sand and gravel deposits.

The overall grading of samples of glacial sand and gravel from the Banchory/Stonehaven area is fines 3 per cent, sand 48 per cent and gravel 49 per cent (gravel). The higher proportions of coarse and medium-grained sand, and cobble-gravel serve to distinguish the glacial sand and gravel from deposits of fluvial and fluvioglacial origin.

The presence of a high proportion of angular clasts of the underlying bedrock is also characteristic of glacial sand and gravel deposits recognised in this sheet area.

*Alluvium*

Most of the fluvial and lacustrine alluvium on the Banchory/Stonehaven sheet is composed of silt and clay, but thin spreads of pebbly sand overlie coarse gravel below the floodplain of the River Dee. Beds of silty pebbly sand are also present within the clayey lacustrine sequences deposited in ice-scoured depressions throughout the area.

The mean grading of samples of the alluvium is fines 8 per cent, sand 78 per cent and gravel 14 per cent (pebbly sand). The deposit is better sorted than either the fluvioglacial or the glacial deposits, with a mode in the medium sand grade (Figure 6d). The grading envelope is relatively narrow, but this probably reflects the small number of samples analysed, rather than being an indication of homogenity.

*Glaciolacustrine deposits*

In the Banchory area, glaciolacustrine deposits are chiefly composed of grey, finely laminated silt and clay. In the Stonehaven district, however, deposits of fine-grained silty sand are often present towards the top of thick glaciolacustrine sequences, which mainly comprise reddish brown silt and clay. In general, the beds of fine-grained sand are only potentially workable where they are overlain by sandy fluvioglacial deposits.

Glaciolacustrine deposits that have been classed as potentially workable have a mean grading of 'clayey' sand. The range of grading is generally small, as shown by the tight grading envelope in Figure 6e. The deposit is very well sorted, with a well developed mode in the fine sand fraction; pebbles are rare (<2 per cent by weight). The sandy beds tend to be discontinuous, merging laterally into more silty deposits.

*Late-Glacial and Post-Glacial raised beach deposits*

Some potentially workable sand and gravel is present within the raised beach deposits of both Late-Glacial and Post-Glacial age that occur along the coast between Downie Point [NO 883 853] and Muchalls [NO 903 923]. No grading or petrological data is presented for these deposits, but field mapping indicates that the potentially workable material is generally thin and has a very patchy distribution. The deposits are heterogeneous, ranging in composition from clayey silt at resistivity site 88 NE R2B, at Garron point, to well rounded coarse gravel near the Mains of Cowie [NO 877 868]. The thickest spreads of sand and gravel are thought to occur along the sea front at Stonehaven where more than 9m of gravel has been recorded in site investigation boreholes, but the deposits have been rendered sterile by urban development.

**General**

*Morainic drift and potentially workable till*

Large amounts of poor grade, heterogeneous sand and gravel occur on the Dunecht and Banchory/Stonehaven resource sheets in the form of morainic drift. The material, which is generally delineated on the basis of landform, is typically very poorly sorted, slightly cohesive and contains a large proportion of angular cobble and boulder-grade material composed mainly of local bedrock. The deposits are mostly composed of multiple sequences of matrix-supported diamictons that merge locally into clast-supported rubble. Beds of water-sorted, non-cohesive sand and gravel are common, but individual beds are usually thin and laterally impersistent over distances of a few metres. Interbeds of silt and clay, sometimes finely laminated, are also common.

Potentially workable till can be regarded as the sandy end-member of the suite of glacially deposited diamictons that blanket the area. It is generally more compact than morainic drift, but the two types of deposit are often indistinguishable lithologically. Both types of deposit were mainly formed by mass-flowage of glacial debris with little or no water sorting. Both are essentially ablation till and flow-till complexes that overlie, or merge down into more clayey and far more compact and dense lodgement till (non-mineral). Morainic drift can be mapped on the basis of geomorphology, but it has proved impracticable to delineate potentially workable till from that which is not workable, hence no assessment of mean grading or volume is attempted for this category of mineral.

Grading data for the morainic drift and potentially workable till in the Banchory/Stonehaven resource sheet area are shown graphically in Figure 6f and 6g. Both types of deposit are poorly sorted and contain more than 10 per cent of cobble-grade material. Neither deposit can be regarded as a particularly attractive source of aggregate, but the morainic drift is generally less clayey than the till (7 per cent as opposed to 12 per cent fines) and parts of the deposit, notably in the valley of the Burn of Day and in the vicinity of Millsburn are a potential source of coarse gravel. Most of the remainder of the morainic drift is regarded as being not potentially workable either because it is too clayey or it contains too much cobble or boulder-grade material.

Grading data for the morainic drift and potentially workable till (combined) in the Inverurie and Dunecht resource sheet areas is given in Figure 5. Neither deposit is regarded as an attractive sand and gravel resource.

### *Weathered bedrock*

Granite underlies most of the Dunecht resource sheet and a large proportion of the Banchory/ Stonehaven sheet (see Figures 3 and 4). The rock is locally deeply weathered at the surface and, in such a condition, it constitutes a potentially very large resource of sharp, slightly cohesive coarse-grained sand. The material generally grades as 'clayey' pebbly sand and has proved to be ideal for bedding pipe-lines and for constructing footpaths and tracks. The material is best worked intermittently, allowing the rock to become disaggregated by over-wintering.

## MECHANICAL AND PHYSICAL PROPERTIES OF THE AGGREGATE

A series of mechanical and physical tests were conducted in accordance with BS 812 parts 2 and 3 (British Standards Institution, 1975), on the 10 to 14 mm gravel fraction from the 16 composite samples listed in Table 4. The samples represent the major deposits of sand and gravel within the survey area. The material for testing was generally obtained by sieving the residues of bulk samples taken for particle size analysis from trial pits and boreholes, or was collected from graded stockpiles or working faces in sand and gravel quarries. The grouping of the samples was designed to provide a basic evaluation of the mechanical and physical properties of aggregates currently being worked; to provide a comparison between worked deposits and nearby sources of potentially workable material and to compare deposits formed in similar depositional environments. The sources and geological classification of the composite samples are given in Table 4.

The tests carried out included measurement of aggregate impact value (AIV), aggregate crushing value (ACV), relative density (on both an oven-dried and surface-dried basis), apparent relative density and water absorption. In addition, the aggregate impact value residue (AIVR) and aggregate crushing value residue (ACVR) as defined by Ramsay (1965) and Ramsay, Dhir and Spence (1973, 1974) were determined. Pebble-counts (compositional analyses) were also undertaken on the 10 to 14 mm samples in order that a direct comparison could made between the petrographic composition of the gravel and the mechanical and physical properties. The results of the pebble-counts are given in Table 6. Approximately 15kg of material is required for a complete series of tests, but there was not always sufficient for the full range (see Table 7).

Aggregate strength has been shown, by the work of Ramsay and Ramsay, Dhir and Spence, to be dependent on several petrographical features. In an aggregate composed of clasts of sedimentary rock types, the main petrographical factor influencing the strength of the aggregate is the strength of the intergranular cement. In clasts of igneous rocks, strength is governed by the degree of crystal interlocking, which is inversely proportional to grain size. In clasts of metamorphic rocks, which are derived from either sedimentary or igneous rocks, the relative importance of both factors is dependent on the original rock type and also the grade and type of metamorphism (and hence the degree of recrystallisation) that they have undergone. In coarse-grained igneous and metamorphic rocks the strength of individual crystals is important. This is influenced by twinning, cleavage and the presence of microfracture planes within the crystals. In clasts of finer grained metamorphic rocks, planes of weakness caused by cleavage and schistosity influence not only the strength of the clasts, but also their shape and angularity.

The shape and degree of weathering of individual clasts also affect the strength of an aggregate. These factors are partly controlled by petrography, but are also dependent on the distance and mode of transportaton and the environment of deposition.

The resistance of an aggregate to both sudden impact and slowly applied compressive-load reflects its suitability for various end-uses, particularly as a roadstone. Aggregate impact value (AIV) is an indicator of impact resistance: it measures the relative amount of comminuted material passing through a 2.36 mm sieve after the sample has been subjected to fifteen blows of standard magnitude. Aggregate crushing value (ACV) is an indicator of resistance of an aggregate to applied compressive load: it measures the relative amount of comminuted material passing through a 2.36 mm sieve after the sample has been subjected to a load that has been uniformly increased to 400KN in ten minutes. Although these tests give an indication of the strength of intergranular bonding, it is usually the ability of a clast to withstand impact and loading relatively intact, rather than to fragment, that is the most important attribute. For this reason Ramsey introduced the concept of the aggregate impact value residue (AIVR) and aggregate crushing value residue (ACVR), which are calculated by measuring the amount of 10 to 14 mm material remaining intact after the AIV and ACV tests and expressing this as a percentage of the original mass.

The results of the mechanical and physical tests carried out on the composite samples are shown in Table 7. The AIV values range from 17 to 32 and average 25. The range of AIV values is quite large, similar to that (22-34) recorded for the adjoining assessment area (Auton and Crofts, 1986). It is well above the average of 19, quoted by Edwards (1970), for a selection of worked Scottish gravels. The highest values are 32 (sample 11), for glacial and fluvioglacial sand and gravel at Leuchar Moss and 29 (samples 1, 8, 10) for the fluvioglacial sand and gravel from the Burn of Knock, Pitcaple and Corskie Burn areas. The lowest AIV values are 17 (sample 5), from the 'Red Series' fluvioglacial deposits of the Stonehaven area, and 18 (sample 4), from the 'Inland Series' fluvioglacial sand and gravel of the terraces of the River Dee between Crathes and Drumoak.

There is a good correlation between the proportion of coarse-grained igneous rock-types in a sample and AIV (Spearman's Rank Correlation Coefficient = 0.8). This is likely to reflect the degree to which many of these rocks are weathered in the study area.

The results of the aggregate crushing value test show a close correlation to the AIV results, the samples with the greatest impact resistance are shown to also have the greatest compressive strength. The AIVR and ACVR results show a broad inverse relationship to the AIV and ACV values.

The suitability of an aggregate for use in concrete manufacture depends not only on its impact and crushing strength, but also on its water absorption and drying shrinkage (Table 7). The water absorption value is a measure of the amount of water absorbed by the aggregate after 24 hours of immersion, expressed as a percentage of its oven-dried weight: it is thought to have a broadly linear relationship to the drying shrinkage, both of the aggregate itself and of any concrete manufactured from it (Edwards, 1970). The drying shrinkage, in turn, is a key factor affecting the stress-carrying ability and resistance to weathering of concrete. The water absorption values of the aggregates from the present study area range from 1.1 to 2.9 per cent, with an average of 2.0. This is above the average of 1.48 per cent quoted by Edwards for a selection of Scottish and English gravels. The relatively high water absorption levels are thought to be largely due to the presence of rough-surfaced or porous clasts, such as weathered granite, psammite and basic igneous rocks. Weathering tends to increase the water absorption potential of the gravel. Porous sedimentary rock types and clayey rock types such as shales and mudstones, which absorb water readily and swell when immersed, are not common in the gravels within the assessment area.

By using the graph published by Edwards (1970, Figure 1) a very rough estimate of the drying shrinkage properties of aggregate in this study area can be obtained. The *inferred* drying shrinkages calculated in this way (Table 7, column 10) range from 0.052 per cent to 0.088 per cent with an average of 0.069 per cent. Gravels yielding concrete drying shrinkage values greater than 0.085 per cent lie in the category defined by the Building Research Station Digest 35 (1968) that requires the greatest care to be exercised when they are used in concrete manufacture. Those with values lying between 0.066 and 0.085 per cent are said to be suitable for most structural purposes other than unreinforced or thin reinforced members. Gravels yielding concrete drying shrinkages between 0.046 and 0.065 lie in the category defined by Digest 35 as being potentially suitable for most applications although "special care" should be taken in the design of certain precast products required to be of low shrinkage, such as thin reinforced sections, cladding panels and concrete floors cast *in situ*.

It should be emphasised that derived shrinkage values must be interpreted with caution and that the quality of an aggregate may often be improved by washing and crushing after stockpiling to remove deleterious, weathered and friable components.

*Definitive* (measured) values for concrete drying shrinkage, wetting expansion and moisture absorption are given (Table 8) for seven specially prepared composite samples of aggregate from the study area. The tests involved the manufacture of concrete prisms (200x50x50 mm) using Ordinary Portland cement (BS 12, 1978), <5mm "Zone M" sand and 200 mm to 5 mm graded gravel from each separate sample provided. The tests were carried out in a commercial laboratory, using the method described in Building Research Station Digest 35.

The laboratory procedure involves immersing the prisms in water for a period of four days at a temperature of between 14 and 19°C with one of the larger (200mm) faces just breaking the surface of the water. The length of each prism is then measured (this is the 'original wet measurement'). Each prism is dried in an oven for a period of three weeks, cooled for four hours in a dessicator (containing solid calcium chloride in a saturated solution of calcium chloride) and its length measured. After a further week in the oven, the cycle of drying, cooling and measurement is repeated (the final reading being taken as the 'dry measurement'). The test measurements are then used to calculate the values for moisture absorption and moisture expansion. The 'drying shrinkage' is calculated as the "difference between the original wet measurement and the dry measurement expressed as a percentage of the dry length".

The 'drying shrinkage' values obtained for the seven samples are listed in Table 8: they range from 0.040 per cent to 0.065 per cent and average 0.048 per cent. These definitive values indicate that the derived shrinkage values given in Table 7 (ranging from 0.052 to 0.088 per cent) are rather high. The definitive values are sufficiently accurate to provide a good guide as to the suitability of aggregates from the assessment area for use in concrete manufacture, but it must be emphasised that the material tested is mostly 'as dug' and has not been processed.

Relative density values were obtained for twelve composite samples, on both an oven-dried and a saturated surface-dried basis. The apparent relative density of the samples was also calculated (Table 7, columns 6-8). As expected there was little difference between the oven-dried and surface-dried measurements and the range of values for all three parameters was small. Composite sample 8 from the Pitcaple area showed consistently high results, attributable to the high proportion of gabbro present, gabbro being a relatively dense rock. The values are comparable to those obtained by Merritt (1981) for the Ellon area, and Auton and Crofts (1986) for the Aberdeen area. It is apparent that there is little or no correlation between the strength of these aggregates and the density of their components.

In general, aggregates containing a large proportion of weathered, coarsely crystalline granite clasts (such as composite sample 1) are weaker than aggregates (such as sample 16) that contain a high proportion of fine-grained, indurated rock types, which are less susceptible to weathering and are consequently stronger. The angularity of the clasts ranges widely within most groups and there is little evidence that the degree of rounding has any significant effect on the strength of the material.

## THE MAPS

The two sand and gravel resource maps are folded into pockets at the end of this report. The topographic base is the Ordnance Survey 1:25 000 Outline Edition, which, together with the contours, is printed in grey: the geological lines and symbols are in black. Mineral resource information is presented in shades of red.

### Geological data

The geological boundary lines are the result of mapping at 1:10 000 or 1:10 560 scale; these offer the latest interpretation of the available data but, because the deposits are highly variable, the accuracy of the maps will be improved as new evidence from boreholes and excavations becomes available.

Data from boreholes, shallow pits and temporary exposures, including stratigraphical relations and mean particle-size analysis of the sand and gravel samples collected during the assessment, are shown on the maps as computer-generated graphic arrays in black.

Geophysical data in the form of interpreted resistivity soundings (see Appendix I) are presented in a similar manner to data from boreholes, pits and exposures, but are printed on the maps in red.

### Mineral resource information

The maps are divided into resource blocks (see Appendix B) within which the extent of mineral-bearing ground is shown in shades of red. The dark shade denotes where mineral is exposed, that is, the overburden averages less than 1.0m in thickness: a lighter tone is used to identify where mineral is present in relatively continuous spreads beneath overburden averaging more than 1.0m in thickness. Within these areas, however, there may be small patches where sand and gravel is absent or not potentially workable.

A further category, which is shown on the resource maps in the lightest tone of red, shows where mineral is considered to be discontinuous. The recognition of these categories depends upon the proportion of sample points which did not prove potentially workable sand and gravel and the distribution of these barren sites within a block.

Spreads of morainic drift, which contain mixed deposits of potentially workable sand and gravel and till, are shown on the map by an ornament of open red circles.

Areas where sand and gravel is deemed to be not potentially workable, where superficial deposits do not contain mineral, or where bedrock crops out, are shown uncoloured. Sand and gravel within built-up areas is indicated by red stipple.

For the most part, the distribution of resource categories is based on mapped geological boundaries. Where transitions between categories of mineral have been mapped within a geologically distinct deposit (for example, alluvium constituting exposed mineral adjoining alluvium containing concealed mineral), the boundary is shown by a pecked line in red. Where the transitions cannot be directly related to the geological map, inferred boundaries have been inserted. Such boundaries, drawn primarily for the purpose of volume estimation, are shown by a distinctive zigzag symbol, in red, which is intended to convey an approximate location within a likely zone of occurrence rather than to represent the breadth of the zone; its width is dictated by cartographic considerations. For the purpose of measuring areas the centre-line of the symbol is used.

### The areas of assessment

The Dunecht sheet is divided into six resource blocks for assessment and the Banchory/Stonehaven sheet is divided into seven. The Inverurie sheet, however, is assessed as a whole, there being too little mineral-bearing ground to warrant any sub-division into resource blocks. Principal built-up areas have been excluded from the assessment. The positioning of the block boundaries is a compromise to meet the aims of the survey: on the one hand to provide sufficient sample points on which to base an assessment and on the other to group together deposits of broadly similar origin, grade and composition. As far as possible the block boundaries are determined by geological lines.

## RESULTS OF THE VOLUMETRIC ASSESSMENT

The results of the volumetric assessment of resources are summarised in Table 9; more detailed grading and thickness data are given block by block in Tables 10 to 23. The statistical procedure adopted for the volumetric assessment of the mineral resources is outlined in Appendix C. At the level of sampling allowed for in the present survey, potentially workable deposits are too patchy and diverse in many cases to warrant sufficient sample points on which to base 'statistical' assessments. 'Inferred' or 'speculative' assessments are offered for these resources.

In the Inverurie and Dunecht areas, resources of potentially workable aggregate occur as fluvioglacial sand and gravel, glacial sand and gravel, alluvium, glaciolacustrine deposits, morainic drift, till and weathered bedrock: in the borehole records deposits of the first four categories are identified as 'Mineral I'; morainic drift, till and weathered bedrock as 'Mineral II'.

In the Banchory/Stonehaven area, potentially workable aggregate can be found also within Post-Glacial and Late-Glacial raised beach deposits. On this sheet, only potentially workable till and weathered bedrock are recognised as 'Mineral II'. Some deposits of fluvioglacial sand and gravel, glacial sand and gravel, glaciolacustrine deposits and till have been additionally distinguished as being of 'Red Series' type if they have been so mapped.

The sub-division of potentially workable aggregate into 'Mineral I' and 'Mineral II' has been made because the two types of deposit pose different problems in terms of exploitation. It is not practical to offer a volumetric assessment of 'Mineral II' deposits as they are only considered to be potentially workable locally, and in any case, they are usually of low grade.

Fluvioglacial sand and gravel (mainly gravel forming kame-terraces and underlying floodplain alluvium) is the most extensive potentially workable deposit in each assessment area. Glacial sand and gravel (deposited as kames, eskers and spreads of glacial outwash) forms the second major source of sand and gravel. The remaining deposits classified as 'Mineral I' constitute less important sources of potentially workable material, being both thinner and less extensive than the fluvioglacial and glacial sands and gravels.

### Accuracy of results

For a 'statistical' assessment, the accuracy of the estimated volume is given at the 95 per cent probability level; for example, the accuracy of the statistical assessment for block B on the Banchory/Stonehaven Sheet, is ±28 per cent. In other words, it is probable that on average, nineteen out of every twenty sets of confidence limits constructed in this way contain the true value for the volume of mineral. However, the real value is more likely to be near the median than near the limits. Moreover, it is probable that roughly the same percentage limits would apply to the estimate of mineral volume within a very much smaller parcel of ground (for example, 100 hectares) containing similar sand and gravel deposits, if the results from the same number of sample points (as provided by, say ten boreholes) were used in the calculation. Thus, if closer limits are needed for the quotation of reserves, data from more sample points would be required, even if the area is quite small.

For each block the total volume present in the ground is given in millions of cubic metres. An impression of the quantities present over part of a block may be gained by careful examination of the thickness of mineral proved in boreholes and other sample points lying within or close to a particular area of interest, but such data must be considered within the context of the mean thickness and range of values proved for the block as a whole. It cannot be over-emphasized that any attempt to use the data presented in this report to evaluate parts of a block must be undertaken most cautiously, for data quoted for an individual borehole or pit refer strictly to that site and in many cases the deposits are known to change rapidly in thickness and character.

The amount of recoverable resources will depend on many factors not least of which are working practice, the size and shape of the area for exploitation, planning and judicial constraints. Because there are so many variables, it is not possible to suggest what proportion of the *in-situ* resources either for a block as a whole, or for part of it, may prove to be recoverable.

## DESCRIPTION OF RESOURCE SHEET NJ 72 (INVERURIE)

This resource sheet can be regarded as a single resource block that has been divided informally into three sub-blocks for the purposes of assessment. Separate assessments are offered for the resources occurring within the valley of the River Urie, the valley of the Lochter Burn, and the valley of the River Don.

The resources of sheet NJ 72 are almost entirely restricted to valley-side terraces and alluvium within the main valleys. Therefore the assessment follows the practice that has been adopted previously for geologically similar areas, such as the ground covered by Mineral Assessment Report 58 (Peterhead). Separate assessments are offered for 'valley-side' and 'valley-floor' deposits; in this way resources are divided between those lying mainly above the water-table and those lying mainly below the water-table. Valley-side deposits include any mineral deposit underlying the fluvioglacial and higher alluvial terraces, whereas valley-floor deposits include mineral underlying floodplains, low-lying alluvial terraces and alluvial flats.

**The valley of the River Urie upstream of Milton of Inveramsay**

*Valley-side deposits*

The most widespread resources of sand and gravel within sheet NJ 72 are located upstream of Milton of Inveramsay [NJ 741 248]. The mineral underlies discontinuous fluvioglacial terraces that border the floodplain of the River Urie and its tributary, the Burn of Durno. The terraced deposits, which have been locally degraded, generally stand at about 4 to 6m above the level of the floodplain and thus the sand and gravel lies mainly above the water-table. Although some of the terraces are entirely flat-topped and have clear back features, others are more irregular in form and must have been deposited in close association with down-wasting ice; they are kame-terraces. An example of the regular type occurs [NJ 709 257] in the vicinity of Logie Durno, where trial pit 72 NW 1 revealed 3.7m of sandy gravel (unbottomed). This type of terraced deposit is likely to be relatively homogeneous over a wide area. An example of the more irregular type of terrace occurs a little downstream, at Mill of Durno, where trial pit 72 NW 2 proved 3.0m of sandy gravel (unbottomed); the pit was dug on top of a 2m high ridge which is probably of different composition to the deposits underlying the surrounding terrace.

The fluvioglacial sand and gravel is most widespread around Whiteford [NJ 721 263], where it has been worked in several small-scale operations, and Pitcaple Castle [NJ 7278 2613], where it is worked intermittantly in a small pit [NJ 7298 2591] within the estate. The terrace upon which Whiteford is sited has no clear back feature and the position of the boundary thereabout is therefore uncertain. Borehole 72 NW 4 was sited close to this boundary and proved only 1.0m of sandy gravel but the deposit thickens towards the centre of the valley.

In general, the terraced fluvioglacial sand and gravel fines downstream from sandy gravel to pebbly sand. With the exception of trial pit 72 NW 3, which proved coarse clast-supported gravel including many cobbles and small boulders, the gravels are predominantly fine. Coarse-grained basic igneous rocks, semipelitic gneiss and schist dominate the gravel fraction, which also includes granite, quartzite and psammite. The fine gravel and coarse sand categories contain platy clasts of schistose pelite and slate. The medium and fine-grained sand is quartzo-feldspathic; it is typically speckled black owing to the relative abundance of mafic minerals derived from the basic crystalline rocks that crop out within the area.

The terraced valley-side deposits upstream of Milton of Inveramsay have a mean thickness of 2.5m (see Table 10) based on seven sample points, three of which do not penetrate the complete thickness of mineral. Based on these sample points, the mean grading is fines 2 per cent, sand 64 per cent and gravel 34 per cent (sandy gravel).

*Valley-floor deposits*

The floodplains of the River Urie and the Burn of Durno probably conceal deposits of water-saturated sand and gravel, but there are no boreholes to confirm this view. A resistivity sounding (72 NW R1) made on the floodplain near Legatesden House [NJ 7408 2580] indicates that 1.3m of gravelly sand, with negligible overburden, overlies silt. The sand and gravel may thicken upstream from this locality, but it seems nevertheless to be a minor resource. The discontinuous spreads of sand and gravel indicated on the resource map to occur beneath the floodplain of the Burn of Durno, are conjectural.

A low-lying alluvial terrace abuts the floodplain of the River Urie immediately to the south of Whiteford. Another alluvial terrace lies between Pitcaple Castle and an isolated remnant of a formerly more extensive spread of fluvioglacial sand and gravel in the middle of the valley, which was formed when the River Urie took a more southerly course. Both of these terraces stand about 1.5 to 2m above the floodplain and seem to be underlain by loamy gravel, but there are no sample points.

An assessment of the valley-floor deposits, both upstream and downstream of Milton of Inveramsay, is given in Table 10.

**The valley of the River Urie downstream of Milton of Inveramsay**

*Valley-side deposits*

The lower reaches of the valley of the River Urie were ponded up for a while during the deglaciation of the area, possibly behind a barrier of residual ice that blocked the valley downstream of Inverurie. Glaciolacustrine deposits, comprising interlaminated, very fine-grained sand, silt and clay were laid down in the resulting glacial lake, which stood at approximately 63m above OD. Glacial meltwater flowed along the main valley from the northwest and formed a fan-delta, which prograded downstream. The deltaic deposits merge into terraced fluvioglacial sand and gravel upstream of Milton of Inveramsay [NJ 741 248]. The upper sand and gravel unit of the deltaic sequence is classified and mapped as fluvioglacial sand and gravel, whereas the fine-grained sediments are classified as glaciolacustrine deposits and are mapped as such where they can be identified. The fluvioglacial component is formed chiefly of sand or pebbly sand. The gravel is predominantly fine and the sand is mainly fine to medium-grained. The composition of the mineral is similar to that of the valley-side deposits upstream of Milton of Inveramsay.

The deltaic sand and gravel underlies clearly distinguishable terraces upstream of Howford Bridge [NJ 767 230], but the deposits become more fragmentary and heterogeneous downstream. Complex sequences of interbedded (glacial) sand and gravel, laminated glaciolacustrine deposits and diamictons were proved at boreholes 72 SE 5 and 72 SE 7, which demonstrate the local complexity of the drift sequence in the lower reaches of the valley. Sand and gravel is worked intermittently on a very small scale at two sites, [NJ 7516 2350] and [NJ 7836 2060].

The degraded alluvial terrace lying immediately to the east of Urieside [NJ 773 225] and upon which borehole 72 SE 10 was sited, has been included with the valley-side deposits for the purposes of assessment. The mineral beneath the terrace is considered to be contiguous with the fluvioglacial sand and gravel underlying the higher terrace to the west, rather than being river alluvium.

Based on six sample points (Table 10), the valley-side deposits downstream of Milton of Inveramsay have a mean thickness of 4.3m; they have a mean grading of fines 7 per cent, sand 76 per cent and gravel 17 per cent (pebbly sand).

*Valley-floor deposits*

The floodplain is underlain by a complex sequence of drift deposits that includes some mineral, but the resource is discontinuous. The fragmentary alluvial terraces, on the other hand, appear to be underlain by more or less continuous spreads of sand and gravel, but the mineral is probably thin and clay-bound, as for example, the 1.7m of 'clayey' sandy gravel proved at borehole 72 SE 1.

Only one borehole (72 SE 9) was sited on the floodplain. This proved a complicated sub-alluvial sequence that included interbedded glaciolacustrine deposits, diamictons and glacial sand and gravel. Three resistivity soundings provide extra data; 72 SE R1A and R1B suggest that no mineral is present beneath the floodplain, at least in the vicinity of Conglas [NJ 7546 2312], whereas 72 SE R2, sited downstream, indicates that mineral may be present, but beneath 8m of overburden.

Apart from the alluvial terrace at Urieside [NJ 773 225], the other lower lying alluvial terraces have been included with the floodplain for the purposes of assessment; any mineral underlying these features lies predominantly below the water-table, unlike the valley-side deposits.

Based on five data points (Table 10), the mean thickness of mineral underlying the floodplain and alluvial terraces of the River Urie (both upstream and downstream of Milton of Inveramsay) is 2.1m; it is concealed beneath a mean thickness of 2.7m of overburden. Based on just two sample points, the mean grading of the mineral is fines 12 per cent, sand 56 per cent and gravel 32 per cent ('clayey' sandy gravel).

**The valley of the Lochter Burn**

The glacial lake that occupied the lower reaches of the valley of the River Urie also extended northwards into the valley of the Lochter Burn. Widespread terraced deposits of silt, clayey silt and plastic clay accumulated in the lake and they merge southwards into the terraces of deltaic fluvioglacial sand and gravel flanking the main valley. No sample points were sited on the glaciolacustrine deposits, which are thought unlikely to either include, or overlie, any important deposits of sand and gravel.

The broad alluvial flat extending between Sauchenloan [NJ 770 258] and Newton of Mournie [NJ 759 289] is thought to conceal some discontinuous spreads of mineral, but there are too few data points on which to base anything other than an entirely speculative assessment. Gravel is exposed in ditches locally, especially towards the north of the alluvial flat, and sand was formerly dug from a small pit [NJ 7734 2628] situated beside the now dismantled railway that linked Inverurie with Oldmeldrum. Over 1.9m of sandy gravel was found to lie beneath 1.6m of overburden just to the south of the old workings. A resistivity sounding (72 NE R1), taken a little to the north, suggests that the mineral deposit is no more than about 2m thick. In any case, most of the mineral lies below the water-table and cannot, therefore, be regarded as an important resource.

An isolated mound formed of very heterogeneous, poorly sorted gravel has been worked in a small pit [NJ 7682 2826] to the northwest of Netherton of Mournie. A mechanical excavator was used to clean up a face in the old working (72 NE 1), which revealed just 1.7m of mineral resting on till. This deposit is too small to assess.

Based on three data points (Table 11), a mean thickness of 1.9m has been assumed in the assessment of mineral lying within the valley of the Lochter Burn.

**The valley of the River Don**

*Valley-side deposits*

The River Don flows through a deep valley for a distance of 5km upstream of Inverurie. During the final deglaciation of the area, a residual mass of ice blocked the valley for some time, causing meltwaters upstream to be diverted along a more direct route towards Kintore (see MAR 146). The present valley was bypassed until meltwater began to pass the ice barrier, building up fragmentary kame-terrace deposits along the valley-sides. Such fluvioglacial sand and gravel is most widespread between Haughton [NJ 756 201] and Burnhervie [NJ 732 194].

The only sample point in the fluvioglacial sand and gravel was provided by a section in the small gravel pit near Haughton, at the foot of which a trial pit was dug. The combined log (72 SE 4) records 6.6m of gravel (unbottomed), mainly clast-supported, with scattered cobbles and boulders. The composition of the sand and gravel at this site is probably typical for this stretch of the valley. Extra data points are provided by two ancillary trial pit logs (72 SE X4 and X7), but no grading information is available.

Based on three data points (Table 11), none of which record the complete thickness of the deposit, the mean thickness of the valley-side deposits is taken as 3.6m.

*Valley-floor deposits*

There is no floodplain as such to the River Don immediately upstream of Inverurie owing to the relatively steep gradient of the river in this stretch of the valley, but there is a flat strath, which is flanked by fragmentary, low-lying river terraces. Both the strath and the terraces are underlain by dense, often very coarse, clast-supported gravel. There is commonly a layer of interlocking boulders at the surface. The gravels tend to be durable owing to the relatively high flow-regime in which they were laid down. The sand is mainly coarse-grained.

It is clear that the valley was once much deeper than it is today and that there is a complex sequence of drift deposits concealed at depth. Site investigation boreholes (including 72 SE X5 and X6) for a proposed new bridge at Port Elphinstone proved a variety of deposits including diamictons, silt, clay, sand and gravel; some of the material almost certainly pre-dates the last glaciation.

The assessment of the valley-floor deposits (Table 11) is based on six sample points, one of which (71 NW 15) is sited on the Kemnay resource sheet (Mineral Assessment Report 146). The thickest mineral deposit was identified at borehole 72 SE 6 where 8m of alluvial gravel rested directly on bedrock. Elsewhere the deposits are thinner and generally rest on stiff lodgement till.

The mean thickness of the valley-floor deposits (alluvial deposits only) is taken as 3.3m; the mean grading is fines 2 per cent, sand 48 per cent and gravel 50 per cent (gravel).

## DESCRIPTION OF RESOURCE SHEET NJ 70 (DUNECHT)

**Resource block A**

Block A is confined to the catchment area of the Corskie (Kinnernie) Burn,flows southeastwards into the Loch of Skene. The valley of the Corskie Burn is flanked by spreads of fluvioglacial sand and gravel (valley-side deposits) that border a narrow floodplain, which broadens downstream to form an alluvial flat adjacent to the Loch. Deposits of sand and gravel underlying the alluvial tract, which is partly covered by peat, are classed as 'valley-floor deposits' for the purposes of assessment. The terrace and sub-alluvial deposits were laid down during the deglaciation of the area, before all of the residual masses of ice had melted. The loch occupies a large kettle-hole.

*Valley-side deposits*

Some of the most important mineral resources lying above the water-table on sheet NJ 70 occur in the valley of the Corskie Burn. To the west of Dunecht, fluvioglacial sand and gravel underlies kettled terraces that become increasingly moundy upstream. Individual mounds within the terraces are generally 2 to 3m in height, but in the vicinity of Tillybrig Wood [NJ 739 096] the terraces merge into a complex of mounds and ridges standing up to about 5m in height. A pit (70 NW 3) was sited on one of the ridges in this area; it proved 4.2m of loose cross-stratified sandy gravel. Judging from the exposures seen, the deposits hereabout are predominantly sandy. Downstream the mineral is more gravelly and the mounds are more subdued. For example, pit 70 NW 5 proved 3.2m of dense, clast-supported, cobble-gravel beneath a 3m high flat-topped mound. The deposit was not bottomed.

Most of the meltwater that laid down the sand and gravel flowed down the main valley whilst some residual masses of ice still remained there, but some meltwater also entered from tributary streams, such as in the valley of the Bogentory Burn. This burn drains a large topographic depression centred on Skene Moss, just to the north of Sheet NJ 70, and joins the Corskie Burn at Dunecht. Sand and gravel occurs within this side valley, but its extent is unclear.

The fluvioglacial terraces become more prominent and widespread downstream of Dunecht, where they stand between 4 and 6m above floodplain level. The maximum recorded thickness of mineral is 10.6m at borehole 70 NE 1. Sand and gravel is worked intermittently at a small pit near to the South Lodge of Skene House, where a section (70 NE 2) revealed 3.0m of pebbly sand resting on till. The mineral was thicker at the now abandoned workings at Cragiedarg [NJ 7652 0884] and [NJ 7606 0848] near Dunecht Lodge.

Based on six data points (see Table 12), three of which do not record the total thickness of mineral, the valley-side deposits of block A have a mean thickness of 5.0m; the mean grading is fines 2 per cent, sand 59 per cent and gravel 39 per cent (sandy gravel). The gravel fraction is mainly composed of pink and grey granite with some psammite, quartzite, red porphyry and semipelitic gneiss, and rare platy pelite. The sand is medium to coarse-grained, quartzo-feldspathic and sharp.

### *Valley-floor deposits*

The Loch of Skene occupies a large kettle-hole which lies at the centre of an elongated ice-scoured depression that is largely infilled with sand. The mineral is overlain by peat to the west of the Loch, but it is only concealed beneath thin alluvial deposits to the east. Borehole 70 NE 3, located beside the Corskie Burn, proved 8.5m of water-saturated pebbly sand. Only the uppermost 1.6m of this deposit is regarded as being of alluvial (Post-Glacial) origin, the rest is probably fluvioglacial outwash. Borehole 70 NE 10, which was located to the east of the loch, proved 5.7m of water-saturated sand overlying interlaminated glaciolacustrine clay, silt and sand. The whole of the upper sand unit is classified as alluvium, but only the uppermost 1.5m is definitely alluvial, the rest is probably Late-Glacial in age and deltaic in origin.

Based on just three sample points (Table 12), one of which did not bottom the mineral, the mean thickness of the valley-floor deposits is 5.5m; the mean grading is fines 5 per cent, sand 79 per cent and gravel 16 per cent (pebbly sand). The composition of the gravel component is similar to that of the valley-side gravels described above, being dominated by granite. The sand appears to fine downstream, being medium to coarse-grained at borehole 70 NE 3 and fine to medium-grained at borehole 70 NE 10; it is predominantly quartzo-feldspathic with scattered lithic fragments (mostly granite) and mica.

### *Other Mineral deposits*

The Moss of Air [NJ 778 066] occupies another small ice-scoured topographic depression to the south of the Loch of Skene. No borehole was sited here and it is therefore not known if any mineral underlies the thick deposits of peat hereabout. There is, however, a small terrace lying to the north of, and adjacent to the moss, where over a metre of bedded gravel and sand was seen in a ditch section. The terraced deposits may extend beneath the moss.

The granite, which underlies most of sheet NJ 70 (see Figure 3), is weathered at the surface locally and as such constitutes a potentially large resource of sharp, coarse-grained sand. Pockets of disaggregated granite are common wherever granite crops out, but it is also widespread beneath till. A 10m high face in weathered granite is worked intermittantly in a small quarry [NJ 7586 0770] on the Dunecht Estate. Three resistivity soundings were made in the vicinity of this quarry, but the results were not very informative; it was not possible to distinguish weathered from fresh rock.

No attempt has been made to estimate volumes of granite sand because there is inadequate knowledge of both its thickness and areal extent.

**Resource block B**

Block B falls within the catchment area of the Gormack Burn. The topography of the area is dominated by elongated, E-W orientated depressions that were scoured out by ice as it flowed eastwards around the northern side of the high ground formed by the Hill of Fare and Greymore [NJ 710 039]. The depressions were partly filled with diamictic mass-flow deposits and sand and gravel during, and immediately following deglaciation. This material is overlain by fluviatile or lacustrine alluvium and is capped widely by peat. There are probably no important mineral resources in the block.

The Gormack Burn flows across three topographic depressions. The first, which lies to the west of South Kirktown [NJ 7395 0520], is relatively well drained, probably because it is underlain by sand and gravel. The only sample point (72 NW 2) proved just 1.9m of gravel beneath 1.1m of alluvial clay. The gravel probably thickens towards the centre of the valley, and also upstream, where it crops out widely at the surface. To the south, at Woodside [NJ 7233 0474], the Greymore Burn has constructed a small alluvial cone of cobble-gravel.

The Gormack Burn enters a second and much more extensive topographic depression immediately downstream of South Kirktown. In the west of this flat-lying area there is some well drained fertile land, but in the east the ground surface is largely underlain by water-logged peat. Borehole 70 SW 8, sited in Marketmuir Wood, towards the centre of the depression, proved 2.0m of clayey sandy gravel and 4.1m of clean sandy gravel separated by a waste parting of gravelly clay 1.1m thick. To the west of this site, trial pit 70 SW 9 proved 1.3m of sandy gravel (unbottomed) beneath 1.7m of interbedded clay and sand. The deposits are clearly quite heterogeneous. Gravel crops out along the northern edge of the depression and passes southwards beneath alluvial silt, clay and peat.

The depression just described links with another, smaller one to the north. It is mostly wooded and underlain by peat. Terraced deposits of fluvioglacial sand and gravel border the western side of this flat-lying area and gravel also underlies the floodplain of the burn that flows into it from the northwest. There are no sample points, but the mineral is probably thin and mostly occurs beneath the water-table.

The Gormack Burn flows southwards into another depression to the south of Marketmuir Wood. This depression is drained by the Landerberry Burn; there is some mineral here, but it is patchy. Trial pit 70 SW 10 proved just 1.2m of mineral, although resistivity soundings made nearby indicate that the sand and gravel thickens to about 2.8m towards the centre of the depression. An alluvial cone constructed of gravel has been formed by the Landerberry Burn at Hillbrae [NJ 7382 0425].

Pockets of weathered, disaggregated granite are widespread on the flanks of Greymore and also in the vicinity of Backstrip Wood [NJ 757 045]; this coarse-grained granite sand is probably the most attractive resource within the block.

Based on five data points (see Table 13), one of which did not prove the full thickness of mineral, the mean thickness of all the potentially workable sand and gravel identified within block B is calculated to be 2.7m; the mean grading is fines 5 per cent, sand 60 per cent and gravel 35 per cent (sandy gravel). Most of the mineral lies below the water-table.

**Resource block C**

Block C includes the headwaters of the Leuchar Burn, which flows southwards out of the Loch of Skene. The main tributary of the Leuchar Burn, the Garrack Burn, joins the main stream at Garlogie [NJ 7810 0550]. The Garrack Burn drains an elongated ice-scoured depression lying to the west of Garlogie. Downstream of Garlogie,the Leuchar Burn enters a broad glacially scoured valley that stretches southeastwards beyond the eastern boundary of the sheet; some of the most important mineral resources within the sheet area occur in this valley.

*Valley of the Leuchar Burn*

*Glacial sand and gravel* During the deglaciation of the area, meltwaters entered the valley of the Leuchar Burn from the southwest by way of a series of glacial drainage channels. Little or no sand and gravel is associated with these channels except for one narrow esker, which leads from Forbridge Cottage [NJ 7774 0456] northeastwards into the main valley. The ridge is 3 to 6m high and about 40m wide at its base. A mechanical excavator was used to obtain samples from a small overgrown pit (70 SE 16) sited in the ridge; it revealed 5.3m of poorly consolidated, heterogeneous sand and gravel (unbottomed) which included some very large boulders. A trial pit (70 SE 17) was dug close to the ridge to investigate whether mineral extended laterally beyond the feature, but it appears not to do so.

The esker leads northeastwards into a complex of mounds and ridges separated by peat-filled kettle-holes. These moundy ice-contact deposits (glacial sand and gravel) are separated by the floodplain alluvium of the Leuchar Burn from a more extensive spread of moundy deposits along the northern flank of the valley. The latter deposits are possibly thickest to the south of Roadside of Garlogie [NJ 790 054] where borehole 70 NE 9 proved 4.1m of sand and gravel. This borehole was sited at the base of a 6m high mound, which indicates that the mineral is locally as much as 10m thick hereabout. The mounds decrease in height and become increasingly isolated eastwards.

Perhaps the largest mound of glacial sand and gravel has been almost completely removed at the former Garlogie Pit [NJ 7985 0555], which is now used by the local authority as a storage site for road material and salt. To the west of the pit, and on the opposite side of the A974 road, there is a tree-covered plateau that appears to be constructed of sand and gravel, but a trial pit (70 NE 12) sited there proved just 1.0m of poorly sorted gravel. Sand and gravel also underlies Torshinach Wood [NJ 798 053], to the south of Garlogie Pit, but its thickness is not known. Farther to the south there is an isolated mound of very loose, well sorted, pebbly sand where section 70 SE 19 revealed 5.5m of mineral (unbottomed). Apart from this mound, the sand and gravel in the vicinity is probably thin.

Assessment details are presented in Table 14. Mean gradings have been calculated separately for the fluvioglacial and glacial sand and gravel separately as the two types of deposit have distinctive grading characteristics. Inferred estimates of volume have been calculated for the deposits separately, but a statistical estimate is offered for the deposits combined.

*Fluvioglacial sand and gravel* The glacial sand and gravel described above was deposited whilst residual masses of ice were still widespread, especially in the centre of the valley. As the ice melted, the valley became ponded-up and a series of fan-deltas were constructed as meltwater continued to enter from the southwest. The most extensive fan originates to the southwest of Standingstones [NJ 7850 0420], where it is constructed of cobble-gravel. The fan merged into a delta downstream, as indicated by the drilling results at boreholes 70 SE 18, 70 SE 20 and 70 SE 21, which show the sand and gravel to fine progressively down-valley and to overstep laminated glaciolacustrine silts and clays. As the surface of the fan decreases in height downstream and approaches the level of the floodplain of the Leuchar Burn, an increasing proportion of the mineral lies below water-table.

Important resources of coarse-grained sand and fine gravel occur in the vicinity of a back-filled and landscaped sand and gravel pit [NJ 7900 0430] near Newleuchar, but the most attractive resources that remain, lie to the northwest of the gravel pit. Here there are terraced, heather-covered spreads of gravel bordering Leuchar Moss . Resistivity soundings 70 SE R2A and R2B indicate that there is in the order of 5.4 to 5.7m of gravel overlying glaciolacustrine silt and clay. Most of the mineral lies above the water-table. The peat of Leuchar Moss is underlain by water-saturated sand overlying glaciolacustrine silt and clay.

Thickness and grading data are summarised in Table 14. The composition of the gravel fraction (glacial and fluvioglacial deposits) is dominated by grey and brown granite with some amphibolite, quartzite, red porphyry and diorite. The sand fraction of the glacial deposits is mainly coarse to medium-grained whereas that of the fluvioglacial deposits is mainly fine to medium-grained. The sand is composed mostly of quartz and feldspar with a little mica.

*The valley of the Garrack Burn*

Terraced deposits of sand and gravel were laid down around a mass of stagnant ice, which remained stranded in the centre of the glacially scoured valley of the Garrack Burn during the final stages of deglaciation in the area. Meltwaters entered the valley via drainage channels on all sides of the ice mass.

The only sample point, 70 NE 8, proved just 1.7m of pebbly sand, but over 2.5m of cross-bedded sands were recorded in a pipeline trench that was dug across the western end of the valley, adjacent to the peat moss, prior to this survey. At the other end of the valley, over 2.5m of cross-bedded pebbly sand was exposed in the banks of the artificially lowered section of the burn towards Garlogie. It is interesting to note that the direction of cross-bedding here indicates a westward palaeocurrent, that is, up the valley and not down it. The reason for this is unclear. Water-saturated sand probably underlies the peat occupying the centre of the valley.

A speculative assessment is made of the mineral lying within the valley of the Garrack Burn; it is based on the one sample point listed in Table 14 together with the recorded thicknesses at the two exposures noted above.

**Resource block D**

This block includes a complicated mosaic of deposits occupying a large, elongate topographic depression that strethes for 4.5km to the southeast of Northton [NJ 7710 0395]. The depression was scoured out by glacier ice as it moved northeastwards around the Hill of Fare and Meikle Tap [NJ 7229 0260]. As the ice melted, the depression was partly filled with outwash sand and gravel, glaciolacustrine silt and clay and diamictic mass-flow deposits. This material was then buried widely beneath Post-Glacial alluvium and peat. The Gormack Burn flows into the low-lying ground from the northwest, near Tillishogle [NJ 7540 0380] and it leaves it via an artificially cut route to the south, near Blackdams [NJ 7575 0225].

The block includes relatively large resources of sand and gravel, but most of it lies below the water-table and much is of poor grade. The most attractive resources are those classified as glacial sand and gravel; these mainly lie above the water-table. Other resources of sand and gravel are grouped together as 'valley-floor deposits' for the purposes of assessment; they are predominantly water-saturated. The morainic drift is assessed separately.

*Glacial sand and gravel*

Mounds of glacial sand and gravel, separated by alluvial flats and peat-filled kettle-holes, occupy the northeastern end of the topographic depression described above. To the south of Little Finnarcy [NJ 7676 0416] the mounds reach a maximum height of about 10m above the level of the surrounding peat bogs. Borehole 70 SE 7 was sited about 5m below the highest point of the highest mound; it proved 11.0m of heterogeneous sand and gravel suggesting that the mineral extends several metres below the level of the surrounding flats. To the southeast of this site, a trial pit was dug into the side of a much smaller mound; it proved 3.7m of mineral, unbottomed. Moundy sand and gravel flanks the valley-sides but the mineral is probably thin.

A very large, isolated mound lies 150m to the northeast of Northton; it stands at about 16m above the level of the surrounding land. Borehole 70 SE 13 was sited almost at the top and it proved 13.8m of mineral, mostly sand. The deposit is cut by a glacial meltwater channel that extends northeastwards towards the valley of the Leuchar Burn in block C; the mound was therefore formed quite early in the deglaciation of the area.

The only other notable deposit of glacial sand and gravel forms a narrow, 3m high esker that lies to the east of Nether Woodside [NJ 7460 0290]. A mechanical excavator was used to clean up a small disused working in the ridge; the section (70 SW 12) revealed 4.6m of mineral, unbottomed.

Based on four sample points (see Table 15), two of which did not bottom the mineral, the mean thickness of the potentially workable sand and gravel described above is 8.3m; the mean grading is fines 9 per cent, sand 63 per cent and gravel 28 per cent (sandy gravel).

*Valley-floor deposits*

The thickest deposit of mineral was proved at borehole 70 SE 1, which was sited on peat at the centre of an extensive area of flat, poorly drained ground. At this site, 4.2m of alluvial pebbly sand is separated from a lower unit of fluvioglacial sandy gravel 6.0m thick, by 1.7m of laminated silt and clay. The alluvium is probably the distal part of an alluvial fan constructed by the Gormack Burn and partly concealed beneath peat. Alluvial coarse-grained pebbly sand crops out from beneath the peat 500m to the west of the borehole site, and it is also exposed in many ditches around the periphery of the flat. A large resource of pebbly sand undoubtedly underlies this flat-lying area but virtually all of it is below the water-table.

The peat moss, upon which borehole 70 SE 1 was sited, is bordered to the southwest by a low-lying, kettled spread of fluvioglacial sand and gravel south of Nether Woodside [NJ 746 029]. There are no sample points within this spread of mineral, but there are many small exposures of coarse gravel. For example, over 2m of bedded, clast-supported cobble-gravel with lenses of clean, medium-grained sand, was exposed in the foundations of a new building at [NJ 7450 0252]. The mineral, which is probably less than 3m thick in general, was deposited by meltwaters that debouched from a broad glacial drainage channel to the southwest. Meltwaters constrained within the ice-sheet to flow in the same direction as those which cut the drainage channel, had previously formed the esker that borders the fluvioglacial spread to the north.

The spread of fluvioglacial sand and gravel south of Nether Woodside borders an extensive and thick deposit of basin peat between Birks Farm [NJ 742 025] and the Silverstripe Burn. The peat underlies low-lying ground in the vicinity of the B977 and the B9125 road junction, but it also extends southwards beyond the topographic basin, towards Red Moss [NJ 747 014], where it forms a blanket moss which is several metres thick and locally uncut. Patches of sand and gravel may underlie the peat within the basin, but it is unlikely to do so beneath Red Moss.

Another low-lying spread of fluvioglacial gravel borders the basin peat to the southwest. It was probably deposited late in the deglaciation of the area as meltwaters entered the ice-scoured depression from glacial drainage channels lying to the southwest. The deposit, which is locally concealed beneath peat, is generally coarse. For example, the first two attempts at digging trial pit 70 SW 6 had to be abandoned because the mechanical excavator could not penetrate a continuous, interlocking network of boulders up to 1m in size. The third attempt proved 2.1m of cobble-gravel, but the deposit was not bottomed. Resistivity soundings (70 SW R2A and R2B) conducted at this site, suggest that the mineral is about 4.1m thick.

The spread of fluvioglacial gravel seems to continue eastwards into the shallow valley of the Silverstripe Burn, where trial pit 70 SW 16 proved 3.1m of relatively clean and well sorted sandy gravel; the deposit was not bottomed. Over 1.5m of clast-supported gravel was also seen in a temporary exposure on the opposite side of the burn, and farther to the southwest, trial pit 70 SW 17 proved 1.3m of gravel resting on till. The isolated mounds of glacial sand and gravel that have been mapped out in this vicinity have been considered together with the deposits of morainic drift for the purposes of assessment.

Based on six data points (Table 15), two of which did not prove the full thickness of mineral, the mean thickness of the potentially workable valley-floor deposits is 3.7m; the mean grading is fines 7 per cent, sand 62 per cent and gravel 31 per cent (sandy gravel).

### *Morainic drift*

Deposits of morainic drift occur widely in block D where they constitute a large resource of poor grade, heterogeneous sand and gravel. The material has been dug on a very small scale at numerous localities, mainly for filling potholes in rough tracks, for roadbase and inert fill. The most attractive resources occur around Tillyorn [NJ 7534 0250] and Westerton [NJ 7615 0290]; elsewhere the material is exceedingly coarse.

A mechanical excavator was used to clean up a face in a disused roadside pit [NJ 7468 0228] dug into the side of a 4m-high mound of morainic drift. The section (70 SW 13) revealed 4.6m of potentially workable diamicton (Mineral II) grading as 'clayey' sandy gravel, overlying 1.6m of laminated glaciolacustrine deposits (waste). The diamictic material displayed in this face is typical of what is considered in this report to be morainic drift. The poor sorting, slightly clay-bound matrix, a lack of any laterally persistant bedding and the presence of large angular blocks of local rock are all characteristic of the morainic drift, which was formed mainly by mass-flowage of unconsolidated glacial debris during the final stages of deglaciation. The degree to which the material has been water-sorted is highly variable, even over distances of a few centimetres.

Morainic drift typically forms very irregular, hummocky topography and light sandy soils, and for these reasons it is often difficult to distinguish it from moundy deposits of water-sorted sand and gravel. Indeed, the two types of deposit interdigitate locally and merge one with another, as they do, for example, at borehole 70 SW 15. Morainic drift generally has been delineated on the basis of landform, but this can be misleading. For example, trial pit 70 SW 3 was dug into a bracken-covered mound of morainic drift but proved only 1.3m of diamictic clayey sand overlying very stiff lodgement till. On the other hand, trial pit 70 SW 7 was sited on relatively flat, poorly-drained ground mapped as till and yet proved over 2.5m of potentially workable diamicton that was more typical of morainic drift than till.

Assessment details are given in Table 15. The results of pit 70 SW 7 are included in the calculations of mean thickness and grading even though the deposit is not classified as morainic drift in the log. As the resource is known to be discontinuous, the total area of morainic drift has been reduced by 25 per cent for the purposes of calculating the volume.

### Resource block E

This block includes the northern fringe of an extensive, shallow ice-scoured basin that lies to the south of Druggam [NJ 7430 0062], mainly within the area covered by the adjacent resource sheet (NO 79). The block includes insignificant resources of sand and gravel and some potentially workable morainic drift. Pockets of weathered, disaggregated granite are widespread beneath the higher ground, but particularly within the Howe of Corriechie [NJ 705 025]; as in block B, this coarse-grained granite sand is probably the most attractive resource within the block.

*Sand and gravel (undivided)*

The alluvium of the Burn of Corriechie (which downstream becomes the Hatton Burn) is locally gravelly, especially where the burn emerges from the mountain glen to the northwest of Craigton [NJ 7168 0060], but there are no sample points. A borehole (70 SW 1) was drilled on a mound of glacial sand and gravel lying to the west of Craigton; it proved just 2.0m of 'very-clayey' sandy gravel.

Alluvial sand and gravel borders the northwestern side of Black Moss [NJ 743 001]. There are no sample points here but up to 1.5m of clast-supported, moderately well-sorted gravel was observed in several of the drainage ditches that run southeastwards towards the moss. The mineral is probably generally less than about 2m in thickness. Sand and gravel was formerly dug in a small pit [NJ 7425 0042] to the south of Druggam and probably also at the site of a local authority coup [NJ 7362 0002], to the east of Hirn. A resistivity sounding (70 SW R1) undertaken on Black Moss suggests that the peat is underlain hereabout by about 1.5m of gravelly sand resting on non-mineral flow-till and glaciolacustrine deposits.

*Morainic drift*

Deposits of morainic drift occur in the vicinity of Hares Wood [NJ 750 000] and to the northeast. The material forms irregularly-shaped mounds up to about 5m high, separated by marshy hollows. The only sample point, trial pit/section 70 SE 5, revealed 3.7m of potentially workable diamicton (Mineral II) grading as 'clayey' pebbly sand. For general remarks about the morainic drift please see notes on block D. Much of the till within the block is also potentially workable, for example, that proved in trial pit 70 SW 4.

Assessment data is given in Table 16.

**Resource block F**

This block includes the valley of the Gormack Burn downstream of Milltown of Cullerlie [NJ 7620 0226] and contains some modest resources of sand and gravel in the form of moundy glacial deposits, together with alluvial and sub-alluvial valley-floor deposits. Pockets of weathered, disaggregated granite are common on the high ground, especially in the vicinity of Drum Hill [NJ 7920 0020], where the material is being worked in a small quarry, mainly as grit for footpaths and roads within the grounds of Drum Castle.

*Glacial sand and gravel and other valley-side deposits*

During the deglaciation, whilst ice still occupied the valley of the Gormack Burn, meltwaters took a northeasterly to easterly route across the area. In the vicinity of Lower Candyglirach [NJ 761 014], they carved out a system of glacial drainage channels that lead downhill towards a discontinuous, sinuous esker. Trial pit 70 SE 12 was sited at the western end of the esker string; it proved over 3.3m of cross-bedded, unconsolidated sandy gravel. The esker ridges are generally less than 3m in height but they were higher at Horsewell Hillocks [NJ 777 018], where they have now been completely dug away in a large gravel working. The esker is mainly composed of large boulders to the west of Horsewell Hillocks, but to the east the deposit appears to be more sandy. It merges into moundy spreads of glacial sand and gravel in the vicinity of Hardgate [NJ 7902 0168], where borehole 70 SE 22 proved 3.5m of sandy gravel resting on till. There are low mounds of sand and gravel in the vicinity of Horsewells [NJ 7788 0162], but borehole 70 SE 15 proved only 0.4m of sand, mainly because it was sited right on the edge of the mineral deposit. Over 1.5m of bedded sand and gravel was exposed in a small working [NJ 7910 0147] to the southeast of Hardgate. To the east of here, the moundy deposits merge downstream into terraced fluvioglacial sand and gravel, which flanks both sides of the valley.

Based on just two sample points (Table 17), one of which did not prove the full thickness of mineral, the mean thickness of glacial sand and gravel is 3.4m; the mean grading is fines 3 per cent, sand 65 per cent and gravel 32 per cent (sandy gravel). The gravel is mainly composed of pink and grey granite with psammite, gneiss and some quartzite. The sand is chiefly medium to coarse-grained, angular and quartzo-feldspathic. The mineral lies mainly above the water-table.

*Valley-floor deposits*

The Gormack Burn flows through an artificial cut to join the Silverstripe Burn at Mill Croft [NJ 760 022]. Downstream of here, the valley broadens out considerably as a result of glacial scouring. Quartains Moss [NJ 775 020] occupies the centre of the valley. The Gormack Burn follows another artificial channel that has been cut through this wide expanse of peat. Borehole 70 SE 14 was sited towards the northern edge of the moss where it proved 3.5m of clean fluvioglacial sand and gravel beneath 3.0m of overburden consisting of peat and alluvial silt. At the western end of the moss, resistivity soundings 70 SE R1A and R1B indicate that between 1.4 and 1.5m of gravelly sand overlies till. The mineral is exposed nearby in several of the deeper ditches; it comprises clean, relatively well sorted, coarse-grained pebbly sand. As sand was also seen underlying peat in ditches towards the eastern end of the moss, it is reasonable to suggest that sand underlies the whole of the moss, but it all lies below the water-table. There are no sample points downstream of here but the alluvium appears to be sandy, and locally gravelly.

Based on just two data points, the mean thickness of the potentially workable valley-floor deposits is 2.5m; the mean grading based on borehole 70 SE 14 is fines 8 per cent, sand 60 per cent and gravel 32 per cent (sandy gravel). The resource is almost wholly water-saturated.

## DESCRIPTION OF THE BANCHORY/STONEHAVEN RESOURCE SHEET

### Resource block A

This block covers all of the Banchory/Stonehaven resource sheet that lies to the north of the valley of the River Dee; the town of Banchory covers 1.2km$^2$ of ground in the southwestern corner. Most of the high ground is covered by thin spreads of till on bedrock and is considered to be barren. The main deposits of mineral lie within the valleys drained by the Burn of Coy, Bo Burn and the Burn of Bennie and within the topographic depression centred on Cunnach Moss [NO 754 996].

Twenty-five sample points were sited within the block (Table 18), of which twelve proved potentially workable sand and gravel (Mineral I); two proved potentially workable till (Mineral II) and two proved potentially workable weathered granitic bedrock.

The bedrock (see Figure 4) comprises granitic rocks of the Crathes and Hill of Fare masses except at the western edge of the block, north of Banchory, where migmatitic gneiss and pelitic and semipelitic schist crop out. In places, the granitic rocks are weathered to a depth of several metres and have been worked locally. At Sunnybrae [NO 779 985], 4m of light grey medium-grained granite, weathered to clayey quartzo-feldspathic sand, is exposed in a small pit. The pit is worked as a source of fill used in the construction of farm tracks. Similar material has been recorded in trial pits at Bush Croft (79 NW 11) and at Nether Park (79 NE 7).

The broad depression centred on Cunnach Moss is the principal topographic feature of block A. It extends northwards into the area covered by the adjoining Dunecht resource map and marks the site of a former proglacial lake which covered approximately 6km$^2$ of ground between Mill of Hirn [NO 728 996] and Lochside [NO 771 985]. The lake basin was formed by glacial scouring of the weathered Crathes granite, which is exposed in the bank of Black Burn at grid reference [NO 7618 9895]. The lake was ponded behind ice that blocked the southeastward drainage of meltwater, derived mainly from the downwasting of ice on the flanks of the Hill of Fare.

Eight sample points were sited within the former lake basin, five proved thin deposits of mineral (mainly silty medium and fine-grained quartzose sand up to 2.8m thick) lying at or near groundwater level; a sixth (trial pit 79 NE 2, at Collonach Plantation) proved a thin deposit of gravelly flow-till overlying 2m of clayey morainic drift, not bottomed. Most of the silty sand occurs within the flat spreads of lacustrine alluvium to the west of the Loch of Park [NO 768 988], but discontinuous spreads of sand and fine gravel also occur beneath peat between Cunnach Moss and Lochside, and within the underlying glaciolacustrine deposits.

Thicker deposits of exposed mineral were proved in the two remaining boreholes, sited near the centre of the basin. In borehole 79 NW 16, 2.6m of dry pebbly sand rests on 3.3m of clayey sand lying below the water-table, and in borehole 79 NW 24, 1.9m of dry sandy gravel overlies 1.3m of wet pebbly sand on clayey flow till.

The Loch of Park, at the western end of the basin, was a body of open water at the time of the first geological survey of the area, published in 1897. The Loch has since been drained and is now a flat marsh with a surface level of approximately 68m above O.D. It is underlain by thick spreads of peat overlying glaciolacustrine silt containing discontinuous lenses of fine-grained sand.

Flat-topped spreads of fluvioglacial sand and gravel flank the peat marsh near Lochside. These spreads rise between 2 and 3m above the level of the peat and constitute a small resource of clean, well-sorted, pebbly, fine-grained sand.

In the vicinity of Myrebird Plantation [NO 746 992] the lacustrine alluvium and glaciolacustrine deposits, which include some potentially workable sand and gravel, rest on till (see cross-section B-B'). To the west, near Newmill [NO 734 993] stratified sequences of flow-till and mass flow deposits, which contain no potentially workable material, infill the basin.

A linear ridge of morainic drift up to 20m in height stretches between Collonach [NO 765 998] and Lochside and marks a position of still-stand during the decay of the ice barrier to the east of the proglacial lake. The moundy morainic deposits comprise gravelly diamictons which have a matrix of silty clay and sand containing rounded boulders of coarse-grained pink and light grey granite up to 2m in diameter (probably derived from the Crathes granite). Intercalated lenses of poorly sorted, matrix-rich gravel present within the morainic drift sequence may constitute a potential source of aggregate, though their thickness and extent are highly variable locally.

A complex group of glacial drainage channels, trending NW-SE, are cut into granite bedrock in the vicinity of Tersets [NO 780 990]. Some of the channels are thought to have been cut by meltwater draining beneath the ice barrier. The undulating long profiles of the channels are characteristic of erosion by subglacial meltwater streams under hydrostatic pressure.

Mounds of glacial sand and gravel were deposited in contact with ice that blocked the valley of Bo Burn south of Bohill [NO 714 993]. A working in the deposit (79 NW 26) shows 2.7m of pebbly sand overlying till. During deglaciation a small proglacial lake formed in the valley to the west of the ice contact deposits; the extent of the lake is indicated by thick spreads of peat overlying silt and sand. As the ice decayed, a second lake formed in the valley to the east and glacial meltwater drained towards the Mill of Hirn. A thick sequence of glaciolacustrine deposits overlain by peat was deposited in this lake. The glaciolacustrine deposits contain discontinous lenses of fine-grained sand, some of which crop out beneath the peat in the banks of Bo Burn south of Lightwood [NO 721 994].

The Loch of Leys [NO 702 978], north of Banchory, also marks the position of a former proglacial lake that drained southwards, via the valley of the Burn of Bennie, towards the valley of the River Dee. The Loch of Leys has been partially drained in the recent past, and is now a waterlogged peat marsh with ephemeral patches of standing water. Hummocky spreads of glacial sand and gravel overlying till flank the southern edge of the lake basin and flat-topped spreads of fluvioglacial sand and gravel crop out around the edges of the loch. A small disused working (79 NW 25) in the fluvioglacial deposits showed 2.2m of pebbly sand exposed above the water-table.

A pit (79 NW 8) sited on the thin spread of lacustrine alluvium in the valley of the Burn of Bennie proved 1.4m of horizontally bedded sandy gravel overlying clayey till. Previous excavations carried out by the landowner indicate, however, that much of the alluvium to the west of the pit site consists of silt and clay. A similar sequence of alluvial deposits is present in the valley of the Burn of Coy where exposed spreads of pebbly sand occur north of Baldarroch Wood [NO 749 975], but a pit (79 NW 18) sited near Denwood belt [NO 739 972], proved 1.7m of 'clayey' pebbly sand, unbottomed, beneath 0.4m of soil and 1.0m of laminated clay. A pit (79 NE 4) further to the east, proved only 0.7m of poorly sorted gravel overlying stiff clayey till.

A discontinuous esker ridge, near Denwood Belt, was deposited by a subglacial meltwater stream which drained eastwards towards the valley of the Burn of Coy. The esker leads from one of several steep-sided glacial drainage channels cut into granite bedrock that crops out north of Crathes Castle [NO 734 968]. The esker stands up to 3m above the surrounding alluvium and is mainly composed of fine gravel containing abundant rounded clasts of Crathes granite. Faces in a small disused working in a similar esker ridge, south of Baldarroch Wood, revealed up to 1.5m of coarse granitic sand overlain by poorly sorted gravel.

**Resource block B**

The boundaries of block B are drawn to include the terraces and the floodplain of the River Dee between Banchory and Drumoak. The block also includes the terraces and alluvium of the Water of Feugh near its confluence with the River Dee. A statistical assessment for the sand and gravel in this block is based on the records of eleven assessment boreholes, excavations in three disused sand and gravel workings, two shallow pits and data from two resistivity sounding sites (see Table 19).

Most of the ground in block B is mineral-bearing; less than 1m of overburden was proved at each sample point. Sand and gravel lying beneath the villages of Crathes and Drumoak, however, has been excluded from the assessment. Barren ground is largely confined to small spreads of till on the flanks of the main valley and to bedrock, which is exposed in places in the banks of the River Dee and the Water of Feugh. Areas of made ground are also considered to be barren.

The main sand and gravel resources of this block are found beneath the kame-terraces and fluvial terraces that flank the floodplain alluvium of the River Dee; they represent more than half the total resources of sand and gravel within the sheet as a whole (see Table 9).

The kame-terraces between Banchory and Drumoak rise up to 20m above the floodplain of the River Dee on both flanks of the valley. In the vicinity of Crathes [NO 750 964] the surfaces of many of the higher terraces are kettled, whereas those to the south of the river, between Kirkton of Durris [NO 773 962] and Nether Balfour [NO 786 969], are relatively flat.

Excavations in a disused gravel pit at Milton Wood (79 NW 21) proved 11.6m of clast-supported fluvioglacial sand and gravel, not bottomed, underlying the kame-terrace between Milton [NO 742 962] and Crathes Castle [NO 734 968]. The sequence is horizontally bedded; several fining-downwards cycles are present in the top 3.5m of the section. The clasts are generally well rounded, comprising mainly red and light grey granite of local affinity with subordinate amounts of psammite and fine-grained acid volcanic rocks. An excavation (79 NW 22) in a nearby working in the terraced deposits near Milton Cottage [NO 746 961], proved 5.2m of well-sorted sandy gravel, not bottomed.

Terraced spreads of fluvioglacial sand and gravel stand up to 15m above the floodplain on the southern side of the valley, between Balbridie [NO 737 957] and Knappach Toll [NO 724 959]. A section (79 NW 14) in the deposits exposed 7.0m of coarse gravel, not bottomed. The gravel shows well-developed sub-horizontal bedding and contains abundant subangular to subrounded granitic clasts. The deposit, which becomes silty towards the base of the section, contains a high proportion of cobble-grade material and thins rapidly westwards; it abuts a vertical rock cliff to the north of Maryfield [NO 720 957].

Extensive spreads of gravel underlie lower lying kame-terraces between Knappach Toll and Birkwood [NO 713 959]. Two boreholes (79 NW 9 and NW 12), sited on the terraces, proved 4.1m and 14.5m of coarse gravel respectively, overlying till. The excessive washing and comminution of material caused by chiseling whilst drilling these boreholes, has probably resulted in considerable underestimation of the proportion of fines and cobble-grade material present.

The thickest deposits of sand and gravel in block B occur at the eastern margin of the sheet, in the vicinity of Keiths' Hill [NO 799 982]. The sand and gravel extends into the area covered by the adjoining Peterculter resource sheet (Mineral Assessment Report 146), where the deposits are being worked in the recently opened Park Quarry, at Gallow Hill [NO 806 978].

In the Keiths' Hill area the ground surface is formed into a series of NW-SE and N-S trending steep-sided hillocks and ridges up to 25m in height. Some of the ridges are thought to be primarily of depositional origin. They formed as eskers composed of coarse glacial gravel deposited by meltwater streams within the ice-sheet. Many of the smaller ridges, however, are the remnants of a previously more extensive kame-terrace, which has been highly dissected by glacial meltwater. The complexity of the topography is mirrored by the variations in grade and composition of the sand and gravel recorded in borehole 79 NE 12,sited on top of Keiths' Hill, and in the nearby sand and gravel pit. The borehole proved 15.4m of gravel and pebbly sand, overlying weathered reddish-brown granite bedrock. The sand and gravel, which occurs in several fining-downwards cycles, ranges in composition and grade from 'clayey' fine and medium-grained sand with scattered pebbles of granite, pelite, psammite and basic igneous rocks, to silty coarse gravel with abundant cobbles of psammite, quartzite and gneiss. The deposit is very variable in thickness locally; east of Keiths' Hill, for example, the sand and gravel thins rapidly beneath a kettle-hole infilled with laminated silt and clay.

More extensive mineral deposits occur beneath the low-lying fluvial terraces and floodplain of the River Dee. Most of this material lies below groundwater level, however, and is therefore less attractive as a potential source of aggregate than the kame-terrace deposits.

Four assessment boreholes, two shallow pits and four resistivity soundings (taken at two locations: 79 NW R1A and R1B and 79 NE R3A and R3B) were sited on the floodplain and fluvial terraces. Two of the boreholes (79 NE 5 and NE 9) failed to bottom the sand and gravel at depths of 10.1m and 11.3m respectively (both were terminated due to drilling difficulties caused by large boulders at the base of the hole). Resistivity soundings on the fluvial terrace northwest of Balbridie (79 NW R1A and R1B) and on the alluvium north of Nether Balfour (79 NE R3A and R3B) gave interpreted thicknesses for the sand and gravel of 7.8 and 9.9m respectively. These figures, together with a total thickness of 11.1m of sand and gravel proved in assessment borehole 79 NW 13, suggest that the two unbottomed boreholes penetrated almost the total thickness of mineral.

The terraced fluvial deposits south and east of Drumoak are thinner than elsewhere in block B. A pit (79 NE 13) north of East Park [NO 792 981] proved only 1.7m of clast-supported sandy gravel overlying weathered granite bedrock and borehole 79 NE 11, to the southeast of the village, proved 5.1m of gravel overlying till. Thicker deposits of sand and gravel occur beneath a forestry plantation at Keiths' Muir [NO 795 985], where flat-topped terraced spreads of sandy cobble gravel rise up to 8m above the floodplain. They also occur between Park House [NO 780 976] and East Park where a narrow flat-topped ridge of sandy gravel stands up to 15 metres above the alluvium.

An alluvial cone has been formed at the mouth of the Burn of Coy. A temporary excavation, east of Milton [NO 742 962], showed 2m of dry, clast-supported cobble-gravel resting on water-saturated gravel in the floor of the pit. The cobble-gravel is well sorted and horizontally bedded; it is mainly composed of rounded granite and tabular psammite clasts and contains little interstitial sand, silt or clay-grade material. The cone was deposited from rapidly flowing water debouching into the valley of the River Dee from the north. The water dissected the earlier spreads of fluvioglacial sand and gravel in the vicinity, and redeposited the coarse gravel and cobble-grade material as a flat-topped alluvial cone.

**Resource block C**

Block C covers most of Sheet NO 79 lying to south of the valley of the River Dee. It is bounded to the southwest by the high ground forming the watershed between the catchment of the River Dee and the streams that flow towards the coastal lowlands in the east of the district. Much of the ground is drained by the Burn of Sheeoch and its tributaries, which flow northwards to join the River Dee near Kirkton of Durris [NO 773 962]. The northeastern margin of the block is drained by the Burn of Durris, which flows northwards from Craigiedaff [NO 799 945] to join the River Dee near Drumallan [NO 797 979]. The high ground in the southwestern corner of the block is drained by the Burn of Knock, which flows northwestwards towards the Water of Feugh.

Most of the potentially workable deposits of sand and gravel occur on the flanks of these tributary valleys, which were the principal routes of glacial meltwater drainage across the area.

A total of 27 sample points were sited in the block of which 18 proved potentially workable sand and gravel (Mineral I) and three proved potentially workable till (Mineral II).

A statistical assessment (Table 20) is given for the sand and gravel deposits in valleys of the Burn of Sheeoch, Garrol Burn, Strathie Burn and the Burn of Durris, together with the deposits south of Bogforran [NO 731 929]. A separate inferred assessment is offered for the fluvioglacial sand and gravel and morainic drift in the valley of the Burn of Knock.

*Fluvioglacial sand and gravel, glacial sand and gravel and glaciolacustrine deposits in the valleys of the Burn of Sheeoch and Garrol Burn*

The principal mineral resources in block C occur on the flanks of the valleys of the Garrol Burn and the Burn of Sheeoch, between its confluence with Garrol Burn, east of Westerton [NO 736 913] and its confluence with Strathie Burn, west of Little Tulloch [NO 778 951]. Minor resources are also present in the floor of the valley of the Burn of Sheeoch, upstream of Sheeoch Linn [NO 742 909] and downstream of its confluence with Strathie Burn.

The thickest deposits of sand and gravel form kettled mounds and ridges, up to 15m high, lying to the east of the Mains of Blairydryne [NO 742 924], (see cross-section C-C´). Borehole 79 SW 13, sited on top of one of the ridges, proved 14.2m of sand and sandy gravel overlying 2.9m of light olive brown lodgement till. The till rests on weathered granite bedrock. The top 11.1m of the sand and gravel were laid down in two fining-downwards cycles; the basal 4.1m (which occur below the water-table) show less evidence of sorting than the material that was dry-sampled and contains a higher proportion of gravel and cobble-grade clasts. The mounds represent the dissected remnants of a delta, which prograded into a temporary high level proglacial lake that occupied this part of the valley during deglaciation. A small esker ridge of poorly sorted gravel and silty sand trends eastwards from the Mains of Blairydryne and merges with the moundy deposits described above.

Similar scattered deposits of moundy sand and gravel crop out along the northern flank of the valley upstream of Blairydryne [NO 749 927]. Borehole 79 SW 11, sited on a flat-topped ridge of gravel south of Westerton, for example, proved 4.0m of gravel, interbedded with thin diamictons and overlying laminated sandy silt. Exposures (recorded prior to this assessment) during the excavation of a pipeline trench nearby, indicated that the sand and gravel deposits interdigitate with flow till and glaciolacustrine silt. Geological mapping, undertaken as part of the assessment, indicates that a flat spread of glaciolacustrine silt and clay is present on the northern flank of the valley to the northwest of Garrol Farm [NO 728 908]. This helps confirm the former presence of a narrow proglacial lake in this part of the valley. Meltwater that debouched into the lake from the valley of the Burn of Sheeoch to the south, and from the upper reaches of the Garrol Burn to the west, deposited spreads of sand and coarse gravel as deltas and fans on the margins of the lake.

An excavation within a small sand and gravel working (79 SW 8) near Garrol Farm showed fluvioglacial sand and gravel passing down into laminated 'clayey' sand and silt. The sand and gravel, which is again thought to be of deltaic origin, shows clear evidence of water sorting; planar lamination and small scale ripple cross-stratification are prominent in the more sandy horizons.

Several flat-topped spreads of sand and gravel flank the Burn of Sheeoch, downstream of Blairydryne. A large active sand and gravel pit (Lochton Pit) is situated in the deposits between Blairydryne and Lochton [NO 756 925]. A trial pit (79 SE 1) sited at the base of a working face proved a total thickness of 5.4m of sandy gravel, overlying 2.0m of waxy clay and laminated silt. The sand and gravel forms large scale (up to 2m) foresets that dip northwestwards at the southern end of the working; at the northern end of the working the foresets dip towards the edges of the deposit. Most of the gravel occurs as a lag deposit resting on the foreset bedding planes; the dominant clasts comprise rounded and subangular pebbles of red and pink granite with subordinate amounts of psammite and schist (see composition of the mineral deposits, Table 6, column 15). The morphology of the spread and the bedding structures seen in the faces of the working pit, both suggest that this deposit is also of deltaic origin; possibly contemporaneous glaciolacustrine deposits cover much of the valley-floor in the surrounding area. Similar flat-topped mounds of fluvioglacial sand and gravel occur near Quithelhead [NO 745 932] and north of Wardend Cottages [NO 756 934].

A discontinuous (beaded) esker flanks the Burn of Sheeoch from south of Balrownie [NO 749 916] to Lochton Cottage [NO 751 923], where it merges with the fluvioglacial deposits worked at Lochton Pit. An excavation (79 SW 15) in a disused sand and gravel pit in the side of the esker ridge, near Balrownie, proved 3.7m of gravel overlying yellowish brown till. The upper part of the gravel was deposited as a fining-upwards sequence filling a NW-SE trending channel with gently sloping sides. The gravel-filled channel is truncated by a second steep-sided channel, filled with laminated silty sand containing scattered pebbles. The channels are cut into poorly sorted angular gravel, which also fines upwards. A similar fining-upwards sequence (overlying workable glaciolacustrine deposits) was recorded from assessment pit 79 SW 14, sited on top of an isolated esker 'bead' 400m to the north.

Poorly sorted fluvioglacial sand and gravel crops out within a forestry plantation at Balladrum Wood [NO 768 945]. The deposit has been worked in two small pits to provide material for the construction and repair of forestry tracks. An excavation (79 SE 4) in the base of the southern pit proved 4.1m of clast-supported, coarse gravel, which was not bottomed. The deposit thins rapidly eastwards against granitic bedrock that crops out at the top of the hill.

No sample points were sited on the discontinuous spreads of sand and gravel that are present within the alluvium of the Burn of Sheeoch. Because the mineral deposits within the alluvium are generally thin and occur below the water-table, their attractiveness as a potential source of aggregate is slight. Likewise, the deposits of gravel and sand that form thin alluvial cones on the floor of the valley are of minor importance.

*The fluvioglacial sand and gravel and glacial sand and gravel in the valleys of Strathie Burn and the Burn of Durris*

Flat-topped spreads of fluvioglacial sand and gravel are present on the southern side of the valley of Strathie Burn, near its confluence with the Burn of Sheeoch. Although no sample points were sited on the deposits, mapping indicated that the resource is relatively thin and ranges in grade from pebbly sand to cobble-gravel. The mineral deposits rest on till, which crops out in the steep bluff cut into the drift sequence by Strathie Burn.

An esker ridge composed of coarse gravel abuts the fluvioglacial deposits lying to the north of Calladrum [NO 774 943] and merges with a hummocky spread of poorly sorted gravel at Calladrum Wood [NO 779 948]. A shallow pit (79 SE 5) sited at the northern edge of the hummocky ground, proved 1.0m of unstratified cobble-gravel overlying sandy till. The gravel appears to thicken southwards, but is not regarded here as an attractive source of aggregate owing to the high proportion of boulders present. Deposits within the esker ridge are thought to be more attractive. They are probably thicker (the ridge rises between 3m and 5m above the surface of the adjacent fluvioglacial deposits) and exposures near the crest of the ridge suggest that the sand and gravel includes a smaller proportion of oversized material.

Two small ridges of coarse gravel occur on the southern side of the valley, east of Little Tulloch [NO 778 951], but temporary exposures in drainage ditches, excavated by the landowner at the time of the assessment, showed little more than a metre of clayey gravel overlying till and bedrock.

Workable deposits of sand and gravel were thought to be present within an area of steep-sided elongated mounds that occupy much of the low-lying ground between Strathie [NO 786 950] and the village of Woodlands [NO 788 957]. However, a shallow pit (79 NE 10) excavated on top of one of the mounds proved 0.8m of potentially workable flow-till, overlying clayey till with no sand and gravel. The mounds impinge on flat marshy ground southeast of Woodlands, underlain by silty lacustrine alluvium.

A narrow spread of fluvioglacial sand and gravel is present on the eastern side of the valley of the Burn of Durris. Much of the deposit has been sterilised by recent housing development, but exposures in the spread, north of Durris House [NO 799 968], proved over a metre of bedded cobble-gravel beneath negligible overburden.

Further resources of minor importance may occur within the morainic mounds, which flank the high ground to the southwest of the valley, and within thin spreads of gravelly alluvium in the valley of the Burn of Durris. Some workable material also remains on the flanks of an isolated mound of clayey glacial sand and gravel near Durris Cottage [NO 796 958], but the deposit has been largely worked out.

*Fluvioglacial sand and gravel south of Bogforran*

Four sample points were sited on the deposits of fluvioglacial sand and gravel that flank the flat-lying spread of peat, south of Bogforran [NO 731 929]. The most attractive resources occur within three mounds situated between East Mulloch [NO 735 924] and West Mulloch [NO 725 922]. A shallow pit in the mound nearest to East Mulloch, proved gravel fining-downwards into pebbly sand. The deposit was not bottomed at a depth of 3.0m. An excavation (79 SW 7) within a disused gravel working in the large mound at West Mulloch proved 2.2m of poorly stratified boulder-gravel fining-downwards into horizontally bedded pebbly sand; the deposit was not bottomed at a depth of 4.2m. Two resistivity soundings (79 SW R3A and R3B) were made on ground adjacent to the gravel pit. They gave a combined interpreted thickness of 5.6m for the sand and gravel.

A small mound of fluvioglacial sand and gravel is present close to Bogforran. The deposit has been largely worked out, but faces in the small active working (79 SW 16) at the western end of the mound, showed 2.4m of sandy gravel in three well-developed fining-downwards units. The units are each separated by thin partings of laminated clayey silt. The fluvioglacial deposits overlie silt resting on clayey till which is exposed in the pit floor; they are themselves overlain by 1.2m of unstratified sandy diamicton that becomes more gravelly with depth. The diamicton, which is interpreted as a flow-till, has a grading of pebbly sand.

A resistivity sounding (79 SW R1), taken on the spread of peat that covers the low-lying ground between Bogforran and East Mulloch, suggests that the depression is floored by till overlying bedrock. Concealed deposits of potentially workable sand and gravel are unlikely to be present.

*Fluvioglacial sand and gravel and morainic drift in the valley of the Burn of Knock*

Six sample points were sited in the valley of the Burn of Knock, of which four proved potentially workable sand and gravel (Mineral I) with an average thickness of 5.0m and a mean grading of fines 3 per cent, sand 60 per cent and gravel 37 per cent (sandy gravel). The most extensive resources are found within the kettled spreads of fluvioglacial sand and gravel southwest of Knockhill Farm [NO 703 920]. These deposits extend beyond the western margin of the resource sheet; they were laid down as fans and deltas in a large proglacial lake that occupied the marshy ground between Craigside [NO 702 930] and Knockhill Farm, and which also covered low-lying ground west of the present study area.

An assessment pit that was sited on the fluvioglacial sand and gravel 500m southwest of Knockhill Farm proved 3.3m of well sorted sand and gravel (unbottomed) beneath neglible overburden. Borehole 79 SW 2, subsequently drilled at the pit site, proved that 6.6m of sand and gravel overlies 1.0m of potentially workable till. Another assessment pit (79 SW 3) sited 450m south of the borehole, penetrated 2.7m of clast-supported gravel resting on large rounded boulders of coarse-grained pink granite and pegmatite. A section recorded from an old trial pit [NO 7019 9186] to the east of the burn, however, showed only 1.2m of clayey pebbly sand resting on till. At each site, the gravel is dominantly of local origin, being composed of subangular to well rounded clasts of pink and orange Kincardine granite.

The sand is also granitic, being chiefly composed of angular to subangular grains of quartz and pink feldspar and some rock fragments. Most of the sand-grade material has been derived from the deeply weathered granite that mantles the lower hillslopes to the south.

Similar deposits, rich in locally derived granitic material, form a steep-sided kame at the head of the valley. The kame has been worked for ballast in a small pit (79 SW 6), which shows 2.1m of coarse gravel passing down into 6.9m of cross-bedded sandy gravel. An excavation in the floor of the pit showed that the sand and gravel rests on horizontally laminated clayey silt.

Morainic mounds are present in the valley of the Burn of Knock in the vicinity of Midtown, and also in the valley of Green Burn, north of Knock Hill [NO 709 916]. Most of the mounds are composed of complex sequences of clayey diamictons, with interstratified lenses of clayey gravel and coarse sand; they are not regarded here as being an attractive source of sand and gravel. However, many of these deposits are potentially workable in terms of the limiting criteria adopted for the present survey. A pit (79 SW 4) sited on top of a mound southwest of Knockhill Farm, for example, proved 1.6m of 'clayey' pebbly sand overlying a stiff, unstratified diamicton containing cobbles of schist and friable weathered granite.

Other minor resources of potentially workable material occur within thin spreads of fine-grained sandy lacustrine alluvium south of Craigside, although a pit (79 SW 1) sited on the alluvium north of Knockhill Farm proved only 0.5m of pebbly sand overlying glaciolacustrine silt. Potentially workable deposits are also present within a terraced spread of sand and gravel bordering the lacustrine alluvium southwest of Craigside. Although no information is available on the thickness and quality of this resource, mapping suggests that much of the sand and gravel lies above the water-table.

**Resource block D**

This block covers a large area of generally barren upland between the southern margin of the Peterculter resource sheet (MAR 146) to the north, and the outcrop of glacial deposits belonging to the 'Red Series' south and west of the Bridge of Muchalls [NO 894 912]. The coastline between Bridge of Muchalls and Downies Haven [NO 927 949] forms the eastern margin of the block; the western edge coincides with the high ground forming the watershed between the catchment of the River Dee and streams and rivers which flow eastwards towards the coast. No sample points were sited in the block because most of the area is considered to be barren, being covered by thin deposits of till overlying Dalradian metasediments. Potentially workable mineral is thought to be confined to patches of sand and gravel within the alluvium of the Burn of Elsick and to a very small outcrop of glacial sand and gravel, which extends into the block from the north (between Westwinds [NO

912 950] and Burn of Daff Farm [NO 922 948]). Moundy deposits of sand and gravel are present, but not assessed, within the urban areas of Newtonhill and Muchalls. Some sand and gravel may be present beneath the extensive spreads of peat in marshy areas such as Red Moss [NO 860 940], but none was recorded in the original survey of the district in 1897 nor during the reconnaissance resurvey in 1984.

*Resource block D*

| | |
|---|---|
| Total area (excluding Newtonhill and Muchalls) | 46.04km$^2$ |
| Urban areas (including 0.03km$^2$ sand and gravel, not assessed) | 0.47km$^2$ |
| Area of exposed mineral | <0.01km$^2$ |
| Area of discontinuous spreads of mineral | 0.19km$^2$ |
| Area of ground worked for sand and gravel | <0.01km$^2$ |

**Resource block E**

This block includes the interfluves of the Carron Water and the Cowie Water, and their tributaries lying directly to the west of the coastal lowland around Stonehaven; its western limit is the watershed of the catchment of the River Dee. Most of the ground is barren, apart from the moundy deposits of morainic drift that flank the valley of the Cowie Water and the Burn of Day (its northward flowing tributary). Discontinuous spreads of mineral are also present within a small area of alluvium southwest of Millsburn [NO 805 892].

Four assessment pits (Table 21) sited on the morainic drift demonstrated the highly variable nature of this kind of deposit, which ranges in composition from a clast-supported coarse gravel, as found in a small working (88 NW 6) near Burn of Day Croft [NO 808 872], to a compact poorly stratified diamicton containing boulders up to 0.7m in diameter, as proved in assessment pit 88 NW 5, sited 500m to the north. Most of the workable aggregate occurs within the spreads of morainic drift in the vicinity of Millsburn, where the deposits have been worked at several localities. Exposures in a small working [NO 805 894] north of Millsburn, showed the deposit to consist of more than 3m of very sandy diamicton containing scattered boulders of pink granite and grey granodiorite, together with lenses of fine to coarse-grained micaceous sand. A nearby assessment pit (88 NW 1), proved 2.7m of sandy gravel resting of sandy till.

Morainic drift overlies granite of Kincardine type on the sides of the valley of Black Burn and those of its tributaries in the northwestern corner of the block. The granite is weathered in places to a depth of several metres; much of the weathered material, together with angular boulders of unweathered bedrock, is incorporated in the drift deposits that form linear ridges (lateral moraines) on the valley sides. The high proportion of cobbles and boulders recorded in assessment pit 79 SE 6, sited on the morainic deposits, suggest that the lateral moraines do not represent an attractive mineral resource in this part of the block. However, mapping indicates that some more attractive material may be present within transverse ridges of morainic drift on the floor of the valley near Lady's Moss [NO 782 901]. The ridges were laid down in contact with ice that occupied the valley to the north after most of the surrounding upland had become ice-free. A resistivity sounding (79 SE R1), taken on the flat peat marsh in the valley to the north of the Lady's Moss Moraine, indicates that thin spreads of till and clayey morainic drift are present beneath the peat.

**Resource block F**

The boundaries of block F are drawn to include all of the potentially workable sand and gravel deposits within the valley of the Cowie Water from Snob Cottage [NO 801 885] (on the eastern margin of 1:10 000 Sheet NO 88 NW) to the built-up area of Stonehaven. The block also includes the flat-lying spread of 'Red Series' glaciolacustrine deposits and lacustrine alluvium lying between Stonehaven and Cheyne [NO 844 869]. An inferred assessment is made for the fluvioglacial sand and gravel and glaciolacustrine deposits between Snob Cottage and Bossholes (see Table 22). A statistical assessment is given for the sand and gravel of various kinds lying between Glenton Hill [NO 822 886] and Stonehaven. Workable sand and gravel was proved at fifteen sites in total: most of the gravel clasts from deposits in the vicinity of Snob Cottage are derived from Caledonian and Dalradian rocks; sand and gravel downstream of Glenton Hill includes some material of Silurian and Devonian provenance.

*The sand and gravel deposits between Snob Cottage and Bossholes*

The kettled spreads of fluvioglacial sand and gravel on the flanks of the Cowie Water are an attractive mineral resource lying above groundwater level. Mounds of sand and gravel in the vicinity of Snob Cottage rise up to 25m above the floodplain of the Cowie Water, but the deposits are actually much thinner than might be thought at first sight, probably being generally less than 5m thick (see cross-section D-D′). The sand and gravel overlies till resting on benches cut into the bedrock. Mapping suggests that the thickness of mineral shows a considerable variation locally; for example, 300m southeast of Snob Cottage [NO 8048 8842] small exposures of sand and gravel occur throughout the 20m high face of a former river bank cut into the fluvioglacial deposits, but 400m farther downstream [NO 8088 8854] bedrock crops out several metres above the base of the river bank. A nearby borehole (88 NW 7) sited on top of the fluvioglacial deposits proved 2.8m of horizontally-bedded gravel overlying till and glaciolacustrine deposits of the 'Red Series'.

Faces in a small working (88 NW 16) in the moundy deposits (near Bossholes) on the southern side of the valley showed 2.5m of clast-supported, cross-bedded sandy gravel, fining downwards into fine-grained micaceous quartz sand with partings of laminated clay. Similar deposits were exposed in a disused pit (88 NW 4) north of Whitehill [NO 805 880], where 5.4m of gravel and pebbly sand (unbottomed) were proved in an excavation at the northern end of the working (the sand and gravel occurs in two fining-downwards cycles). A sequence coarsening downwards was recorded in an assessment pit (88 NW 3) sited on the fluvioglacial sand and gravel deposits northwest of Whitehill. The pit proved 2.4m of unbottomed sandy gravel beneath negligible overburden.

The fluvioglacial gravel proved at all of the samples point in this area, contains a high proportion of rounded clasts of pink granite, psammite and fine-grained basic igneous rocks; subangular pebbles of schist are also present. The sand is predominantly medium to coarse-grained with fragments of granitic rock common in the coarser fraction.

A transverse ridge of morainic drift is present north of Snob Cottage. The moraine was deposited in contact with ice that retreated northwestwards up the valley of the Black Burn, towards the watershed at Cairn-mon-earn [NO 783 919]. A similar moraine crosses the valley near Lady's Moss (in block E) 2.5km to the northwest. A pit (88 NW 2) in the Snob Cottage Moraine proved that, at least locally, the ridge has a bedrock core with a thin cover of unstratified diamicton; thicker morainic deposits containing poorly sorted angular gravel are present nearby.

Workable mineral, lying mainly below the water-table, is present within the terraced fluvial deposits which flank the alluvium of the Cowie Water. No sample points were sited on the terraces, which rise from 3 to 4m above the floodplain, but mapping suggests that gravel and fine-grained sand are present beneath thin spreads of humic silt and clay. Discontinuous spreads of mineral also occur within the alluvium, as demonstrated by the beds of silty sand and cobble-gravel that crop out in places along the banks of the Cowie Water.

*Sand and gravel deposits between Glenton Hill and Stonehaven*

The Cowie Water flows through a deep steep-sided, valley between Glenton Hill and the Hill of Swanley [NO 815 873]. The valley was cut by glacier ice and meltwater which flowed southeastwards towards the coast. The sides of the valley are mantled by thin deposits of till overlying Dalradian metamorphic rocks; potentially workable mineral deposits are confined to thin, discontinuous spreads of silty sand and cobble-gravel within the alluvium of the valley floor.

Linear ridges of sandy gravel are present on the northern side of the valley of the Cowie Water, in the lee of Glenton Hill. Borehole 88 NW 10 proved 6.7m of sandy gravel over 5.6m of pebbly sand, with an intervening waste parting 0.9m thick. The ridges of sand and gravel were deposited by meltwater that flowed northwards between the valley side and ice on the valley floor. The ridges are analogous to the kame-terraces on the sides of the valley of the River Dee. Isolated mounds of sand and gravel are also present on the western side of the valley of a tributary stream (the Cowton Burn) that joins the Cowie Water east of Rickarton House [NO 838 886].

Some of the fluvioglacial deposits in the valley of Cowton Burn are flat-topped spreads of pebbly sand. These spreads were deposited as fans and cones at the mouths of glacial drainage channels, cut by meltwater draining into the valley from the interfluves between Meikle Carewe Hill [NO 828 920] and Glenton Hill.

Two ridges of fluvioglacial sand and gravel, aligned NW-SE, occupy the northern flank of the valley near the confluence of the Cowie Water and Cowton Burn. Excavations in a small working (88 NW 17) at the northwestern end of the deposit, proved 6.9m of mineral, not bottomed, beneath negligible overburden. The sand and gravel occurs in several fining-downwards cycles; it shows small scale faulting and contorted bedding structures, which suggest that the deposits were laid down on top of stagnant ice. Channels filled with poorly sorted cobble-gravel are present near the top of the working face, but the bedding of the top-most 0.8m of the sequence is locally disrupted by cryoturbation structures, formed by freeze-thaw action under periglacial conditions. Assessment borehole 88 NW 12 sited on the same ridge to the south of Findlayston [NO 841 890], proved 6.5m of clayey sand and gravel overlying reddish glaciolacustrine sandy clay and silt. Water-saturated sandy gravel, filling a deep channel cut into bedrock, is present beneath the glaciolacustrine deposits.

The most attractive sand and gravel resources in block F occur within a flat-topped spread of coarse outwash gravel that covers the floor of the valley of the Cowie Water, south of its confluence with Ury Burn. The outwash deposits are worked in a large gravel pit at Glen Ury (88 NE 9) where 6.3m of poorly sorted, clast-supported, coarse gravel overlies finely laminated silt and clay of the 'Red Series'. The gravel contains a mixture of clasts of both 'Inland' and 'Red Series' provenance; clasts of Silurian and Devonian sandstone and quartzite are common, as is material derived from granitic and metamorphic rocks. The gravel was laid down as both horizontally bedded and trough cross-stratified units, between 1.0m and 1.4m thick; the sand and fines occur in the interstices between the gravel clasts. The outwash deposits thicken towards Stonehaven; an assessment borehole (88 NE 10), sited on farmland between the gravel pit and the town, proved 8.5m of coarse gravel overlying 2.1m of silty pebbly sand that passes down into the reddish brown sandy silt (see cross-section E-E′).

Only 1.0m of coarse gravel, overlying stiff till, was recorded from borehole 88 NE 6, sited on the terrace just 400m northwest of Glen Ury gravel pit, indicating that the outwash gravel thins rapidly upstream of the working pit.

The fluvial deposits laid down in the valley of the Cowie Water include some mineral beneath negligible overburden. Small exposures of pebbly sand are present in the river banks and spreads of pebbly soil were revealed in ploughed fields adjacent to the river. However, sample point 88 NE 5, sited on the low ground (initially thought to be a fluvial terrace) west of Ury House [NO 859 877], showed the terrace feature to be an erosional bench cut in bedrock and only mantled by 1.3m of flow-till. A shallow pit (88 NW 9), sited on the alluvium of the Cowton Burn, proved 0.4m of 'clayey' pebbly sand overlying 1.1m of imbricated dry gravel. Similar gravel is also present in the stream bed and is thought to extend several metres below groundwater level beneath the alluvium in the vicinity of Rickarton House.

**Resource block G**

Block G is divided in two for the purpose of assessment. A statistical assessment is given (Table 23) for the fluvioglacial sand and gravel and glacial sand and gravel of the 'Red Series' between Stonehaven and Muchalls, together with the raised beach deposits and morainic drift to the north of Stonehaven. A separate statistical assessment has been made of the fluvioglacial sand and gravel and alluvial deposits in the valley of the Carron Water.

**Sub-block $G^1$**

The northern and western boundary of the sub-block is drawn close to the maximum inland extent of of the 'Red Series' between Newbigging [NO 839 895] and Muchalls. The southern margin is the valley of the Cowie Water and the eastern margin runs along the coastline north of Cowie Harbour [NO 882 867].

The sand and gravel deposits in this sub-block are of three main types: firstly, isolated mounds and ridges of silty pebbly sand, deposited in fining downwards cycles and associated with the principal routes of glacial drainage; secondly, undulating spreads of coarse, poorly sorted gravel, deposited as outwash fans at the mouths of glacial drainage channels; and thirdly, raised beach deposits, which include thin spreads of silt and clay, as well as beds of fine-grained sand and rounded gravel.

All of the assessment boreholes and trial pits in sub-block G1 proved sand and gravel beneath less than one metre of overburden. Of the five resistivity sounding sites, only one (88 NE R2B) indicated that no mineral was present; the remainder of the interpreted soundings indicated exposed mineral. Barren ground is mainly confined to spreads of clayey till overlying metamorphic bedrock as shown by ancilliary boreholes (such as 88 NE X2 and X3) that were drilled prior to the construction of the Stonehaven by-pass.

The most important mineral resources occur in three distinct areas: around the valley of the Burn of Ury, at the mouth of a deep glacial drainage channel drained by Limpet Burn, and in the vicinity of Cantlayhills [NO 881 905].

*The Burn of Ury*

The moundy deposits in the vicinity of the Burn of Ury have been investigated in considerable detail in a trial exercise. Two assessment boreholes and two trial pits were excavated in the area. Four resistivity soundings were also made in the area, together with detailed remapping and an electromagnetic conductivity survey (see Appendix F). This work has resulted in a large reduction in the area of ground that was judged to be mineral-bearing before the survey was begun.

A steep-sided hill, 25m high, to the south of Houff Burn, is formed of reddish brown sand and gravel overlying till and glaciolacustrine silt (see cross-section D-D'). Borehole 88 NE 4, sited on top of the hill at the Houff of Ury [NO 856 889], proved 12.4m of reddish-brown clay-bound sand and gravel beneath 0.4m of overburden. The sand and gravel passes downwards into flow-till and glaciolacustrine silt. Exposures in the sides of a flat-topped mound to the west of the borehole site, show gravel and fine sand overlying silt and reddish-brown clayey till. These sequences suggest that the sand and gravel deposits were laid down as a delta in an ice-marginal lake that formed between 'Inland' ice, which covered the high ground to the north and west, and 'Red Series' ice, which covered the lower ground to the south. Trial pit 88 NE 8, on top of a smaller mound at Den of Glithno [NO 861 889], proved 3.2m of sand and gravel (unbottomed). The deposit fines downwards from cross-stratified gravel into pebbly sand and is also probably deltaic in origin.

Potentially workable deposits of sand and gravel occur within a series of irregular mounds, which stand up to 12m above the level of a waterlogged peat moss, between Broomhill [NO 844 902] and Monboys [NO 856 898]. A borehole (88 NE 2) sited on the crest of one of the mounds, recorded 2.2m of clay-bound gravel (ungraded) overlying till. This suggests that the deposits are of only limited value. Doubt is thrown on this borehole record, however, by high interpreted resistivity values (6206 to 2198 ohm.m) from a sounding made (88 NE R3A) at the borehole site, which indicates that up to 14.5m of sand and gravel may be present. The gravelly nature of the deposits is also suggested by an interpreted resistivity value of 4062 ohm.m from sounding 88 NE R3B, made 150m north of the borehole site. The resistivity data is supported by conductivity values of <0.1 millimho/m recorded over most of the moundy ground. The geophysical data, together with numerous small exposures of pebbly sand and coarse gravel on the sides of mounds, indicate that the deposits are thicker than the borehole record suggests. Furthermore, the presence of potentially workable deposits is confirmed by a backfilled gravel pit [NO 853 897] on the eastern side of the mounds.

The ruins of Ury House [NO 859 877] stand on a steep-sided, flat-topped spread of fluvioglacial sand and gravel near the confluence of Ury Burn and the Cowie Water. The top of the spread stands approximately 30m above the two floodplains, and although no sample points were sited on the deposits, a thick deltaic sequence is probably present. The terraced deposits on the flanks of the valley of the Cowie Water upstream of Ury House, however, are too thin to be a major resource.

Deposits of fine-grained sand and coarse imbricated gravel form terraced spreads on the floor of a deeply incised valley that is drained by the Burn of Monboys and Ury Burn. The narrowness of the valley and the steepness of its sides preclude easy access to the potentially workable deposits, which in any case are only a minor resource.

*Limpet Burn*

A steep-sided glacial drainage channel, trending W-E, is cut into grit and banded psammite bedrock between Megray Wood [NO 873 890] and Limpet Wood [NO 884 889]. An undulating spread of coarse gravel, which emerges from the eastern end of the drainage channel, is being worked in a pit at Logie Farm [NO 886 888]. A trial pit (88 NE 13) excavated at the foot of the working face proved a total thickness of 6.4m of poorly sorted cobble-gravel resting on reddish brown lodgement till. In the main, the gravel comprises a mixture of rounded Devonian quartzite cobbles and angular clasts of locally derived Dalradian psammite and grit. Farther-travelled pebbles of granite, mica-schist, mudstone and chert (the latter probably derived from rocks of the Highland Border Complex) are also present. The gravel, which shows only limited evidence of water sorting was probably formed as a sub-aqueous debris flow.

*Cantlayhills*

Steep-sided mounds of fluvioglacial sand and gravel occur in the vicinity of Cantlayhills [NO 881 905] and Hillhead of Cowie [NO 892 902]. Two assessment pits were sited on the deposits at Cantlayhills during the Aberdeen sand and gravel assessment (described in sub-block $P^2$ of Mineral Assessment Report 146). One of the pits (89 SE 1), excavated in the floor of a small working, revealed at least 7.1m of sandy gravel. Remapping of the area in 1986 showed that the workable deposits are less extensive than shown on the previously published resource map. Furthermore, a mineral deposit, not recognised during the Aberdeen assessment, has been mapped at Hillhead of Cowie, where an exposure in the farmyard showed more than 3m of unstratified gravel containing abundant clasts of well-rounded Devonian quartzite.

The mapped extent of potentially workable mineral in the vicinity of Bridge of Muchalls has also been modified since the Aberdeen assessment survey was completed. Spreads of glacial sand and gravel shown on the northern side of the valley of the Burn of Muchalls, upstream of Bridge of Muchalls, for example, are in fact bedrock knolls with a thin covering of till. Discontinuous spreads of mineral are present, however, beneath the floodplain.

*Other areas*

Mounds of glacial sand and gravel west of Auquorthies [NO 889 898] were laid down in close proximity to both the 'Inland' and 'Red Series' ice sheets, which were juxtaposed in the vicinity. The deposits are generally thin; an excavation in a abandoned gravel working (88 NE 12) in one of the mounds proved 3.6m of sand and gravel overlying stiff reddish-brown till. The sand and gravel contains clasts of Dalradian, Caledonian and Devonian provenance; clasts of Devonian quartzite and sandstone predominate in the bottom 1.9m of the deposit.

Small amounts of fine-grained pebbly quartzitic sand are present in moundy spreads of fluvioglacial origin in the vicinity of Stonehaven Golf Course [NO 887 876] and small isolated mounds of gravel also occur south of Forester's Croft [NO 872 884] and west of Logie Farm. Deposits of poorly-sorted, clay-bound boulder gravel have been worked in a small pit between Megray Wood and Forester's Croft. This gravel deposit is interstratified with sandy flow-till; it forms an alluvial cone that splays out from the eastern end of a glacial drainage channel which extends northeastwards from the valley of Ury Burn towards Megray Wood.

Thin deposits of potentially workable sand and gravel are present within the Late-Glacial raised beach deposits between Stonehaven and Garron Point. The deposits rest on a bench cut in reddish-brown lodgement till at a height of 25 to 30m above present sea level. Up to 3m of well-rounded cobble-gravel crops out southwest of the Mains of Cowie [NO 877 868], but elsewhere the deposits are generally much thinner and more clayey. For example, resistivity soundings 88 NE R2A and R2B, made on the Late-Glacial beach deposits between Stonehaven and Garron Point, indicated just 1.5m of pebbly sand 200m west of the Coastguard Station [NO 891 876], whereas nearer to the Coastguard Station itself, the beach deposits are probably represented by 2.4m of clayey silt.

Potentially workable sand and gravel is present within the Post-Glacial raised beaches that flank the coast between Cowie Harbour and Bridge of Muchalls. The workable deposits are generally thin and of small extent, and as such they constitute a resource of only minor interest. Likewise, sand and gravel within the morainic drift deposits is also not regarded as an attractive resource in this area.

**Sub-block $G^2$**

Sub-block $G^2$ extends along the southern margin of the resource sheet. It includes the sand and gravel deposits along the course of the Carron Water and on the northern flank of its valley. The flat-topped spreads of sand and gravel in the coastal area to the south of Stonehaven have been included in the assessment, but those within the urban area itself have been excluded.

Thick mineral deposits are found on the side of the valley of the Carron Water (see cross-section E-E'). Steep-sided conical hills between Nether Wyndings [NO 817 853] and St Ciaran's Church [NO 853 857] are underlain by sequences of reddish-brown silty pebbly sand, interbedded with laminated silt and clay. The hills are, in fact, the degraded remnants of large deltas and outwash fans, that were deposited in a body of water which occupied the valley during deglaciation. Grading data from assessment boreholes (such as 88 NW 8 and NW 13) sited on top of the hills show multiple sequences of sand and gravel fining downwards into silt and waxy red clay. The waterlain deposits rest on reddish-brown lodgement till, overlying Silurian and Devonian sandstones that include subordinate beds of shale and conglomerate. The sandstone bedrock is deeply weathered in the vicinity of Fetteresso Castle [NO 843 855] and might provide a potential source of fine to medium-grained sand that requires little or no crushing. The presence of a significant amount of feldspar and mica in the rock, however, are likely to preclude its use as building sand.

An excavation (88 NE 7) at the foot of a working face in the sand pit at Beattie's Hill revealed 11.2m of pebbly sand (unbottomed). The top 5.1m of the deposit showed well-developed large scale (1-2m) cross-stratification, the dip of the foreset beds being between 080°-100° from north. The deposit is worked for fill.

Flat-topped spreads of reddish brown fluvioglacial sand and gravel are present on the southern side of the valley of the Carron Water between Marischal Aisle [NO 863 852] and Carbisdale [NO 868 851]. An excavation (88 NE 11) in a disused gravel pit in the Woods of Dunnottar [NO 866 851] proved more than 4.4m of gravel and pebbly sand beneath 0.1m of overburden. Mapping suggests that the sand and gravel extends northwards beneath a thin-spread of flow-till that covers much of the interfluve between the Burn of Glaslaw and the Carron Water. A similar flat-topped spread of sand and gravel was present at Braehead [NO 872 852]; it has been largely worked-out.

Spreads of gravel are present beneath the floodplain of the Carron Water and within the terraced deposits that flank the floodplain in the vicinity of Kirkton of Fetteresso [NO 853 856]. Site investigation boreholes (such as 88 NE X14 and X15) located on the alluvium prior to the construction of the Stonehaven by-pass, proved up to 3m of coarse gravel lying below the water-table. Exposures in the flat-topped terrace, in the vicinity of the railway viaduct, suggest that up to 5m of coarse gravel is present, some of which lies above groundwater level. Upstream of Kirkton of Fetteresso, the sand and gravel beneath the floodplain is generally much thinner; for example, an assessment pit (88 NW 15) at Pond Haugh proved more than 0.9m of coarse imbricated gravel beneath 0.7m of overburden, before the water-table was reached and halted further progress.

## CONCLUSIONS

### General

The sand and gravel resources of the assessment area have been described systematically and the results of the volumetric calculations summarised in Table 9. It is repeated that the survey concerns the estimation of *resources* rather than *reserves* and that the assessment of the deposits is judged solely in terms of the limiting physical criteria that have been adopted here to define potentially workable material. These criteria are that a deposit is at least one metre thick; that the ratio of overburden to mineral does not exceed 3:1; that the proportion of fines does not exceed 40%; and that it must lie within 25m of the surface. No account is taken of prevailing economic considerations and the quoted volumetric estimates bear no simple relationship to the amount of sand and gravel that might be extracted in practice.

### Planning aspects

The assessment survey reported here has been undertaken essentially to provide the physical planner with a portrait of the sand and gravel resources in the hinterland of Aberdeen. This is an area identified by the Scottish Development Department as having a high priority for investigation on planning grounds because of land-use problems around this rapidly expanding city and also to ensure continuity of sand and gravel supply to the local market. The chief aim is to provide data on the extent and character of the potentially workable deposits and to estimate volumes at a stated level of confidence.

The results provide planning authorities with an independent, geologically-based assessment which is required to enable them to develop coherent minerals policies. These policies are necessary in order to help prevent sterilisation of potential resources and to rationalise the conflicts which may occur between conservation and mineral exploitation.

By comparison with the widespread terraced deposits of sand and gravel in the Thames and Trent valleys of England the resources of the study area are limited and patchy in their distribution, and highly variable in composition and character. The amount of sand and gravel in the Inverurie and Dunecht sheet areas, in particular, is modest even compared with other areas of assessment in northeast Scotland. The detailed mapping and sampling undertaken for the survey have shown that the total area of mineral-bearing ground is between 34% and 67% of what had been anticipated from the limited information and incomplete drift mapping that was available previously.

**Method of investigation**

Patchy, heterogeneous deposits of sand and gravel, such as those occurring in the study area, are more difficult and costly to assess than widespread deposits. As far as possible pits have been dug, often adjacent to sampled sections, in order to avoid drilling expensive boreholes. This has been particularly successful throughout northeast Scotland where deposits are generally thin. Pits have the added advantage over boreholes (apart from time and cost) in allowing close inspection of sedimentary structures within the drift deposits; pits cannot, however, be dug below the water-table.

Two types of geophysical sounding were made on an experimental basis to investigate the possibility of reducing the costs of assessment still further. The Offset Wenner method of ground resistivity sounding (see Appendix E) provided useful site specific information akin to drilling results. It was especially useful for estimating the total thickness of sand and gravel at sites (mainly pits) where the mineral deposit had not been bottomed, where drilling had to be abandoned owing to slow progress, and at sites where access was physically or otherwise difficult. The main disadvantages of ground resistivity (or any geophysical method) are firstly that its success is entirely dependent on the skill and prior knowledge of the interpreter, which is based largely on good borehole control, and secondly that it cannot provide samples of sand and gravel for laboratory analysis. Furthermore, although initially quick on the ground, the interpretation of the results of the soundings can be time-consuming; it also requires sophisticated computer back-up. In conclusion, ground resistivity has proved to be a valuable additional tool allowing improved interpolation between sample points and some decrease in the total number of boreholes required; it is not a complete substitute for drilling. Electromagnetic conductivity sounding, attempted in a small area near Stonehaven, proved to be an aid to geological surveying, but it was not found to be particularly useful or cost-effective here.

**Resources**

The factors that govern the attractiveness of a sand and gravel deposit for exploitation (leaving aside the environmental and economic factors which are outwith the remit of this report), include deposit grade, deposit thickness, overburden thickness and gravel quality. However, because it is customary not to permit the dredging of wet deposits in Scotland, a most important factor governing the future development of sand and gravel resources in the area is probably the disposition of the material relative to the water-table.

*Relation to the water-table*

As far as possible, resources in the Inverurie and Dunecht sheet areas have been divided, for the purposes of assessment, into those lying mainly above and those lying mainly below the water-table ('valley-side deposits' and 'valley-floor deposits' respectively). The resources of the Banchory/Stonehaven sheet have not been so divided, but they are described in respect to their position relative to the water-table in the detailed notes on the resource blocks. Water-saturated deposits mainly underlie the floodplains of the major rivers, but they also underlie many of the low-lying areas underlain by peat and alluvium.

*Grade and thickness*

Conclusions as to deposit grading and thickness can be most conveniently summarised sheet by sheet. The terraced deposits are perhaps the most attractive type of resource of coarse aggregate as they are relatively consistent in terms of thickness, grading and lateral continuity. Apart from kettle-hole infills, overburden is generally thin. The moundy deposits tend to be more variable in thickness and grading over short distances; they also incorporate waste (silt, clay and clayey diamicton) in amounts that are very difficult to predict and which will require a great deal of site investigation to delimit in detail. On the other hand, moundy deposits can be much thicker than the average terrace deposit; they also tend to be more available to exploitation because they often form land of quite low agricultural potential that might be significantly improved by levelling. Furthermore, because the moundy deposits are more variable in grading, they have a potential for producing a wider range of aggregates. Indeed, most of the resources of fine to medium-grained sand form mounds.

*Composition and end uses*

On the whole, the gravels of the survey area should be suitable for most purposes provided that an appropriate form of processing is used and the petrography and soundness of the material is duly taken into account in the choice of end-use. The results of the limited number of pebble-counts and mechanical and physical tests that were undertaken are given in Tables 6, 7 and 8. Granite is the most common constituent of the gravel across the survey area and the sand is mainly formed of comminuted granite (quartz, feldspar and a little mica). Coarse-grained basic igneous rocks (gabbro and amphibolite) assume a greater importance in the deposits of the valley of the River Urie. Psammite and quartzite are most abundant in the gravel around Stonehaven.

The test results demonstrate that there is a broad relationship between composition and physical and mechanical properties; in particular, there is a good correlation between AIV and percentage of coarse-grained igneous rock (granite, pegmatite, diorite and gabbro). These rock-types are more susceptible to weathering than psammite or quartzite.

**Selection of resource targets**

Many of the resources identified on the accompanying maps and described in this report will repay further investigation by the industry as potential reserves for future exploitation. These *target resources* are considered more fully in a companion study, commissioned by DOE, collating the results of all the sand and gravel assessment surveys that have been conducted in northeast Scotland (Merritt, Auton and Ross, 1988), from Peterhead in the north to the area around Stonehaven included in the present study. Potential end-use of the sand and gravel is considered more fully in the collation report.

Selecting targets is difficult as there are many variables to consider and, with the still limited amounts of data available, judgements cannot be wholly objective, but some of the more noteworthy resources lying above the water-table are listed below.

*Inverurie sheet*

The resources of this sheet (see Table 9) are modest compared to those of other resource sheet areas in northeastern Scotland. There is very little scope for large-scale extraction involving fixed plant, but there is good quality sand and gravel available to be worked on a small scale, especially in the valley of the River Urie upstream of Milton of Inveramsay [NJ 741 248].

*Dunecht sheet*

The resources of this sheet (Table 9) are also not great in the regional context, but there are some deposits large enough to command attention. These include the terraces of the Corskie Burn (block A); moundy deposits lying to the west and north of Leuchar Moss [NJ 790 047] in block C; an extensive outwash fan lying to the south and east of Leuchar Moss, also in block C; moundy deposits in the northeast of block D between Milltown of Finnarcy [NJ 761 039] and Northton [NJ 771 040]; moundy deposits in the vicinity of Hardgate [NJ 787 017] in block F.

*Banchory/Stonehaven sheet*

The sand and gravel deposits on this sheet constitute the principal resources of the assessment area as a whole. The largest resources are found within the terraced deposits of the valley of the River Dee (block B), although a significant proportion of the workable material lies close to the water-table. Moundy deposits within the 'Red Series' constitute a potential source of sand (block G) as do some of the mounds within the valley of the Burn of Sheeoch (block C), notably those in the vicinity of the Mains of Blairydryne [NO 743 924]. Other notable deposits include those between Snob Cottage [NO 801 885] and Bossholes [NO 812 885] and those beneath the low-lying coastal plain lying immediately inland of Stonehaven in block F.

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## GLOSSARY

A comprehensive glossary of geological terms is given in Bates and Jackson (1987).

ABLATION Surface processes by which snow and ice are removed from a glacier or ice-sheet (including melting and evaporation)

ABLATION TILL Poorly sorted, loosely consolidated till, which accumulated in place as the surface ice was removed by ablation, preserved as thin discontinuous sheets and lenses overlying lodgement till and sand and gravel

CRYOTURBATION A collective term to describe the disturbance and modification of a deposit by frost action including frost heaving, solifluction and mass movement

DIAMICTON A sedimentary deposit (irrespective of origin) characterised by a lack of sorting; commonly a mixture of clay, sand and angular boulders

ENGLACIAL Formed within a glacier or ice-sheet

ESKER A sinuous steep-sided ridge of irregularly stratified sand and gravel originally deposited by a subglacial or englacial meltwater stream. A beaded-esker is an esker with numerous bulges and swellings (commonly representing fans and deltas) along its length

EUSTATIC Pertaining to global changes of sea-level caused by additions of water to, or removal of water from, ice-sheets

FLOW-TILL A supraglacial till that is modified and transported by plastic mass flow; it forms thin, discontinuous sheets overlying lodgement till, sand and gravel or bedrock

FLUVIOGLACIAL Pertaining to meltwater streams flowing from (or beyond) the margins of wasting ice-sheets and glaciers; especially applied to deposits and landforms produced by such streams

FLUVIOGLACIAL SAND AND GRAVEL Characteristically moderately well sorted and bedded sand and gravel, often forming flat-topped mounds and terraces

FLUVIAL Pertaining to river action

FREEZE-THAW The mechanical weathering process caused by repeated cycles of freezing and thawing of water in pores and cracks in material at the ground surface

GLACIAL Pertaining to the action of glacier ice or ice-sheets. Glacial material is produced, deposited by, or derived directly from such ice

GLACIAL SAND AND GRAVEL Characteristically heterogeneous, poorly sorted and unstratified sand and gravel, deposited in contact with glacier ice or an ice-sheet; often forming steep ridges or hummocky topography

GLACIOLACUSTRINE Pertaining to deposition in temporary lakes bordering a glacier or ice-sheet

INTERSTADIAL A warmer climatic episode within a glaciation during which a secondary recession, or still-stand, of glaciers took place

INTERFLUVE The ground between two adjacent river or stream valleys

INTERGLACIAL A period of relatively warm climate between two periods of glaciation

ISOSTATIC RECOVERY Upward movement of the land surface relative to sea level after the melting of an ice-sheet

KAME A mound or lenticular ridge of stratified sand and gravel, deposited as a fan or delta, at the margin of a glacier or ice-sheet by a subglacial or englacial stream,

KAME-TERRACE Stratified fluvioglacial sand and gravel, laid down from meltwater flowing between a melting glacier or stagnant ice-lobe and a valley side or lateral moraine, and left standing as a flat-topped terrace after the disappearance of the ice

KETTLE-HOLE A steep-sided depression in a glacial or fluvioglacial deposit, formed by the melting of a large detached block of stagnant ice, that was partly or wholly buried in the deposit

LATERAL MORAINE A morainic ridge deposited at the side of a valley glacier

LODGEMENT TILL A poorly-sorted, compact, fissile till (often clay-rich), laid down beneath an active ice-sheet or glacier; it forms extensive, undulating sheets covering the bedrock on most of the low ground

MASS WASTING A general term for the dislodgement and downslope transport of soil and rock material under the force of gravity

MELT-OUT TILL Till derived from the slow melting of a thick mass of debris-rich stagnant ice, buried beneath sufficient overburden to inhibit deformation under gravity; it forms, irregular lenses overlying lodgement till and sand and gravel locally

MORAINE A mound or ridge of poorly sorted unstratified glacial debris, deposited in contact with the margins of a glacier or ice-sheet

PERIGLACIAL Pertaining to the processes, areas, climate and topographic features at the margins of areas covered by glaciers and ice-sheets

SOLIFLUCTION The slow, viscous, downslope flow of waterlogged soil and other unconsolidated superficial material in regions underlain by frozen ground

SUBGLACIAL Formed, or accummulated in, at the base of a glacier or ice-sheet

SUPRAGLACIAL Formed, or accummulated on top of a glacier or ice-sheet

STADE A climatic episode within a glaciation, during which a secondary advance of glaciers took place

STRATH A flat-bottomed valley, formed by fluvial erosion (*not* a floodplain)

TERMINAL MORAINE Morainic ridge deposited in front of a valley glacier at its maximum extent

TILL Dominantly unsorted and unstratified glacial diamicton, consisting of a heterogeneous mixture of clay, silt, sand and gravel, and boulders; typically occurs as laterally extensive sheets of variable thickness

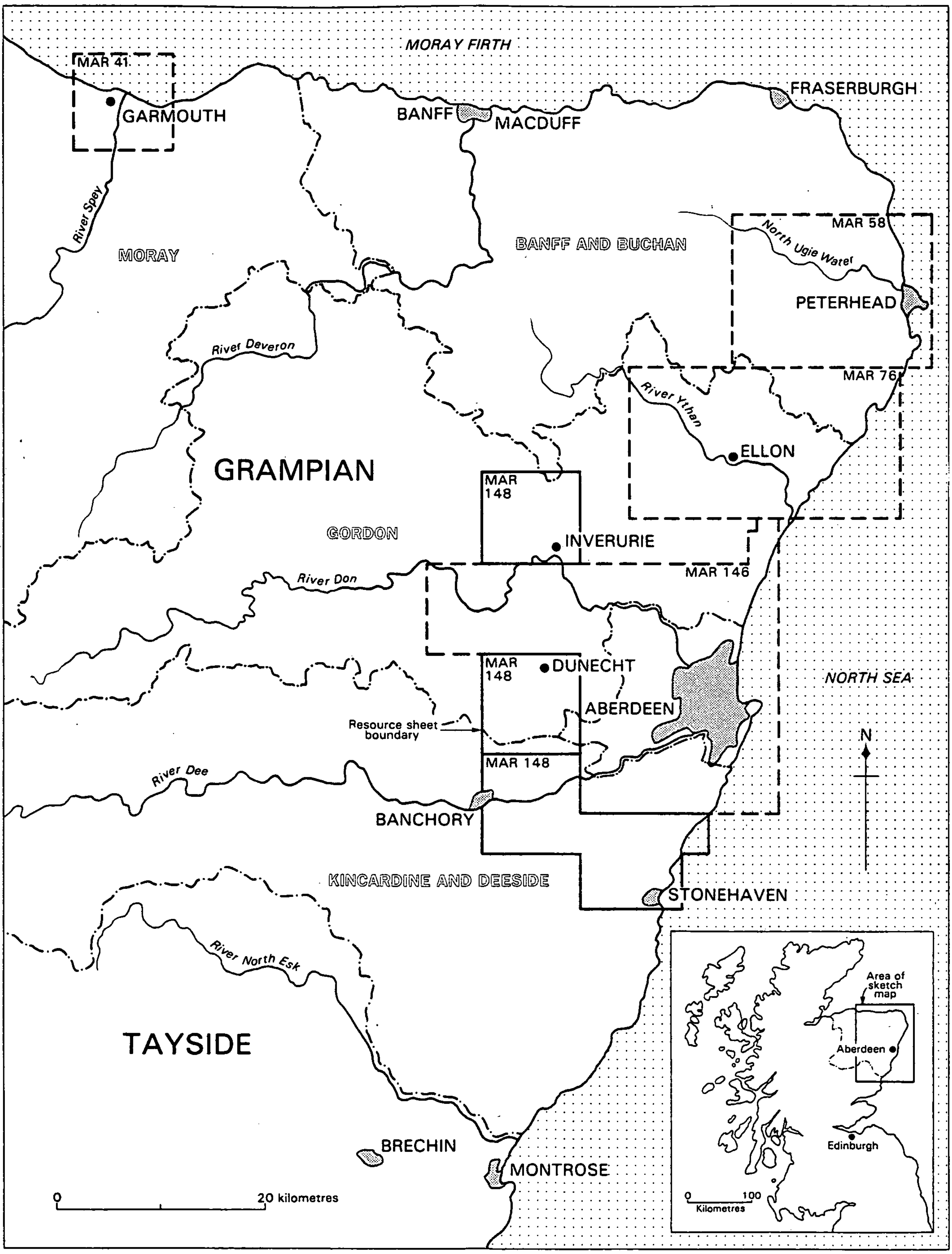



**Figure 1.** Sketch-map showing the location of the resource sheets

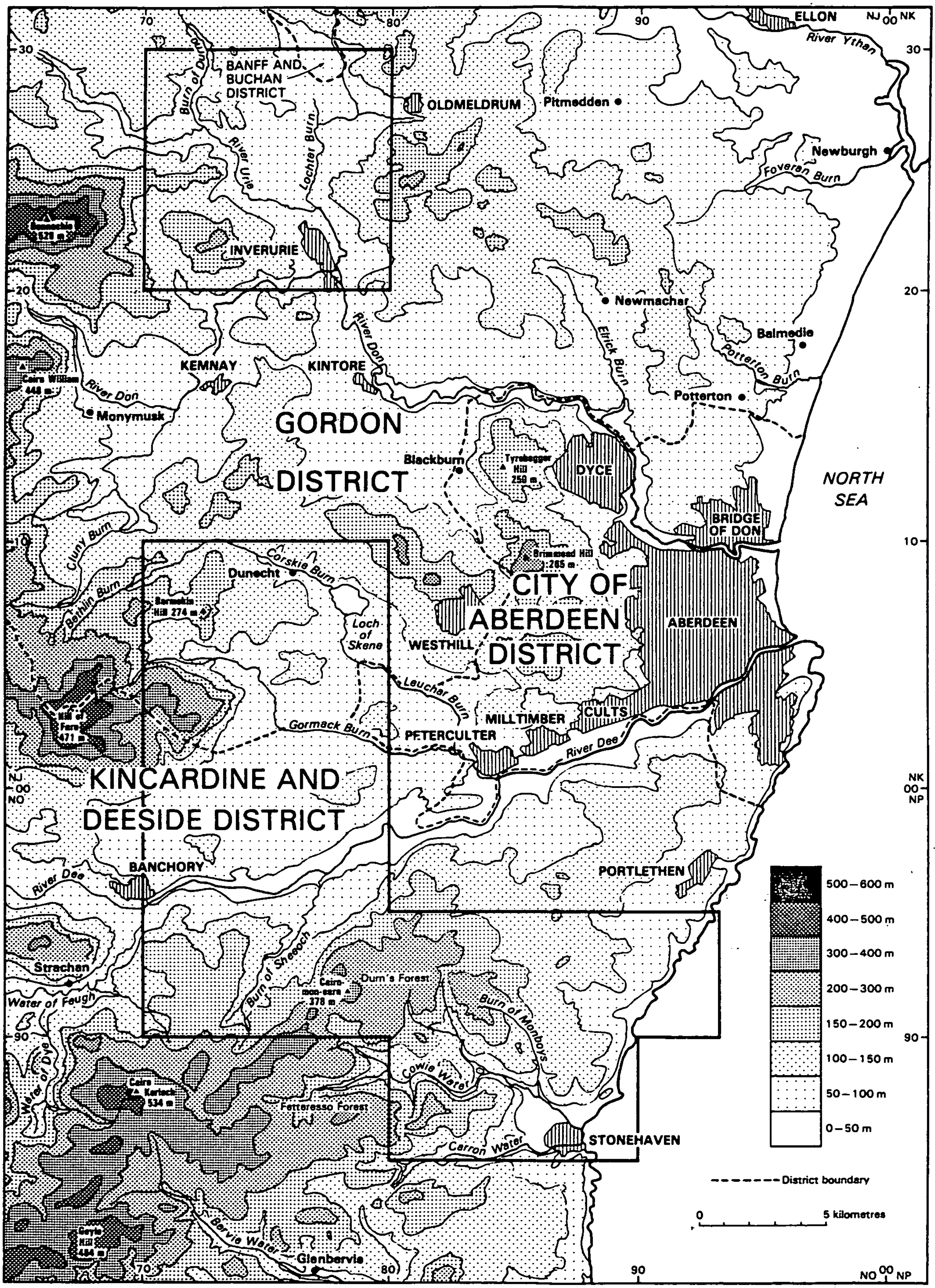
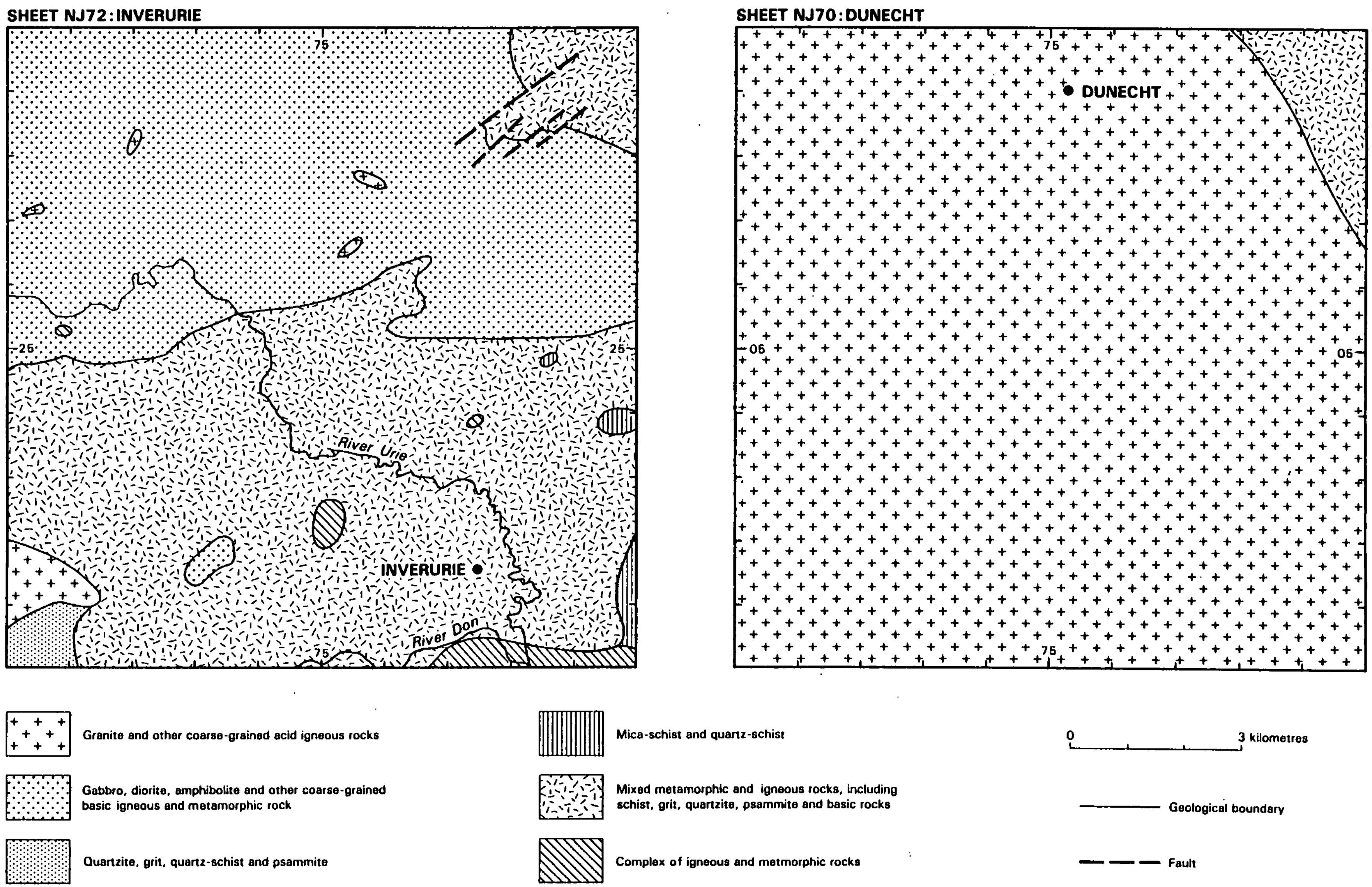



**Figure 2.** Topography of the district




There are numerous minor intrusions too small to delineate on these maps. They include felsite and other fine-grained acid igneous rocks, together with dolerite, microdiorite and other fine-grained basic igneous rocks.

**Figure 3.** Sketch-maps of the solid geology of the Inverurie and Dunecht resource sheet-areas

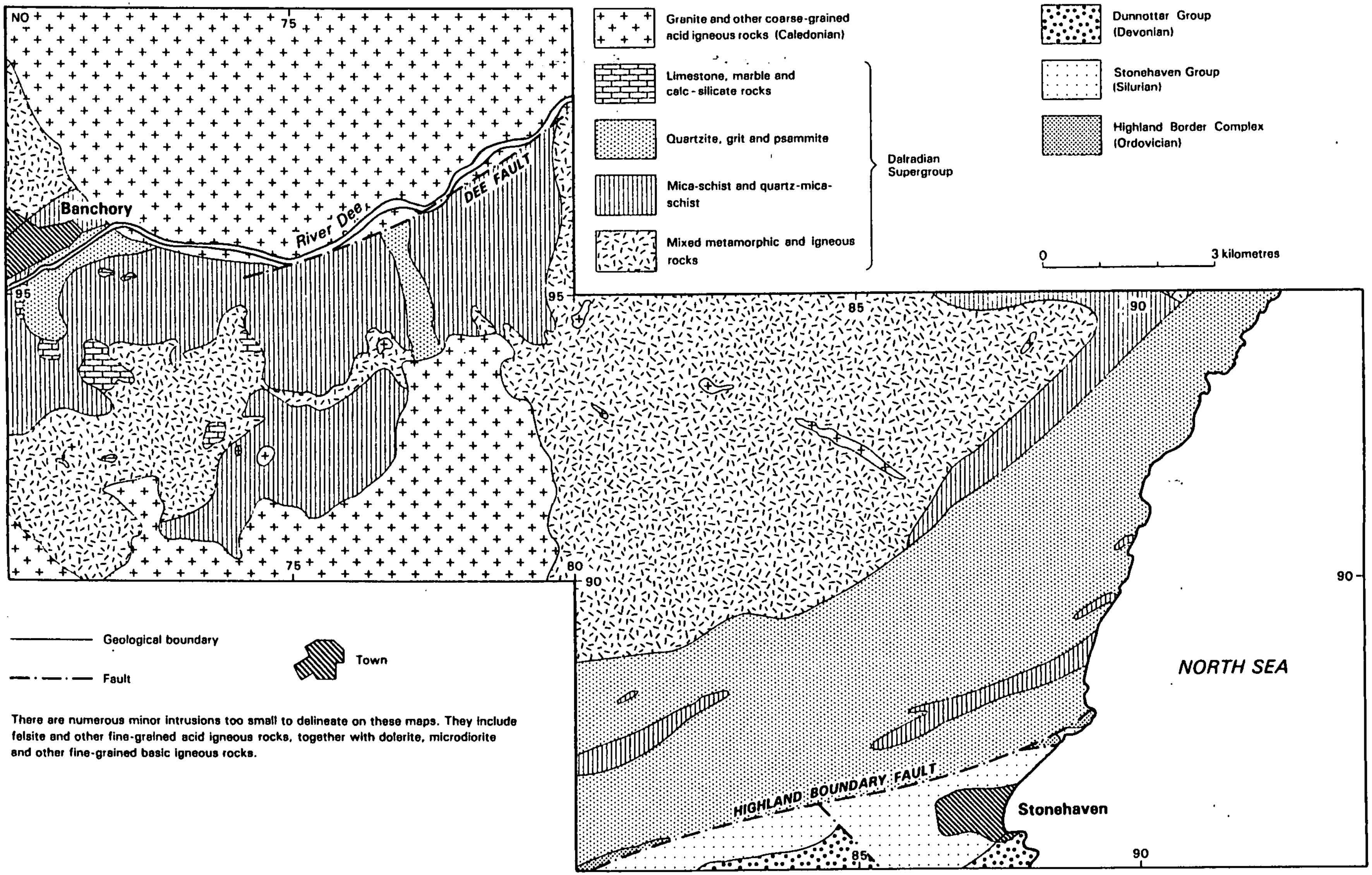



**Figure 4.** Sketch-map of the solid geology of the Banchory/Stonehaven resource sheet-area

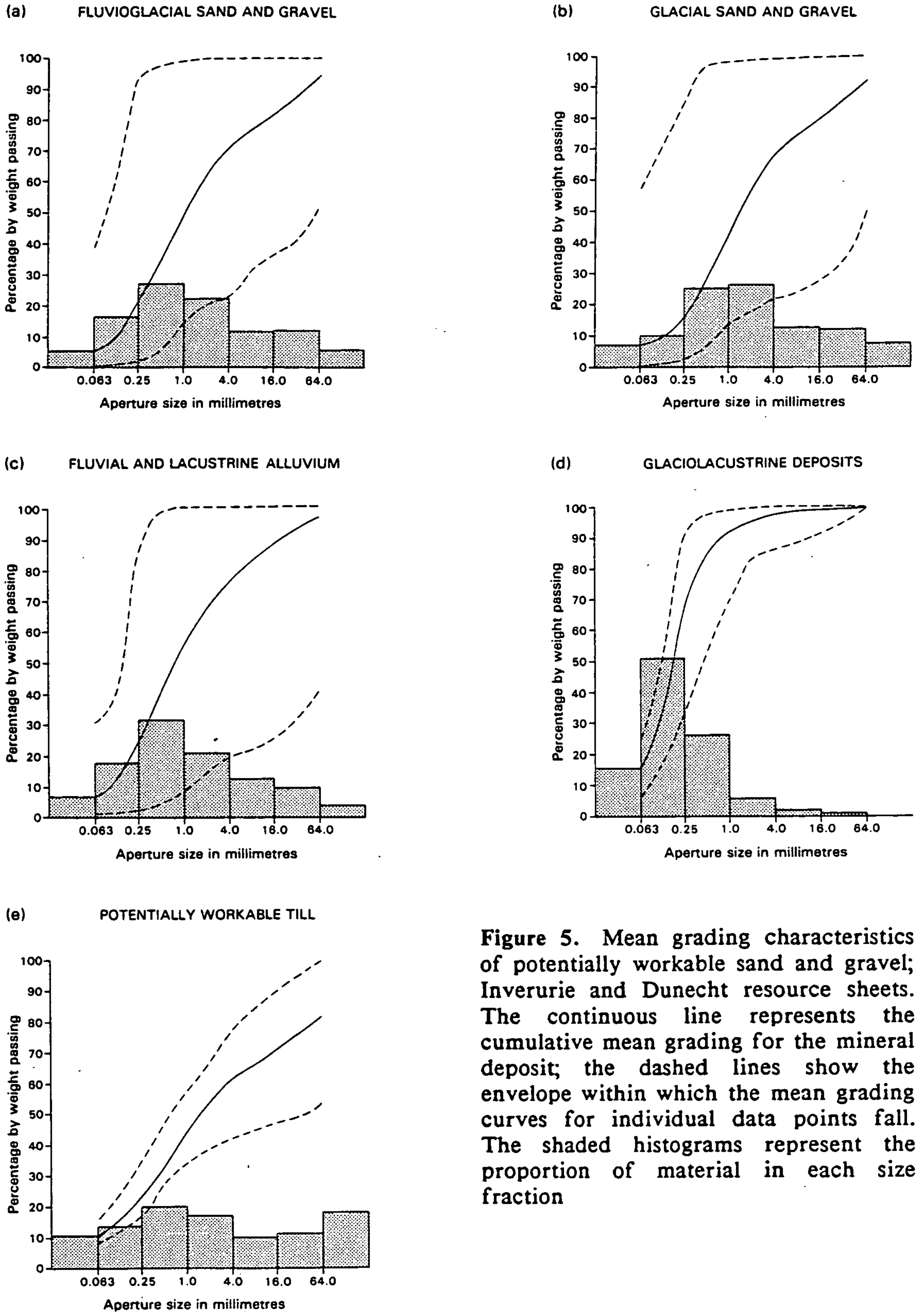
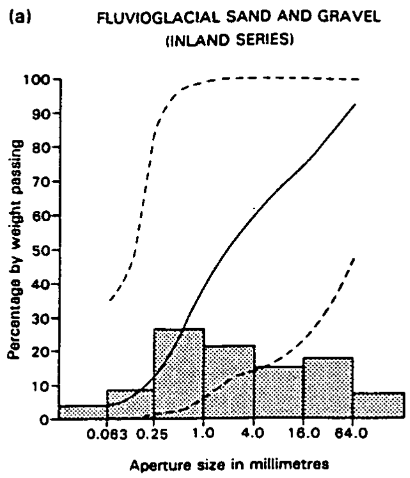
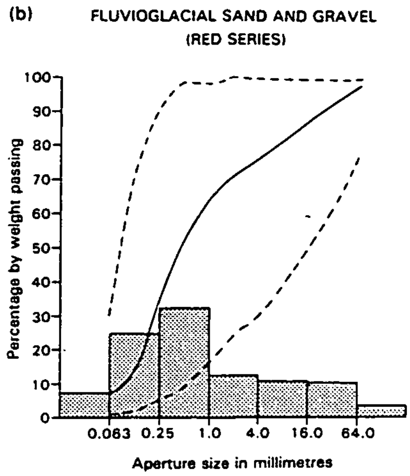
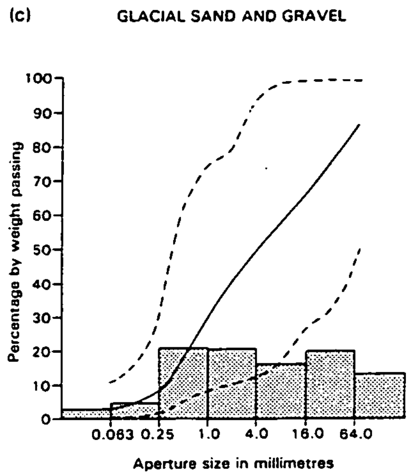
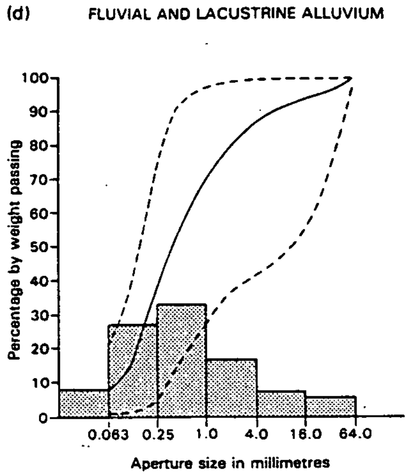


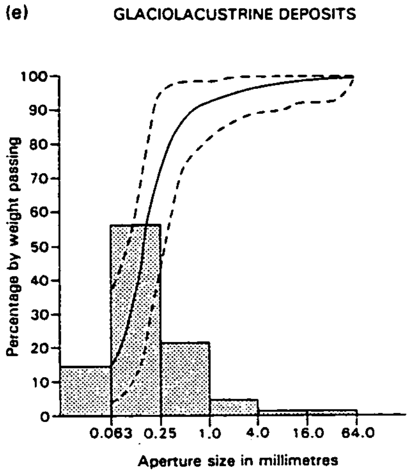

**Figure 5.** Mean grading characteristics of potentially workable sand and gravel; Inverurie and Dunecht resource sheets. The continuous line represents the cumulative mean grading for the mineral deposit; the dashed lines show the envelope within which the mean grading curves for individual data points fall. The shaded histograms represent the proportion of material in each size fraction

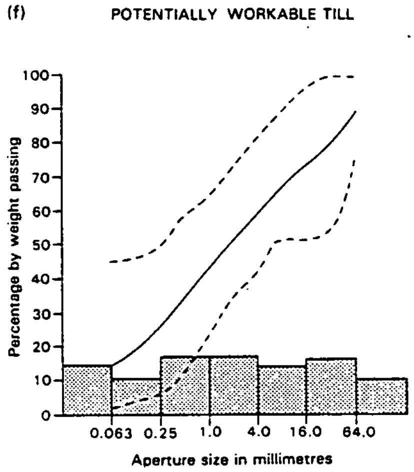


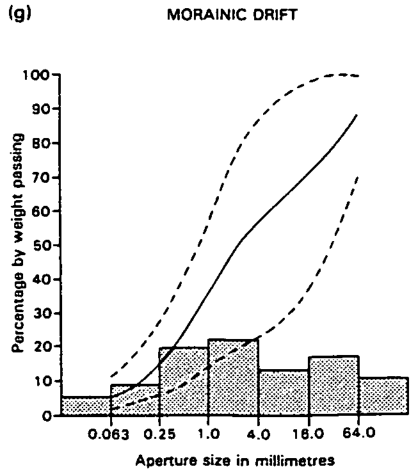




**Figure 6.** Mean grading characteristics of potentially workable sand and gravel; Banchory/Stonehaven resource sheet

**Table 1.** Geological classification of deposits

| | |
|---|---|
| **DRIFT** (Quaternary) | |
| Pleistocene and Recent | Peat<br>Alluvium<br>Alluvial cone<br>Lacustrine alluvium<br>Present-day beach deposits<br>Post-Glacial raised beach deposits<br>Late-Glacial raised beach deposits |
| *'Inland Series'* | Fluvioglacial sand and gravel<br>Glacial sand and gravel<br>Glaciolacustrine deposits<br>Morainic drift<br>Till |
| *'Red Series'* | Fluvioglacial sand and gravel<br>Glacial sand and gravel<br>Glaciolacustrine deposits<br>Till |
| **SOLID** | |
| Permo-Carboniferous | Igneous (intrusive) rocks - mainly dolerite |
| Devonian (Dunnottar Group | Conglomerate and sandstone |
| Silurian (Stonehaven Group) | Sandstone and mudstone |
| Ordovician (Highland Border Complex) | Serpentinised ultrabasic rocks, spilitic lava, chert and mudstone |
| Caledonian | Younger Igneous Intrusions: syn- to post-tectonic, granitic and basic plutonic and hypabyssal rocks |
| Dalradian (?late Precambrian to Cambrian) | Metasedimentary rocks (mainly psammite, pelite, semipelite and calc-silicate rock) |

Note: It should be assumed that a drift deposit belongs to the 'Inland Series' unless stated to the contrary

**Table 2** Mean gradings of potentially workable deposits; Inverurie and Dunecht resource sheets

| Deposits | Number of data points* | Number of samples | Mean grading percentage | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}-\frac{1}{4}$ mm | Medium sand $+\frac{1}{4}-1$mm | Coarse sand +1–4mm | Fine gravel +4–16mm | Coarse gravel +16–64mm | Cobbles and boulders +64mm |
| Fluvioglacial sand and gravel | 29 | 74 | 5 | 16 | 27 | 22 | 12 | 12 | 6 |
| Glacial sand and gravel | 19 | 66 | 7 | 10 | 25 | 26 | 13 | 12 | 7 |
| Alluvium (fluvial sand and gravel) | 17 | 38 | 6 | 17 | 32 | 21 | 12 | 9 | 3 |
| Glaciolacustrine deposits | 5 | 8 | 15 | 50 | 26 | 6 | 2 | 1 | 0 |
| Potentially workable morainic drift and till | 11 | 8 | 10 | 13 | 21 | 17 | 10 | 11 | 18 |

* Including assessment boreholes, trial pits and measured sections

**Table 3** Mean gradings of potentially workable deposits; Banchory/Stonehaven resource sheet

| Deposits | Number of data points* | Number of samples | Mean grading percentage | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}-\frac{1}{4}$ mm | Medium sand $+\frac{1}{4}-1$mm | Coarse sand +1–4mm | Fine gravel +4–16mm | Coarse gravel +16–64mm | Cobbles and boulders +64mm |
| Fluvioglacial sand and gravel ('Inland Series') | 48 | 219 | 4 | 8 | 27 | 21 | 15 | 18 | 7 |
| Fluvioglacial sand and gravel ('Red Series') | 12 | 54 | 7 | 25 | 33 | 12 | 10 | 10 | 3 |
| Glacial sand and gravel | 8 | 19 | 3 | 5 | 22 | 21 | 16 | 20 | 13 |
| Fluvial and lacustrine alluvium | 9 | 13 | 8 | 28 | 33 | 17 | 8 | 6 | 0 |
| Glaciolacustrine deposits | 5 | 10 | 15 | 56 | 22 | 5 | 1 | 1 | 0 |
| Morainic drift | 3 | 7 | 6 | 9 | 20 | 23 | 14 | 17 | 11 |
| Potentially workable till | 9 | 12 | 15 | 11 | 17 | 17 | 14 | 16 | 10 |

* Including assessment boreholes, trial pits and measured sections

**Table 4** Source and geological classification of composite samples used in pebble counts and mechanical and physical tests

| Source | Composite sample number | Geological classification of composite sample | Boreholes and pits from which samples were taken | Depth range (m) |
|---|---|---|---|---|
| Burn of Knock | 1 | Fluvioglacial sand and gravel | NO 79 SW 2 | 0.4- 8.0 |
| | | | NO 79 SW 3 | 0.3- 1.5 |
| | | | NO 79 SW 6 | 0.3- 9.3 |
| Mulloch | 2 | Fluvioglacial sand and gravel | NO 79 SW 7 | 1.5- 4.2 |
| | | | NO 79 SW 10 | 0.2- 1.8 |
| | | | NO 79 SW 16 | 2.8- 4.4 |
| Dee terraces (Banchory-Crathes) | 3 | Fluvioglacial sand and gravel | NO 79 NW 5 | 0.4- 9.2 |
| | | | NO 79 NW 9 | 0.4- 4.5 |
| | | | NO 79 NW 12 | 0.4-14.9 |
| | | | NO 79 NW 13 | 0.4- 6.8 |
| | | | NO 79 NW 14 | 0.5- 6.5 |
| | | | NO 79 NW 21 | 0.4-11.8 |
| | | | NO 79 NW 22 | 0.0- 5.2 |
| Dee terraces (Crathes-Drumoak) | 4 | Fluvioglacial sand and gravel | NO 79 NE 1 | 0.4- 7.1 |
| | | | NO 79 NE 5 | 0.3-10.1 |
| | | | NO 79 NE 6 | 0.3- 4.0 |
| | | | NO 79 NE 9 | 1.8-11.3 |
| | | | NO 79 NE 11 | 0.3- 5.5 |
| | | | NO 79 NE 12 | 0.4-15.8 |
| | | | NO 79 NE 14 | 0.3- 4.0 |
| Stonehaven | 5 | Fluvioglacial sand and gravel (Red Series) | NO 88 NW 8 | 7.7-14.8 |
| | | | NO 88 NW 11 | 4.6- 8.5 |
| | | | NO 88 NW 13 | 0.1- 1.4 |
| | | | NO 88 NW 14 | 0.3- 1.5 |
| | | | NO 88 NE 3 | 0.5- 3.5 |
| | | | NO 88 NE 4 | 0.4-12.8 |
| | | | NO 88 NE 7 | 2.7- 5.1 |
| | | | NO 88 NE 8 | 0.2- 3.4 |
| | | | NO 88 NE 11 | 0.1- 4.5 |
| Cowie Water | 6 | Fluvioglacial sand and gravel | NO 88 NW 3 | 0.4- 2.8 |
| | | | NO 88 NW 4 | 0.5- 5.9 |
| | | | NO 88 NW 7 | 0.3- 3.1 |
| | | | NO 88 NW 10 | 0.2-13.4 |
| | | | NO 88 NW 12 | 0.2- 4.7 |
| | | | NO 88 NW 16 | 0.0- 2.5 |
| | | | NO 88 NW 17 | 0.2- 6.0 |
| Garrol Burn/ Burn of Sheeoch | 7 | Glacial and fluvioglacial sand and gravel | NO 79 SW 8 | 0.0- 2.8 |
| | | | NO 79 SW 11 | 0.2- 3.0 |
| | | | NO 79 SW 12 | 0.3- 4.4 |
| | | | NO 79 SW 13 | 0.3- 4.3 |
| | | | | 8.4-14.5 |
| | | | NO 79 SW 14 | 0.3- 2.2 |
| | | | NO 79 SE 1 | 0.0- 2.9 |
| | | | NO 79 SE 2 | 0.4- 2.6 |
| | | | NO 79 SE 4 | 0.3- 4.4 |
| Pitcaple | 8 | Fluvioglacial sand and gravel | NJ 72 NW 1 | 0.2- 3.9 |
| | | | NJ 72 NW 2 | 0.3- 3.3 |
| | | | NJ 72 NW 4 | 0.3- 1.3 |
| | | | NJ 72 NW 5 | 0.3- 2.5 |
| | | | NJ 72 NW 6 | 0.7- 2.1 |
| | | | NJ 72 NW 7 | 0.2- 3.0 |
| | | | NJ 72 SW 1 | 0.5- 3.5 |
| Don floodplain and terraces | 9 | Alluvial and fluvioglacial sand and gravel | NJ 72 SE 3 | 1.2- 3.0 |
| | | | NJ 72 SE 4 | 0.2- 6.8 |
| | | | NJ 72 SE 6 | 1.6- 8.4 |
| | | | NJ 72 SE 13 | 1.6- 3.6 |
| Valley of the Corskie Burn | 10 | Fluvioglacial sand and gravel | NJ 70 NW 3 | 0.1- 4.3 |
| | | | NJ 70 NW 5 | 0.3- 3.5 |
| | | | NJ 70 NE 1 | 0.4- 9.5 |
| | | | NJ 70 NE 2 | 0.2- 3.2 |
| | | | NJ 70 NE 4 | 0.5- 3.5 |

Table 4 continued

| Source | Composite sample number | Geological classification of composite sample | Boreholes and pits from which samples were taken | Depth range (m) |
|---|---|---|---|---|
| Leuchar Moss | 11 | Glacial and fluvioglacial sand and gravel | NJ 70 SE 16 | 0.3- 5.6 |
| | | | NJ 70 SE 18 | 0.3- 3.6 |
| | | | NJ 70 SE 19 | 0.0- 5.5 |
| | | | NJ 70 SE 20 | 0.5- 7.3 |
| | | | NJ 70 SE 21 | 2.4- 3.9 |
| | | | NJ 70 NE 9 | 0.3- 9.8 |
| Cullerlie/ Finnarcy | 12 | Glacial and fluvioglacial sand and gravel | NJ 70 SE 1 | 2.1-12.7 |
| | | | NJ 70 SE 7 | 0.5-11.5 |
| | | | NJ 70 SE 8 | 0.4- 5.0 |
| | | | NJ 70 SE 13 | 0.2- 8.0 |
| | | | NJ 70 SW 12 | 0.2- 5.5 |
| Valley of the Gormack Burn | 13 | Glacial and fluvioglacial sand and gravel | NJ 70 SE 12 | 0.2- 3.5 |
| | | | NJ 70 SE 14 | 3.0- 6.5 |
| | | | NJ 70 SE 22 | 0.4- 3.9 |
| Stonehaven area | 14 | Fluvioglacial sand and gravel | stockpile in working pit | - |
| Burn of Sheeoch | 15 | Fluvioglacial sand and gravel | stockpile in working pit | - |
| North of Stonehaven | 16 | Glacial sand and gravel (Red Series) | face in working pit | - |

Table 5 Lithological classification of pebbles used in this report

| Toughness | Composition | Fissility | Grain size | Colour | Group |
|---|---|---|---|---|---|
| Friable | | | | | 1. Soft rock. Mudstone, shale, coal, poorly-cemented sandstone, badly weathered igneous or metamorphic rocks |
| Tough | Silicate | Homogeneous or bonded but not fissile | Coarse to medium-grained rocks | pale | 2. Granite, granodiorite, syenite, pegmatite, vein-quartz, quartzite, coarse-grained sandstone, arkose, quartzo-feldspathic granulite (psammite), gneiss |
| | | | | dark | 3. Gabbro, norite, diorite, coarse-grained greywackes and metagreywackes |
| | | | Medium to fine-grained rocks (disregarding phenocrysts or porphyroblasts) | pale | 4. Porphyry, quartz porphyry, aplite, felsite, rhyolite, trachyte, pale hornfels, calc-silicate rock, fine-grained sandstones |
| | | | | dark | 5. Basalt, andesite, serpentinite, microdiorite, lamprophyre, fine-grained greywackes and metagreywackes, semipelitic granulite, dark hornfels, dolerite, amphibolite |
| | | | Cryptocrystalline | | 6. Flint, chert, pitchstone |
| | | Fissile rocks | Coarse to medium-grained rocks | | 7. Schist, mica-schist, quartz-mica-schist, hornblende-schist |
| | | | Fine-grained rocks (disregarding porphyroblasts) | | 8. Phyllite, slate, chlorite-schist, schistose extrusive rocks. |
| | Non-silicate | | | | 9. Limestone, dolomite, marble, ironstone |
| Tough rocks known to be deleterious in concrete | | | | | 10. Special. Rocks known to shrink in concrete e.g. some greywackes. Rocks which react with cement e.g. those containing pyrite or sulphates |

**Table 6** Compositional analysis (pebble counts) of composite test samples (see Table 4 for origin of samples and Table 5 for lithological classification)

| Composite sample number | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lithological Group | Rock-type | | | | | | | | | | | | | | | | |
| Soft rock (1) | Mudstone, friable sandstone and highly weathered rocks | ** | ** | ** | ** | ** | ** | 8 | ** | 1 | ** | ** | ** | ** | ** | ** | 6 |
| Granite (2) | Granite and granodiorite | 62+ | 46 | 40 | 26 | 8 | 34 | 38 | 16 | 21 | 64 | 72 | 66 | 52 | 18 | 54 | 1 |
| | Vein-quartz and pegmatite | 15 | 16 | 3 | 9 | 16 | 22 | 10 | 5 | 11 | 7 | 5 | 4 | 16 | 5 | 5 | 8 |
| | Psammite, quartzite and coarse-grained sandstone | 6 | 14 | 27 | 35 | 24 | 17 | 21 | 5 | 31 | 10 | 8 | 6 | 14 | 60 | 29 | 65 |
| | Group, undivided | 83 | 76 | 70 | 70 | 48 | 73 | 69 | 26 | 63 | 81 | 85 | 76 | 82 | 83 | 88 | 74 |
| Gabbro (3) | Norite, diorite and gabbro | 2 | 1 | 5 | 4 | 1 | 1 | - | 34 | 2 | 4 | 5 | 5 | 6 | - | 4 | - |
| Porphyry (4) | Porphyry, felsite and fine-grained sandstone | 11 | 10 | 6 | 9 | 20 | 4 | 5 | 2 | 3 | 5 | 6 | 5 | 4 | 1 | 1 | 4 |
| Basalt (5) | Andesite, basalt, dolerite, amphibolite and pelite | 2 | 3 | 6 | 13 | 11 | 7 | 4 | 30 | 5 | 5 | 1 | 2 | 2 | 2 | 1 | 7 |
| Flint (6) | Flint and chert | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | ** |
| Schist (7) | Mica-schist, quartz-mica-schist and hornblende-schist | 2 | 10 | 13 | 4 | 20 | 14 | 14 | 1 | 26 | 5 | 3 | 12 | 6 | 14 | 6 | 5 |
| Phyllite (8) | Phyllite and slate | - | - | - | - | - | 1 | - | 7 | - | - | - | - | - | - | - | 4 |
| Angularity§ | | sa-sr | a-sr | a-sr | a-r | a-r | a-r | a | a-sa | a-r | a-r | a-r | a-r | a-wr | a | a-sa | a-r |
| Number of pebbles counted | | 329 | 300 | 280 | 288 | 434 | 282 | 371 | 406 | 282 | 269 | 307 | 293 | 346 | 377 | 282 | 362 |

** Trace amounts (less than 0.5 per cent)
\+ Results are given in frequency per cent. (Calculations of weight per cent are closely correlated)
§ a = angular sa = subangular sr = subrounded r = rounded wr = well-rounded

**Table 7** Results of mechanical and physical tests*

| Composite sample | AIV (%) | AIVR (%) | ACV (%) | ACVR (%) | Relative density (oven-dried basis) | Relative density (surface-dried basis) | Apparent relative density | Water absorption (%) | Inferred drying shrinkage+ (%) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 29 | 31 | - | - | - | - | - | - | - |
| 2 | 25 | 40 | - | - | - | - | - | - | - |
| 3 | 20 | 47 | 17 | 45 | 2.62 | 2.64 | 2.69 | 1.1 | 0.052 |
| 4 | 18 | 52 | 16 | 48 | 2.60 | 2.63 | 2.68 | 1.2 | 0.054 |
| 5 | 17 | 43 | 16 | 40 | 2.52 | 2.58 | 2.68 | 2.3 | 0.076 |
| 6 | 24 | 38 | 18 | 42 | - | - | - | - | |
| 7 | 25 | 39 | 21 | 39 | 2.53 | 2.58 | 2.66 | 2.0 | 0.070 |
| 8 | 29 | 28 | 21 | 34 | 2.61 | 2.68 | 2.82 | 2.9 | 0.088 |
| 9 | 26 | 28 | 22 | 37 | 2.58 | 2.63 | 2.72 | 2.0 | 0.070 |
| 10 | 29 | 33 | 22 | 37 | 2.54 | 2.58 | 2.66 | 1.8 | 0.066 |
| 11 | 32 | 31 | 24 | 39 | - | - | - | - | - |
| 12 | 28 | 29 | 23 | 37 | 2.53 | 2.58 | 2.66 | 2.1 | 0.072 |
| 13 | 28 | 35 | - | - | 2.52 | 2.56 | 2.62 | 1.5 | 0.060 |
| 14 | 23 | 32 | 19 | 32 | 2.56 | 2.61 | 2.71 | 2.2 | 0.073 |
| 15 | 24 | 35 | 20 | 39 | 2.53 | 2.58 | 2.66 | 1.9 | 0.068 |
| 16 | 24 | 26 | 20 | 34 | 2.51 | 2.59 | 2.71 | 2.9 | 0.088 |

* Tests conducted in accordance with BS 812 (1975).

+ The derivation of these values is explained in the text

**Table 8** Concrete drying shrinkage, wetting expansion and moisture absorption tests*

| Composite sample | Source | Deposit type | Drying shrinkage % | Wetting expansion % | Moisture absorption % |
|---|---|---|---|---|---|
| A | Durris area (Dee terraces) | Fluvioglacial sand and gravel | 0.040 | 0.039 | 5.1 |
| B | Stonehaven area | Fluvioglacial ('Red Series') | 0.050 | 0.045 | 5.8 |
| C | Burn of Sheeoch | Fluvioglacial sand and gravel | 0.045 | 0.040 | 5.4 |
| E | Pitcaple area | Fluvioglacial sand and gravel | 0.065 | 0.058 | 5.6 |
| F | Valley of the Corskie Burn | Fluvioglacial sand and gravel | 0.050 | 0.043 | 5.2 |
| G | Leuchar Moss | Fluvioglacial/glacial sand and gravel | 0.045 | 0.039 | 5.4 |
| H | Finnarcy area | Glacial sand and gravel | 0.045 | 0.038 | 5.4 |

* Conducted commercially according to the method described in Building Research Station Digest No 35 (second-series), 1968.

**Table 9** Summary of the sand and gravel resources of the three resource sheets

| Resource block or sub-block | Area of assessed ground* | | Mean thickness | | Volume of sand and gravel | | | Mean grading percentage | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Block | Mineral | Over-burden | Mineral | | Limits at the 95% probability level§ | | Fines | Sand | Gravel |
| | $km^2$ | $km^2$ | m | m | $m^3x10^6$ | ±% | $\pm m^3x10^6$ | $-\frac{1}{16}$ mm | $+\frac{1}{16}$ $-4$ mm | +4 mm |
| INVERURIE SHEET | | | | | | | | | | |
| Valley of the River Urie | - | 5.0 | 0.9 | 3.0 | 15 | 40% | 6 | 7 | 68 | 25 |
| Valley of the River Don | - | 0.7 | 0.7 | 3.4 | 2 | 54% | 1 | 2 | 48 | 50 |
| Valley of the Lochter Burn | - | 0.5 | 0.9 | 1.9 | 1 | - | - | 4 | 53 | 43 |
| **Whole sheet** | **97.7** | **6.2** | **0.9** | **3.0** | **19** | **27%** | **5** | **4** | **57** | **39** |
| DUNECHT SHEET | | | | | | | | | | |
| Block A | 29.5 | 3.5 | 0.6 | 5.2 | 18 | 47% | 3 | 3 | 66 | 29 |
| Block B | 22.5 | 2.8 | 0.7 | 2.7 | 8 | - | - | 5 | 60 | 35 |
| Block C | 10.5 | 3.1 | 0.4 | 4.5 | 14 | 43% | 6 | 10 | 77 | 13 |
| Block D | 11.5 | 2.1 | 0.5 | 5.5 | 12 | 61% | 7 | 7 | 62 | 31 |
| Block E | 14.0 | 0.7 | 0.4 | 1.8 | 1 | - | - | - | - | - |
| Block F | 12.0 | 1.5 | 1.0 | 3.0 | 4 | - | - | 5 | 63 | 32 |
| **Whole sheet** | **100** | **13.7** | **0.7** | **3.8** | **51** | **18%** | **9** | **6** | **67** | **27** |
| BANCHORY/STONEHAVEN SHEET | | | | | | | | | | |
| Block A | 28.5 | 3.6 | 0.3 | 2.1 | 8 | 46% | 4 | 6 | 81 | 13 |
| Block B | 10.0 | 8.7 | 0.4 | 7.7 | 67 | 28% | 19 | 4 | 56 | 44 |
| Block C | 53.6 | 2.7 | 0.4 | 4.7 | 13 | 34% | 4 | 4 | 61 | 35 |
| Block D | 46.0 | | | Too little sand and gravel present to assess | | | | | | |
| Block E | 29.0 | 0.8 | 0.4 | 2.6 | 2 | - | - | 5 | 45 | 50 |
| Block F | 4.7 | 2.5 | 0.3 | 5.4 | 14 | 36% | 5 | 5 | 51 | 44 |
| Block G | 22.6 | 3.4 | 0.3 | 6.4 | 22 | 29% | 6 | 9 | 62 | 29 |
| **Whole sheet** | **194.4** | **21.7** | **0.3** | **5.6** | **122** | **16%** | **19** | **5** | **59** | **36** |

Note: some figures differ slightly from those quoted elsewhere due to rounding and re-calculation

* Excluding built-up areas
§ Only quoted for statistical assessments

**Table 10** Sheet NJ 72 (Inverurie): Data from sample points and the assessment of resources in the valley of the River Urie and the Burn of Durno

| Data point<br>Borehole, pit, exposure or resistivity sounding | Recorded thickness<br>Total mineral m | <br>Depth of burial m | <br>Inter-vening waste m | Mean grading percentage<br>Fines −1/16 mm | <br>Fine sand +1/16 −1/4mm | <br>Medium sand +1/4 −1 mm | <br>Coarse sand +1 −4 mm | <br>Fine gravel +4 −16 mm | <br>Coarse gravel +16 −64 mm | <br>Cobbles and boulders +64 mm | Descriptive category (see the diagram in Appendix C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Valley-side deposits upstream of Milton of Inveramsay | | | | | | | | | | | |
| NJ 72 NW 1 | 3.7+ | 0.2 | - | 2 | 6 | 26 | 29 | 24 | 13 | 0 | SG |
| NJ 72 NW 2 | 3.0+ | 0.3 | - | 2 | 3 | 22 | 28 | 22 | 23 | 0 | SG |
| NJ 72 NW 3 | 3.0+ | 0.2 | - | 2 | 5 | 16 | 14 | 14 | 23 | 26 | G |
| NJ 72 NW 4 | 1.0 | 0.3 | - | 3 | 17 | 30 | 21 | 16 | 13 | 0 | SG |
| NJ 72 NW 5 | 2.2 | 0.3 | - | 1 | 6 | 34 | 39 | 19 | 1 | 0 | PS |
| NJ 72 NW 6 | 1.4 | 0.7 | - | 7 | 23 | 37 | 30 | 3 | 0 | 0 | S |
| NJ 72 NW 7 | 3.0 | 0.2 | - | 2 | 9 | 38 | 35 | 16 | 0 | 0 | PS |
| **Mean** | **2.5** | **0.3** | | **2** | **8** | **28** | **28** | **18** | **12** | **4** | **SG** |
| Valley-side deposits downstream of Milton of Inveramsay | | | | | | | | | | | |
| NJ 72 SW 1 | 3.0 | 0.5 | - | 3 | 23 | 36 | 30 | 8 | 0 | 0 | PS |
| NJ 72 SE 2 | 1.0 | 0.1 | - | 2 | 12 | 56 | 29 | 1 | 0 | 0 | S |
| NJ 72 SE 5 | 4.6 | 0.4 | 2.7 | 6 | 22 | 42 | 20 | 10 | 0 | 0 | PS |
| NJ 72 SE 7 | 8.4 | 1.1 | 3.7 | 8 | 17 | 21 | 16 | 17 | 19 | 2 | SG |
| NJ 72 SE 10 | 3.2 | 1.6 | - | 13 | 44 | 37 | 5 | 1 | 0 | 0 | CS |
| NJ 72 SE 12 | 5.3 | 0.3 | 0.2 | 8 | 39 | 35 | 12 | 5 | 1 | 0 | PS |
| **Mean** | **4.3** | **0.7** | | **7** | **26** | **33** | **17** | **10** | **6** | **1** | **PS** |
| **Combined mean** | **3.3** | **0.5** | | **5** | **19** | **31** | **21** | **13** | **9** | **2** | **SG** |
| Valley-floor deposits (undivided) | | | | | | | | | | | |
| NJ 72 SE 1 | 1.7 | 1.1 | - | 14 | 17 | 21 | 21 | 23 | 4 | 0 | CSG |
| NJ 72 SE 9 | 7.2 | 1.5 | 5.6 | 12 | 27 | 15 | 13 | 12 | 18 | 3 | CSG |
| NJ 72 NW R1 | 1.3 | 0.2 | - | - | - | - | - | - | - | - | - |
| NJ 72 SE R1 | 0.0 | - | - | - | - | - | - | - | - | - | - |
| NJ 72 SE R2 | 0.1+ | 8.0 | - | - | - | - | - | - | - | - | - |
| **Mean** | **2.1** | **2.7** | | **12** | **25** | **16** | **15** | **14** | **15** | **3** | **CSG** |
| **Overall mean for whole valley** | **3.0** | **0.9** | | **7** | **21** | **27** | **20** | **13** | **10** | **2** | **PS** |

*Statistical assessment of the valley-side deposits upstream of Milton of Inveramsay*

| | |
|---|---|
| Area of exposed mineral | 1.08km$^2$ |
| Area of ground worked for sand and gravel | 0.02km$^2$ |
| Mean thickness of overburden | 0.3m |
| Mean thickness of mineral | 2.5m |
| Estimated volume of mineral | 2.7 million m$^3$ (± 38% or 1.0 million m$^3$) |
| Estimated yield of mineral per hectare | 25 thousand m$^3$ (± 38% or 10 thousand m$^3$) |

*Statistical assessment of the valley-side deposits downstream of Milton of Inveramsay*

| | |
|---|---|
| Area of exposed mineral | 0.91km$^2$ |
| Area of concealed mineral | 0.31km$^2$ |
| Total area of mineral-bearing ground | 1.22km$^2$ |
| Area of ground worked for sand and gravel | 0.01km$^2$ |
| Mean thickness of overburden | 0.7m |
| Mean thickness of mineral | 4.3m |
| Estimated volume of mineral | 5.2 million m$^3$ (± 65% or 3.4 million m$^3$) |
| Estimated yield of mineral per hectare | 43 thousand m$^3$ (± 65% or 28 thousand m$^3$) |

*Inferred assessment of the valley-floor deposits in the valley of the River Urie and the Burn of Durno (undivided)*

| | |
|---|---|
| Area of concealed mineral | 1.21km$^2$ |
| Area of discontinuous spreads of mineral | 2.00km$^2$ |
| Total area of mineral-bearing ground | 2.71km$^2$* |
| Mean thickness of overburden | 2.7m |
| Mean thickness of mineral | 2.1m |
| Estimated volume of mineral | 5.7 million m$^3$ |
| Estimated yield of mineral per hectare | 21 thousand m$^3$ |

*In the calculation of this figure, 75 per cent of the area of discontinuous spreads is assumed to be mineral-bearing

**Table 11** Sheet NJ 72 (Inverurie): Data from sample points and the assessment of resources in the valleys of the River Don and the Lochter Burn

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive category (see the diagram in Appendix C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Intervening waste m | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$mm | Medium sand $+\frac{1}{4}$ −1 mm | Coarse sand +1 −4 mm | Fine gravel +4 −16 mm | Coarse gravel +16 −64 mm | Cobbles and boulders +64 mm | |
| VALLEY OF THE RIVER DON | | | | | | | | | | | |
| Valley-side deposits | | | | | | | | | | | |
| NJ 72 SE 4 | 6.6+ | 0.2 | - | 2 | 4 | 22 | 22 | 16 | 21 | 13 | G |
| NJ 72 SE X4 | 2.5+ | 0.5 | - | - | - | - | - | - | - | - | - |
| NJ 72 SE X7 | 1.7+ | 0.3 | - | - | - | - | - | - | - | - | - |
| **Mean** | **3.6** | **0.3** | | **2** | **4** | **22** | **22** | **16** | **21** | **13** | **G** |
| Valley-floor deposits | | | | | | | | | | | |
| NJ 71 NW 15 | 1.9 | 2.5 | | 3 | 10 | 40 | 25 | 7 | 5 | 10 | PS |
| NJ 72 SE 3 | 1.8+ | 1.2 | - | 1 | 1 | 6 | 11 | 6 | 16 | 59 | G |
| NJ 72 SE 6 | 8.0 | 0.4 | - | 1 | 3 | 21 | 23 | 23 | 27 | 2 | G |
| NJ 72 SE 13 | 2.0* | 1.6 | - | 6 | 12 | 24 | 17 | 18 | 19 | 4 | SG |
| NJ 72 SE X5 | 3.0* | 0.3 | - | - | - | - | - | - | - | - | - |
| NJ 72 SE X6 | 3.3* | 0.5 | - | - | - | - | - | - | - | - | - |
| **Mean** | **3.3** | **1.1** | | **2** | **5** | **22** | **21** | **18** | **21** | **11** | **G** |
| **Combined mean** | **3.4** | **0.7** | | **2** | **5** | **22** | **21** | **17** | **21** | **12** | **G** |
| VALLEY OF THE LOCHTER BURN | | | | | | | | | | | |
| NJ 72 NE 1 | 1.7 | 0.7 | - | 3 | 3 | 14 | 18 | 17 | 17 | 28 | G |
| NJ 72 NE 2 | 1.9+ | 1.6 | - | 4 | 9 | 35 | 25 | 21 | 6 | 0 | SG |
| NJ 72 NE R1 | 2.0 | 0.5 | - | - | - | - | - | - | - | - | - |
| **Mean** | **1.9** | **0.9** | | **4** | **6** | **25** | **22** | **19** | **11** | **13** | **SG** |

* Further deposits of mineral occur at depth

*Inferred assessment of the valley-side deposits in the valley of the River Don*

| | |
|---|---|
| Area of exposed sand and gravel | 0.19km$^2$ |
| Area of ground worked for sand and gravel | 0.002km$^2$ |
| Mean thickness of overburden | 0.3m* |
| Mean thickness of mineral | 3.6m* |
| Estimated volume of mineral | 0.7 million m$^3$ |
| Estimated yield of mineral per hectare | 36 thousand m$^3$ |

*Inferred assessment of the valley-floor deposits in the valley of the River Don*

| | |
|---|---|
| Area of concealed mineral | 0.51km$^2$ |
| Mean thickness of overburden | 1.1m* |
| Mean thickness of mineral | 3.3m* |
| Estimated volume of mineral | 1.7 million m$^3$ |
| Estimated yield of mineral per hectare | 33 thousand m$^3$ |

*Speculative assessment of the sand and gravel deposits in the valley of the Lochter Burn*

| | |
|---|---|
| Area of exposed mineral | 0.02km$^2$ |
| Area of discontinuous spreads of mineral | 1.72km$^2$ |
| Mean thickness of mineral | 1.9m |
| Estimated volume of mineral | 0.9 million m$^3$** |

* Data from sample points on the adjoining resource sheet have been included in the calculation of this figure.
** In the calculation of this figure, 25 per cent of the area of discontinuous spreads is assumed to be mineral-bearing

**Table 12** Sheet NJ 70 (Dunecht): Data from sample points and the assessment of resources in Block A

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive category (see the diagram in Appendix C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Intervening waste m | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$mm | Medium sand $+\frac{1}{4}$ −1 mm | Coarse sand +1 −4 mm | Fine gravel +4 −16 mm | Coarse gravel +16 −64 mm | Cobbles and boulders +64 mm | |
| Valley-side deposits | | | | | | | | | | | |
| NJ 70 NW 3 | 4.2+ | 0.1 | - | 1 | 5 | 24 | 30 | 14 | 23 | 3 | SG |
| NJ 70 NW 5 | 3.2+ | 0.3 | - | 1 | 4 | 17 | 19 | 12 | 17 | 30 | G |
| NJ 70 NE 1 | 10.6 | 0.4 | - | 4 | 6 | 26 | 22 | 15 | 19 | 8 | SG |
| NJ 70 NE 2 | 3.0 | 0.2 | - | 1 | 7 | 49 | 33 | 9 | 1 | 0 | PS |
| NJ 70 NE 4 | 3.0+ | 0.5 | - | 1 | 5 | 38 | 20 | 12 | 21 | 3 | SG |
| NJ 70 NE R2 | 5.8 | 0.5 | - | - | - | - | - | - | - | - | - |
| **Mean** | **5.0** | **0.3** | | **2** | **6** | **29** | **24** | **13** | **17** | **9** | **SG** |
| Valley-floor deposits | | | | | | | | | | | |
| NJ 70 NW 4 | 1.3+ | 2.2 | - | 19 | 10 | 55 | 15 | 1 | 0 | 0 | CS |
| NJ 70 NE 3 | 8.5 | 0.4 | - | 3 | 7 | 32 | 33 | 16 | 9 | 0 | PS |
| NJ 70 NE 10 | 6.8 | 0.4 | 2.9 | 4 | 38 | 40 | 11 | 4 | 3 | 0 | PS |
| **Mean** | **5.5** | **1.0** | | **5** | **20** | **37** | **22** | **10** | **6** | **0** | **PS** |
| **Overall mean for whole block** | **5.2** | **0.6** | | **3** | **11** | **32** | **24** | **12** | **13** | **5** | **SG** |

*Statistical assessment of the valley-side deposits in block A*

| | |
|---|---|
| Area of exposed mineral | 1.53km$^2$ |
| Area of ground worked for sand and gravel | 0.01km$^2$ |
| Mean thickness of overburden | 0.3m |
| Mean thickness of mineral | 5.0m |
| Estimated volume of mineral | 7.7 million m$^3$ (±66% or 5 million m$^3$) |
| Estimated yield of mineral per hectare | 50 thousand m$^3$ (±66% or 33 thousand m$^3$) |

*Inferred assessment of the valley-floor deposits in block A*

| | |
|---|---|
| Area of exposed mineral | 0.67km$^2$ |
| Area of concealed mineral | 1.30km$^2$ |
| Total area of mineral-bearing ground | 1.97km$^2$ |
| Mean thickness of overburden | 1.0m |
| Mean thickness of mineral | 5.5m |
| Estimated volume of mineral | 10.8 million m$^3$ |
| Estimated yield of mineral per hectare | 55 thousand m$^3$ |

**Table 13** Sheet NJ 70 (Dunecht): Data from sample points and the assessment of resources in Block B

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive category (see the diagram in Appendix C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Inter-vening waste m | Fines −1/16 mm | Fine sand +1/16 −1/4 mm | Medium sand +1/4 −1 mm | Coarse sand +1 −4 mm | Fine gravel +4 −16 mm | Coarse gravel +16 −64 mm | Cobbles and boulders +64 mm | |
| NJ 70 NW 2 | 1.9* | 1.1 | - | 2 | 4 | 18 | 24 | 15 | 26 | 11 | G |
| NJ 70 SW 8 | 6.1 | 0.2 | 1.1 | 8 | 11 | 27 | 29 | 10 | 15 | 0 | SG |
| NJ 70 SW 9 | 1.3+ | 1.7 | - | 1 | 5 | 25 | 37 | 28 | 4 | 0 | SG |
| NJ 70 SW 10 | 1.2 | 0.2 | - | 1 | 1 | 11 | 25 | 18 | 22 | 22 | G |
| NJ 70 SW R3 | 2.8 | 0.2 | - | - | - | - | - | - | - | - | - |
| **Mean** | **2.7** | **0.7** | | **5** | **8** | **23** | **29** | **14** | **16** | **5** | **SG** |

* Overlies 2.0m of potentially workable till

*Inferred assessment of the sand and gravel in block B*

| | |
|---|---|
| Area of exposed mineral | 1.11km$^2$ |
| Area of concealed mineral | 1.42km$^2$ |
| Area of discontinuous spreads of mineral | 0.34km$^2$ |
| Total area of mineral-bearing ground | 2.79km$^2$* |
| Mean thickness of overburden | 0.7m |
| Mean thickness of mineral | 2.7m |
| Estimates volume of mineral | 7.5 million m$^3$ |
| Estimated yield of mineral per hectare | 27 thousand m$^3$ |

* In the calculation of this figure, 75 per cent of the area of discontinuous spreads is assumed to be mineral-bearing

**Table 14** Sheet NJ 70 (Dunecht): Data from sample points and the assessment of resources in Block C

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive category (see the diagram in Appendix C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Intervening waste m | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$ mm | Medium sand $+\frac{1}{4}$ $-1$ mm | Coarse sand +1 −4 mm | Fine gravel +4 −16 mm | Coarse gravel +16 −64 mm | Cobbles and boulders +64 mm | |
| THE VALLEY OF THE LEUCHAR BURN | | | | | | | | | | | |
| Glacial sand and gravel (moundy deposits) | | | | | | | | | | | |
| NJ 70 SE 16 | 5.3+ | 0.3 | - | 2 | 7 | 23 | 23 | 10 | 15 | 20 | SG |
| NJ 70 NE 9 | 4.1* | 0.3 | - | 15 | 22 | 37 | 13 | 7 | 6 | 0 | CPS |
| NJ 70 NE 12 | 1.0 | 0.3 | - | 1 | 7 | 21 | 21 | 13 | 12 | 25 | G |
| NJ 70 SE 19 | 5.5+ | 0.0 | - | 1 | 2 | 18 | 64 | 10 | 2 | 3 | PS |
| **Mean** | **4.0** | **0.2** | | **5** | **9** | **25** | **35** | **9** | **8** | **9** | **SG** |
| Fluvioglacial sand and gravel (terraced deposits) | | | | | | | | | | | |
| NJ 70 SE 18 | 3.9 | 0.3 | - | 12 | 21 | 34 | 22 | 9 | 2 | 0 | CPS |
| NJ 70 SE 20 | 6.6 | 0.5 | 0.2 | 12 | 51 | 31 | 5 | 1 | 0 | 0 | CS |
| NJ 70 SE 21 | 10.9 | 1.5 | - | 16 | 54 | 23 | 6 | 1 | 0 | 0 | CS |
| NJ 70 SE R2 | 5.6 | 0.4 | - | - | - | - | - | - | - | - | - |
| **Mean** | **6.8** | **0.7** | | **14** | **47** | **28** | **9** | **2** | **0** | **0** | **CS** |
| **Combined mean** | **5.4** | **0.4** | | **10** | **31** | **26** | **20** | **5** | **4** | **4** | **CPS** |
| THE VALLEY OF THE GARRACK BURN | | | | | | | | | | | |
| NJ 70 NE 8 | 1.7 | 0.2 | - | 2 | 8 | 38 | 39 | 13 | 0 | 0 | PS |
| **Overall mean for whole block** | **4.5** | **0.4** | | **10** | **30** | **27** | **20** | **6** | **3** | **4** | **CPS** |

* Overlies 2.8m of disaggregated granite

*Inferred assessment of the glacial sand and gravel in the valley of the Leuchar Burn*

| | |
|---|---|
| Area of exposed mineral | 0.75km$^2$ |
| Area of concealed mineral | 0.10km$^2$ |
| Total area of mineral-bearing ground | 0.86km$^2$ |
| Area of ground worked for sand and gravel | 0.01km$^2$ |
| Mean thickness of overburden | 0.2m |
| Mean thickness of mineral | 4.0m |
| Estimated volume of mineral | 3.4 million m$^3$ |
| Estimated yield of mineral per hectare | 40 thousand m$^3$ |

*Inferred assessment of the fluvioglacial sand and gravel in the valley of the Leuchar Burn*

| | |
|---|---|
| Area of exposed mineral | 1.01km$^2$ |
| Area of concealed mineral | 0.52km$^2$ |
| Total area of mineral-bearing ground | 1.53km$^2$ |
| Area of ground worked for sand and gravel | 0.02km$^2$ |
| Mean thickness of overburden | 0.7m |
| Mean thickness of mineral | 6.8m |
| Estimated volume of mineral | 10.4 million m$^3$ |
| Estimated yield of mineral per hectare | 68 thousand m$^3$ |

*Speculative assessment of the sand and gravel in the valley of the Garrack Burn*

| | |
|---|---|
| Area of exposed mineral | 0.42km$^2$ |
| Area of concealed mineral | 0.28km$^2$ |
| Total area of mineral-bearing ground | 0.70km$^2$ |
| Mean thickness of overburden | 0.2m |
| Mean thickness of mineral | 2.2m |
| Estimated volume of mineral | 1.6 million m$^3$ |

**Table 15** Sheet NJ 70 (Dunecht): Data from sample points and the assessment of resources in Block D

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive category (see the diagram in Appendix C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Intervening waste m | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$mm | Medium sand $+\frac{1}{4}$ $-1$ mm | Coarse sand $+1$ $-4$ mm | Fine gravel $+4$ $-16$ mm | Coarse gravel $+16$ $-64$ mm | Cobbles and boulders $+64$ mm | |
| **Glacial sand and gravel (moundy deposits)** | | | | | | | | | | | |
| NJ 70 SW 12 | 4.6+ | 0.2 | 0.7 | 2 | 3 | 17 | 20 | 11 | 23 | 24 | G |
| NJ 70 SE 7 | 11.0* | 0.5 | - | 8 | 12 | 31 | 23 | 11 | 9 | 6 | PS |
| NJ 70 SE 8 | 3.7+ | 0.4 | 0.9 | 2 | 5 | 33 | 20 | 6 | 12 | 22 | SG |
| NJ 70 SE 13 | 13.8 | 0.2 | 1.5 | 13 | 15 | 29 | 27 | 9 | 7 | 0 | CPS |
| **Mean** | **8.3** | **0.3** | | **9** | **11** | **28** | **24** | **10** | **10** | **8** | **SG** |
| **Valley-floor deposits (terraced and other flat-lying deposits)** | | | | | | | | | | | |
| NJ 70 SE 1 | 10.2 | 2.1 | 1.7 | 6 | 8 | 32 | 34 | 14 | 5 | 1 | PS |
| NJ 70 SW 6 | 2.1+ | 0.9 | - | 3 | 2 | 10 | 18 | 11 | 27 | 29 | G |
| NJ 70 SW 14 | 1.2 | 0.2 | - | 4 | 5 | 15 | 15 | 10 | 15 | 36 | G |
| NJ 70 SW 16 | 3.1+ | 0.2 | - | 2 | 4 | 26 | 21 | 13 | 15 | 19 | SG |
| NJ 70 SW 17 | 1.3 | 0.2 | - | 1 | 2 | 11 | 15 | 18 | 25 | 28 | G |
| NJ 70 SW R2 | 4.1 | 0.2 | - | - | - | - | - | - | - | - | - |
| **Mean** | **3.7** | **0.6** | | **5** | **6** | **26** | **27** | **13** | **11** | **12** | **SG** |
| **Combined mean** | **5.5** | **0.5** | | **7** | **9** | **28** | **25** | **11** | **11** | **9** | **SG** |
| **Morainic drift and potentially workable till** | | | | | | | | | | | |
| NJ 70 SW 7 | 2.8+ | 0.2 | - | 12 | 12 | 16 | 15 | 9 | 9 | 27 | CG |
| NJ 70 SW 13 | 4.6 | 0.3 | - | 10 | 13 | 18 | 16 | 6 | 9 | 28 | CSG |
| NJ 70 SW 15 | 2.9** | 0.2 | 1.9 | 9 | 12 | 22 | 17 | 11 | 20 | 9 | SG |
| NJ 70 SE 2 | 2.7+ | 0.3 | - | 10 | 16 | 25 | 19 | 13 | 17 | 0 | CSG |
| NJ 70 SE 10 | 2.5+ | 0.2 | - | 8 | 12 | 14 | 8 | 5 | 7 | 46 | G |
| **Mean** | **3.1** | **0.2** | | **11** | **13** | **17** | **15** | **9** | **10** | **25** | **CSG** |

* Not including 1.5m disaggregated granite at bottom
**Uppermost 0.9m is classified as glacial sand and gravel

*Inferred assessment of the glacial sand and gravel*

| | |
|---|---|
| Area of exposed mineral | 0.25km$^2$ |
| Area of concealed mineral | 0.12km$^2$ |
| Total area of mineral-bearing ground | 0.37km$^2$ |
| Mean thickness of overburden | 0.3m |
| Mean thickness of mineral | 8.3m |
| Estimated volume of mineral | 3.1 million m$^3$ |
| Estimated yield of mineral per hectare | 83 thousand m$^3$ |

*Inferred assessment of the valley-floor deposits*

| | |
|---|---|
| Area of exposed mineral | 0.59km$^2$ |
| Area of concealed mineral | 0.84km$^2$ |
| Area of discontinuous spreads of mineral | 0.58km$^2$ |
| Total area of mineral-bearing ground | 1.72km$^2$* |
| Mean thickness of overburden | 0.6m |
| Mean thickness of mineral | 3.7m |
| Estimated volume of mineral | 6.4 million m$^3$ |
| Estimated yield of mineral per hectare | 37 thousand m$^3$ |

*Speculative assessment of the morainic drift*

| | |
|---|---|
| Area of exposed, discontinuous spreads of mineral (II) | 2.05km$^2$ |
| Mean thickness of overburden | 0.2m |
| Mean thickness of mineral (II) | 3.1m |
| Estimated volume of mineral (II) | 4.8 million m$^3$** |

* In the calculation of this figure, 50 per cent of the area of discontinuous spreads is assumed to be mineral-bearing
** In the calculation of this figure, 75 per cent of the area of morainic drift is assumed to be mineral-bearing

**Table 16** Sheet NJ 70 (Dunecht): Data from sample points and the assessment of resources in Block E

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive category (see the diagram in Appendix C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Inter-vening waste m | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$mm | Medium sand $+\frac{1}{4}$ -1 mm | Coarse sand +1 -4 mm | Fine gravel +4 -16 mm | Coarse gravel +16 -64 mm | Cobbles and boulders +64 mm | |
| Sand and gravel (undivided) | | | | | | | | | | | |
| NJ 70 SW 1 | 2.0 | 0.4 | - | 31 | 29 | 9 | 11 | 10 | 10 | 0 | VCSG |
| NJ 70 SW R1 | 1.5 | 0.4 | - | - | - | - | - | - | - | - | - |
| **Mean** | **1.8** | **0.4** | | **31** | **29** | **9** | **11** | **10** | **10** | **0** | **VCSG** |
| Morainic drift and potentially workable till | | | | | | | | | | | |
| NJ 70 SW 4 | 1.8 | 0.2 | - | 15 | 20 | 22 | 20 | 13 | 10 | 0 | CSG |
| NJ 70 SE 5 | 3.7 | 0.2 | - | 17 | 15 | 27 | 21 | 11 | 9 | 0 | CPS |
| **Mean** | **2.8** | **0.2** | | **16** | **17** | **25** | **21** | **12** | **9** | **0** | **CPS** |

*Speculative assessment of the sand and gravel*

| | |
|---|---|
| Area of exposed mineral | 0.51km$^2$ |
| Area of discontinuous spreads of mineral | 0.33km$^2$ |
| Total area of mineral-bearing ground | 0.67km$^2$* |
| Mean thickness of overburden | 0.4m |
| Mean thickness of mineral | 1.8m |
| Estimated volume of mineral | 1.2 million m$^3$ |

*Speculative assessment of the morainic drift*

| | |
|---|---|
| Area of exposed, discontinuous spreads of mineral (II) | 0.81km$^2$ |
| Mean thickness of overburden | 0.2m |
| Mean thickness of mineral (II) | 2.8m |
| Estimated volume of mineral (II) | 1.7 million m$^3$** |

* In the calculation of this figure, 50 per cent of the area of discontinuous spreads is assumed to be mineral-bearing

** In the calculation of this figure, 75 per cent of the area of morainic drift is assumed to be mineral-bearing

**Table 17** Sheet NJ 70 (Dunecht): Data from sample points and the assessment of resources in Block F

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive category (see the diagram in Appendix C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Intervening waste m | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$mm | Medium sand $+\frac{1}{4}$ -1 mm | Coarse sand +1 -4 mm | Fine gravel +4 -16 mm | Coarse gravel +16 -64 mm | Cobbles and boulders +64 mm | |
| Glacial sand and gravel and other valley-side deposits | | | | | | | | | | | |
| NJ 70 SE 12 | 3.3+ | 0.2 | - | 3 | 5 | 31 | 35 | 17 | 9 | 0 | SG |
| NJ 70 SE 22 | 3.5 | 0.4 | - | 3 | 6 | 26 | 27 | 20 | 18 | 0 | SG |
| **Mean** | **3.4** | **0.3** | | **3** | **6** | **28** | **31** | **18** | **14** | **0** | **SG** |
| Valley-floor deposits | | | | | | | | | | | |
| NJ 70 SE 14 | 3.5 | 3.0 | - | 8 | 10 | 24 | 26 | 12 | 19 | 1 | SG |
| NJ 70 SE R1 | 1.5 | 0.2 | - | - | - | - | - | - | - | - | - |
| **Mean** | **2.5** | **1.6** | | **8** | **10** | **24** | **26** | **12** | **19** | **1** | **SG** |
| **Overall mean for whole block** | **3.0** | **1.0** | | **5** | **7** | **27** | **29** | **16** | **16** | **trace** | **SG** |

*Inferred assessment of the glacial sand and gravel and other valley-side deposits*

| | |
|---|---|
| Area of exposed mineral | $0.46km^2$ |
| Area of ground worked for sand and gravel | $0.05km^2$ |
| Mean thickness of overburden | 0.3m |
| Mean thickness of mineral | 3.4m |
| Estimated volume of mineral | 1.6 million $m^3$ |
| Estimated yield of mineral per hectare | 34 million $m^3$ |

*Inferred assessment of the valley-floor deposits*

| | |
|---|---|
| Area of exposed mineral | $0.20km^2$ |
| Area of concealed mineral | $0.79km^2$ |
| Total area of mineral-bearing ground | $0.99km^2$ |
| Mean thickness of overburden | 1.6m |
| Mean thickness of mineral | 2.5m |
| Estimated volume of mineral | 2.5 million $m^3$ |
| Estimated yield of mineral per hectare | 25 thousand $m^3$ |

**Table 18** Banchory/Stonehaven sheet: Data from sample points and the assessment of resources in Block A

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive category (see the diagram in Appendix C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Inter-vening waste m | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$mm | Medium sand $+\frac{1}{4}$ -1 mm | Coarse sand +1 -4 mm | Fine gravel +4 -16 mm | Coarse gravel +16 -64 mm | Cobbles and boulders +64 mm | |
| NO 79 NW 8 | 1.4 | 0.3 | - | 4 | 4 | 26 | 27 | 23 | 15 | 1 | SG |
| NO 79 NW 11 | 0.9 | 0.3 | - | 1 | 3 | 21 | 21 | 23 | 19 | 12 | G |
| NO 79 NW 16 | 5.9 | 0.4 | - | 8 | 40 | 37 | 11 | 2 | 2 | 0 | PS |
| NO 79 NW 17 | 1.2 | 0.4 | - | 10 | 39 | 37 | 13 | 1 | 0 | 0 | CS |
| NO 79 NW 18 | 1.7+ | 1.4 | - | 14 | 13 | 33 | 30 | 8 | 2 | 0 | CPS |
| NO 79 NW 24 | 3.2 | 0.2 | - | 4 | 7 | 37 | 32 | 14 | 6 | 0 | PS |
| NO 79 NW 25 | 2.2+ | 0.2 | - | 3 | 4 | 33 | 37 | 18 | 5 | 0 | PS |
| NO 79 NW 26 | 2.7 | 0.2 | - | 2 | 3 | 37 | 53 | 5 | 0 | 0 | PS |
| NO 79 NE 3 | 1.4+ | 0.1 | - | 4 | 68 | 25 | 3 | 0 | 0 | 0 | S |
| NO 79 NE R1AB | 2.8 | 0.2 | - | - | - | - | - | - | - | - | - |
| NO 79 NE R2A | 0.9 | 0.1 | - | - | - | - | - | - | - | - | - |
| NO 79 NE R2B | 0.9 | 0.1 | - | - | - | - | - | - | - | - | - |
| **Mean** | **2.1** | **0.3** | | **6** | **22** | **34** | **25** | **9** | **4** | **trace** | **PS** |

*Statistical assessment of the fluvial and lacustrine alluvium, fluvioglacial sand and gravel and glacial sand and gravel north of the valley of the River Dee (Block A)*

| | |
|---|---|
| Total area (excluding Banchory urban area) | 28.48km$^2$ |
| Banchory urban area (including 0.43km$^2$ sand and gravel, not assessed) | 1.22km$^2$ |
| Area of exposed mineral | 1.82km$^2$ |
| Area of concealed mineral | 0.04km$^2$ |
| Area of discontinuous spreads of mineral | 2.57km$^2$ |
| Total area of mineral-bearing ground | 3.55km$^2$* |
| Area of morainic drift (not assessed) | 0.93km$^2$ |
| Area of ground worked for sand and gravel | 0.01km$^2$ |
| Mean thickness of overburden | 0.3m |
| Mean thickness of mineral | 2.1m |
| Estimated volume of mineral | 7.5 million m$^3$ (± 46% or 3.5 million m$^3$) |
| Estimated yield of mineral per hectare | 21 thousand m$^3$ (± 46% or 10 thousand m$^3$) |

* In the calculation of this figure, 50 per cent of the area of discontinuous spreads is assumed to be mineral-bearing

**Table 19** Banchory/Stonehaven sheet: Data from sample points and the assessment of resources in Block B

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive category (see the diagram in Appendix C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Intervening waste m | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$ mm | Medium sand $+\frac{1}{4}$ $-1$ mm | Coarse sand +1 -4 mm | Fine gravel +4 -16 mm | Coarse gravel +16 -64 mm | Cobbles and boulders +64 mm | |
| NO 79 NW 5 | 8.8+ | 0.4 | - | 6 | 6 | 16 | 19 | 19 | 22 | 12 | G |
| NO 79 NW 9 | 4.1* | 0.4 | - | 11 | 8 | 12 | 14 | 16 | 19 | 20 | CG |
| NO 79 NW 12 | 14.5 | 0.4 | - | 2 | 5 | 19 | 20 | 18 | 30 | 6 | G |
| NO 79 NW 13 | 11.1 | 0.4 | - | 2 | 11 | 48 | 11 | 10 | 14 | 4 | SG |
| NO 79 NW 14 | 7.0+ | 0.5 | - | 2 | 4 | 16 | 25 | 20 | 22 | 11 | G |
| NO 79 NW 21 | 11.6+ | 0.4 | - | 2 | 4 | 28 | 13 | 17 | 30 | 6 | G |
| NO 79 NW 22 | 5.2+ | - | - | trace | 8 | 33 | 20 | 15 | 23 | 1 | SG |
| NO 79 NW 23 | 1.9+ | 0.5 | - | 4 | 9 | 23 | 16 | 20 | 28 | 0 | SG |
| NO 79 NW R1AB | 7.8 | 0.3 | - | - | - | - | - | - | - | - | - |
| NO 79 NE 1 | 6.7 | 0.4 | - | 2 | 5 | 39 | 27 | 19 | 8 | 0 | SG |
| NO 79 NE 5 | 9.8+ | 0.3 | - | 2 | 4 | 23 | 15 | 18 | 36 | 2 | G |
| NO 79 NE 6 | 3.7 | 0.3 | - | 4 | 12 | 28 | 26 | 15 | 13 | 2 | SG |
| NO 79 NE 9 | 10.8+ | 0.5 | - | 4 | 8 | 22 | 24 | 18 | 17 | 7 | SG |
| NO 79 NE 11 | 5.1 | 0.4 | - | 3 | 3 | 17 | 27 | 27 | 21 | 2 | G |
| NO 79 NE 12 | 15.4 | 0.4 | - | 6 | 14 | 38 | 15 | 9 | 14 | 4 | SG |
| NO 79 NE 13 | 1.7** | 0.3 | - | 1 | 3 | 39 | 17 | 17 | 23 | 0 | SG |
| NO 79 NE 14 | 3.7+ | 0.3 | - | 9 | 7 | 22 | 12 | 11 | 20 | 19 | G |
| NO 79 NE R3AB | 9.9 | 0.3 | - | - | - | - | - | - | - | - | - |
| **Mean** | **7.7** | **0.4** | | **4** | **7** | **27** | **18** | **16** | **22** | **6** | **SG** |

* Overlies 2.0m+ potentially workable till
** Overlies 0.4m+ potentially workable weathered bedrock

*Statistical assessment of the fluvioglacial terraces and alluvium of the River Dee from Banchory to Drumoak (Block B)*

| | |
|---|---|
| Total area (excluding Drumoak and Crathes) | 9.97km$^2$ |
| Villages of Drumoak and Crathes (including 0.15km$^2$ sand and gravel, not assessed) | 0.18km$^3$ |
| Area of exposed mineral | 8.55km$^2$ |
| Area of concealed mineral | 0.07km$^2$ |
| Area of discontinuous spreads of mineral | 0.08km$^2$ |
| Total area of mineral-bearing ground | 8.66km$^2$* |
| Area of ground worked for sand and gravel | 0.04m$^2$ |
| Mean thickness of overburden | 0.4m |
| Mean thickness of mineral | 7.7m |
| Estimated volume of mineral | 66.7 million m$^3$ (± 28% or 18.7 million m$^3$) |
| Estimated yield of mineral per hectare | 77 thousand m$^3$ (± 28% or 22 thousand m$^3$) |

* In the calculation of this figure, 50 per cent of the area of discontinuous spreads is assumed to be mineral-bearing

**Table 20** Banchory/Stonehaven sheet: Data from sample points and the assessment of resources in Block C

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Inter-vening waste m | Fines -1/16 mm | Fine sand +1/16 -1/4mm | Medium sand +1/4 -1 mm | Coarse sand +1 -4 mm | Fine gravel +4 -16 mm | Coarse gravel +16 -64 mm | Cobbles and boulders +64 mm | (see the diagram in Appendix C) |
| Fluvioglacial sand and gravel and morainic drift in the valley of the Burn of Knock | | | | | | | | | | | |
| NO 79 SW 2 | 6.6* | 0.4 | - | 4 | 7 | 19 | 37 | 19 | 9 | 5 | SG |
| NO 79 SW 3 | 2.7+ | 0.3 | - | 1 | 9 | 57 | 8 | 4 | 9 | 12 | SG |
| NO 79 SW 4 | 1.6 | 0.2 | - | 10 | 16 | 29 | 30 | 13 | 2 | 0 | CPS |
| NO 79 SW 6 | 9.0 | 0.3 | - | 1 | 3 | 14 | 34 | 29 | 18 | 1 | SG |
| **Mean** | **5.0** | **0.3** | | **3** | **6** | **23** | **31** | **21** | **12** | **4** | **SG** |
| Fluvioglacial sand and gravel, glacial sand and gravel and glaciolacustrine deposits in the valleys of the Burn of Sheeoch, Garrol Burn, Strathie Burn and south of Bogforran | | | | | | | | | | | |
| NO 79 SW 7 | 3.9+ | 0.3 | - | 3 | 2 | 22 | 32 | 12 | 13 | 16 | SG |
| NO 79 SW 8 | 6.6+ | - | - | 11 | 46 | 20 | 8 | 5 | 7 | 3 | CPS |
| NO 79 SW 10 | 2.8+ | 0.2 | - | 1 | 6 | 56 | 26 | 8 | 3 | 0 | PS |
| NO 79 SW 11 | 4.0 | 0.2 | - | 4 | 5 | 10 | 13 | 11 | 20 | 37 | G |
| NO 79 SW 12 | 6.2 | 0.3 | - | 5 | 14 | 30 | 28 | 12 | 9 | 2 | PS |
| NO 79 SW 13 | 14.2 | 0.3 | - | 4 | 17 | 36 | 19 | 10 | 9 | 5 | SG |
| NO 79 SW 14 | 3.4+ | 0.3 | - | 8 | 6 | 24 | 27 | 15 | 16 | 4 | SG |
| NO 79 SW 15 | 3.7 | - | - | 3 | 5 | 20 | 20 | 20 | 28 | 4 | G |
| NO 79 SW 16 | 2.4 | 2.8** | - | 5 | 13 | 35 | 20 | 14 | 13 | 0 | SG |
| NO 79 SW R3AB | 5.6 | 0.2 | - | - | - | - | - | - | - | - | - |
| NO 79 SE 1 | 5.4 | - | - | 0 | 1 | 18 | 39 | 14 | 11 | 17 | SG |
| NO 79 SE 2 | 2.2 | 0.4 | - | 1 | 2 | 20 | 51 | 17 | 9 | 0 | SG |
| NO 79 SE 4 | 4.1+ | 0.3 | - | trace | 1 | 10 | 25 | 15 | 31 | 18 | G |
| NO 79 SE 5 | 1.0 | 0.3 | - | 3 | 3 | 7 | 6 | 7 | 23 | 51 | G |
| **Mean** | **4.7** | **0.4** | | **4** | **13** | **26** | **23** | **12** | **13** | **9** | **SG** |
| **Overall mean for whole block** | **4.7** | **0.4** | | **4** | **11** | **25** | **25** | **14** | **13** | **8** | **SG** |

* Overlies 1.0m of potentially workable till
** Includes 1.2m of potentially workable till

*Inferred assessment of the fluvioglacial sand and gravel and morainic drift deposits in the valley of the Burn of Knock (Block C)*

| | |
|---|---|
| Total area | 6.10km$^2$ |
| Area of exposed mineral | 0.37km$^2$ |
| Area of concealed mineral | 0.09km$^2$ |
| Area of morainic drift | 0.48km$^2$ |
| Total area of mineral-bearing ground | 0.71km$^2$* |
| Area of ground worked for sand and gravel | <0.01km$^2$ |
| Mean thickness of overburden | 0.3m |
| Mean thickness of mineral | 5.0m |
| Estimated volume of mineral | 3.6 million m$^3$ |
| Estimated yield of mineral per hectare | 50 thousand m$^3$ |

* In the calculation of this figure, 33 per cent of the area of morainic drift is assumed to be mineral-bearing

*Statistical assessment of the fluvioglacial and glacial sand and gravel, and glaciolacustrine deposits in the valleys of the Burn of Sheeoch, Garrol Burn, Strathie Burn, and south of Bogforran (Block C)*

| | |
|---|---|
| Total area (excluding Woodlands) | 47.52km$^2$ |
| Woodlands village (containing 0.06km$^2$ of sand and gravel, not assessed) | 0.19km$^2$ |
| Area of exposed mineral | 1.77km$^2$ |
| Area of concealed mineral | 0.07km$^2$ |
| Area of discontinuous spreads of mineral | 0.28km$^2$ |
| Total area of mineral-bearing ground | 1.98km$^2$* |
| Area of ground worked for sand and gravel | 0.13km$^2$ |
| Area of morainic drift | 0.11km$^2$ |
| Mean thickness of overburden | 0.4m |
| Mean thickness of mineral | 4.7m |
| Estimated volume of mineral | 9.3 million m$^3$ (± 41% or 3.8 million$^3$) |
| Estimated yield of mineral per hectare | 47 thousand m$^3$ (± 41% or 19 thousand m$^3$) |

* In the calculation of this figure, 50 per cent of the area of discontinuous spreads is assumed to be mineral-bearing

**Table 21** Banchory/Stonehaven sheet: Data from sample points and the assessment of resources in Block E

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive category (see the diagram in Appendix C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Inter-vening waste m | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$mm | Medium sand $+\frac{1}{4}$ -1 mm | Coarse sand +1 -4 mm | Fine gravel +4 -16 mm | Coarse gravel +16 -64 mm | Cobbles and boulders +64 mm | |
| NO 88 NW 1 | 2.7 | 0.4 | - | 3 | 10 | 27 | 32 | 15 | 13 | 0 | SG |
| NO 88 NW 6 | 2.5 | 0.3 | - | 7 | 5 | 7 | 7 | 12 | 32 | 30 | G |
| **Mean** | **2.6** | **0.4** | | **5** | **8** | **17** | **20** | **14** | **22** | **14** | **G** |

*Speculative assessment of Block E (mainly morainic drift deposits from Cairn-mon-earn to the Hill of Pitspunkie and in the valley of the Burn of Day)*

| | |
|---|---|
| Total area | 28.96km$^2$ |
| Area of exposed mineral | <0.01km$^2$ |
| Area of discontinuous spreads of mineral | 0.01km$^2$ |
| Area of morainic drift | 2.33km$^2$ |
| Total area of mineral-bearing ground | 0.79km$^2$* |
| Area of ground worked for sand and gravel | <0.01km$^2$ |
| Mean thickness of overburden | 0.4m |
| Mean thickness of mineral | 2.6m |
| Estimated volume of mineral | 2.1 million m$^3$ |

* In the calculation of this figure, 50 per cent of the area of discontinuous spreads and 33 per cent of the area of morainic drift is assumed to be mineral-bearing

**Table 22** Banchory/Stonehaven sheet: Data from sample points and the assessment of resources in Block F

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive category (see the diagram in Appendix C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Inter-vening waste m | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$mm | Medium sand $+\frac{1}{4}$ $-1$ mm | Coarse sand $+1$ $-4$ mm | Fine gravel $+4$ $-16$ mm | Coarse gravel $+16$ $-64$ mm | Cobbles and boulders $+64$ mm | |
| **Fluvioglacial sand and gravel and glaciolacustrine deposits between Snob Cottage and Bossholes** | | | | | | | | | | | |
| NO 88 NW 3 | 2.4+ | 0.4 | - | 1 | 4 | 35 | 29 | 10 | 21 | 0 | SG |
| NO 88 NW 4 | 5.4+ | 0.5 | - | 1 | 5 | 21 | 27 | 11 | 17 | 18 | SG |
| NO 88 NW 7 | 2.8 | 0.3 | - | 1 | 1 | 16 | 26 | 9 | 14 | 33 | G |
| NO 88 NW 16 | 5.0+ | - | - | 11 | 38 | 16 | 14 | 7 | 8 | 6 | CPS |
| **Mean** | **3.9** | **0.3** | | **4** | **15** | **21** | **23** | **9** | **14** | **14** | **SG** |
| **Fluvioglacial sand and gravel, alluvium and glaciolacustrine deposits of the Cowie Water between Glenton Hill and Stonehaven** | | | | | | | | | | | |
| NO 88 NW 9 | 1.5+ | - | - | 3 | 9 | 21 | 15 | 11 | 25 | 16 | G |
| NO 88 NW 10 | 12.3 | 0.2 | 0.9 | 7 | 12 | 37 | 25 | 11 | 7 | 1 | PS |
| NO 88 NW 12 | 8.4 | 0.2 | 6.1 | 9 | 22 | 29 | 21 | 9 | 8 | 2 | PS |
| NO 88 NW 17 | 6.9+ | 0.2 | - | 3 | 8 | 21 | 19 | 14 | 23 | 12 | SG |
| NO 88 NE 6 | 1.0 | 0.4 | - | 7 | 6 | 12 | 18 | 15 | 35 | 7 | G |
| NO 88 NE 9 | 6.3 | - | - | 1 | 1 | 9 | 15 | 13 | 31 | 30 | G |
| NO 88 NE 10 | 10.6 | 0.3 | - | 5 | 14 | 20 | 16 | 17 | 19 | 9 | SG |
| NO 88 NE X6 | 4.4+ | 0.5 | - | 1 | 3 | 6 | 9 | 15 | 50 | 16 | G |
| NO 88 NE X7 | 4.1 | 0.1 | - | - | - | - | - | - | - | - | - |
| NO 88 NE X8 | 6.6+ | 0.5 | - | 4 | 5 | 10 | 13 | 23 | 38 | 7 | G |
| NO 88 NE X9 | 3.7+ | 0.5 | - | 11 | 8 | 9 | 12 | 17 | 35 | 8 | CG |
| **Mean** | **6.0** | **0.3** | | **5** | **10** | **21** | **18** | **14** | **23** | **9** | **SG** |
| **Overall mean for whole block** | **5.4** | **0.3** | | **5** | **11** | **21** | **19** | **13** | **21** | **10** | **SG** |

*Inferred assessment of the fluvioglacial sand and gravel and glaciolacustrine deposits between Snob Cottage and Bossholes (Block F)*

| | |
|---|---|
| Total area | 1.13km$^2$ |
| Area of exposed mineral | 0.81km$^2$ |
| Area of concealed mineral | 0.01km$^2$ |
| Area of discontinuous spreads of mineral | 0.11km$^2$ |
| Total area of mineral-bearing ground | 0.88km$^2$* |
| Area of ground worked for sand and gravel | <0.01km$^2$ |
| Area of morainic drift (not assessed) | 0.07km$^2$ |
| Mean thickness of overburden | 0.3m |
| Mean thickness of mineral | 3.9m |
| Estimated volume of mineral | 3.4 million m$^3$ |
| Estimated yield of mineral | 39 thousand m$^3$ |

*Statistical assessment of the fluvioglacial sand and gravel, alluvium and glaciolacustrine deposits in the valley of the Cowie Water between Glenton Hill and Stonehaven (Block F)*

| | |
|---|---|
| Total area | 3.58km$^2$ |
| Area of exposed mineral | 1.36km$^2$ |
| Area of discontinuous spreads of mineral | 0.44km$^2$ |
| Total area of mineral-bearing ground | 1.58km$^2$* |
| Area of ground worked for sand and gravel | 0.18km$^2$ |
| Area of morainic drift (not assessed) | 0.05km$^2$ |
| Mean thickness of overburden | 0.3m |
| Mean thickness of mineral | 6.0m |
| Estimated volume of mineral | 9.5 million m$^3$ (± 43% or 4.1 million m$^3$) |
| Estimated yield of mineral per hectare | 61 thousand m$^3$ (± 43% or 26 thousand m$^3$) |

* In the calculation of this figure, 50 per cent of the area of discontinuous spreads is assumed to be mineral-bearing

**Table 23** Banchory/Stonehaven sheet: Data from sample points and the assessment of resources in Block G

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive category |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Inter-vening waste m | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$mm | Medium sand $+\frac{1}{4}$ -1 mm | Coarse sand +1 -4 mm | Fine gravel +4 -16 mm | Coarse gravel +16 -64 mm | Cobbles and boulders +64 mm | (see the diagram in Appendix C) |
| SUB-BLOCK G1 Fluvioglacial sand and gravel and glacial sand and gravel of the 'Red Series' between Stonehaven and Muchalls; Late-Glacial and Post-Glacial raised beach deposits and morainic drift to the north of Stonehaven | | | | | | | | | | | |
| NO 88 NE 2 | 2.2 | 0.2 | - | - | - | - | - | - | - | - | - |
| NO 88 NE 3 | 3.0+ | 0.5 | - | 4 | 70 | 14 | 6 | 5 | 1 | 0 | PS |
| NO 88 NE 4 | 12.4 | 0.4 | - | 8 | 9 | 17 | 23 | 24 | 18 | 1 | SG |
| NO 88 NE 8 | 3.2+ | 0.2 | - | 3 | 15 | 43 | 10 | 10 | 12 | 7 | SG |
| NO 88 NE 12 | 3.6 | 0.1 | - | 6 | 12 | 28 | 11 | 16 | 15 | 12 | SG |
| NO 88 NE 13 | 6.4 | - | - | 2 | 2 | 8 | 10 | 21 | 31 | 26 | G |
| NO 88 NE R1AB | 7.3 | 0.2 | - | - | - | - | - | - | - | - | - |
| NO 88 NE R2A | 1.5 | 0.2 | - | - | - | - | - | - | - | - | - |
| NO 88 NE R3A | 14.5 | 0.4 | - | - | - | - | - | - | - | - | - |
| NO 88 NE R3B | 6.7 | 0.6 | - | - | - | - | - | - | - | - | - |
| NO 89 SE 1 | 7.1+ | 0.2 | - | 6 | 17 | 28 | 14 | 15 | 13 | 7 | SG |
| NO 89 SE 2 | 3.2+ | 0.1 | - | 3 | 4 | 11 | 17 | 21 | 31 | 13 | G |
| **Mean** | **5.9** | **0.3** | | **5** | **14** | **21** | **15** | **18** | **18** | **9** | **SG** |
| SUB-BLOCK G2 Fluvioglacial sand and gravel of the 'Red Series' and alluvium of the valley of the Carron Water | | | | | | | | | | | |
| NO 88 NW 8 | 15.0 | 0.3 | 2.5 | 7 | 16 | 44 | 14 | 9 | 9 | 1 | PS |
| NO 88 NW 11 | 5.7 | 1.6 | 1.2 | 20 | 38 | 33 | 7 | 1 | 1 | 0 | VCS |
| NO 88 NW 13 | 5.2 | 0.1 | 1.2 | 11 | 33 | 40 | 8 | 4 | 4 | 0 | CPS |
| NO 88 NW 14 | 5.2 | 0.3 | - | 7 | 62 | 14 | 6 | 7 | 4 | 0 | PS |
| NO 88 NW 15 | 0.9+ | 0.7 | - | 4 | 6 | 7 | 13 | 21 | 31 | 18 | G |
| NO 88 NW R1A | 9.2 | 0.3 | - | - | - | - | - | - | - | - | - |
| NO 88 NW R1B | 4.2 | 0.3 | - | - | - | - | - | - | - | - | - |
| NO 88 NE 7 | 11.2+ | - | - | 6 | 33 | 41 | 6 | 5 | 6 | 3 | PS |
| NO 88 NE 11 | 4.4+ | 0.1 | - | 2 | 10 | 49 | 10 | 7 | 11 | 11 | SG |
| NO 88 NE X13 | 16.1+ | 0.3 | - | 21 | 30 | 40 | 6 | 3 | 0 | 0 | VCS |
| NO 88 NE X14 | 2.6* | 0.5 | - | - | - | - | - | - | - | - | - |
| NO 88 NE X15 | 3.0 | 0.5 | - | 14 | 9 | 9 | 10 | 13 | 45 | 0 | CG |
| **Mean** | **6.9** | **0.3** | | **12** | **28** | **36** | **9** | **6** | **7** | **2** | **CPS** |
| **Overall mean for whole block** | **6.4** | **0.3** | | **9** | **22** | **28** | **12** | **12** | **12** | **5** | **SG** |

* Overlies 1.7m of potentially workable till

*Statistical assessment of sub-block G1*

| | |
|---|---|
| Total area | 18.41km$^2$ |
| Area of exposed mineral | 1.46km$^2$ |
| Area of concealed mineral | 0.36km$^2$ |
| Area of discontinuous spreads of mineral | 0.13km$^2$ |
| Area of morainic drift | 0.20km$^2$ |
| Total area of mineral-bearing ground | 1.96km$^2$* |
| Area of ground worked for sand and gravel | 0.9km$^2$ |
| Mean thickness of overburden | 0.3m |
| Mean thickness of mineral | 5.9m |
| Estimated volume of mineral | 11.6 million m$^3$ (± 46% or 5.3 million m$^3$) |
| Estimated yield of mineral per hectare | 59 thousand m$^3$ (± 46% or 27 thousand m$^3$) |

* In the calculation of this figure, 50 per cent of the area of discontinuous spreads and 33 per cent of the area of morainic drift is assumed to be mineral-bearing

*Statistical assessment of sub-block G2*

| | |
|---|---|
| Total area (excluding Stonehaven) | 4.17km$^2$ |
| Stonehaven urban area (including 1.01km$^2$ sand and gravel, not assessed) | 2.30km$^2$ |
| Area of exposed mineral | 1.25km$^2$ |
| Area of concealed mineral | 0.13km$^2$ |
| Area of discontinuous spreads of mineral | 0.15km$^2$ |
| Total area of mineral-bearing ground | 1.46km$^2$* |
| Area of ground worked for sand and gravel | 0.12km$^2$ |
| Mean thickness of overburden | 0.3m † |
| Mean thickness of mineral | 6.9m † |
| Estimated volume of mineral | 10.1 million m$^3$ (± 47% or 4.7 million m$^3$) |
| Estimated yield of mineral per hectare | 69 thousand m$^3$ (± 47% or 32 thousand m$^3$) |

* In the calculation of this figure, 50 per cent of the area of discontinuous spreads is assumed to be mineral-bearing

† Commercial data have been used in the calculation of these figures

## APPENDIX A: DETAILED ACCOUNT OF THE SOLID GEOLOGY AND THE WEATHERING OF BEDROCK

### Solid geology

Sketch-maps of the solid geology of the study area are shown in Figures 3 and 4. The oldest rocks crop out to the north of the Highland Boundary Fault where they comprise a thick sequence of metamorphosed sedimentary rocks and subordinate basic igneous intrusions (Table 1). The sequence forms part of the Dalradian Supergroup (Harris and Pitcher, 1975) and is of Late Precambrian to Cambrian age (between about 750 and 550 million years old). The detailed sedimentology of these Dalradian rocks records a gradual change from deposition on a relatively stable, but slowly subsiding continental shelf, through a period of rapid but irregular subsidence (with associated basaltic volcanism), to widespread deep marine conditions.

These rocks were strongly deformed and metamorphosed by heat and pressure during the Grampian (early Caledonian) orogeny, from about 510 to 480 million years ago. As in the adjoining Aberdeen area, the Dalradian rocks show the classical Barrovian zonation of metamorphic grade first propounded by Barrow (1893, 1912) during the primary geological survey of the southeastern Highlands and Deeside; a subdivision of part of the Barrovian zonation, the Stonehaven metamorphic sequence (Harte and Hudson, 1979) is displayed in coastal exposures north of Stonehaven.

Throughout the Dalradian sequence, sandy sediments are now represented by quartz-feldspar granulites (psammites), clean sandstones by quartzite and coarser-grained sandy rocks by psammitic grits. Clayey rocks have been metamorphosed to form mica-schists and slates (pelites), sediments that contained significant proportions of both clay and sand have become quartz-mica-schists (semipelites), sandy limestones have been altered to calc-silicate rocks and beds of purer limestone have become marble. The calcareous metasediments have been quarried and burnt for lime, notably in the vicinity of Glack's Well [NO 715 937] and Maryfield [NO 719 957]. The basaltic rocks, which were originally intruded as dykes and sheets within the Dalradian sedimentary sequence, have been altered to amphibolite and hornblende-schist.

Where heat and pressure were sufficiently intense, some of the Dalradian rocks, but particularly the semipelites, were partially melted (migmatised) to produce alternating thin layers of granitic material and schist. Most, but not all, of the mixed metamorphic and igneous rocks shown in Figures 3 and 4, are, in fact, coarse-grained migmatitic gneisses.

The Dalradian rocks have been subjected to a complex (polyphase) sequence of folding and deformation, before, during and after the main period of metamorphic recrystallisation.

Although the interpretation of the major fold structures is hampered by poor exposure, absence of obvious marker horizons and extensive migmatisation, the major axis of folding appears to trend NE-SW; in coastal exposures (north of Stonehaven), at least three discrete episodes of minor folding are evident.

During and shortly after the Grampian orogeny, the Dalradian rocks were intruded by large masses of granitic, basic and ultrabasic rocks. These have been grouped in this report under the title of 'Younger Igneous Intrusions' (they are identified as 'Caledonian', both in Table 1 and in the appended borehole logs).

Part of the Insch Mass, which is composed of basic and ultrabasic intrusive rocks, crops out in the northern part of the Inverurie resource sheet area. The mass was intruded into the Dalradian rocks at the peak of the metamorphic episode (about 490 million years ago). The suite of rocks includes layered sequences of peridotite (often altered to serpentinite), troctolite, norite and gabbro.

The most extensive igneous intrusions are syn- to post-tectonic, of calc-alkaline granitic composition, and of Silurian to Devonian age (about 400 to 470 million years old). Granitic rocks of the Hill of Fare, Crathes and Tillyfourie masses (Munro, 1986, Figure 26) form the bedrock for most of the assessment area between the valley of the River Dee and the town of Inverurie. The Hill of Fare Mass is a pink granite, the Tillyfourie Mass is a grey granodiorite and the Crathes Mass includes both grey granodiorite and grey to pink granite with large potash feldspar phenocrysts, together with diorite in the vicinity of the Loch of Skene. The high ground forming the watershed between the catchment of the River Dee and the coastal area to the southeast, is underlain by the Kincardine (Mount Battock) Mass. This is a coarse-grained pink granite containing large feldspar phenocrysts.

Detailed descriptions of the petrography, composition and ages of the various large intrusions, can be found in the section entitled 'A geological history of N.E. Scotland', by B.C. Kneller (1987), within the excursion guide to the geology of the Aberdeen area, and also within the itineraries of excursions 15, 16, 19 and 20 of that guide.

Apart from small veins of aplite and pegmatite (associated with individual granitic plutons) injected into the Dalradian rocks, most of the minor intrusions take the form of narrow sheets and dykes composed of intermediate and acid hypabyssal rocks. The main rock types include felsite, quartz- and quartz-feldspar porphyry, microdiorite and lamprophyre. The trend of the dykes and sheets is generally NE-SW. Their intrusion is related to brittle deformation associated with the emplacement of the Caledonian igneous masses.

Two major faults, the Dee Fault and the Highland Boundary Fault, cross the southern part of the study area. The Highland Boundary Fault is in fact a complex zone of dislocations, rather than a simple fault, that separates the highly deformed Dalradian rocks from unmetamorphosed 'Old Red Sandstone' sediments. The latter crop out along the southern margin of the Banchory/Stonehaven resource sheet (Figure 4). A complicated sequence of rocks, known as the Highland Border Complex, crop out as tectonically bounded slices along the Highland Boundary Fault zone. In the Stonehaven area, the Highland Border Complex includes spilitic basalt pillow lavas and black shales, together with bands of chert and jasper; fossils (brachiopods, graptolites and acritarchs) indicate that most of the rocks are of Ordovician age (Curry and others, 1984).

The line of the Dee Fault, which is difficult to trace accurately, trends ENE-WSW and truncates the southern margin of the Crathes granite mass. The fault can be mapped only because it is coincident with a linear gravity anomaly, which extends along the valley of the River Dee. In contrast, the Highland Boundary Fault zone, which is one of the principal lines of structural displacement in Scotland, can be mapped accurately along much of its length. The main fault plane is often obscured inland by a zone of shattered rock, but it is exposed at the coast at Garron Point [NO 894 877] where it is marked by a distinctive dolomitic fault gouge. Blocks of this distinctive rock are present in the beds of the Burn of Graham and the Burn of Baulks, both of which cross the fault zone south of Nether Baulk [NO 817 850].

The Highland Boundary Fault has been active for a considerable period of time. During the Caledonian orogeny, the principal movements appear to have been strike-slip, but by Devonian times, the dislocation had become a normal fault, with a downthrow towards the south. The development of the Strathmore syncline, with its thick sequence of 'Old Red Sandstone' sedimentary and volcanic rocks, is clearly related to movements along the fault line. In fact, a disrupted unit containing angular blocks of sandstone (up to 30m in length) within the 'Old Red Sandstone' sequence south of Downie Point [NO 883 853], indicates syn-sedimentary fault movement, close to the margin of the syncline, during the Devonian (Robertson, 1987).

The stratigraphy of the 'Lower Old Red Sandstone' of Strathmore has been revised by Armstrong and Paterson (1970). The rocks crop out along the southern edge of 1:10 000 sheets NO 88 NW and NE, where they rest unconformably on rocks of the Highland Border Complex. The lowest division, the Stonehaven Group, is well exposed along the coast between Garron Point and Stonehaven. The lower part (the Cowie Formation) is predominantly composed of fine to medium-grained red, brown and grey sandstones, overlain by fossiliferous red and grey mudstones. Fossil fish and arthropods from a unit within the Cowie Formation (the Cowie Harbour Fish Bed), suggest a Downtonian (Upper Silurian) age for this part of the sequence (Westoll, 1977).

The Dunnottar Group, which overlies the Stonehaven Group, crops out south of the town. It chiefly comprises coarse conglomerates (containing rounded boulders of Dalradian quartzite and schistose grit, which may be more than a metre across), interbedded with lavas and thin beds of sandstone.

The youngest solid rocks in the assessment area are a series of quartz-dolerite dykes of Permo-Carboniferous age, which trend ENE-WSW. A good example, 2m thick, was recorded during the excavation of a pipeline trench in the vicinity of Upper Middleton [NJ 729 220]; the positions and orientations of many poorly-exposed examples are evident only as magnetic anomalies on maps produced by geomagnetic surveys of the area.

**Weathering of bedrock**

For much of the Mesozoic and Tertiary eras the

East Grampians appear to have been part of an eroding landmass. Consequently much of the bedrock in the area of this study has been subjected to deep chemical weathering, most of which took place prior to the glaciation of the district during the Quaternary era. Glacial, periglacial and fluvial erosion removed most of this decomposed rock but many pockets remain. Much weathered rock has been incorporated into the superficial deposits of the district, contributing to their sandy nature.

The extent and depth of weathering is difficult to determine, as only the remnants of a formerly extensive weathering cover are now preserved. There appears to be little correlation between the degree of weathering and lithology or topography. Coarse-grained, well jointed igneous rocks, such as granite, may be mantled by several metres of unconsolidated material, in which the feldspar and mica crystals have been altered to clay minerals.

Psammites and quartzites are also affected, although generally to a smaller degree, whereas pelitic rocks are often thoroughly altered to silty sandy clay. Sandstones and conglomerates are apparently unaffected in some areas, but locally they are decomposed to resemble modern sand and gravel, from which they can usually be distinguished by the traces of original sedimentary structures preserved in the weathered material.

The decomposition of the bedrock is regarded as being primarily a result of weathering under humid, tropical or sub-tropical conditions, which last occurred in Scotland during the late Miocene (Hall, 1983). Many of the weathering profiles have been modified by subsequent weathering under more temperature Pliocene and Pleistocene preglacial or interglacial conditions (Fitzpatrick, 1963). The contention that much of the weathering is of subtropical or tropical origin is supported by the mineralogy of the clays formed during the weathering process (Hall, 1986), and is also suggested by the presence of rounded 'core stones' within weathering profiles developed in some areas, notably in sandstone bedrock in the vicinity of Fetteresso Castle [NO 842 855]. These 'core stones' are similar to features described by Ruxton and Berry (1957, 1961), from areas of deeply weathered granite bedrock in the tropics.

## APPENDIX B: FIELD AND LABORATORY PROCEDURE

Initial studies of the laterally extensive glacial deposits of East Anglia and Essex showed that an absolute minimum of five sample points evenly distributed across a deposit of sand and gravel are needed to provide a worthwhile statistical assessment, but that, where possible, there should not be less than ten. In the present area of study, as elsewhere in northern Britain, the glacial deposits are patchy and heterogeneous; it is not always possible to provide as many as ten sample points in such discontinuous deposits. Sample points are any points for which adequate information exists about the nature and thickness of the deposit and may include boreholes other than those drilled during the survey, together with trial pits and exposures. In particular, the cooperation of sand and gravel operators ensures that boreholes are not drilled where reliable information is already available; although this information may be used in the calculations, it is held confidentially by BGS and cannot be disclosed without the permission of the company or person concerned.

The mineral shown on each 1:25 000 sheet is divided into resource blocks. The arbitrary size selected, is a compromise to meet the aims of the survey by providing sufficient sample points in each block. As far as possible the block boundaries are determined by geological boundaries so that, for example, glacial and terraced river gravels are separated. Otherwise the division is by arbitrary lines, which may bear no simple relationship to the geology. The blocks are drawn provisionally before sampling begins.

A reconnaissance of the ground is carried out to record any exposures and enquiries are made to ascertain what borehole information is available. Borehole and trial pit sites are then selected to provide as even a pattern of sample points as is practicable at a density of approximately one per square kilometre. However, because broad trends are independently overlain by smaller scale characteristically random variations, it is not been found necessary to adhere strictly to a square grid pattern. Thus such factors as ease of access, the need to minimise disturbance to land and to the public are also taken into account in siting the holes; at the same time, it is necessary to guard against the possibility that ease of access (that is, the positions of roads and farms) may reflect particular geological conditions which may bias the sampling results.

The drilling machine employed should be capable of providing a continuous series of samples representative of all unconsolidated deposits, so that the *in-situ* grading can be determined, if necessary, to a depth of 30m beneath different types of overburden. The drilling machine should be reliable, quiet, mobile and relatively small (so that it can be moved to sites of difficult access). Shell and auger rigs have proved to be almost ideal.

The rigs are modified to enable deposits above the water-table to be drilled 'dry', (instead of with water added to facilitate the drilling), in order to minimise the amount of material drawn in from outside the limits of the hole. The samples thus obtained are representative of the *in-situ* grading, and satisfy one of the most important aims of the survey. Below the water-table the rigs are used conventionally, although this results in the loss of some of the fines fraction. The pumping action of the bailer tends to draw material into the hole from the sides and the bottom, but care is taken to discard, as far as possible, this unwanted material.

Thin spreads of sand and gravel are sampled by means of shallow trial pits.

A continuous series of bulk samples is taken throughout the sand and gravel. Ideally samples are composed exclusively of the whole of the material encountered in the borehole or pit, between stated depths. A new sample is commenced whenever there is an appreciable lithological change within the sand and gravel, or at every 1m depth. The samples, each weighing between 25 and 45kg, are despatched in heavy duty polythene bags to a laboratory for grading. The results are reported as cumulative particle size distribution curves, examples of which are shown in Figure 7. The grading procedure is based on British Standard 1377 (1975). Random checks on the accuracy of the grading are made by BGS staff.

In the current survey, additional data on the thickness and extent of the mineral deposits have been obtained in some areas by measurements of apparent ground electromagnetic conductivity and resistivity following the methods outlined in Clarke and others (1982). The methods employed and the results obtained are discussed in more detail in Appendix E.

All data is coded up for analysis by computer. Abbreviated logs of assessment boreholes, trial pits and measured sections together with grading data are reproduced in Appendix F. Resistivity sounding measurements together with interpreted geological logs are presented in Appendix I.

Detailed records may be consulted on application to the Manager, Highlands and Islands Research Programme, Murchison House, West Mains Road, Edinburgh EH9 3LA.

## APPENDIX C: STATISTICAL PROCEDURES

### Statistical assessment

1 A statistical assessment can be made if there is a minimum of five evenly spaced sample points in the resource block (for smaller areas see paragraph 12 below).

2 The simple methods used in the calculations are consistent with the amount of data provided by the survey (Hull, 1981). Conventional symmetrical confidence limits are calculated for the 95 per cent probability level; that is, there is a 5 per cent or one in twenty chance of a result falling outside the stated limits.

3 The volume estimate (V) for the mineral in a given block is the product of the two variables, the sampled area (A) and the mean thickness ($\bar{d}_m$) calculated from the individual thicknesses at the sample points. The standard deviations (S) for these variables are related such that

$$S_V = (S_A^2 + S_{\bar{d}_m}^2)^{\frac{1}{2}}. \qquad [1]$$

4 The above relationship may be transposed such that

$$S_V = S_{\bar{d}_m} \times (1 + S_A^2/S_{\bar{d}_m}^2)^{\frac{1}{2}} \qquad [2]$$

From this it can be seen that $S_A^2/S_{\bar{d}_m}^2$ tends to 0 whereas $S_V$ tends to $S_{\bar{d}_m}$.

If, therefore, the standard deviation for area is small with respect to that for mean thickness, the standard deviation for volume approximates to that for mean thickness.

5 Given that the number of approximately evenly spaced sample points in the sampled area is n, with mineral thickness measurements $d_{m_1}, d_{m_2} \ldots d_{m_n}$, then the best estimate of mean thickness, $\bar{d}_m$, is given by

$$\Sigma\,(d_{m_1} + d_{m_2} + \ldots d_{m_n})/n.$$

For groups of closely spaced boreholes a discretionary weighting factor may be applied to avoid bias (see note on weighting below). The standard deviation for mean thickness $S_{d_m}$ expressed as a proportion of the mean thickness, is given by

$$S_{\bar{d}_m} = (1/\bar{d}_m)[\Sigma(d_m - d_m)^2/(n-1)]^{\frac{1}{2}}$$

where $d_m$ is any value in the series $d_{m_1}$ to $d_{m_n}$.

6 The mineral-bearing areas in each resource block are coloured pink on the map. Wherever possible, calculations relate to the mineral within mapped geological boundaries (which may not necessarily correspond to the limits of deposit). Where the area is not defined by a mapped boundary, that is, where the boundary is inferred, a distinctive symbol is used.

Experience suggests that the errors in determining area are usually small relative to those in thickness. The relationship $S_A/S_{\bar{d}_m} \leq 1/3$ is assumed in all cases. It follows from equation [2] that $S_{\bar{d}_m} \leq S_V \leq 1.05S_{\bar{d}_m}$.

7 The limits on the estimate of mean thickness of mineral, $L_{\bar{d}_m}$, may be expressed in absolute units $\pm(t/n^{\frac{1}{2}})S_{\bar{d}_m}$ or as a percentage $\pm(t/n^{\frac{1}{2}})S_{\bar{d}_m}(100/\bar{d}_m)$ per cent, where t is Student's t at the 95 per cent probability level for (n-1) degrees of freedom, evaluated by reference to statistical tables. (In applying Student's t it is assumed that the measurements are distributed normally).

8 Values of t at the 95 per cent probability level for values of n up to 20 are as follows:

| n | t | n | t |
|---|---|---|---|
| 1 | infinity | 11 | 2.228 |
| 2 | 12.706 | 12 | 2.201 |
| 3 | 4.303 | 13 | 2.179 |
| 4 | 3.182 | 14 | 2.160 |
| 5 | 2.776 | 15 | 2.145 |
| 6 | 2.571 | 16 | 2.131 |
| 7 | 2.447 | 17 | 2.120 |
| 8 | 2.365 | 18 | 2.110 |
| 9 | 2.306 | 19 | 2.101 |
| 10 | 2.262 | 20 | 2.093 |

(from Table 12, Biometrika Tables for Statisticians, Volume 1, Second Edition, Cambridge University Press, 1962). When n is greater than 20, 1.96 is used (the value of t when n is infinity).

9 In calculating confidence limits for volume, $L_V$, the following inequality corresponding to equation [3] is applied:

$$L_{\bar{d}_m} \leq L_V \leq 1.05L_{\bar{d}_m}.$$

10 In summary, for values of n between 5 and 20, $L_V$ is calculated as

$$[(1.05t)/\bar{d}_m] \times [\Sigma(d_m-\bar{d}_m)^2/n(n-1)]^{\frac{1}{2}} \times 100 \text{ per cent},$$

and when n is greater than 20, as

$$[(1.05 \times 1.96)/\bar{d}_m] \times [\Sigma(d_m-\bar{d}_m)^2/n(n-1)]^{\frac{1}{2}} \times 100 \text{ per cent},$$

(weighting factors may be included: see paragraph 15).

11 The application of this procedure to a fictitious area is illustrated in Figure 8.

**Inferred assessment**

12 If the sampled area of mineral in a resource block contains less than five sample points, an assessment is *inferred*. The volume of mineral is calculated as the product of the area, measured from field data, and the estimated thickness. Confidence limits are not calculated.

**Speculative assessment**

13 In some cases a resource block may include deposits for which little information is available or it may include an area within which mineral (as defined) is interpreted to be patchy or generally absent. If there is reason to believe that some mineral may be present, a *speculative* assessment may be made.

14 **Note on weighting** The thickness of a deposit at any point may be governed solely by the position of the point in relation to a broad trend. However, most sand and gravel deposits also exhibit a random pattern of local, and sometimes considerable, variation in thickness. Thus the distribution of sample points need be only approximately regular and in estimating the mean thickness only simple weighting is necessary. In practice, equal weighting can often be applied to thicknesses at all sample points. If, however, there is a distinctly unequal distribution of points, bias is avoided by dividing the sampled area into broad zones, to each of which a value roughly proportional to its area is assigned. This value is then shared between the data points within the zone as the weighting factor.

## APPENDIX D: CLASSIFICATION AND DESCRIPTION OF SAND AND GRAVEL

For the purposes of assessing resources of sand and gravel a classification should take account of economically important characteristics of the deposits, in particular the absolute content of fines and the ratio of sand to gravel.

The terminology commonly used by geologists when describing sedimentary rocks (Wentworth, 1922) is not entirely satisfactory for this purpose. For example, Wentworth proposed that a deposit should be described as a 'gravelly sand' when it contains more sand than gravel and there is at least 10 per cent of gravel, provided that there is less than 10 per cent of material finer than sand (less than 0.063 mm) and coarser than pebbles (more than 64 mm in diameter). Because deposits containing more than 10 per cent fines are not embraced by this system a modified binary classification based on Willman (1942) has been adopted here. The twelve descriptive categories that result from this modified scheme are shown in Figure 9.

When the fines content exceeds 40 per cent the material is not considered to be potentially workable and falls outwith the definition of mineral. Deposits which contain 40 per cent fines or less are classified primarily on the ratio of sand to gravel. For example, the boundaries between sand, pebbly sand, sandy gravel and gravel are drawn at sand to gravel ratios of 19:1, 3:1 and 1:1 respectively. This primary classification is qualified in the light of the fines content, as follows: less than 10 per cent fines - no qualification; 10 to 20 per cent fines - 'clayey'; 20 to 40 per cent fines - 'very clayey'.

The term 'clay' (as written, with single quote marks) is used to describe all material passing 0.063 mm. Thus, it has no mineralogical significance and includes particles falling within the size range of silt (0.063mm to 0.0039mm) and clay (less than 0.0039mm). The normal meaning of the term clay applies where it does not appear in single quotation marks.

The procedure to classify mineral into one of the twelve descriptive categories shown in Figure 9 is thus as follows:

1 Classify according to ratio of sand to gravel.
2 Classify according to fines content

For example, a deposit grading 32 per cent gravel, 59 per cent sand and 19 per cent fines is classified as 'clayey' sandy gravel. This short description is included in the borehole log (see Note 11, Appendix F).

Many differing proposals exist for the classification of the grain size of sediments (Atterberg, 1905; Udden, 1914; Wentworth, 1922, 1935; Allen, 1936; Twenhofel, 1937; Lane and others, 1974). As Archer (1970a,b) has emphasised, there is a pressing need for a simple metric scale acceptable to both scientific and engineering interests, for which the class limit sizes correspond closely with certain marked changes in the natural properties of mineral particles. For example, there is an important change in the degree of cohesion between particles at about the 0.063 mm size, which approximates to the generally accepted boundary between silt and sand. These and other requirements are met by a system based on Udden's geometric scale and a simplified form of Wentworth's terminology, which is used in this report (see Table D1)

The fairly wide intervals in the scale are consistent with the general level of accuracy of the quantitative assessments of the resource blocks. Three sizes of sand are recognised, fine (0.063-0.25mm), medium (0.25 mm-1 mm) and coarse (1-4 mm). The boundary at 16 mm distinguishes a range of finer gravel (from 4 mm to 16 mm), often characterised by abundance of worn, tough pebbles of vein-quartz, from larger pebbles, often of notably different materials. Boundaries at 64 mm and 256 mm distinguish pebbles from cobbles and cobbles from boulders respectively. The term 'gravel' is used loosely to denote both pebble-sized and cobble-sized material.

The size distribution of borehole samples is determined by sieve analysis (British Standard 1377:1975), which is presented by the laboratory as logarithmic cumulative curves (Figure 7). In this report the grading is tabulated in the assessment records (Appendix G), the intercepts corresponding with the simple geometric scale 0.063 mm, 0.25 mm, 1 mm, 4 mm, 16 mm and so on, as required. All of the original sample grading curves are available for reference at the appropriate office of BGS.

Each bulk sample is described, subjectively, by a geologist at the borehole site. Being based on visual examination, the initial description of the grading is inexact, the accuracy depending on the experience of the observer. The descriptions recorded are modified, as necessary, when the laboratory results become available.

The relative proportions of the rock types present in the gravel fraction are indicated by the use of the words 'and' or 'with'. For example, 'gabbro and schist' indicates approximately equal proportions of each rock type with neither constituent accounting for less than about 25 per cent of the whole; 'gabbro with schist' indicates that gabbro is dominant and schist, the principal accessory rock type, comprises 5 to 25 per cent of the whole. Where the accessory material accounts for less than 5 per cent of the whole, but is still readily apparent, the phrase 'with some' has been used. Minor constituents are referred to as rare or as 'trace'.

The terms used in the field to describe the degree of rounding of particles are concerned with the sharpness of the edges and corners of clasts and not their shape (Pettijohn, 1975). They are as follows:

**Angular**: showing little or no evidence of wear; sharp edges and corners.

**Subangular**: showing definite effects of wear. Fragments still have their original form but edges and corners begin to be rounded off.

**Subrounded**: showing considerable wear. The edges and corners are rounded off to smooth curves. Original grain shape is still distinct.

**Rounded**: original faces completely destroyed, but some comparatively flat surfaces may still remain. All original edges and corners have been smoothed off to rather broad curves. Original shape is still apparent.

**Well-rounded**: no original faces, edges or corners left. The entire surface consists of broad curves; flat areas are absent. The original shape is suggested by the present form of the grain.

## APPENDIX E: GEOPHYSICAL INVESTIGATIONS

### Resistivity survey

In order to evaluate various techniques for the assessment of scattered sand and gravel deposits, the Industrial Minerals Assessment Unit of the Institute of Geological Sciences (now British Geological Survey, BGS), conducted a feasibility study in the Redditch-Solihull area of the English Midlands during 1981 (Clarke and others, 1982). The new techniques that were investigated included various drilling, geophysical and remote sensing methods. It became apparent that drilling boreholes using shell and auger drilling rigs in the manner of previous sand and gravel assessments remained the best method of obtaining reliable data on the thickness and composition of concealed deposits of sand and gravel. Of the geophysical methods investigated ground resistivity surveying, and, in particular, the Offset Wenner sounding system was found to be the most effective. This method has subsequently been used successfully to supplement the data obtained from shell and auger drilling in the assessment of sand and gravel resources in the Henley-in-Arden district of Warwickshire (Cannell and Crofts, 1984) and in the Harleston and Bungay areas of East Anglia (Auton, Morigi and Price 1985).

As most of the potentially workable sand and gravel in northeast Scotland occurs as small, (but sometimes thick) scattered spreads, it was thought appropriate that ground resistivity measurements be made as part of the present assessment, in order to evaluate the application of the technique to the study of resources of sand and gravel in a Scottish context.

*Theory and methods*

Resistivity is defined as the resistance to electrical flow of a volume of ground of unit length and unit cross-sectional area. Apparent resistivity (measured in ohm.metres, ohm.m) is a weighted combination of the resistivities of sub-surface layers, and it is obtained by passing a current (I) between two current electrodes (C1 and C2) and measuring the potential difference ($\Delta V$) between two potential electrodes (P1 and P2). By changing the positions of the electrodes systematically for a particular configuration, a series of apparent resistivity readings may be obtained in order to resolve the sub-surface layering. For the Wenner electrode configuration, (Figure 10a) the apparent resistivity ($\rho a$) is given by:-

$$\rho a = 2\pi\, a\, \Delta V/I$$

where (a) is the electrode separation.

At all of the ground resistivity sites in the present survey, the *Offset Wenner* sounding system was used, in conjunction with a measuring instrument (in this case an ABEM Terrameter SAS 300) which incorporated a signal averaging system for improved accuracy of the results and a digital read-out of the measured resistances. The Offset Wenner system was designed for operation with two multi-core cables containing metal connections for each of the electrode positions, which feed back to a central switching box. This technique uses a central electrode in addition to the conventional Wenner array electrode positions. The distance of each pair of electrodes (from the central electrode) doubles for succeeding sets of measurements. This can be seen in Figure 10b, where for the first set of readings ($R_A$), electrode 3 is the central electrode, numbers 2 and 4 are the pair of potential electrodes (both 0.5m from electrode 3); numbers 1 and 5 are the pair of current electrodes (both 1m away from electrode 3). In the present study, a maximum of nine pairs of electrodes were used, the farthest pair of electrodes being spaced 128m either side of the central electrode (giving a total array length of 256m).

The depth of investigation of an electrode configuration can be considered as a depth below which there is little contribution to the measured signal; for homogeneous ground this has been evaluated as 0.11D, where D is the distance between the outermost two electrodes. The maximum depth of investigation theoretically possible using a total array length of 256m (for homogeneous ground) is 0.11 x 256m = 28.2m, which is comparable to the maximum depth (25m) to which assessment boreholes are drilled (see Appendix B). In practice, drift sequences are often very heterogeneous and the depth of penetration may be increased or decreased as a result.

By combining measurements from different electrode configurations (such as $R_B$, $R_C$, $R_{D1}$ and $R_{D2}$, selected by using the switching box), it is possible to check the consistency of the reading, to compensate for the effect of near-surface lateral variations and to reduce the total number of electrode positions occupied. By this means, all the electrodes can be planted and connected at the same time, making the system practical for one-man operation as well as being rapid and cost-effective.

In many instances, the sites chosen for resistivity sounding measurements are surrounded by fences, hedges or buildings, which restrict the length of the array that can be used. In fact, it requires a much larger area of ground than might at first be thought to enable two soundings to be made along straight arrays (both 256m long) centred at the same point.

The resistivity readings obtained from the ABEM terrameter were plotted in the field using log-log graph paper in order to obtain preliminary 'field curves'. These give an immediate indication of the likely geological sequence encountered and the depth to rock-head. Detailed interpretation of the data was achieved in the laboratory by a curve-matching process, which involved the production of geo-electric models (resistivity curves) using a suite of computer programs developed specifically for this process by BGS. The programs are based on those published by Finch (1984), but modified to run on GEC 4090 and VAX 8600 main-frame computers. This computer-generated output forms the basis of the geological interpretation of the resistivity sounding data presented in the detailed resistivity records given in Appendix I.

*Results*

Using the Offset Wenner sounding system, 43 resistivity depth soundings were taken at 25 sites to augment the assessment data obtained from trial pits, measured sections and boreholes. In general, two sets of soundings were conducted at each site, the electrode arrays being orientated approximately perpendicular to one another. The positions of the arrays had sometimes to be varied from the ideal depending on geological conditions and local physical constraints such as field boundaries. The interpreted resistivity values from both sets of soundings were then averaged to provide a mean value for each site. Eight of the resistivity sites were positioned close to sample points (boreholes, trial pits, or measured sections) in order to calibrate the resistivity results. A frequency distribution plot of the ground resistivity values, calculated from the interpreted resistivity values, is shown in Figure 11.

High interpreted resistivity values (>1000 ohm.m) can invariably be attributed to either sand and gravel or to igneous or metamorphic bedrock, but distinguishing between them without some prior knowledge of the geology of the area is difficult. It is particularly difficult to distinguish between granitic and metamorphic rocks simply on the basis of resistivity, as the range of interpreted values is similar for both rock-types. Very high apparent resistivities (>2000 ohm.m) suggest that the igneous and metamorphic bedrock has relatively high permeability: generally, the higher the value, the more fractured the rock.

In contrast, four resistivity soundings were conducted at sites underlain by Ordovician and Devonian bedrock which gave interpreted resistivity values that ranged between 100-300 ohm.m. These values indicate a higher proportion of clayey material in the Ordovician and Devonian rocks as compared to unweathered granite and metamorphic bedrock. This increase in clay and silt is explained, in part, by the fact that beds of mudstone are present within the Ordovician (Highland Border Complex) and within the Devonian ('Old Red Sandstone') sequences. Disseminated silt and clay is also present within the beds of sandstone and conglomerate which constitute the principal rock types within the 'Old Red sandstone' sequence in the study area.

The majority of the soundings indicated that there is a layer of low resistivity towards the base of the drift sequence. This low resistivity layer was attributed to till or clayey gravel overlying the bedrock, and this interpretation is confirmed in many of the assessment boreholes, notably those sited on the terraced deposits in the valley of the River Dee.

The sandy nature of the till and morainic drift deposits over most of the survey area (compared with till sequences in southern Britain, for which resistivity data is available) caused many of the interpreted resistivity values to be much higher than might be expected for such deposits. In the Henley-in-Arden survey area, for example, most of the till deposits gave interpreted resistivity values between 20-70 ohm.m, whereas most of the glacial sand and gravel had values between 100-300 ohm.m. In the area of the present study, values of less than about 75 ohm.m could be attributed to deposits of clayey till, but sandy till gave values between 100-300 ohm.m.

Intermediate values (100-1000 ohm.m) needed careful interpretation as there were only subtle differences between predominantly sandy and predominantly clayey deposits. The soundings conducted over fine-grained glaciolacustrine sediments gave values between 100-200 ohm.m, illustrating the silty nature of these deposits.

### *Conclusions*

A basal till of low resistivity, underlain by igneous or metamorphic bedrock of high resistivity, enabled the depth to the base of the drift to be fixed accurately over much of the study area. Large differences between the resistivity ranges of sand and gravel and underlying clayey till tended to 'mask' the effect of any intervening layers of moderate resistivity, such as glaciolacustrine deposits. Thus, in many instances, careful interpretation of the results coupled with close borehole or other means of control was required. The confidence of the geological interpretation of the resistivity results is generally high, but only because data from so many boreholes and pits were available to aid that interpretation. The highly variable nature of the sequence is reflected in the wide range of resistivity values encountered (20-20,000 ohm.m). The high proportion of sand present in many of the drift deposits meant that the contrast between overburden, or waste, and potentially workable sand and gravel was not as clear as in areas of southern Britain where similar resistivity surveys have been conducted.

Resistivity soundings using the Offset Wenner system proved to be a rapid method for investigating the drift deposits of the survey area; up to ten separate sets of soundings could be made each day. The detailed interpretation of the results, however, can be very time-consuming and this should be borne in mind when geophysical methods are considered as part of any further assessment.

Boreholes or trial pits are required for definitive measurements but resistivity soundings are a good alternative in areas of difficult terrain that would otherwise be inaccessible to a drilling rig, for example, areas of marshy ground, such as Black Moss, and on ground where disturbance has to be avoided. Local difficulties (small fields, wire fences, etc) can be overcome by careful positioning of the sounding site, but in most instances the fields were too small for the full array to be used.

The Offset Wenner system provided a valuable additional 'tool' for the assessment of sand and gravel in the study area. It was especially useful in proving the total thickness of sand and gravel at sites in the valley of the River Dee, where the coarse nature of the gravels made the penetration of the full sequence by shell and auger drilling an expensive and often impossible task. The system is also useful for rapidly determining areas where quantitive investigations using 'traditional' drilling and sampling methods are warranted.

## **Conductivity Survey**

Electromagnetic conductivity measurements were made with portable, non-contacting conductivity meters as an aid to geological mapping of sedimentary rock sequences by BGS staff in southern Britain (Zalasiewicz, Mathers and Cornwell, 1985). Conductivity measurements made on traverses across an area of ground to be mapped showed that clay-rich sediments could be rapidly distinguished from sands and gravels as well as from sandstones and limestones. Similar methods were employed, on a trial basis, during the geological mapping undertaken in preparation for the present assessment. The purpose was to evaluate the cost-effectiveness of such measurements of ground conductivity in delineating areas of potentially workable sand and gravel within the drift deposits, and an area was chosen in the vicinity of Stonehaven.

*Theory and Methods*

The electromagnetic conductivity technique is based upon the detection of secondary magnetic fields that are generated as an induced response to an alternating primary magnetic field. The equipment used in this trial was a Geonics EM 31 terrain conductivity meter. This device comprises two glass-fibre booms (housing the transmitter and receiver coils), that plug in on either side of a control box, which houses the operating switches, power pack and galvanometer (for the data read-out). The assembled equipment has a fixed span of 3.7m, weighs about 9kg and is designed to be operated at waist height by one person.

The transmitting coil produces a primary magnetic field that induces horizontal current loops in the ground; these in turn give rise to a secondary magnetic field. The meter is designed so that the ratio of the two magnetic fields has a linear relationship (within certain limits) to ground conductivity. The receiving coil detects both magnetic fields and the resulting conductivity values, recorded in millimohos per metre, are displayed on the instrument panel of the control box. The detailed operation of the EM 31 conductivity meter is described fully in its operating manual (Geonics, 1982).

The measurements of electromagnetic conductivity can be related to values of ground resistivity, so that data obtained using the Offset Wenner system (described above) can be compared to data from the EM 31 traverses. In fact, resistivity is the reciprocal of conductivity, so that, for example, a reading of 4 millimhos per metre, is equivalent to a resistivity of 250 ohm.m.

The useful depth of penetration of the EM 31 is generally about 5m from the ground surface and so its direct use for evaluating thick sedimentary sequences is slight; its primary use is for distinguishing between various rock types at or near the ground surface.

*Results*

A series of traverses were made across an area of 2km$^2$ of ground in the vicinity of the Houff of Ury [NO 856 889] at the northeastern edge of 1:10 000 sheet NO 88 NE. The primary geological survey of the area (completed in 1884) indicated that most of the ground was underlain by an extensive spread of sand and gravel. Subsequent mapping undertaken in preparation for the present study suggested that the deposits of sand and gravel were, in fact, much less extensive than shown on the published geological map (based on the original survey).

Conductivity measurements were taken at approximately 40m intervals along north-south traverses spaced 40m apart. This produced a regular grid of data points. The traverses took eight working days to complete, but steep slopes (such as the sides of the valley of the Burn of Monboys) and thickly wood coniferous plantations had to be omitted.

Contouring of the spot data identified several areas of very low conductivity (<1 millimho/m), which corresponded with mapped spreads of sand and gravel and bedrock. Several areas of higher conductivity (>6 millimhos/m) were also apparent; these corresponded with deposits of till and glaciolacustrine silt and clay mapped at the surface.

*Conclusions*

Areas of exposed sand and gravel or bedrock were rapidly distinguished from ground underlain by clayey drift deposits, but it was not possible to distinguish between sand and gravel and bedrock solely on the results of the conductivity survey. This is not surprising, as the results of the resistivity survey indicated that (in most instances) both sand and gravel and bedrock would have overlapping conductivity values in the range of 0.1 to 1.0 millimho/m. This indeed proved to be the case in the Houff of Ury area.

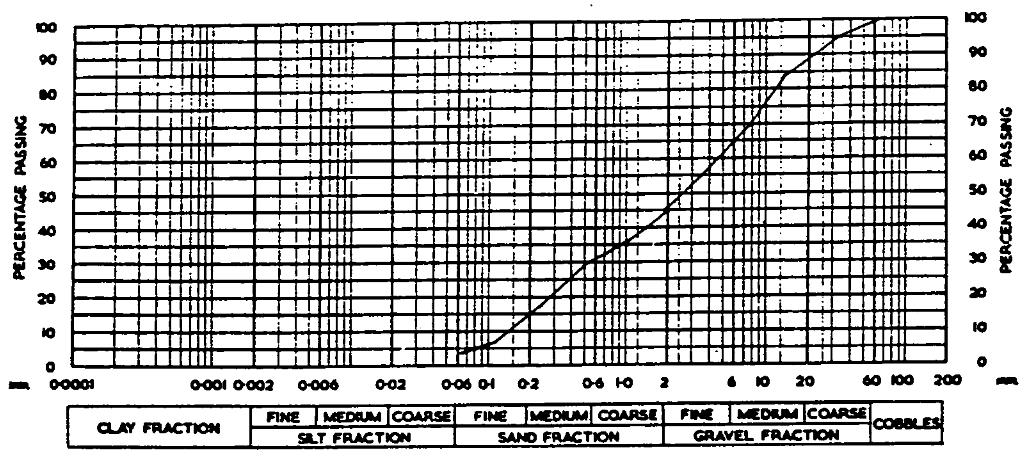
The geological map, produced by re-surveying the area in the conventional manner, required only minor modification following the conductivity survey. This suggests, that for the trial area at least, the conductivity survey was not a particularly useful or cost-effective method of improving the geological interpretation of the ground surveyed.

The conductivity results however, did broadly confirm the amount of potentially workable sand and gravel that was identified by conventional mapping and the drilling programme. The conductivity values also correlated well with data from the resistivity soundings made in the area.

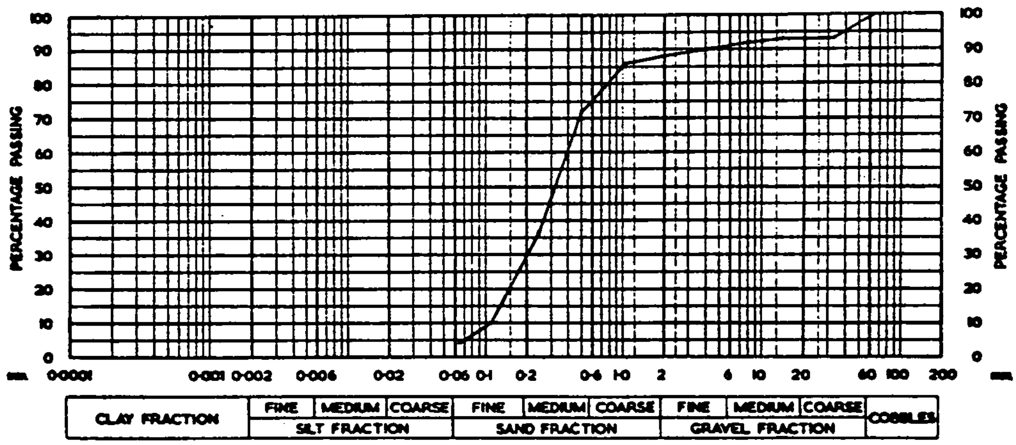
Conductivity measurements could not be made in thickly wooded areas or on steep valley sides, and furthermore, measurements made in the vicinity of pipelines and high-voltage electricity lines gave anomalously high readings. These impediments are commonplace in northeast Scotland, where much of the ground is forested and many areas are crossed by pipelines carrying oil and natural gas. These factors alone tend to make conductivity surveying a less attractive aid to geological mapping than is the case in some other parts of Britain. Conductivity measurements would, however, be a useful tool for the extractive industry in delineating areas for sand and gravel exploration in areas where no modern geological map coverage is available.

## PARTICLE SIZE DISTRIBUTION

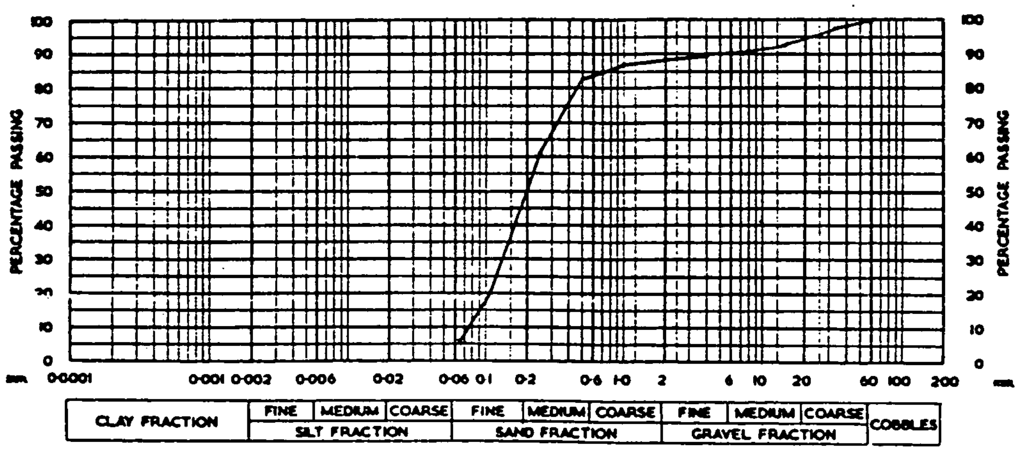
SITE. Aberdeen II Sand and Gravel Survey REF. No. T-1274




BOREHOLE No. SAMPLE No. BA 97 DEPTH m




BOREHOLE No. SAMPLE No. BA 98 DEPTH m




BOREHOLE No. SAMPLE No. BA 99 DEPTH. m

**Figure 7.** Examples of particle size distribution curves

Assessment details

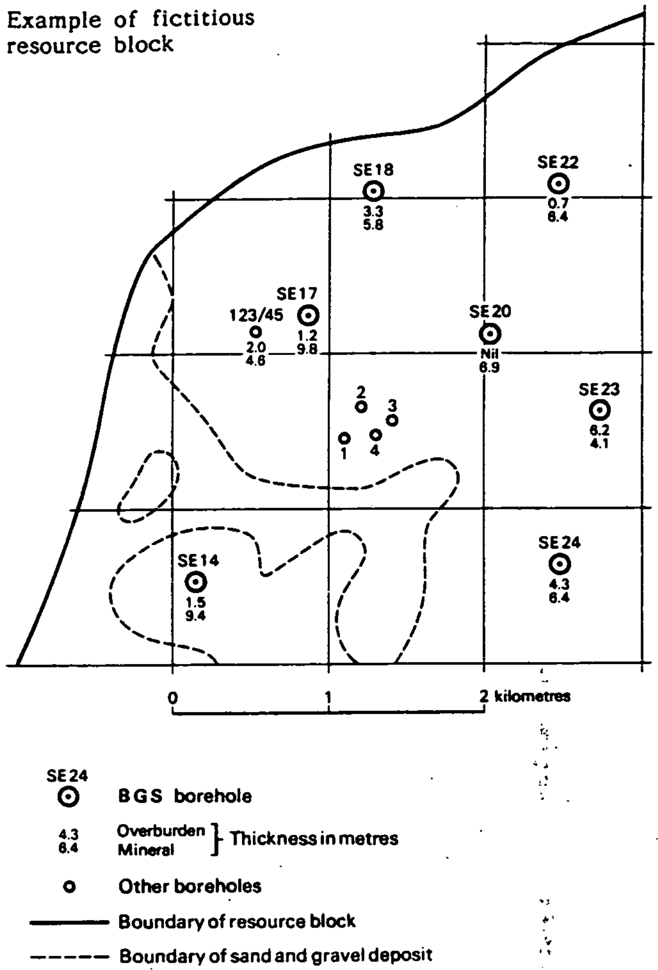
**Area**
Block: 11.08 $km^2$
Mineral: 8.32 $km^2$

**Mean thickness**
Overburden: 2.5 m
Mineral: 6.5 m

**Volume**
Overburden: 21 million $m^3$
Mineral: 54 million $m^3$

Confidence limits of the estimate of mineral volume at the 95 per cent probability level: $\pm$ 20 per cent
That is, the volume of mineral (with 95 per cent probability): 54 $\pm$ 11 million $m^3$

Example of fictitious resource block




Calculation of mean thickness

| Sample point | Weighting $w$ | Overburden $l_o$ | $wl_o$ | Mineral $l_m$ | $wl_m$ | Remarks |
|---|---|---|---|---|---|---|
| SE 14 | 1 | 1.5 | 1.5 | 9.4 | 9.4 | BGS boreholes |
| SE 18 | 1 | 3.3 | 3.3 | 5.8 | 5.8 | |
| SE 20 | 1 | nil | - | 6.9 | 6.9 | |
| SE 22 | 1 | 0.7 | 0.7 | 6.4 | 6.4 | |
| SE 23 | 1 | 6.2 | 6.2 | 4.1 | 4.1 | |
| SE 24 | 1 | 4.3 | 4.3 | 6.4 | 6.4 | |
| SE 17 | ½ | 1.2 | 1.6 | 9.8 | 7.2 | |
| 123/45 | ½ | 2.0 | | 4.6 | | Hydrogeology Unit record |
| 1 | ¼ | 2.7 | 2.6 | 7.3 | 5.8 | Close group of four boreholes (commercial) |
| 2 | ¼ | 4.5 | | 3.2 | | |
| 3 | ¼ | 0.4 | | 6.8 | | |
| 4 | ¼ | 2.8 | | 5.9 | | |
| Totals | $\Sigma w = 8$ | | $\Sigma wl_o = 20.2$ | | $\Sigma wl_m = 52.0$ | |
| Means | | | $\overline{wl}_o = 2.5$ | | $\overline{wl}_m = 6.5$ | |

Calculation of confidence limits

| $wl_m$ | $\lvert(wl_m - \overline{wl}_m)\rvert$ | $(wl_m - \overline{wl}_m)^2$ |
|---|---|---|
| 9.4 | 2.9 | 8.41 |
| 5.8 | 0.7 | 0.49 |
| 6.9 | 0.4 | 0.16 |
| 6.4 | 0.1 | 0.01 |
| 4.1 | 2.4 | 5.76 |
| 6.4 | 0.1 | 0.01 |
| 7.2 | 0.7 | 0.49 |
| 5.8 | 0.7 | 0.49 |

$\Sigma(wl_m - \overline{wl}_m)^2 = 15.82$

$n = 8$

$t = 2.365$

$L_V$ is calculated as

$1.05\,(t/\overline{wl}_m)\sqrt{[\Sigma(wl_m - \overline{wl}_m)^2/n(n-1)]} \times 100$

$= 1.05 \times (2.365/6.5)\sqrt{[15.82/(8 \times 7)]} \times 100$

$= 20.3$

$\simeq 20$ per cent.

**Figure 8.** Example of a statistical assessment of a fictitious resource block

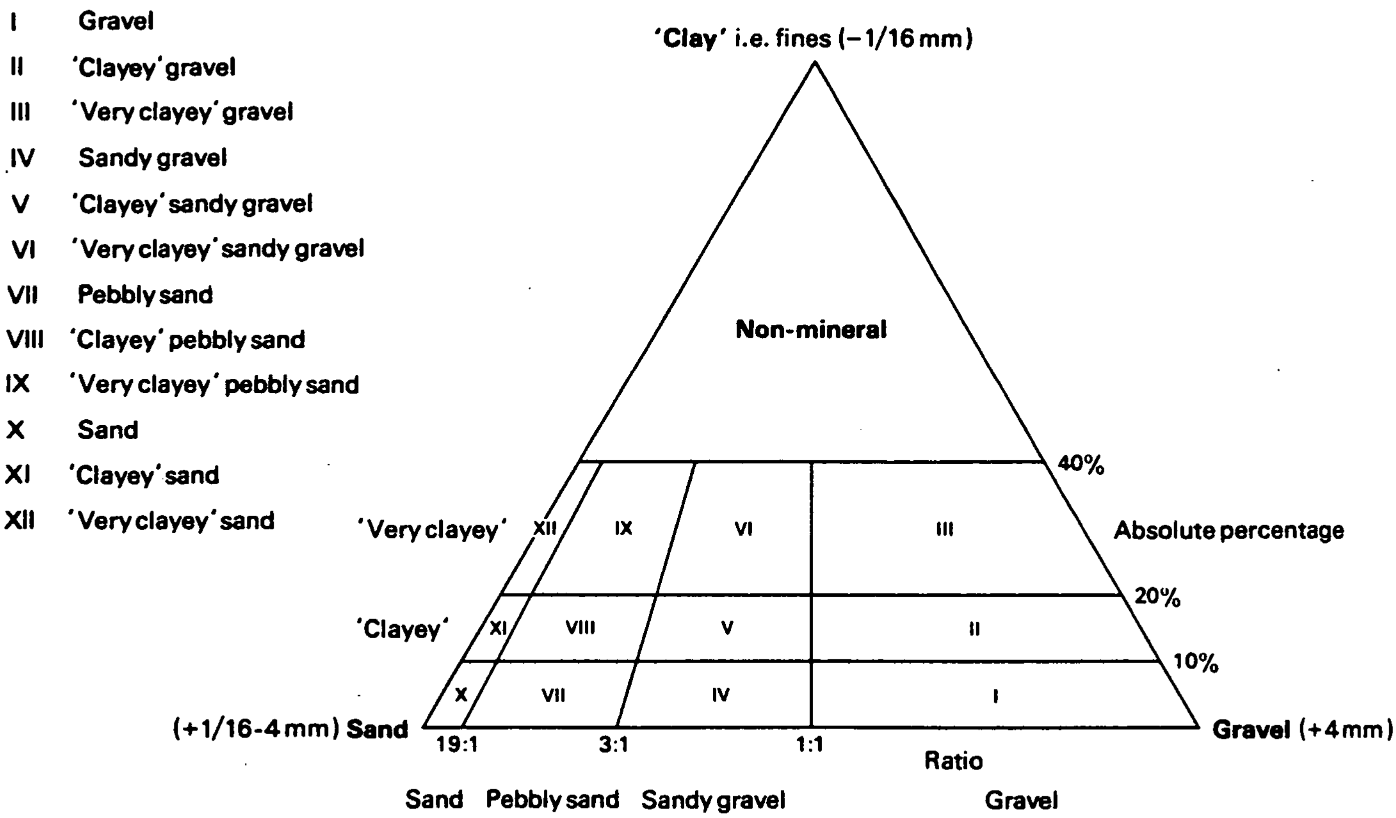
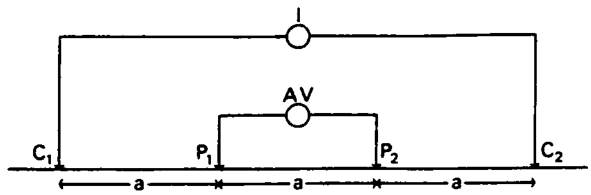
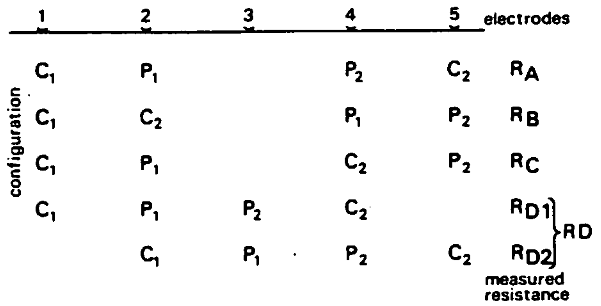



**Figure 9.** Diagram showing the descriptive categories used in the classification of sand and gravel




a. Wenner




b. Offset Wenner (five electrode array)

**Figure 10. Example of the Wenner and Offset Wenner five electrode array**

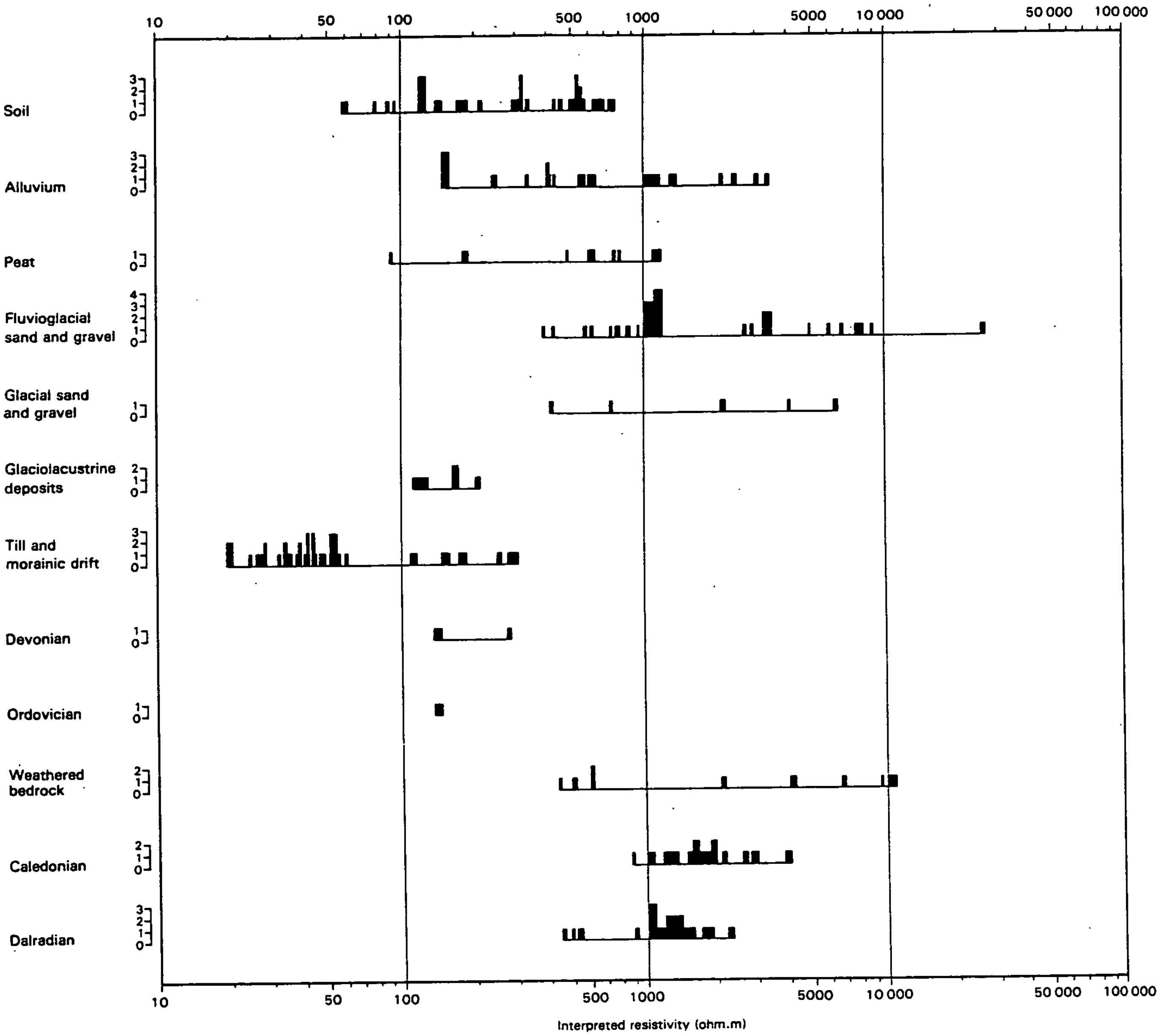



**Figure 11.** Frequency distribution of the resistivity results

**Table D1.** Classification of gravel, sand and fines

| Size limits | Grain-size description | Qualification | Primary classification |
| --- | --- | --- | --- |
| | Boulder | | |
| 256 mm | | | |
| | Cobble | | |
| 64 mm | | | |
| | Pebble | Coarse | Gravel |
| 16 mm | | | |
| | | Fine | |
| 4 mm | | | |
| | Sand | Coarse | Sand |
| 1 mm | | | |
| | | Medium | |
| 0.25 mm | | | |
| | | Fine | |
| 0.063 mm | | | |
| | Fines (silt and clay) | | Fines |

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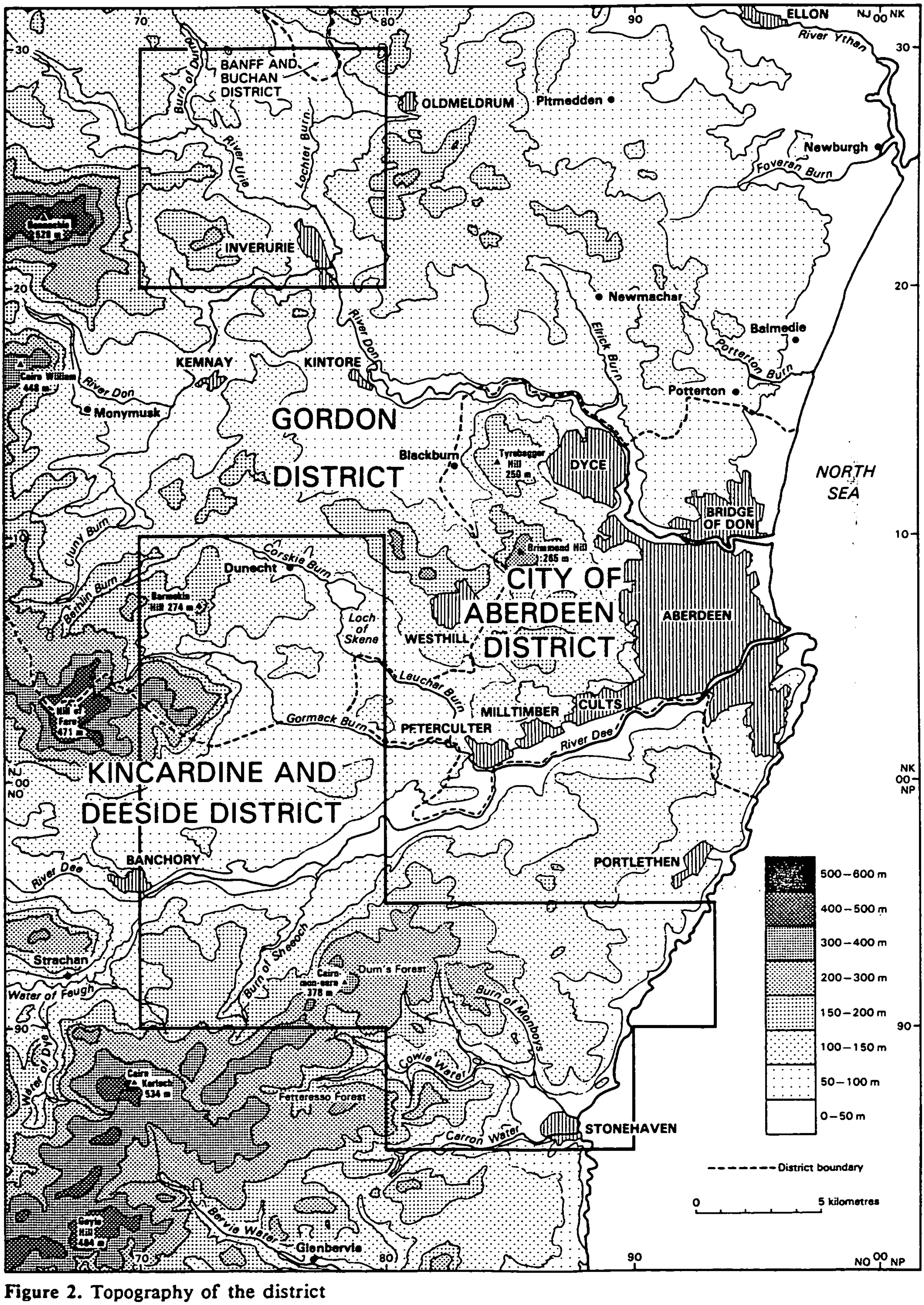
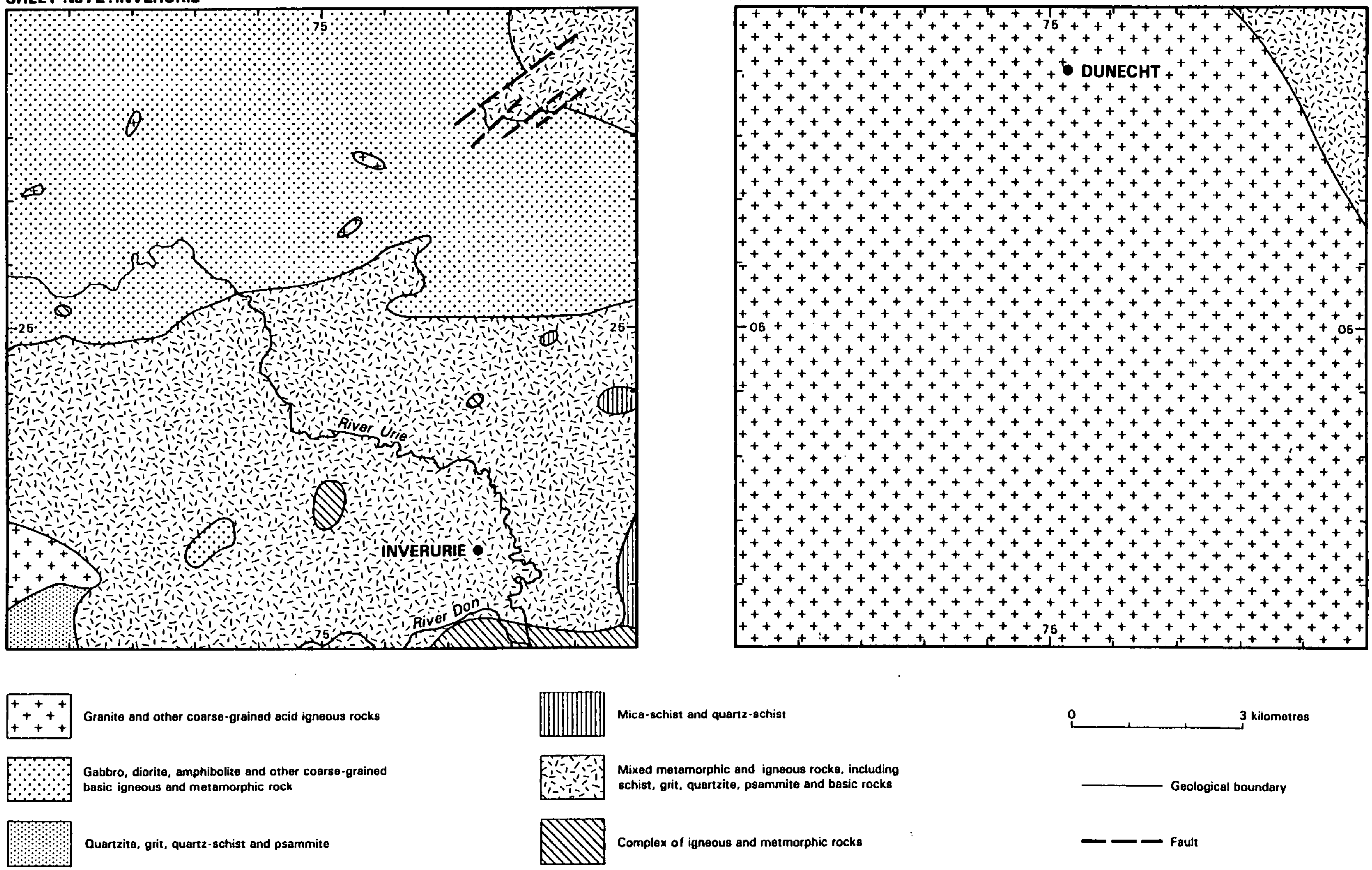



**Figure 2.** Topography of the district




There are numerous minor intrusions too small to delineate on these maps. They include felsite and other fine-grained acid igneous rocks, together with dolerite, microdiorite and other fine-grained basic igneous rocks.

**Figure 3.** Sketch-maps of the solid geology of the Inverurie and Dunecht resource sheet-areas

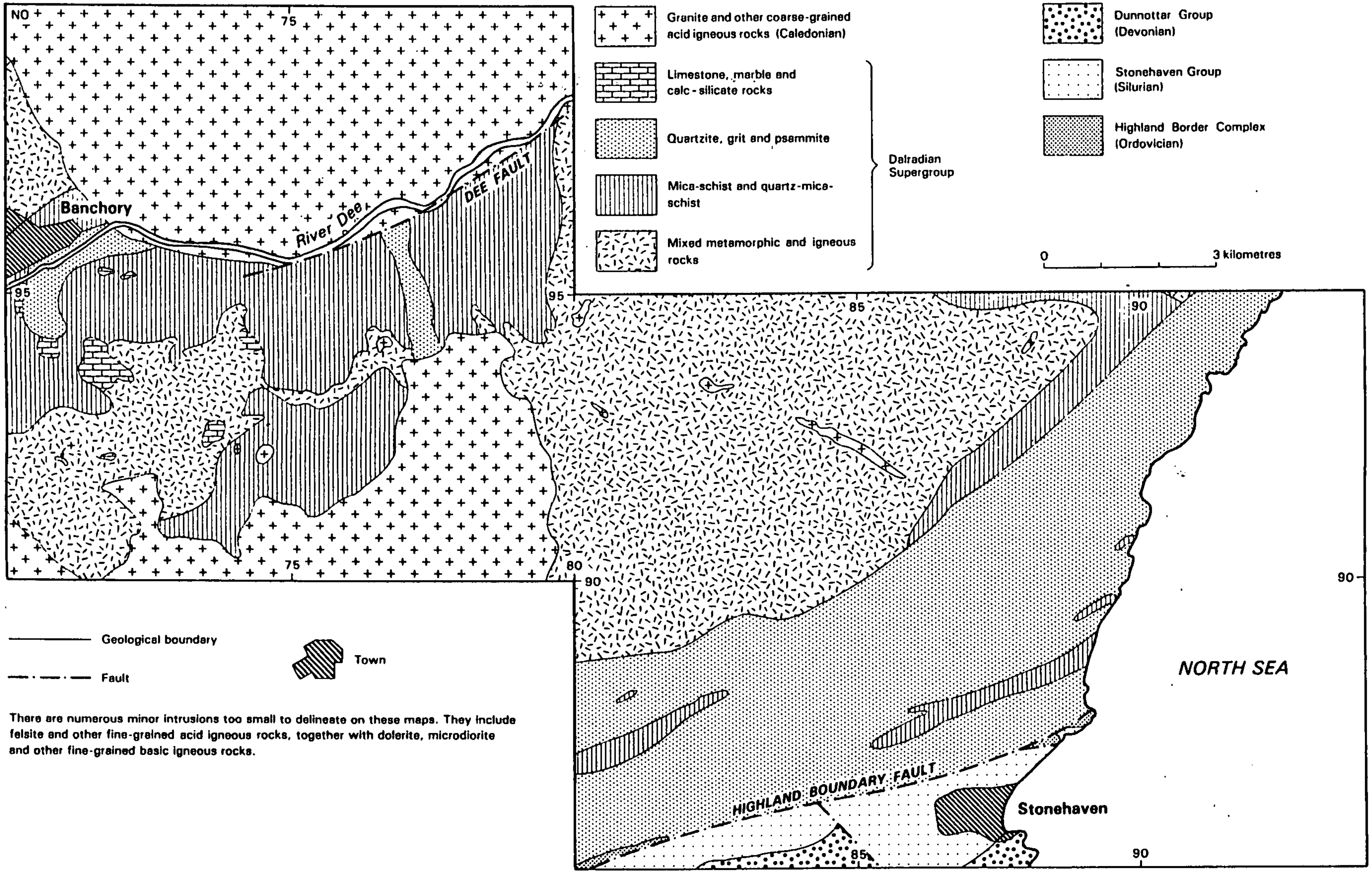
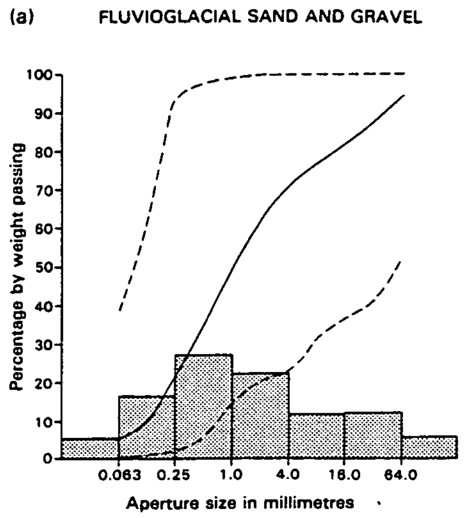
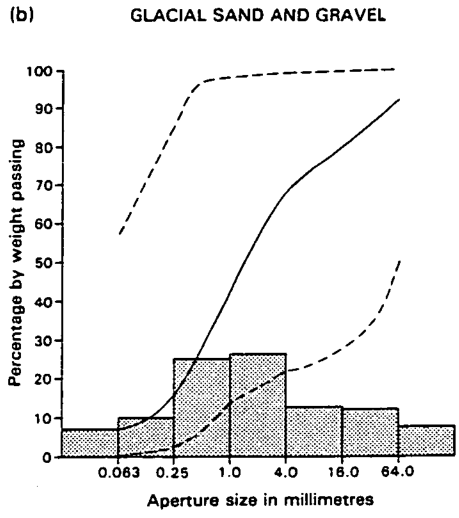
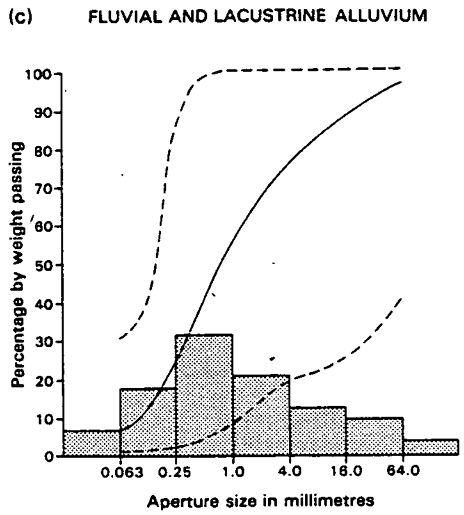
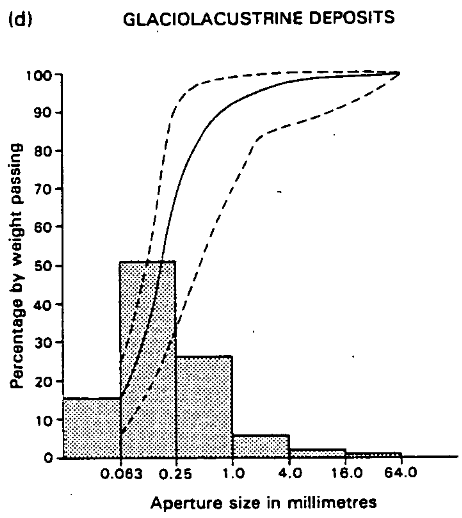



**Figure 4. Sketch-map of the solid geology of the Banchory/Stonehaven resource sheet-area**



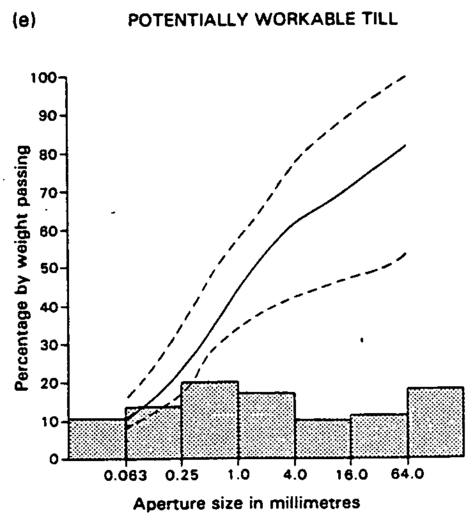
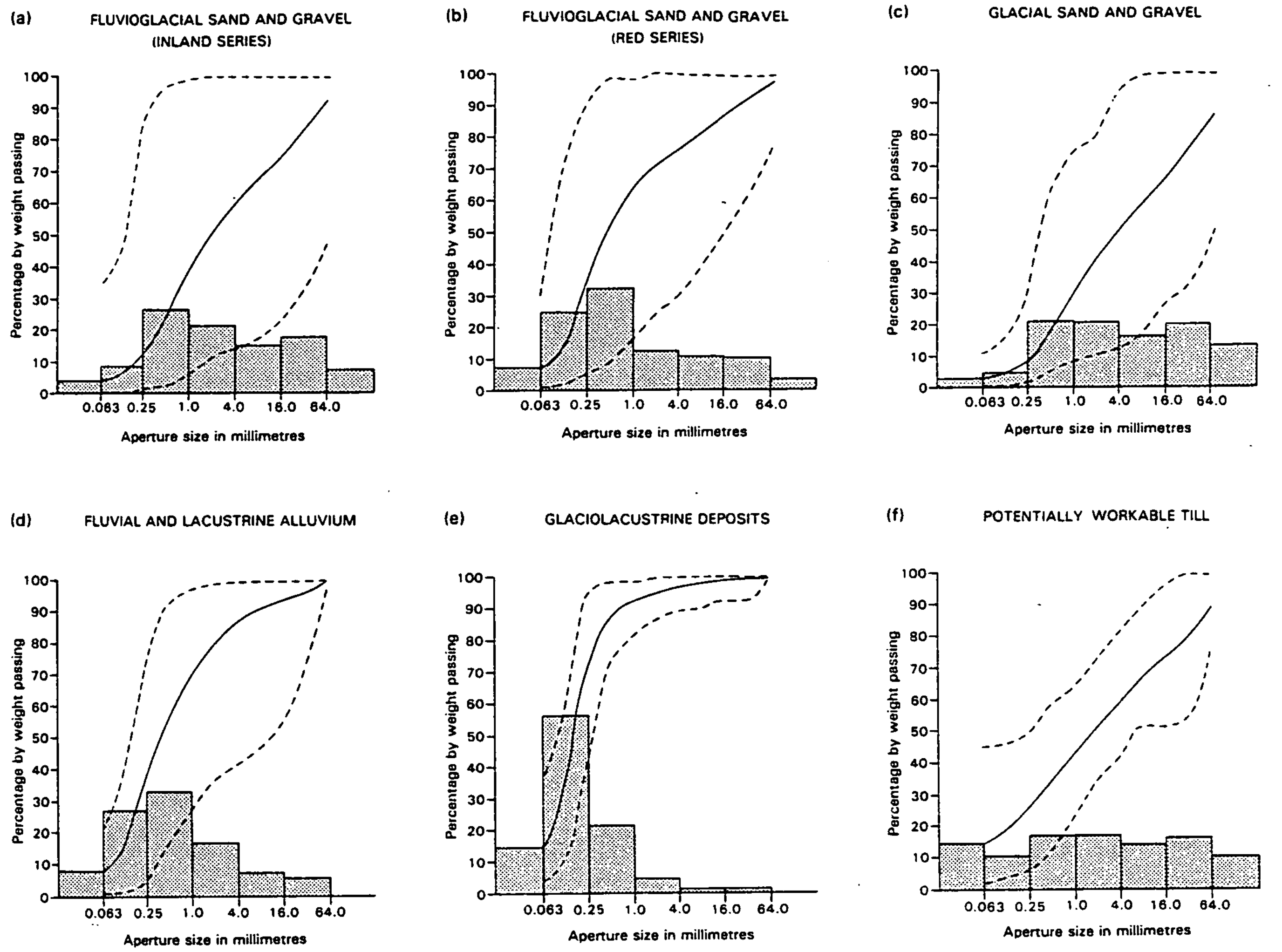




**Figure 5.** Mean grading characteristics of potentially workable sand and gravel; Inverurie and Dunecht resource sheets. The continuous line represents the cumulative mean grading for the mineral deposit; the dashed lines show the envelope within which the mean grading curves for individual data points fall. The shaded histograms represent the proportion of material in each size fraction



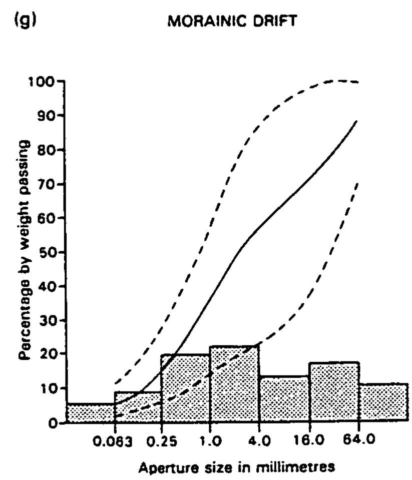




**Figure 6.** Mean grading characteristics of potentially workable sand and gravel; Banchory/Stonehaven resource sheet

**Table 1.** Geological classification of deposits

| | |
|---|---|
| **DRIFT** (Quaternary) | |
| Pleistocene and Recent | Peat<br>Alluvium<br>Alluvial cone<br>Lacustrine alluvium<br>Present-day beach deposits<br>Post-Glacial raised beach deposits<br>Late-Glacial raised beach deposits |
| *'Inland Series'* | Fluvioglacial sand and gravel<br>Glacial sand and gravel<br>Glaciolacustrine deposits<br>Morainic drift<br>Till |
| *'Red Series'* | Fluvioglacial sand and gravel<br>Glacial sand and gravel<br>Glaciolacustrine deposits<br>Till |
| **SOLID** | |
| Permo-Carboniferous | Igneous (intrusive) rocks - mainly dolerite |
| Devonian (Dunnottar Group | Conglomerate and sandstone |
| Silurian (Stonehaven Group) | Sandstone and mudstone |
| Ordovician (Highland Border Complex) | Serpentinised ultrabasic rocks, spilitic lava, chert and mudstone |
| Caledonian | Younger Igneous Intrusions: syn- to post-tectonic, granitic and basic plutonic and hypabyssal rocks |
| Dalradian (?late Precambrian to Cambrian) | Metasedimentary rocks (mainly psammite, pelite, semipelite and calc-silicate rock) |

Note: It should be assumed that a drift deposit belongs to the 'Inland Series' unless stated to the contrary

**Table 2** Mean gradings of potentially workable deposits; Inverurie and Dunecht resource sheets

| Deposits | Number of data points* | Number of samples | Mean grading percentage | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}-\frac{1}{4}$ mm | Medium sand $+\frac{1}{4}-1$mm | Coarse sand +1–4mm | Fine gravel +4–16mm | Coarse gravel +16–64mm | Cobbles and boulders +64mm |
| Fluvioglacial sand and gravel | 29 | 74 | 5 | 16 | 27 | 22 | 12 | 12 | 6 |
| Glacial sand and gravel | 19 | 66 | 7 | 10 | 25 | 26 | 13 | 12 | 7 |
| Alluvium (fluvial sand and gravel) | 17 | 38 | 6 | 17 | 32 | 21 | 12 | 9 | 3 |
| Glaciolacustrine deposits | 5 | 8 | 15 | 50 | 26 | 6 | 2 | 1 | 0 |
| Potentially workable morainic drift and till | 11 | 8 | 10 | 13 | 21 | 17 | 10 | 11 | 18 |

* Including assessment boreholes, trial pits and measured sections

**Table 3** Mean gradings of potentially workable deposits; Banchory/Stonehaven resource sheet

| Deposits | Number of data points* | Number of samples | Mean grading percentage | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}-\frac{1}{4}$ mm | Medium sand $+\frac{1}{4}-1$mm | Coarse sand +1–4mm | Fine gravel +4–16mm | Coarse gravel +16–64mm | Cobbles and boulders +64mm |
| Fluvioglacial sand and gravel ('Inland Series') | 48 | 219 | 4 | 8 | 27 | 21 | 15 | 18 | 7 |
| Fluvioglacial sand and gravel ('Red Series') | 12 | 54 | 7 | 25 | 33 | 12 | 10 | 10 | 3 |
| Glacial sand and gravel | 8 | 19 | 3 | 5 | 22 | 21 | 16 | 20 | 13 |
| Fluvial and lacustrine alluvium | 9 | 13 | 8 | 28 | 33 | 17 | 8 | 6 | 0 |
| Glaciolacustrine deposits | 5 | 10 | 15 | 56 | 22 | 5 | 1 | 1 | 0 |
| Morainic drift | 3 | 7 | 6 | 9 | 20 | 23 | 14 | 17 | 11 |
| Potentially workable till | 9 | 12 | 15 | 11 | 17 | 17 | 14 | 16 | 10 |

* Including assessment boreholes, trial pits and measured sections

**Table 4** Source and geological classification of composite samples used in pebble counts and mechanical and physical tests

| Source | Composite sample number | Geological classification of composite sample | Boreholes and pits from which samples were taken | Depth range (m) |
|---|---|---|---|---|
| Burn of Knock | 1 | Fluvioglacial sand and gravel | NO 79 SW 2 | 0.4- 8.0 |
| | | | NO 79 SW 3 | 0.3- 1.5 |
| | | | NO 79 SW 6 | 0.3- 9.3 |
| Mulloch | 2 | Fluvioglacial sand and gravel | NO 79 SW 7 | 1.5- 4.2 |
| | | | NO 79 SW 10 | 0.2- 1.8 |
| | | | NO 79 SW 16 | 2.8- 4.4 |
| Dee terraces (Banchory-Crathes) | 3 | Fluvioglacial sand and gravel | NO 79 NW 5 | 0.4- 9.2 |
| | | | NO 79 NW 9 | 0.4- 4.5 |
| | | | NO 79 NW 12 | 0.4-14.9 |
| | | | NO 79 NW 13 | 0.4- 6.8 |
| | | | NO 79 NW 14 | 0.5- 6.5 |
| | | | NO 79 NW 21 | 0.4-11.8 |
| | | | NO 79 NW 22 | 0.0- 5.2 |
| Dee terraces (Crathes-Drumoak) | 4 | Fluvioglacial sand and gravel | NO 79 NE 1 | 0.4- 7.1 |
| | | | NO 79 NE 5 | 0.3-10.1 |
| | | | NO 79 NE 6 | 0.3- 4.0 |
| | | | NO 79 NE 9 | 1.8-11.3 |
| | | | NO 79 NE 11 | 0.3- 5.5 |
| | | | NO 79 NE 12 | 0.4-15.8 |
| | | | NO 79 NE 14 | 0.3- 4.0 |
| Stonehaven | 5 | Fluvioglacial sand and gravel (Red Series) | NO 88 NW 8 | 7.7-14.8 |
| | | | NO 88 NW 11 | 4.6- 8.5 |
| | | | NO 88 NW 13 | 0.1- 1.4 |
| | | | NO 88 NW 14 | 0.3- 1.5 |
| | | | NO 88 NE 3 | 0.5- 3.5 |
| | | | NO 88 NE 4 | 0.4-12.8 |
| | | | NO 88 NE 7 | 2.7- 5.1 |
| | | | NO 88 NE 8 | 0.2- 3.4 |
| | | | NO 88 NE 11 | 0.1- 4.5 |
| Cowie Water | 6 | Fluvioglacial sand and gravel | NO 88 NW 3 | 0.4- 2.8 |
| | | | NO 88 NW 4 | 0.5- 5.9 |
| | | | NO 88 NW 7 | 0.3- 3.1 |
| | | | NO 88 NW 10 | 0.2-13.4 |
| | | | NO 88 NW 12 | 0.2- 4.7 |
| | | | NO 88 NW 16 | 0.0- 2.5 |
| | | | NO 88 NW 17 | 0.2- 6.0 |
| Garrol Burn/ Burn of Sheeoch | 7 | Glacial and fluvioglacial sand and gravel | NO 79 SW 8 | 0.0- 2.8 |
| | | | NO 79 SW 11 | 0.2- 3.0 |
| | | | NO 79 SW 12 | 0.3- 4.4 |
| | | | NO 79 SW 13 | 0.3- 4.3 |
| | | | | 8.4-14.5 |
| | | | NO 79 SW 14 | 0.3- 2.2 |
| | | | NO 79 SE 1 | 0.0- 2.9 |
| | | | NO 79 SE 2 | 0.4- 2.6 |
| | | | NO 79 SE 4 | 0.3- 4.4 |
| Pitcaple | 8 | Fluvioglacial sand and gravel | NJ 72 NW 1 | 0.2- 3.9 |
| | | | NJ 72 NW 2 | 0.3- 3.3 |
| | | | NJ 72 NW 4 | 0.3- 1.3 |
| | | | NJ 72 NW 5 | 0.3- 2.5 |
| | | | NJ 72 NW 6 | 0.7- 2.1 |
| | | | NJ 72 NW 7 | 0.2- 3.0 |
| | | | NJ 72 SW 1 | 0.5- 3.5 |
| Don floodplain and terraces | 9 | Alluvial and fluvioglacial sand and gravel | NJ 72 SE 3 | 1.2- 3.0 |
| | | | NJ 72 SE 4 | 0.2- 6.8 |
| | | | NJ 72 SE 6 | 1.6- 8.4 |
| | | | NJ 72 SE 13 | 1.6- 3.6 |
| Valley of the Corskie Burn | 10 | Fluvioglacial sand and gravel | NJ 70 NW 3 | 0.1- 4.3 |
| | | | NJ 70 NW 5 | 0.3- 3.5 |
| | | | NJ 70 NE 1 | 0.4- 9.5 |
| | | | NJ 70 NE 2 | 0.2- 3.2 |
| | | | NJ 70 NE 4 | 0.5- 3.5 |

Table 4 continued

| Source | Composite sample number | Geological classification of composite sample | Boreholes and pits from which samples were taken | Depth range (m) |
|---|---|---|---|---|
| Leuchar Moss | 11 | Glacial and fluvioglacial sand and gravel | NJ 70 SE 16 | 0.3- 5.6 |
| | | | NJ 70 SE 18 | 0.3- 3.6 |
| | | | NJ 70 SE 19 | 0.0- 5.5 |
| | | | NJ 70 SE 20 | 0.5- 7.3 |
| | | | NJ 70 SE 21 | 2.4- 3.9 |
| | | | NJ 70 NE 9 | 0.3- 9.8 |
| Cullerlie/ Finnarcy | 12 | Glacial and fluvioglacial sand and gravel | NJ 70 SE 1 | 2.1-12.7 |
| | | | NJ 70 SE 7 | 0.5-11.5 |
| | | | NJ 70 SE 8 | 0.4- 5.0 |
| | | | NJ 70 SE 13 | 0.2- 8.0 |
| | | | NJ 70 SW 12 | 0.2- 5.5 |
| Valley of the Gormack Burn | 13 | Glacial and fluvioglacial sand and gravel | NJ 70 SE 12 | 0.2- 3.5 |
| | | | NJ 70 SE 14 | 3.0- 6.5 |
| | | | NJ 70 SE 22 | 0.4- 3.9 |
| Stonehaven area | 14 | Fluvioglacial sand and gravel | stockpile in working pit | - |
| Burn of Sheeoch | 15 | Fluvioglacial sand and gravel | stockpile in working pit | - |
| North of Stonehaven | 16 | Glacial sand and gravel (Red Series) | face in working pit | - |

Table 5 Lithological classification of pebbles used in this report

| Toughness | Composition | Fissility | Grain size | Colour | Group |
|---|---|---|---|---|---|
| Friable | | | | | 1. Soft rock. Mudstone, shale, coal, poorly-cemented sandstone, badly weathered igneous or metamorphic rocks |
| Tough | Silicate | Homogeneous or bonded but not fissile | Coarse to medium-grained rocks | pale | 2. Granite, granodiorite, syenite, pegmatite, vein-quartz, quartzite, coarse-grained sandstone, arkose, quartzo-feldspathic granulite (psammite), gneiss |
| | | | | dark | 3. Gabbro, norite, diorite, coarse-grained greywackes and metagreywackes |
| | | | Medium to fine-grained rocks (disregarding phenocrysts or porphyroblasts) | pale | 4. Porphyry, quartz porphyry, aplite, felsite, rhyolite, trachyte, pale hornfels, calc-silicate rock, fine-grained sandstones |
| | | | | dark | 5. Basalt, andesite, serpentinite, microdiorite, lamprophyre, fine-grained greywackes and metagreywackes, semipelitic granulite, dark hornfels, dolerite, amphibolite |
| | | | Cryptocrystalline | | 6. Flint, chert, pitchstone |
| | | Fissile rocks | Coarse to medium-grained rocks | | 7. Schist, mica-schist, quartz-mica-schist, hornblende-schist |
| | | | Fine-grained rocks (disregarding porphyroblasts) | | 8. Phyllite, slate, chlorite-schist, schistose extrusive rocks. |
| | Non-silicate | | | | 9. Limestone, dolomite, marble, ironstone |
| Tough rocks known to be deleterious in concrete | | | | | 10. Special. Rocks known to shrink in concrete e.g. some greywackes. Rocks which react with cement e.g. those containing pyrite or sulphates |

**Table 6** Compositional analysis (pebble counts) of composite test samples (see Table 4 for origin of samples and Table 5 for lithological classification)

| Composite sample number | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lithological Group | Rock-type | | | | | | | | | | | | | | | | |
| Soft rock (1) | Mudstone, friable sandstone and highly weathered rocks | ** | ** | ** | ** | ** | ** | 8 | ** | 1 | ** | ** | ** | ** | ** | ** | 6 |
| Granite (2) | Granite and granodiorite | 62+ | 46 | 40 | 26 | 8 | 34 | 38 | 16 | 21 | 64 | 72 | 66 | 52 | 18 | 54 | 1 |
| | Vein-quartz and pegmatite | 15 | 16 | 3 | 9 | 16 | 22 | 10 | 5 | 11 | 7 | 5 | 4 | 16 | 5 | 5 | 8 |
| | Psammite, quartzite and coarse-grained sandstone | 6 | 14 | 27 | 35 | 24 | 17 | 21 | 5 | 31 | 10 | 8 | 6 | 14 | 60 | 29 | 65 |
| | Group, undivided | 83 | 76 | 70 | 70 | 48 | 73 | 69 | 26 | 63 | 81 | 85 | 76 | 82 | 83 | 88 | 74 |
| Gabbro (3) | Norite, diorite and gabbro | 2 | 1 | 5 | 4 | 1 | 1 | - | 34 | 2 | 4 | 5 | 5 | 6 | - | 4 | - |
| Porphyry (4) | Porphyry, felsite and fine-grained sandstone | 11 | 10 | 6 | 9 | 20 | 4 | 5 | 2 | 3 | 5 | 6 | 5 | 4 | 1 | 1 | 4 |
| Basalt (5) | Andesite, basalt, dolerite, amphibolite and pelite | 2 | 3 | 6 | 13 | 11 | 7 | 4 | 30 | 5 | 5 | 1 | 2 | 2 | 2 | 1 | 7 |
| Flint (6) | Flint and chert | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | ** |
| Schist (7) | Mica-schist, quartz-mica-schist and hornblende-schist | 2 | 10 | 13 | 4 | 20 | 14 | 14 | 1 | 26 | 5 | 3 | 12 | 6 | 14 | 6 | 5 |
| Phyllite (8) | Phyllite and slate | - | - | - | - | - | 1 | - | 7 | - | - | - | - | - | - | - | 4 |
| Angularity§ | | sa-sr | a-sr | a-sr | a-r | a-r | a-r | a | a-sa | a-r | a-r | a-r | a-r | a-wr | a | a-sa | a-r |
| Number of pebbles counted | | 329 | 300 | 280 | 288 | 434 | 282 | 371 | 406 | 282 | 269 | 307 | 293 | 346 | 377 | 282 | 362 |

** Trace amounts (less than 0.5 per cent)
+ Results are given in frequency per cent. (Calculations of weight per cent are closely correlated)
§ a = angular    sa = subangular    sr = subrounded    r = rounded    wr = well-rounded

**Table 7** Results of mechanical and physical tests*

| Composite sample | AIV (%) | AIVR (%) | ACV (%) | ACVR (%) | Relative density (oven-dried basis) | Relative density (surface-dried basis) | Apparent relative density | Water absorption (%) | Inferred drying shrinkage+ (%) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 29 | 31 | - | - | - | - | - | - | - |
| 2 | 25 | 40 | - | - | - | - | - | - | - |
| 3 | 20 | 47 | 17 | 45 | 2.62 | 2.64 | 2.69 | 1.1 | 0.052 |
| 4 | 18 | 52 | 16 | 48 | 2.60 | 2.63 | 2.68 | 1.2 | 0.054 |
| 5 | 17 | 43 | 16 | 40 | 2.52 | 2.58 | 2.68 | 2.3 | 0.076 |
| 6 | 24 | 38 | 18 | 42 | - | - | - | - | |
| 7 | 25 | 39 | 21 | 39 | 2.53 | 2.58 | 2.66 | 2.0 | 0.070 |
| 8 | 29 | 28 | 21 | 34 | 2.61 | 2.68 | 2.82 | 2.9 | 0.088 |
| 9 | 26 | 28 | 22 | 37 | 2.58 | 2.63 | 2.72 | 2.0 | 0.070 |
| 10 | 29 | 33 | 22 | 37 | 2.54 | 2.58 | 2.66 | 1.8 | 0.066 |
| 11 | 32 | 31 | 24 | 39 | - | - | - | - | - |
| 12 | 28 | 29 | 23 | 37 | 2.53 | 2.58 | 2.66 | 2.1 | 0.072 |
| 13 | 28 | 35 | - | - | 2.52 | 2.56 | 2.62 | 1.5 | 0.060 |
| 14 | 23 | 32 | 19 | 32 | 2.56 | 2.61 | 2.71 | 2.2 | 0.073 |
| 15 | 24 | 35 | 20 | 39 | 2.53 | 2.58 | 2.66 | 1.9 | 0.068 |
| 16 | 24 | 26 | 20 | 34 | 2.51 | 2.59 | 2.71 | 2.9 | 0.088 |

* Tests conducted in accordance with BS 812 (1975).

+ The derivation of these values is explained in the text

**Table 8** Concrete drying shrinkage, wetting expansion and moisture absorption tests*

| Composite sample | Source | Deposit type | Drying shrinkage % | Wetting expansion % | Moisture absorption % |
|---|---|---|---|---|---|
| A | Durris area (Dee terraces) | Fluvioglacial sand and gravel | 0.040 | 0.039 | 5.1 |
| B | Stonehaven area | Fluvioglacial ('Red Series') | 0.050 | 0.045 | 5.8 |
| C | Burn of Sheeoch | Fluvioglacial sand and gravel | 0.045 | 0.040 | 5.4 |
| E | Pitcaple area | Fluvioglacial sand and gravel | 0.065 | 0.058 | 5.6 |
| F | Valley of the Corskie Burn | Fluvioglacial sand and gravel | 0.050 | 0.043 | 5.2 |
| G | Leuchar Moss | Fluvioglacial/glacial sand and gravel | 0.045 | 0.039 | 5.4 |
| H | Finnarcy area | Glacial sand and gravel | 0.045 | 0.038 | 5.4 |

* Conducted commercially according to the method described in Building Research Station Digest No 35 (second-series), 1968.

**Table 9** Summary of the sand and gravel resources of the three resource sheets

| Resource block or sub-block | Area of assessed ground* | | Mean thickness | | Volume of sand and gravel | | | Mean grading percentage | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Block km$^2$ | Mineral km$^2$ | Over-burden m | Mineral m | m$^3$x10$^6$ | Limits at the 95% probability level§ ±% | ±m$^3$x10$^6$ | Fines $-\frac{1}{16}$ mm | Sand $+\frac{1}{16}$ $-4$ mm | Gravel $+4$ mm |
| INVERURIE SHEET | | | | | | | | | | |
| Valley of the River Urie | - | 5.0 | 0.9 | 3.0 | 15 | 40% | 6 | 7 | 68 | 25 |
| Valley of the River Don | - | 0.7 | 0.7 | 3.4 | 2 | 54% | 1 | 2 | 48 | 50 |
| Valley of the Lochter Burn | - | 0.5 | 0.9 | 1.9 | 1 | - | - | 4 | 53 | 43 |
| **Whole sheet** | **97.7** | **6.2** | **0.9** | **3.0** | **19** | **27%** | **5** | **4** | **57** | **39** |
| DUNECHT SHEET | | | | | | | | | | |
| Block A | 29.5 | 3.5 | 0.6 | 5.2 | 18 | 47% | 3 | 3 | 66 | 29 |
| Block B | 22.5 | 2.8 | 0.7 | 2.7 | 8 | - | - | 5 | 60 | 35 |
| Block C | 10.5 | 3.1 | 0.4 | 4.5 | 14 | 43% | 6 | 10 | 77 | 13 |
| Block D | 11.5 | 2.1 | 0.5 | 5.5 | 12 | 61% | 7 | 7 | 62 | 31 |
| Block E | 14.0 | 0.7 | 0.4 | 1.8 | 1 | - | - | - | - | - |
| Block F | 12.0 | 1.5 | 1.0 | 3.0 | 4 | - | - | 5 | 63 | 32 |
| **Whole sheet** | **100** | **13.7** | **0.7** | **3.8** | **51** | **18%** | **9** | **6** | **67** | **27** |
| BANCHORY/STONEHAVEN SHEET | | | | | | | | | | |
| Block A | 28.5 | 3.6 | 0.3 | 2.1 | 8 | 46% | 4 | 6 | 81 | 13 |
| Block B | 10.0 | 8.7 | 0.4 | 7.7 | 67 | 28% | 19 | 4 | 56 | 44 |
| Block C | 53.6 | 2.7 | 0.4 | 4.7 | 13 | 34% | 4 | 4 | 61 | 35 |
| Block D | 46.0 | | | Too little sand and gravel present to assess | | | | | | |
| Block E | 29.0 | 0.8 | 0.4 | 2.6 | 2 | - | - | 5 | 45 | 50 |
| Block F | 4.7 | 2.5 | 0.3 | 5.4 | 14 | 36% | 5 | 5 | 51 | 44 |
| Block G | 22.6 | 3.4 | 0.3 | 6.4 | 22 | 29% | 6 | 9 | 62 | 29 |
| **Whole sheet** | **194.4** | **21.7** | **0.3** | **5.6** | **122** | **16%** | **19** | **5** | **59** | **36** |

Note: some figures differ slightly from those quoted elsewhere due to rounding and re-calculation

* Excluding built-up areas
§ Only quoted for statistical assessments

**Table 10** Sheet NJ 72 (Inverurie): Data from sample points and the assessment of resources in the valley of the River Urie and the Burn of Durno

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive category |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Inter-vening waste m | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$mm | Medium sand $+\frac{1}{4}$ −1 mm | Coarse sand +1 −4 mm | Fine gravel +4 −16 mm | Coarse gravel +16 −64 mm | Cobbles and boulders +64 mm | (see the diagram in Appendix C) |
| **Valley-side deposits upstream of Milton of Inveramsay** | | | | | | | | | | | |
| NJ 72 NW 1 | 3.7+ | 0.2 | - | 2 | 6 | 26 | 29 | 24 | 13 | 0 | SG |
| NJ 72 NW 2 | 3.0+ | 0.3 | - | 2 | 3 | 22 | 28 | 22 | 23 | 0 | SG |
| NJ 72 NW 3 | 3.0+ | 0.2 | - | 2 | 5 | 16 | 14 | 14 | 23 | 26 | G |
| NJ 72 NW 4 | 1.0 | 0.3 | - | 3 | 17 | 30 | 21 | 16 | 13 | 0 | SG |
| NJ 72 NW 5 | 2.2 | 0.3 | - | 1 | 6 | 34 | 39 | 19 | 1 | 0 | PS |
| NJ 72 NW 6 | 1.4 | 0.7 | - | 7 | 23 | 37 | 30 | 3 | 0 | 0 | S |
| NJ 72 NW 7 | 3.0 | 0.2 | - | 2 | 9 | 38 | 35 | 16 | 0 | 0 | PS |
| **Mean** | **2.5** | **0.3** | | **2** | **8** | **28** | **28** | **18** | **12** | **4** | **SG** |
| **Valley-side deposits downstream of Milton of Inveramsay** | | | | | | | | | | | |
| NJ 72 SW 1 | 3.0 | 0.5 | - | 3 | 23 | 36 | 30 | 8 | 0 | 0 | PS |
| NJ 72 SE 2 | 1.0 | 0.1 | - | 2 | 12 | 56 | 29 | 1 | 0 | 0 | S |
| NJ 72 SE 5 | 4.6 | 0.4 | 2.7 | 6 | 22 | 42 | 20 | 10 | 0 | 0 | PS |
| NJ 72 SE 7 | 8.4 | 1.1 | 3.7 | 8 | 17 | 21 | 16 | 17 | 19 | 2 | SG |
| NJ 72 SE 10 | 3.2 | 1.6 | - | 13 | 44 | 37 | 5 | 1 | 0 | 0 | CS |
| NJ 72 SE 12 | 5.3 | 0.3 | 0.2 | 8 | 39 | 35 | 12 | 5 | 1 | 0 | PS |
| **Mean** | **4.3** | **0.7** | | **7** | **26** | **33** | **17** | **10** | **6** | **1** | **PS** |
| **Combined mean** | **3.3** | **0.5** | | **5** | **19** | **31** | **21** | **13** | **9** | **2** | **SG** |
| **Valley-floor deposits (undivided)** | | | | | | | | | | | |
| NJ 72 SE 1 | 1.7 | 1.1 | - | 14 | 17 | 21 | 21 | 23 | 4 | 0 | CSG |
| NJ 72 SE 9 | 7.2 | 1.5 | 5.6 | 12 | 27 | 15 | 13 | 12 | 18 | 3 | CSG |
| NJ 72 NW R1 | 1.3 | 0.2 | - | - | - | - | - | - | - | - | - |
| NJ 72 SE R1 | 0.0 | - | - | - | - | - | - | - | - | - | - |
| NJ 72 SE R2 | 0.1+ | 8.0 | - | - | - | - | - | - | - | - | - |
| **Mean** | **2.1** | **2.7** | | **12** | **25** | **16** | **15** | **14** | **15** | **3** | **CSG** |
| **Overall mean for whole valley** | **3.0** | **0.9** | | **7** | **21** | **27** | **20** | **13** | **10** | **2** | **PS** |

*Statistical assessment of the valley-side deposits upstream of Milton of Inveramsay*

| | |
|---|---|
| Area of exposed mineral | 1.08km$^2$ |
| Area of ground worked for sand and gravel | 0.02km$^2$ |
| Mean thickness of overburden | 0.3m |
| Mean thickness of mineral | 2.5m |
| Estimated volume of mineral | 2.7 million m$^3$ (± 38% or 1.0 million m$^3$) |
| Estimated yield of mineral per hectare | 25 thousand m$^3$ (± 38% or 10 thousand m$^3$) |

*Statistical assessment of the valley-side deposits downstream of Milton of Inveramsay*

| | |
|---|---|
| Area of exposed mineral | 0.91km$^2$ |
| Area of concealed mineral | 0.31km$^2$ |
| Total area of mineral-bearing ground | 1.22km$^2$ |
| Area of ground worked for sand and gravel | 0.01km$^2$ |
| Mean thickness of overburden | 0.7m |
| Mean thickness of mineral | 4.3m |
| Estimated volume of mineral | 5.2 million m$^3$ (± 65% or 3.4 million m$^3$) |
| Estimated yield of mineral per hectare | 43 thousand m$^3$ (± 65% or 28 thousand m$^3$) |

*Inferred assessment of the valley-floor deposits in the valley of the River Urie and the Burn of Durno (undivided)*

| | |
|---|---|
| Area of concealed mineral | 1.21km$^2$ |
| Area of discontinuous spreads of mineral | 2.00km$^2$ |
| Total area of mineral-bearing ground | 2.71km$^2$* |
| Mean thickness of overburden | 2.7m |
| Mean thickness of mineral | 2.1m |
| Estimated volume of mineral | 5.7 million m$^3$ |
| Estimated yield of mineral per hectare | 21 thousand m$^3$ |

*In the calculation of this figure, 75 per cent of the area of discontinuous spreads is assumed to be mineral-bearing

**Table 11** Sheet NJ 72 (Inverurie): Data from sample points and the assessment of resources in the valleys of the River Don and the Lochter Burn

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive category |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Intervening waste m | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$mm | Medium sand $+\frac{1}{4}$ -1 mm | Coarse sand +1 -4 mm | Fine gravel +4 -16 mm | Coarse gravel +16 -64 mm | Cobbles and boulders +64 mm | (see the diagram in Appendix C) |
| VALLEY OF THE RIVER DON | | | | | | | | | | | |
| Valley-side deposits | | | | | | | | | | | |
| NJ 72 SE 4 | 6.6+ | 0.2 | - | 2 | 4 | 22 | 22 | 16 | 21 | 13 | G |
| NJ 72 SE X4 | 2.5+ | 0.5 | - | - | - | - | - | - | - | - | - |
| NJ 72 SE X7 | 1.7+ | 0.3 | - | - | - | - | - | - | - | - | - |
| **Mean** | **3.6** | **0.3** | | **2** | **4** | **22** | **22** | **16** | **21** | **13** | **G** |
| Valley-floor deposits | | | | | | | | | | | |
| NJ 71 NW 15 | 1.9 | 2.5 | | 3 | 10 | 40 | 25 | 7 | 5 | 10 | PS |
| NJ 72 SE 3 | 1.8+ | 1.2 | - | 1 | 1 | 6 | 11 | 6 | 16 | 59 | G |
| NJ 72 SE 6 | 8.0 | 0.4 | - | 1 | 3 | 21 | 23 | 23 | 27 | 2 | G |
| NJ 72 SE 13 | 2.0* | 1.6 | - | 6 | 12 | 24 | 17 | 18 | 19 | 4 | SG |
| NJ 72 SE X5 | 3.0* | 0.3 | - | - | - | - | - | - | - | - | - |
| NJ 72 SE X6 | 3.3* | 0.5 | - | - | - | - | - | - | - | - | - |
| **Mean** | **3.3** | **1.1** | | **2** | **5** | **22** | **21** | **18** | **21** | **11** | **G** |
| **Combined mean** | **3.4** | **0.7** | | **2** | **5** | **22** | **21** | **17** | **21** | **12** | **G** |
| VALLEY OF THE LOCHTER BURN | | | | | | | | | | | |
| NJ 72 NE 1 | 1.7 | 0.7 | - | 3 | 3 | 14 | 18 | 17 | 17 | 28 | G |
| NJ 72 NE 2 | 1.9+ | 1.6 | - | 4 | 9 | 35 | 25 | 21 | 6 | 0 | SG |
| NJ 72 NE R1 | 2.0 | 0.5 | - | - | - | - | - | - | - | - | - |
| **Mean** | **1.9** | **0.9** | | **4** | **6** | **25** | **22** | **19** | **11** | **13** | **SG** |

* Further deposits of mineral occur at depth

*Inferred assessment of the valley-side deposits in the valley of the River Don*

| | |
|---|---|
| Area of exposed sand and gravel | 0.19km$^2$ |
| Area of ground worked for sand and gravel | 0.002km$^2$ |
| Mean thickness of overburden | 0.3m* |
| Mean thickness of mineral | 3.6m* |
| Estimated volume of mineral | 0.7 million m$^3$ |
| Estimated yield of mineral per hectare | 36 thousand m$^3$ |

*Inferred assessment of the valley-floor deposits in the valley of the River Don*

| | |
|---|---|
| Area of concealed mineral | 0.51km$^2$ |
| Mean thickness of overburden | 1.1m* |
| Mean thickness of mineral | 3.3m* |
| Estimated volume of mineral | 1.7 million m$^3$ |
| Estimated yield of mineral per hectare | 33 thousand m$^3$ |

*Speculative assessment of the sand and gravel deposits in the valley of the Lochter Burn*

| | |
|---|---|
| Area of exposed mineral | 0.02km$^2$ |
| Area of discontinuous spreads of mineral | 1.72km$^2$ |
| Mean thickness of mineral | 1.9m |
| Estimated volume of mineral | 0.9 million m$^3$** |

* Data from sample points on the adjoining resource sheet have been included in the calculation of this figure.

** In the calculation of this figure, 25 per cent of the area of discontinuous spreads is assumed to be mineral-bearing

**Table 12** Sheet NJ 70 (Dunecht): Data from sample points and the assessment of resources in Block A

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive category (see the diagram in Appendix C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Intervening waste m | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$mm | Medium sand $+\frac{1}{4}$ -1 mm | Coarse sand +1 -4 mm | Fine gravel +4 -16 mm | Coarse gravel +16 -64 mm | Cobbles and boulders +64 mm | |
| Valley-side deposits | | | | | | | | | | | |
| NJ 70 NW 3 | 4.2+ | 0.1 | - | 1 | 5 | 24 | 30 | 14 | 23 | 3 | SG |
| NJ 70 NW 5 | 3.2+ | 0.3 | - | 1 | 4 | 17 | 19 | 12 | 17 | 30 | G |
| NJ 70 NE 1 | 10.6 | 0.4 | - | 4 | 6 | 26 | 22 | 15 | 19 | 8 | SG |
| NJ 70 NE 2 | 3.0 | 0.2 | - | 1 | 7 | 49 | 33 | 9 | 1 | 0 | PS |
| NJ 70 NE 4 | 3.0+ | 0.5 | - | 1 | 5 | 38 | 20 | 12 | 21 | 3 | SG |
| NJ 70 NE R2 | 5.8 | 0.5 | - | - | - | - | - | - | - | - | - |
| **Mean** | **5.0** | **0.3** | | **2** | **6** | **29** | **24** | **13** | **17** | **9** | **SG** |
| Valley-floor deposits | | | | | | | | | | | |
| NJ 70 NW 4 | 1.3+ | 2.2 | - | 19 | 10 | 55 | 15 | 1 | 0 | 0 | CS |
| NJ 70 NE 3 | 8.5 | 0.4 | - | 3 | 7 | 32 | 33 | 16 | 9 | 0 | PS |
| NJ 70 NE 10 | 6.8 | 0.4 | 2.9 | 4 | 38 | 40 | 11 | 4 | 3 | 0 | PS |
| **Mean** | **5.5** | **1.0** | | **5** | **20** | **37** | **22** | **10** | **6** | **0** | **PS** |
| **Overall mean for whole block** | **5.2** | **0.6** | | **3** | **11** | **32** | **24** | **12** | **13** | **5** | **SG** |

*Statistical assessment of the valley-side deposits in block A*

| | |
|---|---|
| Area of exposed mineral | 1.53km$^2$ |
| Area of ground worked for sand and gravel | 0.01km$^2$ |
| Mean thickness of overburden | 0.3m |
| Mean thickness of mineral | 5.0m |
| Estimated volume of mineral | 7.7 million m$^3$ (±66% or 5 million m$^3$) |
| Estimated yield of mineral per hectare | 50 thousand m$^3$ (±66% or 33 thousand m$^3$) |

*Inferred assessment of the valley-floor deposits in block A*

| | |
|---|---|
| Area of exposed mineral | 0.67km$^2$ |
| Area of concealed mineral | 1.30km$^2$ |
| Total area of mineral-bearing ground | 1.97km$^2$ |
| Mean thickness of overburden | 1.0m |
| Mean thickness of mineral | 5.5m |
| Estimated volume of mineral | 10.8 million m$^3$ |
| Estimated yield of mineral per hectare | 55 thousand m$^3$ |

**Table 13** Sheet NJ 70 (Dunecht): Data from sample points and the assessment of resources in Block B

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive category (see the diagram in Appendix C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Inter-vening waste m | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$mm | Medium sand $+\frac{1}{4}$ -1 mm | Coarse sand +1 -4 mm | Fine gravel +4 -16 mm | Coarse gravel +16 -64 mm | Cobbles and boulders +64 mm | |
| NJ 70 NW 2 | 1.9* | 1.1 | - | 2 | 4 | 18 | 24 | 15 | 26 | 11 | G |
| NJ 70 SW 8 | 6.1 | 0.2 | 1.1 | 8 | 11 | 27 | 29 | 10 | 15 | 0 | SG |
| NJ 70 SW 9 | 1.3+ | 1.7 | - | 1 | 5 | 25 | 37 | 28 | 4 | 0 | SG |
| NJ 70 SW 10 | 1.2 | 0.2 | - | 1 | 1 | 11 | 25 | 18 | 22 | 22 | G |
| NJ 70 SW R3 | 2.8 | 0.2 | - | - | - | - | - | - | - | - | - |
| **Mean** | **2.7** | **0.7** | | **5** | **8** | **23** | **29** | **14** | **16** | **5** | **SG** |

* Overlies 2.0m of potentially workable till

*Inferred assessment of the sand and gravel in block B*

| | |
|---|---|
| Area of exposed mineral | 1.11km$^2$ |
| Area of concealed mineral | 1.42km$^2$ |
| Area of discontinuous spreads of mineral | 0.34km$^2$ |
| Total area of mineral-bearing ground | 2.79km$^2$* |
| Mean thickness of overburden | 0.7m |
| Mean thickness of mineral | 2.7m |
| Estimates volume of mineral | 7.5 million m$^3$ |
| Estimated yield of mineral per hectare | 27 thousand m$^3$ |

* In the calculation of this figure, 75 per cent of the area of discontinuous spreads is assumed to be mineral-bearing

**Table 14** Sheet NJ 70 (Dunecht): Data from sample points and the assessment of resources in Block C

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive category (see the diagram in Appendix C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Inter-vening waste m | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$mm | Medium sand $+\frac{1}{4}$ -1 mm | Coarse sand +1 -4 mm | Fine gravel +4 -16 mm | Coarse gravel +16 -64 mm | Cobbles and boulders +64 mm | |
| THE VALLEY OF THE LEUCHAR BURN | | | | | | | | | | | |
| Glacial sand and gravel (moundy deposits) | | | | | | | | | | | |
| NJ 70 SE 16 | 5.3+ | 0.3 | - | 2 | 7 | 23 | 23 | 10 | 15 | 20 | SG |
| NJ 70 NE 9 | 4.1* | 0.3 | - | 15 | 22 | 37 | 13 | 7 | 6 | 0 | CPS |
| NJ 70 NE 12 | 1.0 | 0.3 | - | 1 | 7 | 21 | 21 | 13 | 12 | 25 | G |
| NJ 70 SE 19 | 5.5+ | 0.0 | - | 1 | 2 | 18 | 64 | 10 | 2 | 3 | PS |
| **Mean** | **4.0** | **0.2** | | **5** | **9** | **25** | **35** | **9** | **8** | **9** | **SG** |
| Fluvioglacial sand and gravel (terraced deposits) | | | | | | | | | | | |
| NJ 70 SE 18 | 3.9 | 0.3 | - | 12 | 21 | 34 | 22 | 9 | 2 | 0 | CPS |
| NJ 70 SE 20 | 6.6 | 0.5 | 0.2 | 12 | 51 | 31 | 5 | 1 | 0 | 0 | CS |
| NJ 70 SE 21 | 10.9 | 1.5 | - | 16 | 54 | 23 | 6 | 1 | 0 | 0 | CS |
| NJ 70 SE R2 | 5.6 | 0.4 | - | - | - | - | - | - | - | - | - |
| **Mean** | **6.8** | **0.7** | | **14** | **47** | **28** | **9** | **2** | **0** | **0** | **CS** |
| **Combined mean** | **5.4** | **0.4** | | **10** | **31** | **26** | **20** | **5** | **4** | **4** | **CPS** |
| THE VALLEY OF THE GARRACK BURN | | | | | | | | | | | |
| NJ 70 NE 8 | 1.7 | 0.2 | - | 2 | 8 | 38 | 39 | 13 | 0 | 0 | PS |
| **Overall mean for whole block** | **4.5** | **0.4** | | **10** | **30** | **27** | **20** | **6** | **3** | **4** | **CPS** |

* Overlies 2.8m of disaggregated granite

*Inferred assessment of the glacial sand and gravel in the valley of the Leuchar Burn*

| | |
|---|---|
| Area of exposed mineral | 0.75km$^2$ |
| Area of concealed mineral | 0.10km$^2$ |
| Total area of mineral-bearing ground | 0.86km$^2$ |
| Area of ground worked for sand and gravel | 0.01km$^2$ |
| Mean thickness of overburden | 0.2m |
| Mean thickness of mineral | 4.0m |
| Estimated volume of mineral | 3.4 million m$^3$ |
| Estimated yield of mineral per hectare | 40 thousand m$^3$ |

*Inferred assessment of the fluvioglacial sand and gravel in the valley of the Leuchar Burn*

| | |
|---|---|
| Area of exposed mineral | 1.01km$^2$ |
| Area of concealed mineral | 0.52km$^2$ |
| Total area of mineral-bearing ground | 1.53km$^2$ |
| Area of ground worked for sand and gravel | 0.02km$^2$ |
| Mean thickness of overburden | 0.7m |
| Mean thickness of mineral | 6.8m |
| Estimated volume of mineral | 10.4 million m$^3$ |
| Estimated yield of mineral per hectare | 68 thousand m$^3$ |

*Speculative assessment of the sand and gravel in the valley of the Garrack Burn*

| | |
|---|---|
| Area of exposed mineral | 0.42km$^2$ |
| Area of concealed mineral | 0.28km$^2$ |
| Total area of mineral-bearing ground | 0.70km$^2$ |
| Mean thickness of overburden | 0.2m |
| Mean thickness of mineral | 2.2m |
| Estimated volume of mineral | 1.6 million m$^3$ |

**Table 15** Sheet NJ 70 (Dunecht): Data from sample points and the assessment of resources in Block D

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive category (see the diagram in Appendix C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Intervening waste m | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$mm | Medium sand $+\frac{1}{4}$ -1 mm | Coarse sand +1 -4 mm | Fine gravel +4 -16 mm | Coarse gravel +16 -64 mm | Cobbles and boulders +64 mm | |
| Glacial sand and gravel (moundy deposits) | | | | | | | | | | | |
| NJ 70 SW 12 | 4.6+ | 0.2 | 0.7 | 2 | 3 | 17 | 20 | 11 | 23 | 24 | G |
| NJ 70 SE 7 | 11.0* | 0.5 | - | 8 | 12 | 31 | 23 | 11 | 9 | 6 | PS |
| NJ 70 SE 8 | 3.7+ | 0.4 | 0.9 | 2 | 5 | 33 | 20 | 6 | 12 | 22 | SG |
| NJ 70 SE 13 | 13.8 | 0.2 | 1.5 | 13 | 15 | 29 | 27 | 9 | 7 | 0 | CPS |
| **Mean** | **8.3** | **0.3** | | **9** | **11** | **28** | **24** | **10** | **10** | **8** | **SG** |
| Valley-floor deposits (terraced and other flat-lying deposits) | | | | | | | | | | | |
| NJ 70 SE 1 | 10.2 | 2.1 | 1.7 | 6 | 8 | 32 | 34 | 14 | 5 | 1 | PS |
| NJ 70 SW 6 | 2.1+ | 0.9 | - | 3 | 2 | 10 | 18 | 11 | 27 | 29 | G |
| NJ 70 SW 14 | 1.2 | 0.2 | - | 4 | 5 | 15 | 15 | 10 | 15 | 36 | G |
| NJ 70 SW 16 | 3.1+ | 0.2 | - | 2 | 4 | 26 | 21 | 13 | 15 | 19 | SG |
| NJ 70 SW 17 | 1.3 | 0.2 | - | 1 | 2 | 11 | 15 | 18 | 25 | 28 | G |
| NJ 70 SW R2 | 4.1 | 0.2 | - | - | - | - | - | - | - | - | - |
| **Mean** | **3.7** | **0.6** | | **5** | **6** | **26** | **27** | **13** | **11** | **12** | **SG** |
| **Combined mean** | **5.5** | **0.5** | | **7** | **9** | **28** | **25** | **11** | **11** | **9** | **SG** |
| Morainic drift and potentially workable till | | | | | | | | | | | |
| NJ 70 SW 7 | 2.8+ | 0.2 | - | 12 | 12 | 16 | 15 | 9 | 9 | 27 | CG |
| NJ 70 SW 13 | 4.6 | 0.3 | - | 10 | 13 | 18 | 16 | 6 | 9 | 28 | CSG |
| NJ 70 SW 15 | 2.9** | 0.2 | 1.9 | 9 | 12 | 22 | 17 | 11 | 20 | 9 | SG |
| NJ 70 SE 2 | 2.7+ | 0.3 | - | 10 | 16 | 25 | 19 | 13 | 17 | 0 | CSG |
| NJ 70 SE 10 | 2.5+ | 0.2 | - | 8 | 12 | 14 | 8 | 5 | 7 | 46 | G |
| **Mean** | **3.1** | **0.2** | | **11** | **13** | **17** | **15** | **9** | **10** | **25** | **CSG** |

* Not including 1.5m disaggregated granite at bottom
**Uppermost 0.9m is classified as glacial sand and gravel

*Inferred assessment of the glacial sand and gravel*

| | |
|---|---|
| Area of exposed mineral | 0.25km$^2$ |
| Area of concealed mineral | 0.12km$^2$ |
| Total area of mineral-bearing ground | 0.37km$^2$ |
| Mean thickness of overburden | 0.3m |
| Mean thickness of mineral | 8.3m |
| Estimated volume of mineral | 3.1 million m$^3$ |
| Estimated yield of mineral per hectare | 83 thousand m$^3$ |

*Inferred assessment of the valley-floor deposits*

| | |
|---|---|
| Area of exposed mineral | 0.59km$^2$ |
| Area of concealed mineral | 0.84km$^2$ |
| Area of discontinuous spreads of mineral | 0.58km$^2$ |
| Total area of mineral-bearing ground | 1.72km$^2$* |
| Mean thickness of overburden | 0.6m |
| Mean thickness of mineral | 3.7m |
| Estimated volume of mineral | 6.4 million m$^3$ |
| Estimated yield of mineral per hectare | 37 thousand m$^3$ |

*Speculative assessment of the morainic drift*

| | |
|---|---|
| Area of exposed, discontinuous spreads of mineral (II) | 2.05km$^2$ |
| Mean thickness of overburden | 0.2m |
| Mean thickness of mineral (II) | 3.1m |
| Estimated volume of mineral (II) | 4.8 million m** |

* In the calculation of this figure, 50 per cent of the area of discontinuous spreads is assumed to be mineral-bearing
** In the calculation of this figure, 75 per cent of the area of morainic drift is assumed to be mineral-bearing

**Table 16** Sheet NJ 70 (Dunecht): Data from sample points and the assessment of resources in Block E

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive category (see the diagram in Appendix C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Inter-vening waste m | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$mm | Medium sand $+\frac{1}{4}$ -1 mm | Coarse sand +1 -4 mm | Fine gravel +4 -16 mm | Coarse gravel +16 -64 mm | Cobbles and boulders +64 mm | |
| Sand and gravel (undivided) | | | | | | | | | | | |
| NJ 70 SW 1 | 2.0 | 0.4 | - | 31 | 29 | 9 | 11 | 10 | 10 | 0 | VCSG |
| NJ 70 SW R1 | 1.5 | 0.4 | - | - | - | - | - | - | - | - | - |
| **Mean** | **1.8** | **0.4** | | **31** | **29** | **9** | **11** | **10** | **10** | **0** | **VCSG** |
| Morainic drift and potentially workable till | | | | | | | | | | | |
| NJ 70 SW 4 | 1.8 | 0.2 | - | 15 | 20 | 22 | 20 | 13 | 10 | 0 | CSG |
| NJ 70 SE 5 | 3.7 | 0.2 | - | 17 | 15 | 27 | 21 | 11 | 9 | 0 | CPS |
| **Mean** | **2.8** | **0.2** | | **16** | **17** | **25** | **21** | **12** | **9** | **0** | **CPS** |

*Speculative assessment of the sand and gravel*

| | |
|---|---|
| Area of exposed mineral | 0.51km$^2$ |
| Area of discontinuous spreads of mineral | 0.33km$^2$ |
| Total area of mineral-bearing ground | 0.67km$^2$* |
| Mean thickness of overburden | 0.4m |
| Mean thickness of mineral | 1.8m |
| Estimated volume of mineral | 1.2 million m$^3$ |

*Speculative assessment of the morainic drift*

| | |
|---|---|
| Area of exposed, discontinuous spreads of mineral (II) | 0.81km$^2$ |
| Mean thickness of overburden | 0.2m |
| Mean thickness of mineral (II) | 2.8m |
| Estimated volume of mineral (II) | 1.7 million m$^3$** |

* In the calculation of this figure, 50 per cent of the area of discontinuous spreads is assumed to be mineral-bearing

** In the calculation of this figure, 75 per cent of the area of morainic drift is assumed to be mineral-bearing

**Table 17** Sheet NJ 70 (Dunecht): Data from sample points and the assessment of resources in Block F

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive category (see the diagram in Appendix C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Intervening waste m | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$mm | Medium sand $+\frac{1}{4}$ -1 mm | Coarse sand +1 -4 mm | Fine gravel +4 -16 mm | Coarse gravel +16 -64 mm | Cobbles and boulders +64 mm | |
| Glacial sand and gravel and other valley-side deposits | | | | | | | | | | | |
| NJ 70 SE 12 | 3.3+ | 0.2 | - | 3 | 5 | 31 | 35 | 17 | 9 | 0 | SG |
| NJ 70 SE 22 | 3.5 | 0.4 | - | 3 | 6 | 26 | 27 | 20 | 18 | 0 | SG |
| **Mean** | **3.4** | **0.3** | | **3** | **6** | **28** | **31** | **18** | **14** | **0** | **SG** |
| Valley-floor deposits | | | | | | | | | | | |
| NJ 70 SE 14 | 3.5 | 3.0 | - | 8 | 10 | 24 | 26 | 12 | 19 | 1 | SG |
| NJ 70 SE R1 | 1.5 | 0.2 | - | - | - | - | - | - | - | - | - |
| **Mean** | **2.5** | **1.6** | | **8** | **10** | **24** | **26** | **12** | **19** | **1** | **SG** |
| **Overall mean for whole block** | **3.0** | **1.0** | | **5** | **7** | **27** | **29** | **16** | **16** | **trace** | **SG** |

*Inferred assessment of the glacial sand and gravel and other valley-side deposits*

| | |
|---|---|
| Area of exposed mineral | 0.46km$^2$ |
| Area of ground worked for sand and gravel | 0.05km$^2$ |
| Mean thickness of overburden | 0.3m |
| Mean thickness of mineral | 3.4m |
| Estimated volume of mineral | 1.6 million m$^3$ |
| Estimated yield of mineral per hectare | 34 million m$^3$ |

*Inferred assessment of the valley-floor deposits*

| | |
|---|---|
| Area of exposed mineral | 0.20km$^2$ |
| Area of concealed mineral | 0.79km$^2$ |
| Total area of mineral-bearing ground | 0.99km$^2$ |
| Mean thickness of overburden | 1.6m |
| Mean thickness of mineral | 2.5m |
| Estimated volume of mineral | 2.5 million m$^3$ |
| Estimated yield of mineral per hectare | 25 thousand m$^3$ |

**Table 18** Banchory/Stonehaven sheet: Data from sample points and the assessment of resources in Block A

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive category (see the diagram in Appendix C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Inter-vening waste m | Fines −1/16 mm | Fine sand +1/16 −1/4 mm | Medium sand +1/4 −1 mm | Coarse sand +1 −4 mm | Fine gravel +4 −16 mm | Coarse gravel +16 −64 mm | Cobbles and boulders +64 mm | |
| NO 79 NW 8 | 1.4 | 0.3 | - | 4 | 4 | 26 | 27 | 23 | 15 | 1 | SG |
| NO 79 NW 11 | 0.9 | 0.3 | - | 1 | 3 | 21 | 21 | 23 | 19 | 12 | G |
| NO 79 NW 16 | 5.9 | 0.4 | - | 8 | 40 | 37 | 11 | 2 | 2 | 0 | PS |
| NO 79 NW 17 | 1.2 | 0.4 | - | 10 | 39 | 37 | 13 | 1 | 0 | 0 | CS |
| NO 79 NW 18 | 1.7+ | 1.4 | - | 14 | 13 | 33 | 30 | 8 | 2 | 0 | CPS |
| NO 79 NW 24 | 3.2 | 0.2 | - | 4 | 7 | 37 | 32 | 14 | 6 | 0 | PS |
| NO 79 NW 25 | 2.2+ | 0.2 | - | 3 | 4 | 33 | 37 | 18 | 5 | 0 | PS |
| NO 79 NW 26 | 2.7 | 0.2 | - | 2 | 3 | 37 | 53 | 5 | 0 | 0 | PS |
| NO 79 NE 3 | 1.4+ | 0.1 | - | 4 | 68 | 25 | 3 | 0 | 0 | 0 | S |
| NO 79 NE R1AB | 2.8 | 0.2 | - | - | - | - | - | - | - | - | - |
| NO 79 NE R2A | 0.9 | 0.1 | - | - | - | - | - | - | - | - | - |
| NO 79 NE R2B | 0.9 | 0.1 | - | - | - | - | - | - | - | - | - |
| **Mean** | **2.1** | **0.3** | | **6** | **22** | **34** | **25** | **9** | **4** | **trace** | **PS** |

*Statistical assessment of the fluvial and lacustrine alluvium, fluvioglacial sand and gravel and glacial sand and gravel north of the valley of the River Dee (Block A)*

| | |
|---|---|
| Total area (excluding Banchory urban area) | 28.48km$^2$ |
| Banchory urban area (including 0.43km$^2$ sand and gravel, not assessed) | 1.22km$^2$ |
| Area of exposed mineral | 1.82km$^2$ |
| Area of concealed mineral | 0.04km$^2$ |
| Area of discontinuous spreads of mineral | 2.57km$^2$ |
| Total area of mineral-bearing ground | 3.55km$^2$* |
| Area of morainic drift (not assessed) | 0.93km$^2$ |
| Area of ground worked for sand and gravel | 0.01km$^2$ |
| Mean thickness of overburden | 0.3m |
| Mean thickness of mineral | 2.1m |
| Estimated volume of mineral | 7.5 million m$^3$ (± 46% or 3.5 million m$^3$) |
| Estimated yield of mineral per hectare | 21 thousand m$^3$ (± 46% or 10 thousand m$^3$) |

* In the calculation of this figure, 50 per cent of the area of discontinuous spreads is assumed to be mineral-bearing

**Table 19** Banchory/Stonehaven sheet: Data from sample points and the assessment of resources in Block B

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive category |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Inter-vening waste m | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$mm | Medium sand $+\frac{1}{4}$ $-1$ mm | Coarse sand +1 -4 mm | Fine gravel +4 -16 mm | Coarse gravel +16 -64 mm | Cobbles and boulders +64 mm | (see the diagram in Appendix C) |
| NO 79 NW 5 | 8.8+ | 0.4 | - | 6 | 6 | 16 | 19 | 19 | 22 | 12 | G |
| NO 79 NW 9 | 4.1* | 0.4 | - | 11 | 8 | 12 | 14 | 16 | 19 | 20 | CG |
| NO 79 NW 12 | 14.5 | 0.4 | - | 2 | 5 | 19 | 20 | 18 | 30 | 6 | G |
| NO 79 NW 13 | 11.1 | 0.4 | - | 2 | 11 | 48 | 11 | 10 | 14 | 4 | SG |
| NO 79 NW 14 | 7.0+ | 0.5 | - | 2 | 4 | 16 | 25 | 20 | 22 | 11 | G |
| NO 79 NW 21 | 11.6+ | 0.4 | - | 2 | 4 | 28 | 13 | 17 | 30 | 6 | G |
| NO 79 NW 22 | 5.2+ | - | - | trace | 8 | 33 | 20 | 15 | 23 | 1 | SG |
| NO 79 NW 23 | 1.9+ | 0.5 | - | 4 | 9 | 23 | 16 | 20 | 28 | 0 | SG |
| NO 79 NW R1AB | 7.8 | 0.3 | - | - | - | - | - | - | - | - | - |
| NO 79 NE 1 | 6.7 | 0.4 | - | 2 | 5 | 39 | 27 | 19 | 8 | 0 | SG |
| NO 79 NE 5 | 9.8+ | 0.3 | - | 2 | 4 | 23 | 15 | 18 | 36 | 2 | G |
| NO 79 NE 6 | 3.7 | 0.3 | - | 4 | 12 | 28 | 26 | 15 | 13 | 2 | SG |
| NO 79 NE 9 | 10.8+ | 0.5 | - | 4 | 8 | 22 | 24 | 18 | 17 | 7 | SG |
| NO 79 NE 11 | 5.1 | 0.4 | - | 3 | 3 | 17 | 27 | 27 | 21 | 2 | G |
| NO 79 NE 12 | 15.4 | 0.4 | - | 6 | 14 | 38 | 15 | 9 | 14 | 4 | SG |
| NO 79 NE 13 | 1.7** | 0.3 | - | 1 | 3 | 39 | 17 | 17 | 23 | 0 | SG |
| NO 79 NE 14 | 3.7+ | 0.3 | - | 9 | 7 | 22 | 12 | 11 | 20 | 19 | G |
| NO 79 NE R3AB | 9.9 | 0.3 | - | - | - | - | - | - | - | - | - |
| **Mean** | **7.7** | **0.4** | | **4** | **7** | **27** | **18** | **16** | **22** | **6** | **SG** |

* Overlies 2.0m+ potentially workable till
** Overlies 0.4m+ potentially workable weathered bedrock

*Statistical assessment of the fluvioglacial terraces and alluvium of the River Dee from Banchory to Drumoak (Block B)*

| | |
|---|---|
| Total area (excluding Drumoak and Crathes) | 9.97km$^2$ |
| Villages of Drumoak and Crathes (including 0.15km$^2$ sand and gravel, not assessed) | 0.18km$^3$ |
| Area of exposed mineral | 8.55km$^2$ |
| Area of concealed mineral | 0.07km$^2$ |
| Area of discontinuous spreads of mineral | 0.08km$^2$ |
| Total area of mineral-bearing ground | 8.66km$^2$* |
| Area of ground worked for sand and gravel | 0.04m$^2$ |
| Mean thickness of overburden | 0.4m |
| Mean thickness of mineral | 7.7m |
| Estimated volume of mineral | 66.7 million m$^3$ (± 28% or 18.7 million m$^3$) |
| Estimated yield of mineral per hectare | 77 thousand m$^3$ (± 28% or 22 thousand m$^3$) |

* In the calculation of this figure, 50 per cent of the area of discontinuous spreads is assumed to be mineral-bearing

**Table 20** Banchory/Stonehaven sheet: Data from sample points and the assessment of resources in Block C

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Intervening waste m | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$mm | Medium sand $+\frac{1}{4}$ -1 mm | Coarse sand +1 -4 mm | Fine gravel +4 -16 mm | Coarse gravel +16 -64 mm | Cobbles and boulders +64 mm | (see the diagram in Appendix C) |
| **Fluvioglacial sand and gravel and morainic drift in the valley of the Burn of Knock** | | | | | | | | | | | |
| NO 79 SW 2 | 6.6* | 0.4 | - | 4 | 7 | 19 | 37 | 19 | 9 | 5 | SG |
| NO 79 SW 3 | 2.7+ | 0.3 | - | 1 | 9 | 57 | 8 | 4 | 9 | 12 | SG |
| NO 79 SW 4 | 1.6 | 0.2 | - | 10 | 16 | 29 | 30 | 13 | 2 | 0 | CPS |
| NO 79 SW 6 | 9.0 | 0.3 | - | 1 | 3 | 14 | 34 | 29 | 18 | 1 | SG |
| **Mean** | **5.0** | **0.3** | | **3** | **6** | **23** | **31** | **21** | **12** | **4** | **SG** |
| **Fluvioglacial sand and gravel, glacial sand and gravel and glaciolacustrine deposits in the valleys of the Burn of Sheeoch, Garrol Burn, Strathie Burn and south of Bogforran** | | | | | | | | | | | |
| NO 79 SW 7 | 3.9+ | 0.3 | - | 3 | 2 | 22 | 32 | 12 | 13 | 16 | SG |
| NO 79 SW 8 | 6.6+ | - | - | 11 | 46 | 20 | 8 | 5 | 7 | 3 | CPS |
| NO 79 SW 10 | 2.8+ | 0.2 | - | 1 | 6 | 56 | 26 | 8 | 3 | 0 | PS |
| NO 79 SW 11 | 4.0 | 0.2 | - | 4 | 5 | 10 | 13 | 11 | 20 | 37 | G |
| NO 79 SW 12 | 6.2 | 0.3 | - | 5 | 14 | 30 | 28 | 12 | 9 | 2 | PS |
| NO 79 SW 13 | 14.2 | 0.3 | - | 4 | 17 | 36 | 19 | 10 | 9 | 5 | SG |
| NO 79 SW 14 | 3.4+ | 0.3 | - | 8 | 6 | 24 | 27 | 15 | 16 | 4 | SG |
| NO 79 SW 15 | 3.7 | - | - | 3 | 5 | 20 | 20 | 20 | 28 | 4 | G |
| NO 79 SW 16 | 2.4 | 2.8** | - | 5 | 13 | 35 | 20 | 14 | 13 | 0 | SG |
| NO 79 SW R3AB | 5.6 | 0.2 | - | - | - | - | - | - | - | - | - |
| NO 79 SE 1 | 5.4 | - | - | 0 | 1 | 18 | 39 | 14 | 11 | 17 | SG |
| NO 79 SE 2 | 2.2 | 0.4 | - | 1 | 2 | 20 | 51 | 17 | 9 | 0 | SG |
| NO 79 SE 4 | 4.1+ | 0.3 | - | trace | 1 | 10 | 25 | 15 | 31 | 18 | G |
| NO 79 SE 5 | 1.0 | 0.3 | - | 3 | 3 | 7 | 6 | 7 | 23 | 51 | G |
| **Mean** | **4.7** | **0.4** | | **4** | **13** | **26** | **23** | **12** | **13** | **9** | **SG** |
| **Overall mean for whole block** | **4.7** | **0.4** | | **4** | **11** | **25** | **25** | **14** | **13** | **8** | **SG** |

* Overlies 1.0m of potentially workable till
** Includes 1.2m of potentially workable till

*Inferred assessment of the fluvioglacial sand and gravel and morainic drift deposits in the valley of the Burn of Knock (Block C)*

| | |
|---|---|
| Total area | $6.10km^2$ |
| Area of exposed mineral | $0.37km^2$ |
| Area of concealed mineral | $0.09km^2$ |
| Area of morainic drift | $0.48km^2$ |
| Total area of mineral-bearing ground | $0.71km^2$* |
| Area of ground worked for sand and gravel | $<0.01km^2$ |
| Mean thickness of overburden | 0.3m |
| Mean thickness of mineral | 5.0m |
| Estimated volume of mineral | 3.6 million $m^3$ |
| Estimated yield of mineral per hectare | 50 thousand $m^3$ |

* In the calculation of this figure, 33 per cent of the area of morainic drift is assumed to be mineral-bearing

*Statistical assessment of the fluvioglacial and glacial sand and gravel, and glaciolacustrine deposits in the valleys of the Burn of Sheeoch, Garrol Burn, Strathie Burn, and south of Bogforran (Block C)*

| | |
|---|---|
| Total area (excluding Woodlands) | $47.52km^2$ |
| Woodlands village (containing $0.06km^2$ of sand and gravel, not assessed) | $0.19km^2$ |
| Area of exposed mineral | $1.77km^2$ |
| Area of concealed mineral | $0.07km^2$ |
| Area of discontinuous spreads of mineral | $0.28km^2$ |
| Total area of mineral-bearing ground | $1.98km^2$* |
| Area of ground worked for sand and gravel | $0.13km^2$ |
| Area of morainic drift | $0.11km^2$ |
| Mean thickness of overburden | 0.4m |
| Mean thickness of mineral | 4.7m |
| Estimated volume of mineral | 9.3 million $m^3$ (± 41% or 3.8 million$^3$) |
| Estimated yield of mineral per hectare | 47 thousand $m^3$ (± 41% or 19 thousand $m^3$) |

* In the calculation of this figure, 50 per cent of the area of discontinuous spreads is assumed to be mineral-bearing

**Table 21** Banchory/Stonehaven sheet: Data from sample points and the assessment of resources in Block E

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive category (see the diagram in Appendix C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Inter-vening waste m | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$mm | Medium sand $+\frac{1}{4}$ -1 mm | Coarse sand +1 -4 mm | Fine gravel +4 -16 mm | Coarse gravel +16 -64 mm | Cobbles and boulders +64 mm | |
| NO 88 NW 1 | 2.7 | 0.4 | - | 3 | 10 | 27 | 32 | 15 | 13 | 0 | SG |
| NO 88 NW 6 | 2.5 | 0.3 | - | 7 | 5 | 7 | 7 | 12 | 32 | 30 | G |
| **Mean** | **2.6** | **0.4** | | **5** | **8** | **17** | **20** | **14** | **22** | **14** | **G** |

*Speculative assessment of Block E (mainly morainic drift deposits from Cairn-mon-earn to the Hill of Pitspunkie and in the valley of the Burn of Day)*

| | |
|---|---|
| Total area | 28.96km$^2$ |
| Area of exposed mineral | <0.01km$^2$ |
| Area of discontinuous spreads of mineral | 0.01km$^2$ |
| Area of morainic drift | 2.33km$^2$ |
| Total area of mineral-bearing ground | 0.79km$^2$* |
| Area of ground worked for sand and gravel | <0.01km$^2$ |
| Mean thickness of overburden | 0.4m |
| Mean thickness of mineral | 2.6m |
| Estimated volume of mineral | 2.1 million m$^3$ |

* In the calculation of this figure, 50 per cent of the area of discontinuous spreads and 33 per cent of the area of morainic drift is assumed to be mineral-bearing

**Table 22** Banchory/Stonehaven sheet: Data from sample points and the assessment of resources in Block F

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive category |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Inter-vening waste m | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$mm | Medium sand $+\frac{1}{4}$ -1 mm | Coarse sand +1 -4 mm | Fine gravel +4 -16 mm | Coarse gravel +16 -64 mm | Cobbles and boulders +64 mm | (see the diagram in Appendix C) |
| **Fluvioglacial sand and gravel and glaciolacustrine deposits between Snob Cottage and Bossholes** | | | | | | | | | | | |
| NO 88 NW 3 | 2.4+ | 0.4 | - | 1 | 4 | 35 | 29 | 10 | 21 | 0 | SG |
| NO 88 NW 4 | 5.4+ | 0.5 | - | 1 | 5 | 21 | 27 | 11 | 17 | 18 | SG |
| NO 88 NW 7 | 2.8 | 0.3 | - | 1 | 1 | 16 | 26 | 9 | 14 | 33 | G |
| NO 88 NW 16 | 5.0+ | - | - | 11 | 38 | 16 | 14 | 7 | 8 | 6 | CPS |
| **Mean** | **3.9** | **0.3** | | **4** | **15** | **21** | **23** | **9** | **14** | **14** | **SG** |
| **Fluvioglacial sand and gravel, alluvium and glaciolacustrine deposits of the Cowie Water between Glenton Hill and Stonehaven** | | | | | | | | | | | |
| NO 88 NW 9 | 1.5+ | - | - | 3 | 9 | 21 | 15 | 11 | 25 | 16 | G |
| NO 88 NW 10 | 12.3 | 0.2 | 0.9 | 7 | 12 | 37 | 25 | 11 | 7 | 1 | PS |
| NO 88 NW 12 | 8.4 | 0.2 | 6.1 | 9 | 22 | 29 | 21 | 9 | 8 | 2 | PS |
| NO 88 NW 17 | 6.9+ | 0.2 | - | 3 | 8 | 21 | 19 | 14 | 23 | 12 | SG |
| NO 88 NE 6 | 1.0 | 0.4 | - | 7 | 6 | 12 | 18 | 15 | 35 | 7 | G |
| NO 88 NE 9 | 6.3 | - | - | 1 | 1 | 9 | 15 | 13 | 31 | 30 | G |
| NO 88 NE 10 | 10.6 | 0.3 | - | 5 | 14 | 20 | 16 | 17 | 19 | 9 | SG |
| NO 88 NE X6 | 4.4+ | 0.5 | - | 1 | 3 | 6 | 9 | 15 | 50 | 16 | G |
| NO 88 NE X7 | 4.1 | 0.1 | - | - | - | - | - | - | - | - | - |
| NO 88 NE X8 | 6.6+ | 0.5 | - | 4 | 5 | 10 | 13 | 23 | 38 | 7 | G |
| NO 88 NE X9 | 3.7+ | 0.5 | - | 11 | 8 | 9 | 12 | 17 | 35 | 8 | CG |
| **Mean** | **6.0** | **0.3** | | **5** | **10** | **21** | **18** | **14** | **23** | **9** | **SG** |
| **Overall mean for whole block** | **5.4** | **0.3** | | **5** | **11** | **21** | **19** | **13** | **21** | **10** | **SG** |

*Inferred assessment of the fluvioglacial sand and gravel and glaciolacustrine deposits between Snob Cottage and Bossholes (Block F)*

| | |
|---|---|
| Total area | 1.13km$^2$ |
| Area of exposed mineral | 0.81km$^2$ |
| Area of concealed mineral | 0.01km$^2$ |
| Area of discontinuous spreads of mineral | 0.11km$^2$ |
| Total area of mineral-bearing ground | 0.88km$^2$* |
| Area of ground worked for sand and gravel | <0.01km$^2$ |
| Area of morainic drift (not assessed) | 0.07km$^2$ |
| Mean thickness of overburden | 0.3m |
| Mean thickness of mineral | 3.9m |
| Estimated volume of mineral | 3.4 million m$^3$ |
| Estimated yield of mineral | 39 thousand m$^3$ |

*Statistical assessment of the fluvioglacial sand and gravel, alluvium and glaciolacustrine deposits in the valley of the Cowie Water between Glenton Hill and Stonehaven (Block F)*

| | |
|---|---|
| Total area | 3.58km$^2$ |
| Area of exposed mineral | 1.36km$^2$ |
| Area of discontinuous spreads of mineral | 0.44km$^2$ |
| Total area of mineral-bearing ground | 1.58km$^2$* |
| Area of ground worked for sand and gravel | 0.18km$^2$ |
| Area of morainic drift (not assessed) | 0.05km$^2$ |
| Mean thickness of overburden | 0.3m |
| Mean thickness of mineral | 6.0m |
| Estimated volume of mineral | 9.5 million m$^3$ (± 43% or 4.1 million m$^3$) |
| Estimated yield of mineral per hectare | 61 thousand m$^3$ (± 43% or 26 thousand m$^3$) |

* In the calculation of this figure, 50 per cent of the area of discontinuous spreads is assumed to be mineral-bearing

**Table 23** Banchory/Stonehaven sheet: Data from sample points and the assessment of resources in Block G

| Data point | Recorded thickness | | | Mean grading percentage | | | | | | | Descriptive category (see the diagram in Appendix C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borehole, pit, exposure or resistivity sounding | Total mineral m | Depth of burial m | Inter-vening waste m | Fines $-\frac{1}{16}$ mm | Fine sand $+\frac{1}{16}$ $-\frac{1}{4}$ mm | Medium sand $+\frac{1}{4}$ −1 mm | Coarse sand +1 −4 mm | Fine gravel +4 −16 mm | Coarse gravel +16 −64 mm | Cobbles and boulders +64 mm | |
| **SUB-BLOCK G1** Fluvioglacial sand and gravel and glacial sand and gravel of the 'Red Series' between Stonehaven and Muchalls; Late-Glacial and Post-Glacial raised beach deposits and morainic drift to the north of Stonehaven | | | | | | | | | | | |
| NO 88 NE 2 | 2.2 | 0.2 | - | - | - | - | - | - | - | - | - |
| NO 88 NE 3 | 3.0+ | 0.5 | - | 4 | 70 | 14 | 6 | 5 | 1 | 0 | PS |
| NO 88 NE 4 | 12.4 | 0.4 | - | 8 | 9 | 17 | 23 | 24 | 18 | 1 | SG |
| NO 88 NE 8 | 3.2+ | 0.2 | - | 3 | 15 | 43 | 10 | 10 | 12 | 7 | SG |
| NO 88 NE 12 | 3.6 | 0.1 | - | 6 | 12 | 28 | 11 | 16 | 15 | 12 | SG |
| NO 88 NE 13 | 6.4 | - | - | 2 | 2 | 8 | 10 | 21 | 31 | 26 | G |
| NO 88 NE R1AB | 7.3 | 0.2 | - | - | - | - | - | - | - | - | - |
| NO 88 NE R2A | 1.5 | 0.2 | - | - | - | - | - | - | - | - | - |
| NO 88 NE R3A | 14.5 | 0.4 | - | - | - | - | - | - | - | - | - |
| NO 88 NE R3B | 6.7 | 0.6 | - | - | - | - | - | - | - | - | - |
| NO 89 SE 1 | 7.1+ | 0.2 | - | 6 | 17 | 28 | 14 | 15 | 13 | 7 | SG |
| NO 89 SE 2 | 3.2+ | 0.1 | - | 3 | 4 | 11 | 17 | 21 | 31 | 13 | G |
| **Mean** | **5.9** | **0.3** | | **5** | **14** | **21** | **15** | **18** | **18** | **9** | **SG** |
| **SUB-BLOCK G2** Fluvioglacial sand and gravel of the 'Red Series' and alluvium of the valley of the Carron Water | | | | | | | | | | | |
| NO 88 NW 8 | 15.0 | 0.3 | 2.5 | 7 | 16 | 44 | 14 | 9 | 9 | 1 | PS |
| NO 88 NW 11 | 5.7 | 1.6 | 1.2 | 20 | 38 | 33 | 7 | 1 | 1 | 0 | VCS |
| NO 88 NW 13 | 5.2 | 0.1 | 1.2 | 11 | 33 | 40 | 8 | 4 | 4 | 0 | CPS |
| NO 88 NW 14 | 5.2 | 0.3 | - | 7 | 62 | 14 | 6 | 7 | 4 | 0 | PS |
| NO 88 NW 15 | 0.9+ | 0.7 | - | 4 | 6 | 7 | 13 | 21 | 31 | 18 | G |
| NO 88 NW R1A | 9.2 | 0.3 | - | - | - | - | - | - | - | - | - |
| NO 88 NW R1B | 4.2 | 0.3 | - | - | - | - | - | - | - | - | - |
| NO 88 NE 7 | 11.2+ | - | - | 6 | 33 | 41 | 6 | 5 | 6 | 3 | PS |
| NO 88 NE 11 | 4.4+ | 0.1 | - | 2 | 10 | 49 | 10 | 7 | 11 | 11 | SG |
| NO 88 NE X13 | 16.1+ | 0.3 | - | 21 | 30 | 40 | 6 | 3 | 0 | 0 | VCS |
| NO 88 NE X14 | 2.6* | 0.5 | - | - | - | - | - | - | - | - | - |
| NO 88 NE X15 | 3.0 | 0.5 | - | 14 | 9 | 9 | 10 | 13 | 45 | 0 | CG |
| **Mean** | **6.9** | **0.3** | | **12** | **28** | **36** | **9** | **6** | **7** | **2** | **CPS** |
| **Overall mean for whole block** | **6.4** | **0.3** | | **9** | **22** | **28** | **12** | **12** | **12** | **5** | **SG** |

* Overlies 1.7m of potentially workable till

*Statistical assessment of sub-block* $G^1$

| | |
|---|---|
| Total area | 18.41km$^2$ |
| Area of exposed mineral | 1.46km$^2$ |
| Area of concealed mineral | 0.36km$^2$ |
| Area of discontinuous spreads of mineral | 0.13km$^2$ |
| Area of morainic drift | 0.20km$^2$ |
| Total area of mineral-bearing ground | 1.96km$^2$* |
| Area of ground worked for sand and gravel | 0.9km$^2$ |
| Mean thickness of overburden | 0.3m |
| Mean thickness of mineral | 5.9m |
| Estimated volume of mineral | 11.6 million m$^3$ (± 46% or 5.3 million m$^3$) |
| Estimated yield of mineral per hectare | 59 thousand m$^3$ (± 46% or 27 thousand m$^3$) |

* In the calculation of this figure, 50 per cent of the area of discontinuous spreads and 33 per cent of the area of morainic drift is assumed to be mineral-bearing

*Statistical assessment of sub-block* $G^2$

| | |
|---|---|
| Total area (excluding Stonehaven) | 4.17km$^2$ |
| Stonehaven urban area (including 1.01km$^2$ sand and gravel, not assessed) | 2.30km$^2$ |
| Area of exposed mineral | 1.25km$^2$ |
| Area of concealed mineral | 0.13km$^2$ |
| Area of discontinuous spreads of mineral | 0.15km$^2$ |
| Total area of mineral-bearing ground | 1.46km$^2$* |
| Area of ground worked for sand and gravel | 0.12km$^2$ |
| Mean thickness of overburden | 0.3m † |
| Mean thickness of mineral | 6.9m † |
| Estimated volume of mineral | 10.1 million m$^3$ (± 47% or 4.7 million m$^3$) |
| Estimated yield of mineral per hectare | 69 thousand m$^3$ (± 47% or 32 thousand m$^3$) |

* In the calculation of this figure, 50 per cent of the area of discontinuous spreads is assumed to be mineral-bearing

† Commercial data have been used in the calculation of these figures

## APPENDIX A: DETAILED ACCOUNT OF THE SOLID GEOLOGY AND THE WEATHERING OF BEDROCK

### Solid geology

Sketch-maps of the solid geology of the study area are shown in Figures 3 and 4. The oldest rocks crop out to the north of the Highland Boundary Fault where they comprise a thick sequence of metamorphosed sedimentary rocks and subordinate basic igneous intrusions (Table 1). The sequence forms part of the Dalradian Supergroup (Harris and Pitcher, 1975) and is of Late Precambrian to Cambrian age (between about 750 and 550 million years old). The detailed sedimentology of these Dalradian rocks records a gradual change from deposition on a relatively stable, but slowly subsiding continental shelf, through a period of rapid but irregular subsidence (with associated basaltic volcanism), to widespread deep marine conditions.

These rocks were strongly deformed and metamorphosed by heat and pressure during the Grampian (early Caledonian) orogeny, from about 510 to 480 million years ago. As in the adjoining Aberdeen area, the Dalradian rocks show the classical Barrovian zonation of metamorphic grade first propounded by Barrow (1893, 1912) during the primary geological survey of the southeastern Highlands and Deeside; a subdivision of part of the Barrovian zonation, the Stonehaven metamorphic sequence (Harte and Hudson, 1979) is displayed in coastal exposures north of Stonehaven.

Throughout the Dalradian sequence, sandy sediments are now represented by quartz-feldspar granulites (psammites), clean sandstones by quartzite and coarser-grained sandy rocks by psammitic grits. Clayey rocks have been metamorphosed to form mica-schists and slates (pelites), sediments that contained significant proportions of both clay and sand have become quartz-mica-schists (semipelites), sandy limestones have been altered to calc-silicate rocks and beds of purer limestone have become marble. The calcareous metasediments have been quarried and burnt for lime, notably in the vicinity of Glack's Well [NO 715 937] and Maryfield [NO 719 957]. The basaltic rocks, which were originally intruded as dykes and sheets within the Dalradian sedimentary sequence, have been altered to amphibolite and hornblende-schist.

Where heat and pressure were sufficiently intense, some of the Dalradian rocks, but particularly the semipelites, were partially melted (migmatised) to produce alternating thin layers of granitic material and schist. Most, but not all, of the mixed metamorphic and igneous rocks shown in Figures 3 and 4, are, in fact, coarse-grained migmatitic gneisses.

The Dalradian rocks have been subjected to a complex (polyphase) sequence of folding and deformation, before, during and after the main period of metamorphic recrystallisation.

Although the interpretation of the major fold structures is hampered by poor exposure, absence of obvious marker horizons and extensive migmatisation, the major axis of folding appears to trend NE-SW; in coastal exposures (north of Stonehaven), at least three discrete episodes of minor folding are evident.

During and shortly after the Grampian orogeny, the Dalradian rocks were intruded by large masses of granitic, basic and ultrabasic rocks. These have been grouped in this report under the title of 'Younger Igneous Intrusions' (they are identified as 'Caledonian', both in Table 1 and in the appended borehole logs).

Part of the Insch Mass, which is composed of basic and ultrabasic intrusive rocks, crops out in the northern part of the Inverurie resource sheet area. The mass was intruded into the Dalradian rocks at the peak of the metamorphic episode (about 490 million years ago). The suite of rocks includes layered sequences of peridotite (often altered to serpentinite), troctolite, norite and gabbro.

The most extensive igneous intrusions are syn- to post-tectonic, of calc-alkaline granitic composition, and of Silurian to Devonian age (about 400 to 470 million years old). Granitic rocks of the Hill of Fare, Crathes and Tillyfourie masses (Munro, 1986, Figure 26) form the bedrock for most of the assessment area between the valley of the River Dee and the town of Inverurie. The Hill of Fare Mass is a pink granite, the Tillyfourie Mass is a grey granodiorite and the Crathes Mass includes both grey granodiorite and grey to pink granite with large potash feldspar phenocrysts, together with diorite in the vicinity of the Loch of Skene. The high ground forming the watershed between the catchment of the River Dee and the coastal area to the southeast, is underlain by the Kincardine (Mount Battock) Mass. This is a coarse-grained pink granite containing large feldspar phenocrysts.

Detailed descriptions of the petrography, composition and ages of the various large intrusions, can be found in the section entitled 'A geological history of N.E. Scotland', by B.C. Kneller (1987), within the excursion guide to the geology of the Aberdeen area, and also within the itineraries of excursions 15, 16, 19 and 20 of that guide.

Apart from small veins of aplite and pegmatite (associated with individual granitic plutons) injected into the Dalradian rocks, most of the minor intrusions take the form of narrow sheets and dykes composed of intermediate and acid hypabyssal rocks. The main rock types include felsite, quartz- and quartz-feldspar porphyry, microdiorite and lamprophyre. The trend of the dykes and sheets is generally NE-SW. Their intrusion is related to brittle deformation associated with the emplacement of the Caledonian igneous masses.

Two major faults, the Dee Fault and the Highland Boundary Fault, cross the southern part of the study area. The Highland Boundary Fault is in fact a complex zone of dislocations, rather than a simple fault, that separates the highly deformed Dalradian rocks from unmetamorphosed 'Old Red Sandstone' sediments. The latter crop out along the southern margin of the Banchory/Stonehaven resource sheet (Figure 4). A complicated sequence of rocks, known as the Highland Border Complex, crop out as tectonically bounded slices along the Highland Boundary Fault zone. In the Stonehaven area, the Highland Border Complex includes spilitic basalt pillow lavas and black shales, together with bands of chert and jasper; fossils (brachiopods, graptolites and acritarchs) indicate that most of the rocks are of Ordovician age (Curry and others, 1984).

The line of the Dee Fault, which is difficult to trace accurately, trends ENE-WSW and truncates the southern margin of the Crathes granite mass. The fault can be mapped only because it is coincident with a linear gravity anomaly, which extends along the valley of the River Dee. In contrast, the Highland Boundary Fault zone, which is one of the principal lines of structural displacement in Scotland, can be mapped accurately along much of its length. The main fault plane is often obscured inland by a zone of shattered rock, but it is exposed at the coast at Garron Point [NO 894 877] where it is marked by a distinctive dolomitic fault gouge. Blocks of this distinctive rock are present in the beds of the Burn of Graham and the Burn of Baulks, both of which cross the fault zone south of Nether Baulk [NO 817 850].

The Highland Boundary Fault has been active for a considerable period of time. During the Caledonian orogeny, the principal movements appear to have been strike-slip, but by Devonian times, the dislocation had become a normal fault, with a downthrow towards the south. The development of the Strathmore syncline, with its thick sequence of 'Old Red Sandstone' sedimentary and volcanic rocks, is clearly related to movements along the fault line. In fact, a disrupted unit containing angular blocks of sandstone (up to 30m in length) within the 'Old Red Sandstone' sequence south of Downie Point [NO 883 853], indicates syn-sedimentary fault movement, close to the margin of the syncline, during the Devonian (Robertson, 1987).

The stratigraphy of the 'Lower Old Red Sandstone' of Strathmore has been revised by Armstrong and Paterson (1970). The rocks crop out along the southern edge of 1:10 000 sheets NO 88 NW and NE, where they rest unconformably on rocks of the Highland Border Complex. The lowest division, the Stonehaven Group, is well exposed along the coast between Garron Point and Stonehaven. The lower part (the Cowie Formation) is predominantly composed of fine to medium-grained red, brown and grey sandstones, overlain by fossiliferous red and grey mudstones. Fossil fish and arthropods from a unit within the Cowie Formation (the Cowie Harbour Fish Bed), suggest a Downtonian (Upper Silurian) age for this part of the sequence (Westoll, 1977).

The Dunnottar Group, which overlies the Stonehaven Group, crops out south of the town. It chiefly comprises coarse conglomerates (containing rounded boulders of Dalradian quartzite and schistose grit, which may be more than a metre across), interbedded with lavas and thin beds of sandstone.

The youngest solid rocks in the assessment area are a series of quartz-dolerite dykes of Permo-Carboniferous age, which trend ENE-WSW. A good example, 2m thick, was recorded during the excavation of a pipeline trench in the vicinity of Upper Middleton [NJ 729 220]; the positions and orientations of many poorly-exposed examples are evident only as magnetic anomalies on maps produced by geomagnetic surveys of the area.

### Weathering of bedrock

For much of the Mesozoic and Tertiary eras the

East Grampians appear to have been part of an eroding landmass. Consequently much of the bedrock in the area of this study has been subjected to deep chemical weathering, most of which took place prior to the glaciation of the district during the Quaternary era. Glacial, periglacial and fluvial erosion removed most of this decomposed rock but many pockets remain. Much weathered rock has been incorporated into the superficial deposits of the district, contributing to their sandy nature.

The extent and depth of weathering is difficult to determine, as only the remnants of a formerly extensive weathering cover are now preserved. There appears to be little correlation between the degree of weathering and lithology or topography. Coarse-grained, well jointed igneous rocks, such as granite, may be mantled by several metres of unconsolidated material, in which the feldspar and mica crystals have been altered to clay minerals.

Psammites and quartzites are also affected, although generally to a smaller degree, whereas pelitic rocks are often thoroughly altered to silty sandy clay. Sandstones and conglomerates are apparently unaffected in some areas, but locally they are decomposed to resemble modern sand and gravel, from which they can usually be distinguished by the traces of original sedimentary structures preserved in the weathered material.

The decomposition of the bedrock is regarded as being primarily a result of weathering under humid, tropical or sub-tropical conditions, which last occurred in Scotland during the late Miocene (Hall, 1983). Many of the weathering profiles have been modified by subsequent weathering under more temperature Pliocene and Pleistocene preglacial or interglacial conditions (Fitzpatrick, 1963). The contention that much of the weathering is of subtropical or tropical origin is supported by the mineralogy of the clays formed during the weathering process (Hall, 1986), and is also suggested by the presence of rounded 'core stones' within weathering profiles developed in some areas, notably in sandstone bedrock in the vicinity of Fetteresso Castle [NO 842 855]. These 'core stones' are similar to features described by Ruxton and Berry (1957, 1961), from areas of deeply weathered granite bedrock in the tropics.

## APPENDIX B: FIELD AND LABORATORY PROCEDURE

Initial studies of the laterally extensive glacial deposits of East Anglia and Essex showed that an absolute minimum of five sample points evenly distributed across a deposit of sand and gravel are needed to provide a worthwhile statistical assessment, but that, where possible, there should not be less than ten. In the present area of study, as elsewhere in northern Britain, the glacial deposits are patchy and heterogeneous; it is not always possible to provide as many as ten sample points in such discontinuous deposits. Sample points are any points for which adequate information exists about the nature and thickness of the deposit and may include boreholes other than those drilled during the survey, together with trial pits and exposures. In particular, the cooperation of sand and gravel operators ensures that boreholes are not drilled where reliable information is already available; although this information may be used in the calculations, it is held confidentially by BGS and cannot be disclosed without the permission of the company or person concerned.

The mineral shown on each 1:25 000 sheet is divided into resource blocks. The arbitrary size selected, is a compromise to meet the aims of the survey by providing sufficient sample points in each block. As far as possible the block boundaries are determined by geological boundaries so that, for example, glacial and terraced river gravels are separated. Otherwise the division is by arbitrary lines, which may bear no simple relationship to the geology. The blocks are drawn provisionally before sampling begins.

A reconnaissance of the ground is carried out to record any exposures and enquiries are made to ascertain what borehole information is available. Borehole and trial pit sites are then selected to provide as even a pattern of sample points as is practicable at a density of approximately one per square kilometre. However, because broad trends are independently overlain by smaller scale characteristically random variations, it is not been found necessary to adhere strictly to a square grid pattern. Thus such factors as ease of access, the need to minimise disturbance to land and to the public are also taken into account in siting the holes; at the same time, it is necessary to guard against the possibility that ease of access (that is, the positions of roads and farms) may reflect particular geological conditions which may bias the sampling results.

The drilling machine employed should be capable of providing a continuous series of samples representative of all unconsolidated deposits, so that the *in-situ* grading can be determined, if necessary, to a depth of 30m beneath different types of overburden. The drilling machine should be reliable, quiet, mobile and relatively small (so that it can be moved to sites of difficult access). Shell and auger rigs have proved to be almost ideal.

The rigs are modified to enable deposits above the water-table to be drilled 'dry', (instead of with water added to facilitate the drilling), in order to minimise the amount of material drawn in from outside the limits of the hole. The samples thus obtained are representative of the *in-situ* grading, and satisfy one of the most important aims of the survey. Below the water-table the rigs are used conventionally, although this results in the loss of some of the fines fraction. The pumping action of the bailer tends to draw material into the hole from the sides and the bottom, but care is taken to discard, as far as possible, this unwanted material.

Thin spreads of sand and gravel are sampled by means of shallow trial pits.

A continuous series of bulk samples is taken throughout the sand and gravel. Ideally samples are composed exclusively of the whole of the material encountered in the borehole or pit, between stated depths. A new sample is commenced whenever there is an appreciable lithological change within the sand and gravel, or at every 1m depth. The samples, each weighing between 25 and 45kg, are despatched in heavy duty polythene bags to a laboratory for grading. The results are reported as cumulative particle size distribution curves, examples of which are shown in Figure 7. The grading procedure is based on British Standard 1377 (1975). Random checks on the accuracy of the grading are made by BGS staff.

In the current survey, additional data on the thickness and extent of the mineral deposits have been obtained in some areas by measurements of apparent ground electromagnetic conductivity and resistivity following the methods outlined in Clarke and others (1982). The methods employed and the results obtained are discussed in more detail in Appendix E.

All data is coded up for analysis by computer. Abbreviated logs of assessment boreholes, trial pits and measured sections together with grading data are reproduced in Appendix F. Resistivity sounding measurements together with interpreted geological logs are presented in Appendix I.

Detailed records may be consulted on application to the Manager, Highlands and Islands Research Programme, Murchison House, West Mains Road, Edinburgh EH9 3LA.

## APPENDIX C: STATISTICAL PROCEDURES

### Statistical assessment

1 A statistical assessment can be made if there is a minimum of five evenly spaced sample points in the resource block (for smaller areas see paragraph 12 below).

2 The simple methods used in the calculations are consistent with the amount of data provided by the survey (Hull, 1981). Conventional symmetrical confidence limits are calculated for the 95 per cent probability level; that is, there is a 5 per cent or one in twenty chance of a result falling outside the stated limits.

3 The volume estimate (V) for the mineral in a given block is the product of the two variables, the sampled area (A) and the mean thickness ($\bar{d}_m$) calculated from the individual thicknesses at the sample points. The standard deviations (S) for these variables are related such that

$$S_V = (S_A{}^2 + S_{\bar{d}_m}{}^2)^{\frac{1}{2}}. \qquad [1]$$

4 The above relationship may be transposed such that

$$S_V = S_{\bar{d}_m} \times (1 + S_A{}^2/S_{\bar{d}_m}{}^2)^{\frac{1}{2}} \qquad [2]$$

From this it can be seen that $S_A{}^2/S_{\bar{d}_m}{}^2$ tends to 0 whereas $S_V$ tends to $S_{\bar{d}_m}$.

If, therefore, the standard deviation for area is small with respect to that for mean thickness, the standard deviation for volume approximates to that for mean thickness.

5 Given that the number of approximately evenly spaced sample points in the sampled area is n, with mineral thickness measurements $d_{m_1}, d_{m_2} \dots d_{m_n}$, then the best estimate of mean thickness, $\bar{d}_m$, is given by

$$\Sigma\ (d_{m_1} + d_{m_2} + \dots d_{m_n})/n.$$

For groups of closely spaced boreholes a discretionary weighting factor may be applied to avoid bias (see note on weighting below). The standard deviation for mean thickness $S_{d_m}$ expressed as a proportion of the mean thickness, is given by

$$S_{\bar{d}_m} = (1/\bar{d}_m)[\Sigma(d_m - d_m)^2/(n-1)]^{\frac{1}{2}}$$

where $d_m$ is any value in the series $d_{m_1}$ to $d_{m_n}$.

6 The mineral-bearing areas in each resource block are coloured pink on the map. Wherever possible, calculations relate to the mineral within mapped geological boundaries (which may not necessarily correspond to the limits of deposit). Where the area is not defined by a mapped boundary, that is, where the boundary is inferred, a distinctive symbol is used.

Experience suggests that the errors in determining area are usually small relative to those in thickness. The relationship $S_A/S_{\bar{d}_m} \leq 1/3$ is assumed in all cases. It follows from equation [2] that $S_{\bar{d}_m} \leq S_V \leq 1.05S_{\bar{d}_m}$.

7 The limits on the estimate of mean thickness of mineral, $L_{\bar{d}_m}$, may be expressed in absolute units $\pm(t/n^{\frac{1}{2}})S_{\bar{d}_m}$ or as a percentage $\pm(t/n^{\frac{1}{2}})S_{\bar{d}_m}(100/\bar{d}_m)$ per cent, where t is Student's t at the 95 per cent probability level for (n-1) degrees of freedom, evaluated by reference to statistical tables. (In applying Student's t it is assumed that the measurements are distributed normally).

8 Values of t at the 95 per cent probability level for values of n up to 20 are as follows:

| n | t | n | t |
|---|---|---|---|
| 1 | infinity | 11 | 2.228 |
| 2 | 12.706 | 12 | 2.201 |
| 3 | 4.303 | 13 | 2.179 |
| 4 | 3.182 | 14 | 2.160 |
| 5 | 2.776 | 15 | 2.145 |
| 6 | 2.571 | 16 | 2.131 |
| 7 | 2.447 | 17 | 2.120 |
| 8 | 2.365 | 18 | 2.110 |
| 9 | 2.306 | 19 | 2.101 |
| 10 | 2.262 | 20 | 2.093 |

(from Table 12, Biometrika Tables for Statisticians, Volume 1, Second Edition, Cambridge University Press, 1962). When n is greater than 20, 1.96 is used (the value of t when n is infinity).

9 In calculating confidence limits for volume, $L_V$, the following inequality corresponding to equation [3] is applied:

$$L_{\bar{d}_m} \leq L_V \leq 1.05L_{\bar{d}_m}.$$

10 In summary, for values of n between 5 and 20, $L_V$ is calculated as

$$[(1.05t)/\bar{d}_m] \times [\Sigma(d_m-\bar{d}_m)^2/n(n-1)]^{\frac{1}{2}} \times 100 \text{ per cent},$$

and when n is greater than 20, as

$$[(1.05 \times 1.96)/\bar{d}_m] \times [\Sigma(d_m-\bar{d}_m)^2/n(n-1)]^{\frac{1}{2}} \times 100 \text{ per cent},$$

(weighting factors may be included: see paragraph 15).

11 The application of this procedure to a fictitious area is illustrated in Figure 8.

**Inferred assessment**

12 If the sampled area of mineral in a resource block contains less than five sample points, an assessment is *inferred*. The volume of mineral is calculated as the product of the area, measured from field data, and the estimated thickness. Confidence limits are not calculated.

**Speculative assessment**

13 In some cases a resource block may include deposits for which little information is available or it may include an area within which mineral (as defined) is interpreted to be patchy or generally absent. If there is reason to believe that some mineral may be present, a *speculative* assessment may be made.

14 **Note on weighting** The thickness of a deposit at any point may be governed solely by the position of the point in relation to a broad trend. However, most sand and gravel deposits also exhibit a random pattern of local, and sometimes considerable, variation in thickness. Thus the distribution of sample points need be only approximately regular and in estimating the mean thickness only simple weighting is necessary. In practice, equal weighting can often be applied to thicknesses at all sample points. If, however, there is a distinctly unequal distribution of points, bias is avoided by dividing the sampled area into broad zones, to each of which a value roughly proportional to its area is assigned. This value is then shared between the data points within the zone as the weighting factor.

## APPENDIX D: CLASSIFICATION AND DESCRIPTION OF SAND AND GRAVEL

For the purposes of assessing resources of sand and gravel a classification should take account of economically important characteristics of the deposits, in particular the absolute content of fines and the ratio of sand to gravel.

The terminology commonly used by geologists when describing sedimentary rocks (Wentworth, 1922) is not entirely satisfactory for this purpose. For example, Wentworth proposed that a deposit should be described as a 'gravelly sand' when it contains more sand than gravel and there is at least 10 per cent of gravel, provided that there is less than 10 per cent of material finer than sand (less than 0.063 mm) and coarser than pebbles (more than 64 mm in diameter). Because deposits containing more than 10 per cent fines are not embraced by this system a modified binary classification based on Willman (1942) has been adopted here. The twelve descriptive categories that result from this modified scheme are shown in Figure 9.

When the fines content exceeds 40 per cent the material is not considered to be potentially workable and falls outwith the definition of mineral. Deposits which contain 40 per cent fines or less are classified primarily on the ratio of sand to gravel. For example, the boundaries between sand, pebbly sand, sandy gravel and gravel are drawn at sand to gravel ratios of 19:1, 3:1 and 1:1 respectively. This primary classification is qualified in the light of the fines content, as follows: less than 10 per cent fines - no qualification; 10 to 20 per cent fines - 'clayey'; 20 to 40 per cent fines - 'very clayey'.

The term 'clay' (as written, with single quote marks) is used to describe all material passing 0.063 mm. Thus, it has no mineralogical significance and includes particles falling within the size range of silt (0.063mm to 0.0039mm) and clay (less than 0.0039mm). The normal meaning of the term clay applies where it does not appear in single quotation marks.

The procedure to classify mineral into one of the twelve descriptive categories shown in Figure 9 is thus as follows:

1 Classify according to ratio of sand to gravel.
2 Classify according to fines content

For example, a deposit grading 32 per cent gravel, 59 per cent sand and 19 per cent fines is classified as 'clayey' sandy gravel. This short description is included in the borehole log (see Note 11, Appendix F).

Many differing proposals exist for the classification of the grain size of sediments (Atterberg, 1905; Udden, 1914; Wentworth, 1922, 1935; Allen, 1936; Twenhofel, 1937; Lane and others, 1974). As Archer (1970a,b) has emphasised, there is a pressing need for a simple metric scale acceptable to both scientific and engineering interests, for which the class limit sizes correspond closely with certain marked changes in the natural properties of mineral particles. For example, there is an important change in the degree of cohesion between particles at about the 0.063 mm size, which approximates to the generally accepted boundary between silt and sand. These and other requirements are met by a system based on Udden's geometric scale and a simplified form of Wentworth's terminology, which is used in this report (see Table D1)

The fairly wide intervals in the scale are consistent with the general level of accuracy of the quantitative assessments of the resource blocks. Three sizes of sand are recognised, fine (0.063-0.25mm), medium (0.25 mm-1 mm) and coarse (1-4 mm). The boundary at 16 mm distinguishes a range of finer gravel (from 4 mm to 16 mm), often characterised by abundance of worn, tough pebbles of vein-quartz, from larger pebbles, often of notably different materials. Boundaries at 64 mm and 256 mm distinguish pebbles from cobbles and cobbles from boulders respectively. The term 'gravel' is used loosely to denote both pebble-sized and cobble-sized material.

The size distribution of borehole samples is determined by sieve analysis (British Standard 1377:1975), which is presented by the laboratory as logarithmic cumulative curves (Figure 7). In this report the grading is tabulated in the assessment records (Appendix G), the intercepts corresponding with the simple geometric scale 0.063 mm, 0.25 mm, 1 mm, 4 mm, 16 mm and so on, as required. All of the original sample grading curves are available for reference at the appropriate office of BGS.

Each bulk sample is described, subjectively, by a geologist at the borehole site. Being based on visual examination, the initial description of the grading is inexact, the accuracy depending on the experience of the observer. The descriptions recorded are modified, as necessary, when the laboratory results become available.

The relative proportions of the rock types present in the gravel fraction are indicated by the use of the words 'and' or 'with'. For example, 'gabbro and schist' indicates approximately equal proportions of each rock type with neither constituent accounting for less than about 25 per cent of the whole; 'gabbro with schist' indicates that gabbro is dominant and schist, the principal accessory rock type, comprises 5 to 25 per cent of the whole. Where the accessory material accounts for less than 5 per cent of the whole, but is still readily apparent, the phrase 'with some' has been used. Minor constituents are referred to as rare or as 'trace'.

The terms used in the field to describe the degree of rounding of particles are concerned with the sharpness of the edges and corners of clasts and not their shape (Pettijohn, 1975). They are as follows:

**Angular**: showing little or no evidence of wear; sharp edges and corners.

**Subangular**: showing definite effects of wear. Fragments still have their original form but edges and corners begin to be rounded off.

**Subrounded**: showing considerable wear. The edges and corners are rounded off to smooth curves. Original grain shape is still distinct.

**Rounded**: original faces completely destroyed, but some comparatively flat surfaces may still remain. All original edges and corners have been smoothed off to rather broad curves. Original shape is still apparent.

**Well-rounded**: no original faces, edges or corners left. The entire surface consists of broad curves; flat areas are absent. The original shape is suggested by the present form of the grain.

## APPENDIX E: GEOPHYSICAL INVESTIGATIONS

### Resistivity survey

In order to evaluate various techniques for the assessment of scattered sand and gravel deposits, the Industrial Minerals Assessment Unit of the Institute of Geological Sciences (now British Geological Survey, BGS), conducted a feasibility study in the Redditch-Solihull area of the English Midlands during 1981 (Clarke and others, 1982). The new techniques that were investigated included various drilling, geophysical and remote sensing methods. It became apparent that drilling boreholes using shell and auger drilling rigs in the manner of previous sand and gravel assessments remained the best method of obtaining reliable data on the thickness and composition of concealed deposits of sand and gravel. Of the geophysical methods investigated ground resistivity surveying, and, in particular, the Offset Wenner sounding system was found to be the most effective. This method has subsequently been used successfully to supplement the data obtained from shell and auger drilling in the assessment of sand and gravel resources in the Henley-in-Arden district of Warwickshire (Cannell and Crofts, 1984) and in the Harleston and Bungay areas of East Anglia (Auton, Morigi and Price 1985).

As most of the potentially workable sand and gravel in northeast Scotland occurs as small, (but sometimes thick) scattered spreads, it was thought appropriate that ground resistivity measurements be made as part of the present assessment, in order to evaluate the application of the technique to the study of resources of sand and gravel in a Scottish context.

*Theory and methods*

Resistivity is defined as the resistance to electrical flow of a volume of ground of unit length and unit cross-sectional area. Apparent resistivity (measured in ohm.metres, ohm.m) is a weighted combination of the resistivities of sub-surface layers, and it is obtained by passing a current (I) between two current electrodes (C1 and C2) and measuring the potential difference ($\Delta V$) between two potential electrodes (P1 and P2). By changing the positions of the electrodes systematically for a particular configuration, a series of apparent resistivity readings may be obtained in order to resolve the sub-surface layering. For the Wenner electrode configuration, (Figure 10a) the apparent resistivity ($\rho a$) is given by:-

$$\rho a = 2\pi \, a \, \Delta V/I$$

where (a) is the electrode separation.

At all of the ground resistivity sites in the present survey, the *Offset Wenner* sounding system was used, in conjunction with a measuring instrument (in this case an ABEM Terrameter SAS 300) which incorporated a signal averaging system for improved accuracy of the results and a digital read-out of the measured resistances. The Offset Wenner system was designed for operation with two multi-core cables containing metal connections for each of the electrode positions, which feed back to a central switching box. This technique uses a central electrode in addition to the conventional Wenner array electrode positions. The distance of each pair of electrodes (from the central electrode) doubles for succeeding sets of measurements. This can be seen in Figure 10b, where for the first set of readings ($R_A$), electrode 3 is the central electrode, numbers 2 and 4 are the pair of potential electrodes (both 0.5m from electrode 3); numbers 1 and 5 are the pair of current electrodes (both 1m away from electrode 3). In the present study, a maximum of nine pairs of electrodes were used, the farthest pair of electrodes being spaced 128m either side of the central electrode (giving a total array length of 256m).

The depth of investigation of an electrode configuration can be considered as a depth below which there is little contribution to the measured signal; for homogeneous ground this has been evaluated as 0.11D, where D is the distance between the outermost two electrodes. The maximum depth of investigation theoretically possible using a total array length of 256m (for homogeneous ground) is 0.11 x 256m = 28.2m, which is comparable to the maximum depth (25m) to which assessment boreholes are drilled (see Appendix B). In practice, drift sequences are often very heterogeneous and the depth of penetration may be increased or decreased as a result.

By combining measurements from different electrode configurations (such as $R_B$, $R_C$, $R_{D1}$ and $R_{D2}$, selected by using the switching box), it is possible to check the consistency of the reading, to compensate for the effect of near-surface lateral variations and to reduce the total number of electrode positions occupied. By this means, all the electrodes can be planted and connected at the same time, making the system practical for one-man operation as well as being rapid and cost-effective.

In many instances, the sites chosen for resistivity sounding measurements are surrounded by fences, hedges or buildings, which restrict the length of the array that can be used. In fact, it requires a much larger area of ground than might at first be thought to enable two soundings to be made along straight arrays (both 256m long) centred at the same point.

The resistivity readings obtained from the ABEM terrameter were plotted in the field using log-log graph paper in order to obtain preliminary 'field curves'. These give an immediate indication of the likely geological sequence encountered and the depth to rock-head. Detailed interpretation of the data was achieved in the laboratory by a curve-matching process, which involved the production of geo-electric models (resistivity curves) using a suite of computer programs developed specifically for this process by BGS. The programs are based on those published by Finch (1984), but modified to run on GEC 4090 and VAX 8600 main-frame computers. This computer-generated output forms the basis of the geological interpretation of the resistivity sounding data presented in the detailed resistivity records given in Appendix I.

*Results*

Using the Offset Wenner sounding system, 43 resistivity depth soundings were taken at 25 sites to augment the assessment data obtained from trial pits, measured sections and boreholes. In general, two sets of soundings were conducted at each site, the electrode arrays being orientated approximately perpendicular to one another. The positions of the arrays had sometimes to be varied from the ideal depending on geological conditions and local physical constraints such as field boundaries. The interpreted resistivity values from both sets of soundings were then averaged to provide a mean value for each site. Eight of the resistivity sites were positioned close to sample points (boreholes, trial pits, or measured sections) in order to calibrate the resistivity results. A frequency distribution plot of the ground resistivity values, calculated from the interpreted resistivity values, is shown in Figure 11.

High interpreted resistivity values (>1000 ohm.m) can invariably be attributed to either sand and gravel or to igneous or metamorphic bedrock, but distinguishing between them without some prior knowledge of the geology of the area is difficult. It is particularly difficult to distinguish between granitic and metamorphic rocks simply on the basis of resistivity, as the range of interpreted values is similar for both rock-types. Very high apparent resistivities (>2000 ohm.m) suggest that the igneous and metamorphic bedrock has relatively high permeability: generally, the higher the value, the more fractured the rock.

In contrast, four resistivity soundings were conducted at sites underlain by Ordovician and Devonian bedrock which gave interpreted resistivity values that ranged between 100-300 ohm.m. These values indicate a higher proportion of clayey material in the Ordovician and Devonian rocks as compared to unweathered granite and metamorphic bedrock. This increase in clay and silt is explained, in part, by the fact that beds of mudstone are present within the Ordovician (Highland Border Complex) and within the Devonian ('Old Red Sandstone') sequences. Disseminated silt and clay is also present within the beds of sandstone and conglomerate which constitute the principal rock types within the 'Old Red sandstone' sequence in the study area.

The majority of the soundings indicated that there is a layer of low resistivity towards the base of the drift sequence. This low resistivity layer was attributed to till or clayey gravel overlying the bedrock, and this interpretation is confirmed in many of the assessment boreholes, notably those sited on the terraced deposits in the valley of the River Dee.

The sandy nature of the till and morainic drift deposits over most of the survey area (compared with till sequences in southern Britain, for which resistivity data is available) caused many of the interpreted resistivity values to be much higher than might be expected for such deposits. In the Henley-in-Arden survey area, for example, most of the till deposits gave interpreted resistivity values between 20-70 ohm.m, whereas most of the glacial sand and gravel had values between 100-300 ohm.m. In the area of the present study, values of less than about 75 ohm.m could be attributed to deposits of clayey till, but sandy till gave values between 100-300 ohm.m.

Intermediate values (100-1000 ohm.m) needed careful interpretation as there were only subtle differences between predominantly sandy and predominantly clayey deposits. The soundings conducted over fine-grained glaciolacustrine sediments gave values between 100-200 ohm.m, illustrating the silty nature of these deposits.

*Conclusions*

A basal till of low resistivity, underlain by igneous or metamorphic bedrock of high resistivity, enabled the depth to the base of the drift to be fixed accurately over much of the study area. Large differences between the resistivity ranges of sand and gravel and underlying clayey till tended to 'mask' the effect of any intervening layers of moderate resistivity, such as glaciolacustrine deposits. Thus, in many instances, careful interpretation of the results coupled with close borehole or other means of control was required. The confidence of the geological interpretation of the resistivity results is generally high, but only because data from so many boreholes and pits were available to aid that interpretation. The highly variable nature of the sequence is reflected in the wide range of resistivity values encountered (20-20,000 ohm.m). The high proportion of sand present in many of the drift deposits meant that the contrast between overburden, or waste, and potentially workable sand and gravel was not as clear as in areas of southern Britain where similar resistivity surveys have been conducted.

Resistivity soundings using the Offset Wenner system proved to be a rapid method for investigating the drift deposits of the survey area; up to ten separate sets of soundings could be made each day. The detailed interpretation of the results, however, can be very time-consuming and this should be borne in mind when geophysical methods are considered as part of any further assessment.

Boreholes or trial pits are required for definitive measurements but resistivity soundings are a good alternative in areas of difficult terrain that would otherwise be inaccessible to a drilling rig, for example, areas of marshy ground, such as Black Moss, and on ground where disturbance has to be avoided. Local difficulties (small fields, wire fences, etc) can be overcome by careful positioning of the sounding site, but in most instances the fields were too small for the full array to be used.

The Offset Wenner system provided a valuable additional 'tool' for the assessment of sand and gravel in the study area. It was especially useful in proving the total thickness of sand and gravel at sites in the valley of the River Dee, where the coarse nature of the gravels made the penetration of the full sequence by shell and auger drilling an expensive and often impossible task. The system is also useful for rapidly determining areas where quantitive investigations using 'traditional' drilling and sampling methods are warranted.

**Conductivity Survey**

Electromagnetic conductivity measurements were made with portable, non-contacting conductivity meters as an aid to geological mapping of sedimentary rock sequences by BGS staff in southern Britain (Zalasiewicz, Mathers and Cornwell, 1985). Conductivity measurements made on traverses across an area of ground to be mapped showed that clay-rich sediments could be rapidly distinguished from sands and gravels as well as from sandstones and limestones. Similar methods were employed, on a trial basis, during the geological mapping undertaken in preparation for the present assessment. The purpose was to evaluate the cost-effectiveness of such measurements of ground conductivity in delineating areas of potentially workable sand and gravel within the drift deposits, and an area was chosen in the vicinity of Stonehaven.

*Theory and Methods*

The electromagnetic conductivity technique is based upon the detection of secondary magnetic fields that are generated as an induced response to an alternating primary magnetic field. The equipment used in this trial was a Geonics EM 31 terrain conductivity meter. This device comprises two glass-fibre booms (housing the transmitter and receiver coils), that plug in on either side of a control box, which houses the operating switches, power pack and galvanometer (for the data read-out). The assembled equipment has a fixed span of 3.7m, weighs about 9kg and is designed to be operated at waist height by one person.

The transmitting coil produces a primary magnetic field that induces horizontal current loops in the ground; these in turn give rise to a secondary magnetic field. The meter is designed so that the ratio of the two magnetic fields has a linear relationship (within certain limits) to ground conductivity. The receiving coil detects both magnetic fields and the resulting conductivity values, recorded in millimohos per metre, are displayed on the instrument panel of the control box. The detailed operation of the EM 31 conductivity meter is described fully in its operating manual (Geonics, 1982).

The measurements of electromagnetic conductivity can be related to values of ground resistivity, so that data obtained using the Offset Wenner system (described above) can be compared to data from the EM 31 traverses. In fact, resistivity is the reciprocal of conductivity, so that, for example, a reading of 4 millimhos per metre, is equivalent to a resistivity of 250 ohm.m.

The useful depth of penetration of the EM 31 is generally about 5m from the ground surface and so its direct use for evaluating thick sedimentary sequences is slight; its primary use is for distinguishing between various rock types at or near the ground surface.

*Results*

A series of traverses were made across an area of 2km$^2$ of ground in the vicinity of the Houff of Ury [NO 856 889] at the northeastern edge of 1:10 000 sheet NO 88 NE. The primary geological survey of the area (completed in 1884) indicated that most of the ground was underlain by an extensive spread of sand and gravel. Subsequent mapping undertaken in preparation for the present study suggested that the deposits of sand and gravel were, in fact, much less extensive than shown on the published geological map (based on the original survey).

Conductivity measurements were taken at approximately 40m intervals along north-south traverses spaced 40m apart. This produced a regular grid of data points. The traverses took eight working days to complete, but steep slopes (such as the sides of the valley of the Burn of Monboys) and thickly wood coniferous plantations had to be omitted.

Contouring of the spot data identified several areas of very low conductivity (<1 millimho/m), which corresponded with mapped spreads of sand and gravel and bedrock. Several areas of higher conductivity (>6 millimhos/m) were also apparent; these corresponded with deposits of till and glaciolacustrine silt and clay mapped at the surface.

*Conclusions*

Areas of exposed sand and gravel or bedrock were rapidly distinguished from ground underlain by clayey drift deposits, but it was not possible to distinguish between sand and gravel and bedrock solely on the results of the conductivity survey. This is not surprising, as the results of the resistivity survey indicated that (in most instances) both sand and gravel and bedrock would have overlapping conductivity values in the range of 0.1 to 1.0 millimho/m. This indeed proved to be the case in the Houff of Ury area.

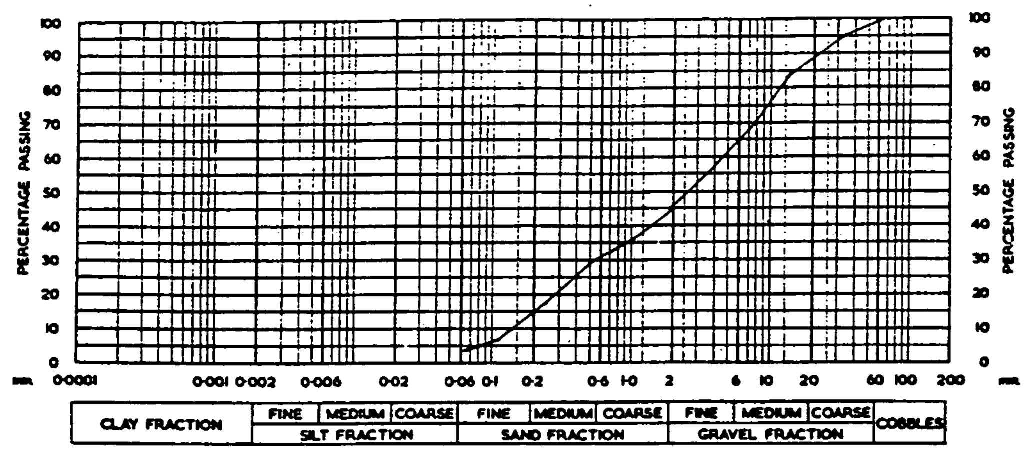
The geological map, produced by re-surveying the area in the conventional manner, required only minor modification following the conductivity survey. This suggests, that for the trial area at least, the conductivity survey was not a particularly useful or cost-effective method of improving the geological interpretation of the ground surveyed.

The conductivity results however, did broadly confirm the amount of potentially workable sand and gravel that was identified by conventional mapping and the drilling programme. The conductivity values also correlated well with data from the resistivity soundings made in the area.

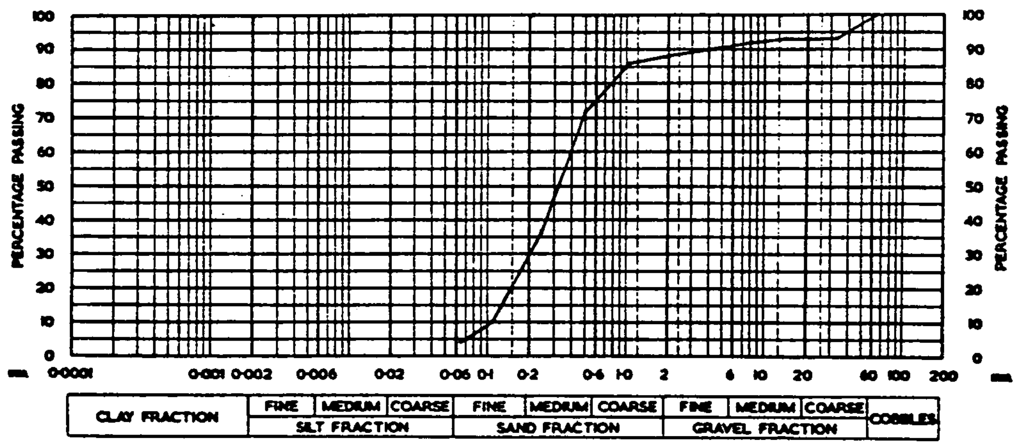
Conductivity measurements could not be made in thickly wooded areas or on steep valley sides, and furthermore, measurements made in the vicinity of pipelines and high-voltage electricity lines gave anomalously high readings. These impediments are commonplace in northeast Scotland, where much of the ground is forested and many areas are crossed by pipelines carrying oil and natural gas. These factors alone tend to make conductivity surveying a less attractive aid to geological mapping than is the case in some other parts of Britain. Conductivity measurements would, however, be a useful tool for the extractive industry in delineating areas for sand and gravel exploration in areas where no modern geological map coverage is available.

## PARTICLE SIZE DISTRIBUTION

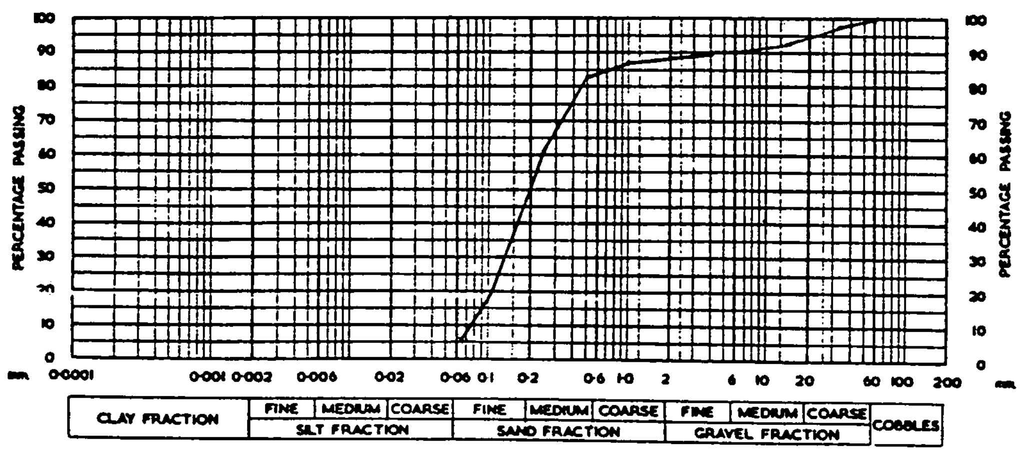
SITE. Aberdeen II Sand and Gravel Survey REF. No. T-1274




BOREHOLE No. SAMPLE No. BA 97 DEPTH m




BOREHOLE No. SAMPLE No. BA 98 DEPTH m




BOREHOLE No. SAMPLE No. BA 99 DEPTH. m

Figure 7. Examples of particle size distribution curves

## Assessment details

**Area**

| | |
|---|---|
| Block: | 11.08 km$^2$ |
| Mineral: | 8.32 km$^2$ |

**Mean thickness**

| | |
|---|---|
| Overburden: | 2.5 m |
| Mineral: | 6.5 m |

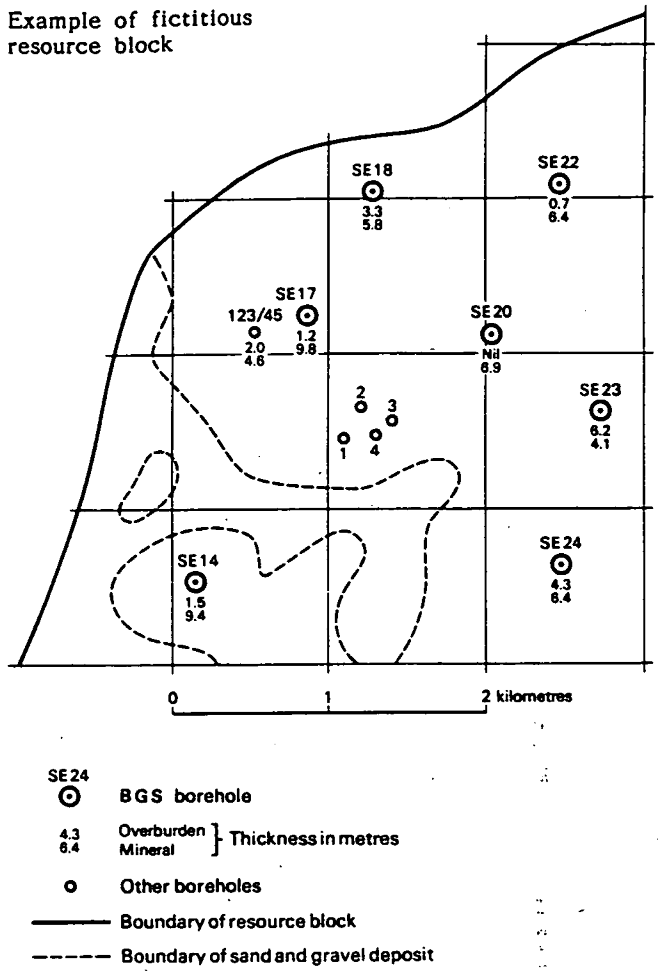
**Volume**

| | |
|---|---|
| Overburden: | 21 million m$^3$ |
| Mineral: | 54 million m$^3$ |

Confidence limits of the estimate of mineral volume at the 95 per cent probability level: $\pm$ 20 per cent

That is, the volume of mineral (with 95 per cent probability): 54 $\pm$ 11 million m$^3$

Example of fictitious resource block




## Calculation of mean thickness

| Sample point | Weighting $w$ | Overburden $l_o$ | Overburden $wl_o$ | Mineral $l_m$ | Mineral $wl_m$ | Remarks |
|---|---|---|---|---|---|---|
| SE 14 | 1 | 1.5 | 1.5 | 9.4 | 9.4 | BGS boreholes |
| SE 18 | 1 | 3.3 | 3.3 | 5.8 | 5.8 | |
| SE 20 | 1 | nil | - | 6.9 | 6.9 | |
| SE 22 | 1 | 0.7 | 0.7 | 6.4 | 6.4 | |
| SE 23 | 1 | 6.2 | 6.2 | 4.1 | 4.1 | |
| SE 24 | 1 | 4.3 | 4.3 | 6.4 | 6.4 | |
| SE 17 | ½ | 1.2 | 1.6 | 9.8 | 7.2 | |
| 123/45 | ½ | 2.0 | | 4.6 | | Hydrogeology Unit record |
| 1 | ¼ | 2.7 | 2.6 | 7.3 | 5.8 | Close group of four boreholes (commercial) |
| 2 | ¼ | 4.5 | | 3.2 | | |
| 3 | ¼ | 0.4 | | 6.8 | | |
| 4 | ¼ | 2.8 | | 5.9 | | |
| Totals | $\Sigma w = 8$ | $\Sigma wl_o = 20.2$ | | $\Sigma wl_m = 52.0$ | | |
| Means | | $\overline{wl}_o = 2.5$ | | $\overline{wl}_m = 6.5$ | | |

## Calculation of confidence limits

| $wl_m$ | $\lvert(wl_m - \overline{wl}_m)\rvert$ | $(wl_m - \overline{wl}_m)^2$ |
|---|---|---|
| 9.4 | 2.9 | 8.41 |
| 5.8 | 0.7 | 0.49 |
| 6.9 | 0.4 | 0.16 |
| 6.4 | 0.1 | 0.01 |
| 4.1 | 2.4 | 5.76 |
| 6.4 | 0.1 | 0.01 |
| 7.2 | 0.7 | 0.49 |
| 5.8 | 0.7 | 0.49 |

$\Sigma(wl_m - \overline{wl}_m)^2 = 15.82$

$n = 8$

$t = 2.365$

$L_V$ is calculated as

$1.05\ (t/\overline{wl}_m)\ \sqrt{[\Sigma(wl_m - \overline{wl}_m)^2/n(n-1)]} \times 100$

$= 1.05 \times (2.365/6.5)\ \sqrt{[15.82/(8 \times 7)]} \times 100$

$= 20.3$

$\simeq$ 20 per cent.

**Figure 8. Example of a statistical assessment of a fictitious resource block**

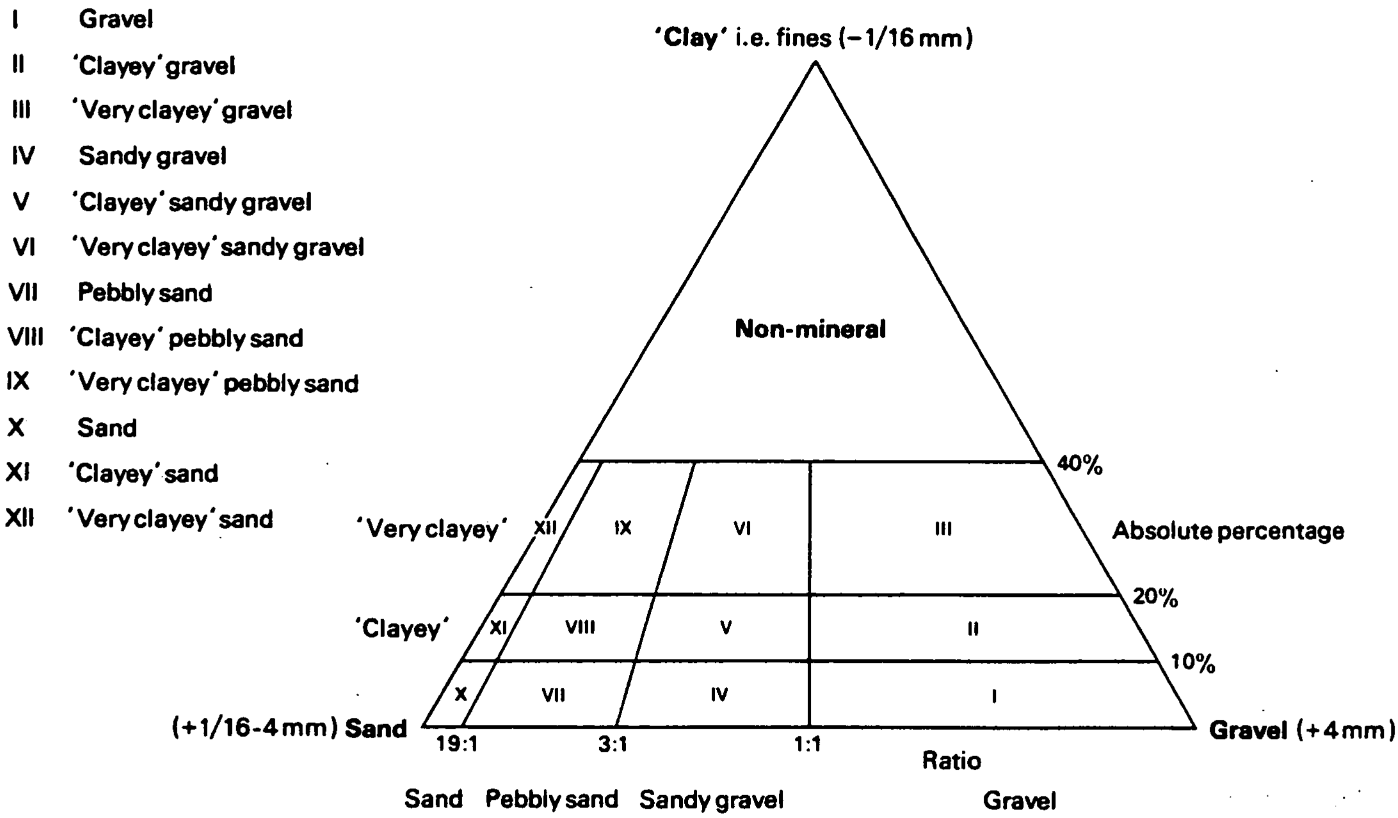
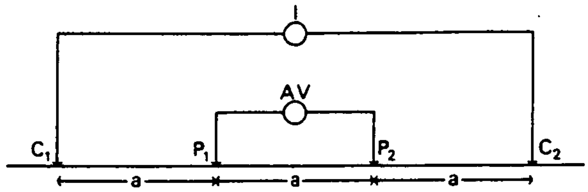
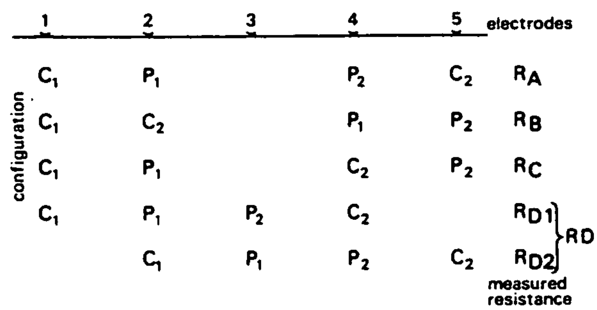



**Figure 9.** Diagram showing the descriptive categories used in the classification of sand and gravel




a. Wenner




b. Offset Wenner (five electrode array)

**Figure 10. Example of the Wenner and Offset Wenner five electrode array**

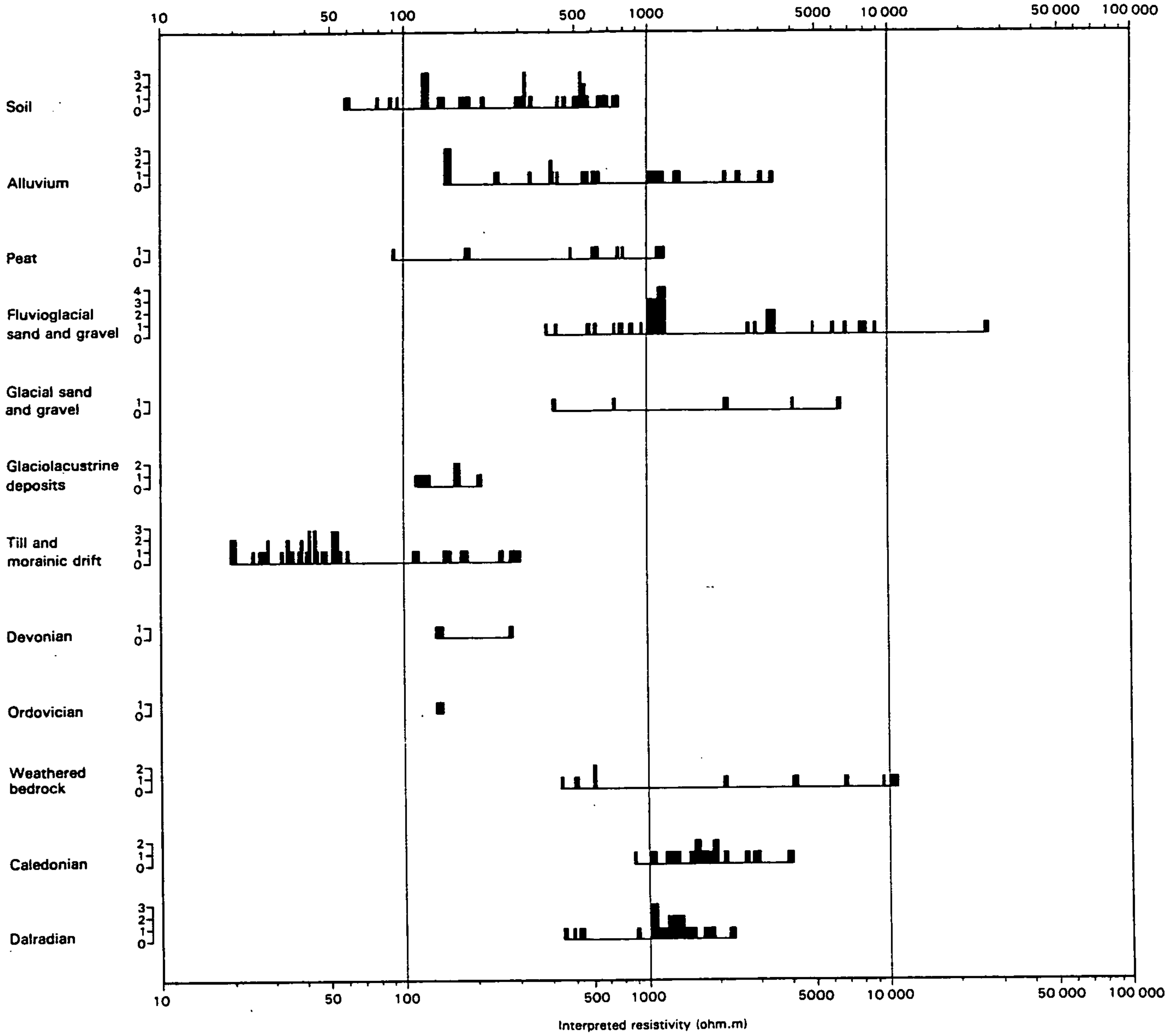



**Figure 11.** Frequency distribution of the resistivity results

**Table D1.** Classification of gravel, sand and fines

| Size limits | Grain-size description | Qualification | Primary classification |
|---|---|---|---|
| | Boulder | | |
| 256 mm | | | |
| | Cobble | | |
| 64 mm | | | |
| | | Coarse | Gravel |
| 16 mm | Pebble | | |
| | | Fine | |
| 4 mm | | | |
| | | Coarse | |
| 1 mm | | | |
| | Sand | Medium | Sand |
| 0.25 mm | | | |
| | | Fine | |
| 0.063 mm | | | |
| | Fines (silt and clay) | | Fines |

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1:25000 sheets NJ70, 72 , NO 79, and parts NO88, 89, 99

## Part 2: Borehole and geophysical logs

C A Auton, J W Merritt and D L Ross

BRITISH GEOLOGICAL SURVEY

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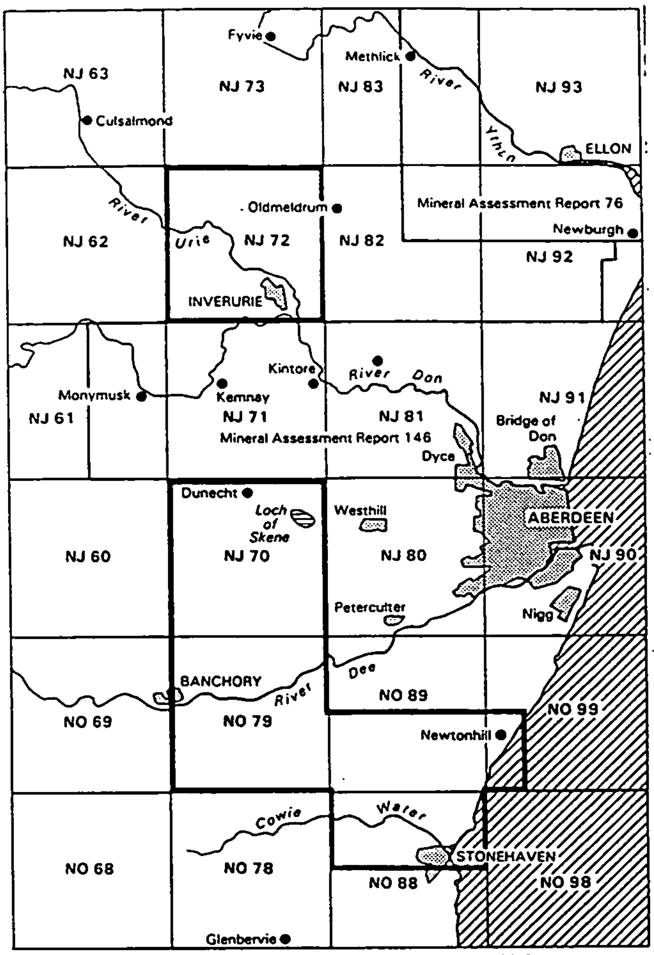


# The sand and gravel resources of the country around Inverurie and Dunecht, and between Banchory and Stonehaven, Grampian Region

Description of 1:25 000 sheets NJ 70, 72 and NO 79, and parts of NO 88, 89 and 99

## Part 2: Borehole and geophysical logs


C A Auton, J W Merritt and D L Ross

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Mineral Assessment Report 148

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**Auton, C A, Merritt, J W, and Ross, D L.** 1988. The sand and gravel resources of the country around Inverurie and Dunecht, and between Banchory and Stonehaven, Grampian Region. *British Geological Survey Technical Report* WF/88/1.




Keyworth, Nottingham British Geological Survey 1988

CONTENTS (PART 2)



**A full explanation of the sampling and assessment procedures, the grain-size classification and resource criteria, is given in part 1*

## APPENDIX F: EXPLANATION OF THE ASSESSMENT RECORDS
## ANNOTATED FICTITIOUS EXAMPLE

NJ 79 NE 20[1] 7234 9567[2] **Deeside Farm, Banchory**[3] **Block P**

Surface level +83m[4]
Water struck at +77m[5]
250 and 200mm percussion[6]
September 1984

| | |
|---|---|
| Overburden | 0.2m[7] |
| Mineral I | 3.3m |
| Waste | 1.7m |
| Mineral II | 1.3m |
| Waste | 2.9m |
| Bedrock | 0.4m+[8] |

| Geological classification[10] | Lithology[11] | Thickness m | Depth[9] m |
|---|---|---|---|
| | Soil, clayey and sandy, pale brown | 0.2 | 0.2 |
| ?Glacial sand and gravel | a 'Clayey' sandy gravel<br>Gravel: coarse and fine, with some cobbles, subangular to rounded, red and pink granite, basic igneous rocks and pink quartzite; some schist and grey granite<br>Sand: medium with coarse and fine, angular quartz and rock<br>Fines: silt and clay, loosely binding the deposit; moderate reddish brown (10 R 4/6) becoming moderate yellowish brown (10 YR 5/3) with depth | 3.3 | 3.5 |
| Glaciolacustrine deposits | Clay, sandy, moderate reddish brown (10 R 4/6), interlaminated with clayey silt; thin stringers of vein quartz and red granite pebbles | 0.5 | 4.0 |
| | Silt, clayey, sandy, laminated, reddish to light olive brown, (5 Y 5/6) abundant pebbles (?dropstones) of granite, quartz and schist | 1.2 | 5.2 |
| Flow-till | b 'Very clayey' pebbly sand, cleaner with depth<br>Gravel: fine and coarse, rounded, red quartzite and schist with some granite<br>Sand: medium and coarse with fine, angular, quartz and rock<br>Fines: silt and clay binding deposit above 6.0m depth, moderate, olive brown (5 Y 4/4) to dark yellowish brown (10 YR 4/2) | 1.3 | 6.5 |
| Till | Clay, sandy, very compact, brown. Angular pebbles of schist, brown (Devonian) sandstone, vein quartz and granite | 2.9 | 9.4 |
| Caledonian | Basic rock, hard, greenish black (5 GY 2/1), possibly metamorphosed | 0.4+ | 9.8 |

Grading

| | Mean for Deposit[15] percentages | | | Depth below[12] surface (m) | percentages[13] | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm | |
| a | 19 | 49 | 32 | 0.2- 1.2 | 14 | 20 | 27 | 12 | 17 | 10 | 0 | |
| | | | | 1.2- 2.5 | 30 | 11 | 24 | 14 | 11 | 10 | 0 | |
| | | | | 2.5- 3.5 | 11 | 11 | 12 | 16 | 18 | 26 | 6 | |
| | | | | Mean | 19 | 14 | 21 | 14 | 15 | 15 | 2 | |
| b | 28 | 53 | 19 | 5.2- 6.0 | 37 | 10 | 27 | 16 | 8 | 2 | 0 | |
| | | | | 6.0- 6.5 | 14 | 12 | 20 | 21 | 14 | 19 | 0 | §[14] |
| | | | | Mean | 28 | 11 | 24 | 18 | 10 | 9 | 0 | |
| a&b | 22 | 50 | 28 | Mean | 22 | 13 | 22 | 15 | 14 | 13 | 1 | |

The numbered paragraphs below correspond with the annotations given on the specimen record above.

**1 Sample point registration number**
Each British Geological Survey (BGS) borehole, shallow pit or measured section is identified by a registration number. This consists of two statements

1 The number of the 1:25 000 sheet on which the sample point lies, for example NJ 79

2 The quarter of the 1:25 000 sheet on which the sample point lies and its number in a series for that quarter, for example NE 20

Thus the full registration number is NJ 79 NE 20.

**2 The National Grid reference**
All National Grid references in this publication lie within the 100-km squares NJ and NO. Grid references are given to eight figures, accurate to within 10m for sample point locations.

**3 Location**
The position of the sample point is referred to the nearest named locality on the 1:25 000 base map, usually followed by the name of the parish or nearest community. The resource block in which it lies is also stated.

**4 Surface level**
The surface level at the sample point is given in metres above Ordnance Datum. Measurements were made in metres using a surveying aneroid barometer.

**5 Groundwater conditions**
If groundwater was present the level at which it was encountered is normally given (in metres above Ordnance Datum).

**6 Method and date of sampling**
Modified shell and auger rigs were used for the drilling of boreholes in this survey. The drilling method, the external diameter of the casing used, and the month and year of completion of the borehole are given. Where appropriate, other methods of sampling are stated (for example shallow pits and sections sampled by hand).

**7 Overburden, mineral, waste and bedrock**
Mineral is sand and gravel which, as part of a deposit, falls within the arbitrary definition of potentially workable material. Mineral I is potentially workable sand and gravel; Mineral II is potentially workable till (or potentially workable weathered rock). Bedrock is the 'formation', 'country rock' or 'rock head' below which potentially workable sand and gravel will not be found. Waste is any material other than bedrock or mineral. Where waste occurs between the surface and mineral it is classified as overburden.

**8 Thickness and depth**
All measurements were made in metres.

9 The plus sign (+) indicates that the base of the deposit was not reached during drilling

**10 Geological classification**
The geological classification is given whenever possible.

**11 Lithological description**
When sand and gravel is recorded a general description based on the mean grading characteristics (for details see Appendix D) is followed by more detailed particulars. The description of other rocks is based on visual examination, in the field. Details of colour are based on the Rock-color Chart distributed by the Geological Survey of America: the colour is followed by the relevent colour code.

**12 Sampling**
A continuous series of bulk samples is taken through the thickness of sand and gravel. A new sample is commenced whenever there is an appreciable lithological change within the sand and gravel or at every 1m of depth.

**13 Grading results**
The results are expressed as per cent by weight passing on British Standard sieves whose aperture sizes are given in millimetres or fractions thereof.

**14 Bailed samples**
Fully representative sampling of sand and gravel is difficult to achieve, particularly where groundwater levels are high. Comparison between boreholes and adjacent exposures suggests that in borehole samples the proportion of sand may be higher and the proportion of fines and coarse gravel (+16mm) may be lower. Samples obtained by the bailing technique (that is, from deposits below the water-table) are indicated thus: §.

**15 Mean grading**
The grading of the full thickness of the mineral deposit identified in the log is the mean of the individual sample gradings weighted by the thickness represented. The classification used is shown in Table D1. Where two or more units of mineral are distinguished, the mean grading for each is given in addition to the combined calculation for all of the graded deposits. For multiple mineral units, each is designated by a letter, for example, a, b, etc.

## APPENDIX G: BRITISH GEOLOGICAL SURVEY BOREHOLE, SECTION AND SHALLOW PIT RECORDS

**DUNECHT RESOURCE SHEET**

**NJ 70 NW 1** | **7077 0994** | **Linton House, Midmar** | **Block A**

Surface level c+108m
Groundwater level c+105.4m
Pit
September 1986

Waste 2.6m
Bedrock 0.4m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Till | Diamicton; very sandy clay, stiff but crumbly, olive grey (5 Y 4/1) weathering pale brown (5 YR 5/6). Clasts up to boulder size, angular to rounded granites with some schist | 2.4 | 2.6 |
| Caledonian | Granite, coarse-grained, grey, decomposed to a sand but hardening dowards | 0.4+ | 3.0 |

**NJ 70 NW 2** | **7247 0511** | **Woodside, Echt** | **Block B**

Surface level +92m
Water Struck at +91.4m
Pit and 250mm percussion
November 1986

Overburden 1.1m
Mineral I 1.9m
Mineral II 2.0m
Waste 1.8m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.3 | 0.3 |
| Alluvium | Clay and coarse sand, firm, angular to subangular granitic clasts, dark yellowish orange (10 YR 6/6) | 0.3 | 0.6 |
| | Very sandy clay, unstratified, stiff, scattered pebbles; pale olive grey (5 Y 5/2), mottled with orange | 0.5 | 1.1 |
| Fluvioglacial sand and gravel | a Gravel; very poorly sorted, no bedding discernable<br>Gravel: coarse with fine and cobble, angular to subrounded, coarse and fine-grained pink and grey granite, some quartzite, amphibolite, gneiss and vein-quartz<br>Sand: coarse, with some medium, angular to subangular granite, with some quartz and feldspar<br>Fines: silt, loosely binding deposit, greyish yellowish brown (10 YR 5/2) | 1.9 | 3.0 |
| Flow-till | b Sandy gravel<br>Gravel: coarse and fine, angular coarse-grained pink granite, with some subangular basic rock<br>Sand: medium and coarse, with some fine, subangular quartz, rock and feldspar<br>Fines: silt, disseminated and thin beds of stiff clay binding the deposit, especially towards the base; moderate yellowish brown (10 YR 5/4) to light brown (5 YR 6/4) | 2.0 | 5.0 |
| Till | Diamicton; waxy clay and sand, stiff; tabular and subangular clasts up to 300mm of very pale fine-grained granite, weathered coarse-grained intermediate plutonic rock, fine-grained basic, schist and coarse-grained pink granite; matrix supported; pale reddish brown (10 R 5/4) to light brown (5 YR 6/4) | 1.8+ | 6.8 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm | |
| a | 2 | 46 | 52 | 1.1- 2.1 | 2 | 3 | 13 | 18 | 15 | 29 | 20 | § |
| | | | | 2.1- 3.0 | 2 | 5 | 23 | 30 | 15 | 25 | 0 | § |
| | | | | Mean | 2 | 4 | 18 | 24 | 15 | 26 | 11 | |
| b | 9 | 64 | 27 | 3.0- 5.0 | 9 | 8 | 29 | 27 | 12 | 15 | 0 | § |
| a&b | 6 | 54 | 40 | Mean | 6 | 6 | 23 | 25 | 14 | 21 | 5 | |

**NJ 70 NW 3** **7417 0953** **Tilly Brig** **Block B**

Surface level c.+107m
Groundwater level c.+103m
Pit
September 1986

Overburden 0.1m
Mineral I 4.2m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.1 | 0.1 |
| Fluvioglacial sand and gravel | Sandy gravel; large scale cross-bedding eastwards<br>Gravel: fine to coarse, becoming coarser down with cobbles and boulders at base. Subangular to subrounded pink and grey granites with some psammite, vein-quartz and platy pelite<br>Sand: coarse with medium, angular to subangular quartz and feldspar, pale olive grey but heavily iron-stained towards top.<br>Fines: a little silt | 4.2+ | 4.3 |
| | Pit collapsing badly | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 1 | 59 | 40 | 0.1- 1.3 | 1 | 3 | 29 | 46 | 11 | 10 | 0 |
| | | | 1.3- 2.3 | 1 | 4 | 24 | 28 | 12 | 20 | 11 |
| | | | 2.3- 4.3 | 2 | 7 | 20 | 22 | 16 | 33 | 0 |
| | | | Mean | 1 | 5 | 24 | 30 | 14 | 23 | 3 |

| NJ 70 NW 4 | 7417 0959 | Tilly Brig | Block A |
|---|---|---|---|

Surface level c.+102m
Groundwater level c.+100.1m
Pit
September 1986

Overburden 2.2m
Mineral I 1.3m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.3 | 0.3 |
| Alluvium | Sandy clayey silt, soft to firm, dusky yellowish brown (10 YR 2/2), peaty, interbedded with clean coarse-grained granitic sand | 1.6 | 1.9 |
| | Peat, very silty, soft to firm, olive-black | 0.3 | 2.2 |
| | 'Clayey' sand<br>Gravel: fine, granite<br>Sand: medium with coarse and fine, angular to subangular quartz and feldspar<br>Fines: silty with sticky clayey bands and rare seams of peaty silt | 1.3+ | 3.5 |
| | Pit continuously caving in at base | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 19 | 80 | 1 | 2.2- 3.5 | 19 | 10 | 55 | 15 | 1 | 0 | 0 § |

NJ 70 NW 5 7488 0935 **Dunecht School** **Block A**

Surface level c.+104m
Water not struck
Pit
September 1986

Overburden 0.3m
Mineral I 3.2m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.3 | 0.3 |
| Fluvioglacial sand and gravel | Gravel; clast-supported, becoming more sandy downwards<br>Gravel: chiefly cobbles above 2.1m, finer below, subangular to rounded pink and grey granite, pink porphyry with some gneiss and psammite<br>Sand: coarse to medium, angular to subangular quartz and feldspar, rusty brown to yellowish brown<br>Fines: little. Heavy iron staining at 2.1m | 3.2+ | 3.5 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 1 | 40 | 59 | 0.3- 2.1 | 1 | 3 | 11 | 15 | 8 | 15 | 47 |
| | | | 2.1- 3.5 | 1 | 5 | 24 | 24 | 17 | 20 | 9 |
| | | | Mean | 1 | 4 | 17 | 19 | 12 | 17 | 30 |

NJ 70 NE 1 7592 0862 **Waulkendale, Echt** **Block A**

Surface level +98m
Water struck at +94.2m
250 and 200mm percussion
November 1986

Overburden 0.4m
Mineral I 10.6m
Waste 0.6m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy | 0.4 | 0.4 |
| Fluvioglacial sand and gravel | Sandy gravel<br>Gravel: fine and coarse with some cobbles, subangular to subrounded, pink coarse-grained granite with grey granite, red porphyry, basic igneous rocks, semi-pelite, quartzite, vein-quartz and amphibolite<br>Sand: coarse with medium, angular to subangular, quartz with feldspar, granite and other rock fragments, 'sharp'<br>Fines: a little disseminated silt and clay, possibly being lost due to drilling action | 10.6 | 11.0 |
| Till | Diamicton: clay, silty, sandy, generally very stiff, olive grey (5 Y 5/2) with clasts of fine gravel, generally subangular and with similar composition to overlying gravel | 0.6+ | 11.6 |
| | Borehole terminated owing to slow progress | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1–4 | +4–16 | +16–64 | +64 mm |
| 4 | 54 | 42 | 0.4– 1.4 | 4 | 7 | 45 | 25 | 7 | 4 | 8 |
| | | | 1.4– 2.4 | 7 | 2 | 7 | 7 | 16 | 36 | 25 |
| | | | 2.4– 3.4 | 8 | 9 | 27 | 17 | 12 | 27 | 0 |
| | | | 3.4– 4.4 | 3 | 6 | 19 | 16 | 9 | 22 | 25 |
| | | | 4.4– 5.4 | 3 | 5 | 23 | 30 | 19 | 20 | 0 |
| | | | 5.4– 6.4 | 3 | 5 | 19 | 25 | 23 | 25 | 0 |
| | | | 6.4– 8.0 | 3 | 5 | 22 | 25 | 20 | 17 | 8 |
| | | | 8.0– 9.5 | 2 | 9 | 43 | 25 | 11 | 10 | 0 |
| | | | 9.5–11.0 | No grading data available | | | | | | |
| | | | Mean | 4 | 6 | 26 | 22 | 15 | 19 | 8 |

**NJ 70 NE 2** **7684 0887** **South Lodge, Skene** **Block A**

Surface level c.+96m
Water not struck
Section and pit
September 1986

Overburden 0.2m
Mineral I 3.0m
Waste 3.0m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Fluvioglacial sand and gravel | Pebbly sand; unconsolidated, horizontal bedding<br>Gravel: fine with coarse, rare cobbles, angular to subrounded pink and grey granites with some porphyry, vein-quartz and gneiss<br>Sand: medium and coarse, some fine, angular to subrounded quartz and feldspar, buff-coloured<br>Fines: very little | 3.0 | 3.2 |
| Till | Diamicton; gritty sandy clay, stiff but crumbly, moderate olive brown (5 YR 4/6), unstratified, angular to subrounded clasts up to 500mm, chiefly grey granite | 3.0+ | 6.2 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 1 | 89 | 10 | 0.2- 1.7 | 1 | 7 | 58 | 26 | 7 | 1 | 0 |
| | | | 1.7- 3.2 | 1 | 8 | 38 | 41 | 11 | 1 | 0 |
| | | | Mean | 1 | 7 | 49 | 33 | 9 | 1 | 0 |

NJ 70 NE 3 | 7699 0843 | Wantonwells, Echt | Block A

Surface level +84m
Water struck at +82.3m
200 and 150mm percussion
November 1986

Overburden 0.4m
Mineral I 8.5m
Waste 2.3m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil: silty brown loam | 0.4 | 0.4 |
| Alluvium | a Pebbly sand<br>Gravel: fine, angular to subangular, granite<br>Sand: coarse with medium and some fine, subangular to angular, granite, quartz and feldspar<br>Fines: disseminated silt and clay, with a thin silty clay seam at c. 1.8m, moderate brown (5 YR 4/4) | 1.6 | 2.0 |
| Fluvioglacial sand and gravel | b Sandy gravel<br>Gravel: fine with coarse, subangular with subrounded, granite with psammite and pelite, vein-quartz and basic igneous rocks. Bed of coarse with fine, tabular psammite with subrounded granite at 4.7m. Weathered granite towards base<br>Sand: coarse with medium and fine, subangular lithic fragments (chiefly granite) and quartz<br>Fines: disseminated silt and clay and rare seams of sandy silt | 6.9 | 8.9 |
| Till | Diamicton: sand, silty, clayey, firm to stiff, pale olive grey (5 Y 5/2). Angular to subangular clasts up to cobble size, chiefly granite, some metamorphic rock types. Occasional thin seams of coarse-grained silty sand | 2.3+ | 11.2 |
| | Borehole terminated for technical reasons | | |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm | |
| a | 7 | 78 | 15 | 0.4- 2.0 | 7 | 11 | 30 | 37 | 14 | 1 | 0 | |
| b | 2 | 70 | 28 | 2.0- 3.7 | 4 | 8 | 26 | 19 | 18 | 25 | 0 | § |
| | | | | 3.7- 4.7 | 1 | 4 | 41 | 35 | 8 | 11 | 0 | § |
| | | | | 4.7- 5.7 | 1 | 4 | 29 | 28 | 24 | 14 | 0 | § |
| | | | | 5.7- 6.9 | 1 | 5 | 31 | 40 | 19 | 4 | 0 | § |
| | | | | 6.9- 7.9 | 1 | 6 | 32 | 42 | 18 | 1 | 0 | § |
| | | | | 7.9- 8.9 | 4 | 12 | 38 | 34 | 12 | 0 | 0 | § |
| | | | | Mean | 2 | 7 | 31 | 32 | 17 | 11 | 0 | |
| a&b | 3 | 72 | 25 | Mean | 3 | 7 | 32 | 33 | 16 | 9 | 0 | |

**NJ 70 NE 4** **7667 0836** **Knockquarn Lodge, Echt** **Block A**

Surface level c.+94m
Water not struck
Pit
September 1986

Overburden 0.5m
Mineral I 3.0m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Peat | 0.5 | 0.5 |
| Fluvioglacial sand and gravel | Sandy gravel; becoming more sandy downwards<br>Gravel: coarse with fine, cobbles up to 150mm common, subangular to subrounded, chiefly pink and grey granites with some psammite and gneiss<br>Sand: medium with coarse, some fine, angular to subangular quartz and feldspar, buff-coloured<br>Fines: very little | 3.0+ | 3.5 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 1 | 63 | 36 | 0.5- 1.5 | 1 | 2 | 34 | 19 | 13 | 24 | 7 |
| | | | 1.5- 2.1 | 1 | 5 | 28 | 19 | 12 | 30 | 5 |
| | | | 2.1- 3.5 | 1 | 7 | 44 | 22 | 12 | 14 | 0 |
| | | | Mean | 1 | 5 | 38 | 20 | 12 | 21 | 3 |

**NJ 70 NE 5** **7624 0602** **Nashick, Echt** **Block C**

Surface level c.+83m
Groundwater level c.+80.7m
Pit
September 1986

Waste 3.0m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Till | Diamicton; very sandy clay, firm to stiff but crumbly, moderate yellowish brown (10 YR 5/4), angular to subrounded clasts up to 500mm of grey granite with some porphyry | 1.0 | 1.2 |
| | Diamicton; clayey coarse-grained sand with boulders up to 800mm, pale olive grey (5 YR 5/1), crude stratification | 1.8+ | 3.0 |
| | Pit continuously slumping at base | | |

**NJ 70 NE 6** **7790 0694** **Boathouse Wood, Echt** **Block A**

Surface level c.+90m
Water not struck
Pit
September 1986

Waste 2.4m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Till | Diamicton; gritty sandy clay, stiff but crumbly, moderate yellowish brown (10 YR 5/4), clasts up to 500mm or larger, chiefly angular to subrounded pink and grey granites with some amphibolite and gneiss. Unstratified but with oxidised vertical fissures at 400mm intervals | 2.2+ | 2.4 |

**NJ 70 NE 7** **7753 0590** **Mill of Air Cottage, Echt** **Block C**

Surface level c.+84m
Water not struck
Pit
September 1986

Waste 3.0m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, peaty, black | 0.2 | 0.2 |
| Till | Diamicton; gritty sandy clay, very stiff but ultimately crumbly, moderate yellowish brown (10 YR 5/4) weathered orange-brown in upper 0.3m. Angular to subrounded clasts up to 500mm, chiefly grey granites with some diorite quartzite, psammite and ?dolerite. Unstratified but with vertical oxidised fissures at about 600mm intervals. | 2.8+ | 3.0 |
| | Sited on terrace feature | | |

NJ 70 NE 8 | 7702 0565 | Garrick, Echt | Block C

Surface level c.+82m
Water not struck
Pit
September 1986

Overburden 0.2m
Mineral I 1.7m
Waste 1.6m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Fluvioglacial sand and gravel | Pebbly sand; thin horizontal bedding<br>Gravel: fine, angular to subangular granite<br>Sand: coarse-medium with some fine, angular to subangular quartz and feldspar, stained rusty brown at top and along silty laminae<br>Fines: some silty seams | 1.7 | 1.9 |
| Till | Diamicton: very sandy silty clay, firm but crumbly, moderate yellowish brown (10 YR 5/4). Angular to subrounded clasts up to 700mm, chiefly grey granite with some hornblende-schist, psammite and vein-quartz. Unstratified. | 1.6+ | 3.5 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 2 | 85 | 13 | 0.2- 1.9 | 2 | 8 | 38 | 39 | 13 | 0 | 0 |

NJ 70 NE 9 | 7885 0512 | **Roadside of Garlogie, Skene** | **Block C**

Surface level +76m
Water struck at +73.5m
250mm percussion
October 1986

| | |
|---|---|
| Overburden | 0.3m |
| Mineral I | 4.1m |
| Waste | 2.6m |
| Mineral II | 2.8m |
| Bedrock | 0.1m+ |

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil; organic silty sandy loam, very dark brown | 0.3 | 0.3 |
| Glacial sand and gravel | a 'Very clayey' sand; rare cobbles of granite and occasional fine pebbles of vein-quartz.<br>Sand: medium with fine and some coarse, subangular to subrounded quartz, mica and feldspar<br>Fines: silt, binding the deposit in places, orange brown to 0.7m then yellowish brown | 2.7 | 3.0 |
| | b Sandy gravel; becomes coarser with depth<br>Gravel: fine with coarse and rare cobbles, angular to subrounded granite and vein-quartz<br>Sand: coarse with medium and some fine, angular to subrounded, quartz, feldspar, mica and lithic fragments<br>Fines: disseminated silt | 1.4 | 4.4 |
| Till | Diamicton; clay, silty and slightly sandy with clasts up to coarse gravel size. Becomes less clayey with depth, grading down into sandy gravel | 2.6 | 7.0 |
| Caledonian | c Sandy gravel; possibly all decomposed granite bedrock<br>Gravel: coarse with fine and cobble, angular to subrounded granite and vein-quartz with some subrounded to rounded metasedimentary clasts. Some +250mm boulders of granite from 8.0m<br>Sand: medium with coarse and some fine, angular to subrounded quartz, feldspar with some mica and lithic fragments<br>Fines: disseminated silt almost slurrying deposit, brownish pink | 2.8 | 9.8 |
| Caledonian | Granite, coarse-grained, hard | 0.1+ | 9.9 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm | |
| a | 21 | 77 | 2 | 0.3- 1.3 | 10 | 49 | 32 | 4 | 0 | 5 | 0 | |
| | | | | 1.3- 3.0 | 28 | 18 | 53 | 1 | 0 | 0 | 0 | |
| | | | | Mean | 21 | 29 | 46 | 2 | trace | 2 | 0 | |
| b | 3 | 65 | 32 | 3.0- 4.4 | 3 | 8 | 23 | 34 | 19 | 13 | 0 | § |
| c | 4 | 67 | 29 | 7.0- 8.0 | 4 | 10 | 33 | 24 | 7 | 13 | 9 | § |
| | | | | 8.0- 9.0 | 4 | 11 | 32 | 20 | 8 | 14 | 11 | § |
| | | | | 9.0- 9.8 | 5 | 11 | 33 | 29 | 9 | 13 | 0 | § |
| | | | | Mean | 4 | 10 | 33 | 24 | 8 | 14 | 7 | |
| a&b | 15 | 72 | 13 | Mean | 15 | 22 | 37 | 13 | 7 | 6 | 0 | |
| a-c | 10 | 71 | 19 | Mean | 10 | 17 | 36 | 18 | 7 | 9 | 3 | |

**NJ 70 NE 10** **7946 0704** **Kirktonbridge Cottages, Skene** **Block A**

Surface level +84m
Groundwater level +82.1m
250mm and 200m percussion
November 1986

| | |
|---|---|
| Overburden | 0.4m |
| Mineral I | 5.7m |
| Waste | 2.9m |
| Mineral I | 1.1m |
| Waste | 1.0m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, peaty, sandy | 0.4 | 0.4 |
| Alluvium | a Sand<br>Gravel: rare fine, pink granite<br>Sand: fine and medium with some coarse, angular to subangular quartz with feldspar and some mafic minerals and mica<br>Fines: silt, disseminated. Peaty in upper 1.5m. Pale yellowish brown becoming pale greenish grey downwards and then dark greenish grey (5 GY 4/1) below 4.5m | 5.7 | 6.1 |
| Glaciolacustrine deposits | Sand, as above, interlaminated with silty clay, greyish olive green (5 GY 3/2) | 0.4 | 6.5 |
| | Clay, very silty and with fine-grained sand to clayey silt, finely laminated, greyish olive green (5 GY 3/2), soft to firm | 0.5 | 7.0 |
| | Silty clay, moderate yellowish brown (10 YR 5/4), in seams 10-15mm thick interleaved with clean fine-grained sand in 2-3mm thick seams. Becoming mainly unstratified silt with fine-grained sand by 7.3m. Soft | 1.2 | 8.2 |
| | Silty clay, clayey silt and very fine-grained sand all finely interlaminated, soft to firm (clay laminae leathery), pale olive grey (5 Y 5/2) or moderate yellowish brown (10 YR 5/4). Some seams, up to 15mm, of dark fine-grained sand below 8.6m | 0.8 | 9.0 |
| Glacial sand and gravel | b Sandy gravel; poorly sorted<br>Gravel: fine and coarse with rare cobbles, angular to subangular red granite with porphyry, amphibolite, grey granite, pelite, quartzite and vein-quartz<br>Sand: coarse with medium and some fine, angular to subangular quartz and feldspar<br>Fines: clayey silt, disseminated and as discrete finely laminated seams | 1.1 | 10.1 |
| | Silty clay, massive, firm to stiff, moderate yellowish brown | 0.2 | 10.3 |
| Till | Diamicton, clayey sand to sandy clay, firm to stiff but friable, pale olive grey (5 Y 5/2). Angular to subangular clasts up to cobble size, composition as gravel above | 0.8+ | 11.1 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | | |
| | | | | from to | - 1/16 | + 1/16 - 1/4 | + 1/4 -1 | +1-4 | +4-16 | +16-64 | +64 mm | |
| a | 4 | 95 | 1 | 0.4- 1.5 | 7 | 39 | 44 | 9 | 1 | 0 | 0 | |
| | | | | 1.5- 3.0 | 3 | 47 | 40 | 9 | 1 | 0 | 0 | § |
| | | | | 3.0- 4.5 | 2 | 46 | 43 | 8 | 1 | 0 | 0 | § |
| | | | | 4.5- 6.1 | 3 | 44 | 45 | 8 | 0 | 0 | 0 | § |
| | | | | Mean | 4 | 44 | 43 | 8 | 1 | 0 | 0 | |
| b | 6 | 54 | 40 | 9.0-10.1 | 6 | 7 | 20 | 27 | 21 | 19 | 0 | § |
| a&b | 4 | 89 | 7 | Mean | 4 | 38 | 40 | 11 | 4 | 3 | 0 | |

| NJ 70 NE 11 | 7948 0610 | Gask, Skene | Block C |
|---|---|---|---|

Surface level c.+84m
Groundwater level c.+82.8m
Pit
September 1986

Waste 3.0m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Peat | 0.3 | 0.3 |
| Till | Diamicton; very clayey coarse-grained sand becoming more clayey and consolidated below 2.9m, pale olive grey (5 Y 5/1) with a bluish tint becoming pale brown (5 YR 5/6) below 2.9m, scattered clasts up to 1m, angular to subrounded grey and pink granites with some ?amphibolite and gneiss | 2.7+ | 3.0 |
| | Pit continuously caving in below 1.2m | | |

| NJ 70 NE 12 | 7950 0561 | Garlogie School, Skene | Block C |
|---|---|---|---|

Surface level c.+84m
Water not struck
Pit
September 1986

Overburden 0.3m
Mineral I 1.0m
Waste 1.9m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Peat | 0.3 | 0.3 |
| Glacial sand and gravel | Gravel; matrix-rich, poorly sorted, channeled into underlying deposit<br>Gravel: coarse and fine, many cobbles up to 200mm, angular to subrounded pink and grey granites with some amphibolite and quartzite<br>Sand: medium-coarse with some fine, angular to subangular quartz and feldspar<br>Fines: some silt loosely binding deposit, pale yellowish brown | 1.0 | 1.3 |
| | Clayey silt interbedded with clean coarse-grained sand, the former being firm but crumbly, pale olive grey (5 Y 5/2) and crudely laminated | 0.3 | 1.6 |
| | Sand; medium with fine, 'soft', buff-coloured, fine horizonal lamination | 0.3 | 1.9 |
| Till | Diamicton; gritty sandy clay, firm to stiff but crumbly, moderate yellowish brown (10 YR 5/4). Angular to subrounded clasts up to 300mm, chiefly grey granite with rare quartzite and pink felsite. Unstratified | 1.3+ | 3.2 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 1 | 49 | 50 | 0.3- 1.3 | 1 | 7 | 21 | 21 | 13 | 12 | 25 |

**NJ 70 SW 1** **7143 0066** **Craigton, Banchory** **Block E**

Surface level c.123m
Water not struck
200mm percussion
November 1986

| | |
|---|---|
| Overburden | 0.4m |
| Mineral I | 2.0m |
| Waste | 0.6m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil; sandy with turf, dark to moderate yellowish brown | 0.4 | 0.4 |
| Glacial sand and gravel | 'Very clayey' sandy gravel; sandy at top, becoming gravelly with depth from 1.4m and clay-bound<br>Gravel: fine and coarse with rare cobbles, angular to subrounded granite and pelite<br>Sand: fine with coarse and medium, angular to subangular granitic fragments<br>Fines: clay and silt, disseminated and binding the deposit. Yellowish brown | 2.0 | 2.4 |
| Till? | Diamicton?; boulder deposit, hard, possibly with clay matrix | 0.6+ | 3.0 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 31 | 49 | 20 | 0.4- 1.4 | 38 | 47 | 6 | 5 | 4 | 0 | 0 |
| | | | 1.4- 2.4 | 21 | 12 | 13 | 18 | 17 | 19 | 0 |
| | | | Mean | 31 | 29 | 9 | 11 | 10 | 10 | 0 |

**NJ 70 SW 2** **7283 0174** **Birk Wood Cottage, Echt** **Block D**

Surface level c.+122m
Water not struck
Pit
September 1986

| | |
|---|---|
| Waste | 1.6m |
| Bedrock | 0.2m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, peaty | 0.3 | 0.3 |
| Till | Diamicton; clayey medium to coarse-grained sand, crudely stratified (10-30mm), clay content quite variable between beds, rare seams of fine sandy silt. Angular clasts up to 500mm of brown granite. Becoming a clast-supported granite 'rubble' below 1.6m, too hard to penetrate | 1.3 | 1.6 |
| Caledonian | Granite | 0.2+ | 1.8 |
| | Sited on a 3m-high, irregularly shaped mound | | |

**NJ 70 SW 3** | **7287 0165** | **Birk Wood Cottage, Echt** | **Block D**

Surface level c.+114m
Water not struck
Section and pit
September 1986

Waste 4.7m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, peaty | 0.2 | 0.2 |
| Till | Diamicton; clayey sand, firm, passing down into sandy clay, stiff. Pale olive grey (5 Y 5/2) weathered rusty brown in upper 0.3m. Scattered clasts up to 250mm, chiefly brown granite. Crude stratification (10-30mm), winnowed horizons | 1.3 | 1.5 |
| | Diamicton; gritty sandy clay, stiff to very stiff but ultimately friable, dark greenish grey (5 G 4/1). Angular to subangular clasts of pinkish brown granite with well rounded cobbles of schistose grit, vein-quartz and grey granite. Unstratified. | 3.2+ | 4.7 |

**NJ 70 SW 4** | **7233 0079** | **Broomhillock Croft, Banchory** | **Block E**

Surface level c.+107m
Groundwater level c.+105m
Pit
September 1986

| | |
|---|---|
| Overburden | 0.2m |
| Mineral II | 1.8m |
| Waste | 0.5m |
| Bedrock | 0.5m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Flow-till | Diamicton; matrix a mixture of very sandy clay, pale olive grey (5 Y 5/2), and clean coarse to medium-grained sand, dusky yellow (5 Y 6/4) or orangey brown. Firm to stiff but friable, more clayey and stiff below 2.0m. Scattered clasts up to 400mm, chiefly pink granite with some gabbro, amphibolite and quartzite. Grades, when crumbled, as a 'clayey' sandy gravel. Non-mineral below 2.0m | 2.3 | 2.5 |
| Caledonian | Granite rubble, coarse-grained, fresh, brownish pink. Angular blocks up to 1m with a little sandy clay matrix. Not solid | 0.5+ | 3.0 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 15 | 62 | 23 | 0.2- 2.0 | 15 | 20 | 22 | 20 | 13 | 10 | 0 |

**NJ 70 SW 5** | **7366 0451** | **Sandyhillock, Echt** | **Block B**

Surface level c.+95m
Water not struck
Pit
September 1986

Waste 1.7m
Bedrock 0.2m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Till | Diamicton; gritty sandy clay, firm to stiff but crumbly, pale brown (5 YR 5/6), scattered clasts up to boulder size, chiefly granite. Unstratified. | 1.5 | 1.7 |
| Caledonian | Granite, medium to coarse-grained, grey, fresh, fractured. | 0.2+ | 1.9 |

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**NJ 70 SW 6** | **7360 0190** | **Wickerinn, Banchory** | **Block D**

Surface level c.+87m
Groundwater level c.+84.9m
Pit
September 1986

Overburden 0.9m
Mineral I 2.1m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.3 | 0.3 |
| | Diamicton; gritty sandy clay, firm but crumbly, pale olive grey, scattered clasts up to boulder size. Stratified with seams of silt and coarse-grained sand. | 0.6 | 0.9 |
| Fluvioglacial sand and gravel | Gravel; clast-supported, matrix-rich in part<br>Gravel: cobbles and boulders up to 700mm, coarse and fine, angular to subrounded, chiefly pink granite with ?amphibolite, gabbro and rare quartzite and vein-quartz<br>Sand: coarse with medium, angular quartz and feldspar, partly iron-stained<br>Fines: silt/clay cuticles to clasts | 2.1+ | 3.0 |

A pit dug on an adjacent 2m-high mound proved large (up to 1.0m) interlocking boulders of pink granite

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 3 | 30 | 67 | 0.9- 3.0 | 3 | 2 | 10 | 18 | 11 | 27 | 29 |

**NJ 70 SW 7** | **7359 0148** | **Wickerinn, Banchory** | **Block D**

Surface level c.+90m
Groundwater level c.+88.5m
Pit
September 1986

Overburden 0.2m
Mineral II 2.8m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Flow-till | Diamicton; gritty sandy clay becoming a clayey sand downwards, stiff above 1.5m, less consolidated below, greyish yellowish brown (10 YR 5/2). Angular to subrounded clasts up to 700mm, chiefly pinkish brown granite with some ?amphibolite. Unstratified. Grades, when crumbled, as a 'clayey' gravel | 2.8+ | 3.0 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 12 | 43 | 45 | 0.2- 3.0 | 12 | 12 | 16 | 15 | 9 | 9 | 27 |

**NJ 70 SW 8** | **7476 0481** | **Marketmuir Wood, Echt** | **Block B**

Surface level c.+84m
Water struck at +80.6m
200mm percussion
November 1986

Overburden 0.2m
Mineral I 2.0m
Waste 1.1m
Mineral I 4.1m
Bedrock 0.3m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Alluvium | a 'Clayey' sandy gravel<br>Gravel: coarse with fine, some cobbles, angular to subrounded, chiefly granite with some vein-quartz and metasediments<br>Sand: medium with fine and some coarse, subangular to subrounded quartz, feldspar and rock fragments<br>Fines: silt and clay in layers and also loosely binding the deposit, greyish brown | 2.0 | 2.2 |
| | Clay-bound gravel, firm to plastic clay matrix yellowish to reddish brown | 1.1 | 3.3 |
| Fluvioglacial sand and gravel | b Sandy gravel; fining downwards a little.<br>Gravel: fine and coarse, angular to subangular, chiefly granite with some gneiss<br>Sand: coarse with medium and some fine, subangular to subrounded quartz and feldspar. Relatively mafic-rich<br>Fines: silt, disseminated, grey | 4.1 | 7.4 |
| Dalradian | Hornblende gneiss, coarse-grained with pinkish feldspar. Rotted to a sandy clay but rapidly hardening downwards | 0.3+ | 7.7 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm | |
| a | 16 | 62 | 22 | 0.2- 2.2 | 16 | 20 | 28 | 14 | 4 | 18 | 0 | |
| b | 4 | 68 | 28 | 3.3- 5.4 | 4 | 6 | 21 | 34 | 18 | 17 | 0 | § |
| | | | | 5.4- 7.4 | 4 | 7 | 32 | 37 | 9 | 11 | 0 | § |
| | | | | Mean | 4 | 6 | 26 | 36 | 14 | 14 | 0 | |
| a&b | 8 | 67 | 25 | Mean | 8 | 11 | 27 | 29 | 10 | 15 | 0 | |

**NJ 70 SW 9** **7429 0464** **Marketmuir Wood, Echt** **Block B**

Surface level c.+85m
Groundwater level +82.2m
Pit
September 1986

Overburden 1.7m
Mineral I 1.3m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.1 | 0.1 |
| Alluvium | Sand; coarse with medium, angular quartz and feldspar, very little fines (2%), yellowish to rusty brown. Fine sub-horizontal bedding, channelled into underlying deposit | 0.5 | 0.6 |
| | Clay, very silty, some granitic sand and rare fine gravel, soft to firm, barely plastic, unstratified, disseminated peat, pale olive grey (5 Y 5/2) becoming bluish downwards. Sharp lower contact | 0.6 | 1.2 |
| | Clay, sandy, silty, pebbly with disseminated peat, firm but crumbly, dark yellowish brown (10 YR 4/2), in seams up to 20mm, interbedded with clean fine to coarse-grained sand in seams up to 5mm. Bedding impersistent laterally; sharp lower contact | 0.3 | 1.5 |
| | Clay, as above, but less sandy, olive grey (5 YR 5/2) with bluish tint | 0.2 | 1.7 |
| | Sandy gravel<br>Gravel; fine with some coarse, angular to subangular, chiefly grey granite. Cobbles at base<br>Sand: coarse with medium, angular quartz and feldspar, buff coloured<br>Fines: little. Rare thin clayey sand seams | 1.3+ | 3.0 |

Upper unit of sand appears to thicken to about 1.5m locally. Pit continually caving below 1.2m

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 1 | 67 | 32 | 1.7- 3.0 | 1 | 5 | 25 | 37 | 28 | 4 | 0 |

**NJ 70 SW 10** | **7429 0416** | **Wellwood, Echt** | **Block B**

Surface level c.+88m
Groundwater level c.+86m
Pit
September 1986

Overburden 0.2m
Mineral I 1.2m
Waste 1.3m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Alluvium | Gravel; unconsolidated<br>Gravel: cobbles and boulders up to 500mm, coarse and fine, chiefly angular to subrounded grey granite with rare quartzite<br>Sand: coarse with medium, angular quartz and feldspar, rusty brown<br>Fines: little | 1.0 | 1.2 |
| | Boulders, continuous network, some up to 1m | 0.2 | 1.4 |
| Till | Diamicton; matrix a mixture of sandy, silty clay and clayey sand and gravel, scattered clasts up to boulder size, unconsolidated but becoming firmer downwards, pale olive grey | 1.3+ | 2.7 |
| | Pit continuously caving in | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 1 | 37 | 62 | 0.2- 1.2 | 1 | 1 | 11 | 25 | 18 | 22 | 22 |
| | | | 1.2- 1.4 | No grading data available | | | | | | |
| | | | Mean | 1 | 1 | 11 | 25 | 18 | 22 | 22 |

**NJ 70 SW 11** | **7464 0300** | **Nether Woodside, Echt** | **Block D**

Surface level c.+78m
Water not struck
Pit
September 1986

Waste 2.6m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, peaty | 0.5 | 0.5 |
| Till | Diamicton;gritty sandy clay, very stiff becoming hard downwards, moderate yellowish brown (10 YR 5/4) reduced to greenish grey (5 GY 6/1) along vertical fissures and mottled in upper metre. Clasts up to 500mm of pink and grey granites, porphyry, ?dolerite with some rotten granodiorite. Unstratified, typical lodgement till | 2.1+ | 2.6 |

**NJ 70 SW 12** **7482 0285** **Nether Woodside, Echt** **Block D**

Surface level c.+78m
Groundwater level c.+73m
Section and pit
September 1986

Overburden 0.2m
Mineral I 4.1m
Waste 0.7m
Mineral I 0.5m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Glacial sand and gravel | a Gravel; sandy between 1.5 and 2.0m, cross-bedded at base<br>Gravel: cobbles, coarse and fine, some boulders up to 400mm, cobble bed at 2.5m. Angular to subrounded pink granite with ?amphibolite, gabbro and red porphyry<br>Sand: coarse and medium, angular to subangular quartz and feldspar, yellowish brown<br>Fines: little | 4.1 | 4.3 |
| | Crudely interbedded sequence of medium to fine-grained sand, silt, very fine-grained silty sand (all in beds 50-100mm) and laminae of clay. Mainly pale olive grey. Unstratified silty fine-grained sand at base. Sharp lower contact | 0.7 | 5.0 |
| | b Sandy gravel<br>Gravel: fine with coarse, chiefly pink granite<br>Sand: coarse with medium, angular to subangular quartz and feldspar<br>Fines: little | 0.5+ | 5.5 |
| | Section in side of 2 to 3m-high esker. Pit collapsing below 5.0m | | |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 2 | 36 | 62 | 0.2- 1.5 | 2 | 3 | 10 | 14 | 10 | 26 | 35 |
| | | | | 1.5- 2.5 | 0 | 4 | 24 | 18 | 7 | 28 | 19 |
| | | | | 2.5- 4.3 | 3 | 2 | 14 | 20 | 13 | 22 | 26 |
| | | | | Mean | 2 | 3 | 15 | 18 | 11 | 25 | 26 |
| b | 1 | 73 | 26 | 5.0- 5.5 | 1 | 2 | 31 | 40 | 16 | 10 | 0 |
| a&b | 2 | 40 | 58 | Mean | 2 | 3 | 17 | 20 | 11 | 23 | 24 |

NJ 70 SW 13 | 7468 0228 | The Birks, Echt | Block D

Surface level c.+77m
Groundwater level c.+72.1m
Section and pit
September 1986

Overburden 0.3m
Mineral II 4.6m
Waste 1.6m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Peat | 0.3 | 0.3 |
| Morainic drift | Diamicton; matrix a mixture of clean coarse to medium-grained sand, very clayey coarse-grained sand and sandy clay, hard but friable, moderate yellowish brown (10 YR 5/4). Scattered clasts up to 800mm, angular to subangular pink granite and porphyry with some gabbro and ?dolerite. Clusters of angular porphyry gravel in upper metre. Some crude stratification | 2.7 | 3.0 |
| | Diamicton; matrix either orange-brown coarse-grained sand or pale olive grey sandy clay, crude laterally impersistent bedding (10-50mm), scattered clasts up to boulder size | 1.9 | 4.9 |
| Glaciolacustrine deposits | Silt, clayey, interbedded with silt and fine-grained sand, beds mainly about 10mm thick, some crudely laminated, rare laminae of clean fine to medium-grained sand. Generally firm, dark greenish grey (5 G 4/1) to medium-bluish grey (5 B 5/1). Some contorted bedding | 1.6+ | 6.5 |

The two units of diamicton, taken together, grade as 'clayey' sandy gravel. The log includes a 3m section in the side of a 3 to 5m-high mound. Pit continually caving in below 4.9m

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 10 | 47 | 43 | 0.3- 3.0 | 10 | 15 | 19 | 16 | 6 | 8 | 26 |
| | | | 3.0- 4.9 | 9 | 11 | 17 | 16 | 7 | 10 | 30 |
| | | | Mean | 10 | 13 | 18 | 16 | 6 | 9 | 28 |

NJ 70 SW 14 7424 0198 **The Birks, Echt** **Block D**

Surface level c.+79m
Groundwater level c.+77.6m
Pit
September 1986

Overburden 0.2m
Mineral I 1.2m
Waste 1.8m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, peaty | 0.2 | 0.2 |
| Fluvioglacial sand and gravel | Gravel; crude bedding, partially clast-supported, partially matrix-rich<br>Gravel: cobbles and boulders up to 600mm, coarse and fine, angular to subrounded, chiefly pink granite with pink porphyry, psammite and gabbro<br>Sand: coarse and medium, some fine, angular to subangular quartz and feldspar, ferruginous<br>Fines: silty in part with some clayey bands | 1.2 | 1.4 |
| Till | Diamicton; gritty sandy silty clay, stiff but friable becoming softer downwards, greenish grey (5 GY 6/1 to 5 G 6/1). Angular to subangular clasts up to 500mm, chiefly granite. Unstratified | 1.8+ | 3.2 |
| | Pit continuously caving in below 1.4m | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 4 | 35 | 61 | 0.2- 1.4 | 4 | 5 | 15 | 15 | 10 | 15 | 36 |

NJ 70 SW 15 7478 0193 **Silverstripe Burn, Echt** **Block D**

Surface level +73m
Water struck at +71.9m
250mm percussion
November 1986

| | |
|---|---|
| Overburden | 0.2m |
| Mineral I | 0.9m |
| Waste | 1.9m |
| Mineral II | 1.0m |
| Waste | 2.1m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, gravel with large boulders | 0.2 | 0.2 |
| ?Glacial sand and gravel | a Gravel, poorly sorted<br>Gravel: coarse, with fine and cobbles, subangular to subrounded, pink granite with some schist and psammite<br>Sand: mainly coarse and medium, angular rock, quartz and feldpar<br>Fines: silt, disseminated, binding the deposit; dusky yellowish brown (10 YR 3/2) | 0.9 | 1.1 |
| Morainic drift | Diamicton; silt and sand matrix, greyish olive (10 Y 4/2). Abundant tabular and angular pebbles of granite and fine-grained basic rock, becoming sandier below 1.5m depth, a layer of boulders at 1.7m depth | 1.9 | 3.0 |
| | b 'Clayey' sandy gravel<br>Gravel: coarse, with fine and cobble, angular granite and fine-grained basic rock<br>Sand: medium with coarse and fine, angular rock and quartz<br>Fines: silt and clay, binding deposit; greenish grey (5G 6/1) | 1.0 | 4.0 |
| | Diamicton; silt, sand and clay matrix, greenish grey (5 G 6/1). Clasts of coarse gravel and cobbles, pink granite and basic igneous rock | 2.1+ | 6.1 |
| | Borehole abandoned owing to slow progress | | |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 5 | 39 | 56 | 0.2- 1.1 | 5 | 8 | 15 | 16 | 14 | 30 | 12 |
| b | 13 | 63 | 24 | 3.0- 4.0 | 13 | 16 | 30 | 17 | 8 | 11 | 5 § |
| a&b | 9 | 51 | 40 | Mean | 9 | 12 | 22 | 17 | 11 | 20 | 9 |

**NJ 70 SW 16** **7449 0180** **Red Moss, Drumoak** **Block D**

Surface level c.+73m
Groundwater level c.+70.2m
Pit
September 1986

Overburden 0.2m
Mineral I 3.1m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Fluvioglacial sand and gravel | Sandy gravel; clast-supported, poor imbrication with pebbles dipping WSW<br>Gravel: coarse and fine, cobbles up to 250mm, subangular to subrounded pink granite with some pink porphyry and ?dolerite<br>Sand: medium and coarse, angular to subangular quartz and feldspar, reddish brown<br>Fines: little except below 2.8m where quite silty, medium bluish grey with 10-30mm seams of clayey silt, soft | 3.1+ | 3.5 |

Pit sited on a 2m-high, irregularly shaped mound. Pit caving in below 1.8m

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 2 | 51 | 47 | 0.2- 1.8 | 2 | 2 | 16 | 19 | 11 | 15 | 35 |
| | | | 1.8- 2.8 | 2 | 6 | 43 | 22 | 14 | 13 | 0 |
| | | | 2.8- 3.5 | 1 | 5 | 28 | 24 | 15 | 18 | 9 § |
| | | | Mean | 2 | 4 | 26 | 21 | 13 | 15 | 19 |

**NJ 70 SW 17** **7428 0152** **Wickerinn Plantation, Banchory** **Block D**

Surface level c.+78m
Groundwater level c.+76.5m
Pit
September 1986

Overburden 0.2m
Mineral I 1.3m
Waste 1.5m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, peaty | 0.2 | 0.2 |
| Fluvioglacial sand and gravel | Gravel; clast-supported<br>Gravel: coarse and fine, cobbles up to 300mm, subangular to subrounded pink granite with some ?amphibolite, ?dolerite and pink porphyry<br>Sand: coarse and medium, angular to subangular quartz and feldspar, rusty brown<br>Fines: little | 1.3 | 1.5 |
| Till | Diamicton; very sandy clay to very clayey sand and gravel matrix, firm, medium bluish grey (5 B 5/1), rare contorted laminae of clay. Scattered gravel clasts, mainly fine but some cobbles | 1.5+ | 3.0 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 1 | 28 | 71 | 0.2- 1.5 | 1 | 2 | 11 | 15 | 18 | 25 | 28 |

**NJ 70 SW 18** **7418 0145** **Wickerinn Plantation, Banchory** **Block D**

Surface level c.+80m
Groundwater level c.+77.6m
Pit
September 1986

Waste 3.2m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, peaty | 0.2 | 0.2 |
| Till | Diamicton; sandy clay becoming more sandy downwards, stiff, mottled moderate yellowish brown (10 YR 5/4) and pale olive grey (5 Y 5/2). Clasts up to 600mm, chiefly pink granite. Crude stratification. Irregular lenses of clayey sand and gravel | 2.2 | 2.4 |
| | Diamicton; sandy clay, very stiff, pale olive grey (5 YR 5/2), scattered clasts up to 500mm, unstratified | 0.8+ | 3.2 |

**NJ 70 SE 1** **7568 0328** **Westerton, Echt** **Block D**

Surface level c.+73m
Water struck at +71.6m
250mm and 200mm percussion
October 1986

| | |
|---|---|
| Overburden | 2.1m |
| Mineral I | 4.2m |
| Waste | 1.7m |
| Mineral I | 6.0m |
| Bedrock | 0.1m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil; silt, clayey with rootlets and some reddish brown clay masses, dark yellowish brown | 0.6 | 0.6 |
| Peat | Clay; silty with patches of peaty material, pale yellowish brown to grey | 0.2 | 0.8 |
| | Peat; dark brown | 1.3 | 2.1 |
| Alluvium | a Pebbly sand<br>Gravel: fine, angular to subrounded, granitic clasts<br>Sand: medium with coarse and some fine, angular to subrounded quartz, feldspar and lithic fragments<br>Fines: disseminated silt with some silt seams below 5.0m. Pale grey at top becoming pinkish brown, then yellowish brown below 5.5m | 4.2 | 6.3 |
| Glaciolacustrine deposits | Silt; fine sandy, laminated, yellowish grey becoming yellowish brown with depth | 1.7 | 8.0 |

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| Glacial sand and gravel | b Sandy gravel; with some silty seams below 10m. Lower part of deposit (13.7 to 14.0m) may include rotted bedrock<br>Gravel: fine with coarse, some cobbles, subangular to rounded, granite with some metasediments<br>Sand: coarse with medium and some fine, subangular to subrounded, quartz, feldspar and lithic fragments<br>Fines: disseminated silt, reddish brown | 6.0 | 14.0 |
| Bedrock | Granite, hard; only chips recovered | 0.1+ | 14.1 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | | |
| | | | | from to | - 1/16 | + 1/16 - 1/4 | + 1/4 -1 | +1- | +4-16 | +16-64 | +64 mm | |
| a | 5 | 90 | 5 | 2.1- 3.1 | 4 | 12 | 46 | 34 | 4 | 0 | 0 | § |
| | | | | 3.1- 4.0 | 3 | 13 | 51 | 31 | 2 | 0 | 0 | § |
| | | | | 4.0- 5.0 | 4 | 9 | 35 | 44 | 8 | 0 | 0 | § |
| | | | | 5.0- 6.3 | 9 | 12 | 44 | 30 | 5 | 0 | 0 | § |
| | | | | Mean | 5 | 11 | 45 | 34 | 5 | 0 | 0 | |
| b | 7 | 63 | 30 | 8.0- 9.0 | 6 | 2 | 24 | 39 | 24 | 5 | 0 | § |
| | | | | 9.0-10.4 | 5 | 3 | 22 | 37 | 26 | 7 | 0 | § |
| | | | | 10.4-11.5 | 7 | 4 | 20 | 30 | 26 | 10 | 3 | § |
| | | | | 11.5-12.7 | 11 | 6 | 23 | 36 | 16 | 8 | 0 | § |
| | | | | 12.7-14.0 | 4 | 9 | 29 | 31 | 14 | 9 | 4 | § |
| | | | | Mean | 7 | 5 | 24 | 34 | 21 | 8 | 1 | |
| a&b | 6 | 74 | 20 | Mean | 6 | 8 | 32 | 34 | 14 | 5 | 1 | |

**NJ 70 SE 2** **7508 0274** **Tillyorn, Echt** **Block D**

Surface level c.+73m
Water struck at c.+70m
Pit
September 1986

Overburden 0.3m
Mineral II 2.7m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil; peaty | 0.3 | 0.3 |
| Flow-till | Diamicton; matrix a mixture of clayey coarse with medium and some fine sand, very sandy clay and clean coarse-grained sand, hard but friable, pale olive grey (5 Y 6/1). Mainly a clast-supported rubble of angular clasts of pink and grey granite up to 500mm. Some gabbro. No overall stratification but appears to have winnowed horizons. Grades, when crumbled, as a 'clayey' sandy gravel | 2.7+ | 3.0 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | - 1/16 | + 1/16 - 1/4 | + 1/4 -1 | +1-4 | +4-16 | +16-64 | +64 mm |
| 10 | 60 | 30 | 0.3- 3.0 | 10 | 16 | 25 | 19 | 13 | 17 | 0 |

| NJ 70 SE 3 | 7594 0261 | **Westerton, Echt** | | **Block D** |
|---|---|---|---|---|

Surface level c.+82m
Water not struck
Pit
September 1986

Waste 2.4m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Morainic drift | Diamicton; sandy clay to very clayey coarse-grained sand matrix, hard but friable, moderate yellowish brown (10 YR 5/4) with an olive tint, weathered in upper 0.4m. Angular to subrounded clasts up to 500mm, chiefly grey and pink granite with some ?amphibolite, gneiss, gabbro, psammite, quartzite and pink porphyry. Mostly unstratified but one sub-horizontal boundary identified | 2.2+ | 2.4 |

| NJ 70 SE 4 | 7540 0227 | **Blackdams, Echt** | | **Block D** |
|---|---|---|---|---|

Surface level c.+70m
Groundwater level +67.9m
Pit
October 1986

Waste 2.5m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Made ground, old stone-filled drain | 0.5 | 0.5 |
| Alluvium | Sand, coarse with medium, rare fine pebbles, silty, pale yellow to rusty brown, including some irregular masses of pale olive grey silty clay. (Possibly disturbed ground) | 0.4 | 0.9 |
| | Silt, clayey, interbedded with clean fine to coarse-grained sand and fine gravel, silty fine-grained sand and soft peat. Olive grey to black (5 Y 4/1-2/1) | 0.4 | 1.3 |
| | Silt, clayey, firm to stiff, pale olive grey (5 YR 5/2) | 0.1 | 1.4 |
| Till | Diamicton; clayey sand to sandy clay matrix, soft to firm, pale olive grey (5 YR 5/2) with a bluish tint. Angular to subangular clasts up to 600mm, chiefly pink granite | 1.1+ | 2.5 |

**NJ 70 SE 5** **7553 0049** **Candyglirach Croft, Drumoak** **Block E**

| | |
|---|---|
| Surface level c.+80m | Overburden 0.2m |
| Groundwater level +76.1m | Mineral II 3.7m |
| Section and pit | Bedrock 0.1m+ |
| September 1986 | |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Morainic drift | Diamicton; clayey sand to sandy clay matrix, hard but generally friable, pale yellowish brown (10 YR 6/2) to moderate yellowish brown (10 YR 5/4) with ferruginous horizons. Widely scattered clasts up to 100mm, chiefly granite. Crude, laterally impersistent bedding consisting of 10-30mm beds of sandy clay with 10mm-thick winnowed tops of sand | 1.8 | 2.0 |
| | Diamicton; as above, but more sandy and gravelly and including discrete lenses of clean fine to medium-grained sand<br>Gravel: up to 40mm, angular to subangular, chiefly brownish granite<br>Sand: medium with coarse and fine, angular to subangular granites | 1.9 | 3.9 |
| Caledonian | Granite, coarse-grained, brownish, rapidly hardening downwards | 0.1+ | 4.0 |

The two units of diamicton, taken together and when crumbled, grade as 'clayey' pebbly sand. The upper 2.0m sampled from a section. Pit continually caving in.

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 17 | 63 | 20 | 0.2- 2.0 | 24 | 16 | 24 | 22 | 10 | 4 | 0 |
| | | | 2.0- 3.9 | 11 | 14 | 29 | 21 | 11 | 14 | 0 |
| | | | Mean | 17 | 15 | 27 | 21 | 11 | 9 | 0 |

**NJ 70 SE 6** **7609 0374** **Little Finnercy, Echt** **Block D**

| | |
|---|---|
| Surface level c.+82m | Waste 1.7m+ |
| Water not struck | |
| Pit | |
| October 1986 | |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.3 | 0.3 |
| Till | Diamicton; clayey sand to sandy clay matrix, hard but friable, pale olive grey (5 Y 5/2) weathering orangey or yellowishing browns in upper 0.5m. Clasts up to 600mm, chiefly angular grey granite, almost clast-supported in parts, large boulders at base. Approximately 0.4m-thick float of subangular to well rounded fine to cobble gravel, rusty brown, at top, passing down into underlying diamicton. Some crude stratification. | 1.4+ | 1.7 |

**NJ 70 SE 7** **7652 0378** **West Cullerley, Echt** **Block D**

Surface level c.+82m
Water not struck
250mm and 200mm percussion
November 1986

Overburden 0.5m
Mineral I 11.0m
Bedrock (mineral) 1.5m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil; peaty and stony, black | 0.5 | 0.5 |
| Glacial sand and gravel | a Pebbly sand, becoming finer with depth<br>Gravel: fine with coarse with rare cobbles and boulders, subangular to subrounded, granite, porphyry, quartzite, amphibolite, gneissose metasediment and pelite<br>Sand: medium with coarse and fine, angular to subangular quartz, feldspar and lithic fragments<br>Fines: peaty silt near top, becoming disseminated with depth, pale yellowish brown | 2.5 | 3.0 |
| | b Sandy gravel Matrix-rich in places and very hard with layers of cobbles and boulders<br>Gravel: coarse, fine and cobbles with some boulders, subangular to rounded granite and some fine-grained metasediments<br>Sand: coarse and medium with fine, angular to subrounded quartz, feldspar, lithic fragments and mica<br>Fines: disseminated silt and clay, binding deposit in places | 5.2 | 8.2 |
| | c 'Clayey' pebbly sand<br>Gravel: fine with some coarse, subangular to subrounded, granite<br>Sand: medium with coarse and fine, subangular to subrounded, quartz, feldspar, rock fragments and mica<br>Fines: disseminated silt and clay, binding deposit in places, orange brown to grey from 9.0 to 10.1m | 3.3 | 11.5 |
| Caledonian | d Sandy gravel; rotted granite bedrock<br>Gravel: fine with coarse, angular, granite<br>Sand: coarse and medium with fine, angular to subrangular, quartz, lithic fragments, feldspar and mica<br>Fines: silt and clay slurrying deposits | 1.5+ | 13.0 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | from to | Fines | Sand | | | Gravel | | |
| | | | | | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 2 | 86 | 12 | 0.5- 1.6 | 3 | 7 | 40 | 29 | 11 | 10 | 0 |
| | | | | 1.6- 3.0 | 2 | 18 | 50 | 25 | 5 | 0 | 0 |
| | | | | Mean | 2 | 13 | 46 | 27 | 8 | 4 | 0 |
| b | 8 | 48 | 44 | 3.0- 4.0 | 5 | 20 | 21 | 14 | 8 | 17 | 15 |
| | | | | 4.0- 5.0 | 3 | 10 | 17 | 23 | 11 | 18 | 18 |
| | | | | 5.0- 6.0 | 4 | 5 | 12 | 20 | 13 | 17 | 29 |
| | | | | 6.0- 7.0 | 12 | 2 | 8 | 24 | 38 | 16 | 0 |
| | | | | 7.0- 8.2 | 13 | 19 | 29 | 12 | 8 | 13 | 6 |
| | | | | Mean | 8 | 11 | 18 | 19 | 15 | 16 | 13 |
| c | 12 | 80 | 8 | 8.2- 9.0 | 14 | 11 | 34 | 38 | 3 | 0 | 0 |
| | | | | 9.0-10.1 | 12 | 12 | 36 | 28 | 11 | 1 | 0 |
| | | | | 10.1-11.5 | 10 | 16 | 41 | 25 | 6 | 2 | 0 |
| | | | | Mean | 12 | 13 | 38 | 29 | 7 | 1 | 0 |
| d | 8 | 67 | 25 | 11.5-13.0 | 8 | 9 | 29 | 29 | 20 | 5 | 0 |
| a-c | 8 | 66 | 26 | Mean | 8 | 12 | 31 | 23 | 11 | 9 | 6 |
| a-d | 8 | 66 | 26 | Mean | 8 | 12 | 30 | 24 | 12 | 8 | 6 |

| NJ 70 SE 8 | 7606 0353 | Little Finnercy, Echt | Block D |
|---|---|---|---|

Surface level c.+76m
Groundwater level c.+71.5
Pit
September 1986

| | |
|---|---|
| Overburden | 0.4m |
| Mineral I | 2.7m |
| Waste | 0.9m |
| Mineral I | 1.0m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Glacial sand and gravel | Sand, fine-grained and very silty, to sandy silt, finely laminated; pale olive grey to moderate yellowish brown | 0.2 | 0.4 |
| | a Gravel; crudely bedded, fining down to 1.9m<br>Gravel: cobbles, coarse and fine, boulders up to 500mm common below 1.9m, subangular to subrounded pink granite with rare amphibolite, quartzite and vein-quartz<br>Sand: coarse with medium and some fine, angular to subangular quartz and feldspar, poorly sorted and ferruginous below 1.9m<br>Fines: little, deposit loose | 2.7 | 3.1 |
| | Sand, medium to coarse-grained, interbedded with laminated fine sandy silt and fine sand, pale olive grey (5 Y 5/2) weathering dusky yellow (5 Y 6/4) | 0.9 | 4.0 |
| | b Sand<br>Gravel: rare, fine and coarse<br>Sand: chiefly medium with coarse and fine, angular to subangular, clean, more quartzose than is typical for the area<br>Fines: little | 1.0+ | 5.0 |
| | Pit caving in below 4.0m. Dug into the side of a 3m-high mound | | |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 2 | 44 | 54 | 0.4- 1.9 | 2 | 4 | 19 | 30 | 6 | 14 | 25 |
| | | | | 1.9- 3.1 | 1 | 4 | 13 | 17 | 9 | 20 | 36 |
| | | | | Mean | 2 | 4 | 16 | 24 | 7 | 17 | 30 |
| b | 2 | 95 | 3 | 4.0- 5.0 | 2 | 8 | 77 | 10 | 2 | 1 | 0 |
| a&b | 2 | 58 | 40 | Mean | 2 | 5 | 33 | 20 | 6 | 12 | 22 |

NJ 70 SE 9 | 7674 0342 | **West Cullerley, Echt** | **Block D**

Surface level c.+85m
Groundwater level c.+81.9m
Pit
September 1986

Waste 3.2m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Till | Diamicton; very clayey sand to sandy clay matrix, hard but friable, pale olive grey (5 Y 6/1) weathering rusty brown in upper 0.3m. Scattered angular to subrounded clasts up to 400mm of brown granite. Unstratified | 2.7 | 2.9 |
| | Diamicton; silty sandy clay matrix, firm but friable, dark greenish grey (5 G 4/1) | 0.3+ | 3.2 |

NJ 70 SE 10 | 7601 0236 | **Mill Croft, Echt** | **Block D**

Surface level c.+82m
Water not struck
Pit
October 1986

Overburden 0.2m
Mineral II 2.5m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Morainic drift | Diamicton; clayey silty sand to sandy clay matrix, hard but friable, upper metre more clayey and stiff than below, moderate yellowish brown (10 YR 5/4). Clasts up to 500mm, larger ones chiefly angular pink granite, otherwise subrounded to well rounded quartzite with grey granite, amphibolite and red porphyry | 2.5+ | 2.7 |
| | Deposit grades, when crumbled, as gravel | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 8 | 34 | 58 | 0.2- 2.7 | 8 | 12 | 14 | 8 | 5 | 7 | 46 |

| NJ 70 SE 11 | 7662 0245 | **Carpenters Croft, Echt** | **Block F** |
|---|---|---|---|

Surface level c.+73m
Water not struck
Pit
September 1986

Waste 1.6m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Till | Diamicton; sandy clay, stiff and very hard to dig, pale olive grey (5 Y 5/2) mottled moderate yellowish brown (10 YR 5/4). Angular to well rounded clasts up to 1m, chiefly brownish granite with some red granite and ?amphibolite. Gleyed vertical fissures at 400mm intervals | 1.4+ | 1.6 |

| NJ 70 SE 12 | 7657 0166 | **Quiddies Mill Croft, Drumoak** | **Block F** |
|---|---|---|---|

Surface level c.+69m
Water not struck
Pit
September 1986

Overburden 0.2m
Mineral I 3.3m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Glacial sand and gravel | Sandy gravel; crude down-valley cross-bedding<br>Gravel: fine and coarse, rare cobbles, angular to subrounded, chiefly pink and grey granite with gneiss, psammite and well rounded quartzite<br>Sand: coarse and medium with trace of fine, angular to subangular quartz and feldspar, ferruginous in upper 1.2m, cleaner below<br>Fines: generally little but seams up to 10mm thick of pale olive grey (5 Y 5/2) sandy clay in upper 1.2m, and of micaceous silt below 2.4m | 3.3+ | 3.5 |
| | Pit sited on low, sinuous esker | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 3 | 71 | 26 | 0.2- 1.4 | 3 | 6 | 37 | 28 | 14 | 12 | 0 |
| | | | 1.4- 2.4 | 3 | 3 | 36 | 38 | 15 | 5 | 0 |
| | | | 2.4- 3.5 | 2 | 7 | 21 | 40 | 22 | 8 | 0 |
| | | | Mean | 3 | 5 | 31 | 35 | 17 | 9 | 0 |

NJ 70 SE 13 7720 0405 **Northtown, Echt** **Block D**

Surface level +104m
Water struck at +96.1m
250mm and 200mm percussion
October 1986

| | |
|---|---|
| Overburden | 0.2m |
| Mineral I | 7.8m |
| Waste | 1.5m |
| Mineral I | 6.0m |
| Bedrock | 0.9m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil; sandy, pebbly, dark yellowish brown | 0.2 | 0.2 |
| Glacial sand and gravel | a Pebbly sand Gravel and silt content rather variable<br>Gravel: fine with coarse, subangular to subrounded, granite<br>Sand: medium and coarse with fine, subangular to subrounded quartz, lithic fragments and mica<br>Fines: disseminated silt and silt layers from 1.3 to 5.0m and 6.1 to 8.0m | 7.8 | 8.0 |
| Till | Diamicton; clay, sandy, gravelly, compacted and hard, yellowish brown. Grades down into underlying deposit | 1.5 | 9.5 |
| Glacial sand and gravel | b 'Clayey' pebbly sand; gravelly in top metre<br>Gravel: coarse and fine with rare cobbles, subangular to rounded, granite with some metasedimentary clasts<br>Sand: medium and coarse with fine, subangular to subrounded, quartz, feldspar, lithic fragments and mica<br>Fines: disseminated silt. Yellowish brown with pinkish tint | 6.0 | 15.5 |
| Caledonian | Granite; coarse-grained, feldspar phenocrysts up to 15mm | 0.9+ | 16.4 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm | |
| a | 9 | 73 | 18 | 0.2- 1.3 | 3 | 7 | 31 | 31 | 22 | 6 | 0 | |
| | | | | 1.3- 2.1 | 8 | 9 | 29 | 30 | 21 | 3 | 0 | |
| | | | | 2.1- 3.6 | 4 | 7 | 39 | 41 | 6 | 3 | 0 | |
| | | | | 3.6- 5.0 | 9 | 13 | 36 | 28 | 8 | 6 | 0 | |
| | | | | 5.0- 6.1 | 19 | 44 | 22 | 10 | 3 | 2 | 0 | |
| | | | | 6.1- 8.0 | 12 | 13 | 21 | 27 | 12 | 15 | 0 | |
| | | | | Mean | 9 | 15 | 30 | 28 | 11 | 7 | 0 | |
| b | 18 | 69 | 13 | 9.5-10.6 | 3 | 6 | 20 | 25 | 17 | 29 | 0 | § |
| | | | | 10.6-11.5 | 5 | 8 | 41 | 38 | 5 | 3 | 0 | § |
| | | | | 11.5-13.0 | 4 | 11 | 43 | 34 | 4 | 4 | 0 | § |
| | | | | 13.0-15.0 | 34 | 23 | 20 | 18 | 4 | 1 | 0 | § |
| | | | | 15.0-15.5 | 56 | 21 | 12 | 6 | 3 | 2 | 0 | § |
| | | | | Mean | 18 | 14 | 30 | 25 | 6 | 7 | 0 | |
| a&b | 13 | 71 | 16 | Mean | 13 | 15 | 29 | 27 | 9 | 7 | 0 | |

**NJ 70 SE 14** | **7792 0230** | **Cornhill, Echt** | **Block F**

Surface level +60m
Water struck at +59.3m and +54.5m
250mm percussion
November 1986

| | |
|---|---|
| Overburden | 3.0m |
| Mineral I | 3.5m |
| Waste | 1.0m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil; peaty, silty, dark brown to black | 0.7 | 0.7 |
| Alluvium | Silt, very clayey, slightly laminated and soft, pale grey | 2.3 | 3.0 |
| Fluvioglacial sand and gravel | Sandy gravel; becoming more gravelly and coarser with depth<br>Gravel: coarse with fine, some cobbles and boulders, subangular to rounded granite with some amphibolite and schist<br>Sand: coarse and medium with fine, subangular to rounded quartz, feldspar and lithic fragments<br>Fines: disseminated silt | 3.5 | 6.5 |
| Till | Diamicton; compositionally similar to overlying deposit, but clay-bound and non-mineral. Some evidence that gravel occurs below 7.5m, but hole abandoned due to technical problems | 1.0+ | 7.5 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1–4 | +4–16 | +16–64 | +64 mm |
| 8 | 60 | 32 | 3.0– 3.8 | 8 | 9 | 30 | 36 | 10 | 7 | 0 § |
| | | | 3.8– 5.3 | 8 | 12 | 25 | 26 | 11 | 15 | 3 § |
| | | | 5.3– 6.5 | 7 | 7 | 18 | 20 | 16 | 32 | 0 § |
| | | | Mean | 8 | 10 | 24 | 26 | 12 | 19 | 1 |

**NJ 70 SE 15** | **7791 0179** | **Horsewells, Drumoak** | **Block F**

Surface level +66m
Water not struck
250mm percussion
November 1986

| | |
|---|---|
| Waste | 4.8m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil: peaty loam, dark brown | 0.5 | 0.5 |
| Glacial sand and gravel | Sand; rare pebbles<br>Gravel: fine, subangular to subrounded granite<br>Sand: medium with fine and coarse, moderate brown (5 YR 4/4), subangular<br>Fines: disseminated silt and clay | 0.4 | 0.9 |
| Till | Diamicton: clay, very sandy, moderate yellowish brown (10 YR 5/4). Many fine gravel size clasts, chiefly granite. Occasional cobbles and boulders below 1.8m. Thin seams of coarse, subangular sand at 3.4m | 3.9+ | 4.8 |

Borehole terminated owing to slow progress

**NJ 70 SE 16** **7818 0479** **Brewthin, Echt** **Block C**

Surface level c.+88m
Water not struck
Section and pit
September 1986

Overburden 0.3m
Mineral I 5.3m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.3 | 0.3 |
| Glacial sand and gravel | a Gravel; clast-supported, matrix-rich in part<br>Gravel: cobbles, boulders, coarse and fine, subrounded to rounded, chiefly grey (rotten) granite and brownish pink granite with some ?amphibolite, quartzite, red porphyry and gabbro<br>Sand: medium with coarse and some fine, angular to subangular quartz and feldspar, pale yellowish brown<br>Fines: little | 1.3 | 1.6 |
| | b Pebbly sand; bedded, some open-work beds<br>Gravel: fine with coarse, as above<br>Sand: coarse with medium and some fine, as above<br>Fines: silt, disseminated | 1.8 | 3.4 |
| | c Sandy gravel; boulders up to 1m between 4.2m and 4.6m<br>Gravel: cobbles, coarse and fine, as above<br>Sand: medium with coarse and some fine, clean, quartzose<br>Fines: little | 2.2+ | 5.6 |
| | Includes a 2.6m section in the side of a 3 to 5m-high esker | | |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 0 | 22 | 78 | 0.3- 1.6 | 0 | 3 | 11 | 8 | 6 | 22 | 50 |
| b | 4 | 76 | 20 | 1.6- 3.4 | 4 | 7 | 27 | 42 | 13 | 7 | 0 |
| c | 2 | 51 | 47 | 3.4- 4.2 | 2 | 9 | 21 | 15 | 11 | 18 | 24 |
| | | | | 4.2- 4.6 | No grading data available | | | | | | |
| | | | | 4.6- 5.6 | 2 | 8 | 31 | 18 | 9 | 16 | 16 |
| | | | | Mean | 2 | 8 | 26 | 17 | 10 | 17 | 20 |
| a-c | 2 | 53 | 45 | Mean | 2 | 7 | 23 | 23 | 10 | 15 | 20 |

| NJ 70 SE 17 | 7809 0460 | Redhill, Echt | Block C |
|---|---|---|---|

Surface level c.+88m
Water not struck
Section and pit
September 1986

Waste 2.3m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, peaty | 0.2 | 0.2 |
| Till | Diamicton; sandy clay to clayey sand matrix, very hard but ultimately friable, pale yellowish brown (10 YR 6/2) to moderate yellowish brown (10 YR 5/4). Angular to subrounded clasts up to 1m, chiefly brownish or grey granite with some ?amphibolite, quartzite and porphyry. Unstratified | 2.1+ | 2.3 |

| NJ 70 SE 18 | 7870 0439 | Standingstones, Echt | Block C |
|---|---|---|---|

Surface level c.+86m
Water struck at +79.2
(confined)
250mm percussion
October 1986

Overburden 0.3m
Mineral I 3.9m
Waste 2.6m
Bedrock 1.0m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil; sandy organic soil, very dark brown to black | 0.3 | 0.3 |
| Fluvioglacial sand and gravel | 'Clayey' pebbly sand; gravel in top metre becoming finer grained with depth<br>Gravel: fine with some coarse, subangular to rounded granite and fine-grained metasediments;<br>Sand: medium with coarse and fine, subangular to subrounded quartz, feldspar, lithic fragments and mica<br>Fines: disseminated silt, dark yellowish brown, becoming more grey with depth | 3.9 | 4.2 |
| | Silt, sandy, firm, friable, laminated, brownish grey | 2.6 | 6.8 |
| Caledonian | Granite, grey and pinkish, with 10 to 15mm feldspar phenocrysts. Weathered, fractured and veined with quartz porphyry | 1.0+ | 7.8 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 12 | 77 | 11 | 0.3- 1.8 | 4 | 6 | 37 | 33 | 16 | 4 | 0 |
| | | | 1.8- 3.6 | 11 | 25 | 39 | 19 | 5 | 1 | 0 |
| | | | 3.6- 4.2 | 37 | 46 | 13 | 4 | 0 | 0 | 0 |
| | | | Mean | 12 | 21 | 34 | 22 | 9 | 2 | 0 |

NJ 70 SE 19 | 7985 0493 | Leuchar, Skene | Block C

Surface level c.+81m
Water not struck
Section and pit
September 1986

Mineral I 5.5m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| Glacial sand and gravel | a Sandy gravel; fining downwards<br>Gravel: coarse and fine, rare cobbles, subangular to rounded, chiefly pink granite with some ?amphibolite, vein-quartz and quartzite<br>Sand: coarse with medium and a trace of fine, angular to subangular quartz and feldspar<br>Fines: little | 1.0 | 1.0 |
| | b Pebbly sand; good cross-bedding towards SE, many beds of open-work coarse-grained sand-fine gravel. Very unconsolidated<br>Gravel: rare fine, angular to subrounded pink granite<br>Sand: chiefly coarse with some medium, well sorted and clean, angular to subangular quartz and feldspar<br>Fines: very little | 4.5+ | 5.5 |
| | 2m-high section in 5m-high mound. Pit continually collapsing | | |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 0 | 60 | 40 | 0.0- 1.0 | 0 | 2 | 23 | 35 | 16 | 10 | 14 |
| b | 1 | 90 | 9 | 1.0- 5.5 | 1 | 2 | 17 | 71 | 9 | 0 | 0 |
| a&b | 1 | 84 | 15 | Mean | 1 | 2 | 18 | 64 | 10 | 2 | 3 |

NJ 70 SE 20 | 7941 0474 | **Leuchar Moss, Peterculter** | **Block C**

Surface level +76m
Water struck at +74m
250mm and 200mm percussion
October 1986

| | |
|---|---|
| Overburden | 0.5m |
| Mineral I | 1.4m |
| Waste | 0.2m |
| Mineral I | 5.2m |
| Waste | 4.2m |
| Bedrock | 1.4m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Peat; sandy, loamy, black | 0.5 | 0.5 |
| Alluvium | a Sand<br>Gravel: rare<br>Sand: medium with coarse and some fine, quartz<br>Fines: silty seams and laminae from 0.5 to 1.2m, olive grey to grey | 1.4 | 1.9 |
| | Peat; fibrous, very sandy, firm, olive grey (5 3/2) | 0.2 | 2.1 |
| Fluvioglacial sand and gravel | b 'Clayey' sand; some fine granite gravel from to 5.5m. Fines increase from 4.5m<br>Sand: fine with medium and some coarse, subangular to subrounded, quartz, lithic fragments, feldspar and mica<br>Fines: disseminated silt to 5.5m, then laminated to 7.3m. Olive grey (5 Y 6/1) | 5.2 | 7.3 |
| Glaciolacustrine deposits | Silt; inter-laminated with fine-grained sand, clayey, plastic, grey with yellowish brown or grey bands from 8.3m to 9.0m and from about 10.0m downwards | 4.2 | 11.5 |
| Caledonian | Granite, coarse-grained with 10 to 20mm feldspar phenocrysts. Fresh but fractured | 1.4+ | 12.9 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm | |
| a | 6 | 92 | 2 | 0.5- 1.2 | 4 | 17 | 67 | 8 | 4 | 0 | 0 | |
| | | | | 1.2- 1.9 | 7 | 32 | 58 | 2 | 1 | 0 | 0 | |
| | | | | Mean | 6 | 24 | 64 | 4 | 2 | 0 | 0 | |
| b | 13 | 86 | 1 | 2.1- 3.5 | 5 | 63 | 28 | 4 | 0 | 0 | 0 | § |
| | | | | 3.5- 4.5 | 3 | 38 | 39 | 15 | 5 | 0 | 0 | § |
| | | | | 4.5- 5.5 | 12 | 65 | 21 | 2 | 0 | 0 | 0 | § |
| | | | | 5.5- 7.3 | 26 | 63 | 10 | 1 | 0 | 0 | 0 | § |
| | | | | Mean | 13 | 58 | 23 | 5 | 1 | 0 | 0 | |
| a&b | 12 | 87 | 1 | Mean | 12 | 51 | 31 | 5 | 1 | 0 | 0 | |

| NJ 70 SE 21 | 7988 0426 | Leuchar, Peterculter | Block C |
|---|---|---|---|

Surface level +77m
Water struck at +74.3m
250mm and 200mm percussion
October 1986

Overburden 1.5m
Mineral 10.9m
Waste 6.6m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil; sandy, peaty, black | 0.4 | 0.4 |
| Alluvium | Silt; fine sandy, crudely laminated, passing down into fine-grained sand, dark to pale yellowish brown with grey bands | 1.1 | 1.5 |
| | 'Clayey' sand; slightly damp, some peat debris<br>Sand: fine with some medium and rare coarse, subangular to subrounded quartz, lithic fragments and mica<br>Fines: silt, disseminated and as discrete seams, dark to pale yellowish brown with grey bands | 0.9 | 2.4 |
| Fluvioglacial sand and gravel | 'Clayey' sand; some fine pebbles of granite in top 2 to 3m, becoming less abundant with depth. Fines content increasing with depth<br>Sand: fine with medium and some coarse, subangular to rounded quartz, feldspar mica and lithic fragments<br>Fines: disseminated silt and clayey seams from 10m | 10.0 | 12.4 |
| Glaciolacustrine deposits | Silt; sandy, becoming more silty with depth. Clayey and plastic from 16.2m and laminated from 17.7m. Greyish yellowish brown | 6.6+ | 19.0 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm | |
| a | 16 | 84 | 0 | 1.5- 2.4 | 16 | 70 | 13 | 1 | 0 | 0 | 0 | |
| b | 16 | 83 | 1 | 2.4- 2.9 | 5 | 11 | 52 | 29 | 3 | 0 | 0 | § |
| | | | | 2.9- 3.9 | 2 | 15 | 59 | 22 | 2 | 0 | 0 | § |
| | | | | 3.9- 4.9 | 13 | 37 | 36 | 13 | 1 | 0 | 0 | § |
| | | | | 4.9- 6.1 | 15 | 38 | 38 | 8 | 1 | 0 | 0 | § |
| | | | | 6.1- 7.1 | 18 | 59 | 20 | 3 | 0 | 0 | 0 | § |
| | | | | 7.1- 9.0 | 22 | 63 | 14 | 1 | 0 | 0 | 0 | § |
| | | | | 9.0-10.0 | 27 | 66 | 5 | 2 | 0 | 0 | 0 | § |
| | | | | 10.0-12.4 | 17 | 74 | 8 | 1 | 0 | 0 | 0 | § |
| | | | | Mean | 16 | 52 | 24 | 7 | 1 | 0 | 0 | |
| a&b | 16 | 83 | 1 | Mean | 16 | 54 | 23 | 6 | 1 | 0 | 0 | |

NJ 70 SE 22 | 7915 0168 | Hardgate, Drumoak | Block F

Surface level +61m
Water struck but depth not recorded
250mm percussion
November 1986

Overburden 0.4m
Mineral I 3.5m
Waste 1.1m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil; peaty loam | 0.4 | 0.4 |
| Fluvioglacial sand and gravel | Sandy gravel<br>Gravel: fine and coarse, subangular to well rounded, pink granite with psammite, pelite and basic igneous rock<br>Sand: mainly coarse and medium, subangular quartz, granite and feldspar<br>Fines: silt, disseminated, moderate brown (5 YR 4/4) | 3.5 | 3.9 |
| Till | Diamicton; clay, silt and sand matrix, stiff; clasts up to cobble size of subrounded granite, psammite, pelite, quartzite and basic igneous rock; matrix supported, becoming more sandy below 4.7m depth; dark yellowish brown (10 YR 4/2) | 1.1+ | 5.0 |
| | Borehole terminated owing to slow progress | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 3 | 59 | 38 | 0.4- 1.4 | 3 | 7 | 29 | 27 | 20 | 14 | 0 |
| | | | 1.4- 2.4 | 0 | 6 | 27 | 27 | 21 | 19 | 0 |
| | | | 2.4- 3.9 | 4 | 6 | 24 | 27 | 19 | 20 | 0 |
| | | | Mean | 3 | 6 | 26 | 27 | 20 | 18 | 0 |

INVERURIE RESOURCE SHEET

**NJ 72 NW 1** **7094 2567** **Pinewood Cottage, Garioch**

Surface level c.+78m
Water not struck
Pit
October 1986

Overburden 0.2m
Mineral I 3.7m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Fluvioglacial sand and gravel | Sandy gravel; horizontal bedding, rare gravel lags<br>Gravel: fine with coarse, cobbles up to 200mm restricted to basal 0.3m, chiefly gabbro and ?amphibolite with pink granite quartzite, vein-quartz, schistose grit and gneiss<br>Sand: coarse and medium with some fine, angular to subangular feldspar and quartz with conspicuous and relatively large amount of mafic minerals, also some platy slate and pelite<br>Fines: a little silt, disseminated | 3.7+ | 3.9 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 2 | 61 | 37 | 0.2- 1.2 | 1 | 5 | 33 | 32 | 20 | 9 | 0 |
| | | | 1.2- 2.5 | 4 | 7 | 24 | 31 | 26 | 8 | 0 |
| | | | 2.5- 3.9 | 2 | 7 | 22 | 24 | 24 | 21 | 0 |
| | | | Mean | 2 | 6 | 26 | 29 | 24 | 13 | 0 |

**NJ 72 NW 2** **7173 2577** **Mill of Durno, Garioch**

Surface level c.+77m
Water not struck
Pit
September 1986

Overburden 0.3m
Mineral I 3.0m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.3 | 0.3 |
| Fluvioglacial sand and gravel | Sandy gravel; horizontal bedding<br>Gravel: coarse and fine, scattered cobbles up to 100mm, subangular to subrounded, chiefly basic igneous rocks, granite, gneiss, and amphibolite with pelites, platy slate and vein-quartz<br>Sand: coarse with medium, trace of fine, angular to subangular quartz, feldsar and conspicuous mafic mnerals and platy slate and pelite<br>Fines: little | 3.0+ | 3.3 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 2 | 53 | 45 | 0.3- 1.8 | 1 | 2 | 21 | 28 | 21 | 27 | 0 |
| | | | 1.8- 3.3 | 2 | 4 | 23 | 29 | 23 | 19 | 0 |
| | | | Mean | 2 | 3 | 22 | 28 | 22 | 23 | 0 |

**NJ 72 NW 3** **7207 2727** **Glenlogie, Garioch**

Surface level c.+77m
Groundwater level c.+73.9m
Pit
October 1986

Overburden 0.2m
Mineral I 3.0m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Fluvioglacial sand and gravel | Gravel; crude horizontal bedding, largely clast-supported<br>Gravel: coarse and fine, cobbles up to 200mm common, some boulders up to 500mm between 1.5 and 3.2m, subangular to rounded basic igneous rocks with amphibolite, pink granite and pegmatite, vein-quartz, gneiss platy pelite and purple slate<br>Sand: medium and coarse, some fine, angular to subangular feldspar with quartz, mafic minerals and some platy slate and pelite<br>Fines: some disseminated silt | 3.0+ | 3.2 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 2 | 35 | 63 | 0.2- 1.5 | 3 | 7 | 21 | 17 | 20 | 32 | 0 |
| | | | 1.5- 3.2 | 1 | 3 | 12 | 11 | 10 | 16 | 47 |
| | | | Mean | 2 | 5 | 16 | 14 | 14 | 23 | 26 |

NJ 72 NW 4 | 7206 2646 | **Whitefolds, Garioch**

Surface level +77m
Water not struck
250mm percussion
September 1986

Overburden 0.3m
Mineral 1.0m
Waste 1.5m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil; sandy, silty loam with rare cobbles, dark yellowish brown | 0.3 | 0.3 |
| Fluvioglacial sand and gravel | Sandy gravel<br>Gravel: fine with coarse and rare cobbles, subangular to subrounded, schist, metabasic rocks, quartzite, pelitic rocks, vein-quartz, granite and diorite rocks<br>Sand: medium with coarse and fine, subangular to subrounded quartz and lithic fragments<br>Fines: silt and clay, dark yellowish brown, slightly cohesive, binding deposit in places | 1.0 | 1.3 |
| Till | Deposit above becomes clay-bound and non-mineral from 1.3m. Cleaner and sandier from 2.2 to 2.8m, but still non-mineral | 1.5 | 2.8 |
| | Borehole probably terminated on bedrock but no sample obtainable for identification | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 3 | 68 | 29 | 0.3- 1.3 | 3 | 17 | 30 | 21 | 16 | 13 | 0 |

NJ 72 NW 5 | 7298 2591 | **Mill of Pitcaple, Garioch**

Surface level c.+74m
Water not struck
Section and pit
September 1986

Overburden 0.3m
Mineral I 2.2m
Waste 0.2m
Bedrock 0.3m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.3 | 0.3 |
| Fluvioglacial sand and gravel | Pebbly sand; clast-supported gravel in top 0.3m; good horizontal bedding<br>Gravel: chiefly fine with coarse and rare cobbles up to 100mm, subangular to subrounded basic igneous rocks, gneiss, amphibolite with vein-quartz and platy slate<br>Sand: coarse with medium and a trace of fine, angular to subangular quartz, feldspar and conspicuous mafic mineral and platy slate<br>Fines: little | 2.2 | 2.5 |
| Till | Diamicton; sandy clay, firm to stiff, moderate yellowish brown (10 YR 5/4), containing angular blocks of diorite | 0.2 | 2.7 |
| Caledonian | Hornfelsed diorite, medium to coarse-grained, dark grey to black, fresh | 0.3+ | 3.0 |

NJ72NW 5
Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 1 | 79 | 20 | 0.3- 1.3 | 1 | 6 | 32 | 37 | 22 | 2 | 0 |
| | | | 1.3- 2.5 | 1 | 6 | 36 | 40 | 17 | 0 | 0 |
| | | | Mean | 1 | 6 | 34 | 39 | 19 | 1 | 0 |

**NJ 72 NW 6** **7419 2546** **Legatesden Farm, Garioch**

Surface level +72m
Water not struck
250mm percussion
September 1986

Overburden 0.7m
Mineral I 1.4m
Waste 2.1m
Bedrock 0.3m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil; sandy, silty and slightly clayey, some fine and coarse gravel clasts and rare cobbles, dark yellowish brown | 0.7 | 0.7 |
| Fluvioglacial sand and gravel | Sand; slightly pebbly in upper part with rare coarse gravel<br>Sand: medium with coarse and fine, quartz, feldspar, mica and lithic fragments with iron/manganese coats on some grains giving speckled appearance<br>Fines: disseminated silt and some silty bands, dark yellowish brown | 1.4 | 2.1 |
| Till | Diamicton; sandy clay matrix, soft to firm. Clasts up to small boulder size, including abundant quartz-biotite schist, especially near base, and some crystalline limestone. Dark yellowish brown | 2.1 | 4.2 |
| Dalradian | Schist, quartz-biotite, soft and very weathered angular and fragmented | 0.3+ | 4.5 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 7 | 90 | 3 | 0.7- 2.1 | 7 | 23 | 37 | 30 | 3 | trace | 0 |

NJ 72 NW 7 7400 2503 **Milton of Inverammsay, Garioch**

| | |
|---|---|
| Surface level c.+69m | Overburden 0.2m |
| Groundwater level c.+65.8m | Mineral I 3.0m |
| Pit | Waste 0.3m+ |
| September 1986 | |

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Fluvioglacial sand and gravel | Pebbly sand; cobble-bed at base<br>Gravel: fine with coarse up to 20mm, cobbles and small boulders below 3.0m, gneiss (some rotten), semipelite and vein-quartz<br>Sand: medium and coarse with some fine, angular to subangular quartz, feldspar and conspicuous and relatively large amount of mafic minerals, also some platy slate<br>Fines: little | 3.0 | 3.2 |
| | Diamicton; sandy silty clay, soft to firm, moderate yellowish brown (10 YR 5/4), scattered clasts up to cobble-size. Some seams of sand | 0.3+ | 3.5 |
| | Pit caving in below 3.2m | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 2 | 82 | 16 | 0.2- 1.2 | 1 | 3 | 31 | 38 | 26 | 1 | 0 |
| | | | 1.2- 3.0 | 2 | 12 | 42 | 34 | 10 | 0 | 0 |
| | | | 3.0- 3.2 | No grading data available | | | | | | |
| | | | Mean | 2 | 9 | 38 | 35 | 16 | trace | 0 |

**NJ 72 NE 1** **7682 2826** **Netherton of Mounie, Daviot**

| | |
|---|---|
| Surface level c.+81m | Overburden 0.7m |
| Water not struck | Mineral I 1.7m |
| Section and pit | Waste 2.8m+ |
| September 1986 | |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| | Diamicton; sandy gravelly clay with scattered clasts up to 250mm, angular to well rounded. Crude stratification towards base, some vertical clasts, sharp uneven base | 0.5 | 0.7 |
| Glacial sand and gravel | Gravel; very poorly sorted, crude stratification, some vertical clasts<br>Gravel: coarse and fine, cobbles up to 150mm, angular to subrounded, chiefly gabbroic rocks with amphibolite, dolerite, vein-quartz, quartzite and pelite<br>Sand: coarse with medium and some fine, angular to subangular quartz and feldspar with mafic minerals and pelite<br>Fines: clayey cuticles binding deposit in parts | 1.7 | .4 |
| Till | Diamicton; sandy silty clay, stiff but friable, pale yellowish brown (10 YR 5/4). Angular to subangular clasts up to 500mm, chiefly gabbroic rocks with dolerite, hornfels and semi-pelite. Unstratified | 2.8+ | 5.2 |
| | Includes 2.4m section in 3m-high mound | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 3 | 35 | 62 | 0.7- 2.4 | 3 | 3 | 14 | 18 | 17 | 17 | 28 |

NJ 72 NE 2 7728 2620 **Mill of Bourtie, Bourtie**

Surface level c.+67m
Groundwater level c.+64.4m
Pit
October 1986

Overburden 1.6m
Mineral I 1.9m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Made-ground in disused railway cutting | 0.2 | 0.2 |
| Alluvium | Diamicton; silty clayey sand, fine with medium and coarse, crumbly, moderate yellowish brown. Angular to subangular clasts up to 20mm of schistose semipelite, amphibolite and aplite | 1.1 | 1.3 |
| | Sand, fine-grained, silty, mafic-rich, pale grey | 0.1 | 1.4 |
| | Clay, silty with some fine-grained sand, firm, barely plastic, pale yellowish brown, rare disseminated peat. Unstratified | 0.2 | 1.6 |
| | Sandy gravel; crude horizontal bedding<br>Gravel: fine with some coarse, angular to subrounded amphibolite, schistose pelite, vein-quartz, pink granite, quartzite and rare platy slate<br>Sand: medium with coarse and some fine, angular to subangular feldspar, quartz amd mafic minerals, also rare platy pelite and slate<br>Fines: some disseminated silt, especially below 2.0m | 1.9+ | 3.5 |
| | Pit caving in below 2.0m. Ground possibly disturbed down to 1.3m | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 4 | 69 | 27 | 1.6- 3.5 | 4 | 9 | 35 | 25 | 21 | 6 | 0 |

NJ 72 NE 3 7724 2594 **Mill of Bourtie, Bourtie**

Surface level c.+68m
Water not struck
Pit
October 1986

Waste 1.2m
Bedrock 1.2m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| Till | Diamicton; gritty sandy clay, firm, crumbly, pale yellowish brown. Scattered clasts of amphibolite towards base | 1.2 | 1.2 |
| Caledonian | Amphibolite, coarse-grained, some quartz veining, decomposed to a clayey sand | 1.2+ | 2.4 |

NJ 72 SW 1 **7418 2389** **Inverarnsay, Garioch**

Surface level c.+67m
Water not struck
Pit
September 1986

| | |
|---|---|
| Overburden | 0.5m |
| Mineral I | 3.0m |
| Waste | 0.2m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, loam | 0.5 | 0.5 |
| Fluvioglacial sand and gravel | Pebbly sand; fining downwards<br>Gravel: rare fine, pelites<br>Sand: fining downwards from mainly coarse to mainly fine, angular to subangular quartz, feldspar and relatively large amount of mafic minerals and platy pelite<br>Fines: little above 2.5m, seams of silty fine-grained sand and rare seams (10mm) of clayey silt below 2.5m. Moderate yellowish brown (10 YR 5/4) | 3.0 | 3.5 |
| Glaciolacustrine deposits | Silt, clayey, soft to firm, massive, colour as above, possibly interbedded with fine-grained sand | 0.2+ | 3.7 |
| | Pit collapsing below 3.5m | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 3 | 89 | 8 | 0.5- 1.5 | 1 | 8 | 34 | 41 | 16 | 0 | 0 |
| | | | 1.5- 2.5 | 2 | 16 | 45 | 31 | 6 | 0 | 0 |
| | | | 2.5- 3.5 | 7 | 44 | 30 | 17 | 2 | 0 | 0 |
| | | | Mean | 3 | 23 | 36 | 30 | 8 | 0 | 0 |

NJ 72 SE 1 — 7576 2309 — **Conglas, Inverurie**

Surface level +57m
Water struck at +53.2m
200mm percussion
November 1986

Overburden 1.1m
Mineral I 1.7m
Waste 4.4m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil: brown silty loam | 0.6 | 0.6 |
| Alluvium | Silt, sandy, occasional fine gravel clasts, soft, moderate reddish brown (10 R 4/6) | 0.5 | 1.1 |
| | 'Clayey' sandy gravel; claybound in places<br>Gravel: fine with some coarse, angular to subangular, psammite, pelite, vein-quartz, basic igneous rocks and granite<br>Sand: medium with fine and coarse, subangular, lithic fragments, quartz and feldspar<br>Fines: disseminated silt and clay | 1.7 | 2.8 |
| Glaciolacustrine deposits | Silt, sandy, laminated, soft. Many fine silty sand lenses in top 0.3m. Many thin silty clay seams. Moderate reddish brown (10 R 4/6) with light olive grey (5 Y 5/2) | 1.0 | 3.8 |
| Till | Diamicton: clay, silty, sandy, locally cohesive, with angular to subangular clasts up to cobble grade of psammite and pelite with granite and basic igneous rocks | 3.4+ | 7.2 |
| | Borehole terminated for technical reasons | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 14 | 59 | 27 | 1.1- 2.8 | 14 | 17 | 21 | 21 | 23 | 4 | 0 |

**NJ 72 SE 2** **7569 2302** **Conglas Cottages, Inverurie**

Surface level c.+64m
Water not struck
Section and pit
October 1986

| | |
|---|---|
| Overburden | 0.1m |
| Mineral I | 1.0m |
| Waste | 3.6m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.1 | 0.1 |
| Fluvioglacial sand and gravel | Sand; unconsolidated<br>Gravel: rare fine, amphibolite and gabbro<br>Sand: medium with coarse and some fine, angular to subangular quartz, feldspar and conspicuous mafic minerals with rare platy slate<br>Fines: little | 1.0 | 1.1 |
| Glaciolacustrine deposits | Silt with fine-grained sand, micaceous, interbedded with clayey silt and ripple cross-laminated fine to medium-grained sand. Silt beds not clearly defined, 100-200mm thick, massive, firm but friable, moderate yellowish brown (10 YR 5/4) | 1.0 | 2.1 |
| | Sand, fine-grained, clean | 0.2 | 2.3 |
| | Silt, clayey, laminated, fining downwards into silty clay, firm, plastic, moderate yellowish brown (10 YR 5/4). Discrete laminae (less than 10mm) of very fine-grained micaceous sand | 2.1 | 4.4 |
| | Pebbly sand (Poor recovery)<br>Gravel: fine and coarse, cobbles up to 200mm, chiefly gneiss, mica-schist and quartz-schist<br>Sand: fine to medium, soft | 0.3+ | 4.7 |

Includes 1m-high section in small disused working

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 2 | 97 | 1 | 0.1- 1.1 | 2 | 12 | 56 | 29 | 1 | 0 | 0 |

**NJ 72 SE 3** **7540 2022** **Haughton, Kemnay**

Surface level c.+62m
Water not struck
Pit
September 1986

Overburden 1.2m
Mineral I 1.8m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Alluvium | Shingle, clasts up to 64mm, deposit pinching out eastwards | 0.4 | 0.6 |
| | Clay, silty, sandy, firm to crumbly, unstratified, moderate yellowish brown (10 YR 5/4) | 0.6 | 1.2 |
| | Gravel; clast-supported<br>Gravel: cobbles and boulders up to 350mm, coarse and fine, angular to well rounded pink and grey granite with gneiss (often rotten), quartzite and vein-quartz<br>Sand: coarse with medium and trace of fine, angular to subangular quartz and feldspar with platy pelitic schist. Yellowish brown<br>Fines: little | 1.8+ | 3.0 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 1 | 18 | 81 | 1.2- 3.0 | 1 | 1 | 6 | 11 | 6 | 16 | 59 |

**NJ 72 SE 4** **7543 2011** **Haughton, Kemnay**

Surface level c.+70m
Water not struck
Section and pit
September 1986

Overburden 0.2m
Mineral I 6.6m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Fluvioglacial sand and gravel | Gravel; horizontal beds (up to 200mm) of clast-supported gravel separated by low-angle cross-bedded pebbly sand<br>Gravel: coarse and fine, scattered cobbles and boulders up to 300mm. Interlocking boulders up to 500mm or larger below 5.8m. Subangular to subrounded pink and grey granites with psammites, gneiss, vein-quartz, ?amphibolite and semipelite<br>Sand: medium and coarse with some fine, angular to subangular quartz and feldspar<br>Fines: disseminated silt above 5.8m, heavy coatings of silt and clay below. Moderate yellowish brown (10 YR 5/4) | 6.6+ | 6.8 |
| | Includes 3.7m-high section in high river terrace | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 2 | 48 | 50 | 0.2- 1.2 | 1 | 5 | 25 | 19 | 18 | 27 | 5 |
| | | | 1.2- 2.2 | 1 | 3 | 26 | 26 | 18 | 26 | 0 |
| | | | 2.2- 3.7 | 1 | 3 | 32 | 27 | 13 | 15 | 9 |
| | | | 3.7- 4.7 | 2 | 5 | 19 | 17 | 18 | 28 | 11 |
| | | | 4.7- 5.8 | 1 | 4 | 14 | 24 | 16 | 16 | 25 |
| | | | 5.8- 6.8 | 4 | 6 | 12 | 14 | 15 | 19 | 30 |
| | | | Mean | 2 | 4 | 22 | 22 | 16 | 21 | 13 |

**NJ 72 SE 5** **7662 2350** **East Balhalgardy, Garioch**

Surface level +65m
Water not struck
250mm percussion
October 1986

| | |
|---|---|
| Overburden | 0.4m |
| Mineral I | 1.6m |
| Waste | 2.7m |
| Mineral I | 3.0m |
| Waste | 1.9m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil; silty, sandy loam, yellowish brown | 0.4 | 0.4 |
| Fluvioglacial sand and gravel | a Sand; some fine gravel in top metre<br>Sand: medium and fine with some coarse, subangular to subrounded, quartz, feldspar, lithic fragments and some mica<br>Fines: disseminated silt and clay, some cohesive layers in top part of deposit | 1.6 | 2.0 |
| Glaciolacustrine deposits | Silt; sandy, clayey, laminated, cohesive and plastic, wet in places. Yellowish to dark yellowish brown | 2.7 | 4.7 |
| | b 'Clayey' pebbly sand; some clay-bound layers<br>Gravel: fine, subangular to rounded<br>Sand: medium with coarse and fine, subangular to subrounded and rounded, quartz, lithic fragments and feldspar<br>Fines: disseminated silt and clay and some clay binding deposit in places. Yellowish brown | 1.0 | 5.7 |
| Glacial sand and gravel | c Pebbly sand; some cobbles towards base<br>Gravel: fine with trace of coarse, rare cobbles, subangular to subrounded vein-quartz, granitic and quartzose rocks and fine-grained metasediments<br>Sand: medium with coarse and fine, angular to subrounded, quartz, feldspar, mica and lithic fragments<br>Fines: disseminated silt, clay-bound in part, dark greyish brown | 2.0 | 7.7 |
| Till | Diamicton; silty sandy clay, firm to plastic with fine to cobble size clasts. Yellowish to dark yellowish brown | 1.9+ | 9.6 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 8 | 91 | 1 | 0.4- 1.4 | 6 | 24 | 55 | 13 | 2 | 0 | 0 |
| | | | | 1.4- 2.0 | 10 | 59 | 30 | 1 | 0 | 0 | 0 |
| | | | | Mean | 8 | 38 | 45 | 8 | 1 | 0 | 0 |
| b | 13 | 80 | 7 | 4.7- 5.7 | 13 | 20 | 37 | 23 | 7 | 0 | 0 |
| c | 2 | 80 | 18 | 5.7- 6.7 | 2 | 12 | 31 | 30 | 24 | 1 | 0 |
| | | | | 6.7- 7.7 | 2 | 11 | 49 | 26 | 12 | 0 | 0 |
| | | | | Mean | 2 | 12 | 40 | 28 | 18 | trace | 0 |
| a-c | 6 | 84 | 10 | Mean | 6 | 22 | 42 | 20 | 10 | trace | 0 |

**NJ 72 SE 6** **7623 2009** **Ardtannes, Inverurie**

Surface level +61m
Water struck at +58m
250mm percussion
October 1986

Overburden 0.4m
Mineral I 8.0m
Bedrock 0.1m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil; sandy loam, pebbly, yellowish brown | 0.4 | 0.4 |
| Alluvium | Gravel; very hard and compact with interlocking cobbles and boulders above 1.6m<br>Gravel: coarse and fine with some cobbles and small boulders, subangular to subrounded schist, fine-grained metasediments, quartzites, diorite-granitic rocks and vein-quartz<br>Sand: coarse and medium with some fine, angular to subrounded quartz, feldspar, mica and lithic fragments<br>Fines: disseminated silt and some clayey masses, dark yellowish brown | 8.0 | 8.4 |
| Dalradian | Gneiss; weathered and fractured | 0.1+ | 8.5 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm | |
| 1 | 47 | 52 | 0.4- 1.6 | No grading data available | | | | | | | |
| | | | 1.6- 3.0 | 2 | 3 | 14 | 17 | 22 | 34 | 8 | |
| | | | 3.0- 4.0 | 1 | 2 | 23 | 22 | 21 | 31 | 0 | § |
| | | | 4.0- 5.0 | 1 | 1 | 15 | 22 | 33 | 28 | 0 | § |
| | | | 5.0- 6.0 | 2 | 3 | 29 | 21 | 22 | 23 | 0 | § |
| | | | 6.0- 7.0 | 1 | 2 | 27 | 30 | 21 | 19 | 0 | § |
| | | | 7.0- 8.4 | 2 | 4 | 23 | 27 | 21 | 23 | 0 | § |
| | | | Mean | 1 | 3 | 21 | 23 | 23 | 27 | 2 | |

NJ 72 SE 7 7735 2312 **Portstown, Keithall**

Surface level +60m
Water struck at +52.8m
250mm and 200mm percussion
September 1986

| | |
|---|---|
| Overburden | 1.1m |
| Mineral I | 1.6m |
| Waste | 1.3m |
| Mineral | 5.2m |
| Waste | 1.9m |
| Mineral I | 0.6m |
| Waste | 0.5m |
| Mineral I | 1.0m |
| Bedrock | 0.8m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil; silty and clayey, cohesive, passing down into silty clay, pebbly at 0.3m. Dark yellowish brown to yellowish brown | 0.4 | 0.4 |
| Glaciolacustrine deposits | Clay, silty, with carbonaceous fragments, finely laminated, dry and crumbly. Some laminae are sandy towards base of deposit | 0.7 | 1.1 |
| | a 'Very clayey' pebbly sand; becomes more pebbly with depth, silty and clayey seams in top metre<br>Gravel: coarse and fine with some cobbles, subangular to subrounded metasediments and igneous rocks<br>Sand: fine with medium and some coarse, subangular to subrounded quartz, feldspar and mica<br>Fines: silt and clay, laminated and disseminated | 1.6 | 2.7 |
| Flow-till | Diamicton; sandy clay becoming less clayey with depth, with angular to subrounded cobbles and coarse gravel | 0.6 | 3.3 |
| | Diamicton; sandy clay matrix with angular to subangular clasts up to cobble grade of metasediment and quartzose rocks. Clay-bound cobble layer near base of deposit | 0.7 | 4.0 |
| Glacial sand and gravel | b Gravel; boulders at 9.2m<br>Gravel: fine and coarse with some cobbles, angular to rounded schist, quartzose rocks, dioritic rocks and vein-quartz<br>Sand: coarse and medium with some fine angular to subrounded quartz, feldspar and lithic fragments<br>Fines: disseminated silt and clay, dark brown | 5.2 | 9.2 |
| Till | Diamicton; sandy clay with abundant fine clasts of metasedimentary rocks, dark brownish to greenish grey | 1.9 | 11.1 |
| Glacial sand and gravel | c Sandy gravel<br>Gravel: fine with coarse and rare cobbles, angular to subrounded metasedimentary and igneous rocks<br>Sand: coarse with medium and fine, subangular to subrounded, quartz, feldspar and lithic fragments<br>Fines: disseminated silt and clay | 0.6 | 11.7 |
| Till | Diamicton; silty clay with clasts of heavily weathered schist up to cobble size, greyish brown | 0.5 | 12.2 |
| Glacial sand and gravel | d Sandy gravel; junction with underlying weathered bedrock is gradational<br>Gravel: coarse with fine and rare cobbles, subangular to subrounded quartz-biotite schist and some vein-quartz<br>Sand: medium with fine and coarse, angular to subrounded, quartz feldspar, mica and weathered rock fragments<br>Fines: disseminated silt | 1.0 | 13.2 |
| Dalradian | Quartz-biotite gneiss | 0.8+ | 14.0 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | | |
| | | | | from to | - 1/16 | + 1/16 - 1/4 | + 1/4 -1 | +1-4 | +4-16 | +16-64 | +64 mm | |
| a | 20 | 75 | 5 | 1.1- 2.1 | 23 | 56 | 19 | 2 | 0 | 0 | 0 | |
| | | | | 2.1- 2.7 | 15 | 35 | 31 | 6 | 5 | 8 | 0 | |
| | | | | Mean | 20 | 47 | 24 | 4 | 2 | 3 | 0 | |
| b | 5 | 45 | 50 | 4.0- 5.0 | 1 | 9 | 22 | 20 | 28 | 20 | 0 | |
| | | | | 5.0- 6.0 | 10 | 11 | 20 | 23 | 17 | 19 | 0 | |
| | | | | 6.0- 7.0 | 13 | 9 | 19 | 25 | 25 | 9 | 0 | |
| | | | | 7.0- 8.0 | 1 | 3 | 10 | 20 | 30 | 36 | 0 | § |
| | | | | 8.0- 9.2 | 1 | 9 | 16 | 11 | 15 | 31 | 17 | § |
| | | | | Mean | 5 | 8 | 17 | 20 | 23 | 23 | 4 | |
| c | 9 | 53 | 38 | 11.1-11.7 | 9 | 10 | 16 | 27 | 22 | 16 | 0 | § |
| d | 3 | 70 | 27 | 12.2-13.2 | 3 | 18 | 37 | 15 | 5 | 22 | 0 | § |
| a&b | 9 | 51 | 40 | Mean | 9 | 17 | 18 | 16 | 18 | 19 | 3 | |
| a-d | 8 | 54 | 38 | Mean | 8 | 17 | 21 | 16 | 17 | 19 | 2 | |

**NJ 72 SE 8** **7771 2317** **Portsdown, Inverurie**

Surface level +76m
Water not struck
Pit
September 1986

| | |
|---|---|
| Waste | 0.6m |
| Bedrock | 0.2m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| 'Hillwash' | Gravelly clayey sand: gravel clasts up to boulder size, coarse with medium and fine sand, pale yellowish brown | 0.4 | 0.6 |
| Dalradian | Gneiss with quartzo-feldspathic segregations | 0.2+ | 0.8 |

**NJ 72 SE 9** **7720 2274** **Uryside, Inverurie**

Surface level +56m
Water struck at +54.5m and +49.5m
250mm and 200mm percussion
September 1986

| | |
|---|---|
| Overburden | 1.5m |
| Mineral I | 2.0m |
| Waste | 4.0m |
| Mineral I | 1.9m |
| Waste | 1.6m |
| Mineral I | 3.3m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil; silty, clayey, slightly sandy soil, dark brown to grey flecked becoming yellowish brown with depth. Passes down gradually into underlying clay | 0.5 | 0.5 |
| Alluvium | Clay; soft, silty, some fine-grained sand and rare fine pebbles, yellowish and greyish brown | 1.0 | 1.5 |
| | a 'Very clayey' sandy gravel; clayey at top<br>Gravel: fine with coarse, angular to subangular schist, psammite, greywacke, vein-quartz, basic and acid igneous rocks<br>Sand: fine, coarse and medium, subangular to subrounded, quartz, feldspar and lithic fragments<br>Fines: silt and clay, disseminated and in masses. Silt layer from 2.9 to 3.2m. Bluish to dark brownish grey | 2.0 | 3.5 |
| Glaciolacustrine deposits | Silt; sandy, laminated, very clayey, plastic, dark yellowish brown | 4.0 | 7.5 |
| | b 'Clayey' sand; trace of fine gravel<br>Sand: fine with medium and trace of coarse, subangular to subrounded quartz, feldspar and lithic fragments<br>Fines: disseminated silt, yellowish brown | 1.9 | 9.4 |
| | Silt; sandy, with many clayey silt layers, and rare angular coarse gravel clasts at about 10.0m | 0.7 | 10.1 |
| Flow-till | Diamicton; sandy, clayey matrix with fine to cobble size clasts, yellowish brown | 0.9 | 11.0 |
| Glacial sand and gravel | c Gravel<br>Gravel: coarse with medium and some cobbles, with rare boulders below 11.9m, angular to subrounded schist, psammite, greywacke, granitic and dioritic rocks, and vein-quartz<br>Sand: coarse with medium and fine, angular to subangular, quartz, feldspar and lithic fragments<br>Fines: silt, disseminated, binding deposit from 12.9 to 13.0m | 3.3+ | 14.3 |

Borehole abundoned in mineral owing to technical difficulties

Grading

| | Mean for Deposit percentages: Fines | Sand | Gravel | Depth below surface (m) from to | percentages: Fines $-\frac{1}{16}$ | Sand $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | $+1-4$ | Gravel $+4-16$ | $+16-64$ | $+64$ mm | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a | 21 | 50 | 29 | 1.5- 2.5 | 29 | 25 | 19 | 13 | 6 | 8 | 0 | § |
| | | | | 2.5- 3.5 | 14 | 9 | 13 | 21 | 33 | 10 | 0 | § |
| | | | | Mean | 21 | 17 | 16 | 17 | 20 | 9 | 0 | |
| b | 15 | 85 | 0 | 7.5- 8.5 | 14 | 63 | 21 | 2 | 0 | 0 | 0 | § |
| | | | | 8.5- 9.4 | 17 | 63 | 18 | 1 | 1 | 0 | 0 | § |
| | | | | Mean | 15 | 64 | 19 | 2 | trace | 0 | 0 | |
| c | 4 | 41 | 55 | 11.0-11.9 | 4 | 12 | 22 | 20 | 18 | 24 | 0 | § |
| | | | | 11.9-12.9 | 6 | 4 | 4 | 17 | 12 | 42 | 15 | § |
| | | | | 12.9-14.3 | 4 | 15 | 14 | 15 | 15 | 33 | 4 | § |
| | | | | Mean | 4 | 11 | 13 | 17 | 15 | 34 | 6 | |
| a-c | 12 | 55 | 33 | Mean | 12 | 27 | 15 | 13 | 12 | 18 | 3 | |

NJ 72 SE 10 — 7760 2204 — **Uryside, Inverurie**

Surface level +57m
Water struck at +55.4m and +48.8m
250mm percussion
October 1986

| | |
|---|---|
| Overburden | 1.6m |
| Mineral I | 3.2m |
| Waste | 6.1m+ |

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil; sandy silty pebbly loam, more gravelly and clayey with depth to 1.3m. Cohesive in part, friable, dark brown | 1.3 | 1.3 |
| Alluvium | Silt; fine-grained sand in layers; laminated with some plant debris, orange brown to grey and dark brown | 0.3 | 1.6 |
| Fluvioglacial sand and gravel | a 'Clayey' sand: some fine and rare coarse pebbles<br>Sand: fine with medium and some coarse, quartz, feldspar, mica and some lithic fragments<br>Fines: disseminated silt, orange to greyish yellowish brown | 3.2 | 4.8 |
| Glaciolacustrine deposits | Silt; fine sandy, laminated, dry, friable, micaceous, plastic and cohesive, becoming more clayey with depth, dark brown to grey | 3.4 | 8.2 |
| | b 'Very clayey' sand; trace of fine gravel<br>Sand: fine with some medium and coarse, subangular to subrounded quartz, feldspar, mica and lithic fragments<br>Fines: disseminated silt, dark grey | 0.6 | 8.8 |
| | Silt; laminated, clayey, dark greenish grey | 0.4 | 9.2 |
| Till | Diamicton: sandy clay, angular to subrounded clasts up to cobble size, dark yellowish brown to grey | 1.7+ | 10.9 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm | |
| a | 13 | 86 | 1 | 1.6- 2.6 | 12 | 36 | 37 | 12 | 3 | 0 | 0 | § |
| | | | | 2.6- 3.6 | 15 | 61 | 22 | 2 | 0 | 0 | 0 | § |
| | | | | 3.6- 4.8 | 12 | 39 | 49 | 0 | 0 | 0 | 0 | § |
| | | | | Mean | 13 | 44 | 37 | 5 | 1 | trace | 0 | |
| b | 22 | 78 | 0 | 8.2- 8.8 | 22 | 69 | 8 | 1 | trace | 0 | 0 | § |
| a&b | 14 | 85 | 1 | Mean | 14 | 49 | 32 | 4 | 1 | trace | 0 | |

**NJ 72 SE 11** | **7816 2172** | **Souterford, Keithall**

| | |
|---|---|
| Surface level c.54m | Waste 3.0m+ |
| Water not struck | |
| Pit | |
| September 1986 | |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Till | Diamicton; sandy clay matrix, firm becoming stiff to very stiff downwards, mnoderate yellowish brown (10 YR 5/4). Angular to subrounded clasts up to 500mm, chiefly gneiss and amphibolite with some vein-quartz and granite. Unstratified | 2.8+ | 3.0 |

**NJ 72 SE 12** | **7837 2064** | **Urie Cottage, Keithall**

| | | |
|---|---|---|
| Surface level c.+62m | Overburden | 0.3m |
| Water struck at c.+56.3m | Mineral I | 2.1m |
| Section and pit | Waste | 0.2m |
| September 1986 | Mineral I | 3.2m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.3 | 0.3 |
| Fluvioglacial sand and gravel | a Sandy gravel; mostly clast-supported and channeled into underlying deposit<br>Gravel: fine with coarse, chiefly subangular to rounded pink and grey granites with some quartzites, vein-quartz, amphibolite and psammite<br>Sand: coarse with medium, angular to subangular quartz and feldspar<br>Fines: little, yellowish-brown | 1.1 | 1.4 |
| | b Sand; horizontally bedded<br>Sand: medium with fine and trace of coarse, angular to subangular quartz and feldspar. Some mafic and mica-rich laminae<br>Fines: some silt laminae becoming more common downwards | 1.0 | 2.4 |
| Glaciolacustrine deposits | Silt with very fine-grained sand passing down into micaceous silty clay, finely laminated and rippled, firm, pale olive grey (5 Y 5/2) | 0.2 | 2.6 |
| | c 'Clayey' sand<br>An interbedded sequence of sand, as in deposit (b) and in 300 to 500mm-thick beds, with fine sandy silt, in 200mm beds, and finely laminated silty clay, moderate yellowish brown (10 YR 5/4). Sands display fine ripple-drift cross-lamination | 3.2+ | 5.8 |

Pit dug at foot of 2.3m-high section

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 1 | 73 | 26 | 0.3- 1.4 | 1 | 1 | 31 | 41 | 20 | 6 | 0 |
| b | 2 | 97 | 1 | 1.4- 2.4 | 2 | 40 | 53 | 4 | 1 | 0 | 0 |
| c | 12 | 87 | 1 | 2.6- 4.2 | 6 | 40 | 46 | 6 | 2 | 0 | 0 |
| | | | | 4.2- 5.8 | 18 | 62 | 17 | 3 | 0 | 0 | 0 |
| | | | | Mean | 12 | 51 | 31 | 5 | 1 | 0 | 0 |
| a&b | 1 | 85 | 14 | Mean | 1 | 20 | 42 | 23 | 11 | 3 | 0 |
| a-c | 8 | 86 | 6 | Mean | 8 | 39 | 35 | 12 | 5 | 1 | 0 |

**NJ 72 SE 13** **7813 2038** **The Stanners, Inverurie**

Surface level +54m
Water struck at +51.7m and +49.5m
250mm percussion
September 1986

| | |
|---|---|
| Overburden | 1.6m |
| Mineral I | 2.0m |
| Waste | 0.9m |
| Mineral II | 1.0m |
| Waste | 2.3m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil; silty sandy loam, clayey and cohesive with some fine and coarse pebbles, passing down gradually into sandy silty clayey subsoil. More gravelly to 1.6m | 1.6 | 1.6 |
| Alluvium | a Sandy gravel; with boulders from 2.3m, clayey in top metre<br>Gravel: coarse and fine with some cobbles, subangular to rounded schists and other fine-grained metasediments, granitic rocks and vein-quartz<br>Sand: coarse and medium with fine, subangular to subrounded quartz, feldspar, and lithic fragments<br>Fines: disseminated silt and clay, dark yellowish brown | 2.0 | 3.6 |
| Glaciolacustrine deposits | Silt; faintly laminated, plastic, clayey and with some fine-grained sand, grey | 0.9 | 4.5 |
| ?Till | 'Clayey' sandy gravel<br>Gravel: fine and coarse with some cobbles, angular to subrounded schist, granitic and dioritic rocks and vein-quartz<br>Sand: medium and coarse with fine, subangular to subrounded, quartz, feldspar, and lithic fragments<br>Fines: disseminated silt and clay binding deposit in places, dark yellowish brown | 1.0 | 5.5 |
| Till | Diamicton; sandy clay, firm to hard, with fine to coarse angular to subrounded clasts, dark greyish yellow | 2.3+ | 7.8 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm | |
| a | 6 | 53 | 41 | 1.6- 2.3 | 13 | 18 | 20 | 7 | 20 | 22 | 0 | |
| | | | | 2.3- 3.6 | 2 | 9 | 26 | 22 | 17 | 18 | 6 | § |
| | | | | Mean | 6 | 12 | 24 | 17 | 18 | 19 | 4 | |
| b | 11 | 52 | 37 | 4.5- 5.5 | 11 | 11 | 19 | 22 | 23 | 14 | 0 | § |
| a&b | 8 | 51 | 41 | Mean | 8 | 12 | 21 | 18 | 20 | 18 | 3 | |

BANCHORY/STONEHAVEN RESOURCE SHEET

**NO 79 NW 1** **7069 9905** **North of Newton, Banchory** **Block A**

Surface level c+90m
Water not struck
Pit
September 1986

Waste 0.8m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy and silty, scattered pebbles | 0.3 | 0.3 |
| Till | Diamicton, clayey sand and silt, firm to very firm, rounded clasts up to boulder size, of pink and red granite; moderate olive brown (5 Y 4/4) to light olive (10 Y 5/4) | 0.5+ | 0.8 |
| | Pit abandoned | | |

**NO 79 NW 2** **7069 9905** **Newton, Banchory** **Block A**

Surface level c+76m
Water not struck
Pit
September 1986

Waste 3.0m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| Peat | Peat, fibrous, soft, becoming more silty with depth; fragments of pine wood, bark, reeds and rushes, dusky yellowish brown (10 YR 2/2) | 2.2 | 2.2 |
| Glaciolacustrine deposits | Clay, silty, soft, waxy, humic in part, with horizontal lamination; olive grey (5 Y 4/4) | 0.8+ | 3.0 |

**NO 79 NW 3** **7067 9814** **Catterloch Croft, Banchory** **Block A**

Surface level c+77m
Water not struck
Pit
September 1986

Waste 3.2m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy and humic, scattered pebbles | 0.5 | 0.5 |
| Alluvium | Clay, silty, firm, occasional rounded pebbles, light olive grey (5 Y 5/2), mottled with strong yellowish orange (10 YR 5/6) | 0.5 | 1.0 |
| Flow-till | Diamicton, sandy clay, stiff, angular pebbles and boulders of igneous and metamorphic rocks, becoming more pebbly with depth; olive grey (5 Y 4/2), mottled with moderate olive brown (5 Y 4/5) | 1.2 | 2.2 |
| Till | Diamicton, stony clay, compact, waxy; tabular and rounded cobbles of schist, granodiorite, grey granite and sparse fine-grained basic igneous rock; olive grey (5 Y 4/2) | 1.0+ | 3.2 |

**NO 79 NW 4** **7096 9777** **East of Loch of Leys, Banchory** **Block A**

Surface level c+78m
Water not struck
Pit
September 1986

Waste 0.5m
Bedrock 0.3+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, silty and sandy, abundant fragments of bedrock below 0.2m depth | 0.5 | 0.5 |
| Dalradian | Migmatitic pelite, weathered to dusky yellow (5 Y 6/4), sandy clay in top 20cm | 0.3+ | 0.8 |

NO 79 NW 5 | 7038 9526 | **Bridge of Feugh, Banchory** | **Block B**

Surface level +49m
Water struck at +43.6m
250mm percussion
October 1986

Overburden 0.4m
Mineral I 8.8m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil: brown loam with cobbles | 0.4 | 0.4 |
| Fluvioglacial sand and gravel | a Gravel<br>Gravel: cobble and coarse with fine, well rounded to subangular, psammite and pelite, with granite and basic igneous<br>Sand: medium, with coarse and fine, subangular, quartz and lithic fragments<br>Fines: silt and clay, disseminated, moderate brown (10 YR 4/4) | 2.2 | 2.6 |
| | b Sandy gravel<br>Gravel: fine and coarse with some cobble, generally subrounded with subangular, cobbles are well rounded; coarse-grained red, pink and grey granite, felsite, quartzite, psammite and pelite<br>Sand: medium with coarse and some fine, sharp, granite fragments, quartz and feldspar<br>Fines: silt and clay, disseminated, moderate to pale yellowish brown (10 YR 5/2 to 10 YR 6/2). Clayey silt bed at 8.3m | 6.6+ | 9.2 |
| | Borehole terminated for technical reasons | | |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | -- | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm | |
| a | 4 | 24 | 72 | 0.4- 1.4 | 4 | 5 | 8 | 11 | 13 | 32 | 27 | |
| | | | | 1.4- 2.6 | No grading data available | | | | | | | |
| | | | | Mean | 4 | 5 | 8 | 11 | 13 | 32 | 27 | |
| b | 6 | 47 | 47 | 2.6- 3.6 | 13 | 11 | 19 | 20 | 22 | 15 | 0 | |
| | | | | 3.6- 5.3 | 7 | 8 | 15 | 15 | 22 | 18 | 15 | |
| | | | | 5.3- 6.5 | 7 | 9 | 20 | 17 | 21 | 26 | 0 | § |
| | | | | 6.5- 7.5 | 4 | 5 | 20 | 24 | 22 | 19 | 6 | § |
| | | | | 7.5- 8.5 | 1 | 3 | 12 | 26 | 19 | 26 | 13 | § |
| | | | | 8.5- 9.2 | 2 | 4 | 35 | 34 | 17 | 8 | 0 | § |
| | | | | Mean | 6 | 7 | 19 | 21 | 21 | 19 | 7 | |
| a&b | 6 | 41 | 53 | Mean | 6 | 6 | 16 | 19 | 19 | 22 | 12 | |

| | | | |
|---|---|---|---|
| **NO 79 NW 6** | **7121 9956** | **Cairnievhin, Banchory** | **Block A** |

Surface level c+97m
Water not struck
Pit
September 1986

| | |
|---|---|
| Waste | 0.7m |
| Bedrock | 0.2m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, silty, abundant pebbles | 0.5 | 0.5 |
| Till | Diamicton, gravel and clay, very stiff, poorly developed stratification; pebbles of pink and grey coarse-grained granodiorite; dusky yellow (5 Y 6/4) | 0.2 | 0.7 |
| Caledonian | Granodiorite, coarse-grained, weathered in part to coarse sand | 0.2+ | 0.9 |

| | | | |
|---|---|---|---|
| **NO 79 NW 7** | **7135 9882** | **Catterloch, Banchory** | **Block A** |

Surface level c+82m
Water not struck
Pit
September 1986

| | |
|---|---|
| Overburden | 0.3m |
| Mineral I | 0.4m |
| Mineral II | 2.3m |
| Waste | 0.3m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sand with rounded pebbles | 0.3 | 0.3 |
| Glacial sand and gravel | a Sandy gravel<br>Gravel: mainly coarse, rounded pink granite and grey granodiorite<br>Sand: medium, with fine and coarse, subangular quartz and rock<br>Fines: silt, disseminated, prominent iron stain; dark orange | 0.4 | 0.7 |
| Flow-till | b 'Clayey' sandy gravel; unstratified, poorly sorted, matrix supported, with boulders up to 0.8m<br>Gravel: cobble, with coarse and fine; subangular granite, semipelite, fine-grained basic rock and intermediate coarse-grained grey plutonic rock<br>Sand: medium with fine and coarse, subangular to angular quartz, granite and rock<br>Fines: silt and clay, disseminated, binding deposit; pale yellowish brown (10 YR 6/2) | 2.3 | 3.0 |
| Till | Diamicton, clay, sand and silt, with boulders up to 0.5m, stiff, matrix supported; clasts of granite, granodiorite and fine-grained acid volcanic rock; moderate brown (5 YR 4/4) | 0.3+ | 3.3 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1–4 | +4–16 | +16–64 | +64 mm |
| a | 3 | 52 | 45 | 0.3– 0.7 | 3 | 10 | 25 | 17 | 16 | 29 | 0 |
| b | 10 | 46 | 44 | 0.7– 3.0 | 10 | 13 | 21 | 12 | 9 | 13 | 22 |
| a&b | 9 | 46 | 45 | Mean | 9 | 13 | 21 | 12 | 10 | 15 | 20 |

NO 79 NW 8 | 7152 9714 | **Burn of Bennie, Banchory** | **Block A**

Surface level c+61m
Water struck at +60m
Pit
September 1986

Overburden 0.3m
Mineral I 1.4m
Waste 0.2m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| Lacustrine alluvium | Silt, humic, becoming micaceous and laminated with depth, dusky yellowish brown (10 YR 2/2) | 0.3 | 0.3 |
| | a Sandy gravel, with poorly developed horizontal stratification<br>Gravel: fine, pink and red granite, fine-grained acid volcanic rock and sparse vein-quartz<br>Sand: mainly medium and coarse, granitic rock<br>Fines: silt, as thin beds, especially towards the top; light olive grey (5 Y 5/2), becoming greyish red (5 R 5/2) towards the base | 0.7 | 1.0 |
| | b Gravel<br>Gravel: coarse and fine, subangular red granite, semipelite, granodiorite and tabular pelitic schist<br>Sand: coarse and medium, angular granite<br>Fines: silt, disseminated and coating pebbles; light brown (5 YR 5/6) | 0.7 | 1.7 |
| Till | Diamicton, stony clay, stiff, mottled orange and moderate brown (5 YR 4/4); abundant boulders | 0.2+ | 1.9 |
| | Pit collapsing below water-table | | |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm | |
| a | 4 | 69 | 27 | 0.3- 1.0 | 4 | 4 | 35 | 30 | 22 | 5 | 0 | |
| b | 4 | 45 | 51 | 1.0- 1.7 | 4 | 4 | 18 | 23 | 23 | 26 | 2 | § |
| a&b | 4 | 57 | 39 | Mean | 4 | 4 | 26 | 27 | 23 | 15 | 1 | |

| NO 79 NW 9 | 7140 9591 | Birkwood, Banchory | Block B |
|---|---|---|---|

Surface level +47m
Water struck at +42.5m
250mm percussion
October 1986

Overburden 0.4m
Mineral I 4.1m
Mineral II 2.0m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil: loam, sandy, gravelly, brown, many cobbles | 0.4 | 0.4 |
| Fluvioglacial sand and gravel | a 'Clayey' gravel, many cobbles and boulders<br>Gravel: cobble and coarse with some fine, well rounded with subrounded, psammite and pelite, with granite<br>Sand: fine, medium and coarse, subangular, quartz and lithic fragments<br>Fines: sparse disseminated silt, moderate brown (5 YR 4/4), becoming moderate yellowish brown (10 YR 5/4) by 3.4m | 4.1 | 4.5 |
| Flow-till | b Gravel<br>Gravel: fine and coarse, with generally angular to subangular cobbles; psammite and pelite, with granite, basic igneous rocks and vein-quartz<br>Sand: coarse, subangular, lithic fragments and quartz<br>Fines: silt and clay, disseminated (mostly washed out by drilling action), moderate yellowish brown (10 YR 5/4) | 2.0+ | 6.5 |
| | Borehole terminated owing to slow progress | | |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm | |
| a | 11 | 34 | 55 | 0.4- 1.4 | 8 | 4 | 7 | 8 | 10 | 21 | 42 | |
| | | | | 1.4- 3.4 | 14 | 11 | 14 | 14 | 17 | 14 | 16 | |
| | | | | 3.4- 4.5 | 7 | 7 | 14 | 19 | 21 | 25 | 7 | |
| | | | | Mean | 11 | 8 | 12 | 14 | 16 | 19 | 20 | |
| b | 2 | 40 | 58 | 4.5- 5.7 | No grading data available | | | | | | | |
| | | | | 5.7- 6.5 | 2 | 4 | 16 | 20 | 28 | 27 | 3 | § |
| | | | | Mean | 2 | 4 | 16 | 20 | 28 | 27 | 3 | |
| a&b | 8 | 37 | 55 | Mean | 8 | 7 | 14 | 16 | 20 | 21 | 14 | |

**NO 79 NW 10** **7223 9953** **North of Lightwood, Banchory** **Block A**

Surface level c+98m
Water not struck
Pit
September 1986

Waste 2.0m
Bedrock 0.5m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sand and silt with angular boulders | 0.3 | 0.3 |
| Till | Diamicton, clay and sand, very compact, unstratified; pebbles and large boulders of coarse-grained pink granite with feldspar phenocrysts, diorite and weathered medium-grained basic rock in a matrix of granitic sand and silty clay; moderate yellowish brown (10 YR 5/4) | 1.7 | 2.0 |
| Caledonian | Granite, coarse-grained, deeply weathered, greyish pink (5 R 7/2) | 0.5+ | 2.5 |

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**NO 79 NW 11** **7225 9915** **Bush Croft, Banchory** **Block A**

Surface level c+77m
Water not struck
Pit
September 1986

Overburden 0.3m
Mineral I 0.9m
Mineral II 2.2m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy gravel | 0.3 | 0.3 |
| Fluvioglacial sand and gravel | a Gravel, horizontally bedded, moderately to well sorted<br>Gravel: fine with coarse and cobble, subangular coarse and medium-grained red granite, grey granite and sparse subrounded and tabular schistose semipelite<br>Sand: coarse and medium, angular granite<br>Fines: silt, disseminated | 0.9 | 1.2 |
| Caledonian | b 'Clayey' pebbly sand (deeply weathered granite bedrock)<br>Gravel: fine angular granite fragments<br>Sand: coarse, medium and fine disagregated granite, quartz and feldspar crystals<br>Fines: kalonitic clay, binding deposit; light grey (N7) | 2.2+ | 3.4 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 1 | 45 | 54 | 0.3- 1.2 | 1 | 3 | 21 | 21 | 23 | 19 | 12 |
| b | 10 | 68 | 22 | 1.2- 3.4 | 10 | 11 | 24 | 33 | 20 | 2 | 0 |
| a&b | 7 | 62 | 31 | Mean | 7 | 8 | 24 | 30 | 21 | 7 | 3 |

**NO 79 NW 12** **7207 9612** **Maryfield, Banchory** **Block B**

Surface level +47m
Water struck at +36.6m
250 and 200mm percussion
September 1986

Overburden 0.4m
Mineral 14.5m
Waste 0.3m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil: sandy, dusky yellowish brown (10 YR 2/2) with well rounded granite and subangular psammite cobbles | 0.4 | 0.4 |
| Fluvioglacial sand and gravel | a Gravel<br>Gravel: coarse and cobble, with fine, cobbles are generally well rounded, other grades are well rounded to subangular. Psammite, pelite and pink granite, with basic igneous rocks and vein-quartz<br>Sand: fine to coarse, angular, lithic fragments<br>Fines: silt, disseminated, moderate yellowish brown (10 YR 5/4) | 1.3 | 1.7 |
| | b Gravel<br>Gravel: coarse with fine and some cobble, generally subrounded with subangular, cobbles tend to be well rounded; pink granite, psammite, pelite, felsite, basic igneous rocks, vein-quartz and quartzite<br>Sand: medium and coarse, with fine, subangular with subrounded, lithic fragments and quartz<br>Fines: silt and clay, disseminated, moderate yellowish brown (10 YR 5/4) | 11.5 | 13.2 |
| | c Pebbly sand<br>Gravel: fine with coarse, subrounded, granite, psammite and pelite, with felsite, basic igneous rocks, vein-quartz and quartzite<br>Sand: medium, with coarse and fine, subangular, lithic fragments (mainly granite), and quartz<br>Fines: silt and clay, disseminated; thin laminated silt bed at 14.9m, moderate yellowish brown (10 YR 5/4) | 1.7 | 14.9 |
| Till | Diamicton: clay, silty, sandy, light olive brown (5 Y 5/6); coarse gravel and cobble grade clasts, chiefly psammite with pelite and granite | 0.3+ | 15.2 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1−4 | +4−16 | +16−64 | +64 mm | |
| a | 4 | 20 | 76 | 0.4- 1.7 | 4 | 6 | 8 | 6 | 9 | 37 | 30 | |
| b | 2 | 42 | 56 | 1.7- 2.7 | 5 | 10 | 25 | 13 | 20 | 27 | 0 | |
| | | | | 2.7- 4.3 | 2 | 2 | 11 | 25 | 27 | 33 | 0 | |
| | | | | 4.3- 5.5 | 2 | 3 | 11 | 19 | 25 | 35 | 5 | |
| | | | | 5.5- 6.5 | 3 | 7 | 15 | 19 | 24 | 32 | 0 | |
| | | | | 6.5- 8.3 | 1 | 3 | 9 | 21 | 20 | 36 | 10 | |
| | | | | 8.3- 9.4 | 2 | 5 | 21 | 26 | 17 | 24 | 5 | |
| | | | | 9.4-10.4 | 1 | 3 | 19 | 26 | 18 | 33 | 0 | |
| | | | | 10.4-11.9 | 2 | 5 | 29 | 26 | 17 | 21 | 0 | § |
| | | | | 11.9-13.2 | 2 | 3 | 21 | 16 | 15 | 29 | 14 | § |
| | | | | Mean | 2 | 4 | 17 | 21 | 20 | 32 | 4 | |
| c | 2 | 79 | 19 | 13.2-14.0 | 1 | 7 | 42 | 32 | 14 | 4 | 0 | § |
| | | | | 14.0-14.9 | 3 | 17 | 43 | 17 | 10 | 10 | 0 | § |
| | | | | Mean | 2 | 12 | 43 | 24 | 12 | 7 | 0 | |
| a&b | 2 | 40 | 58 | Mean | 2 | 4 | 16 | 20 | 19 | 32 | 7 | |
| b&c | 2 | 48 | 50 | Mean | 2 | 5 | 21 | 22 | 19 | 27 | 4 | |
| a-c | 2 | 44 | 54 | Mean | 2 | 5 | 19 | 20 | 18 | 30 | 6 | |

NO 79 NW 13 | 7239 9616 | **Knappach Toll, Banchory** | **Block B**

Surface level +42m
Water struck at +38.2m
250 and 200mm percussion
September 1986

Overburden 0.4m
Mineral I 11.1m
Waste 0.4m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil: brown sandy loam | 0.4 | 0.4 |
| Fluvioglacial sand and gravel | a Sandy gravel with sparse sand seams<br>Gravel: fine and coarse with occasional cobble, generally subrounded with subangular, some angular, granite, psammite and pelite, with basic igneous rocks, vein-quartz, quartzite and felsite<br>Sand: medium and coarse with some fine, subangular, quartz and lithic fragments<br>Fines: silt and clay, disseminated, moderate brown (5 YR 4/4) | 6.4 | 6.8 |
| | b Sand, with scattered pebbles<br>Gravel: fine with coarse, subrounded with subangular, predominantly psammite and pelite, with granite, basic igneous rocks and vein-quartz<br>Sand: medium, with fine and coarse, subangular to subrounded, quartz and lithic fragments<br>Fines: silt and clay, disseminated, moderate brown (5 YR 4/4) | 4.7 | 11.5 |
| Till | Diamicton: clay, silty, sandy, with clasts (up to coarse gravel grade) of granite, with psammite and pelite | 0.4+ | 11.9 |
| | Borehole terminated on a rock obstruction | | |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 3 | 51 | 46 | 0.4- 1.4 | 2 | 5 | 24 | 12 | 17 | 40 | 0 |
| | | | | 1.4- 2.5 | 6 | 6 | 19 | 13 | 21 | 26 | 9 |
| | | | | 2.5- 3.5 | 3 | 4 | 14 | 9 | 14 | 26 | 30 |
| | | | | 3.5- 4.5 | 4 | 19 | 61 | 9 | 6 | 1 | 0 § |
| | | | | 4.5- 5.7 | 1 | 4 | 32 | 17 | 20 | 26 | 0 § |
| | | | | 5.7- 6.8 | 1 | 5 | 30 | 25 | 21 | 18 | 0 § |
| | | | | Mean | 3 | 7 | 30 | 14 | 17 | 23 | 6 |
| b | 1 | 96 | 3 | 6.8- 8.0 | 1 | 22 | 75 | 1 | 1 | 0 | 0 § |
| | | | | 8.0- 9.4 | 1 | 19 | 73 | 6 | 1 | 0 | 0 § |
| | | | | 9.4-10.6 | 2 | 19 | 70 | 7 | 2 | 0 | 0 § |
| | | | | 10.6-11.5 | 1 | 7 | 71 | 12 | 4 | 5 | 0 § |
| | | | | Mean | 1 | 17 | 73 | 6 | 2 | 1 | 0 |
| a&b | 2 | 70 | 28 | Mean | 2 | 11 | 48 | 11 | 10 | 14 | 4 |

| NO 79 NW 14 | 7282 9599 | East of River Belt, Banchory | Block B |
|---|---|---|---|

Surface level c+50m
Water struck at +42.5m
Section and pit
September 1986

Overburden 0.5m
Mineral I 7.0m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sand and pebbles | 0.5 | 0.5 |
| Fluvioglacial sand and gravel | a Gravel; well developed subhorizontal stratification, moderately to well sorted, becoming more sandy with depth<br>Gravel: coarse, fine and cobble, mainly subrounded coarse-grained pink, red and grey granite, with some semipelite and fine-grained basic igneous rock<br>Sand: mainly coarse, angular granite<br>Fines: silt, disseminated, pale reddish brown (10 R 5/4) | 4.3 | 4.8 |
| | b Sandy gravel<br>Gravel: mainly fine, subrounded granite<br>Sand: coarse, with some medium, angular granite<br>Fines: silt disseminated; moderate reddish brown (10 R 3/6) | 1.7 | 6.5 |
| | c Gravel; becoming silty towards the base<br>Gravel: cobble and coarse, with some fine, subangular to subrounded, granodiorite and coarse-grained granite<br>Sand: fine, medium and coarse, subangular quartz<br>Fines: silt with some clay, disseminated; a thin bed of laminated silt towards the base; pale yellowish brown (10 YR 6/2) | 1.0+ | 7.5 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 1 | 37 | 62 | 0.5- 1.6 | 1 | 2 | 13 | 14 | 15 | 34 | 21 |
| | | | | 1.6- 2.6 | 2 | 1 | 6 | 14 | 19 | 41 | 17 |
| | | | | 2.6- 3.3 | 1 | 2 | 21 | 25 | 21 | 22 | 8 |
| | | | | 3.3- 4.8 | 1 | 2 | 17 | 30 | 25 | 20 | 5 |
| | | | | Mean | 1 | 1 | 14 | 22 | 20 | 30 | 12 |
| b | 2 | 68 | 30 | 4.8- 6.5 | 2 | 1 | 23 | 44 | 25 | 5 | 0 |
| c | 7 | 42 | 51 | 6.5- 7.5 | 7 | 17 | 13 | 12 | 11 | 19 | 21 |
| a&b | 1 | 46 | 53 | Mean | 1 | 1 | 16 | 29 | 22 | 22 | 9 |
| b&c | 3 | 59 | 38 | Mean | 3 | 7 | 19 | 33 | 20 | 10 | 8 |
| a–c | 2 | 45 | 53 | Mean | 2 | 4 | 16 | 25 | 20 | 22 | 11 |

**NO 79 NW 15** **7225 9580** **Maryfield, Banchory** **Block C**

Surface level c+63m
Water not struck
Pit
September 1986

Waste 1.2m
Bedrock 0.1m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, silty sand | 0.3 | 0.3 |
| Till | Diamicton, clay, sand and silt, very stiff, poorly developed stratification; rounded and subangular boulders of granodiorite, weathered schist and fine-grained basic igneous rock, moderate yellowish brown (10 YR 5/3) | 0.9 | 1.2 |
| ?Caledonian | Grey rock, large angular blocks (no sample recovery) | 0.1+ | 1.3 |
| | Pit terminated on rock obstruction, probably bedrock | | |

**NO 79 NW 16** **7453 9963** **North of Myrebird Plantation, Banchory** **Block A**

Surface level +70m
Water struck at +67.9m
250 and 200mm percussion
November 1986

Overburden 0.4m
Mineral I 5.9m
Waste 3.8m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, silt and sand | 0.4 | 0.4 |
| Lacustrine alluvium | a Pebbly sand<br>Gravel: coarse and fine, angular pelite and fine-grained basic rock<br>Sand: mainly medium and fine, well rounded to subrounded, quartz and sparse feldspar<br>Fines: silt, disseminated, pale yellowish brown (10 YR 6/2), becoming light grey (5 Y 5/2) below the water table | 2.6 | 3.0 |
| Glaciolacustrine deposits | b 'Clayey' sand, with sparse pebbles; more micaceous with depth<br>Sand: mainly fine and medium rounded quartz, some mica and granite<br>Fines: silt, disseminated, olive grey (5 Y 5/1) | 3.3 | 6.3 |
| | Silt, slightly sandy, micaceous; becoming clayey and finely laminated below 7.0m depth; greyish olive (10 Y 4/2) | 3.8+ | 10.1 |
| | Borehole terminated; silt jamming between 250 and 200mm casing | | |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}$ -1 | +1-4 | +4-16 | +16-64 | +64 mm | |
| a | 5 | 89 | 6 | 0.4- 2.3 | 5 | 36 | 41 | 10 | 2 | 6 | 0 | |
| | | | | 2.3- 3.0 | 5 | 34 | 46 | 13 | 2 | 0 | 0 | § |
| | | | | Mean | 5 | 35 | 43 | 11 | 2 | 4 | 0 | |
| b | 10 | 88 | 2 | 3.0- 5.2 | 9 | 41 | 35 | 13 | 2 | 0 | 0 | § |
| | | | | 5.2- 6.3 | 12 | 53 | 28 | 6 | 1 | 0 | 0 | § |
| | | | | Mean | 10 | 45 | 32 | 11 | 2 | 0 | 0 | |
| a&b | 8 | 88 | 4 | Mean | 8 | 40 | 37 | 11 | 2 | 2 | 0 | |

**NO 79 NW 17** **7439 9891** **Myrebird Farm, Banchory** **Block A**

Surface level c+73m
Water struck at +71.5m
Pit
October 1986

| | |
|---|---|
| Overburden | 0.4m |
| Mineral I | 1.2m |
| Waste | 1.8m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, silty sand | 0.4 | 0.4 |
| Lacustrine alluvium | 'Clayey' sand, becoming cleaner with depth<br>Sand: fine and medium, with some coarse, subrounded quartz and mica<br>Fines: silt, disseminated; mottled orange and light olive grey (5 Y 5/2); beds of clayey silt up to 4cm thick towards the top of the unit, iron pan towards the base | 1.2 | 1.6 |
| Glaciolacustrine deposits | Silt, sandy, micaceous, very fine horizontal lamination; rubbery, becoming gelatinous with depth; medium bluish grey (5 B 5/1) to dark greenish grey (5 G 4/1) | 1.8+ | 3.4 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 10 | 89 | 1 | 0.4- 1.3 | 11 | 42 | 36 | 10 | 1 | 0 | 0 |
| | | | 1.3- 1.6 | 9 | 29 | 39 | 22 | 1 | 0 | 0 |
| | | | Mean | 10 | 39 | 37 | 13 | 1 | 0 | 0 |

**NO 79 NW 18** **7402 9734** **Denwood Belt, Banchory** **Block A**

Surface level c+57m
Water struck at +55.4m
(perched) and +54m
Pit
October 1986

| | |
|---|---|
| Overburden | 1.4m |
| Mineral I | 1.7m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy, humic | 0.4 | 0.4 |
| Lacustrine alluvium | Clay, sandy and silty, moderately stiff, traces of lamination and rootlets; mottled strong brown (5 YR 4/6), greyish olive (10 Y 4/2) and light olive grey to 0.7m depth; bluish grey (5 B 4/1) below | 1.0 | 1.4 |
| | 'Clayey' pebbly sand<br>Gravel: mainly fine, subrounded vein-quartz and granite<br>Sand: coarse with medium and fine, subrounded quartz and feldspar<br>Fines: clay and silt, binding deposit, moderate yellowish brown (10 YR 5/3) | 1.7+ | 3.1 |
| | Pit collapsing below water-table | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 14 | 76 | 10 | 1.4- 3.1 | 14 | 13 | 33 | 30 | 8 | 2 | 0 |

**NO 79 NW 19** **7369 9718** **North of Crathes Castle, Banchory** **Block A**

Surface level c+63m
Water not struck
Pit
October 1986

Waste 1.5m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, silty sand | 0.4 | 0.4 |
| Till | Diamicton, silty sandy clay, moderately stiff, unstratified; pebbles and rounded cobbles of pink granite, red granite and sparse pelite; becoming very stiff below 0.8m; moderate yellowish brown (10 YR 5/3) | 1.1+ | 1.5 |
| | Pit abandoned owing to slow progress | | |

**NO 79 NW 20** **7462 9741** **Baldarroch Wood, Banchory** **Block A**

Surface level c+62m
Water not struck
Pit
September 1986

Waste 2.2m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Made ground | 0.4 | 0.4 |
| Till | Diamicton, clay and gravel, very compact, unstratified; pebbles and large boulders of coarse-grained red granite, schist and fine-grained basic igneous rock; greyish yellowish brown (10 YR 5/2) | 1.8+ | 2.2 |
| | Pit terminated on large boulders of red and grey granite | | |

NO 79 NW 21 7412 9629 **Milton Wood, Banchory** **Block B**

Surface level c+45m
Water not struck
Section and pit
September 1986

Overburden 0.4m
Mineral I 11.6m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy | 0.4 | 0.4 |
| Fluvioglacial sand and gravel | a Sandy gravel, fining downwards, horizontal bedding<br>Gravel: mainly coarse, with fine and cobble; well rounded pink granite, tabular psammite and fine-grained acid volcanic rock<br>Sand: mainly medium, subrounded quartz, with some feldspar<br>Fines: silt, disseminated, moderate yellowish brown (10 YR 5/4) | 3.1 | 3.5 |
| | b Gravel, clast supported<br>Gravel: coarse and fine; subrounded red and pink granite, with some subrounded vein-quartz and sparse grey quartzite<br>Sand: mainly medium, subangular quartz, granite and feldspar<br>Fines: silt, disseminated; greyish yellowish brown (10 YR 5/2), becoming pale red (10 R 6/2) to pale reddish brown (10 R 5/4) below 7.0m depth | 5.9 | 9.4 |
| | c Gravel; abundant cobbles and boulders, especially towards the base<br>Gravel: coarse, cobble and fine; tabular to well rounded red and pink granite, white quartzite and psammite, some angular gneiss and deeply weathered pelitic schist<br>Sand: mainly coarse and medium, subrounded to rounded rock, some fine subangular quartz<br>Fines: silt and clay, coating clasts and binding deposit, especially towards the base; greyish yellowish brown (10 YR 5/2) | 2.6+ | 12.0 |
| | Pit terminated on rounded boulders of pink, porphyritic coarse-grained granite and tabular blocks of semipelite | | |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 3 | 60 | 37 | 0.4- 3.5 | 3 | 7 | 44 | 9 | 10 | 21 | 6 |
| b | 1 | 49 | 50 | 3.5- 7.0 | 2 | 3 | 32 | 9 | 21 | 33 | 0 |
| | | | | 7.0- 8.4 | 1 | 2 | 26 | 25 | 23 | 23 | 0 |
| | | | | 8.4- 9.4 | 1 | 2 | 23 | 34 | 25 | 15 | 0 |
| | | | | Mean | 1 | 2 | 30 | 17 | 22 | 28 | 0 |
| c | 4 | 21 | 75 | 9.4-10.8 | 4 | 2 | 9 | 9 | 12 | 33 | 31 |
| | | | | 10.8-11.8 | 3 | 3 | 10 | 11 | 17 | 47 | 9 |
| | | | | 11.8-12.0 | No grading data available | | | | | | |
| | | | | Mean | 4 | 2 | 9 | 10 | 14 | 39 | 22 |
| a&b | 2 | 52 | 46 | Mean | 2 | 4 | 34 | 14 | 18 | 26 | 2 |
| b&c | 2 | 40 | 58 | Mean | 2 | 2 | 23 | 15 | 20 | 31 | 7 |
| a-c | 2 | 45 | 53 | Mean | 2 | 4 | 28 | 13 | 17 | 30 | 6 |

NO 79 NW 22 | 7475 9616 | **Milton Cottage, Banchory** | **Block B**

Surface level c+45m
Water not struck
Section and pit
September 1986

Mineral I 5.2m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| Fluvioglacial sand and gravel | Sandy gravel, well bedded and well sorted; horizontally laminated medium to fine sand with scattered cobbles and thin beds of fine gravel at the top<br>Gravel: coarse with fine, well rounded to subangular, coarse-grained orange and red granite, Dalradian quartzite, psammite and schist; sparse fine-grained red tuff below 3.5m depth<br>Sand: medium with coarse and fine, subangular to subrounded quartz, pink feldspar and granite; bedded in horizontal 1m units<br>Fines: silt, disseminated; moderate yellowish brown (10 YR 5/4) to 1.5m depth, moderate reddish orange (10 R 6/6) to 1.2m, becoming moderate red (5 R 5/4) towards the base | 5.2+ | 5.2 |
| | Pit terminated, sand and gravel collapsing in from the sides | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| trace | 61 | 39 | 0.0- 0.8 | 1 | 35 | 35 | 3 | 4 | 15 | 7 |
| | | | 0.8- 2.3 | 0 | 5 | 23 | 17 | 23 | 32 | 0 |
| | | | 2.3- 3.5 | 0 | 2 | 33 | 22 | 14 | 29 | 0 |
| | | | 3.5- 5.2 | 1 | 2 | 36 | 30 | 15 | 16 | 0 |
| | | | Mean | trace | 8 | 33 | 20 | 15 | 23 | 1 |

NO 79 NW 23 | 7398 9567 | **Balbride, Durris** | **Block B**

Surface level c+47m
Water not struck
250mm percussion
September 1986

Overburden 0.5m
Mineral I 1.9m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil; sandy gravelly loam | 0.5 | 0.5 |
| Fluvioglacial sand and gravel | Sandy gravel:<br>Gravel: coarse and fine, subrounded to subangular, granite, psammite, pelite, basic igneous and vein-quartz<br>Sand: medium with coarse and fine, subangular to subrounded, quartz and lithic fragments<br>Fines: disseminated silt and clay, moderate brown (5 YR 4/4) | 1.9+ | 2.4 |
| | Borehole terminated owing to obstruction. Large boulders at bottom of borehole | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 4 | 48 | 48 | 0.5- 1.5 | 6 | 13 | 24 | 17 | 20 | 20 | 0 |
| | | | 1.5- 2.2 | 2 | 3 | 22 | 15 | 21 | 37 | 0 |
| | | | 2.2- 2.4 | No grading data available | | | | | | |
| | | | Mean | 4 | 9 | 23 | 16 | 20 | 28 | 0 |

**NO 79 NW 24** **7370 9992** **North East of Mill of Hirn, Banchory** **Block A**

Surface level +74m
Water struck at +71.9m
Pit and 250mm percussion
November 1986

Overburden 0.2m
Mineral I 3.2m
Waste 1.3m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy, humic | 0.2 | 0.2 |
| Lacustrine alluvium | a Sandy gravel, horizontally bedded<br>Gravel: fine with coarse, rounded pink granite, with some vein quartz and psammite<br>Sand: mainly medium and coarse, subangular to angular granite, quartz and feldspar<br>Fines: silt, disseminated, pale yellowish brown (10 YR 6/2); 1cm beds of dusky brown (5 YR 2/2) humic silt at 0.7m depth | 1.9 | 2.1 |
| Glacial sand and gravel | b Pebbly sand, with cobbles from 2.1m to 2.3m<br>Gravel: mainly fine, subangular, granite, fine-grained basic rock and schist<br>Sand: mainly medium and coarse, subrounded quartz, rock and feldspar<br>Fines: silt and clay, binding deposit and as 5cm thick beds; greyish olive (10 Y 4/2) | 1.3 | 3.4 |
| ?Flow-till | Diamicton, silt and clay, becoming sandy with depth; rounded cobbles, up to 15cm, of fine-grained basic rock; olive grey (5 Y 4/1) | 1.3+ | 4.7 |
| | Borehole terminated on rock obstruction | | |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 2 | 72 | 26 | 0.2- 1.2 | 3 | 5 | 33 | 28 | 17 | 14 | 0 |
| | | | | 1.2- 2.1 | 1 | 3 | 37 | 38 | 18 | 3 | 0 |
| | | | | Mean | 2 | 4 | 36 | 32 | 18 | 8 | 0 |
| b | 7 | 81 | 12 | 2.1- 3.4 | 7 | 11 | 38 | 32 | 10 | 2 | 0 § |
| a&b | 4 | 76 | 20 | Mean | 4 | 7 | 37 | 32 | 14 | 6 | 0 |

**NO 79 NW 25** **7061 9774** **Loch of Leys, Banchory** **Block A**

Surface level c+73m
Water struck at +70.6m
Section and trench (dug by hand)
November 1986
**LOG**

Overburden 0.2m
Mineral I 2.2m+

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy, humic | 0.2 | 0.2 |
| Fluvioglacial sand and gravel | Pebbly sand; scattered cobbles up to 0.5m at the top<br>Gravel: mainly fine, angular, coarse-grained pink, grey and orange granite, pelitic schist, semipelite, quartzite and fine-grained basic igneous rock<br>Sand: coarse and medium, angular pink granite, quartz and feldspar<br>Fines: silt, disseminated, moderate yellowish brown (10 YR 5/4); prominent iron staining at the water table<br><br>Trench collapsing below the water table, still in bedded sand and gravel | 2.2+ | 2.4 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 3 | 74 | 23 | 0.2- 1.6 | 1 | 4 | 37 | 32 | 18 | 8 | 0 |
| | | | 1.6- 2.4 | 5 | 5 | 27 | 46 | 17 | 0 | 0 |
| | | | Mean | 3 | 4 | 33 | 37 | 18 | 5 | 0 |

**NO 79 NW 26** **7147 9903** **South of Bohill, Banchory** **Block A**

Surface level c+76m
Water not struck
Section
November 1986
**LOG**

Overburden 0.2m
Mineral I 2.7m
Waste 0.1m+

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, with large boulders on ground surface | 0.2 | 0.2 |
| Glacial sand and gravel | Pebbly sand<br>Gravel: fine, subangular granite<br>Sand: coarse with medium, angular, granite, quartz and feldspar<br>Fines: silt, disseminated, moderate brown (5 YR 3/4) thick iron pan towards the base | 2.7 | 2.9 |
| Till | Diamicton, sand and clay, stiff, scattered angular pebbles, dark yellowish brown (10 YR 4/2) | 0.1+ | 3.0 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 2 | 93 | 5 | 0.2- 2.9 | 2 | 3 | 37 | 53 | 5 | 0 | 0 |

**NO 79 NE 1** **7529 9649** **Nether Mills of Crathes** **Block B**

Surface level +48m
Water struck at +40.1m
250mm percussion
September 1986
LOG

Overburden 0.4m
Mineral I 6.7m
Waste 3.0m+

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil: brown sandy loam | 0.4 | 0.4 |
| Fluvioglacial sand and gravel | Sandy gravel, poorly bedded<br>Gravel: fine with coarse, subangular to subrounded, granite, psammite and pelite, with vein-quartz, quartzite, felsite and basic igneous rocks<br>Sand: medium and coarse with some fine, subangular, with a little subrounded; quartz, with lithic fragments (mainly granite)<br>Fines: a little disseminated silt, moderate brown (5 YR 4/4) | 6.7 | 7.1 |
| Till | Diamicton: clay, sandy to very sandy; clasts up to 200mm, subangular with subrounded; psammite, pelite, granite, gneiss and basic igneous rocks. Moderate brown (5 YR 4/4), becoming light brown (5 YR 5/6) and stiff by 9.0m | 3.0+ | 10.1 |
| | Borehole terminated due to slow progress | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 2 | 71 | 27 | 0.4- 1.6 | 2 | 6 | 29 | 18 | 24 | 21 | 0 |
| | | | 1.6- 2.6 | 2 | 3 | 33 | 29 | 19 | 14 | 0 |
| | | | 2.6- 3.6 | 2 | 5 | 33 | 40 | 18 | 2 | 0 |
| | | | 3.6- 4.6 | 3 | 3 | 32 | 38 | 22 | 2 | 0 |
| | | | 4.6- 6.2 | 2 | 5 | 60 | 23 | 8 | 2 | 0 |
| | | | 6.2- 7.1 | 2 | 7 | 35 | 19 | 26 | 11 | 0 |
| | | | Mean | 2 | 5 | 39 | 27 | 19 | 8 | 0 |

**NO 79 NE 2** **7625 9900** **Collonach Plantation, Drumoak** **Block A**

Surface level c+70m
Water not struck
Pit
September 1986
LOG

Overburden 0.3m
Mineral II 0.9m
Waste 2.0m+

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy | 0.3 | 0.3 |
| Flow-till | Sandy gravel<br>Gravel: fine and cobble with some coarse, subrounded weathered and fresh coarse-grained granite, some fine-grained basic igneous rock<br>Sand: mainly coarse, angular quartz and feldspar<br>Fines: silt and clay, disseminated, strong brown (5 YR 4/6) | 0.9 | 1.2 |
| Morainic drift | Diamicton; silty clay, with subrounded to subangular boulders up to 1m of weathered and fresh red and grey granite, scattered pebbles of fine-grained basic rock and weathered schist; firm, matrix supported, light olive grey (5 Y 5/2) | 2.0+ | 3.2 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 4 | 51 | 45 | 0.3- 1.2 | 4 | 2 | 19 | 30 | 24 | 5 | 16 |

**NO 79 NE 3** **7598 9878** **Loch of Park, Drumoak** **Block A**

Surface level c+70m
Water struck at +68.9m
Pit
September 1986

Overburden 0.1m
Mineral I 1.4m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy, humic | 0.1 | 0.1 |
| Lacustrine alluvium | Sand, with horizontal lamination<br>Sand: mainly fine subrounded quartz, with some mica<br>Fines: silt, disseminated, humic organic matter in discontinuous lcm beds; pale yellowish brown (10 YR 6/2) above the water table, olive grey (5 Y 4/2) below | 1.4+ | 1.5 |
| | Pit terminated, sand collapsing below the water-table | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 4 | 96 | 0 | 0.1- 1.5 | 4 | 68 | 25 | 3 | 0 | 0 | 0 |

NO 79 NE 4 7589 9807 **Damhead, Drumoak** **Block A**

Surface level c+64m
Water struck at +63.1m
Pit
September 1986

Waste 2.9m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| Alluvium | Soil, sandy, humic, dusky brown (10 YR 2/2) | 0.2 | 0.2 |
| Fluvioglacial sand and gravel | Sandy gravel, poorly sorted<br>Gravel: coarse and fine, with some cobbles up to 0.5m, rounded to subrounded, granite, granodiorite, psammite and semipelite<br>Sand: coarse and medium, angular rock and quartz<br>Fines: silt and clay, disseminated, moderate brown (5 YR 3/4) | 0.7 | 0.9 |
| Till | Diamicton, clay, stiff, waxy, matrix suported; clasts of schist, gneiss, coarse-grained ultrabasic rock; sparse quartzite and granite; olive grey (5 Y 4/2) | 0.7 | 1.6 |
| | Diamicton, clay and sand; abundant angular and rounded pebbles of weathered schist, gneiss and sparse fine-grained red volcanic rock; boulders up to 0.8m of subrounded medium-grained pink granite at the base; moderate olive brown (5 Y 4/4) to light olive brown (5 Y 5/6) | 1.3+ | 2.9 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 3 | 55 | 42 | 0.2- 0.9 | 3 | 5 | 23 | 27 | 17 | 21 | 4 |

**NO 79 NE 5** **7615 9647** **Mills of Drum, Crathes** **Block B**

Surface level +34m
Water struck at +31.3m
250mm percussion
September 1986

Overburden 0.3m
Mineral I 9.8m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil: sandy, silty brown loam | 0.3 | 0.3 |
| Fluvioglacial sand and gravel | a Gravel<br>Gravel: coarse, with fine and cobble, subrounded,with well rounded and subangular; granite, basic igneous rocks, felsite, psammite, pelite, vein-quartz and quartzite<br>Sand: medium, with coarse and some fine, subangular; quartz, feldspar and lithic fragments<br>Fines: silt and clay, disseminated, moderate brown (5 YR 4/4) | 3.0 | 3.3 |
| | b Gravel<br>Gravel: coarse, with fine and cobble, subrounded with subangular; granite, basic igneous rocks, felsite, psammite, pelite, vein-quartz and quartzite<br>Sand: medium to coarse, with fine, subangular, quartz and lithic fragments (including granite)<br>Fines: silt and clay, disseminated, thin beds of finely laminated silt up to 30mm thick at 9.5m. Moderate brown (5 YR 4/4), becoming yellowish brown (5 YR 5/6) at base | 6.8+ | 10.1 |
| | Borehole terminated on a rock obstruction | | |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm | |
| a | 4 | 36 | 60 | 0.3- 1.3 | 5 | 12 | 24 | 10 | 13 | 36 | 0 | |
| | | | | 1.3- 2.3 | 4 | 3 | 14 | 9 | 19 | 51 | 0 | |
| | | | | 2.3- 3.3 | 2 | 3 | 18 | 15 | 22 | 36 | 4 | § |
| | | | | Mean | 4 | 6 | 19 | 11 | 18 | 41 | 1 | |
| b | 1 | 45 | 54 | 3.3- 4.3 | 2 | 3 | 22 | 23 | 19 | 31 | 0 | § |
| | | | | 4.3- 5.3 | 1 | 3 | 21 | 19 | 20 | 31 | 5 | § |
| | | | | 5.3- 6.3 | 1 | 3 | 19 | 9 | 25 | 43 | 0 | § |
| | | | | 6.3- 7.5 | 1 | 4 | 25 | 16 | 15 | 34 | 5 | § |
| | | | | 7.5- 8.5 | 1 | 3 | 25 | 20 | 23 | 28 | 0 | § |
| | | | | 8.5-10.1 | 1 | 4 | 32 | 16 | 11 | 36 | 0 | § |
| | | | | Mean | 1 | 3 | 25 | 17 | 18 | 34 | 2 | |
| a&b | 2 | 42 | 56 | Mean | 2 | 4 | 23 | 15 | 18 | 36 | 2 | |

NO 79 NE 6 | 7672 9616 | Wester Durris, Durris | Block B

Surface level +47m
Water struck at +44.7m
250mm percussion
September 1986

Overburden 0.3m
Mineral I 3.7m
Waste 2.8m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil; sand, stony | 0.3 | 0.3 |
| Fluvioglacial sand and gravel | a Gravel, more sandy with depth; a bed of slightly cohesive coarse sand from 0.9 to about 1.2m<br>Gravel: coarse and fine, with some boulders, subangular to rounded, granite and dioritic rock, schist and quartzite<br>Sand: coarse and medium with some fine, angular to subrounded quartz, lithic fragments and feldspar<br>Fines: disseminated silt and clay, moderate yellowish brown (10 YR 5/4) | 0.7 | 1.0 |
| | b Pebbly sand; hard packed layer of cobbles and boulders from 1.9 to 2.3m<br>Gravel: fine with some coarse, some cobble and boulder, subangular to rounded granitic and dioritic rocks, schist and quartzite with some vein-quartz<br>Sand: medium and coarse with fine, angular to subangular, quartz and feldspar, with lithic fragments<br>Fines: clay and silt; binding deposit near the top and disseminated, greyish yellowish brown (10 YR 5/2) | 3.0 | 4.0 |
| Till | Diamicton; sandy silty clay, stiff to hard, cobbles and boulders in top 0.3m. Passes down into stony silty clay, with occasional angular to subrounded cobbles and boulders; moderate yellowish brown (10 YR 5/4) | 2.8+ | 6.8 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm | |
| a | 3 | 40 | 57 | 0.3- 1.0 | 3 | 3 | 17 | 20 | 26 | 31 | 0 | |
| b | 4 | 72 | 24 | 1.0- 1.9 | 4 | 20 | 36 | 26 | 10 | 4 | 0 | |
| | | | | 1.9- 2.3 | No grading data available | | | | | | | |
| | | | | 2.3- 3.0 | 3 | 10 | 18 | 26 | 21 | 13 | 9 | § |
| | | | | 3.0- 4.0 | 6 | 12 | 31 | 30 | 10 | 11 | 0 | § |
| | | | | Mean | 4 | 14 | 30 | 28 | 13 | 9 | 2 | |
| a&b | 4 | 66 | 30 | Mean | 4 | 12 | 28 | 26 | 15 | 13 | 2 | |

**NO 79 NE 7** **7726 9734** **Nether Park, Drumoak** **Block A**

| | |
|---|---|
| Surface level c+49m | Overburden 1.4m |
| Water not struck | Mineral II 0.9m |
| Pit | Bedrock 0.1m+ |
| September 1986 | |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy and silty | 0.2 | 0.2 |
| Till | Diamicton, sand and silt, stiff; clasts up to 0.6m of weathered and fresh schist, red and pink granite and sparse granodiorite; unstratified, matrix supported; moderate yellowish brown (10 YR 5/4) | 1.2 | 1.4 |
| Caledonian | 'Clayey' pebbly sand (deeply weathered granite bedrock)<br>Gravel: mainly fine, angular fragments of granite<br>Sand: coarse with medium, granite<br>Fines: kaolinitic clay, greyish yellowish brown (10 YR 5/2) | 0.9 | 2.3 |
| | Granite, hard, medium to coarse-grained, with large euhedral phenocrysts of pink feldspar | 0.1+ | 2.4 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 14 | 74 | 12 | 1.4- 2.3 | 14 | 9 | 21 | 44 | 11 | 1 | 0 |

**NO 79 NE 8** **7836 9809** **Home Farm, Drumoak** **Block A**

| | |
|---|---|
| Surface level +44m | Waste 7.5m+ |
| Water struck at +39.2m | |
| 250mm percussion | |
| November 1986 | |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| Made ground | Black clayey soil with boulders of granite, psammite and pelite | 0.8 | 0.8 |
| Till | Diamicton: clay, gravelly, sandy, cohesive, moderate yellowish brown (10 YR 5/4); clasts (up to cobble grade) of granite, with psammite, pelite and basic igneous rocks. Thin beds of clayey sand and silt towards base. | 3.5 | 4.3 |
| Glaciolacustrine deposits | Silt, sandy, moderate yellowish brown (10 YR 5/4); sparse subangular, clasts, fine and coarse gravel grade, granite and metamorphic rocks | 0.9 | 5.2 |
| Till | Diamicton: clay, sandy, silty, stiff to very firm, moderate yellowish brown (10 YR 5/4); many clasts from fine gravel to cobble grade, of granite, psammite, pelite and basic igneous rocks. Weathered granite sand abundant at base. | 2.3+ | 7.5 |
| | Borehole terminated for technical reasons | | |

**NO 79 NE 9** | **7831 9717** | **Nether Balfour, Durris** | **Block B**

Surface level +27m
Water struck at +24.3m
250 and 200mm percussion and shell
September 1986

Overburden 0.5m
Mineral I 10.8m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy, silty | 0.5 | 0.5 |
| Alluvium | a 'Very clayey' sand<br>Sand: fine and medium subangular quartz, with a trace of mica<br>Fines: silt and clay, disseminated, light brown (5 YR 5/6); beds of silt from 1 to 10cm thick towards the base, very pale orange (10 YR 8/5), mottled with light olive grey (5 Y 5/2) | 1.3 | 1.8 |
| Fluvioglacial sand and gravel | b Sandy gravel, abundant cobbles at the top<br>Gravel: fine and coarse, with some cobble; rounded to subrounded, psammite, coarse-grained pink granite, medium-grained granodiorite, fine-grained quartzite and felsite, sparse semipelite, quartz-porphyry and fine-grained basic rock<br>Sand: mainly coarse and medium, subangular to angular, quartz, rock and feldspar, some fine mica<br>Fines: silt and clay, disseminated and loosely binding deposit above the water table; moderate brown (5 YR 4/4) to moderate yellowish brown (10 YR 5/4) | 9.5+ | 11.3 |

Borehole terminated on rock obstruction

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm | |
| a | 20 | 80 | 0 | 0.5- 1.8 | 20 | 47 | 31 | 2 | trace | 0 | 0 | |
| b | 2 | 50 | 48 | 1.8- 2.7 | 2 | 3 | 9 | 9 | 15 | 22 | 40 | |
| | | | | 2.7- 3.7 | 4 | 5 | 20 | 29 | 24 | 18 | 0 | § |
| | | | | 3.7- 4.7 | 2 | 2 | 15 | 24 | 20 | 21 | 16 | § |
| | | | | 4.7- 6.5 | 1 | 1 | 20 | 29 | 22 | 23 | 4 | § |
| | | | | 6.5- 7.5 | 1 | 2 | 44 | 24 | 18 | 11 | 0 | § |
| | | | | 7.5- 8.9 | 4 | 5 | 28 | 27 | 15 | 16 | 5 | § |
| | | | | 8.9- 9.8 | 2 | 1 | 9 | 35 | 25 | 21 | 7 | § |
| | | | | 9.8-11.3 | 2 | 3 | 20 | 23 | 24 | 23 | 5 | § |
| | | | | Mean | 2 | 3 | 21 | 26 | 20 | 20 | 8 | |
| a&b | 4 | 54 | 42 | Mean | 4 | 8 | 22 | 24 | 18 | 17 | 7 | |

**NO 79 NE 10** **7883 9546** **Wheywell, Durris** **Block C**

Surface level c+96m
Water not struck
Pit
October 1986

Overburden 0.3m
Waste 1.6m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sand and silt | 0.3 | 0.3 |
| Flow-till | 'Very clayey' sandy gravel, unstratified, clast supported<br>Gravel: cobble, coarse and fine, rounded semipelite and pelitic schist<br>Sand: medium, coarse and fine; angular rock<br>Fines: clay, binding deposit, moderate yellowish brown (10 YR 5/4) | 0.8 | 1.1 |
| | Diamicton, clay, stiff, unstratified, clasts up to boulder size of red and pale pink granite, migmatite and semipelite, moderate yellowish brown (10 YR 5/4) | 0.8+ | 1.9 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 20 | 40 | 40 | 0.3- 1.1 | 20 | 12 | 15 | 13 | 11 | 12 | 17 |

**NO 79 NE 11** **7962 9883** **The Manse, Drumoak** **Block B**

Surface level +35m
Water struck at +33.2m
250mm percussion
September 1986

Overburden 0.4m
Mineral I 5.1m
Waste 0.5m
Bedrock 0.6m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil: sandy, clayey loam, brown | 0.4 | 0.4 |
| Fluvioglacial sand and gravel | Gravel<br>Gravel: fine and coarse, occasional cobble, subrounded with subangular, granite, gneiss, quartz, quartzite, psammite and pelite<br>Sand: coarse, with medium and some fine, subangular to angular, lithic fragments, (chiefly granite) and quartz<br>Fines: silt and clay, disseminated, moderate brown (5 YR 4/4) | 5.1 | 5.5 |
| Till | Diamicton: clay, silty, locally very sandy, firm, moderate yellowish brown (10 YR 5/4). Many fine gravel clasts, predominantly weathered granite, but also some unweathered clasts of gneiss, schist and basic igneous rocks | 0.5 | 6.0 |
| Caledonian | Granite, highly weathered, becoming harder with depth | 0.6+ | 6.6 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 3 | 47 | 50 | 0.3- 1.3 | 4 | 5 | 28 | 16 | 24 | 23 | 0 |
| | | | 1.3- 2.3 | 6 | 5 | 24 | 27 | 24 | 14 | 0 § |
| | | | 2.3- 3.3 | 1 | 2 | 9 | 27 | 30 | 31 | 0 § |
| | | | 3.3- 4.3 | 0 | 1 | 10 | 28 | 27 | 24 | 10 § |
| | | | 4.3- 5.5 | 2 | 3 | 14 | 39 | 28 | 14 | 0 § |
| | | | Mean | 3 | 3 | 17 | 27 | 27 | 21 | 2 |

**NO 79 NE 12** **7992 9820** **Keith's Hill, Drumoak** **Block B**

Surface level +45m
Water struck at +29m
250 and 200mm percussion
September 1986

Overburden 0.4m
Mineral I 15.4m
Bedrock 1.4m

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil: sandy, gravelly loam | 0.4 | 0.4 |
| Fluvioglacial sand and gravel | a Sand gravel<br>Gravel: coarse and fine with some cobble, subrounded to well rounded, granite, pelite, psammite, quartzite and basic igneous rocks<br>Sand: medium and coarse with fine, subangular quartz and lithic fragments (principally granite)<br>Fines: silt and clay, disseminated, light brown (5 YR 5/6) | 1.9 | 2.3 |
| | b Pebbly sand<br>Gravel: fine, a little coarse, subrounded with subangular, composition as above<br>Sand: medium with fine and coarse subangular with subrounded, quartz, feldspar and lithic fragments (including granite)<br>Fines: silt and clay, disseminated, light brown (5 YR 5/6) | 5.9 | 8.2 |
| | c Gravel<br>Gravel: coarse with fine and some cobbles, subrounded to subangular, many basic igneous clasts<br>Sand: medium with coarse and fine, composition as above<br>Fines: silt and clay, disseminated, light brown (5 YR 5/6) | 2.0 | 10.2 |
| | d Pebbly sand<br>Gravel: sparse, subrounded, fine with coarse, psammite, pelite, quartzite and gneiss<br>Sand: medium, with fine and coarse, composition as above<br>Fines: silt and clay, disseminated | 2.0 | 12.2 |
| | e Sandy gravel<br>Gravel: fine to cobble, subrounded, composition as above<br>Sand: fine to coarse, subangular to subrounded, quartz, felsdspar and lithic fragments<br>Fines: silt and clay, disseminated | 3.6 | 15.8 |
| Caledonian | Granite, weathered, medium to coarse grained, moderate reddish brown (10 R 4/6) | 1.4+ | 17.2 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 6 | 49 | 45 | 0.4- 1.4 | 3 | 6 | 17 | 15 | 19 | 28 | 12 |
| | | | | 1.4- 2.3 | 9 | 8 | 32 | 20 | 15 | 16 | 0 |
| | | | | Mean | 6 | 7 | 25 | 17 | 17 | 22 | 6 |
| b | 9 | 82 | 9 | 2.3- 3.6 | 9 | 16 | 42 | 16 | 4 | 2 | 11 |
| | | | | 3.6- 4.6 | 7 | 26 | 52 | 12 | 3 | 0 | 0 |
| | | | | 4.6- 5.6 | 7 | 21 | 56 | 12 | 4 | 0 | 0 |
| | | | | 5.6- 6.6 | 14 | 24 | 43 | 10 | 4 | 5 | 0 |
| | | | | 6.6- 8.2 | 8 | 28 | 37 | 15 | 6 | 6 | 0 |
| | | | | Mean | 9 | 23 | 46 | 13 | 4 | 3 | 2 |
| c | 5 | 52 | 43 | 8.2- 9.2 | 4 | 7 | 22 | 17 | 15 | 31 | 4 |
| | | | | 9.2-10.2 | 6 | 7 | 35 | 16 | 11 | 25 | 0 |
| | | | | Mean | 5 | 7 | 28 | 17 | 13 | 28 | 2 |
| d | 4 | 91 | 5 | 10.2-11.2 | 4 | 13 | 62 | 20 | 1 | 0 | 0 |
| | | | | 11.2-12.2 | 4 | 10 | 62 | 16 | 6 | 2 | 0 |
| | | | | Mean | 4 | 12 | 61 | 18 | 4 | 1 | 0 |
| e | 4 | 48 | 48 | 12.2-13.2 | 4 | 9 | 29 | 21 | 14 | 14 | 9 |
| | | | | 13.2-14.1 | 9 | 5 | 25 | 13 | 11 | 15 | 22 |
| | | | | 14.1-15.8 | 2 | 9 | 27 | 9 | 13 | 40 | 0 |
| | | | | Mean | 4 | 8 | 27 | 13 | 13 | 27 | 8 |
| a&b | 8 | 74 | 18 | Mean | 8 | 19 | 41 | 14 | 7 | 8 | 3 |
| b&c | 8 | 74 | 18 | Mean | 8 | 19 | 41 | 14 | 7 | 9 | 2 |
| c&d | 5 | 71 | 24 | Mean | 5 | 9 | 45 | 17 | 8 | 15 | 1 |
| d&e | 4 | 65 | 31 | Mean | 4 | 9 | 41 | 15 | 9 | 17 | 5 |
| a-e | 6 | 67 | 27 | Mean | 6 | 14 | 38 | 15 | 9 | 14 | 4 |

**NO 79 NE 13** **7916 9816** **East Park, Drumoak** **Block B**

Surface level c+37m
Water not struck
Pit
September 1986

Overburden 0.3m
Mineral I 1.7m
Mineral II 0.4m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sand with pebbles | 0.3 | 0.3 |
| Fluvioglacial sand and gravel | a Sandy gravel, clast supported, horizontal bedding<br>Gravel: coarse and fine, well rounded to rounded dark red quartz-porphyry, pink, red and grey granite and psammite; some tabular semipelite<br>Sand: mainly medium, subangular granitic rock<br>Fines: silt, disseminated; greyish orange pink (5 YR 7/2) to pale yellowish brown (10 YR 6/2) | 1.7 | 2.0 |
| Caledonian | b Sandy gravel (weathered granite bedrock)<br>Gravel: coarse and fine, blocks of coarse feldspathic porphyritic granite<br>Sand: mainly medium, disaggregated granite<br>Fines: kaolinitic clay | 0.4+ | 2.4 |
| | Pit terminated on large angular blocks of unweathered granite | | |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 1 | 59 | 40 | 0.3- 0.8 | 3 | 7 | 25 | 14 | 18 | 33 | 0 |
| | | | | 0.8- 2.0 | 1 | 1 | 44 | 18 | 17 | 19 | 0 |
| | | | | Mean | 1 | 3 | 39 | 17 | 17 | 23 | 0 |
| b | 2 | 65 | 33 | 2.0- 2.4 | 2 | 2 | 47 | 16 | 13 | 20 | 0 |
| a&b | 1 | 61 | 38 | Mean | 1 | 3 | 41 | 17 | 16 | 22 | 0 |

**NO 79 NE 14** **7948 9773** **Drumallan, Durris** **Block B**

Surface level c+32m
Water not struck
Pit
September 1986

Overburden 0.3m
Mineral I 3.7m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sand and silt | 0.3 | 0.3 |
| Fluvioglacial sand and gravel | Gravel, with prominent large scale cross-bedding; channel filled with finely laminated light olive grey clayey silt (cut to a depth of 2.4m into top of gravel)<br>Gravel: coarse, cobble and fine, rounded pink granite, psammite, quartz-porphyry and granodiorite, some tabular semipelite; clast supported, well sorted<br>Sand: mainly medium, subangular quartz, feldspar and granitic rock<br>Fines: silt and clay, disseminated and coating pebbles; some discontinuous beds of silt from 1.3m to 2.4m; light olive brown (5 Y 5/6), moderate yellowish brown (10 YR 5/4) towards the base | 3.7+ | 4.0 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 9 | 41 | 50 | 0.3- 1.3 | 16 | 5 | 7 | 8 | 9 | 24 | 31 |
| | | | 1.3- 2.4 | 13 | 10 | 31 | 16 | 11 | 19 | 0 |
| | | | 2.4- 4.0 | 3 | 6 | 26 | 12 | 11 | 19 | 23 |
| | | | Mean | 9 | 7 | 22 | 12 | 11 | 20 | 19 |

NO 79 SW 1 | 7020 9223 | **North of Knockhill, Strachan** | **Block C**

Surface level c+112m
Water struck at +111.2m
Pit
October 1986

Waste 2.9m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, silty, sandy, humic | 0.3 | 0.3 |
| Lacustrine alluvium | Pebbly sand, well sorted, horizontally bedded; subangular to subrounded quartz and feldspar; some disseminated silt, moderate brown (5 YR 4/4) | 0.5 | 0.8 |
| Glaciolacustrine deposits | Silt, sandy, rubbery; unstratified, becoming finely laminated with depth, waxy and clayey below 2.0m; bluish grey (5 B 4/1) to medium grey (N5) | 2.1+ | 2.9 |
| | Pit collapsing below the water-table | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 3 | 89 | 8 | 0.3- 0.8 | 3 | 11 | 35 | 43 | 8 | 0 | 0 |

| NO 79 SW 2 | 7017 9155 | South West of Knockhill, Strachan | Block C |
|---|---|---|---|

Surface level c+126m
Water struck at +118.3m
Pit and 250 and 200mm percussion
October 1986

| | |
|---|---|
| Overburden | 0.4m |
| Mineral I | 6.6m |
| Mineral II | 1.0m |
| Waste | 4.2m+ |

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy | 0.4 | 0.4 |
| Fluvioglacial sand and gravel | a Gravel, well sorted, subhorizontal stratification<br>Gravel: fine with some coarse, subangular pink granite, porphyry, schistose semipelite, felsite and sparse vein quartz<br>Sand: mainly coarse, angular granite, quartz and feldspar<br>Fines: silt and clay, disseminated | 1.3 | 1.7 |
| | b Sandy gravel; scattered rounded cobbles of pink granite, porphyry and schist at the top<br>Gravel: fine with coarse, subangular to well rounded, pink granite, schist, vein quartz and felsite; well bedded, moderately sorted<br>Sand: mainly coarse, subangular to angular, granite, quartz and feldspar<br>Fines: silt and clay, disseminated, greyish orange pink (5 YR 7/2) to light brown (5 YR 6/4) | 2.6 | 4.3 |
| | c Sandy gravel<br>Gravel: fine, coarse and cobble; subangular to well rounded granite, schist and felsite<br>Sand: coarse with some medium, subangular rock, quartz and feldspar<br>Fines: silt and clay, disseminated, light brown (5 YR 6/4) | 1.0 | 5.3 |
| | d Pebbly sand, fining downwards<br>Gravel: fine, granite, schist and felsite<br>Sand: coarse, with medium and some fine, angular to subrounded quartz, feldspar and granite<br>Fines: silt and clay, disseminated and as thin beds; light brown (5 YR 6/4) | 1.7 | 7.0 |
| Flow-till | e 'Clayey' pebbly sand, matrix supported<br>Gravel: fine and coarse; sparse cobbles, subangular to angular schist, pink and red granite and vein-quartz<br>Sand: fine, medium and coarse; granite and quartz<br>Fines: silt and clay, binding deposit; light brown (5 YR 6/4) | 1.0 | 8.0 |
| Till | Diamicton, sand, silt and clay, moderately firm; pebbles and cobbles of fresh and weathered pink and red granite, some schist and vein-quartz; lenses of fine silty sand; clasts of weathered granite increase towards the base; light olive brown (5 Y 5/6) to moderate yellowish brown (10 YR 5/4) | 4.2+ | 12.2 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 3 | 48 | 49 | 0.4- 1.7 | 3 | 2 | 11 | 35 | 37 | 12 | 0 |
| b | 1 | 60 | 39 | 1.7- 2.8 | 1 | 1 | 13 | 33 | 20 | 12 | 20 |
| | | | | 2.8- 3.3 | 1 | 1 | 20 | 40 | 19 | 19 | 0 |
| | | | | 3.3- 4.3 | 2 | 4 | 23 | 45 | 20 | 6 | 0 |
| | | | | Mean | 1 | 2 | 18 | 40 | 20 | 11 | 8 |
| c | 4 | 53 | 43 | 4.3- 5.3 | 4 | 4 | 16 | 33 | 18 | 16 | 9 |
| d | 8 | 86 | 6 | 5.3- 6.5 | 5 | 6 | 34 | 47 | 8 | 0 | 0 |
| | | | | 6.5- 7.0 | 15 | 58 | 20 | 5 | 2 | 0 | 0 |
| | | | | Mean | 8 | 21 | 30 | 35 | 6 | 0 | 0 |
| e | 19 | 63 | 18 | 7.0- 8.0 | 19 | 23 | 21 | 19 | 11 | 7 | 0 § |
| a&b | 2 | 56 | 42 | Mean | 2 | 2 | 16 | 38 | 25 | 11 | 6 |
| b&c | 2 | 58 | 40 | Mean | 2 | 3 | 17 | 38 | 19 | 12 | 9 |
| c&d | 7 | 74 | 19 | Mean | 7 | 15 | 25 | 34 | 10 | 6 | 3 |
| a-d | 4 | 63 | 33 | Mean | 4 | 7 | 19 | 37 | 19 | 9 | 5 |
| a-e | 6 | 63 | 31 | Mean | 6 | 9 | 20 | 34 | 18 | 9 | 4 |

**NO 79 SW 3** **7003 9111** **W.S.W. of Knock Wood, Strachan** **Block C**

Surface level c+125m
Water not struck
Pit
September 1986

Overburden 0.3m
Mineral I 2.7m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy, humic | 0.3 | 0.3 |
| Fluvioglacial sand and gravel | a Sandy gravel, horizontal lamination, scattered cobbles<br>Gravel: coarse and fine, coarse-grained orange granite<br>Sand: mainly medium, subangular to subrounded, quartz and feldspar<br>Fines: silt, binding deposit in top 0.5m | 1.2 | 1.5 |
| | b Pebbly sand, traces of horizontal lamination<br>Gravel: coarse and fine, granite<br>Sand: mainly medium, rounded, quartz, biotite and feldspar<br>Fines: silt, disseminated, greyish orange pink (5 YR 7/2) | 0.6 | 2.1 |
| | c Sandy gravel, clast supported, boulders of coarse-grained pink granite up to 0.8m<br>Gravel: coarse and cobble, with some fine, rounded, pink granite, coarse-grained grey granodiorite; sparse angular psammite and pegmatite<br>Sand: medium with some fine and coarse, rounded quartz, mica and feldspar<br>Fines: silt, disseminated, greyish orange pink (5 YR 7/2) | 0.9+ | 3.0 |

Pit terminated on large boulders

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | - 1/16 | + 1/16 - 1/4 | + 1/4 -1 | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 1 | 72 | 27 | 0.3- 1.5 | 1 | 6 | 56 | 10 | 3 | 5 | 19 |
| b | 1 | 94 | 5 | 1.5- 2.1 | 1 | 11 | 78 | 5 | 2 | 3 | 0 |
| c | 1 | 64 | 35 | 2.1- 3.0 | 1 | 12 | 45 | 7 | 6 | 18 | 11 |
| a&b | 1 | 79 | 20 | Mean | 1 | 8 | 63 | 8 | 3 | 4 | 13 |
| b&c | 1 | 76 | 23 | Mean | 1 | 12 | 58 | 6 | 4 | 12 | 7 |
| a-c | 1 | 74 | 25 | Mean | 1 | 9 | 57 | 8 | 4 | 9 | 12 |

**NO 79 SW 4** **7032 9101** **S.W. of Knock Wood, Strachan** **Block C**

Surface level c+132m
Water not struck
Pit
September 1986

Overburden 0.2m
Mineral I 1.6m
Waste 1.4m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy, silty | 0.2 | 0.2 |
| Morainic drift | 'Clayey' pebbly sand, stiff, friable, matrix supported, unstratified<br>Gravel: mainly fine, angular, schist and weathered coarse-grained granite<br>Sand: coarse and medium, with some fine, subangular quartz and rock<br>Fines: clay and silt, binding deposit, moderate yellowish brown (10 YR 5/4) | 1.6 | 1.8 |
| Till | Diamicton, clay, silt and sand, very stiff, unstratified, matrix supported; pebbles and cobbles of schist and weathered granite; moderate yellowish brown (10 Y 5/4) | 1.4+ | 3.2 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | - 1/16 | + 1/16 - 1/4 | + 1/4 -1 | +1-4 | +4-16 | +16-64 | +64 mm |
| 10 | 75 | 15 | 0.2- 1.2 | 8 | 16 | 31 | 32 | 11 | 2 | 0 |
| | | | 1.2- 1.8 | 12 | 15 | 26 | 27 | 17 | 3 | 0 |
| | | | Mean | 10 | 16 | 29 | 30 | 13 | 2 | 0 |

**NO 79 SW 5** **7084 9063** **Midtown, Strachan** **Block C**

Surface level c+124m
Water struck at +122.4m
Pit
September 1986

Overburden 0.4m
Mineral II 1.2m
Waste 0.3m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Made ground | 0.4 | 0.4 |
| ?Flow-till | Gravel, unsorted, poorly stratified<br>Gravel: coarse and fine with cobble, subrounded granite, sparse psammite, schist and felsite<br>Sand: coarse and medium, with some fine, angular rock, granite and quartz<br>Fines: silt and clay, binding deposit; dark yellowish brown (10 YR 4/2) to 0.8m, greenish grey (5 G 6/1) to 1.4m and strong brown (5 YR 4/6) at the base | 1.2 | 1.6 |
| Till | Diamicton, clay and silt, matrix supported, stiff, pebbles and cobbles of granite, schist and psammite; strong brown (5 YR 4/6) | 0.3+ | 1.9 |
| | Pit collapsing below the water table | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 4 | 43 | 53 | 0.4- 1.6 | 4 | 6 | 15 | 22 | 19 | 25 | 9 |

**NO 79 SW 6** **7190 9006** **S.W. of Garrol Wood, Strachan** **Block C**

| | |
|---|---|
| Surface level c+173m | Overburden 0.3m |
| Water not struck | Mineral I 9.0m |
| Section and pit | Waste 0.8m+ |
| September 1986 | |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, gravelly | 0.3 | 0.3 |
| Fluvioglacial sand and gravel (Kame) | a Gravel, cryoturbation in top 0.7m<br>Gravel: coarse and fine with some cobble, subrounded, coarse-grained pink granite, with some tabular felsite and psammite<br>Sand: coarse with medium, angular granite<br>Fines: silt, disseminated, greyish orange pink (5 YR 7/2) | 2.1 | 2.4 |
| | b Sandy gravel, with well developed cross stratification<br>Gravel: fine with coarse, angular to subrounded, coarse-grained pink granite and vein quartz; angular schist and psammite below 8.1m depth<br>Sand: coarse with medium, angular granite, with some quartz and feldspar<br>Fines: silt, disseminated, greyish orange pink (5 YR 7/2), becoming moderate yellowish brown (10 YR 5/4) towards the base; disseminated iron staining above 5.2m | 6.9 | 9.3 |
| Glaciolacustrine deposits | Silt, clayey and sandy, rubbery, with horizontal lamination; some thin graded beds, fining upwards from sandy silt to waxy clayey silt; light brown (5 YR 5/6) | 0.8+ | 10.1 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 1 | 36 | 63 | 0.3- 2.4 | 1 | 1 | 11 | 24 | 21 | 38 | 4 |
| b | 1 | 56 | 43 | 2.4- 5.2 | 1 | 2 | 13 | 43 | 34 | 7 | 0 |
| | | | | 5.2- 6.8 | 1 | 2 | 14 | 31 | 40 | 12 | 0 |
| | | | | 6.8- 8.1 | 3 | 10 | 16 | 33 | 22 | 16 | 0 |
| | | | | 8.1- 9.3 | 1 | 3 | 18 | 36 | 26 | 16 | 0 |
| | | | | Mean | 1 | 4 | 15 | 37 | 32 | 11 | 0 |
| a&b | 1 | 51 | 48 | Mean | 1 | 3 | 14 | 34 | 29 | 18 | 1 |

NO 79 SW 7 | 7246 9205 | **West Mulloch, Banchory** | **Block C**

Surface level c+197m
Water not struck
Section and pit
September 1986

Overburden 0.3m
Mineral I 3.9m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy, humic | 0.3 | 0.3 |
| Fluvioglacial sand and gravel | a Gravel, poorly stratified, some angular boulders up to 1m<br>Gravel: cobble and coarse, with some fine, angular to rounded, fine-grained basic igneous rock and fine-grained red acid volcanic rock, sparse granite<br>Sand: coarse with medium, angular to subangular quartz, feldspar and granite<br>Fines: silt, disseminated | 2.2 | 2.5 |
| | b Pebbly sand, with horizontal bedding<br>Gravel: fine, angular pink and grey granite<br>Sand: coarse and medium, angular, granite, quartz and pink feldspar<br>Fines: silt and clay, disseminated, moderate yellowish brown (10 YR 5/4) | 1.7+ | 4.2 |
| | Pit terminated, pebbly sand collapsing in from the sides | | |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 2 | 36 | 62 | 0.3- 1.5 | 1 | 1 | 12 | 25 | 9 | 22 | 30 |
| | | | | 1.5- 2.5 | 3 | 4 | 15 | 16 | 13 | 22 | 27 |
| | | | | Mean | 2 | 2 | 13 | 21 | 11 | 22 | 29 |
| b | 3 | 83 | 14 | 2.5- 3.7 | 4 | 2 | 35 | 45 | 13 | 1 | 0 |
| | | | | 3.7- 4.2 | 2 | 4 | 29 | 52 | 12 | 1 | 0 |
| | | | | Mean | 3 | 3 | 33 | 47 | 13 | 1 | 0 |
| a&b | 3 | 56 | 41 | Mean | 3 | 2 | 22 | 32 | 12 | 13 | 16 |

| NO 79 SW 8 | 7268 9044 | Garrol, Banchory | Block C |
|---|---|---|---|

Surface level c+187m
Water not struck
Section and pit
September 1986

Mineral I 6.6m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| Fluvioglacial sand and gravel | a Gravel; poorly stratified, moderately to well sorted, clast supported<br>Gravel: coarse with fine, rounded grey and pink granite, with angular gneiss and amphibolite, sparse tabular pelite<br>Sand: coarse and medium, quartz and feldspar<br>Fines: silt, disseminated, moderate brown (5 YR 4/4) | 0.6 | 0.6 |
| | b Pebbly sand; well developed planar lamination in top 0.7m, passing downwards into small scale ripple cross stratification<br>Gravel: fine and coarse, pink acid volcanic rock<br>Sand: coarse and medium, subrounded quartz, sparse mica and feldspar<br>Fines: silt and clay; as finely laminated 1cm partings at the top and disrupted lenses near the base; light olive grey (5 Y 5/2) | 1.1 | 1.7 |
| | c Gravel; interbedded with planar laminated sand<br>Gravel: coarse and cobble, with fine, angular coarse-grained pink granite, banded gneiss and red acid igneous rock; some tabular schist, semipelite and psammite; sparse vein-quartz and fine-grained basic rock below 2.4m<br>Sand: coarse and medium, subrounded, quartz, feldspar and granite<br>Fines: silt, disseminated, light brown (5 YR 6/4) | 1.1 | 2.8 |
| Glaciolacustrine deposits | d 'Clayey' sand, with horizontal lamination and ripple-drift cross lamination, becoming more clayey with depth<br>Sand: mainly fine, subrounded, quartz, feldspar and mica<br>Fines: silt and clay, disseminated and as 1cm horizontal partings, at 25cm intervals to 4.6m depth; some silt and clay drapes to ripples; moderate yellowish brown (10 YR 5/4) to light olive brown (5 YR 5/6); a bed of laminated silty sand, dark yellowish brown (10 YR 4/2), from 4.6m to 6.6m depth | 3.8+ | 6.6 |

Pit terminated, silty sand collapsing in from the sides

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 2 | 48 | 50 | 0.0- 0.6 | 2 | 5 | 20 | 23 | 17 | 33 | 0 |
| b | 5 | 88 | 7 | 0.6- 1.7 | 5 | 36 | 43 | 9 | 4 | 3 | 0 |
| c | trace | 46 | 54 | 1.7- 2.4 | 0 | 1 | 30 | 29 | 8 | 9 | 23 |
| | | | | 2.4- 2.8 | 1 | 2 | 6 | 11 | 23 | 46 | 11 |
| | | | | Mean | trace | 1 | 21 | 24 | 13 | 22 | 19 |
| d | 17 | 82 | 1 | 2.8- 3.8 | 7 | 57 | 35 | 1 | 0 | 0 | 0 |
| | | | | 3.8- 4.6 | 16 | 74 | 9 | 1 | 0 | 0 | 0 |
| | | | | 4.6- 6.6 | 22 | 71 | 5 | 1 | 1 | 0 | 0 |
| | | | | Mean | 17 | 67 | 14 | 1 | 1 | 0 | 0 |
| a&b | 4 | 73 | 23 | Mean | 4 | 25 | 34 | 14 | 9 | 14 | 0 |
| b&c | 3 | 66 | 31 | Mean | 3 | 19 | 31 | 16 | 9 | 13 | 9 |
| a-c | 3 | 63 | 34 | Mean | 3 | 16 | 30 | 17 | 10 | 17 | 7 |
| a-d | 11 | 74 | 15 | Mean | 11 | 46 | 20 | 8 | 5 | 7 | 3 |

**NO 79 SW 9** **7367 9259** **Broomhead, Durris** **Block C**

Surface level c+182m
Water not struck
Pit
September 1986

Waste 0.1m
Bedrock 0.5m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, humic | 0.1 | 0.1 |
| Dalradian | Psammite and semi-pelite with calc-silicate bands, medium dark grey (N4) | 0.5+ | 0.6 |

**NO 79 SW 10** **7323 9235** **West of East Mulloch, Durris** **Block C**

Surface level c+184m
Water not struck
Pit
September 1986

Overburden 0.2m
Mineral I 2.8m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy, pebbly | 0.2 | 0.2 |
| Fluvioglacial sand and gravel | Pebbly sand, with horizontal bedding, fining downwards<br>Gravel: fine with some coarse, subangular to subrounded, medium-grained and coarse-grained red granite, fine-grained red volcanic rock, sparse schist and pegmatitic granite<br>Sand: medium, with some coarse, subrounded quartz and felspar, with some granite<br>Fines: silt, disseminated, greyish orange pink (5 YR 7/2) | 2.8+ | 3.0 |

Pit terminated, sand collapsing in from the sides

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 1 | 88 | 11 | 0.2- 0.6 | 1 | 3 | 33 | 29 | 23 | 11 | 0 |
| | | | 0.6- 1.8 | 1 | 8 | 64 | 20 | 6 | 1 | 0 |
| | | | 1.8- 2.5 | 0 | 4 | 55 | 33 | 5 | 3 | 0 |
| | | | 2.5- 3.0 | 1 | 9 | 53 | 30 | 5 | 2 | 0 |
| | | | Mean | 1 | 6 | 56 | 26 | 8 | 3 | 0 |

**NO 79 SW 11** **7364 9090** **Westerton, Durris** **Block C**

Surface level +150m
Water struck at +145.8m
250mm percussion
October 1986

Overburden 0.2m
Mineral I 4.0m
Waste 8.9m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, brown, sandy | 0.2 | 0.2 |
| Fluvioglacial sand and gravel | Gravel, compact, locally clayey, in part clast-supported<br>Gravel: cobble, with coarse and fine, subangular to subrounded granite, psammite and pelite<br>Sand: coarse, with medium and fine, angular to subangular lithic fragments (chiefly granite), quartz and feldspar<br>Fines: silt and clay, disseminated, moderate brown (5 YR 4/4) | 4.0 | 4.2 |
| Glaciolacustrine deposits | Silt, sandy, soft, becoming firmer towards base, poorly laminated in part, moderate reddish brown (10 R 4/6); sparse clasts of fine and coarse gravel, angular to subangular, granite and psammite | 0.6 | 4.8 |
| Flow-till | Diamicton: clay, silty, sandy, firm to stiff; fine and coarse gravel clasts, angular to subangular, chiefly granite, many weathered, some psammite, pelite and vein-quartz. Thin <50mm silty sand lenses. | 4.1+ | 8.9 |
| | Borehole terminated owing to slow progress | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 4 | 28 | 68 | 0.2- 1.2 | 3 | 3 | 6 | 8 | 9 | 19 | 52 |
| | | | 1.2- 2.0 | No grading data available | | | | | | |
| | | | 2.0- 3.0 | 5 | 6 | 15 | 19 | 13 | 21 | 21 |
| | | | 3.0- 4.2 | No grading data available | | | | | | |
| | | | Mean | 4 | 5 | 10 | 13 | 11 | 20 | 37 |

**NO 79 SW 12** **7486 9325** **Quithelhead, Durris** **Block C**

Surface level +119m
Water struck at +114.2m
250mm percussion
October 1986

Overburden 0.3m
Mineral I 6.2m
Waste 3.3m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, gravelly | 0.3 | 0.3 |
| Fluvioglacial sand and gravel | a Sandy gravel<br>Gravel: fine with coarse, sparse cobble, subangular to subrounded with some angular; predominantly pink granite with psammite, pelite, felsite and basic igneous rocks<br>Sand: coarse with medium, a little fine, subangular, lithic (granite) fragments with quartz and feldspar<br>Fines: silt and clay, disseminated, light brown (5 YR 5/6) | 4.1 | 4.4 |
| | b 'Clayey sand'<br>Gravel: sparse, fine, subrounded, granite<br>Sand: fine to coarse, subangular, lithic fragments, quartz and feldspar<br>Fines: silt, disseminated and in sandy bands, increasing in frequency with depth; moderate reddish brown (10 R 4/6) | 2.1 | 6.5 |
| Glaciolacustrine deposits | Silt, soft, many clay bands and fine sand stringers, moderate reddish brown (10 R 4/6). Laminae most abundant in top 1m | 1.8 | 8.3 |
| Till | Diamicton: clay, silty, sandy, moderately stiff, moderate reddish brown (10 R 4/6); angular to subangular clasts up to cobble grade of pink granite and psammite, with pelite and vein-quartz | 1.2+ | 9.5 |
| | Borehole terminated on an obstruction | | |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm | |
| a | 2 | 62 | 36 | 0.3- 1.3 | 4 | 3 | 12 | 33 | 18 | 15 | 15 | |
| | | | | 1.3- 2.3 | 1 | 2 | 11 | 47 | 24 | 15 | 0 | |
| | | | | 2.3- 3.3 | 2 | 3 | 24 | 39 | 15 | 17 | 0 | |
| | | | | 3.3- 4.4 | 0 | 5 | 37 | 34 | 15 | 9 | 0 | |
| | | | | Mean | 2 | 3 | 21 | 38 | 18 | 14 | 4 | |
| b | 12 | 85 | 3 | 4.4- 5.4 | 9 | 26 | 46 | 13 | 4 | 2 | 0 | § |
| | | | | 5.4- 6.5 | 14 | 42 | 42 | 2 | 0 | 0 | 0 | § |
| | | | | Mean | 12 | 34 | 44 | 7 | 2 | 1 | 0 | |
| a&b | 5 | 72 | 23 | Mean | 5 | 14 | 30 | 28 | 12 | 9 | 2 | |

| NO 79 SW 13 | 7460 9237 | **Blairydryne, Durris** | **Block C** |
|---|---|---|---|

Surface level +135m
Water struck at +123.2m
250 and 200mm percussion
October 1986

| | |
|---|---|
| Overburden | 0.3m |
| Mineral I | 14.2m |
| Waste | 2.9m |
| Bedrock | 0.2m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil: brown, gravelly loam | 0.3 | 0.3 |
| Fluvioglacial sand and gravel | a Pebbly sand, fining downwards<br>Gravel: fine with coarse, mostly in top lm, otherwise as thin stringers. Subangular with subrounded, granite, psammite, felsite, pelite and basic igneous rocks<br>Sand: medium and coarse with fine, subangular, lithic fragments (granite), quartz and feldspar<br>Fines: silt and clay, disseminated, light brown (5 YR 5/6) | 5.2 | 5.5 |
| | b Sand<br>Gravel: very sparse, fine, subangular, composition as above<br>Sand: medium with fine, some coarse, subangular, lithic fragments, quartz and feldspar<br>Fines: silt and clay, disseminated, banded light brown (5 YR 5/6 and 5 YR 6/4) | 2.9 | 8.4 |
| | c Sandy gravel<br>Gravel: fine with coarse to 11.4, then fine to cobble, subangular to angular psammite with granite, pelite, vein-quartz and basic igneous rocks<br>Sand: fine to coarse, subangular, lithic fragments, quartz and feldspar<br>Fines: silt and clay, disseminated and in seams, light brown (5 YR 5/6) to light olive brown (5 Y 5/6) | 6.1 | 14.5 |
| Till | Diamicton: clay, sandy, silty, stiff, light olive brown (5 Y 5/6); angular to subangular clasts of fine to coarse gravel with occasional cobbles, predominantly granite and psammite. Very stiff, and many cobbles, at base | 2.9 | 17.4 |
| Caledonian | Granite, weathered to a sand, with quartz, feldspar and lithic fragments | 0.2+ | 17.6 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 4 | 75 | 21 | 0.3- 1.3 | 2 | 6 | 25 | 28 | 17 | 22 | 0 |
| | | | | 1.3- 2.3 | 1 | 8 | 54 | 24 | 6 | 7 | 0 |
| | | | | 2.3- 3.3 | 2 | 5 | 30 | 42 | 15 | 6 | 0 |
| | | | | 3.3- 4.3 | 12 | 17 | 23 | 28 | 15 | 5 | 0 |
| | | | | 4.3- 5.5 | 2 | 6 | 40 | 35 | 10 | 7 | 0 |
| | | | | Mean | 4 | 8 | 35 | 32 | 12 | 9 | 0 |
| b | 5 | 94 | 1 | 5.5- 6.5 | 4 | 28 | 53 | 11 | 3 | 1 | 0 |
| | | | | 6.5- 7.5 | 6 | 27 | 62 | 5 | 0 | 0 | 0 |
| | | | | 7.5- 8.4 | 5 | 45 | 48 | 2 | 0 | 0 | 0 |
| | | | | Mean | 5 | 33 | 55 | 6 | 1 | trace | 0 |
| c | 5 | 56 | 39 | 8.4- 9.4 | 3 | 26 | 30 | 15 | 12 | 14 | 0 |
| | | | | 9.4-10.4 | 10 | 32 | 35 | 8 | 5 | 1 | 9 |
| | | | | 10.4-11.4 | 10 | 29 | 36 | 19 | 6 | 0 | 0 |
| | | | | 11.4-12.5 | 3 | 6 | 14 | 16 | 15 | 22 | 24 § |
| | | | | 12.5-13.6 | 1 | 5 | 15 | 16 | 20 | 22 | 21 § |
| | | | | 13.6-14.5 | 1 | 9 | 18 | 15 | 18 | 23 | 16 § |
| | | | | Mean | 5 | 18 | 23 | 15 | 13 | 14 | 12 |
| a&b | 4 | 82 | 14 | Mean | 4 | 17 | 43 | 22 | 8 | 6 | 0 |
| b&c | 5 | 69 | 26 | Mean | 5 | 23 | 34 | 12 | 9 | 9 | 8 |
| a-c | 4 | 72 | 24 | Mean | 4 | 17 | 36 | 19 | 10 | 9 | 5 |

**NO 79 SW 14** **7466 9202** **Mains of Blairydryne, Durris** **Block C**

Surface level c+127m
Water not struck
Pit
September 1986

Overburden 0.3m
Mineral I 3.4m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, with pebbles and cobbles | 0.3 | 0.3 |
| Glacial sand and gravel (Esker bead) | a Sandy gravel, coarsening downwards<br>Gravel: coarse and fine, with cobble; angular granite, tabular pelite, psammite and semipelite; sparse cobbles of fine-grained basic igneous rock and pegmatitic granite<br>Sand: coarse and medium, subangular to angular quartz, with some rock; poorly sorted at the top, high angle cross stratification, which becomes better developed with depth<br>Fines: silt, disseminated, moderate yellowish brown (10 YR 5/3) | 2.7 | 3.0 |
| Glaciolacustrine deposits | b 'Very clayey' pebbly sand<br>Gravel: fine and coarse<br>Sand: fine and medium, with some coarse, rounded, quartz and mica<br>Fines: silt, disseminated and as thin, laminated beds containing ?rootlets and organic matter; light olive brown (5 Y 5/6) | 0.7+ | 3.7 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 1 | 56 | 43 | 0.3- 1.3 | 1 | 2 | 30 | 27 | 19 | 21 | 0 |
| | | | | 1.3- 2.2 | 0 | 1 | 22 | 36 | 19 | 16 | 6 |
| | | | | 2.2- 3.0 | 1 | 2 | 22 | 25 | 16 | 22 | 12 |
| | | | | Mean | 1 | 2 | 24 | 30 | 18 | 20 | 5 |
| b | 35 | 57 | 8 | 3.0- 3.7 | 35 | 23 | 23 | 11 | 5 | 3 | 0 |
| a&b | 8 | 57 | 35 | Mean | 8 | 6 | 24 | 27 | 15 | 16 | 4 |

**NO 79 SW 15** **7460 9165** **Balrownie, Durris** **Block C**

Surface level c+122m
Water struck at +118.3m (perched)
Section and pit
September 1986

Mineral I 3.7m
Waste 1.0m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| Glacial sand and gravel (Esker) | a Gravel, coarsening downwards; cut by steep-sided channel, filled with horizontally laminated, fine silty sand, with gravel stringers and sparse dropstones<br>Gravel: coarse with fine, some cobble towards the base, angular, pelite, semipelite and acid igneous rock<br>Sand: coarse and medium, angular, quartz, feldspar and rock<br>Fines: silt, disseminated, light brown (5 YR 6/6) | 2.1 | 2.1 |
| | b Sandy gravel<br>Gravel: coarse and fine, angular pelite and semipelite<br>Sand: medium, with coarse and some fine, angular quartz, feldspar and rock<br>Fines: silt, disseminated, light brown (5 YR 5/5) | 0.8 | 2.9 |
| | c Gravel, poorly sorted<br>Gravel: fine and coarse, with cobble, angular, pelite, semipelite and some granite<br>Sand: coarse with medium, angular quartz, rock and feldspar<br>Fines: silt and clay, disseminated, light brown (5 YR 6/4) | 0.8 | 3.7 |
| Till | Diamicton; clay, silt and sand, very stiff, waxy in part, angular clasts up to 0.7m of pelite, semipelite, amphibolite and coarse-grained pink and grey granite; moderate yellowish brown (10 YR 5/4) | 1.0+ | 4.7 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 2 | 40 | 58 | 0.0- 0.9 | 1 | 1 | 7 | 13 | 23 | 55 | 0 |
| | | | | 0.9- 2.1 | 4 | 3 | 25 | 27 | 17 | 19 | 5 |
| | | | | Mean | 2 | 2 | 17 | 21 | 19 | 36 | 3 |
| b | 3 | 64 | 33 | 2.1- 2.9 | 3 | 9 | 36 | 19 | 16 | 17 | 0 |
| c | 4 | 38 | 58 | 2.9- 3.7 | 4 | 5 | 14 | 19 | 24 | 22 | 12 |
| a&b | 3 | 47 | 50 | Mean | 3 | 4 | 22 | 21 | 18 | 30 | 2 |
| b&c | 3 | 51 | 46 | Mean | 3 | 7 | 25 | 19 | 20 | 20 | 6 |
| a-c | 3 | 45 | 52 | Mean | 3 | 5 | 20 | 20 | 20 | 28 | 4 |

**NO 79 SW 16** **7311 9274** **Bogforran, Banchory** **Block C**

Surface level c+172m
Water not struck
Section
September 1986

Overburden 1.6m
Mineral II 1.2m
Mineral I 2.4m
Waste 0.2m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Made ground | 1.5 | 1.5 |
| | Soil | 0.1 | 1.6 |
| Flow-till | a Pebbly sand, unstratified, poorly sorted and matrix supported at the top; gravelly, clast supported towards the base<br>Gravel: mainly fine, angular, granite, fine-grained red acid volcanic rock, psammite and semipelite<br>Sand: coarse, medium and fine, angular rock<br>Fines: clay, binding the deposit, a thin bed of clayey silt at the base; pale yellowish brown (10 YR 6/2) | 1.2 | 2.8 |
| Fluvioglacial sand and gravel | b Sandy gravel; in three distinct fining downwards, cross bedded units, each 0.8m thick, separated by partings of clayey silt<br>Gravel: fine and coarse, angular, pink and grey granite, sparse felsite and psammitic grit<br>Sand: medium, with coarse and fine, angular granite, with subangular to subrounded quartz<br>Fines: silt, disseminated and thin partings of clayey silt, pale yellowish brown (10 YR 6/2) to moderate brown (5 YR 4/4) | 2.4 | 5.2 |
| Glaciolacustrine deposits | Silt, clayey, waxy, moderate brown (5 YR 4/4) mottled with greyish yellow (5 Y 7/5) and light olive brown (5 Y 5/6) | 0.1 | 5.3 |
| Till | Diamicton, clay, stiff, angular pebbles; moderate brown (5 YR 4/4) | 0.1+ | 5.4 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 8 | 71 | 21 | 1.6- 2.8 | 8 | 11 | 26 | 34 | 18 | 3 | 0 |
| b | 5 | 68 | 27 | 2.8- 3.6 | 4 | 4 | 18 | 35 | 19 | 20 | 0 |
| | | | | 3.6- 4.4 | 7 | 5 | 25 | 22 | 23 | 18 | 0 |
| | | | | 4.4- 5.2 | 4 | 30 | 60 | 4 | 1 | 1 | 0 |
| | | | | Mean | 5 | 13 | 35 | 20 | 14 | 13 | 0 |
| a&b | 6 | 68 | 26 | Mean | 6 | 12 | 32 | 24 | 16 | 10 | 0 |

**NO 79 SE 1** **7541 9290** **Lochton, Durris** **Block C**

Surface level c+121m
Water struck at +115.6m
Section and pit
September 1986

| | |
|---|---|
| Mineral I | 5.4m |
| Waste | 2.0m |
| Bedrock | 0.2m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| Fluvioglacial sand and gravel | a Gravel, with avalanche cross-stratification<br>Gravel: cobble to fine, rounded to subangular red granite and semipelite; as gravel lags on avalanche foresets below 1.5m depth<br>Sand: mainly coarse, angular to subangular quartz, pink granite and feldspar<br>Fines: silt, disseminated, sparse, light brown (5 YR 6/4); iron pan at 2.9m depth | 2.9 | 2.9 |
| | b Sandy gravel, with avalanche cross-stratification, gravel as lags on foresets<br>Gravel: fine and coarse, rounded to subangular red and pink granite and semipelite, sparse angular schist<br>Sand: coarse to medium, angular to subangular granite, feldspar and quartz<br>Fines: silt, disseminated, light brown (5 YR 6/4) | 2.5 | 5.4 |
| Glaciolacustrine deposits | Silt, with fine horizontal lamination; becoming firm, waxy, clayey silt with depth; pale olive (10 Y 6/2) to greenish grey (5 GY 6/1) to 5.6m, light brown (5 YR 5/6), becoming yellowing brown (10 YR 6/2) towards the base | 2.0 | 7.4 |
| Dalradian | Pelitic schist, with quartz veins, soft, highly weathered, greyish black (N2) | 0.2+ | 7.6 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | − 1/16 | + 1/16 − 1/4 | + 1/4 −1 | +1−4 | +4−16 | +16−64 | +64 mm |
| a | 0 | 48 | 52 | 0.0− 1.5 | 0 | 1 | 9 | 38 | 15 | 10 | 27 |
| | | | | 1.5− 2.9 | 0 | 1 | 9 | 39 | 11 | 5 | 35 |
| | | | | Mean | 0 | 1 | 9 | 38 | 13 | 8 | 31 |
| b | 0 | 71 | 29 | 2.9− 4.1 | 0 | 1 | 15 | 47 | 20 | 17 | 0 |
| | | | | 4.1− 5.4 | 0 | 2 | 39 | 36 | 11 | 12 | 0 |
| | | | | Mean | 0 | 2 | 27 | 42 | 15 | 14 | 0 |
| a&b | 0 | 58 | 42 | Mean | 0 | 1 | 18 | 39 | 14 | 11 | 17 |

**NO 79 SE 2** **7560 9358** **Wardend, Durris** **Block C**

Surface level c+113m
Water not struck
Pit
September 1986

| | |
|---|---|
| Overburden | 0.4m |
| Mineral I | 2.2m |
| Waste | 0.7m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy and pebbly | 0.4 | 0.4 |
| Fluvioglacial sand and gravel | Sandy gravel, becoming less pebbly with depth; manganese pan from 2.2m to 2.4m depth<br>Gravel: fine with coarse; in small scale trough cross-bedded units below 1.4m depth; rounded to subangular coarse-grained pink granite, some granodiorite, psammite and felsite<br>Sand: coarse with medium, angular to subangular quartz, with some angular rock and feldspar<br>Fines: silt, clay and manganese oxide, disseminated, light brown (5 YR 5/6) to black (N1) | 2.2 | 2.6 |
| Till | Diamicton, stoney clay, matrix supported, stiff, abundant boulders of grey granodiorite, gneiss and schist; light olive grey (5 Y 5/2) | 0.7+ | 3.3 |
| | Pit terminated on large boulders | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | − 1/16 | + 1/16 − 1/4 | + 1/4 −1 | +1−4 | +4−16 | +16−64 | +64 mm |
| 1 | 73 | 26 | 0.4− 1.4 | 0 | 2 | 19 | 44 | 21 | 14 | 0 |
| | | | 1.4− 2.6 | 1 | 2 | 22 | 57 | 13 | 5 | 0 |
| | | | Mean | 1 | 2 | 20 | 51 | 17 | 9 | 0 |

**NO 79 SE 3** **7609 9321** **North of Darnford, Durris** **Block C**

Surface level c+119m
Water not struck
Pit
September 1986

Waste 1.7m
Bedrock 0.7m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.3 | 0.3 |
| Till | Diamicton, silty clay, unstratified; pebbles and tabular cobbles of pelite, semipelite and granite; quite sandy with traces of horizontal lamination and clasts of weathered pink and light grey granite below 1.4m depth; moderate yellowish brown (10 YR 5/4) | 1.4 | 1.7 |
| Dalradian | Schistose semipelite, weathered in part to coarse sand in a matrix of kaolinitic clay | 0.5 | 2.2 |
| | Pelite, micaceous, deeply weathered, brownish black (5 YR 2/1) | 0.2+ | 2.4 |

**NO 79 SE 4** **7674 9436** **Balladrum Wood, Durris** **Block C**

Surface level c+96m
Water not struck
Section and pit
September 1986

Overburden 0.3m
Mineral I 4.1m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy with tabular cobbles | 0.3 | 0.3 |
| Fluvioglacial sand and gravel | Gravel, clast supported, poorly sorted, boulders at base<br>Gravel: coarse, with cobble and fine, some boulders up to 20cm; crude horizontal stratification; rounded coarse-grained pink granite, orange granite, granodiorite, medium-grained intermediate igneous rock and some semipelite; sparse angular coarse-grained psammitic grit, felsite and schist<br>Sand: mainly coarse, angular rock and subrounded quartz<br>Fines: silt, disseminated, moderate brown (5 YR 4/4) to moderate yellowish brown (10 YR 5/4) | 4.1+ | 4.4 |
| | Pit abandoned on large boulders of gneiss and coarse-grained granite | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | - 1/16 | + 1/16 - 1/4 | + 1/4 -1 | +1-4 | +4-16 | +16-64 | +64 mm |
| trace | 36 | 64 | 0.3- 1.4 | 1 | 1 | 10 | 25 | 15 | 31 | 17 |
| | | | 1.4- 2.9 | 0 | 1 | 11 | 29 | 15 | 31 | 13 |
| | | | 2.9- 3.6 | 0 | 1 | 11 | 26 | 16 | 24 | 22 |
| | | | 3.6- 4.4 | 1 | 1 | 9 | 18 | 13 | 32 | 26 |
| | | | Mean | trace | 1 | 10 | 25 | 15 | 31 | 18 |

**NO 79 SE 5** **7765 9492** **Little Tulloch, Durris** **Block C**

Surface level c+76m
Water struck at +72.8m
Pit
September 1986

Overburden 0.3m
Mineral I 1.0m
Waste 2.0m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy | 0.3 | 0.3 |
| Glacial sand and gravel | Gravel, unstratified, clast supported<br>Gravel: cobbles and boulders up to 80cm, some coarse and fine; subrounded to subangular granodiorite, granite, psammite and semipelite<br>Sand: medium and coarse with some fine, subangular quartz and rock<br>Fines: silt, disseminated, strong brown (5 YR 4/6) | 1.0 | 1.3 |
| Till | Diamicton, sandy clay, unstratified, subrounded boulders up to 1.5m of semipelite and granodiorite, cobbles of highly weathered gabbro and pebbles of granite, schist and psammite; pale yellowish brown (10 YR 6/2) | 0.9 | 2.2 |
| Flow-till | Diamicton, clayey sand, with fine pebbles and sparse ultrabasic cobbles | 0.6 | 2.8 |
| Till | Diamicton, sandy clay, unstratified, scattered subrounded boulders up to 1.5m, sparse highly weathered pebbles of coarse-grained ultra basic rock; moderate brown (5 YR 4/4) to moderate yellowish brown (10 YR 5/4) | 0.5+ | 3.3 |
| | Pit terminated on boulders of granodiorite, hard pelitic schist and leucocratic coarse-grained granite | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 3 | 16 | 81 | 0.3- 1.3 | 3 | 3 | 7 | 6 | 7 | 23 | 51 |

**NO 79 SE 6** **7837 9007** **Lady's Moss, Stonehaven** **Block E**

Surface level c+168m
Water struck at +166.5m
Pit
September 1986

Waste 1.6m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, humic | 0.3 | 0.3 |
| Morainic drift | Diamicton, sandy clay with abundant rounded boulders of fine-grained basic rock; clast supported, poorly developed horizontal bedding, sparse pebbles of medium-grained orange granite and tabular psammite; dusky yellowish brown (10 YR 3/2) | 1.3+ | 1.6 |
| | Pit terminated on large blocks of grey granite | | |

**NO 88 NW 1** **8011 8938** **Millsburn, Stonehaven** **Block E**

Surface level c+140m
Water not struck
Pit
September 1986

Overburden 0.4m
Mineral I 2.7m
Waste 0.1m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy | 0.4 | 0.4 |
| Morainic drift | Sandy gravel, clast supported, crude cross-stratification, iron pan in top 0.6m, manganese pan from 2.0m to 2.4m depth<br>Gravel: fine and coarse, subrounded to subangular coarse-grained pink and white granite, schistose semipelite and sparse rounded pebbles of gneiss<br>Sand: coarse and medium with some fine; angular to subangular quartz and granite with some feldspar and rock<br>Fines: silt and clay; disseminated and in discontinuous seams, dark orange and black (N1); some 1cm beds of silt from 1.4m to 2.4m depth, strong brown (5 YR 4/6); manganese oxide, black (N1) from 2.0m to 2.4m depth; finely laminated beds of micaceous silt and clay, light olive grey (5 Y 5/2) from 2.4m to the base | 2.7 | 3.1 |
| Till | Diamicton, very sandy clay with angular pebbles, stiff, moderate brown (5 YR 4/4) to strong brown (5 YR 4/6) | 0.1+ | 3.2 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 3 | 69 | 28 | 0.4- 1.4 | 2 | 5 | 24 | 33 | 16 | 20 | 0 |
| | | | 1.4- 2.4 | 3 | 10 | 25 | 36 | 16 | 10 | 0 |
| | | | 2.4- 3.1 | 6 | 17 | 33 | 26 | 12 | 6 | 0 |
| | | | Mean | 3 | 10 | 27 | 32 | 15 | 13 | 0 |

**NO 88 NW 2** **8017 8878** **Snob Cottage, Stonehaven** **Block F**

Surface level c+135m
Water not struck
Pit
September 1986

Waste 1.5m
Bedrock 0.3m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, humic with angular boulders and grey sand | 0.3 | 0.3 |
| Morainic drift | Diamicton, pebbly clay and sand, becoming silty with depth; unstratified, matrix supported; angular cobbles of schist, psammite and fine-grained basic igneous rock, sparse pebbles of pink granite; dark yellowish orange (10 YR 6/6) | 1.2 | 1.5 |
| Dalradian | Psammite, fine grained, banded, greyish green (5 G 5/2) | 0.3+ | 1.8 |

NO 88 NW 3 — 8003 8830 — **South of Snob Cottage, Stonehaven** — **Block F**

Surface level c+145m
Water not struck
Section and pit
September 1986

Overburden 0.4m
Mineral I 2.4m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy | 0.4 | 0.4 |
| Fluvioglacial sand and gravel | Sandy gravel, more pebbly with depth<br>Gravel: coarse with fine, rounded pink fine-grained granite, with some psammite and fine-grained basic rock; sparse rounded boulders up to 0.3m, between 0.9m and 1.6m depth<br>Sand: medium and coarse, well sorted, subrounded to subangular quartz with some feldspar and rock; cross-stratified to 1.3m depth<br>Fines: silt, disseminated strong brown (5 YR 4/6) iron staining to 1.3m depth and thin beds of iron pan towards the base | 2.4+ | 2.8 |
| | Pit abandoned, sand and gravel collapsing in from the sides | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 1 | 68 | 31 | 0.4- 1.3 | 2 | 5 | 36 | 36 | 11 | 10 | 0 |
| | | | 1.3- 2.8 | 0 | 3 | 34 | 25 | 10 | 28 | 0 |
| | | | Mean | 1 | 4 | 35 | 29 | 10 | 21 | 0 |

NO 88 NW 4 | 8053 8811 | **Whitehill, Stonehaven** | **Block F**

Surface level c+134m
Water not struck
Section and pit
September 1986

Overburden 0.5m
Mineral I 5.4m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, humic | 0.5 | 0.5 |
| Fluvioglacial sand and gravel | a Gravel, fining downwards<br>Gravel: cobble to fine, mainly rounded and tabular pink granite, schist and psammite<br>Sand: mainly coarse, angular quartz and granitic rock<br>Fines: silt, disseminated, strong yellowish orange (10 YR 4/6) | 3.0 | 3.5 |
| | b Pebbly sand, low angle cross-stratification<br>Gravel: coarse and fine rounded granite, pelite and psammite<br>Sand: medium and coarse, angular to subangular, granitic rock, with some quartz and pink feldspar<br>Fines: silt, disseminated | 1.0 | 4.5 |
| | c Sandy gravel, crude horizontal bedding - start of second fining downwards cycle<br>Gravel: cobble with some coarse and fine, rounded granite, schist and psammite<br>Sand: mainly medium, subrounded quartz and feldspar<br>Fines: silt, disseminated and as discontinuous seams; light brown (5 YR 5/4) | 1.4+ | 5.9 |
| | Pit abandoned, sand and gravel collapsing in from the sides | | |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 1 | 40 | 59 | 0.5- 2.5 | 1 | 2 | 7 | 27 | 12 | 29 | 22 |
| | | | | 2.5- 3.5 | 1 | 1 | 14 | 32 | 15 | 14 | 23 |
| | | | | Mean | 1 | 2 | 9 | 29 | 13 | 24 | 22 |
| b | 1 | 82 | 17 | 3.5- 4.5 | 1 | 3 | 41 | 38 | 8 | 9 | 0 |
| c | 1 | 61 | 38 | 4.5- 5.9 | 1 | 12 | 32 | 17 | 7 | 8 | 23 |
| a&b | 1 | 50 | 49 | Mean | 1 | 2 | 17 | 31 | 12 | 20 | 17 |
| b&c | 1 | 71 | 28 | Mean | 1 | 8 | 37 | 26 | 7 | 8 | 13 |
| a&c | 1 | 46 | 53 | Mean | 1 | 5 | 17 | 24 | 11 | 19 | 23 |
| a-c | 1 | 53 | 46 | Mean | 1 | 5 | 21 | 27 | 11 | 17 | 18 |

**NO 88 NW 5** | **8077 8770** | **South of Whitehill, Stonehaven** | **Block E**

Surface level c+153m
Water not struck
Pit
September 1986

Waste 2.3m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, humic | 0.3 | 0.3 |
| Morainic drift | Diamicton, stony silt and clay, very compact, poorly stratified; pebbles and tabular boulders up to 0.7m, of coarse-grained pink granite, psammite and granodiorite; moderate yellowish brown (10 YR 5/4) | 2.0+ | 2.3 |
| | Pit terminated on large angular boulders | | |

**NO 88 NW 6** | **8078 8715** | **Burn of Day, Stonehaven** | **Block E**

Surface level c+185m
Water not struck
Section and pit
September 1986

Overburden 0.3m
Mineral I 2.5m
Bedrock 0.2m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, silty | 0.3 | 0.3 |
| Morainic drift | Gravel, clayey at the top, clast supported, imbricated, moderately well developed horizontal stratification | 2.5 | 2.8 |
| | Gravel: coarse and cobble with fine, poorly sorted, tabular pelitic and semipelitic schist, angular vein quartz and fine grained acid igneous rock, sparse psammite; rounded and subangular boulders, up to 0.2m, of medium-grained pink granite and schist below 1.3m depth | | |
| | Sand: coarse, medium and fine, angular quartz | | |
| | Fines: mainly silt, micaceous; as discontinuous lenses up to 3cm thick and binding deposit towards the base; strong brown (5 YR 4/6) | | |
| Dalradian | Psammite, fine to coarse-grained, fractured into large angular blocks; medium grey (N5) | 0.2+ | 3.0 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 7 | 19 | 74 | 0.3- 1.3 | 12 | 7 | 5 | 4 | 10 | 33 | 29 |
| | | | 1.3- 2.8 | 3 | 3 | 8 | 9 | 14 | 32 | 31 |
| | | | Mean | 7 | 5 | 7 | 7 | 12 | 32 | 30 |

**NO 88 NW 7** **8082 8860** **Tentyhillock, Stonehaven** **Block F**

Surface level +118m
Water not struck
Pit and 250mm percussion
November 1986

Overburden 0.3m
Mineral I 2.8m
Waste 7.2m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sand and cobbles | 0.3 | 0.3 |
| Fluvioglacial sand and gravel | Gravel, boulders up to 0.3m at the top, crude horizontal stratification<br>Gravel: mainly cobble with some coarse and fine, well rounded to angular, coarse-grained pink and red granite, psammite and psammitic grit; sparse tabular schist and banded gneiss<br>Sand: coarse with medium, subrounded to subangular quartz, some feldspar and rock<br>Fines: silt, disseminated, moderate brown (5 YR 3/4) | 2.8 | 3.1 |
| Flow-till (Red Series) | Diamicton, sandy clay, firm, clasts up to cobble size; moderate yellowish brown (10 YR 5/3) to pale reddish brown (10 R 5/4) | 3.9 | 7.0 |
| Glaciolacustrine deposits (Red Series) | Silt, laminated, moderate yellowish brown (10 YR 5/4) | 1.5 | 8.5 |
| Till (Red Series) | Diamicton, stony clay, hard, abundant pebbles | 1.8+ | 10.3 |

Borehole terminated on rock obstruction

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 1 | 43 | 56 | 0.3- 1.4 | 1 | 2 | 14 | 18 | 8 | 11 | 46 |
| | | | 1.4- 2.3 | 1 | 0 | 17 | 30 | 10 | 12 | 30 |
| | | | 2.3- 3.1 | 1 | 1 | 19 | 31 | 11 | 22 | 15 |
| | | | Mean | 1 | 1 | 16 | 26 | 9 | 14 | 33 |

NO 88 NW 8 8215 8532 **White Hill, Stonehaven** **Block G**

Surface level +104m
Water not struck
250 and 200mm percussion
November 1986

| | |
|---|---|
| Overburden | 0.3m |
| Mineral I | 4.9m |
| Waste | 2.5m |
| Mineral I | 7.1m |
| Mineral I | 3.0m |
| Waste | 2.3m+ |

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy, scattered pebbles, moderate brown | 0.3 | 0.3 |
| Fluvioglacial sand and gravel (Red Series) | a Sand<br>Gravel: sparse, fine with coarse, well rounded Devonian quartzite, tabular sandstone and subangular metamorphic rocks<br>Sand: medium with fine, subrounded to well rounded, quartz, feldspar and mica<br>Fines: silt and clay, disseminated and in seams, moderate reddish brown to light reddish brown (10 R 5/6 to 10 R 4/6) | 4.9 | 5.2 |
| Glaciolacustrine deposits (Red Series) | Silt, sandy, micaceous, reddish brown, laminated, becoming clayey with depth | 2.5 | 7.7 |
| Fluvioglacial sand and gravel (Red Series) | b Sandy gravel<br>Gravel: fine with coarse, sparse cobble, well rounded sandstone and quartzite, tabular psammite and semipelite, fine-grained acid igneous rocks, occasional weathered angular metamorphic rocks, vein quartz, quartzite. Sparse cobbles of well rounded quartzite<br>Sand: fine to coarse, subangular, quartz, lithic fragments and feldspar<br>Fines: silt and clay, disseminated, locally binding the deposit, moderate reddish brown (10 R 4/6) | 7.1 | 14.8 |
| | c Sand<br>Gravel: sparse fine to coarse, subrounded to well rounded, Devonian quartzite and sandstone<br>Sand: medium, with fine and coarse, subangular, lithic fragments, quartz and feldpsar<br>Fines: silt and clay, disseminated and in seams, moderate reddish brown (10 R 4/6) to moderate red (5 R 4/6) | 3.0 | 17.8 |
| Glaciolacustrine deposits (Red Series) | Silt, clayey, firm to stiff, with beds of fine sand up to 50mm thick. Moderate reddish brown (10 R 4/6) to moderate red (5 R 4/6). Thin clay beds at base, poorly developed horizontal laminae | 2.1 | 19.9 |
| Till | Diamicton: clay, sandy, silty, stiff; many angular to subangular clasts, mainly of Devonian sandstone and quartzite. Moderate reddish brown (10 R 4/6). | 0.2+ | 20.1 |

Borehole terminated for technical reasons

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 9 | 90 | 1 | 0.3- 1.5 | 2 | 14 | 70 | 9 | 1 | 4 | 0 |
| | | | | 1.5- 3.0 | 3 | 11 | 78 | 8 | 0 | 0 | 0 |
| | | | | 3.0- 4.5 | 18 | 49 | 32 | 1 | 0 | 0 | 0 |
| | | | | 4.5- 5.2 | 12 | 51 | 36 | 0 | 1 | 0 | 0 |
| | | | | Mean | 9 | 29 | 56 | 5 | trace | 1 | 0 |
| b | 7 | 57 | 36 | 7.7- 8.7 | 7 | 10 | 20 | 21 | 20 | 22 | 0 |
| | | | | 8.7- 9.7 | 8 | 15 | 25 | 17 | 18 | 17 | 0 |
| | | | | 9.7-10.6 | No grading data available | | | | | | |
| | | | | 10.6-11.3 | 8 | 5 | 19 | 32 | 21 | 7 | 8 |
| | | | | 11.3-12.8 | No grading data available | | | | | | |
| | | | | 12.8-13.8 | 7 | 7 | 21 | 22 | 25 | 18 | 0 |
| | | | | 13.8-14.8 | 4 | 6 | 41 | 21 | 9 | 19 | 0 |
| | | | | Mean | 7 | 9 | 26 | 22 | 18 | 17 | 1 |
| c | 5 | 91 | 4 | 14.8-15.8 | 5 | 11 | 68 | 13 | 1 | 2 | 0 |
| | | | | 15.8-17.0 | 5 | 9 | 73 | 9 | 2 | 2 | 0 |
| | | | | 17.0-17.8 | 4 | 12 | 66 | 15 | 2 | 1 | 0 |
| | | | | Mean | 5 | 10 | 69 | 12 | 2 | 2 | 0 |
| a&b | 8 | 69 | 23 | Mean | 8 | 17 | 37 | 15 | 11 | 11 | 1 |
| b&c | 6 | 67 | 27 | Mean | 6 | 9 | 39 | 19 | 13 | 13 | 1 |
| a-c | 7 | 74 | 19 | Mean | 7 | 16 | 44 | 14 | 9 | 9 | 1 |

**NO 88 NW 9** **8317 8892** **South of Cowton, Stonehaven** **Block F**

Surface level c+68m
Water struck at +67m
Pit
September 1986

Mineral I 1.5m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| Alluvium | a 'Clayey' pebbly sand<br>Gravel: mainly fine<br>Sand: medium with fine and coarse, subrounded quartz<br>Fines: silt, disseminated, dark yellowish brown (10 YR 3/2) | 0.4 | 0.4 |
| Fluvioglacial sand and gravel | b Gravel, imbricated, poorly sorted, unstratified, boulders up to 0.8m<br>Gravel: coarse and cobble with some fine, clast supported; tabular schist and subrounded coarse-grained granite<br>Sand: coarse and medium, angular rock and quartz<br>Fines: silt and clay, disseminated and coating boulders; dark yellowish brown (10 YR 3/2)<br>Pit collapsing below water table | 1.1+ | 1.5 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 10 | 85 | 5 | 0.0- 0.4 | 10 | 21 | 47 | 17 | 4 | 1 | 0 |
| b | 1 | 30 | 69 | 0.4- 1.5 | 1 | 4 | 12 | 14 | 14 | 33 | 22 § |
| a&b | 3 | 45 | 52 | Mean | 3 | 9 | 21 | 15 | 11 | 25 | 16 |

NO 88 NW 10 | 8325 8846 | South Glenton, Stonehaven | Block F

Surface level +102m
Water not struck
250mm and 200mm percussion
November 1986

Overburden 0.2m
Mineral I 6.7m
Waste 0.9m
Mineral I 5.6m
Waste 3.6m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy, organic | 0.2 | 0.2 |
| Fluvioglacial sand and gravel | a Sandy gravel; clean and dry<br>Gravel: fine with coarse, a trace of cobble, mainly subangular to subrounded, with some angular; granite with some schist and fine-grained metasediment<br>Sand: medium and coarse, with some fine, subangular to rounded quartz, lithic fragments, feldspar and a trace of mica<br>Fines: disseminated silt, moderate yellowish brown (10 YR 5/3) | 6.7 | 6.9 |
| ?Flow-till | Diamicton; clay-bound boulder deposit. Clasts, mainly of rotted granite, in a matric of clay and fine gravel; very hard, dark yellowish brown (10 YR 4/2) | 0.9 | 7.8 |
| Fluvioglacial sand and gravel | b Pebbly sand; slightly cohesive in part with white (?kaolinite) matrix in some clay lenses<br>Gravel: fine with coarse and a trace of cobble, mainly subangular to subrounded, some angular and well rounded; granite, with some schist, quartzite and psammite<br>Sand: medium, with coarse and fine, mainly subangular to subrounded, some angular and well rounded, quartz, lithic fragments, feldspar and mica<br>Fines: silt, disseminated, some white clay binding the deposit in places | 5.6 | 13.4 |
| Till | Diamicton; clay, stiff to hard; clasts up to cobble size, subangular to rounded, moderate yellowish brown (10 YR 5/3) | 3.6+ | 17.0 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 6 | 70 | 24 | 0.2- 1.3 | 4 | 4 | 26 | 31 | 17 | 13 | 5 |
| | | | | 1.3- 2.6 | 6 | 3 | 27 | 36 | 18 | 10 | 0 |
| | | | | 2.6- 3.8 | 5 | 5 | 29 | 36 | 16 | 9 | 0 |
| | | | | 3.8- 4.0 | 7 | 9 | 37 | 30 | 11 | 1 | 5 |
| | | | | 4.0- 5.0 | 6 | 7 | 54 | 23 | 6 | 4 | 0 |
| | | | | 5.0- 6.9 | 9 | 10 | 36 | 22 | 13 | 10 | 0 |
| | | | | Mean | 6 | 6 | 35 | 29 | 14 | 9 | 1 |
| b | 8 | 82 | 10 | 7.8-10.2 | 10 | 10 | 36 | 31 | 10 | 3 | 0 |
| | | | | 10.2-12.2 | 6 | 23 | 47 | 14 | 5 | 5 | 0 |
| | | | | 12.2-13.4 | 8 | 27 | 51 | 9 | 3 | 2 | 0 |
| | | | | Mean | 8 | 18 | 44 | 20 | 7 | 3 | 0 |
| a&b | 7 | 74 | 19 | Mean | 7 | 12 | 37 | 25 | 11 | 7 | 1 |

NO 88 NW 11 | 8316 8540 | **East Tewel, Stonehaven** | **Block G**

Surface level +87m
Water not struck
250mm and 200mm percussion
November 1986

| | |
|---|---|
| Overburden | 1.6m |
| Mineral I | 1.8m |
| Waste | 1.2m |
| Mineral I | 3.9m |
| Waste | 6.5m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, silty and clayey | 0.2 | 0.2 |
| Glaciolacustrine deposits (Red Series) | Silt, laminated, friable to plastic, fine sandy micaceous laminae; moderate red (5 R 4/1) | 1.4 | 1.6 |
| Fluvioglacial sand and gravel (Red Series) | a 'Clayey' sand; clean and micaceous at the top, becoming more silty with depth<br>Sand: medium with fine and some coarse, subangular to rounded quartz, lithic fragments mica and feldspar<br>Fines: silt, disseminated and binding deposit in part from 2.4m; moderate red (5 R 4/1) | 1.8 | 3.4 |
| Glaciolacustrine deposits (Red Series) | Silt; micaceous, clayey, some fine sand, moderate red (5 R 4/1) | 1.2 | 4.6 |
| Fluvioglacial sand and gravel (Red Series) | b 'Very clayey' sand; gravel in top metre, thin pebbly and clayey beds from 6.5m. Pebbles of subangular to rounded sandstone, quartzite, schist and psammite<br>Sand: fine with medium and some coarse, subangular to rounded, quartz, mica and lithic fragments<br>Fines: silt and clay, disseminated and binding deposit in part, moderate red (5 R 4/1) | 3.9 | 8.5 |
| Glaciolacustrine deposits (Red Series) | Silt, with sand, becoming more clayey with depth, moderate red (5 R 4/1) | 6.5+ | 15.0 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 17 | 83 | 0 | 1.6- 2.4 | 11 | 27 | 58 | 4 | 0 | 0 | 0 |
| | | | | 2.4- 3.4 | 22 | 35 | 40 | 3 | 0 | 0 | 0 |
| | | | | Mean | 17 | 31 | 49 | 3 | 0 | 0 | 0 |
| b | 21 | 76 | 3 | 4.6- 6.5 | 11 | 20 | 45 | 18 | 4 | 2 | 0 |
| | | | | 6.5- 8.5 | 30 | 60 | 9 | 1 | 0 | 0 | 0 |
| | | | | Mean | 21 | 40 | 27 | 9 | 2 | 1 | 0 |
| a&b | 20 | 78 | 2 | Mean | 20 | 38 | 33 | 7 | 1 | 1 | 0 |

NO 88 NW 12 | 8417 8876 | Nether Findlayston, Stonehaven | Block F

Surface level +72m
Water struck at +61.1m
250mm and 200mm percussion
November 1986

| | |
|---|---|
| Overburden | 0.2m |
| Mineral I | 6.5m |
| Waste | 6.1m |
| Mineral I | 1.9m |
| Bedrock | 0.2m+ |

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, silty, sandy | 0.2 | 0.2 |
| Fluvioglacial sand and gravel | a Pebbly sand; becoming clayey with depth<br>Gravel: fine with coarse, subangular to rounded granite, with some dark schist<br>Sand: medium with coarse and fine, subangular to rounded quartz, lithic fragments and feldspar<br>Fines: silt and clay, disseminated, yellowish brown (10 YR 5/3) | 4.5 | 4.7 |
| | b 'Very clayey' sand; becoming more silty and cohesive with depth, grades into underlying clay deposit. Sparse coarse gravel<br>Sand: fine with some medium and a trace of coarse, subangular to subrounded, quartz and mica<br>Fines: silt, disseminated and as sparse thin partings binding the deposit. Moderate yellowish brown (10 YR 5/4) | 2.0 | 6.7 |
| Glaciolacustrine deposits (Red Series) | Clay, waxy, with sandy and silty partings becoming less abundant with depth. Moderate red (5 R 4/1) in thicker bands and with increasing depth. Sand and silt is yellowish brown. | 6.1 | 12.8 |
| Fluvioglacial sand and gravel (Red Series) | c Sandy gravel; boulders from 12.8 to 13.0m depth, probably including some bedrock below 14.5m<br>Gravel: coarse, fine and cobble, subangular granite and angular schist, with vein-quartz and some angular to rounded basic rocks<br>Sand: coarse and medium with fine, angular to subangular, quartz, feldspar and lithic fragments<br>Fines: silt, disseminated | 1.9 | 14.7 |
| Dalradian | Schist; dark, coarse-grained, weathered | 0.2+ | 14.9 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 4 | 75 | 21 | 0.2- 2.1 | 3 | 5 | 38 | 31 | 15 | 8 | 0 |
| | | | | 2.1- 4.7 | 5 | 16 | 35 | 24 | 10 | 10 | 0 |
| | | | | Mean | 4 | 11 | 37 | 27 | 12 | 9 | 0 |
| b | 26 | 73 | 1 | 4.7- 6.3 | 24 | 62 | 12 | 1 | 0 | 1 | 0 |
| | | | | 6.3- 6.7 | 35 | 33 | 31 | 1 | 0 | 0 | 0 |
| | | | | Mean | 26 | 56 | 16 | 1 | 0 | 1 | 0 |
| c | 2 | 61 | 37 | 12.8-14.7 | 2 | 11 | 24 | 26 | 12 | 15 | 10 § |
| a&b | 11 | 74 | 15 | Mean | 11 | 25 | 30 | 19 | 8 | 7 | 0 |
| a&c | 4 | 70 | 26 | Mean | 4 | 11 | 32 | 27 | 12 | 11 | 3 |
| a-c | 9 | 72 | 19 | Mean | 9 | 22 | 29 | 21 | 9 | 8 | 2 |

**NO 88 NW 13** **8389 8514** **Craigies Wood, Stonehaven** **Block G**

| | | |
|---|---|---|
| Surface level +78m | Overburden | 0.1m |
| Water not struck | Mineral I | 1.3m |
| 250mm and 200mm percussion | Waste | 1.2m |
| November 1986 | Mineral I | 3.9m |
| | Waste | 8.6m+ |

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy | 0.1 | 0.1 |
| Fluvioglacial sand and gravel (Red Series) | a 'Clayey' sandy gravel<br>Gravel: fine and coarse, subrounded to subangular, quartzite and sandstone, with psammite, pelite, vein-quartz, acid and basic igneous rocks<br>Sand: medium and fine with some coarse, subangular, lithic, quartz, mica and feldspar<br>Fines: silt and clay, disseminated and as thin beds, moderate reddish brown (10 R 4/6) | 1.3 | 1.4 |
| Glaciolacustrine deposits (Red Series) | Silt, sandy, laminated; beds of micaceous fine clay-bound gravel up to 5cm thick and lenses of fine and medium sand up to 2cm thick | 1.2 | 2.6 |
| Fluvioglacial sand and gravel (Red Series) | b 'Clayey' sand; with sparse fine and coarse subrounded sandstone pebbles<br>Sand: medium and fine with some coarse, subrounded quartz, lithic fragments, mica and feldspar<br>Fines: silt and clay, disseminated and as beds up to 5cm thick, from 5.0 to 6.5m, moderate reddish brown (10 R 4/6) to moderate red (5 R 4/6) | 3.9 | 6.5 |
| Glaciolacustrine deposits (Red Series) | Silt; sandy, micaceous, laminated, frequent fine sand lenses and sparse fine gravel clasts. Fines downwards, occasional beds of silty clay up to 2cm thick from 7.7m; beds of fine sand below 10.6m, moderate reddish brown (10 R 4/6) to moderate red (5 R 4/6) | 6.3 | 12.8 |
| Till (Red Series) | Diamicton; clay, silty, micaceous; clasts of fine to coarse gravel, tabular sandstone and quartzite; moderate reddish brown (10 R 4/6) | 2.3+ | 15.1 |

**Grading**

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 10 | 66 | 24 | 0.1- 1.4 | 10 | 20 | 30 | 16 | 12 | 12 | 0 |
| b | 12 | 86 | 2 | 2.6- 3.6 | 13 | 35 | 43 | 7 | 2 | 0 | 0 |
| | | | | 3.6- 5.0 | 7 | 27 | 56 | 5 | 1 | 4 | 0 |
| | | | | 5.0- 6.5 | 16 | 50 | 30 | 3 | 1 | 0 | 0 |
| | | | | Mean | 12 | 38 | 43 | 5 | 1 | 1 | 0 |
| a&b | 11 | 81 | 8 | Mean | 11 | 33 | 40 | 8 | 4 | 4 | 0 |

**NO 88 NW 14** **8446 8553** **Fetteresso Castle, Stonehaven** **Block G**

| | | | |
|---|---|---|---|
| Surface level c+62m | | Overburden | 0.3m |
| Water not struck | | Mineral I | 5.2m |
| Section and pit | | Waste | 2.9m+ |
| September 1986 | | | |

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| Soil | Soil, stony, blocks of conglomeratic sandstone | 0.3 | 0.3 |
| Fluvioglacial sand and gravel (Red Series) | a Sandy gravel; channel, filled with trough cross-stratified, clast supported gravel comprising tabular and subrounded cobbles and pebbles of schist, quartzite and Devonian sandstone (cut into top of unit)<br>Gravel: fine with coarse, rounded Devonian quartzite and sandstone, some vein-quartz, schist and fine-grained basic igneous rock<br>Sand: medium with coarse and fine, subrounded quartz and mica, some sandstone and quartzite<br>Fines: silt, disseminated, moderate reddish brown (10 R 4/6) | 1.2 | 1.5 |
| | b Sand; well developed subhorizontal lamination, some small scale ripple-drift with silty clay drapes<br>Gravel: fine, rounded quartz, quartzite and sandstone; as pebble lags<br>Sand: mainly fine, rounded quartz and mica; horizontally bedded below 2.6m depth<br>Fines: silt and clay, disseminated and as diffuse horizontal beds, 3cm thick, towards the base; moderate reddish brown (10 R 3/6) | 4.0 | 5.5 |
| Glaciolacustrine deposits (Red Series) | Silt, sandy, finely laminated, micaceous, moderately firm, dark reddish brown (10 R 3/5); sparse partings of reddish brown fine quartz sand near to the top; becoming more clayey with depth | 1.6 | 7.1 |
| | Clay, stiff, waxy, slightly silty, micaceous, finely laminated to homogeneous; moderate to dark reddish brown (10 R 4/6 - 3/4) [brickclay] | 1.3+ | 8.4 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 2 | 56 | 42 | 0.3- 1.5 | 2 | 11 | 26 | 19 | 25 | 17 | 0 |
| b | 8 | 91 | 1 | 1.5- 2.6 | 9 | 65 | 16 | 6 | 4 | 0 | 0 |
| | | | | 2.6- 5.5 | 8 | 83 | 8 | 1 | 0 | 0 | 0 |
| | | | | Mean | 8 | 79 | 10 | 2 | 1 | 0 | 0 |
| a&b | 7 | 82 | 11 | Mean | 7 | 62 | 14 | 6 | 7 | 4 | 0 |

NO 88 NW 15 | 8428 8526 | Pond Haugh, Stonehaven | Block G

Surface level c+43m
Water struck at +42m
Pit
September 1986

Overburden 0.7m
Mineral I 0.9m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, silty clay | 0.3 | 0.3 |
| Alluvium | Silt, sandy, faint lamination; dark yellowish brown (10 YR 4/2) | 0.4 | 0.7 |
| Fluvioglacial sand and gravel | Gravel; unstratified, imbricated, poorly sorted<br>Gravel: coarse with fine and cobble, subangular to rounded Devonian quartzite, psammite, pelite, fine-grained acid igneous rock and tabular semipelite; sparse angular vein-quartz and coarse-grained pink granite<br>Sand: coarse with medium and fine, angular rock<br>Fines: silt and clay, disseminated, dark yellowish brown (10 YR 4/2) | 0.9+ | 1.6 |
| | Pit collapsing below water table | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 4 | 26 | 70 | 0.7- 1.6 | 4 | 6 | 7 | 13 | 21 | 31 | 18 § |

NO 88 NW 16 | 8126 8847 | Bossholes, Stonehaven | Block F

Surface level c+109m
Water not struck
Section and pit
September 1986
LOG

Mineral I 5.0m+

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| Fluvioglacial sand and gravel | a Sandy gravel, cobbles and boulders at top, fining downwards into cross-bedded sand with gravel stringers | 1.4 | 1.4 |
| | Gravel: cobble, fine and coarse; subangular to subrounded granite, schist and psammite; subangular and well rounded boulders up to 0.9m of granite, quartz-porphyry, weathered schist and highly folded psammite; very poorly sorted, clast supported | | |
| | Sand: medium and coarse, angular quartz, feldspar and rock; as lenses and interstitial fill between boulders in top 0.9m, in cross-bedded units towards the base | | |
| | Fines: silt, disseminated, moderate yellowish brown (10 YR 5/4) | | |
| | b Sandy gravel; clast supported, fining downwards into cross-bedded sand with gravel stringers | 1.1 | 2.5 |
| | Gravel: coarse and fine; cobbles up to 0.8m of well rounded coarse-grained pink and orange granite; subangular highly folded semipelite, psammite, pelitic schist and fine-grained basic rock | | |
| | Sand: coarse with medium, angular to subrounded granite and rock; cross-bedded below 1.9m depth | | |
| | Fines: silt, disseminated, light brown (5 YR 5/6) to 1.9m depth; disseminated and as finely laminated lenses, pale yellowish brown (10 YR 6/3), towards the base | | |
| Glaciolacustrine deposits | c Sand, with horizontal and wavy lamination | 1.0 | 3.5 |
| | Sand: fine, rounded quartz and mica | | |
| | Fines: silt, disseminated, pale yellowish brown (10 YR 6/2) to greyish orange pink (10 R 7/2); partings of micaceous waxy clay up to 5mm thick | | |
| | d 'Very clayey' sand, with sparse partings of laminated clay | 1.5+ | 5.0 |
| | Sand: fine, rounded quartz and mica | | |
| | Fines: silt and clay, disseminated and as laminated beds 3 to 5cm thick; greyish orange pink (10 R 7/2) and dusky yellowish brown (10 YR 3/2) | | |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1–4 | +4–16 | +16–64 | +64 mm |
| a | 1 | 60 | 39 | 0.0– 0.9 | 1 | 1 | 20 | 27 | 17 | 9 | 25 |
| | | | | 0.9– 1.4 | 1 | 4 | 57 | 18 | 4 | 16 | 0 |
| | | | | Mean | 1 | 2 | 34 | 24 | 12 | 11 | 16 |
| b | 1 | 52 | 47 | 1.4– 1.9 | 0 | 1 | 11 | 23 | 16 | 31 | 18 |
| | | | | 1.9– 2.5 | 2 | 2 | 26 | 37 | 20 | 13 | 0 |
| | | | | Mean | 1 | 2 | 19 | 31 | 18 | 21 | 8 |
| c | 8 | 91 | 1 | 2.5– 3.5 | 8 | 81 | 8 | 2 | 0 | 1 | 0 |
| d | 28 | 72 | 0 | 3.5– 5.0 | 28 | 67 | 4 | 1 | 0 | 0 | 0 |
| a&b | 1 | 55 | 44 | Mean | 1 | 2 | 26 | 27 | 15 | 16 | 13 |
| c&d | 20 | 80 | 0 | Mean | 20 | 73 | 6 | 1 | 0 | trace | 0 |
| a–c | 3 | 66 | 31 | Mean | 3 | 24 | 22 | 20 | 11 | 11 | 9 |
| a–d | 11 | 68 | 21 | Mean | 11 | 38 | 16 | 14 | 7 | 8 | 6 |

**NO 88 NW 17** **8389 8890** **Mowtie, Stonehaven** **Block F**

Surface level c+79m
Water not struck
Section and pit
September 1986

Overburden 0.2m
Mineral I 6.9m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil; stony | 0.2 | 0.2 |
| Fluvioglacial sand and gravel | a Gravel; cryoturbation in top 0.6m, poorly sorted, fining downwards<br>Gravel: coarse, cobble and fine, poorly sorted, crude horizontal stratification; subrounded to angular, red, pink and grey coarse-grained granite, sparse vein-quartz, weathered schist and psammite<br>Sand: coarse with medium, angular to subrounded, quartz, feldspar and rock<br>Fines: silt, disseminated, moderate yellowish brown (10 YR 5/4) | 2.3 | 2.5 |
| | b Sandy gravel, fining downwards; face shows small scale faulting and contorted bedding at 3.7m depth<br>Gravel: fine and cobble, with some coarse, tabular schist, subangular pink coarse-grained granite, angular psammite and gneiss<br>Sand: coarse and medium, subangular quartz, feldspar and granitic rock<br>Fines: silt, disseminated, moderate yellowish brown (10 YR 5/4) | 1.8 | 4.3 |
| | c Gravel: with cobbles up to 0.5m<br>Gravel: coarse and fine, with cobble, well rounded coarse-grained pink and grey granite, tabular schist and psammite<br>Sand: coarse and medium, angular to subrounded, quartz and feldspar<br>Fines: silt, disseminated, moderate yellowish brown (10 YR 5/4) | 1.7 | 6.0 |
| | d Pebbly sand, prominent cross-bedding<br>Gravel: fine and coarse, angular granite and schist<br>Sand: medium and fine, subangular quartz, sparse coarse angular rock and feldspar<br>Fines: silt and clay in discrete partings up to 1cm thick | 1.1+ | 7.1 |
| | Pit terminated in medium to fine cross-bedded sand, collapsing in from the sides | | |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 1 | 22 | 77 | 0.2- 1.4 | 1 | 0 | 5 | 10 | 11 | 36 | 37 |
| | | | | 1.4- 2.5 | 0 | 1 | 12 | 18 | 15 | 42 | 12 |
| | | | | Mean | 1 | trace | 8 | 14 | 13 | 39 | 25 |
| b | 3 | 62 | 35 | 2.5- 4.3 | 3 | 9 | 27 | 26 | 17 | 8 | 10 |
| c | 2 | 47 | 51 | 4.3- 6.0 | 2 | 3 | 18 | 26 | 18 | 27 | 6 |
| d | 8 | 85 | 7 | 6.0- 7.1 | 8 | 32 | 45 | 8 | 4 | 3 | 0 |
| a&b | 2 | 40 | 58 | Mean | 2 | 4 | 17 | 19 | 15 | 25 | 18 |
| c&d | 4 | 62 | 34 | Mean | 4 | 14 | 29 | 19 | 12 | 18 | 4 |
| a-c | 2 | 42 | 56 | Mean | 2 | 4 | 17 | 21 | 16 | 25 | 15 |
| a-d | 3 | 48 | 49 | Mean | 3 | 8 | 21 | 19 | 14 | 23 | 12 |

**NO 88 NE 2** | **8510 8958** | **Monboys, Stonehaven** | **Block G**

Surface level +148m
Water not struck
250mm percussion
November 1986

Overburden 0.2m
Mineral I 2.2m
Waste 6.1m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.2 | 0.2 |
| Morainic drift | 'Very clayey' cobble gravel, soft to firm, 'clay-bound', patches of laminated silt and sand at top, cobbles towards the base, yellowish brown | 2.2 | 2.4 |
| Till (Red Series) | Diamicton: clay, silty, yellowish brown to reddish brown, occasional cobbles and boulders, very hard below 6.8m | 6.1+ | 8.5 |

Borehole terminated owing to slow progress
No grading data available

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**NO 88 NE 3** | **8514 8938** | **Houff Burn, Stonehaven** | **Block G**

Surface level c+135m
Water not struck
Pit
September 1986

Overburden 0.5m
Mineral I 3.0m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, pebbly sand | 0.5 | 0.5 |
| Fluvioglacial sand and gravel (Red Series) | a Sandy gravel<br>Gravel: fine with coarse, well rounded Devonian quartzite and sandstone, sparse vein-quartz and felsite<br>Sand: medium with coarse and some fine, rounded to angular, quartz and rock<br>Fines: silt, disseminated, moderate brown (5 YR 4/4) | 0.5 | 1.0 |
| | b Sand, with sparse subrounded quartzite pebbles, well developed horizontal bedding<br>Sand: mainly fine, rounded quartz, with mica and rock<br>Fines: silt and clay, disseminated, pale reddish brown (10 YR 5/4) | 2.5+ | 3.0 |

Pit terminated, sand collapsing in from the side

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 3 | 71 | 26 | 0.5- 1.0 | 3 | 10 | 35 | 26 | 18 | 8 | 0 |
| b | 4 | 94 | 2 | 1.0- 3.5 | 4 | 82 | 10 | 2 | 2 | 0 | 0 |
| a&b | 4 | 90 | 6 | Mean | 4 | 70 | 14 | 6 | 5 | 1 | 0 |

**NO 88 NE 4** **8557 8897** **Houff of Ury, Stonehaven** **Block G**

Surface level +125m
Water not struck
250 and 200mm percussion
October 1986

Overburden 0.4m
Mineral I 12.4m
Waste 5.7m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil: brown sandy loam | 0.4 | 0.4 |
| Fluvioglacial sand and gravel (Red Series) | a Sandy gravel<br>Gravel: fine with coarse, angular psammite, semipelite and granite, well rounded Devonian quartzite cobbles, tabular sandstone<br>Sand: fine to coarse, subangular, quartz, lithic fragments and feldspar<br>Fines: silt and clay, disseminated, locally binding the deposit, moderate reddish brown to moderate brown (10 R 4/6 to 5 YR 3/4) | 3.1 | 3.5 |
| | b Gravel, 'clay bound'<br>Gravel: fine to coarse, with cobbles between 7.2m and 8.2m, well rounded to angular psammite, pelite, basic igneous rocks, quartzite, vein-quartz and granite<br>Sand: coarse and medium with fine, angular lithic fragments and quartz; some fine subangular quartz<br>Fines: silty clay, disseminated and in seams, reddish brown to moderate brown (5 YR 3/4 to 10 R 4/6) | 9.3 | 12.8 |
| Flow-till (Red Series) | Diamicton: silt, sandy, very clayey, moderate reddish brown (10 R 4/6); sand lenses and subangular to well rounded clasts (up to cobble grade) of granite, Devonian quartzite, psammite, pelite and vein-quartz | 1.7 | 14.5 |
| Glaciolacustrine deposits (Red Series) | Silt, sandy, soft, locally micaceous, thin fine sand lenses. Sparse clasts below 18.0m. Thin clay beds (<50mm) from 18.3m. Moderate reddish brown (10 R 4/6) | 4.0+ | 18.5 |

Borehole terminated for technical reasons

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 6 | 60 | 34 | 0.4- 1.4 | 8 | 9 | 19 | 27 | 25 | 12 | 0 |
| | | | | 1.4- 2.5 | 5 | 6 | 22 | 32 | 22 | 13 | 0 |
| | | | | 2.5- 3.5 | 4 | 6 | 28 | 31 | 22 | 9 | 0 |
| | | | | Mean | 6 | 7 | 23 | 30 | 23 | 11 | 0 |
| b | 9 | 45 | 46 | 3.5- 5.1 | 12 | 9 | 12 | 12 | 25 | 30 | 0 |
| | | | | 5.1- 6.1 | 14 | 10 | 13 | 19 | 24 | 20 | 0 |
| | | | | 6.1- 7.2 | 7 | 7 | 19 | 29 | 24 | 14 | 0 |
| | | | | 7.2- 8.2 | 4 | 5 | 15 | 22 | 16 | 22 | 16 |
| | | | | 8.2- 9.2 | 4 | 4 | 23 | 26 | 30 | 13 | 0 |
| | | | | 9.2-10.3 | 7 | 12 | 16 | 19 | 25 | 21 | 0 |
| | | | | 10.3-11.3 | 8 | 11 | 14 | 22 | 23 | 22 | 0 |
| | | | | 11.3-12.8 | 12 | 16 | 14 | 17 | 24 | 17 | 0 |
| | | | | Mean | 9 | 10 | 15 | 20 | 24 | 20 | 2 |
| a&b | 8 | 49 | 43 | Mean | 8 | 9 | 17 | 23 | 24 | 18 | 1 |

**NO 88 NE 5** **8582 8802** **S.W. of Ury Home Farm, Stonehaven** **Block F**

Surface level c+40m
Water not struck
Pit
September 1986

Waste 1.3m
Bedrock 0.1m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy clay with boulders | 0.5 | 0.5 |
| Flow-till | Diamicton, pebbly clay, matrix supported; angular pebbles of coarse-grained pink and grey granite, schist, quartzite and vein quartz; moderate brown (5 YR 3/4) | 0.9 | 1.1 |
| | Clay, silty and sandy, faint lamination; brownish grey (5 YR 4/1) to light olive grey (5 YR 6/1) | 0.2 | 1.3 |
| Dalradian | Schistose pelite, with quartz segregations, dark grey (N3) | 0.1+ | 1.4 |

**NO 88 NE 6** **8553 8765** **N.E. of Highfield, Stonehaven** **Block F**

Surface level +41m
Water not struck
250mm percussion
October 1986

Overburden 0.4m
Mineral I 1.0m
Waste 1.3m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, gravel and clay | 0.4 | 0.4 |
| Fluvioglacial sand and gravel | Gravel, sparse boulders up to 0.2m<br>Gravel: coarse, with fine and cobble, well rounded quartzite and psammitic grit, some flakey tabular semipelite, medium-grained rounded pink granite, vein-quartz and sparse angular schist<br>Sand: coarse, with medium and some fine, subangular quartz and rock<br>Fines: silt and clay, disseminated and binding deposit; moderate yellowish brown (10 YR 5/4) | 1.0 | 1.4 |
| Till | Diamicton, clay, silt and sand, compact, abundant pebbles; moderate yellowish brown (10 YR 5/4): sample highly comminuted by chiseling | 1.3+ | 2.7 |
| | Borehole abandoned owing to slow progress | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 7 | 36 | 57 | 0.4- 1.4 | 7 | 6 | 12 | 18 | 15 | 35 | 7 |

**NO 88 NE 7** **8501 8606** **Beattie's Hill, Stonehaven** **Block G**

Surface level c+66m
Water not struck
Section and pit
October 1986

Mineral I 11.2m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| Fluvioglacial sand and gravel (Red Series) | Pebbly sand, becoming cleaner below 5.1m depth; gravel as lags on large scale avalanche foreset and bottomset beds above 5.1m, poorly developed horizontal stratification below 8.6m depth<br>Gravel: coarse and fine, with some cobble from 5.1m to 8.6m depth; rounded vein-quartz, Devonian quartzite, mudstone and siltstone, sparse porphyry, psammitic grit and schist<br>Sand: mainly medium and fine; rounded to subangular, quartz and mica<br>Fines: silt and clay, disseminated and as prominent beds 2 to 3cm thick, at 20cm intervals above 5.1m depth | 11.2+ | 11.2 |

Pit abandoned, sand collapsing in from the sides

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 6 | 80 | 14 | 0.0- 5.1 | 11 | 40 | 29 | 5 | 7 | 8 | 0 |
| | | | 5.1- 8.6 | 1 | 19 | 54 | 9 | 4 | 4 | 9 |
| | | | 8.6-11.2 | 5 | 36 | 49 | 4 | 1 | 5 | 0 |
| | | | Mean | 6 | 33 | 41 | 6 | 5 | 6 | 3 |

**NO 88 NE 8** **8611 8882** **Den of Glithno, Stonehaven** **Block G**

Surface level c+105m
Water not struck
Pit
September 1986

Overburden 0.2m
Mineral I 3.2m+

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sand and pebbles | 0.2 | 0.2 |
| Fluvioglacial sand and gravel (Red Series) | Sandy gravel, fining downwards; channel filled with cross-stratified gravel containing well rounded Devonian quartzite, sandstone and vein-quartz clasts (cut into top of unit)<br>Gravel: coarse and fine with cobble, well rounded to rounded, Devonian quartzite, with some sandstone<br>Sand: mainly medium, with some fine and coarse, subangular to subrounded, quartz, with some rock and mica<br>Fines: silt and clay, disseminated, binding sandier beds from 0.8m to 2.0m depth; moderate reddish brown (10 R 4/6) | 3.2+ | 3.4 |

Pit abandoned, sand collapsing in from the sides

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 3 | 68 | 29 | 0.2- 0.8 | 2 | 9 | 30 | 10 | 20 | 12 | 17 |
| | | | 0.8- 2.0 | 3 | 10 | 44 | 15 | 12 | 7 | 9 |
| | | | 2.0- 3.4 | 3 | 21 | 49 | 6 | 5 | 16 | 0 |
| | | | Mean | 3 | 15 | 43 | 10 | 10 | 12 | 7 |

**NO 88 NE 9** **8581 8733** **Glen Urie, Stonehaven** **Block F**

Surface level c+39m
Water struck at +33.1m
Section and pit
October 1986

Mineral I 6.3m
Waste 0.2m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| Fluvioglacial sand and gravel | Gravel; imbricated, moderately to poorly sorted, clast supported; horizontally bedded and trough cross-stratified units from 1m to 1.4m thick; boulders up to 50cm<br>Gravel: coarse and cobble, with some fine; rounded to angular Devonian quartzite and sandstone, coarse-grained pink granite, fresh and weathered schist and banded gneiss<br>Sand: mainly coarse, angular rock, quartz and feldspar | 6.3 | 6.3 |
| Glaciolacustrine deposits (Red Series) | Clay and silt, stiff, waxy, homogeneous to finely laminated (?varved); moderate reddish brown (10 R 4/6) to pale brown (5 YR 5/2) [brickclay] | 0.2+ | 6.5 |
| | Pit collapsing below water table | | |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 1 | 25 | 74 | 0.0- 1.3 | 0 | 1 | 5 | 8 | 9 | 39 | 38 |
| | | | 1.3- 2.6 | 1 | 1 | 8 | 13 | 8 | 33 | 36 |
| | | | 2.6- 3.7 | 1 | 1 | 5 | 14 | 16 | 38 | 25 |
| | | | 3.7- 4.5 | 1 | 0 | 8 | 13 | 13 | 38 | 27 |
| | | | 4.5- 5.9 | 1 | 0 | 15 | 23 | 15 | 13 | 33 |
| | | | 5.9- 6.3 | 1 | 0 | 16 | 27 | 24 | 32 | 0 |
| | | | Mean | 1 | 1 | 9 | 15 | 13 | 31 | 30 |

**NO 88 NE 10** | **8625 8707** | **Mackie Academy, Stonehaven** | **Block F**

Surface level +35m
Water struck at +29m
250 and 200mm percussion
October 1986

Overburden 0.3m
Mineral I 10.6m
Waste 4.8m+

LOG

| Geological classification | Lithology | Thickness | Depth |
|---|---|---|---|
| | Soil, gravelly | 0.3 | 0.3 |
| Fluvioglacial sand and gravel | a Gravel<br>Gravel: coarse and cobble, with fine, subrounded with subangular, psammite, pelite, quartzite, granite, vein-quartz and basic igneous rocks<br>Sand: coarse with medium and fine, subangular, lithic fragments, quartz and feldspar<br>Fines: silt and clay, disseminated, moderate brown (5 YR 4/4) | 4.9 | 5.2 |
| | b Sandy gravel<br>Gravel: fine with coarse, angular to subangular, tabular sandstone with psammite, pelite and granite<br>Sand: medium and coarse, with some fine, angular to subangular, lithic fragments, quartz and feldspar<br>Fines: silt and clay, disseminated. moderate reddish brown (10 R 4/6) | 3.6 | 8.8 |
| Glaciolacustrine deposits (Red Series) | c Pebbly sand<br>Gravel: coarse with fine, subrounded, sandstone, metamorphic rocks, vein-quartz and granite<br>Sand: fine with medium, sparse coarse, subrounded to subangular, quartz, feldspar, mica and lithic fragments<br>Fines: silt and clay, disseminated and in seams, greyish red (5 R 4/2) | 2.1 | 10.9 |
| | Silt, very sandy, becoming clayey with depth, micaceous, soft, with beds of fine sand; dark reddish brown (10 R 3/4). Sparse fine gravel clasts in top 1m | 4.8+ | 15.7 |
| | Borehole terminated for technical reasons | | |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | | |
| | | | | from to | -1/16 | +1/16 - 1/4 | +1/4 -1 | +1-4 | +4-16 | +16-64 | +64 mm | |
| a | 6 | 33 | 61 | 0.3- 1.3 | 5 | 3 | 7 | 9 | 9 | 25 | 42 | |
| | | | | 1.3- 2.3 | 8 | 7 | 21 | 13 | 14 | 26 | 11 | |
| | | | | 2.3- 3.4 | 3 | 3 | 13 | 18 | 16 | 26 | 21 | |
| | | | | 3.4- 4.4 | 7 | 6 | 15 | 17 | 21 | 34 | 0 | |
| | | | | 4.4- 5.2 | No grading data available | | | | | | | |
| | | | | Mean | 6 | 5 | 14 | 14 | 15 | 27 | 19 | |
| b | 3 | 54 | 43 | 5.2- 6.2 | No grading data available | | | | | | | |
| | | | | 6.2- 7.2 | 2 | 3 | 18 | 35 | 30 | 12 | 0 | |
| | | | | 7.2- 8.8 | 4 | 14 | 18 | 21 | 27 | 16 | 0 | |
| | | | | Mean | 3 | 10 | 18 | 26 | 29 | 14 | 0 | |
| c | 5 | 85 | 10 | 8.8- 9.8 | 4 | 33 | 49 | 4 | 3 | 7 | 0 | § |
| | | | | 9.8-10.9 | 6 | 55 | 27 | 2 | 3 | 7 | 0 | § |
| | | | | Mean | 5 | 45 | 37 | 3 | 3 | 7 | 0 | |
| a&b | 5 | 42 | 53 | Mean | 5 | 7 | 16 | 19 | 21 | 21 | 11 | |
| b&c | 4 | 65 | 31 | Mean | 4 | 23 | 24 | 18 | 19 | 12 | 0 | |
| a-c | 5 | 50 | 45 | Mean | 5 | 14 | 20 | 16 | 17 | 19 | 9 | |

| NO 88 NE 11 | 8646 8511 | Woods of Dunnottar, Stonehaven | Block G |
|---|---|---|---|

Surface level c+40m
Water not struck
Section and pit
September 1986

Overburden 0.1m
Mineral I 4.4m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil | 0.1 | 0.1 |
| Fluvioglacial sand and gravel (Red Series) | a Gravel; poorly developed subhorizontal stratification<br>Gravel: coarse, with cobble and fine, well rounded Devonian quartzite, quartz-dolerite, granite, schist and weathered pink felsite<br>Sand: medium and coarse, subrounded to angular, quartz, mica and rock<br>Fines: silt, disseminated, moderate reddish brown (10 R 4/6) | 0.7 | 0.8 |
| | b Pebbly sand, well bedded; low angle cross-stratification to 2.0m<br>Gravel: fine and coarse: well rounded Devonian quartzite, with sparse angular schist<br>Sand: mainly medium, subrounded to subangular, quartz, with mica and some rock<br>Fines: silt and clay, disseminated and as 1cm partings at 0.8m and 2.0m depth | 2.2 | 3.0 |
| | c Sandy gravel, less pebbly below 4.0m depth; crude horizontal bedding in gravel, low angle cross-bedding in sand - start of second fining downwards cycle<br>Gravel: cobble, with coarse and some fine; well rounded to rounded, Devonian quartzite, with sparse granite and quartz-porphyry<br>Sand: mainly medium, subangular quartz with some mica and rock<br>Fines: silt, disseminated; dark reddish brown (10 R 4/6) | 1.5+ | 4.5 |
| | Pit abandoned, sand and gravel collapsing in from the sides | | |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 1 | 36 | 63 | 0.1- 0.8 | 1 | 4 | 20 | 12 | 16 | 29 | 18 |
| b | 3 | 87 | 10 | 0.8- 2.0 | 3 | 18 | 63 | 8 | 6 | 2 | 0 |
| | | | | 2.0- 3.0 | 2 | 10 | 63 | 13 | 3 | 9 | 0 |
| | | | | Mean | 3 | 14 | 63 | 10 | 5 | 5 | 0 |
| c | 2 | 58 | 40 | 3.0- 4.5 | 2 | 7 | 43 | 8 | 5 | 11 | 24 |
| a&b | 2 | 76 | 22 | Mean | 2 | 12 | 53 | 11 | 7 | 11 | 4 |
| b&c | 2 | 75 | 23 | Mean | 2 | 11 | 55 | 9 | 5 | 8 | 10 |
| a-c | 2 | 69 | 29 | Mean | 2 | 10 | 49 | 10 | 7 | 11 | 11 |

NO 88 NE 12 8828 8975 **Anquorthies, Stonehaven** **Block G**

Surface level c+115m
Water struck at +111.2m
Section and pit
October 1986
LOG

Overburden 0.1m
Mineral I 3.6m
Waste 0.1m+

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, pebbly | 0.1 | 0.1 |
| Glacial sand and gravel | a Gravel, crude horizontal bedding<br>Gravel: cobble, with coarse and fine; well rounded to rounded, 'bleached' Devonian quartzite, coarse-grained pink granite, psammite, fine-grained basic rock and pelite<br>Sand: mainly medium, angular to subrounded, quartz and rock<br>Fines: silt and clay, disseminated; moderate yellowish brown (10 YR 5/4) | 0.5 | 0.6 |
| | b 'Clayey' pebbly sand; thin vertical seams of clay, moderate reddish brown (10 R 4/6) gravel displaced along small-scale, high-angle normal faults<br>Gravel: fine and coarse, rounded to tabular, Devonian quartzite and schist<br>Sand: medium, with some fine and coarse, subrounded quartz, with some angular rock, a trace of mica<br>Fines: silt and clay, disseminated, binding deposit and as discontinuous seams up to 1cm thick, dark reddish brown (10 R 3/5) | 1.2 | 1.8 |
| Glacial sand and gravel (Red Series) | c Gravel, poorly stratified<br>Gravel: fine and coarse, with cobble, rounded Devonian sandstone and quartzite, tabular pelite, semipelite and quartz-porphyry; some schist and vein-quartz<br>Sand: medium, coarse and fine, angular to subrounded, rock and quartz<br>Fines: silt and clay, disseminated and coating pebbles; moderate brown (5 YR 4/4), becoming moderate reddish brown (5 YR 4/5) below 2.9m depth | 1.9 | 3.7 |
| Till (Red Series) | Diamicton, clay, stiff; abundant fine angular schist pebbles; moderate brown (5 YR 4/4), to moderate reddish brown (10 R 4/4) | 0.1+ | 3.8 |
| | Pit terminated at the water table | | |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1–4 | +4–16 | +16–64 | +64 mm |
| a | 2 | 36 | 62 | 0.1– 0.6 | 2 | 7 | 21 | 8 | 13 | 13 | 36 |
| b | 10 | 74 | 16 | 0.6– 1.8 | 10 | 18 | 46 | 10 | 9 | 7 | 0 |
| c | 5 | 40 | 55 | 1.8– 2.9 | 4 | 5 | 10 | 15 | 28 | 26 | 12 |
| | | | | 2.9– 3.7 | 6 | 16 | 30 | 9 | 14 | 11 | 14 |
| | | | | Mean | 5 | 9 | 19 | 12 | 22 | 20 | 13 |
| a&c | 4 | 39 | 57 | Mean | 4 | 9 | 19 | 11 | 21 | 18 | 18 |
| a–c | 6 | 51 | 43 | Mean | 6 | 12 | 28 | 11 | 16 | 15 | 12 |

NO 88 NE 13 | 8883 8885 | **Logie, Stonehaven** | **Block G**

Surface level c+82m
Water struck at +75.6m
Section and pit
October 1986

Mineral I 6.4m
Waste 0.1m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| Glacial sand and gravel (Red Series) | a Gravel, with boulders up to 0.8m, unsorted, unstratified, but with crude imbrication<br>Gravel: coarse, cobble and fine, angular to well rounded, Devonian quartzite and sandstone, some tabular banded psammite, schist and weathered amphibolite, sparse vein-quartz<br>Sand: medium and coarse, angular sandstone and schist<br>Fines: silt and clay, disseminated; dark reddish brown (10 R 3/4) | 2.2 | 2.2 |
| | b Gravel; a bed of medium to fine sand near to the top showing soft-sediment intrusion structures into overlying gravel<br>Gravel: coarse and fine, with some cobble, imbricated, poorly sorted, angular schist and sandstone, with some well rounded Devonian quartzite<br>Sand: mainly coarse, angular schist, quartz and rock<br>Fines: silt and clay, disseminated, dark reddish brown (10 R 3/4) | 1.7 | 3.9 |
| | c Gravel, with some boulders up to 0.3m, a bed of silty medium sand from 4.9 to 5.2m depth<br>Gravel: cobble, with fine and coarse; angular fresh and weathered schist, sandstone and sparse coarse-grained pink granite, some rounded Devonian quartzite<br>Sand: mainly coarse and medium, angular rock<br>Fines: clay, disseminated; sparse thin beds of silt; dark reddish brown (10 R 3/4) | 2.5 | 6.4 |
| Till (Red Series) | Diamicton, clay and silt, stiff, abundant pebbles and angular boulders of schist; moderate reddish brown (10 R 4/6) to dark reddish brown (10 R 3/4) | 0.1+ | 6.5 |

Pit terminated at the water table

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1–4 | +4–16 | +16–64 | +64 mm |
| a | 1 | 10 | 89 | 0.0– 2.2 | 1 | 1 | 5 | 4 | 16 | 41 | 32 |
| b | 3 | 22 | 75 | 2.2– 3.9 | 3 | 2 | 6 | 14 | 31 | 36 | 8 |
| c | 3 | 28 | 69 | 3.9– 4.9 | 2 | 2 | 6 | 13 | 31 | 16 | 30 |
| | | | | 4.9– 6.4 | 4 | 3 | 16 | 14 | 12 | 19 | 32 |
| | | | | Mean | 3 | 3 | 12 | 13 | 19 | 18 | 32 |
| a&b | 2 | 17 | 81 | Mean | 2 | 2 | 6 | 9 | 23 | 36 | 22 |
| b&c | 3 | 26 | 71 | Mean | 3 | 2 | 10 | 14 | 24 | 25 | 22 |
| a–c | 2 | 20 | 78 | Mean | 2 | 2 | 8 | 10 | 21 | 31 | 26 |

NO 89 SE 1 | 8810 9086 | Cantlayhills, Muchalls | Block G

Water not struck
Section and Pit
October 1984

Overburden 0.2m
Mineral 7.1m+

LOG

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy | 0.2 | 0.2 |
| Fluvioglacial sand and gravel (Red Series) | a Sandy gravel<br>Gravel: fine and coarse with cobbles, subangular to subrounded granite and quartzite with some weathered psammite and schist<br>Sand: fine to coarse, angular quartz and granite | 3.8 | 4.0 |
| | b Gravel<br>Gravel: fine to cobble, rounded to well rounded granite with psammite, schist and some quartz<br>Sand: mainly medium and coarse, angular to subangular quartz and granite | 1.6 | 5.6 |
| | c Pebbly sand<br>Gravel: fine and coarse, subrounded to rounded granite and psammite<br>Sand: mainly fine and medium, angular to subangular quartz<br>Fines: silty clay, reddish brown | 1.7+ | 7.3 |

Grading

| | Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| a | 6 | 62 | 32 | 0.2- 2.0 | 8 | 10 | 41 | 14 | 14 | 13 | 0 |
| | | | | 2.0- 4.0 | 4 | 14 | 29 | 17 | 17 | 11 | 8 |
| | | | | Mean | 6 | 12 | 34 | 16 | 16 | 12 | 4 |
| b | 3 | 32 | 65 | 4.0- 5.6 | 3 | 4 | 12 | 16 | 18 | 24 | 23 |
| c | 9 | 75 | 16 | 5.6- 7.3 | 9 | 40 | 26 | 9 | 9 | 7 | 0 |
| a-c | 6 | 59 | 35 | Mean | 6 | 17 | 28 | 14 | 15 | 13 | 7 |

NO 89 SE 2 — 8779 9065 — **Hillocks, Muchalls** — **Block G**

Overburden 0.1m
Mineral 3.2m+

Water not struck
Pit
October 1984

**LOG**

| Geological classification | Lithology | Thickness m | Depth m |
|---|---|---|---|
| | Soil, sandy | 0.1 | 0.1 |
| Fluvioglacial sand and gravel (Red Series) | Gravel<br>Gravel: fine to cobble, rounded to well rounded granite, quartzite and psammite with some schist<br>Sand: medium and coarse, angular to subangular quartz and granite | 3.2+ | 3.3 |

Grading

| Mean for Deposit percentages | | | Depth below surface (m) | percentages | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fines | Sand | Gravel | | Fines | Sand | | | Gravel | | |
| | | | from to | $-\frac{1}{16}$ | $+\frac{1}{16}-\frac{1}{4}$ | $+\frac{1}{4}-1$ | +1-4 | +4-16 | +16-64 | +64 mm |
| 3 | 32 | 65 | 0.1- 1.0 | 3 | 5 | 12 | 19 | 21 | 40 | 0 |
| | | | 1.0- 2.0 | 2 | 4 | 11 | 19 | 22 | 25 | 17 |
| | | | 2.0- 3.3 | 3 | 3 | 10 | 14 | 20 | 31 | 19 |
| | | | Mean | 3 | 4 | 11 | 17 | 21 | 31 | 13 |

**APPENDIX H: EXPLANATION OF THE RESISTIVITY RECORDS**
**ANNOTATED EXAMPLE**

**NJ 70 NE R1a**[1] **7591 0765**[2] **Tillymannoch Wood, Echt** **Block A**[6]

**Azimuth 046°**[3]
**March 1987**[4]

| | |
|---|---|
| Waste | 0.3m |
| Bedrock | 4.5m+ |

**Interpretation**[7]

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, sandy, pebbly | 755 | 0.3 | 0.3 |
| Caledonian | Granite, weathered/fractured | 6644 | 4.5 | 4.8 |
| | Granite, massive | 1682 | - | - |

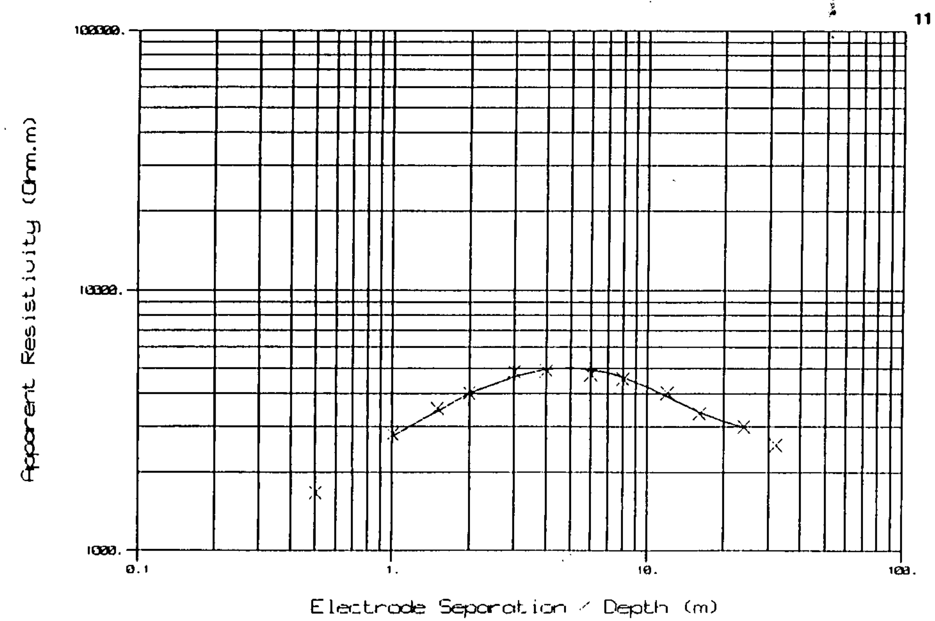
INPUT DATA [5]

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 311.0000 | 769.0000 | 583.0000 | 481.0000 | 42.4000 |
| 1.0 | 637.0000 | 654.0000 | 429.0000 | 465.0000 | 32.4000 |
| 2.0 | 449.0000 | 417.0000 | 330.0000 | 322.0000 | 32.0100 |
| 4.0 | 263.0000 | 248.0000 | 184.4000 | 205.0000 | 14.9100 |
| 8.0 | 121.1000 | 114.7000 | 81.6000 | 100.1000 | 6.2200 |
| 16.0 | 40.7000 | 37.0000 | 25.0000 | 41.7000 | 3.0900 |
| 32.0 | 17.2800 | 16.6900 | 11.0000 | 14.2700 | 0.5200 |

PROCESSING RESULTS [8]

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 1671.33 | -0.0005 | -0.1917 | 0.0698 |
| 1.0 | 2808.58 | 0.0009 | 0.0805 | 0.1457 |
| 1.5 | 3525.10 | | | |
| 2.0 | 4033.81 | 0.0000 | 0.0062 | -0.0069 |
| 3.0 | 4852.55 | | | |
| 4.0 | 4893.34 | 0.0003 | 0.1058 | 0.0871 |
| 6.0 | 4738.31 | | | |
| 8.0 | 4566.62 | 0.0010 | 0.2036 | 0.2168 |
| 12.0 | 4031.59 | | | |
| 16.0 | 3352.71 | 0.0002 | 0.5007 | -0.1633 |
| 24.0 | 2985.73 | | | |
| 32.0 | 2540.42 | 0.0001 | 0.2588 | 0.0000 |
| 48.0 | 2373.87 | | | |
| 64.0 | 3262.00 | | | |

R.M.S. Observational Error = .0006
R.M.S. Offset Wenner Difference = .2431
R.M.S. Potential Ladder Difference = .1313




11

FIELD CURVE DATA [9] INTERPRETED MODEL [10]

| | Electrode Separation | Apparent Resistivity | Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|---|---|---|
| 1 | 0.5 | 1671.33 | 0.25 | | 755.4 | |
| 2 | 1.0 | 2808.58 | | | | |
| 3 | 1.5 | 3525.10 | | 0.25 | -------- | 0.7958 |
| 4 | 2.0 | 4033.81 | | | | |
| 5 | 3.0 | 4852.55 | 4.51 | | 6643.8 | |
| 6 | 4.0 | 4893.34 | | | | |
| 7 | 6.0 | 4738.31 | | 4.76 | -------- | -0.4249 |
| 8 | 8.0 | 4566.62 | | | | |
| 9 | 12.0 | 4031.59 | | | 2681.8 | |
| 10 | 16.0 | 3352.71 | | | ******** | |
| 11 | 24.0 | 2985.73 | | | | |
| 12 | 32.0 | 2540.42 | | | | |

R.M.S. Relative error = 0.0217
Maximum rel. error = 0.0332 at sample 7
Number of trials was 0

Resistivity records of each of the depth soundings used in the assessment are given in Appendix I.

The numbered paragraphs that follow correspond with the annotations given on the annotated example.

**1 Resistivity sounding identification number**
The resistivity sites are registered in a similar manner to the boreholes, shallow pits and sections. The site number has the form 'Rn'; where more than one sounding has been made at a site, the registration number is suffixed by the letters a, b, c etc.

**2 National Grid Reference**
All National Grid references fall in the 100km squares NJ and NO. Grid references for each sounding are given to eight figures and are accurate to within 10m. The position of the site is generally referred to the nearest named locality on the 1:25 000 map.

**3 Azimuth**
Azimuth refers to the compass bearing, in degrees from Grid North, at which the electrode array was laid out (corrected for magnetic variation at March 1987).

**4 Date**
The date of the sounding is given.

**5 Input data**
The input data are the field resistivity readings (measured in ohm.m) taken at different electrode spacings for a particular electrode configuration.

**6 Summary log**
The resource evaluation is presented in a similar manner to that for boreholes, shallow pits and sections; generally, no thickness is given for the lowest layer because the junction with the underlying deposit is undefined.

**7 Geological interpretation**
The resistivity log is derived from the computer-generated model which best fits the field data. The lithological interpretation and geological classification are based upon knowledge of local geology and correlation with nearby sample points.

**8 Processing results**
The processing results are the apparent resistivities calculated for a given electrode spacing (Wenner configuration) together with an indication of the percentage observed, offset and lateral errors (expressed as a decimal). The root of mean square (RMS) percentage errors for the sounding as a whole are also given.

**9 Field curve data**
The field curve data give the apparent resistivitites used in the interpretation, the percentage difference of the theoretical model from the field data (RMS relative error) and an indication where the maximum deviation from the field data points occurred (Maximum relative error).

**10 Interpreted model**
The interpreted model shows the thickness, depth (both in metres) and the apparent resistivity (ohm.m) for each layer recognised in the interpretation of the sounding. The reflection coefficients are an expression of the percentage difference in the resistivities of two adjacent layers.

**11 Plotted results**
The results plotted are those used in the computer modelling. The field data, generally gathered at electrode spacing of 0.5, 1, 2, 4, 8, 16, 32 and 64m, and intermediate values obtained by computer processing of this data are shown. The curve shows the computer-generated model.

# APPENDIX I: RESISTIVITY RECORDS
# DUNECHT RESOURCE SHEET

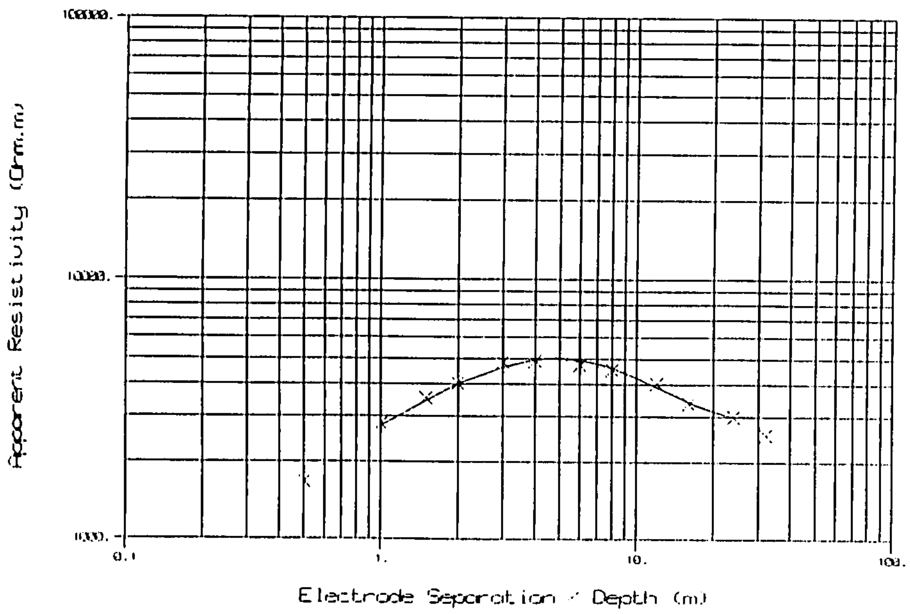
| | | | |
|---|---|---|---|
| NJ 70 NE R1a | 7591 0765 | Tillymannoch Wood, Echt | Block A |

Azimuth 046°
March 1987

| | |
|---|---|
| Waste | 0.3m |
| Bedrock | 4.5m+ |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, sandy, pebbly | 755 | 0.3 | 0.3 |
| Caledonian | Granite, weathered/fractured | 6644 | 4.5 | 4.8 |
| | Granite, massive | 1682 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 811.0000 | 789.0000 | 583.0000 | 481.0000 | 42.4000 |
| 1.0 | 657.0000 | 654.0000 | 429.0000 | 465.0000 | 32.4000 |
| 2.0 | 449.0000 | 417.0000 | 339.0000 | 382.0000 | 32.0000 |
| 4.0 | 263.0000 | 248.0000 | 194.4000 | 285.0000 | 14.9100 |
| 8.0 | 121.1000 | 114.7000 | 31.6000 | 100.1000 | 6.2200 |
| 16.0 | 40.7000 | 37.6000 | 25.0000 | 41.7000 | 3.0900 |
| 32.0 | 17.2800 | 16.6900 | 11.0000 | 14.2700 | 0.5800 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 1671.33 | -0.0005 | -0.1917 | 0.0292 |
| 1.0 | 2808.58 | 0.0009 | 0.0805 | 0.1457 |
| 1.5 | 3525.10 | | | |
| 2.0 | 4033.81 | 0.0000 | 0.0062 | -0.0059 |
| 3.0 | 4852.95 | | | |
| 4.0 | 4893.34 | 0.0003 | 0.1058 | 0.0871 |
| 6.0 | 4738.31 | | | |
| 8.0 | 4566.62 | 0.0010 | 0.2036 | 0.2162 |
| 12.0 | 4031.59 | | | |
| 16.0 | 3352.71 | 0.0002 | 0.5007 | -0.1633 |
| 24.0 | 2985.73 | | | |
| 32.0 | 2540.42 | 0.0001 | 0.2583 | 0.0000 |
| 48.0 | 2373.87 | | | |
| 64.0 | 3252.00 | | | |

R.M.S. Observational Error = .0005
R.M.S. Offset Wenner Difference = .2431
R.M.S. Potential Ladder Difference = .1313

FIELD CURVE DATA / INTERPRETED MODEL

| | Electrode Separation | Apparent Resistivity | Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|---|---|---|
| 1 | 0.5 | 1671.33 | 0.25 | | 755.4 | |
| 2 | 1.0 | 2808.58 | | | | |
| 3 | 1.5 | 3525.10 | | 0.25 | -------- | 0.7958 |
| 4 | 2.0 | 4033.81 | | | | |
| 5 | 3.0 | 4852.95 | 4.51 | | 6643.8 | |
| 6 | 4.0 | 4893.34 | | | | |
| 7 | 6.0 | 4738.31 | | 4.76 | -------- | -0.4249 |
| 8 | 8.0 | 4566.62 | | | | |
| 9 | 12.0 | 4031.59 | | | 2681.8 | |
| 10 | 16.0 | 3352.71 | | | | |
| 11 | 24.0 | 2985.73 | | | ******** | |
| 12 | 32.0 | 2540.42 | | | | |

R.M.S. Relative error = 0.0217
Maximum rel. error = 0.0332 at sample 7
Number of trials was 0

| NJ 70 NE R1b | 7591 0765 | Tillymannoch Wood, Echt | | Block A |
|---|---|---|---|---|
| Azimuth 175° | | | Waste | 0.3m |
| March 1987 | | | Bedrock | 4.9m+ |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness m | Depth m |
|---|---|---|---|---|
| | Soil, sandy, pebbly | 729 | 0.3 | 0.3 |
| Caledonian | Granite, weathered/fractured | 9265 | 4.9 | 5.2 |
| | Granite, massive | 1914 | - | - |

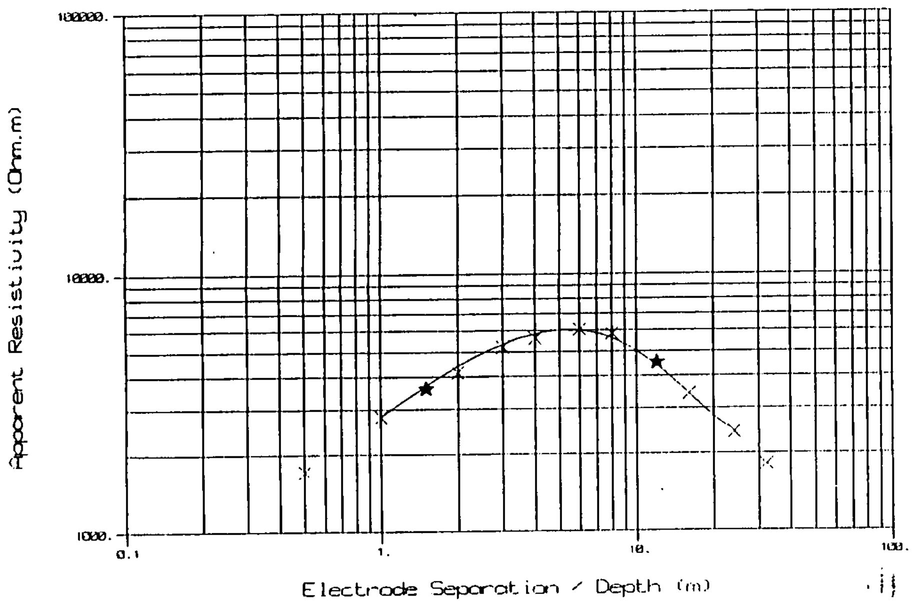
INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 833.0000 | 799.0000 | 613.0000 | 476.0000 | 39.4000 |
| 1.0 | 693.0000 | 667.0000 | 441.0000 | 446.0000 | 25.0000 |
| 2.0 | 482.0000 | 457.0000 | 352.0000 | 295.0000 | 24.5000 |
| 4.0 | 322.0000 | 305.0000 | 230.0000 | 215.0000 | 15.0000 |
| 8.0 | 163.3000 | 156.3000 | 99.2000 | 133.0000 | 7.1000 |
| 16.0 | 43.0000 | 41.2000 | 37.8000 | 29.9000 | 1.6500 |
| 32.0 | 12.0000 | 11.5200 | 9.4600 | 8.5500 | 0.4180 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 1710.60 | -0.0005 | -0.2516 | 0.0734 |
| 1.0 | 2786.59 | 0.0014 | 0.0113 | 0.1313 |
| 1.5 | 3502.51 | | | |
| 2.0 | 4128.05 | 0.0010 | -0.2040 | 0.0786 |
| 3.0 | 5183.53 | | | |
| 4.0 | 5592.04 | 0.0012 | -0.0574 | 0.2208 |
| 6.0 | 6046.82 | | | |
| 8.0 | 5835.82 | -0.0006 | 0.2011 | 0.6862 |
| 12.0 | 5011.20 | | | |
| 16.0 | 3402.97 | 0.0033 | -0.2334 | 0.3238 |
| 24.0 | 2411.30 | | | |
| 32.0 | 1810.56 | 0.0052 | -0.1011 | 0.0000 |
| 48.0 | 1750.95 | | | |
| 64.0 | 2046.68 | | | |

R.M.S. Observational Error = .0035
R.M.S. Offset Wenner Difference = .1924
R.M.S. Potential Ladder Difference = .3339




FIELD CURVE DATA / INTERPRETED MODEL

| | Electrode Separation | Apparent Resistivity | Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|---|---|---|
| 1 | 0.5 | 1710.60 | 0.27 | | 728.7 | |
| 2 | 1.0 | 2786.59 | | | | |
| 3 | 1.5 | 3300.00 | | 0.27 | --------- | 0.8542 |
| 4 | 2.0 | 4128.05 | | | | |
| 5 | 3.0 | 5183.53 | 4.94 | | 9864.7 | |
| 6 | 4.0 | 5592.04 | | | | |
| 7 | 6.0 | 6046.82 | | 5.21 | --------- | -0.6575 |
| 8 | 8.0 | 5835.82 | | | | |
| 9 | 12.0 | 4500.00 | | | 1914.1 | |
| 10 | 16.0 | 3402.97 | | | | |
| 11 | 24.0 | 2411.30 | | | ******** | |
| 12 | 32.0 | 1810.56 | | | | |

R.M.S. Relative error = 0.0328
Maximum rel. error = 0.0561 at sample 5
Number of trials was 0

**NJ 70 NE R1c** **7612 0781** **Tillymannoch Wood, Echt** **Block A**

Azimuth 060°
March 1987

| | |
|---|---|
| Waste | 0.3m |
| Bedrock | 4.6m+ |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, sandy, pebbly | 627 | 0.3 | 0.3 |
| Caledonian | Granite, weathered/fractured | 10329 | 4.6 | 4.9 |
| | Granite, massive | 3947 | - | - |

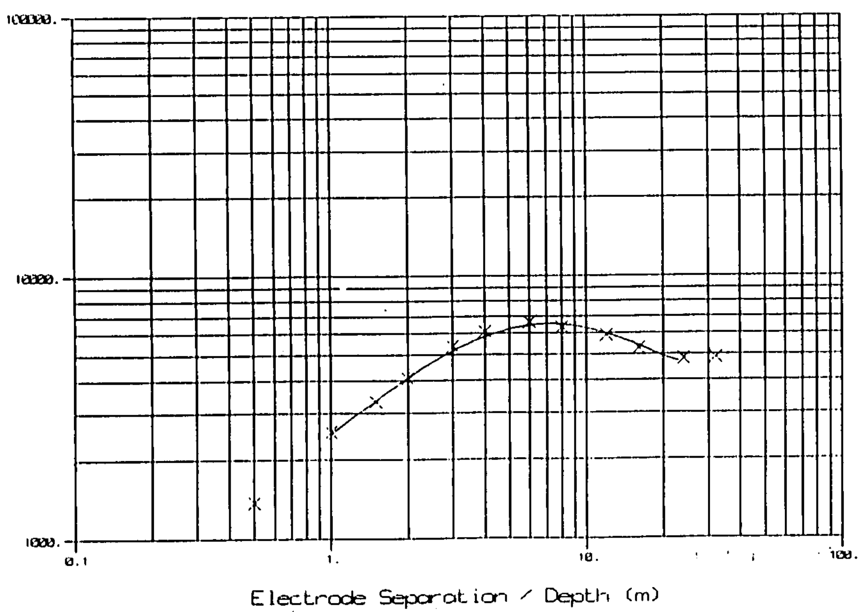
INPUT DATA

| Electrode Spacing | A | C | O1 | O2 | G |
|---|---|---|---|---|---|
| 0.5 | 675.0000 | 635.0000 | 492.0000 | 390.0000 | 40.2000 |
| 1.0 | 641.0000 | 612.0000 | 432.0000 | 374.0000 | 29.1000 |
| 2.0 | 484.0000 | 453.0000 | 341.0000 | 305.0000 | 29.3000 |
| 4.0 | 350.0000 | 329.0000 | 239.0000 | 247.0000 | 21.2000 |
| 8.0 | 159.1000 | 148.6000 | 108.5000 | 142.8000 | 10.4800 |
| 16.0 | 72.2000 | 68.1000 | 48.0000 | 56.7000 | 4.0000 |
| 32.0 | 30.1000 | 27.3000 | 21.4000 | 26.8000 | 2.7600 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 1369.73 | 0.0003 | -0.2569 | -0.0060 |
| 1.0 | 2532.12 | -0.0002 | -0.1439 | 0.1459 |
| 1.5 | 3313.20 | | | |
| 2.0 | 4065.22 | 0.0025 | -0.1082 | 0.0352 |
| 3.0 | 5353.07 | | | |
| 4.0 | 6107.26 | -0.0006 | 0.0329 | 0.1326 |
| 6.0 | 6626.82 | | | |
| 8.0 | 6325.91 | 0.0001 | 0.2694 | -0.0652 |
| 12.0 | 5910.22 | | | |
| 16.0 | 5262.80 | 0.0006 | 0.1662 | 0.1543 |
| 24.0 | 4796.15 | | | |
| 32.0 | 4845.59 | 0.0013 | 0.2241 | 0.0000 |
| 48.0 | 4212.91 | | | |
| 64.0 | 2588.19 | | | |

R.M.S. Observational Error = .0011
R.M.S. Offset Wenner Difference = .1889
R.M.S. Potential Ladder Difference = .1183




FIELD CURVE DATA / INTERPRETED MODEL

| | Electrode Separation | Apparent Resistivity | Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|---|---|---|
| 1 | 0.5 | 1369.73 | 0.28 | | 627.3 | |
| 2 | 1.0 | 2532.12 | | | | |
| 3 | 1.5 | 3313.20 | | 0.28 | -------- | 0.8855 |
| 4 | 2.0 | 4065.22 | | | | |
| 5 | 3.0 | 5353.07 | 4.57 | | 10328.9 | |
| 6 | 4.0 | 6107.26 | | | | |
| 7 | 6.0 | 6626.82 | | 4.85 | -------- | -0.4471 |
| 8 | 8.0 | 6325.91 | | | | |
| 9 | 12.0 | 5910.22 | | | 3946.8 | |
| 10 | 16.0 | 5262.80 | | | | |
| 11 | 24.0 | 4796.15 | | | ******** | |
| 12 | 32.0 | 4845.59 | | | | |

R.M.S. Relative error = 0.0270
Maximum rel. error = -0.0433 at sample 6
Number of trials was 0

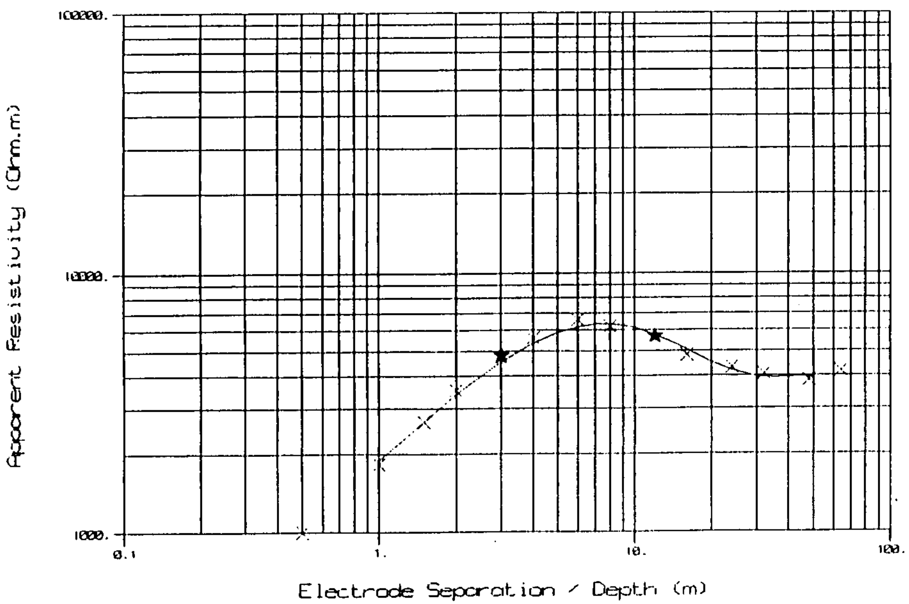
**NJ 70 NE R2** **7652 0837** **Heather Hill, Echt** **Block A**

**Azimuth 120°**
**March 1987**

| | |
|---|---|
| **Overburden** | **0.5m** |
| **Mineral I** | **5.8m** |
| **Bedrock** | **-** |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, sandy, pebbly | 438 | 0.2 | 0.2 |
| Peat | Peat, sandy | 1016 | 0.3 | 0.5 |
| Fluvioglacial sand and gravel | Gravel, cobbles, coarse | 25068 | 1.8 | 2.3 |
| | Gravel, sandy | 6668 | 2.2 | 4.3 |
| | Sand, gravelly | 787 | 1.8 | 6.3 |
| Caledonian | Granite | 4065 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 509.0000 | 489.0000 | 308.0000 | 329.0000 | 19.6900 |
| 1.0 | 479.0000 | 463.0000 | 272.0000 | 311.0000 | 15.9500 |
| 2.0 | 443.0000 | 415.0000 | 271.0000 | 290.0000 | 27.2000 |
| 4.0 | 314.0000 | 285.0000 | 205.0000 | 241.0000 | 28.3000 |
| 8.0 | 165.8000 | 156.0000 | 126.3000 | 120.7000 | 9.7800 |
| 16.0 | 62.6000 | 58.3000 | 46.5000 | 49.7000 | 4.3200 |
| 32.0 | 25.5000 | 23.7000 | 19.5000 | 21.0200 | 1.7480 |
| 64.0 | 13.7400 | 12.9100 | 9.8100 | 11.0100 | 0.8270 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 1000.60 | 0.0006 | 0.0659 | 0.0854 |
| 1.0 | 1831.55 | 0.0001 | 0.1338 | 0.1115 |
| 1.5 | 2660.19 | | | |
| 2.0 | 3524.87 | 0.0018 | 0.0677 | 0.1048 |
| 3.0 | 4957.88 | | | |
| 4.0 | 5604.60 | 0.0022 | 0.1614 | 0.0046 |
| 6.0 | 6573.10 | | | |
| 8.0 | 6207.79 | 0.0001 | -0.0453 | 0.1759 |
| 12.0 | 5070.46 | | | |
| 16.0 | 4835.54 | -0.0003 | 0.0665 | 0.0032 |
| 24.0 | 4329.93 | | | |
| 32.0 | 4071.50 | 0.0030 | 0.0741 | -0.1663 |
| 48.0 | 3848.47 | | | |
| 64.0 | 4186.11 | 0.0002 | 0.1153 | 0.0000 |
| 96.0 | 4091.24 | | | |
| 128.0 | 4023.50 | | | |

R.M.S. Observational Error = .0013
R.M.S. Offset Wenner Difference = .0988
R.M.S. Potential Ladder Difference = .1130

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 1000.60 |
| 2 | 1.0 | 1231.55 |
| 3 | 1.5 | 2660.19 |
| 4 | 2.0 | 3524.87 |
| 5 | 3.0 | 4800.00 |
| 6 | 4.0 | 5604.60 |
| 7 | 6.0 | 6573.10 |
| 8 | 8.0 | 6207.79 |
| 9 | 12.0 | 5700.00 |
| 10 | 16.0 | 4835.54 |
| 11 | 24.0 | 4329.93 |
| 12 | 32.0 | 4071.50 |
| 13 | 48.0 | 3848.47 |
| 14 | 64.0 | 4186.11 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.18 | | 438.0 | |
| | 0.18 | -------- | 0.3976 |
| 0.28 | | 1016.1 | |
| | 0.46 | -------- | 0.9221 |
| 1.87 | | 25068.3 | |
| | 2.33 | -------- | -0.5803 |
| 2.15 | | 6657.7 | |
| | 4.48 | -------- | -0.7885 |
| 1.78 | | 787.2 | |
| | 6.26 | -------- | 0.6755 |
| | | 4065.3 | |
| | | ******** | |

R.M.S. Relative error = 0.0322
Maximum rel. error = -0.0637 at sample 7
Number of trials was 0

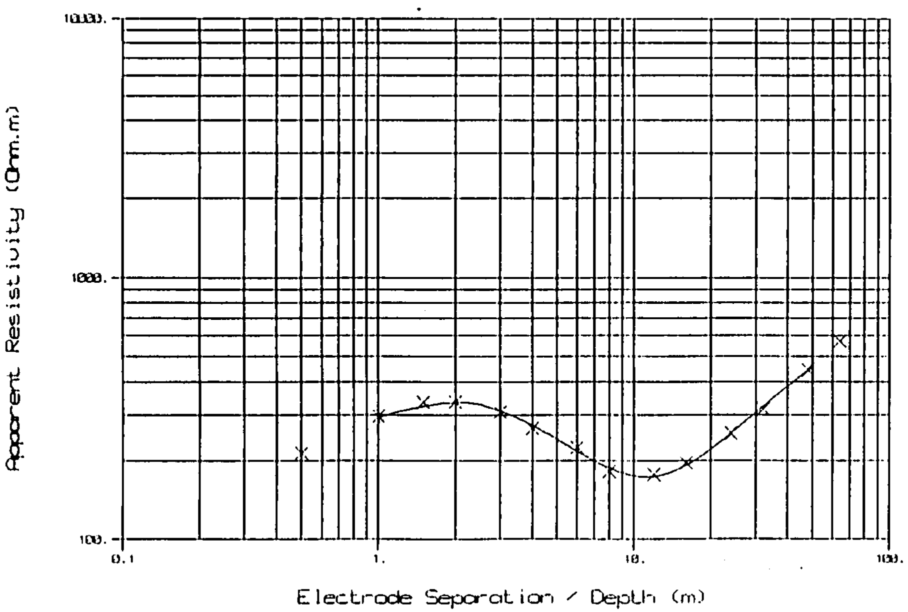
NJ 70 SW R1 | 7451 0003 | Black Moss, Banchory | Block E

Azimuth 040°
March 1987

| | |
|---|---|
| Overburden | 0.4m |
| Mineral I | 1.5m |
| Waste | 8.0m |
| Bedrock | - |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| Peat | Peat | 150 | 0.4 | 0.4 |
| Alluvium | Sand, gravelly | 481 | 1.5 | 1.9 |
| ?Flow-till | Silt, sandy | 175 | 5.9 | 7.8 |
| Till | Clay, firm | 28 | 2.1 | 9.9 |
| Caledonian | Granite | 1531 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 101.9000 | 96.4000 | 69.5000 | 67.6000 | 5.4900 |
| 1.0 | 66.2000 | 62.0000 | 46.1000 | 47.8000 | 4.1500 |
| 2.0 | 36.0000 | 34.2000 | 25.9000 | 27.4000 | 1.8240 |
| 4.0 | 13.5400 | 12.8700 | 10.3000 | 10.9800 | 0.6700 |
| 8.0 | 4.6800 | 4.4400 | 3.4500 | 3.7800 | 0.2380 |
| 16.0 | 2.9300 | 2.7000 | 2.0200 | 1.8810 | 0.1660 |
| 32.0 | 2.3500 | 2.2100 | 1.6840 | 1.4530 | 0.1457 |
| 64.0 | 2.2400 | 2.1500 | 1.6360 | 1.2050 | 0.0948 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 214.41 | 0.0001 | -0.0366 | 0.0997 |
| 1.0 | 295.00 | 0.0008 | 0.0362 | 0.0556 |
| 1.5 | 334.21 | | | |
| 2.0 | 334.89 | -0.0007 | 0.0563 | 0.2105 |
| 3.0 | 307.28 | | | |
| 4.0 | 266.66 | 0.0000 | 0.0584 | 0.1252 |
| 6.0 | 224.65 | | | |
| 8.0 | 181.71 | 0.0004 | 0.0913 | -0.0765 |
| 12.0 | 177.25 | | | |
| 16.0 | 196.09 | 0.0014 | -0.0713 | 0.0173 |
| 24.0 | 254.48 | | | |
| 32.0 | 315.37 | -0.0024 | -0.1473 | -0.0503 |
| 48.0 | 444.52 | | | |
| 64.0 | 571.22 | -0.0021 | -0.3034 | 0.0000 |
| 96.0 | 836.39 | | | |
| 128.0 | 1169.70 | | | |

R.M.S. Observational Error = .0013
R.M.S. Offset Wenner Difference = .1306
R.M.S. Potential Ladder Difference = .1088

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 214.41 |
| 2 | 1.0 | 295.00 |
| 3 | 1.5 | 334.21 |
| 4 | 2.0 | 334.89 |
| 5 | 3.0 | 307.28 |
| 6 | 4.0 | 266.66 |
| 7 | 6.0 | 224.65 |
| 8 | 8.0 | 181.71 |
| 9 | 12.0 | 177.25 |
| 10 | 16.0 | 196.09 |
| 11 | 24.0 | 254.48 |
| 12 | 32.0 | 315.37 |
| 13 | 48.0 | 444.52 |
| 14 | 64.0 | 571.22 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.35 | | 150.2 | |
| | 0.35 | -------- | 0.5242 |
| 1.50 | | 481.2 | |
| | 1.85 | -------- | -0.4862 |
| 5.94 | | 175.2 | |
| | 7.79 | -------- | -0.7270 |
| 2.11 | | 27.7 | |
| | 9.90 | -------- | 0.9644 |
| | | 1530.5 | |
| | | ******** | |

R.M.S. Relative error = 0.0136
Maximum rel. error = 0.0216 at sample 12
Number of trials was 0

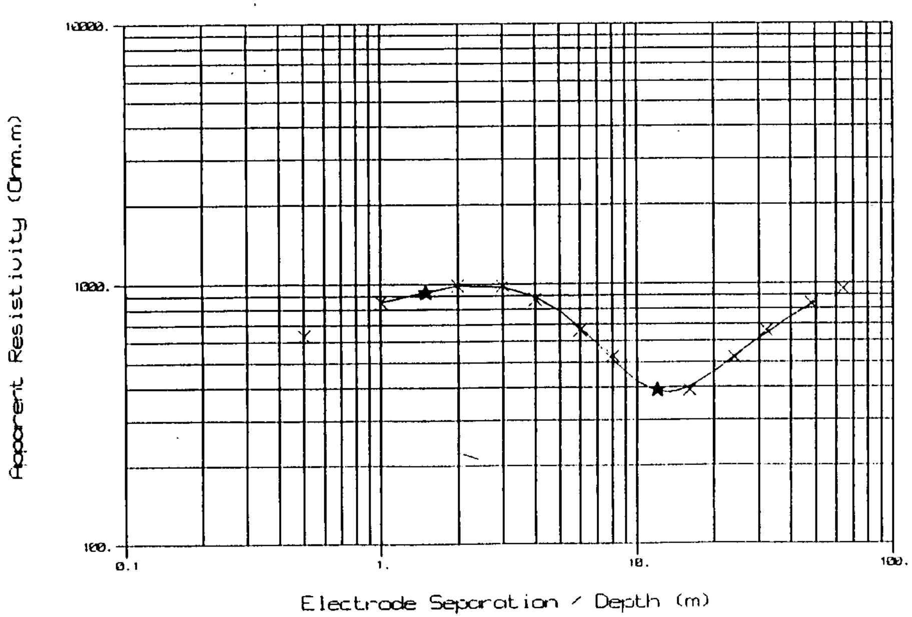
NJ 70 SW R2a | 7357 0188 | South-west of Birks, Echt | Block D

Azimuth 114° 
March 1987

Overburden 0.2m
Mineral I 4.1m
Waste 1.6m
Bedrock -

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, sandy | 335 | 0.2 | 0.2 |
| Fluvioglacial sand and gravel | Gravel, sandy | 1150 | 4.1 | 4.3 |
| Till | Clay, silty | 36 | 1.6 | 5.9 |
| Caledonian | Granite | 1696 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 383.0000 | 289.0000 | 205.0000 | 199.0000 | 14.3000 |
| 1.0 | 156.5000 | 185.0000 | 135.3000 | 136.6000 | 11.4200 |
| 2.0 | 103.0000 | 96.0000 | 77.4000 | 79.1000 | 6.9700 |
| 4.0 | 43.7000 | 41.7000 | 35.0000 | 34.4000 | 1.9820 |
| 8.0 | 13.8100 | 13.3300 | 11.3700 | 9.0500 | 0.4220 |
| 16.0 | 5.6400 | 5.3400 | 3.8900 | 3.8300 | 0.2990 |
| 32.0 | 5.1900 | 4.9400 | 3.7100 | 2.8300 | 0.2520 |
| 64.0 | 3.0700 | 2.7200 | 2.3100 | 2.4000 | 0.3450 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 634.60 | -0.0010 | -0.0297 | 0.1389 |
| 1.0 | 854.20 | 0.0004 | 0.0096 | 0.1273 |
| 1.5 | 982.34 | | | |
| 2.0 | 983.32 | 0.0003 | 0.0217 | 0.0119 |
| 3.0 | 980.62 | | | |
| 4.0 | 872.11 | 0.0004 | -0.0173 | 0.1688 |
| 6.0 | 663.56 | | | |
| 8.0 | 526.78 | -0.0001 | -0.2653 | 0.2507 |
| 12.0 | 423.52 | | | |
| 16.0 | 389.56 | 0.0002 | -0.0077 | -0.0518 |
| 24.0 | 520.18 | | | |
| 32.0 | 657.47 | -0.0004 | -0.2691 | 0.2087 |
| 48.0 | 834.03 | | | |
| 64.0 | 947.00 | 0.0016 | 0.0382 | 0.0000 |
| 96.0 | 988.05 | | | |
| 128.0 | 590.67 | | | |

R.M.S. Observational Error = .0007
R.M.S. Offset Wenner Difference = .1351
R.M.S. Potential Ladder Difference = .1573

FIELD CURVE DATA / INTERPRETED MODEL

| | Electrode Separation | Apparent Resistivity | Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|---|---|---|
| 1 | 0.5 | 634.60 | 0.21 | | 334.6 | |
| 2 | 1.0 | 854.20 | | | | |
| 3 | 1.5 | 925.00 | | 0.21 | -------- | 0.5492 |
| 4 | 2.0 | 983.32 | | | | |
| 5 | 3.0 | 980.62 | 4.13 | | 1149.9 | |
| 6 | 4.0 | 872.11 | | | | |
| 7 | 6.0 | 663.56 | | 4.34 | -------- | -0.9390 |
| 8 | 8.0 | 526.78 | | | | |
| 9 | 12.0 | 390.00 | 1.58 | | 36.2 | |
| 10 | 16.0 | 389.56 | | | | |
| 11 | 24.0 | 520.18 | | 5.92 | -------- | 0.9582 |
| 12 | 32.0 | 657.47 | | | | |
| 13 | 48.0 | 834.03 | | | 1696.0 | |
| 14 | 64.0 | 947.00 | | | | |

********

R.M.S. Relative error = 0.0195
Maximum rel. error = 0.0333 at sample 7
Number of trials was 0

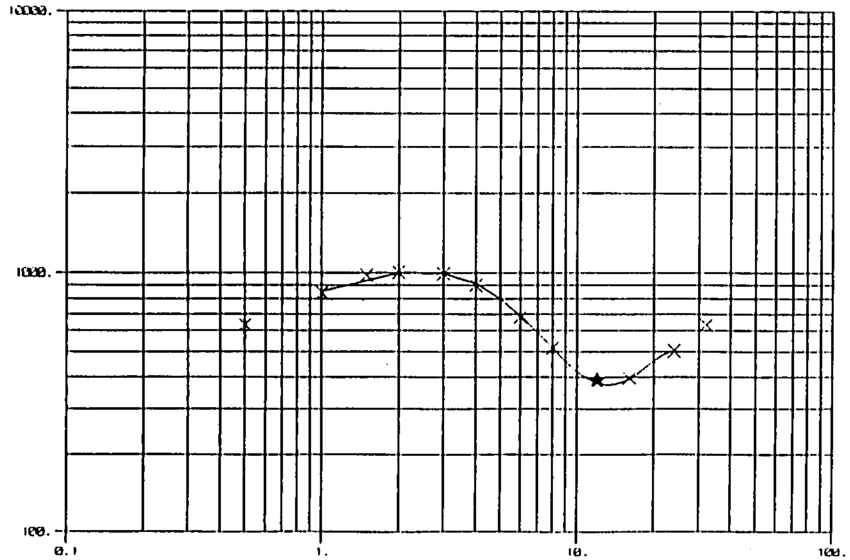
NJ 70 SW R2b    7357 0188    South-west of Birks, Echt    Block D

Azimuth 060°
March 1987

| | |
|---|---|
| Overburden | 0.2m |
| Mineral I | 4.0m |
| Waste | 1.6m |
| Bedrock | - |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, sandy | 314 | 0.2 | 0.2 |
| Fluvioglacial sand and gravel | Gravel, sandy | 1196 | 4.0 | 4.2 |
| Till | Clay, silty | 35 | 1.6 | 5.8 |
| Caledonian | Granite | 1663 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | G |
|---|---|---|---|---|---|
| 0.5 | 238.0000 | 282.0000 | 207.0000 | 197.0000 | 15.2500 |
| 1.0 | 150.4000 | 178.0000 | 133.4000 | 134.4000 | 12.3300 |
| 2.0 | 106.2000 | 99.2000 | 81.6000 | 78.2000 | 7.0300 |
| 4.0 | 45.9000 | 43.9000 | 35.7000 | 35.9000 | 2.0100 |
| 8.0 | 12.9000 | 12.4100 | 9.5000 | 11.0300 | 0.4910 |
| 16.0 | 5.9300 | 5.6900 | 3.6100 | 4.2700 | 0.2700 |
| 32.0 | 4.9200 | 4.6500 | 2.8300 | 3.4600 | 0.2610 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 634.60 | 0.0025 | -0.0495 | 0.1001 |
| 1.0 | 841.32 | 0.0004 | 0.0075 | 0.0523 |
| 1.5 | 979.74 | | | |
| 2.0 | 1004.05 | -0.0003 | -0.0426 | 0.0387 |
| 3.0 | 990.48 | | | |
| 4.0 | 899.75 | -0.0002 | 0.0056 | 0.2386 |
| 6.0 | 679.08 | | | |
| 8.0 | 515.98 | -0.0001 | 0.1491 | 0.0443 |
| 12.0 | 421.00 | | | |
| 16.0 | 396.09 | 0.0000 | 0.1675 | 0.0564 |
| 24.0 | 500.87 | | | |
| 32.0 | 632.34 | 0.0018 | 0.2003 | 0.0000 |
| 48.0 | 926.79 | | | |
| 64.0 | 1213.82 | | | |

R.M.S. Observational Error = .0012
R.M.S. Offset Wenner Difference = .1163
R.M.S. Potential Ladder Difference = .1308

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 634.60 |
| 2 | 1.0 | 841.32 |
| 3 | 1.5 | 979.74 |
| 4 | 2.0 | 1004.05 |
| 5 | 3.0 | 990.48 |
| 6 | 4.0 | 899.75 |
| 7 | 6.0 | 679.08 |
| 8 | 8.0 | 515.98 |
| 9 | 12.0 | 390.00 |
| 10 | 16.0 | 396.09 |
| 11 | 24.0 | 500.87 |
| 12 | 32.0 | 632.34 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.21 | | 313.8 | |
| | 0.21 | -------- | 0.5844 |
| 4.03 | | 1196.3 | |
| | 4.24 | -------- | -0.9428 |
| 1.59 | | 35.2 | |
| | 5.83 | -------- | 0.9586 |
| | | 1663.3 | |
| | | ******** | |

R.M.S. Relative error = 0.0194
Maximum rel. error = 0.0440 at sample 2
Number of trials was 0

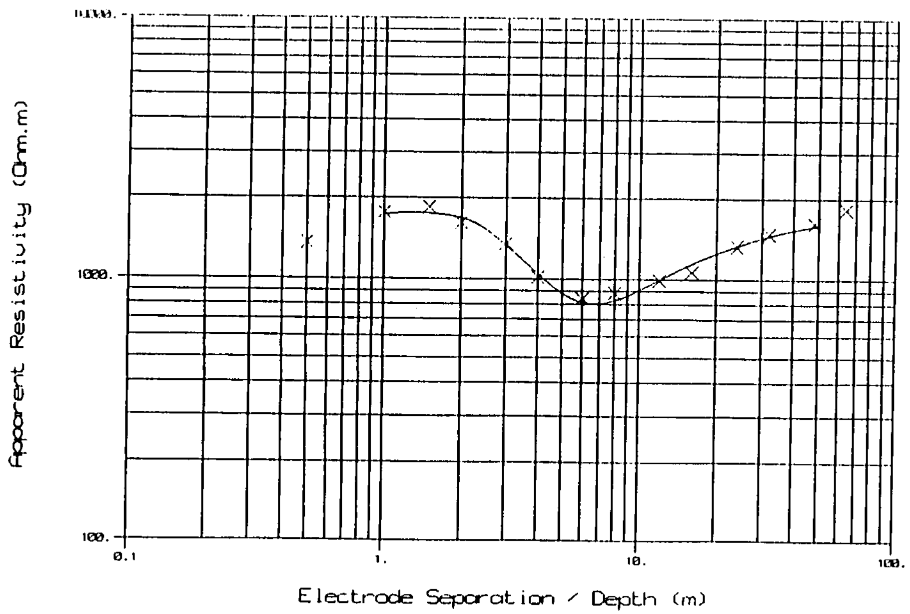
NJ 70 SW R3a 7453 0425 **Landerberry, Echt** **Block B**

Azimuth 110°
March 1987

| | |
|---|---|
| Overburden | 0.2m |
| Mineral I | 2.8m |
| Waste | 0.3m |
| Bedrock | - |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, sandy, pebbly | 694 | 0.2 | 0.2 |
| Alluvium | Gravel, sandy | 2425 | 1.5 | 1.7 |
| | Sand, gravelly | 608 | 1.3 | 3.0 |
| Till | Clay, sandy | 54 | 0.3 | 3.3 |
| Caledonian | Granite | 1777 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 640.0000 | 610.0000 | 455.0000 | 406.0000 | 29.6000 |
| 1.0 | 390.0000 | 358.0000 | 295.0000 | 264.0000 | 21.6000 |
| 2.0 | 155.2000 | 146.3000 | 128.9000 | 127.6000 | 8.8500 |
| 4.0 | 51.0000 | 48.8000 | 43.7000 | 35.7000 | 2.2500 |
| 8.0 | 25.7000 | 24.4000 | 18.3100 | 16.8300 | 1.2560 |
| 16.0 | 14.1800 | 13.0700 | 10.7900 | 10.3100 | 1.1080 |
| 32.0 | 10.8400 | 10.3200 | 8.3600 | 6.2800 | 0.5180 |
| 64.0 | 6.1700 | 5.7500 | 5.1800 | 3.8900 | 0.4240 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 1352.46 | 0.0006 | -0.1138 | 0.1429 |
| 1.0 | 1756.15 | 0.0010 | -0.1109 | 0.1915 |
| 1.5 | 1846.10 | | | |
| 2.0 | 1611.64 | 0.0003 | -0.0101 | -0.0504 |
| 3.0 | 1347.09 | | | |
| 4.0 | 1010.34 | -0.0010 | -0.1741 | -0.0119 |
| 6.0 | 840.03 | | | |
| 8.0 | 883.16 | 0.0017 | -0.0842 | 0.1494 |
| 12.0 | 985.32 | | | |
| 16.0 | 1080.60 | 0.0001 | -0.0455 | -0.1956 |
| 24.0 | 1324.90 | | | |
| 32.0 | 1471.77 | 0.0002 | -0.2842 | 0.1617 |
| 48.0 | 1609.74 | | | |
| 64.0 | 1823.63 | -0.0006 | -0.2845 | 0.0000 |
| 96.0 | 2042.66 | | | |
| 128.0 | 1951.33 | | | |

R.M.S. Observational Error = .0009
R.M.S. Offset Wenner Difference = .1683
R.M.S. Potential Ladder Difference = .1376

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 1352.46 |
| 2 | 1.0 | 1756.15 |
| 3 | 1.5 | 1846.10 |
| 4 | 2.0 | 1611.64 |
| 5 | 3.0 | 1347.09 |
| 6 | 4.0 | 1010.34 |
| 7 | 6.0 | 840.03 |
| 8 | 8.0 | 883.16 |
| 9 | 12.0 | 985.32 |
| 10 | 16.0 | 1080.60 |
| 11 | 24.0 | 1324.90 |
| 12 | 32.0 | 1471.77 |
| 13 | 48.0 | 1609.74 |
| 14 | 64.0 | 1823.63 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.20 | | 694.2 | |
| | 0.20 | -------- | 0.5549 |
| 1.51 | | 2425.3 | |
| | 1.71 | -------- | -0.5991 |
| 1.24 | | 608.0 | |
| | 2.95 | -------- | -0.8382 |
| 0.34 | | 53.5 | |
| | 3.29 | -------- | 0.9415 |
| | | 1776.8 | |
| | | ******** | |

R.M.S. Relative error = 0.0341
Maximum rel. error = 0.0736 at sample 10
Number of trials was 0

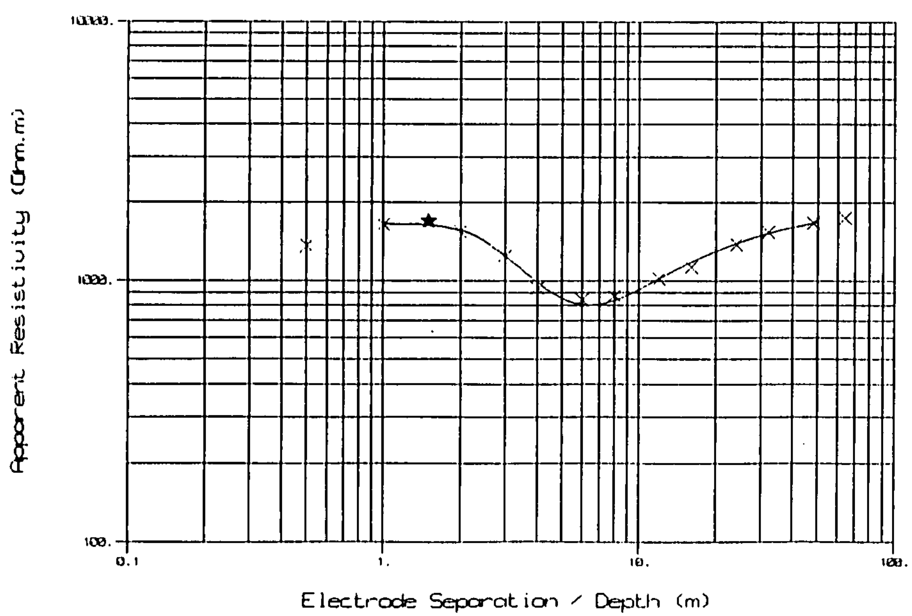
**NJ 70 SW R3b** **7453 0425** **Landerberry, Echt** **Block B**

Azimuth 012°
March 1987

| | |
|---|---|
| Overburden | 0.2m |
| Mineral I | 2.9m |
| Waste | 0.3m |
| Bedrock | - |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, sandy, pebbly | 774 | 0.2 | 0.2 |
| Alluvium | Gravel, sandy | 2151 | 1.6 | 1.8 |
| | Sand, gravelly | 573 | 1.3 | 3.1 |
| Till | Clay, sandy | 52 | 0.3 | 0.3 |
| Caledonian | Granite | 1905 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 660.0000 | 633.0000 | 416.0000 | 452.0000 | 26.4000 |
| 1.0 | 353.0000 | 332.0000 | 237.0000 | 287.0000 | 21.0000 |
| 2.0 | 151.6000 | 144.6000 | 103.7000 | 137.1000 | 7.0400 |
| 4.0 | 44.6000 | 42.4000 | 35.2000 | 39.4000 | 2.1000 |
| 8.0 | 25.1000 | 23.8000 | 16.6300 | 18.0500 | 1.2720 |
| 16.0 | 15.2500 | 14.3000 | 10.7600 | 11.7100 | 0.9560 |
| 32.0 | 11.2100 | 10.7000 | 8.6200 | 6.6900 | 0.5040 |
| 64.0 | 5.3800 | 4.3700 | 4.8800 | 3.8500 | 0.5100 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 1363.45 | 0.0009 | 0.0829 | 0.2606 |
| 1.0 | 1646.19 | 0.0000 | 0.1908 | 0.0696 |
| 1.5 | 1762.79 | | | |
| 2.0 | 1544.41 | -0.0003 | 0.2311 | 0.0813 |
| 3.0 | 1246.69 | | | |
| 4.0 | 937.45 | 0.0022 | 0.1136 | -0.2035 |
| 6.0 | 844.21 | | | |
| 8.0 | 872.61 | 0.0011 | 0.0841 | 0.0744 |
| 12.0 | 1015.45 | | | |
| 16.0 | 1129.47 | -0.0004 | 0.0846 | -0.1000 |
| 24.0 | 1376.49 | | | |
| 32.0 | 1539.13 | 0.0005 | -0.2521 | 0.1983 |
| 48.0 | 1676.35 | | | |
| 64.0 | 1755.27 | 0.0000 | -0.2360 | 0.0000 |
| 96.0 | 1624.60 | | | |
| 128.0 | 812.29 | | | |

R.M.S. Observational Error = .0010
R.M.S. Offset Wenner Difference = .1742
R.M.S. Potential Ladder Difference = .1584

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 1363.45 |
| 2 | 1.0 | 1646.19 |
| 3 | 1.5 | 1700.00 |
| 4 | 2.0 | 1544.41 |
| 5 | 3.0 | 1246.69 |
| 6 | 4.0 | 937.45 |
| 7 | 6.0 | 844.21 |
| 8 | 8.0 | 872.61 |
| 9 | 12.0 | 1015.45 |
| 10 | 16.0 | 1129.47 |
| 11 | 24.0 | 1376.49 |
| 12 | 32.0 | 1539.13 |
| 13 | 48.0 | 1676.35 |
| 14 | 64.0 | 1755.27 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.21 | | 774.1 | |
| | 0.21 | -------- | 0.4706 |
| 1.58 | | 2150.5 | |
| | 1.79 | -------- | -0.5791 |
| 1.28 | | 573.2 | |
| | 3.07 | -------- | -0.8328 |
| 0.32 | | 52.3 | |
| | 3.39 | -------- | 0.9466 |
| | | 1904.8 | |
| | | ******** | |

R.M.S. Relative error = 0.0223
Maximum rel. error = -0.0478 at sample 8
Number of trials was 0

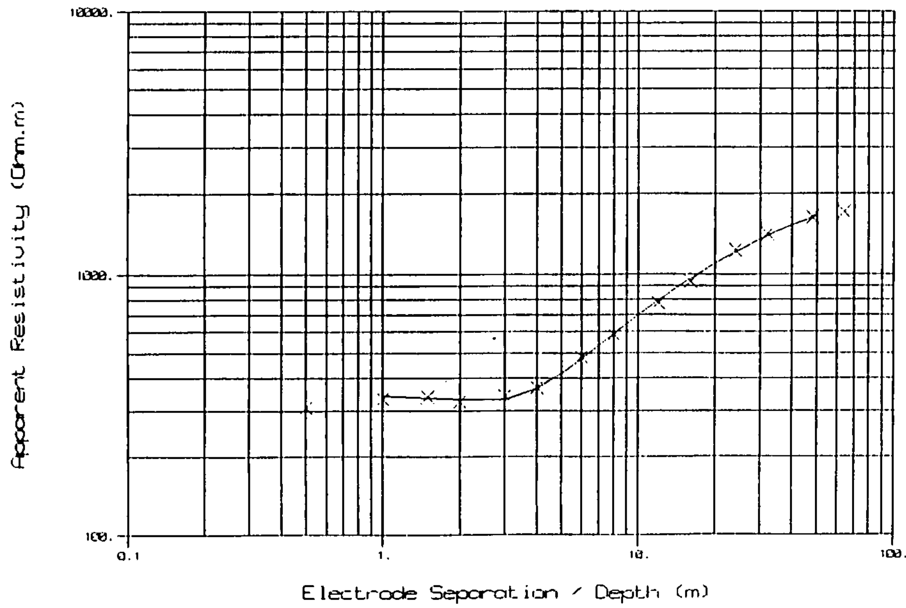
**NJ 70 SE R1a** **7720 0204** **Murphiehowe, Drumoak** **Block F**

Azimuth 090°
March 1987

| | |
|---|---|
| Overburden | 0.2m |
| Mineral I | 1.5m |
| Waste | 0.5m |
| Bedrock | - |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, sandy | 218 | 0.2 | 0.2 |
| Alluvium | Sand, gravelly | 400 | 1.5 | 1.7 |
| Till | Clay, sandy | 55 | 0.5 | 2.2 |
| Caledonian | Granite | 2165 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 141.9000 | 134.7000 | 105.9000 | 91.0000 | 7.2100 |
| 1.0 | 72.5000 | 68.2000 | 55.1000 | 51.4000 | 3.6800 |
| 2.0 | 37.2000 | 35.7000 | 25.5000 | 25.4000 | 1.5490 |
| 4.0 | 21.7000 | 20.4000 | 15.3000 | 13.9500 | 1.1840 |
| 8.0 | 17.7100 | 16.7000 | 11.5900 | 11.6500 | 1.0180 |
| 16.0 | 13.4200 | 12.4200 | 9.3300 | 9.2500 | 0.9910 |
| 32.0 | 9.7100 | 8.9300 | 6.6000 | 7.4400 | 0.7750 |
| 64.0 | 5.1800 | 4.7100 | 4.3800 | 4.1400 | 0.4580 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 309.29 | -0.0001 | -0.1513 | 0.1807 |
| 1.0 | 334.58 | 0.0003 | -0.0595 | 0.0996 |
| 1.5 | 339.96 | | | |
| 2.0 | 336.10 | -0.0013 | -0.0424 | 0.1646 |
| 3.0 | 342.31 | | | |
| 4.0 | 367.82 | 0.0054 | -0.0936 | 0.0000 |
| 6.0 | 481.67 | | | |
| 8.0 | 585.09 | -0.0005 | 0.0086 | 0.0443 |
| 12.0 | 776.27 | | | |
| 16.0 | 933.93 | 0.0007 | -0.0006 | -0.0535 |
| 24.0 | 1225.76 | | | |
| 32.0 | 1411.45 | 0.0015 | 0.1197 | -0.0513 |
| 48.0 | 1634.41 | | | |
| 64.0 | 1709.03 | 0.0023 | -0.0518 | 0.0000 |
| 96.0 | 1371.28 | | | |
| 128.0 | 748.69 | | | |

R.M.S. Observational Error = .0022
R.M.S. Offset Wenner Difference = .0832
R.M.S. Potential Ladder Difference = .1050

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 309.29 |
| 2 | 1.0 | 334.58 |
| 3 | 1.5 | 339.96 |
| 4 | 2.0 | 336.10 |
| 5 | 3.0 | 342.31 |
| 6 | 4.0 | 367.82 |
| 7 | 6.0 | 481.67 |
| 8 | 8.0 | 585.09 |
| 9 | 12.0 | 776.27 |
| 10 | 16.0 | 933.93 |
| 11 | 24.0 | 1225.76 |
| 12 | 32.0 | 1411.45 |
| 13 | 48.0 | 1634.41 |
| 14 | 64.0 | 1709.03 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.24 | | 218.3 | |
| | 0.24 | -------- | 0.2939 |
| 1.43 | | 400.0 | |
| | 1.67 | -------- | -0.7590 |
| 0.55 | | 54.8 | |
| | 2.22 | -------- | 0.9506 |
| | | 2165.2 | |
| | | ******** | |

R.M.S. Relative error = 0.0182
Maximum rel. error = -0.0324 at sample 1
Number of trials was 0

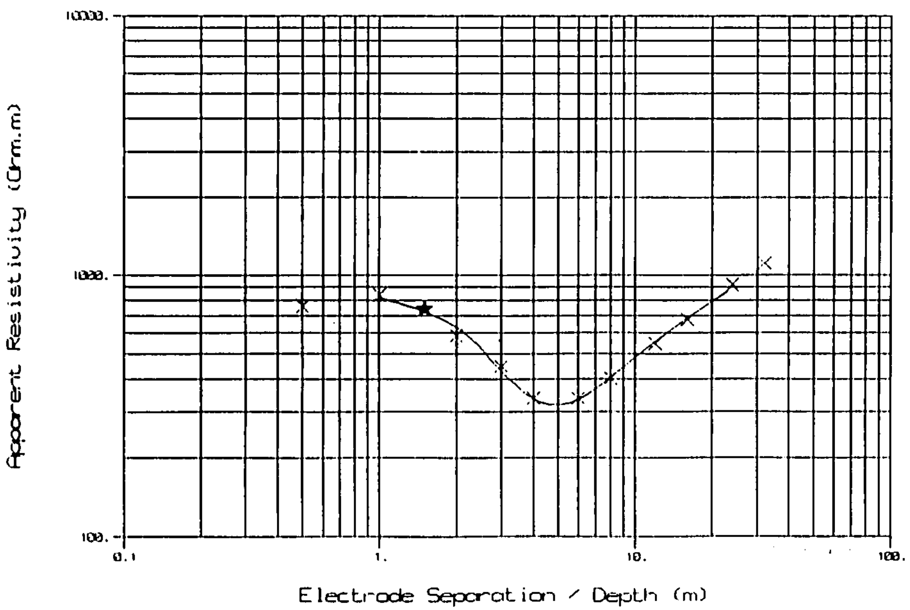
NJ 70 SE R1b | 7714 0211 | Murphiehowe, Drumoak | Block F

Azimuth 009°
March 1987

| | |
|---|---|
| Overburden | 0.2m |
| Mineral I | 1.4m |
| Waste | 0.9m |
| Bedrock | - |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, sandy, pebbly | 538 | 0.2 | 0.2 |
| Alluvium | Sand, gravelly | 1015 | 1.4 | 1.6 |
| Till | Clay, sandy | 42 | 0.9 | 2.5 |
| Caledonian | Granite | 1897 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 357.0000 | 340.0000 | 223.0000 | 260.0000 | 16.9800 |
| 1.0 | 179.5000 | 170.5000 | 120.9000 | 145.8000 | 8.9100 |
| 2.0 | 54.5000 | 51.9000 | 45.1000 | 48.3000 | 2.6200 |
| 4.0 | 18.0000 | 17.1700 | 12.7700 | 14.0800 | 0.8460 |
| 8.0 | 12.1000 | 11.3700 | 8.1000 | 7.9300 | 0.7230 |
| 16.0 | 9.9700 | 9.2300 | 7.1000 | 6.3200 | 0.6880 |
| 32.0 | 7.9900 | 7.4700 | 6.0100 | 5.0300 | 0.5160 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 758.69 | 0.0001 | 0.1532 | 0.2388 |
| 1.0 | 837.86 | 0.0005 | 0.1867 | 0.2964 |
| 1.5 | 772.61 | | | |
| 2.0 | 586.85 | -0.0004 | 0.0665 | -0.1134 |
| 3.0 | 448.05 | | | |
| 4.0 | 337.41 | 0.0002 | 0.0976 | -0.0325 |
| 6.0 | 337.28 | | | |
| 8.0 | 402.88 | 0.0006 | -0.0212 | 0.0005 |
| 12.0 | 545.85 | | | |
| 16.0 | 674.56 | -0.0008 | -0.1162 | -0.0333 |
| 24.0 | 916.77 | | | |
| 32.0 | 1109.86 | 0.0005 | -0.1775 | 0.0000 |
| 48.0 | 1369.31 | | | |
| 64.0 | 1569.79 | | | |

R.M.S. Observational Error = .0005
R.M.S. Offset Wenner Difference = .1299
R.M.S. Potential Ladder Difference = .1633

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 758.69 |
| 2 | 1.0 | 837.86 |
| 3 | 1.5 | 740.00 |
| 4 | 2.0 | 586.85 |
| 5 | 3.0 | 448.05 |
| 6 | 4.0 | 337.41 |
| 7 | 6.0 | 337.28 |
| 8 | 8.0 | 402.88 |
| 9 | 12.0 | 545.85 |
| 10 | 16.0 | 674.56 |
| 11 | 24.0 | 916.77 |
| 12 | 32.0 | 1109.86 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.23 | | 538.2 | |
| | 0.23 | -------- | 0.3071 |
| 1.38 | | 1015.2 | |
| | 1.61 | -------- | -0.9202 |
| 0.89 | | 42.2 | |
| | 2.50 | -------- | 0.9565 |
| | | 1896.9 | |
| | | ******** | |

R.M.S. Relative error = 0.0218
Maximum rel. error = 0.0358 at sample 5
Number of trials used 0

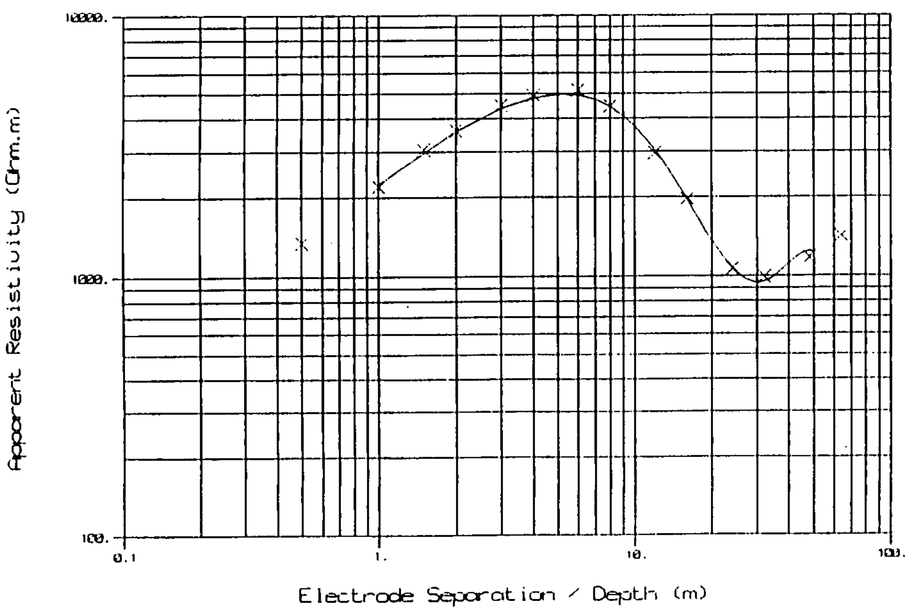
| **NJ 70 SE R2a** | **7855 0473** | **Leuchar Moss, Echt** | **Block C** |
|---|---|---|---|

Azimuth 115°
March 1987

| | |
|---|---|
| Overburden | 0.4m |
| Mineral I | 5.4m |
| Waste | 3.8m |
| Bedrock | - |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Peat, sandy, pebbly | 802 | 0.4 | 0.4 |
| Fluvioglacial sand and gravel | Gravel | 8101 | 5.4 | 5.8 |
| Glaciolacustrine deposits | Silt | 164 | 3.0 | 8.8 |
| Till | Clay, sandy | 44 | 0.8 | 9.6 |
| Caledonian | Granite | 2912 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 688.0000 | 663.0000 | 425.0000 | 431.0000 | 24.5000 |
| 1.0 | 539.0000 | 509.0000 | 343.0000 | 359.0000 | 29.2000 |
| 2.0 | 428.0000 | 402.0000 | 275.0000 | 300.0000 | 25.5000 |
| 4.0 | 258.0000 | 237.0000 | 181.3000 | 210.0000 | 21.0000 |
| 8.0 | 104.3000 | 98.1000 | 87.5000 | 90.3000 | 5.8900 |
| 16.0 | 22.3000 | 21.6000 | 17.9900 | 21.3000 | 0.6800 |
| 32.0 | 7.3600 | 7.0100 | 4.6700 | 5.2000 | 0.3380 |
| 64.0 | 5.0300 | 4.5700 | 3.6400 | 3.4200 | 0.4580 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 1344.60 | 0.0007 | 0.0140 | 0.1702 |
| 1.0 | 2205.40 | 0.0015 | 0.0456 | 0.0509 |
| 1.5 | 3053.28 | | | |
| 2.0 | 3612.83 | -0.0012 | 0.0870 | 0.0840 |
| 3.0 | 4501.99 | | | |
| 4.0 | 4917.22 | 0.0000 | 0.1467 | -0.0349 |
| 6.0 | 5156.88 | | | |
| 8.0 | 4468.60 | 0.0030 | 0.0315 | -0.0243 |
| 12.0 | 2953.44 | | | |
| 16.0 | 1974.93 | -0.0036 | 0.1635 | -0.1117 |
| 24.0 | 1066.13 | | | |
| 32.0 | 992.24 | 0.0016 | 0.1074 | 0.0834 |
| 48.0 | 1173.80 | | | |
| 64.0 | 1419.50 | 0.0004 | -0.0623 | 0.0000 |
| 96.0 | 1764.76 | | | |
| 128.0 | 1674.30 | | | |

R.M.S. Observational Error = .0019
R.M.S. Offset Wenner Difference = .0976
R.M.S. Potential Ladder Difference = .0933

FIELD CURVE DATA / INTERPRETED MODEL

| | Electrode Separation | Apparent Resistivity | Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|---|---|---|
| 1 | 0.5 | 1344.60 | 0.38 | | 801.8 | |
| 2 | 1.0 | 2205.40 | | | | |
| 3 | 1.5 | 3053.28 | | 0.38 | -------- | 0.8199 |
| 4 | 2.0 | 3612.83 | | | | |
| 5 | 3.0 | 4501.99 | 5.44 | | 8100.8 | |
| 6 | 4.0 | 4917.22 | | | | |
| 7 | 6.0 | 5156.88 | | 5.82 | -------- | -0.9602 |
| 8 | 8.0 | 4468.60 | | | | |
| 9 | 12.0 | 2953.44 | 2.93 | | 164.4 | |
| 10 | 16.0 | 1974.93 | | | | |
| 11 | 24.0 | 1066.13 | | 8.75 | -------- | -0.5800 |
| 12 | 32.0 | 992.24 | | | | |
| 13 | 48.0 | 1173.80 | 0.80 | | 43.7 | |
| 14 | 64.0 | 1419.50 | | | | |
| | | | | 9.55 | -------- | 0.9704 |
| | | | | | 2912.3 | |
| | | | | | ******** | |

R.M.S. Relative error = 0.0233
Maximum rel. error = 0.0449 at sample 2
Number of trials used 0

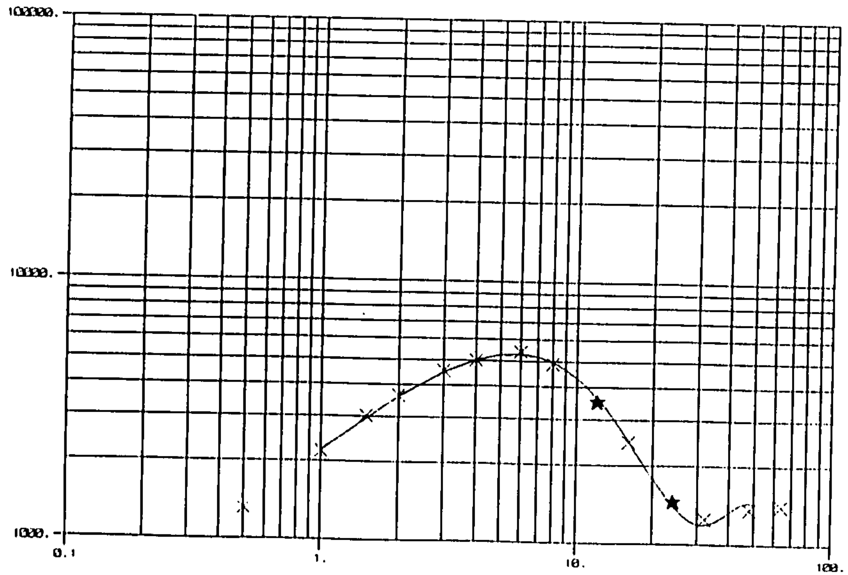
**NJ 70 SE R2b** **7855 0473** **Leuchar Moss, Echt** **Block C**

**Azimuth 176°**
**March 1987**

| | |
|---|---|
| **Overburden** | **0.4m** |
| **Mineral I** | **5.7m** |
| **Waste** | **3.5m** |
| **Bedrock** | **-** |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Peat, sandy | 785 | 0.4 | 0.4 |
| Pluvioglacial sand and gravel | Gravel | 8827 | 5.7 | 6.1 |
| Glaciolacustrine deposits | Silt, sandy | 203 | 2.7 | 8.8 |
| Till | Clay, sandy | 53 | 0.8 | 9.6 |
| Caledonian | Granite | 2819 | - | - |




Apparent Resistivity (Ohm.m)

Electrode Separation / Depth (m)

INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 656.0000 | 620.0000 | 418.0000 | 416.0000 | 27.3100 |
| 1.0 | 536.0000 | 508.0000 | 340.6000 | 358.0000 | 23.0100 |
| 2.0 | 429.0000 | 403.0000 | 285.0000 | 292.0000 | 25.4000 |
| 4.0 | 262.0000 | 241.0000 | 196.3000 | 202.0000 | 21.7000 |
| 8.0 | 122.2000 | 116.0000 | 89.4000 | 105.1000 | 5.3100 |
| 16.0 | 30.7000 | 29.9000 | 18.3400 | 30.7000 | 0.7140 |
| 32.0 | 9.1200 | 8.7500 | 4.9500 | 7.4700 | 0.3730 |
| 64.0 | 4.7400 | 4.2700 | 3.1600 | 3.3100 | 0.4640 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 1310.04 | -0.0005 | -0.0048 | 0.1070 |
| 1.0 | 2192.83 | 0.0000 | 0.0516 | 0.0511 |
| 1.5 | 3010.80 | | | |
| 2.0 | 3625.40 | -0.0009 | 0.0243 | 0.0740 |
| 3.0 | 4565.60 | | | |
| 4.0 | 5005.19 | -0.0027 | 0.0286 | -0.0730 |
| 6.0 | 5409.20 | | | |
| 8.0 | 4888.32 | 0.0024 | 0.1614 | 0.2018 |
| 12.0 | 3357.90 | | | |
| 16.0 | 2466.02 | 0.0038 | 0.5041 | 0.3731 |
| 24.0 | 1623.13 | | | |
| 32.0 | 1248.59 | -0.0003 | 0.4058 | 0.2234 |
| 48.0 | 1358.81 | | | |
| 64.0 | 1401.40 | 0.0013 | 0.1895 | 0.0000 |
| 96.0 | 1581.29 | | | |
| 128.0 | 1267.02 | | | |

R.M.S. Observational Error = .0017
R.M.S. Offset Wenner Difference = .2459
R.M.S. Potential Ladder Difference = .2081

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 1310.04 |
| 2 | 1.0 | 2192.83 |
| 3 | 1.5 | 3010.80 |
| 4 | 2.0 | 3625.40 |
| 5 | 3.0 | 4565.60 |
| 6 | 4.0 | 5205.19 |
| 7 | 6.0 | 5409.20 |
| 8 | 8.0 | 4883.32 |
| 9 | 12.0 | 3500.00 |
| 10 | 16.0 | 2465.02 |
| 11 | 24.0 | 1450.00 |
| 12 | 32.0 | 1248.59 |
| 13 | 48.0 | 1358.81 |
| 14 | 64.0 | 1401.40 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.39 | | 784.9 | |
| | 0.39 | -------- | 0.8367 |
| 5.74 | | 8826.7 | |
| | 6.13 | -------- | -0.9550 |
| 2.71 | | 203.3 | |
| | 8.84 | -------- | -0.5880 |
| 0.74 | | 52.6 | |
| | 9.58 | -------- | 0.9634 |
| | | 2819.2 | |
| | | ******** | |

R.M.S. Relative error = 0.0209
Maximum rel. error = 0.0402 at sample 13
Number of trials used 0

# INVERURIE RESOURCE SHEET

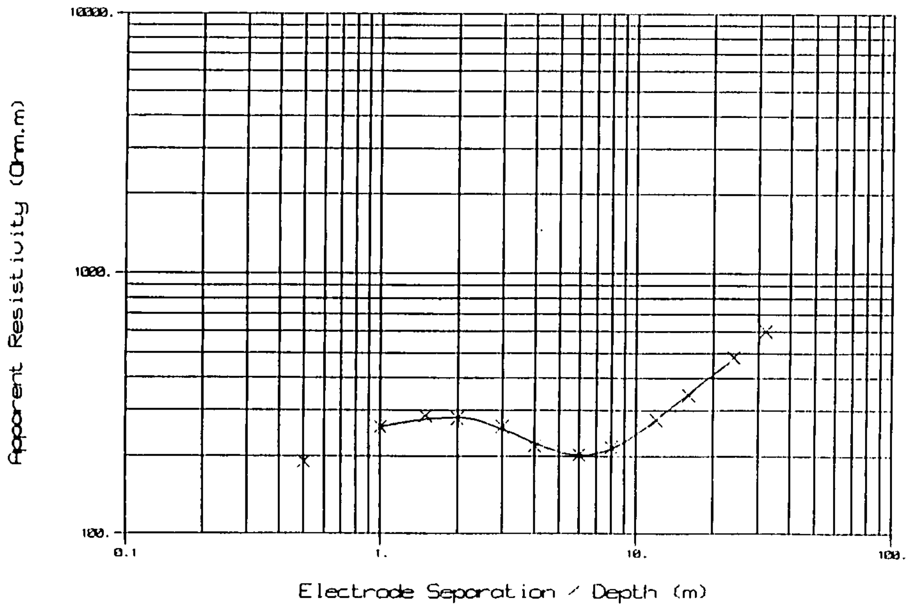
NJ 72 NW R1     7406 2532     Legatesden House, Garioch

Azimuth 034°
March 1987

| | |
|---|---|
| Overburden | 0.2m |
| Mineral I | 1.3m |
| Waste | 3.9m |
| Bedrock | - |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, clayey | 88 | 0.2 | 0.2 |
| Alluvium | Sand, gravelly | 415 | 1.3 | 1.5 |
| | Silt | 159 | 2.7 | 4.2 |
| Till | Clay, silty | 39 | 1.2 | 5.4 |
| Dalradian | Metamorphic rock | 1498 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 90.9000 | 85.1000 | 61.3000 | 60.1000 | 4.7300 |
| 1.0 | 58.4000 | 55.1000 | 41.4000 | 40.5000 | 3.2500 |
| 2.0 | 29.2000 | 27.5000 | 21.7000 | 22.7000 | 1.6360 |
| 4.0 | 11.2400 | 10.7100 | 8.7800 | 8.6100 | 0.5290 |
| 8.0 | 6.5400 | 6.2300 | 4.5000 | 4.1300 | 0.3150 |
| 16.0 | 5.2400 | 4.9400 | 3.5000 | 3.3600 | 0.3040 |
| 32.0 | 4.5400 | 4.2800 | 3.0000 | 2.9400 | 0.2870 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 190.69 | -0.0003 | -0.0158 | 0.1169 |
| 1.0 | 258.55 | 0.0002 | -0.0122 | 0.1286 |
| 1.5 | 284.97 | | | |
| 2.0 | 278.97 | 0.0032 | 0.0450 | 0.1130 |
| 3.0 | 200.03 | | | |
| 4.0 | 218.53 | 0.0001 | -0.0156 | -0.0324 |
| 6.0 | 203.34 | | | |
| 8.0 | 216.64 | -0.0038 | -0.0332 | 0.0524 |
| 12.0 | 274.89 | | | |
| 16.0 | 342.81 | -0.0008 | -0.0523 | 0.0024 |
| 24.0 | 481.64 | | | |
| 32.0 | 603.19 | -0.0015 | -0.0460 | 0.0000 |
| 48.0 | 826.25 | | | |
| 64.0 | 1010.71 | | | |

R.M.S. Observational Error = .0011
R.M.S. Offset Wenner Difference = .0465
R.M.S. Potential Ladder Difference = .0604

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 190.69 |
| 2 | 1.0 | 258.55 |
| 3 | 1.5 | 284.97 |
| 4 | 2.0 | 278.97 |
| 5 | 3.0 | 200.03 |
| 6 | 4.0 | 218.53 |
| 7 | 6.0 | 203.34 |
| 8 | 8.0 | 216.64 |
| 9 | 12.0 | 274.89 |
| 10 | 16.0 | 342.81 |
| 11 | 24.0 | 481.64 |
| 12 | 32.0 | 603.19 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.21 | | 87.8 | |
| | 0.21 | -------- | 0.6907 |
| 1.26 | | 414.9 | |
| | 1.47 | -------- | -0.4451 |
| 2.74 | | 159.3 | |
| | 4.21 | -------- | -0.6058 |
| 1.17 | | 39.1 | |
| | 5.38 | -------- | 0.9491 |
| | | 1498.4 | |
| | | ******** | |

R.M.S. Relative error = 0.0128
Maximum rel. error = 0.0192 at sample 7
Number of trials was 0

**NJ 72 NE R1** **7729 2634** **Muirton, Bourtie**

Azimuth 016°
March 1987

| | |
|---|---|
| Overburden | 0.5m |
| Mineral I | 2.0m |
| Waste | 1.6m |
| ?Mineral II | - |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, clayey | 127 | 0.5 | 0.5 |
| Alluvium | Sand, gravelly | 639 | 2.0 | 2.5 |
| Till | Clay, sandy | 49 | 1.6 | 4.1 |
| ?Caledonian | Sand, gravelly (?rotted basic igneous rock) | 514 | - | - |

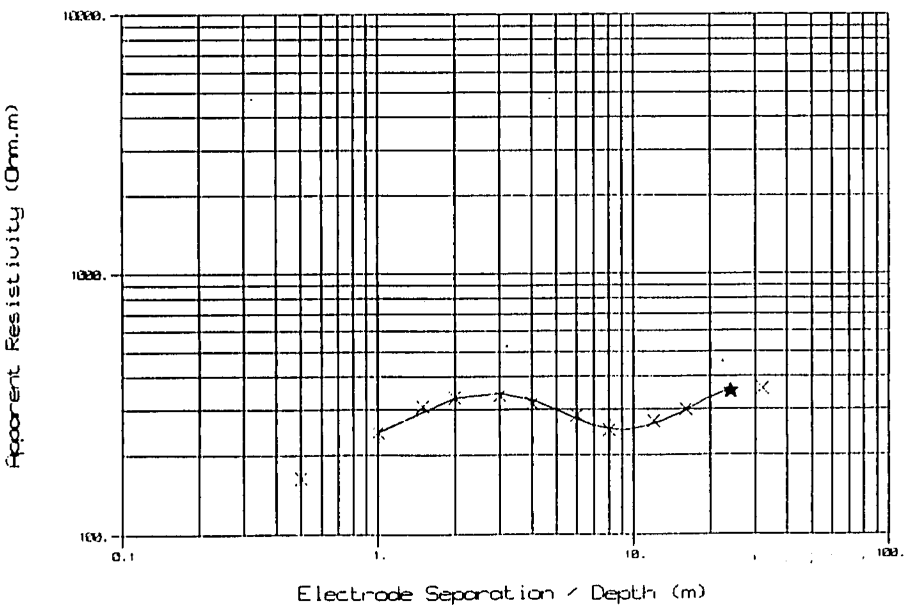
INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 80.3000 | 76.6000 | 59.9000 | 44.2000 | 3.6900 |
| 1.0 | 56.9000 | 53.4000 | 45.5000 | 32.3000 | 3.5200 |
| 2.0 | 37.4000 | 35.4000 | 28.5000 | 24.4000 | 1.9370 |
| 4.0 | 16.5400 | 15.7700 | 13.5200 | 11.5400 | 0.7710 |
| 8.0 | 7.0500 | 6.6200 | 4.2900 | 5.6500 | 0.3770 |
| 16.0 | 4.4300 | 4.2000 | 2.6300 | 3.3100 | 0.2240 |
| 32.0 | 2.3600 | 2.1900 | 1.3610 | 2.2100 | 0.1832 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 163.52 | 0.0001 | -0.3016 | 0.1312 |
| 1.0 | 244.42 | -0.0004 | -0.3393 | 0.0478 |
| 1.5 | 306.34 | | | |
| 2.0 | 332.38 | 0.0003 | -0.1550 | 0.2148 |
| 3.0 | 338.50 | | | |
| 4.0 | 314.91 | -0.0001 | -0.1580 | 0.1518 |
| 6.0 | 284.01 | | | |
| 8.0 | 249.82 | -0.0010 | 0.2736 | 0.0746 |
| 12.0 | 269.61 | | | |
| 16.0 | 298.58 | 0.0014 | 0.2230 | 0.1906 |
| 24.0 | 335.54 | | | |
| 32.0 | 359.00 | -0.0014 | 0.4755 | 0.0000 |
| 48.0 | 375.39 | | | |
| 64.0 | 316.09 | | | |

R.M.S. Observational Error = .0008
R.M.S. Offset Wenner Difference = .2948
R.M.S. Potential Ladder Difference = .1475




FIELD CURVE DATA / INTERPRETED MODEL

| | Electrode Separation | Apparent Resistivity | Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|---|---|---|
| 1 | 0.5 | 163.52 | 0.50 | | 127.2 | |
| 2 | 1.0 | 244.42 | | | | |
| 3 | 1.5 | 306.34 | | 0.50 | -------- | 0.6679 |
| 4 | 2.0 | 332.38 | | | | |
| 5 | 3.0 | 338.50 | 1.98 | | 638.9 | |
| 6 | 4.0 | 314.91 | | | | |
| 7 | 6.0 | 284.01 | | 2.48 | -------- | -0.8583 |
| 8 | 8.0 | 249.82 | | | | |
| 9 | 12.0 | 269.61 | 1.65 | | 48.7 | |
| 10 | 16.0 | 298.58 | | | | |
| 11 | 24.0 | 350.00 | | 4.13 | -------- | 0.8270 |
| 12 | 32.0 | 359.00 | | | | |
| | | | | | 514.4 | |
| | | | | | ******** | |

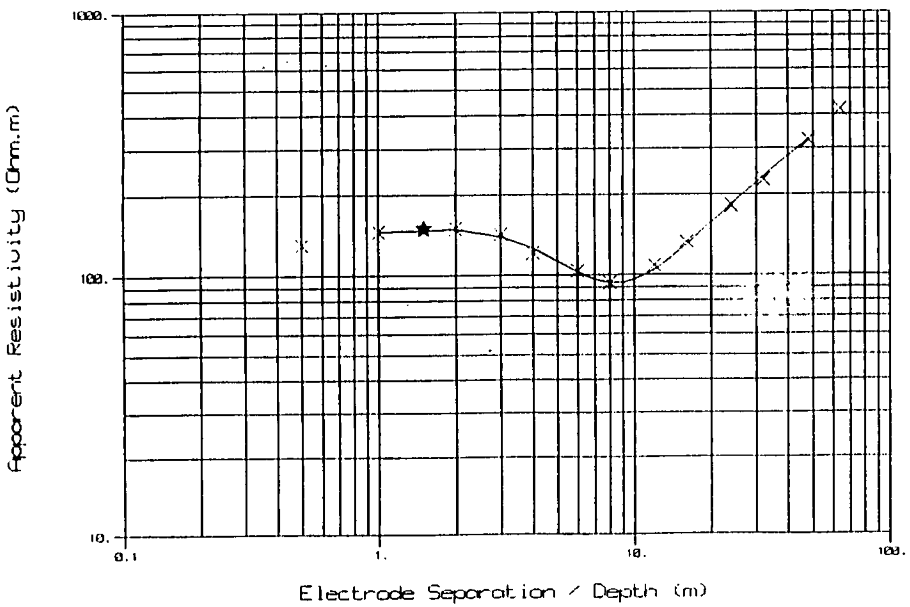
R.M.S. Relative error = 0.0147
Maximum rel. error = 0.0315 at sample 6
Number of trials was 0

NJ 72 SE 81a | 7567 2322 | Conglas, Inverurie

Azimuth 155° | Waste 6.4m
March 1987 | Bedrock -

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, silty | 95 | 0.2 | 0.2 |
| Alluvium | Silt | 159 | 3.7 | 3.9 |
| Till | Clay, firm | 20 | 2.7 | 6.6 |
| Dalradian | Metamorphic rock | 1209 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 58.9000 | 56.1000 | 38.6000 | 44.3000 | 2.8300 |
| 1.0 | 31.9000 | 30.2000 | 21.3000 | 25.2000 | 1.6950 |
| 2.0 | 15.4100 | 14.5600 | 13.2100 | 10.6200 | 0.8670 |
| 4.0 | 6.0500 | 5.7800 | 4.8300 | 4.8100 | 0.2770 |
| 8.0 | 2.6700 | 2.5300 | 1.9610 | 1.7510 | 0.1283 |
| 16.0 | 2.0400 | 1.9360 | 1.3290 | 1.3150 | 0.1073 |
| 32.0 | 1.7580 | 1.6640 | 1.1310 | 1.1350 | 0.0893 |
| 64.0 | 1.6320 | 1.5430 | 1.0270 | 1.0560 | 0.0921 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 130.22 | -0.0005 | 0.1375 | 0.1295 |
| 1.0 | 146.08 | 0.0014 | 0.1677 | 0.0851 |
| 1.5 | 154.65 | | | |
| 2.0 | 149.73 | -0.0011 | -0.2174 | 0.0477 |
| 3.0 | 142.79 | | | |
| 4.0 | 121.01 | 0.0005 | -0.0021 | 0.0207 |
| 6.0 | 103.52 | | | |
| 8.0 | 93.29 | 0.0044 | -0.1131 | 0.0140 |
| 12.0 | 108.61 | | | |
| 16.0 | 132.90 | 0.0033 | -0.0106 | 0.0359 |
| 24.0 | 181.92 | | | |
| 32.0 | 227.80 | 0.0015 | 0.0035 | 0.0130 |
| 48.0 | 322.45 | | | |
| 64.0 | 418.81 | -0.0019 | 0.0278 | 0.0000 |
| 96.0 | 617.32 | | | |
| 128.0 | 804.31 | | | |

R.M.S. Observational Error = .0022
R.M.S. Offset Wenner Difference = .1162
R.M.S. Potential Ladder Difference = .0637

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 130.22 |
| 2 | 1.0 | 146.08 |
| 3 | 1.5 | 150.00 |
| 4 | 2.0 | 149.73 |
| 5 | 3.0 | 142.79 |
| 6 | 4.0 | 121.01 |
| 7 | 6.0 | 103.52 |
| 8 | 8.0 | 93.29 |
| 9 | 12.0 | 108.61 |
| 10 | 16.0 | 132.90 |
| 11 | 24.0 | 181.92 |
| 12 | 32.0 | 227.80 |
| 13 | 48.0 | 322.45 |
| 14 | 64.0 | 418.81 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.20 | | 95.1 | |
| | 0.20 | -------- | 0.2506 |
| 3.72 | | 158.7 | |
| | 3.92 | -------- | -0.7772 |
| 2.69 | | 19.9 | |
| | 6.61 | -------- | 0.9676 |
| | | 1208.6 | |

********

R.M.S. Relative error = 0.0160
Maximum rel. error = 0.0311 at sample 12
Number of trials was 0

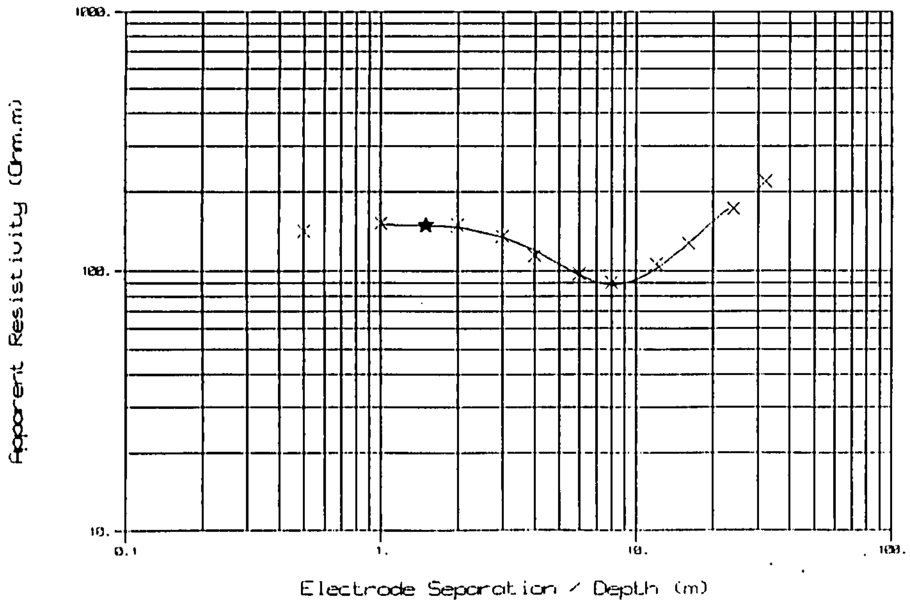
**NJ 72 SE R1b** **7567 2322** **Conglas, Inverurie**

Azimuth 077°
March 1987

Waste 6.4m
Bedrock -

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, silty | 123 | 0.2 | 0.2 |
| Alluvium | Silt | 157 | 3.5 | 3.7 |
| Till | Clay, firm | 20 | 2.7 | 6.4 |
| Dalradian | Metamorphic rock | 915 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 66.8000 | 63.9000 | 43.9000 | 46.6000 | 2.9300 |
| 1.0 | 33.8000 | 31.9000 | 24.0000 | 24.5000 | 1.8840 |
| 2.0 | 15.8500 | 14.9300 | 11.9300 | 11.8500 | 0.8610 |
| 4.0 | 5.7800 | 5.5100 | 4.8300 | 4.2800 | 0.2700 |
| 8.0 | 2.5400 | 2.4000 | 1.7510 | 1.2280 | 0.1375 |
| 16.0 | 1.9400 | 1.8390 | 1.3170 | 1.2260 | 0.1056 |
| 32.0 | 1.6890 | 1.6050 | 1.0950 | 1.0930 | 0.0912 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 142.16 | -0.0004 | 0.0597 | 0.2685 |
| 1.0 | 152.37 | 0.0005 | 0.0206 | 0.1430 |
| 1.5 | 160.55 | | | |
| 2.0 | 149.67 | 0.0006 | -0.0084 | 0.1749 |
| 3.0 | 135.89 | | | |
| 4.0 | 114.48 | 0.0000 | -0.1207 | 0.0337 |
| 6.0 | 97.30 | | | |
| 8.0 | 89.95 | 0.0010 | 0.0430 | -0.0189 |
| 12.0 | 105.41 | | | |
| 16.0 | 127.83 | -0.0019 | -0.0716 | 0.0163 |
| 24.0 | 173.52 | | | |
| 32.0 | 219.96 | -0.0043 | -0.0018 | 0.0000 |
| 48.0 | 313.68 | | | |
| 64.0 | 408.23 | | | |

R.M.S. Observational Error = .0018
R.M.S. Offset Wenner Difference = .0605
R.M.S. Potential Ladder Difference = .1443

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 142.16 |
| 2 | 1.0 | 152.37 |
| 3 | 1.5 | 150.00 |
| 4 | 2.0 | 149.67 |
| 5 | 3.0 | 135.89 |
| 6 | 4.0 | 114.48 |
| 7 | 6.0 | 97.30 |
| 8 | 8.0 | 89.95 |
| 9 | 12.0 | 105.41 |
| 10 | 16.0 | 127.83 |
| 11 | 24.0 | 173.52 |
| 12 | 32.0 | 219.96 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.19 | | 123.2 | |
| | 0.19 | -------- | 0.1191 |
| 3.52 | | 156.5 | |
| | 3.71 | -------- | -0.7724 |
| 2.69 | | 20.1 | |
| | 6.40 | -------- | 0.9570 |
| | | 915.1 | |
| | | ........ | |

R.M.S. Relative error = 0.0197
Maximum rel. error = 0.0321 at sample 11
Number of trials was 0

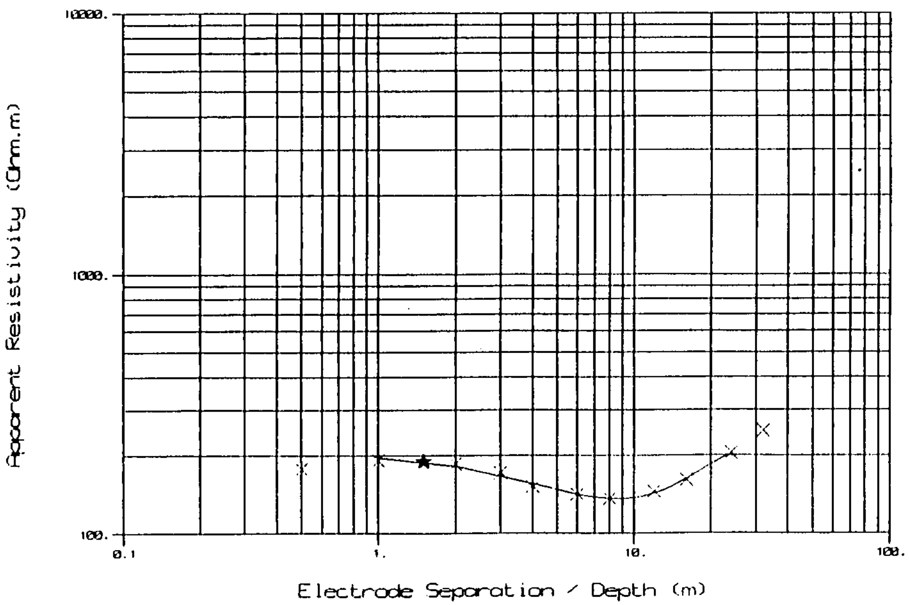
**NJ 72 SE 82** **7792 2140** **North of Holm, Cottage, Inverurie**

Azimuth 085°
March 1987

Overburden 8.0m
Mineral I -

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, clayey | 122 | 0.2 | 0.2 |
| Alluvium | Sand, silty | 240 | 0.7 | 0.9 |
| | Silt | 152 | 5.0 | 5.9 |
| Till | Clay, silty | 34 | 2.1 | 8.0 |
| ?Glacial sand and gravel | Sand, gravelly | 412 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 83.5000 | 79.8000 | 51.8000 | 60.8000 | 3.6400 |
| 1.0 | 41.9000 | 39.5000 | 30.7000 | 30.3000 | 2.3400 |
| 2.0 | 19.5400 | 18.4800 | 14.4300 | 15.0300 | 1.0480 |
| 4.0 | 7.8100 | 7.3700 | 5.9400 | 6.0800 | 0.4260 |
| 8.0 | 3.7800 | 3.5700 | 2.7200 | 2.6900 | 0.1973 |
| 16.0 | 2.3400 | 2.2100 | 1.6000 | 1.6040 | 0.1326 |
| 32.0 | 1.8650 | 1.7560 | 1.2430 | 1.2230 | 0.1099 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 176.87 | 0.0007 | 0.1599 | 0.2714 |
| 1.0 | 191.64 | 0.0014 | -0.0131 | 0.1129 |
| 1.5 | 200.89 | | | |
| 2.0 | 185.10 | 0.0006 | 0.0407 | 0.1249 |
| 3.0 | 171.09 | | | |
| 4.0 | 151.05 | 0.0018 | 0.0233 | 0.0052 |
| 6.0 | 140.83 | | | |
| 8.0 | 135.97 | 0.0034 | -0.0111 | 0.0437 |
| 12.0 | 145.12 | | | |
| 16.0 | 161.05 | -0.0011 | 0.0025 | -0.0065 |
| 24.0 | 204.05 | | | |
| 32.0 | 248.21 | -0.0005 | -0.0138 | 0.0000 |
| 48.0 | 336.48 | | | |
| 64.0 | 419.07 | | | |

R.M.S. Observational Error = .0016
R.M.S. Offset Wenner Difference = .0635
R.M.S. Potential Ladder Difference = .1317

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 176.87 |
| 2 | 1.0 | 191.64 |
| 3 | 1.5 | 190.00 |
| 4 | 2.0 | 185.10 |
| 5 | 3.0 | 171.09 |
| 6 | 4.0 | 151.05 |
| 7 | 6.0 | 140.83 |
| 8 | 8.0 | 135.97 |
| 9 | 12.0 | 145.12 |
| 10 | 16.0 | 161.05 |
| 11 | 24.0 | 204.05 |
| 12 | 32.0 | 248.21 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.22 | | 122.3 | |
| | 0.22 | -------- | 0.3252 |
| 0.74 | | 240.2 | |
| | 0.96 | -------- | -0.2243 |
| 4.95 | | 152.2 | |
| | 5.91 | -------- | -0.6348 |
| 2.10 | | 34.0 | |
| | 8.01 | -------- | 0.8474 |
| | | 411.5 | |
| | | ******** | |

R.M.S. Relative error = 0.0157
Maximum rel. error = -0.0327 at sample 5
Number of trials was 0

## BANCHORY/STONEHAVEN RESOURCE SHEET

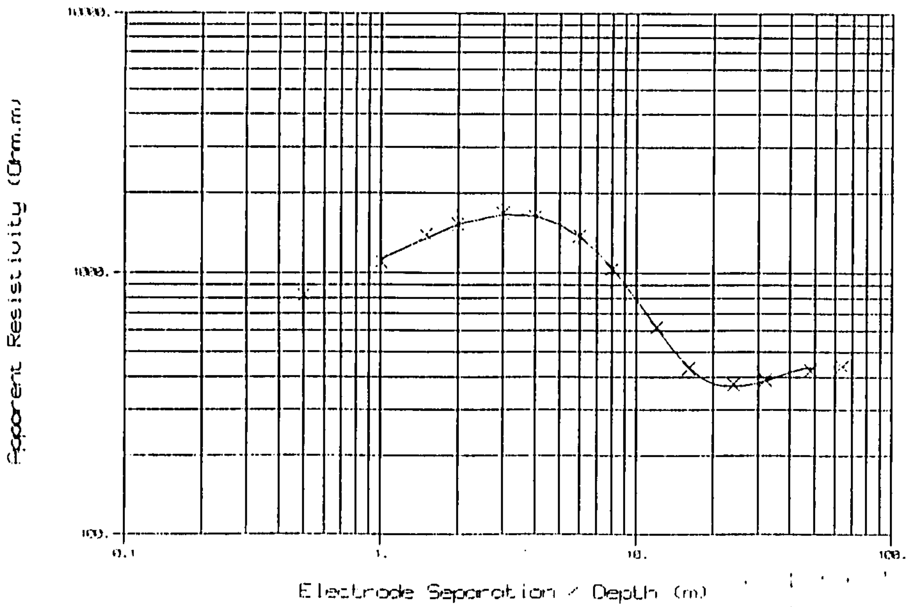
**NO 79 NW R1a** | **7410 9585** | **Balbridie, Durris** | **Block B**

Azimuth 116°
March 1987

| | |
|---|---|
| Overburden | 0.3m |
| Mineral I | 8.2m |
| Waste | 1.4m |
| Bedrock | - |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, sandy | 566 | 0.3 | 0.3 |
| Fluvioglacial sand and gravel (Terrace) | Sand, gravelly | 1135 | 0.5 | 0.8 |
| | Gravel, sandy | 2662 | 2.7 | 3.5 |
| | Sand, gravelly | 563 | 5.0 | 8.5 |
| Till | Clay, sandy | 45 | 1.4 | 9.9 |
| ?Dalradian | ?Metamorphic rock | 497 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 401.0000 | 385.0000 | 258.0000 | 266.0000 | 16.1900 |
| 1.0 | 256.0000 | 241.0000 | 183.2000 | 167.4000 | 15.9300 |
| 2.0 | 163.2000 | 156.8000 | 122.0000 | 120.9000 | 11.4400 |
| 4.0 | 79.9000 | 74.7000 | 65.8000 | 64.3000 | 5.1700 |
| 8.0 | 23.1000 | 22.2000 | 21.6000 | 19.5300 | 0.9380 |
| 16.0 | 5.3400 | 5.0300 | 4.1500 | 4.4500 | 0.3090 |
| 32.0 | 2.5900 | 2.3900 | 2.0800 | 1.8690 | 0.1994 |
| 64.0 | 1.4720 | 1.3910 | 1.1870 | 0.9930 | 0.0310 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 823.10 | -0.0005 | 0.0305 | 0.2011 |
| 1.0 | 1101.44 | -0.0080 | -0.0301 | 0.0390 |
| 1.5 | 1391.79 | | | |
| 2.0 | 1525.19 | -0.0002 | -0.0091 | 0.0431 |
| 3.0 | 1681.45 | | | |
| 4.0 | 1634.88 | 0.0004 | -0.0231 | -0.0301 |
| 6.0 | 1377.52 | | | |
| 8.0 | 1033.71 | -0.0016 | -0.1007 | -0.1240 |
| 12.0 | 618.17 | | | |
| 16.0 | 432.23 | 0.0002 | 0.0538 | -0.1243 |
| 24.0 | 376.09 | | | |
| 32.0 | 390.96 | 0.0002 | -0.0777 | -0.0322 |
| 48.0 | 424.99 | | | |
| 64.0 | 439.52 | 0.0000 | -0.1730 | 0.0000 |
| 96.0 | 437.96 | | | |
| 128.0 | 479.33 | | | |

R.M.S. Observational Error = .0009
R.M.S. Offset Wenner Difference = .0868
R.M.S. Potential Ladder Difference = .1096

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 823.10 |
| 2 | 1.0 | 1101.44 |
| 3 | 1.5 | 1391.79 |
| 4 | 2.0 | 1525.19 |
| 5 | 3.0 | 1681.45 |
| 6 | 4.0 | 1634.83 |
| 7 | 6.0 | 1377.52 |
| 8 | 8.0 | 1033.71 |
| 9 | 12.0 | 618.17 |
| 10 | 16.0 | 432.28 |
| 11 | 24.0 | 376.09 |
| 12 | 32.0 | 390.96 |
| 13 | 48.0 | 424.99 |
| 14 | 64.0 | 439.52 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.30 | | 566.3 | |
| | 0.30 | -------- | 0.3341 |
| 0.47 | | 1134.6 | |
| | 0.77 | -------- | 0.4082 |
| 2.72 | | 2661.5 | |
| | 3.49 | -------- | -0.6507 |
| 4.99 | | 563.1 | |
| | 8.48 | -------- | -0.8532 |
| 1.46 | | 44.6 | |
| | 9.94 | -------- | 0.8352 |
| | | 496.6 | |
| | | ******** | |

R.M.S. Relative error = 0.0191
Maximum rel. error = 0.0428 at sample 2
Number of trials was 0

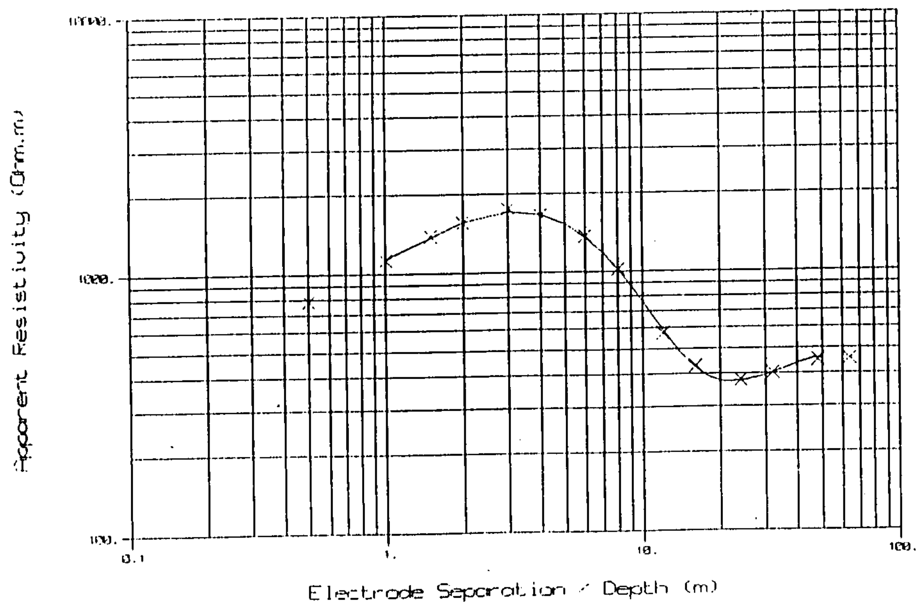
| NO 79 NW R1b | 7410 9585 | Balbridie, Durris | Block B |
|---|---|---|---|

Azimuth 078°
March 1987

| | |
|---|---|
| Overburden | 0.3m |
| Mineral I | 7.4m |
| Waste | 1.6m |
| Bedrock | - |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, sandy | 533 | 0.3 | 0.3 |
| Fluvioglacial sand and gravel (Terrace) | Sand, gravelly | 1129 | 0.4 | 0.7 |
| | Gravel, sandy | 2855 | 2.5 | 3.2 |
| | Sand, gravelly | 605 | 4.5 | 7.7 |
| Till | Clay, sandy | 47 | 1.6 | 9.3 |
| ?Dalradian | ?Metamorphic rock | 535 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 373.0000 | 355.0000 | 262.0000 | 238.0000 | 17.6000 |
| 1.0 | 270.0000 | 256.0000 | 190.9000 | 167.0000 | 13.6900 |
| 2.0 | 170.6000 | 158.4000 | 131.5000 | 116.0000 | 12.1300 |
| 4.0 | 79.3000 | 73.8000 | 70.0000 | 61.3000 | 5.5400 |
| 8.0 | 23.1000 | 22.2000 | 23.9000 | 16.5900 | 0.9050 |
| 16.0 | 5.5800 | 5.3100 | 4.4000 | 4.1600 | 0.2730 |
| 32.0 | 2.7400 | 2.5500 | 2.0300 | 1.9810 | 0.1933 |
| 64.0 | 1.5030 | 1.4120 | 1.0980 | 1.1610 | 0.0903 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 785.40 | 0.0011 | -0.0930 | 0.0878 |
| 1.0 | 1124.38 | 0.0011 | -0.1336 | 0.1233 |
| 1.5 | 1389.57 | | | |
| 2.0 | 1555.09 | 0.0001 | -0.1253 | 0.0279 |
| 3.0 | 1756.46 | | | |
| 4.0 | 1649.96 | -0.0005 | -0.1325 | -0.0384 |
| 6.0 | 1368.68 | | | |
| 8.0 | 1017.62 | -0.0003 | -0.3511 | -0.0439 |
| 12.0 | 575.27 | | | |
| 16.0 | 430.27 | -0.0005 | -0.0561 | 0.0129 |
| 24.0 | 378.47 | | | |
| 32.0 | 403.23 | -0.0012 | -0.0244 | -0.0193 |
| 48.0 | 448.70 | | | |
| 64.0 | 454.20 | 0.0005 | 0.0558 | 0.0000 |
| 96.0 | 449.20 | | | |
| 128.0 | 454.93 | | | |

R.M.S. Observational Error = .0003
R.M.S. Offset Wenner Difference = .1571
R.M.S. Potential Ladder Difference = .0717

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 785.40 |
| 2 | 1.0 | 1124.38 |
| 3 | 1.5 | 1389.57 |
| 4 | 2.0 | 1555.09 |
| 5 | 3.0 | 1756.46 |
| 6 | 4.0 | 1649.96 |
| 7 | 6.0 | 1368.68 |
| 8 | 8.0 | 1017.62 |
| 9 | 12.0 | 575.27 |
| 10 | 16.0 | 430.27 |
| 11 | 24.0 | 378.47 |
| 12 | 32.0 | 403.23 |
| 13 | 48.0 | 448.70 |
| 14 | 64.0 | 454.20 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.29 | | 533.3 | |
| | 0.29 | -------- | 0.3594 |
| 0.42 | | 1129.2 | |
| | 0.71 | -------- | 0.4332 |
| 2.47 | | 2855.2 | |
| | 3.18 | -------- | -0.6504 |
| 4.56 | | 604.8 | |
| | 7.74 | -------- | -0.8566 |
| 1.60 | | 46.7 | |
| | 9.34 | -------- | 0.8394 |
| | | 534.8 | |
| | | ******** | |

R.M.S. Relative error = 0.0124
Maximum rel. error = 0.0278 at sample 9
Number of trials was 0

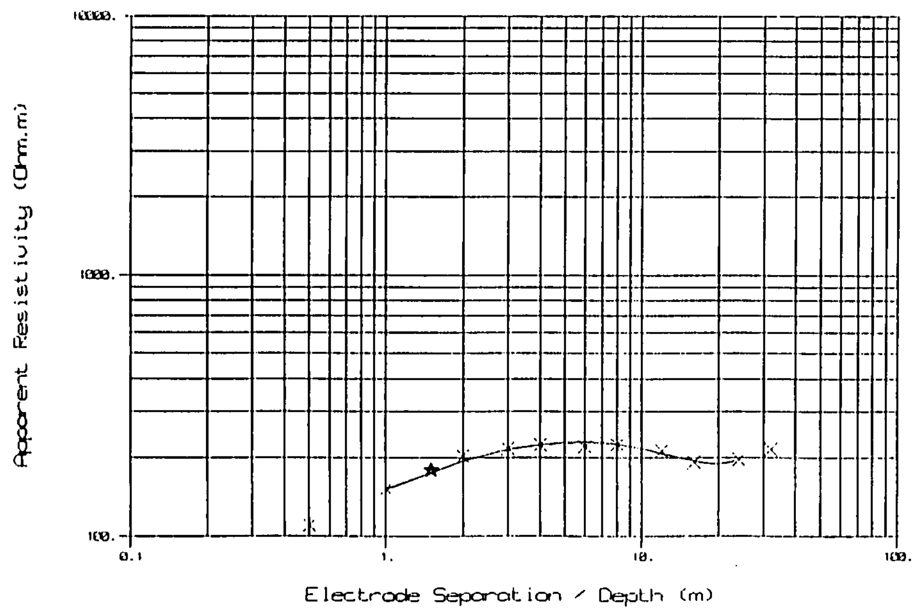
NO 79 NW R2 | 7071 9657 | **Woodside of Arbeadie, Banchory**

Azimuth 098°
March 1987

Waste Bedrock 12.8m
-

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, clayey | 78 | 0.3 | 0.3 |
| Till | Clay, sandy, pebbly | 151 | 0.3 | 0.6 |
| | Clay, gravelly | 250 | 10.0 | 10.6 |
| | Clay, firm | 24 | 2.2 | 12.8 |
| Dalradian | ?Psammite, with calc-silicates | 455 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 56.5000 | 54.6000 | 32.4000 | 33.0000 | 1.8850 |
| 1.0 | 34.8000 | 32.2000 | 24.0000 | 24.4000 | 2.6100 |
| 2.0 | 22.4000 | 20.8000 | 14.9800 | 17.2300 | 1.5770 |
| 4.0 | 12.4100 | 11.6700 | 8.2500 | 9.5500 | 0.7320 |
| 8.0 | 5.9400 | 5.5800 | 4.1100 | 4.8100 | 0.3570 |
| 16.0 | 2.4500 | 2.2800 | 1.8330 | 2.0000 | 0.1678 |
| 32.0 | 1.5660 | 1.4890 | 1.0230 | 1.1180 | 0.0830 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 110.58 | 0.0003 | 0.1591 | 0.3020 |
| 1.0 | 152.05 | -0.0003 | 0.0165 | -0.0035 |
| 1.5 | 196.76 | | | |
| 2.0 | 202.33 | 0.0010 | 0.1397 | 0.0287 |
| 3.0 | 216.22 | | | |
| 4.0 | 223.68 | 0.0006 | 0.1461 | 0.1219 |
| 6.0 | 219.95 | | | |
| 8.0 | 224.13 | 0.0005 | 0.1570 | 0.0844 |
| 12.0 | 212.20 | | | |
| 16.0 | 192.92 | 0.0009 | 0.0844 | -0.1618 |
| 24.0 | 196.87 | | | |
| 32.0 | 215.24 | -0.0032 | 0.0837 | 0.0000 |
| 48.0 | 260.99 | | | |
| 64.0 | 333.87 | | | |

R.M.S. Observational Error = .0014
R.M.S. Offset Wenner Difference = .1231
R.M.S. Potential Ladder Difference = .1529

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 110.58 |
| 2 | 1.0 | 152.05 |
| 3 | 1.5 | 180.00 |
| 4 | 2.0 | 202.38 |
| 5 | 3.0 | 216.22 |
| 6 | 4.0 | 223.68 |
| 7 | 6.0 | 219.95 |
| 8 | 8.0 | 224.18 |
| 9 | 12.0 | 212.20 |
| 10 | 16.0 | 192.92 |
| 11 | 24.0 | 196.87 |
| 12 | 32.0 | 215.24 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.27 | | 77.8 | |
| | 0.27 | -------- | 0.3184 |
| 0.34 | | 150.5 | |
| | 0.61 | -------- | 0.2490 |
| 9.98 | | 250.3 | |
| | 10.59 | -------- | -0.8250 |
| 2.19 | | 24.0 | |
| | 12.78 | -------- | 0.8998 |
| | | 455.0 | |
| | | ******** | |

R.M.S. Relative error = 0.0172
Maximum rel. error = -0.0291 at sample 5
Number of trials was 0

**NO 79 NE R1a** **7598 9878** **Loch of Park, Drumoak** **Block A**

Azimuth 155°
March 1987

| | |
|---|---|
| Overburden | 0.2m |
| Mineral I | 2.8m |
| Waste | 2.5m |
| Bedrock | - |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, sandy, peebly | 674 | 0.2 | 0.2 |
| Lacustrine alluvium | Sand, gravelly | 3008 | 0.5 | 0.7 |
| | Sand, pebbly | 402 | 2.3 | 3.0 |
| Till | Clay, silty | 34 | 2.5 | 5.5 |
| Caledonian | Granite | 1352 | - | - |

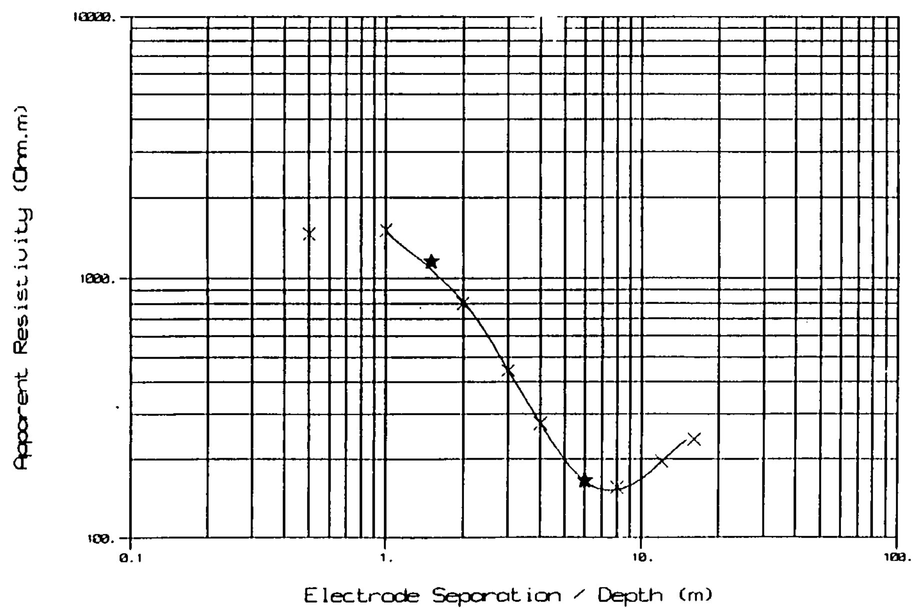
INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 666.0000 | 633.0000 | 487.0000 | 443.0000 | 31.5000 |
| 1.0 | 295.0000 | 279.0000 | 240.0000 | 241.0000 | 16.3500 |
| 2.0 | 71.8000 | 69.2000 | 71.3000 | 55.8000 | 2.5800 |
| 4.0 | 13.9000 | 13.5300 | 10.5100 | 11.3600 | 0.3410 |
| 8.0 | 4.5200 | 4.3100 | 2.9000 | 3.2800 | 0.2190 |
| 16.0 | 3.7200 | 3.5400 | 2.0900 | 2.6600 | 0.1683 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 1460.84 | 0.0023 | -0.0946 | 0.2015 |
| 1.0 | 1511.11 | -0.0012 | 0.0042 | 0.1032 |
| 1.5 | 1289.59 | | | |
| 2.0 | 798.59 | 0.0003 | -0.2439 | 0.0176 |
| 3.0 | 442.64 | | | |
| 4.0 | 274.83 | 0.0021 | 0.0777 | 0.3444 |
| 6.0 | 179.96 | | | |
| 8.0 | 155.32 | -0.0000 | 0.1230 | 0.0119 |
| 12.0 | 196.78 | | | |
| 16.0 | 238.76 | 0.0032 | 0.2400 | 0.0000 |
| 24.0 | 348.02 | | | |
| 32.0 | 470.72 | | | |

R.M.S. Observational Error = .0000
R.M.S. Offset Wenner Difference = .1566
R.M.S. Potential Ladder Difference = .1846




FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 1460.84 |
| 2 | 1.0 | 1511.11 |
| 3 | 1.5 | 1150.00 |
| 4 | 2.0 | 798.59 |
| 5 | 3.0 | 442.64 |
| 6 | 4.0 | 274.83 |
| 7 | 6.0 | 165.00 |
| 8 | 8.0 | 155.32 |
| 9 | 12.0 | 196.78 |
| 10 | 16.0 | 238.76 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.16 | | 673.7 | |
| | 0.16 | -------- | 0.6340 |
| 0.51 | | 3008.2 | |
| | 0.67 | -------- | -0.7644 |
| 2.35 | | 401.7 | |
| | 3.02 | -------- | -0.8427 |
| 2.45 | | 34.3 | |
| | 5.47 | -------- | 0.9506 |
| | | 1352.0 | |
| | | ******** | |

R.M.S. Relative error = 0.0169
Maximum rel. error = -0.0281 at sample 3
Number of trials was 0

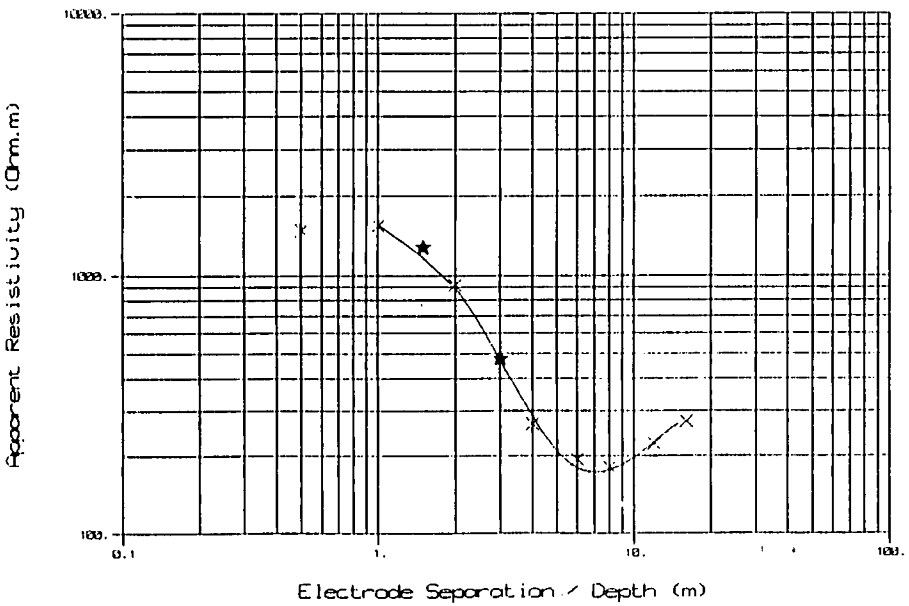
**NO 79 NE 81b** **7598 9878** **Loch of Park, Drumoak** **Block A**

**Azimuth 023°**
**March 1987**

| | |
|---|---|
| **Overburden** | **0.2m** |
| **Mineral I** | **2.9m** |
| **Waste** | **2.2m** |
| **Bedrock** | **-** |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, sandy, pebbly | 653 | 0.2 | 0.2 |
| Lacustrine alluvium | Gravel, sandy | 3326 | 0.5 | 0.7 |
| | Sand, silty, pebbly | 338 | 2.4 | 3.1 |
| Till | Clay, silty, sandy | 42 | 2.2 | 5.3 |
| Caledonian | Granite | 889 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 651.0000 | 623.0000 | 457.0000 | 488.0000 | 27.4000 |
| 1.0 | 321.0000 | 313.0000 | 249.0000 | 242.0000 | 8.4400 |
| 2.0 | 87.0000 | 84.6000 | 75.8000 | 69.6000 | 2.4700 |
| 4.0 | 13.2100 | 12.6800 | 12.5000 | 8.6800 | 0.5060 |
| 8.0 | 5.1800 | 4.8700 | 4.0200 | 3.1800 | 0.3170 |
| 16.0 | 4.0500 | 3.8500 | 3.0100 | 2.4100 | 0.2100 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 1484.40 | 0.0009 | 0.0356 | 0.1142 |
| 1.0 | 1542.52 | -0.0014 | -0.0285 | 0.4255 |
| 1.5 | 1330.61 | | | |
| 2.0 | 913.58 | -0.0008 | -0.0653 | 0.6205 |
| 3.0 | 672.95 | | | |
| 4.0 | 266.16 | 0.0018 | -0.3307 | 0.0838 |
| 6.0 | 193.49 | | | |
| 8.0 | 180.96 | -0.0014 | -0.2333 | -0.0326 |
| 12.0 | 223.58 | | | |
| 16.0 | 272.44 | -0.0025 | -0.2214 | 0.0000 |
| 24.0 | 359.38 | | | |
| 32.0 | 456.51 | | | |

R.M.S. Observational Error = .0016
R.M.S. Offset Wenner Difference = .2025
R.M.S. Potential Ladder Difference = .3427

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 1484.40 |
| 2 | 1.0 | 1542.52 |
| 3 | 1.5 | 1275.00 |
| 4 | 2.0 | 913.58 |
| 5 | 3.0 | 475.00 |
| 6 | 4.0 | 266.16 |
| 7 | 6.0 | 193.49 |
| 8 | 8.0 | 180.96 |
| 9 | 12.0 | 223.58 |
| 10 | 16.0 | 272.44 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.17 | | 652.5 | |
| | 0.17 | -------- | 0.6720 |
| 0.53 | | 3326.0 | |
| | 0.70 | -------- | -0.8156 |
| 2.38 | | 337.9 | |
| | 3.08 | -------- | -0.7770 |
| 2.22 | | 42.4 | |
| | 5.30 | -------- | 0.9089 |
| | | 888.7 | |
| | | ******** | |

R.M.S. Relative error = 0.0303
Maximum rel. error = 0.0479 at sample 2
Number of trials was 0

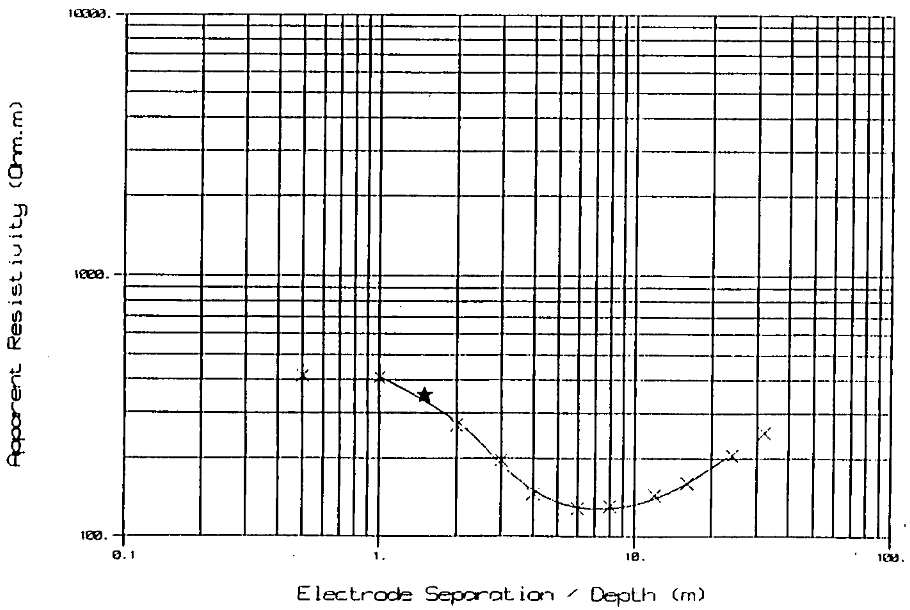
**NO 79 NE R2a** **7532 9913** **Lochmuir, Drumoak** **Block A**

Azimuth 019°
March 1987

| | |
|---|---|
| Overburden | 0.1m |
| Mineral I | 0.9m |
| Waste | 10.3m |
| Bedrock | - |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, clayey, silty | 188 | 0.1 | 0.1 |
| Lacustrine alluvium | Sand, gravelly | 542 | 0.9 | 1.0 |
| Glaciolacustrine deposits | Silt, clayey | 118 | 7.9 | 8.9 |
| Till | Clay, sandy | 48 | 2.4 | 11.3 |
| ?Caledonian | ?Granite | 615 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 191.3000 | 182.4000 | 125.1000 | 138.8000 | 8.8800 |
| 1.0 | 85.7000 | 81.4000 | 65.4000 | 63.8000 | 4.3100 |
| 2.0 | 25.7000 | 24.0000 | 21.4000 | 21.3000 | 1.1830 |
| 4.0 | 7.5300 | 7.1400 | 5.9500 | 5.6100 | 0.3840 |
| 8.0 | 3.6400 | 3.4400 | 2.5600 | 2.6300 | 0.1942 |
| 16.0 | 2.3700 | 2.2300 | 1.6390 | 1.5610 | 0.1328 |
| 32.0 | 1.8940 | 1.7800 | 1.2570 | 1.2450 | 0.1141 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 414.53 | 0.0001 | 0.1038 | 0.2751 |
| 1.0 | 409.04 | -0.0001 | -0.0399 | 0.2632 |
| 1.5 | 364.31 | | | |
| 2.0 | 268.29 | -0.0032 | -0.0047 | 0.0554 |
| 3.0 | 196.72 | | | |
| 4.0 | 145.27 | 0.0008 | -0.0588 | 0.0252 |
| 6.0 | 127.82 | | | |
| 8.0 | 130.44 | 0.0016 | 0.0270 | 0.0298 |
| 12.0 | 143.84 | | | |
| 16.0 | 180.85 | 0.0030 | -0.0188 | 0.0063 |
| 24.0 | 205.71 | | | |
| 32.0 | 251.53 | -0.0001 | -0.0096 | 0.0000 |
| 48.0 | 342.47 | | | |
| 64.0 | 425.41 | | | |

R.M.S. Observational Error = .0018
R.M.S. Offset Wenner Difference = .0522
R.M.S. Potential Ladder Difference = .1579

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 414.53 |
| 2 | 1.0 | 409.04 |
| 3 | 1.5 | 350.00 |
| 4 | 2.0 | 268.29 |
| 5 | 3.0 | 196.72 |
| 6 | 4.0 | 145.27 |
| 7 | 6.0 | 127.82 |
| 8 | 8.0 | 130.44 |
| 9 | 12.0 | 143.84 |
| 10 | 16.0 | 180.85 |
| 11 | 24.0 | 205.71 |
| 12 | 32.0 | 251.53 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.12 | | 187.6 | |
| | 0.12 | -------- | 0.4808 |
| 0.94 | | 542.4 | |
| | 1.06 | -------- | -0.6429 |
| 7.87 | | 117.9 | |
| | 8.93 | -------- | -0.4196 |
| 2.41 | | 48.2 | |
| | 11.34 | -------- | 0.8546 |
| | | 615.0 | |
| | | ******** | |

R.M.S. Relative error = 0.0231
Maximum rel. error = 0.0439 at sample 7
Number of trials was 0

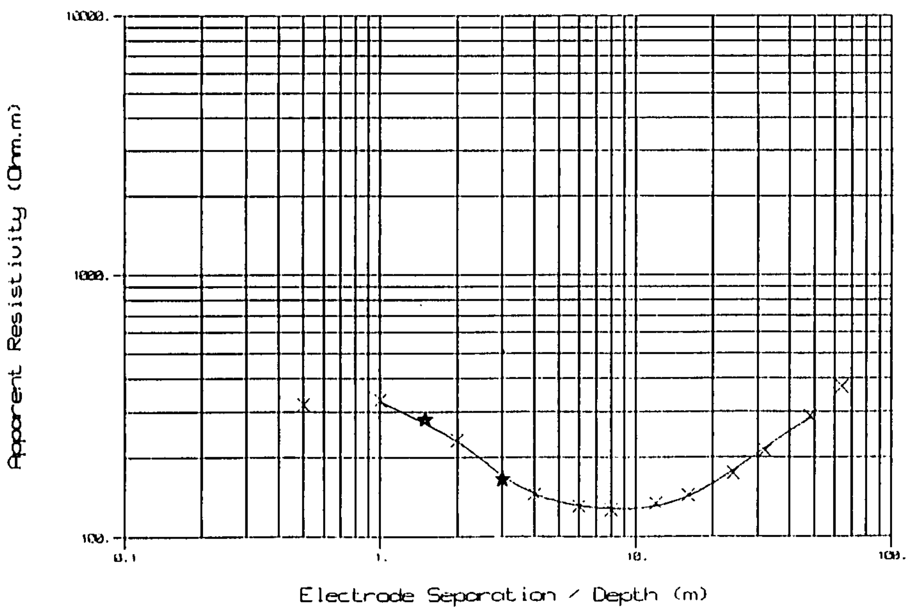
**NO 79 NE R2b.** **7542 9909** **Lochmuir, Drumoak** **Block A**

**Azimuth 135°**
**March 1987**

| | |
|---|---|
| Overburden | 0.1m |
| Mineral I | 0.9m |
| Waste | 12.2m |
| Bedrock | - |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, clayey, silty | 178 | 0.1 | 0.1 |
| Lacustrine alluvium | Sand, gravelly | 432 | 0.9 | 1.0 |
| Glaciolacustrine deposits | Silt, clayey | 124 | 9.2 | 10.2 |
| Till | Clay, sandy | 41 | 3.0 | 13.2 |
| ?Caledonian | ?Granite | 619 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 142.2000 | 134.1000 | 110.3000 | 92.5000 | 8.1200 |
| 1.0 | 69.2000 | 65.5000 | 51.9000 | 53.5000 | 3.0600 |
| 2.0 | 23.1000 | 22.0000 | 17.6500 | 19.3000 | 1.0630 |
| 4.0 | 7.5700 | 7.1800 | 5.8300 | 5.7300 | 0.3870 |
| 8.0 | 3.4700 | 3.2700 | 2.5000 | 2.5300 | 0.1938 |
| 16.0 | 2.0800 | 1.9850 | 1.3610 | 1.5080 | 0.1059 |
| 32.0 | 1.6450 | 1.5770 | 0.9370 | 1.1730 | 0.0711 |
| 64.0 | 1.4270 | 1.3380 | 0.7760 | 1.0790 | 0.0585 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 318.56 | -0.0001 | -0.1755 | 0.1203 |
| 1.0 | 331.12 | 0.0006 | 0.0304 | 0.1939 |
| 1.5 | 293.39 | | | |
| 2.0 | 232.16 | 0.0016 | 0.0893 | 0.1129 |
| 3.0 | 179.64 | | | |
| 4.0 | 145.27 | 0.0004 | -0.0173 | 0.0572 |
| 6.0 | 130.84 | | | |
| 8.0 | 126.42 | 0.0018 | 0.0119 | 0.0284 |
| 12.0 | 134.33 | | | |
| 16.0 | 144.21 | -0.0057 | 0.1035 | 0.0164 |
| 24.0 | 174.53 | | | |
| 32.0 | 212.12 | -0.0019 | 0.2237 | 0.0612 |
| 48.0 | 283.23 | | | |
| 64.0 | 372.97 | -0.0011 | 0.3267 | 0.0020 |
| 96.0 | 538.62 | | | |
| 128.0 | 659.16 | | | |

R.M.S. Observational Error = .0023
R.M.S. Offset Wenner Difference = .1610
R.M.S. Potential Ladder Difference = .1020

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 318.56 |
| 2 | 1.0 | 331.12 |
| 3 | 1.5 | 280.00 |
| 4 | 2.0 | 232.16 |
| 5 | 3.0 | 165.00 |
| 6 | 4.0 | 145.27 |
| 7 | 6.0 | 130.84 |
| 8 | 8.0 | 126.42 |
| 9 | 12.0 | 134.33 |
| 10 | 16.0 | 144.21 |
| 11 | 24.0 | 174.53 |
| 12 | 32.0 | 212.12 |
| 13 | 48.0 | 288.23 |
| 14 | 64.0 | 372.97 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.14 | | 178.4 | |
| | 0.14 | -------- | 0.4155 |
| 0.85 | | 432.0 | |
| | 0.99 | -------- | -0.5554 |
| 9.17 | | 123.5 | |
| | 10.16 | -------- | -0.4979 |
| 3.00 | | 41.4 | |
| | 13.16 | -------- | 0.8746 |
| | | 618.8 | |
| | | ******** | |

R.M.S. Relative error = 0.0176
Maximum rel. error = -0.0305 at sample 13
Number of trials was 0

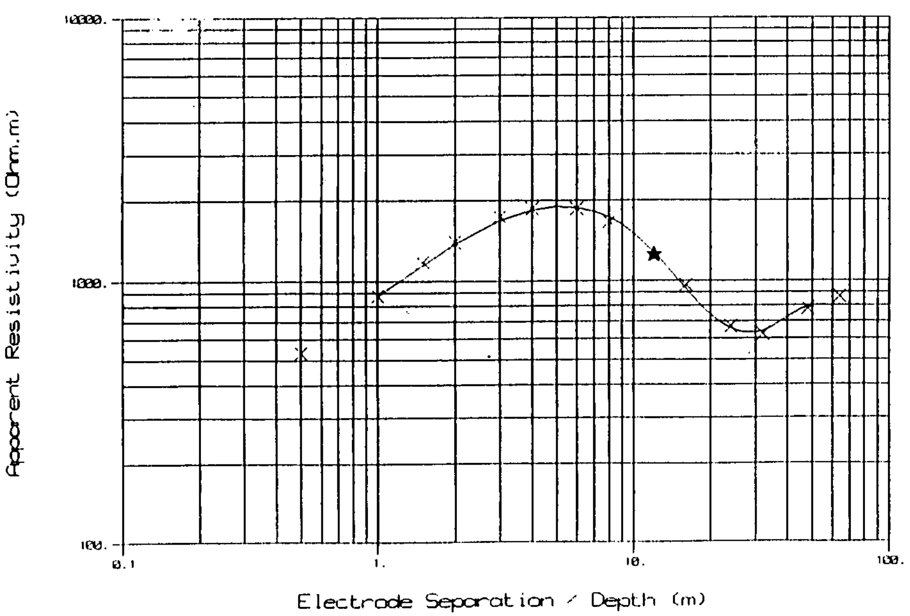
NO 79 NE R3a | 7840 9723 | Nether Balfour, Drumoak | Block B

Azimuth 034°
March 1987

| | |
|---|---|
| Overburden | 0.3m |
| Mineral I | 10.0m |
| Waste | 1.6m |
| Bedrock | - |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, sandy | 310 | 0.3 | 0.3 |
| Alluvium | Sand, gravelly | 1359 | 0.4 | 0.7 |
| Fluvioglacial sand and gravel | Gravel, sandy | 3167 | 4.1 | 4.8 |
| | Sand, pebbly | 778 | 5.5 | 10.3 |
| Till | Clay, sandy | 44 | 1.6 | 11.9 |
| ?Dalradian | ?Metamorphic rock | 1337 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 258.0000 | 246.0000 | 167.5000 | 171.3000 | 12.0000 |
| 1.0 | 215.0000 | 204.0000 | 133.0000 | 146.4000 | 11.2200 |
| 2.0 | 161.2000 | 150.4000 | 111.4000 | 111.3000 | 10.8300 |
| 4.0 | 93.9000 | 92.1000 | 75.4000 | 73.4000 | 6.7700 |
| 8.0 | 38.1000 | 35.9000 | 33.7000 | 32.4000 | 2.2500 |
| 16.0 | 12.2000 | 11.8400 | 10.6800 | 8.3200 | 0.3630 |
| 32.0 | 4.3200 | 4.0000 | 3.3200 | 2.9100 | 0.3180 |
| 64.0 | 3.0300 | 2.8300 | 2.4600 | 1.8410 | 0.2010 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 532.19 | 0.0000 | 0.0224 | 0.0483 |
| 1.0 | 877.76 | -0.0010 | 0.0959 | 0.0765 |
| 1.5 | 1175.64 | | | |
| 2.0 | 1399.27 | -0.0032 | -0.0009 | 0.0247 |
| 3.0 | 1743.39 | | | |
| 4.0 | 1869.88 | 0.0033 | -0.0269 | 0.0360 |
| 6.0 | 1872.40 | | | |
| 8.0 | 1661.27 | 0.0013 | -0.0393 | -0.2087 |
| 12.0 | 1264.09 | | | |
| 16.0 | 957.05 | -0.0002 | -0.2437 | 0.2443 |
| 24.0 | 667.87 | | | |
| 32.0 | 626.31 | 0.0005 | -0.1316 | -0.0880 |
| 48.0 | 780.48 | | | |
| 64.0 | 864.77 | -0.0003 | -0.2878 | 0.0000 |
| 96.0 | 987.52 | | | |
| 128.0 | 1092.22 | | | |

R.M.S. Observational Error = .0006
R.M.S. Offset Wenner Difference = .1464
R.M.S. Potential Ladder Difference = .1315

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 532.19 |
| 2 | 1.0 | 877.76 |
| 3 | 1.5 | 1175.64 |
| 4 | 2.0 | 1399.27 |
| 5 | 3.0 | 1743.39 |
| 6 | 4.0 | 1869.83 |
| 7 | 6.0 | 1872.40 |
| 8 | 8.0 | 1661.27 |
| 9 | 12.0 | 1250.00 |
| 10 | 16.0 | 957.05 |
| 11 | 24.0 | 667.87 |
| 12 | 32.0 | 626.31 |
| 13 | 48.0 | 780.48 |
| 14 | 64.0 | 864.77 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.31 | | 309.6 | |
| | 0.31 | -------- | 0.6288 |
| 0.42 | | 1363.6 | |
| | 0.73 | -------- | 0.3995 |
| 4.09 | | 3166.6 | |
| | 4.82 | -------- | -0.6056 |
| 5.48 | | 777.8 | |
| | 10.30 | -------- | -0.8929 |
| 1.62 | | 44.0 | |
| | 11.92 | -------- | 0.9363 |
| | | 1337.0 | |
| | | ******** | |

R.M.S. Relative error = 0.0220
Maximum rel. error = 0.0352 at sample 12
Number of trials was 0

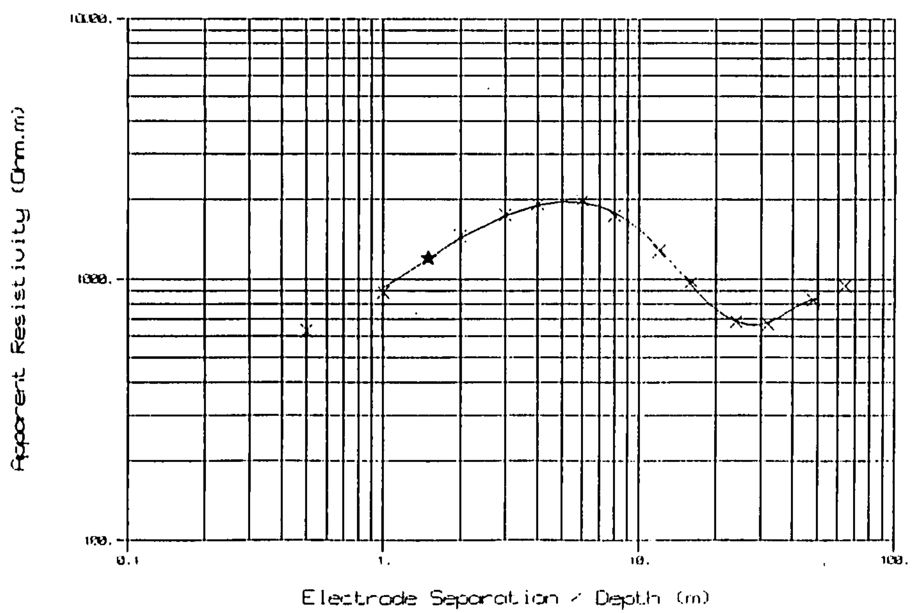
NO 79 NE R3b | 7840 9723 | **Nether Balfour, Drumoak** | **Block B**

Azimuth 174°
March 1987

Overburden 0.4m
Mineral I 9.7m
Waste 1.5m
Bedrock -

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, sandy, pebbly | 450 | 0.4 | 0.4 |
| Alluvium | Sand, gravelly | 1145 | 0.5 | 0.9 |
| Fluvioglacial sand and gravel | Gravel, sandy | 3376 | 4.0 | 4.9 |
| | Sand, pebbly | 769 | 5.2 | 10.1 |
| Till | Clay, sandy | 44 | 1.5 | 11.6 |
| ?Dalradian | ?Metamorphic rock | 1391 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 324.0000 | 314.0000 | 133.3000 | 218.0000 | 10.1700 |
| 1.0 | 210.0000 | 197.0000 | 122.5000 | 159.8000 | 13.3600 |
| 2.0 | 171.5000 | 161.1000 | 111.3000 | 119.8000 | 10.3300 |
| 4.0 | 101.2000 | 93.6000 | 76.2000 | 76.9000 | 7.5300 |
| 8.0 | 40.7000 | 33.3000 | 35.7000 | 33.3000 | 2.3300 |
| 16.0 | 12.2800 | 11.9300 | 10.8200 | 8.5800 | 0.3740 |
| 32.0 | 4.8600 | 4.5700 | 3.8000 | 2.8500 | 0.2900 |
| 64.0 | 3.4100 | 3.2100 | 2.7700 | 1.9060 | 0.1963 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 630.36 | -0.0005 | 0.1729 | 0.3025 |
| 1.0 | 886.87 | -0.0017 | 0.2643 | -0.0181 |
| 1.5 | 1239.65 | | | |
| 2.0 | 1452.04 | 0.0004 | 0.0736 | 0.0955 |
| 3.0 | 1753.64 | | | |
| 4.0 | 1923.91 | 0.0007 | 0.0091 | -0.0049 |
| 6.0 | 1987.70 | | | |
| 8.0 | 1734.16 | 0.0010 | -0.0596 | -0.1063 |
| 12.0 | 1276.38 | | | |
| 16.0 | 975.15 | 0.0005 | -0.2309 | 0.1625 |
| 24.0 | 682.42 | | | |
| 32.0 | 668.53 | 0.0000 | -0.2857 | 0.0335 |
| 48.0 | 828.60 | | | |
| 64.0 | 940.17 | 0.0011 | -0.3395 | 0.0000 |
| 96.0 | 1175.70 | | | |
| 128.0 | 1405.41 | | | |

R.M.S. Observational Error = .0009
R.M.S. Offset Wenner Difference = .2184
R.M.S. Potential Ladder Difference = .1413

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 630.36 |
| 2 | 1.0 | 886.87 |
| 3 | 1.5 | 1200.00 |
| 4 | 2.0 | 1452.04 |
| 5 | 3.0 | 1753.64 |
| 6 | 4.0 | 1923.91 |
| 7 | 6.0 | 1987.70 |
| 8 | 8.0 | 1734.16 |
| 9 | 12.0 | 1276.38 |
| 10 | 16.0 | 975.15 |
| 11 | 24.0 | 682.42 |
| 12 | 32.0 | 668.53 |
| 13 | 48.0 | 828.60 |
| 14 | 64.0 | 940.17 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.39 | | 450.3 | |
| | 0.39 | -------- | 0.4355 |
| 0.48 | | 1145.1 | |
| | 0.87 | -------- | 0.4935 |
| 3.97 | | 3376.2 | |
| | 4.84 | -------- | -0.6289 |
| 5.25 | | 769.1 | |
| | 10.09 | -------- | -0.8927 |
| 1.47 | | 43.6 | |
| | 11.56 | -------- | 0.9392 |
| | | 1390.8 | |
| | | ******** | |

R.M.S. Relative error = 0.0239
Maximum rel. error = 0.0402 at sample 2
Number of trials was 0

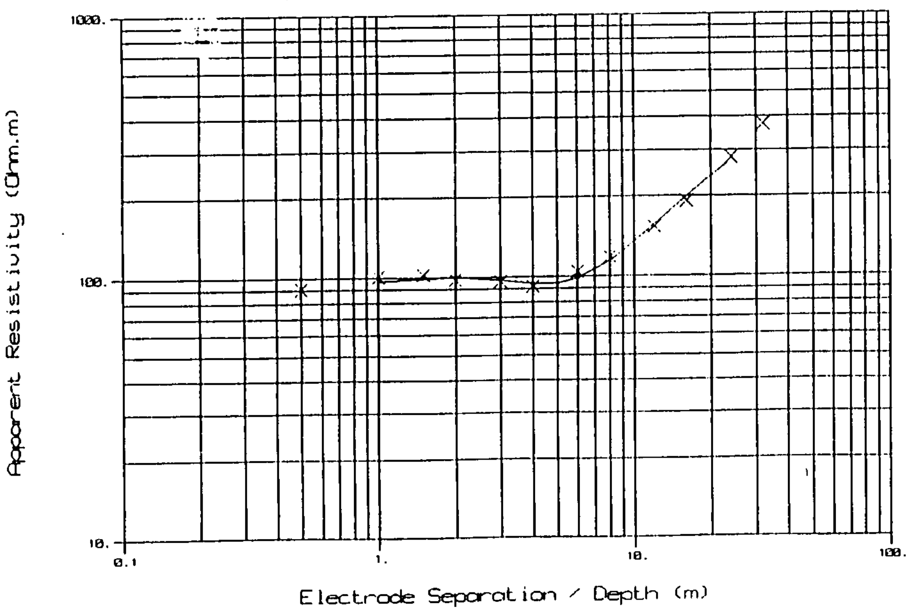
**NO 79 SW R1** **7343 9258** **East Mulloch, Durris** **Block C**

Azimuth 008°
March 1987

Waste 4.7m
Bedrock -

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| Peat | Peat | 92 | 0.9 | 0.9 |
| ?Flow-till | Clay, sandy, pebbly | 118 | 1.9 | 2.8 |
| Till | Clay, firm | 27 | 1.9 | 4.7 |
| Dalradian | Psammite, with calc-silicate | 1021 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 40.5000 | 38.3000 | 29.2000 | 28.4000 | 2.2200 |
| 1.0 | 21.9000 | 20.8000 | 15.7800 | 16.1900 | 1.1630 |
| 2.0 | 10.4500 | 9.9300 | 7.7500 | 7.7900 | 0.5280 |
| 4.0 | 5.1000 | 4.8200 | 3.5900 | 3.7200 | 0.2740 |
| 8.0 | 3.5400 | 3.3500 | 2.2700 | 2.4300 | 0.1762 |
| 16.0 | 3.0000 | 2.8500 | 1.7930 | 2.0300 | 0.1453 |
| 32.0 | 3.0400 | 2.8900 | 1.7510 | 1.9860 | 0.1467 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 90.48 | -0.0005 | -0.0278 | 0.0937 |
| 1.0 | 100.44 | -0.0029 | 0.0256 | 0.1158 |
| 1.5 | 101.97 | | | |
| 2.0 | 97.64 | 0.0002 | 0.0051 | 0.0885 |
| 3.0 | 95.74 | | | |
| 4.0 | 91.86 | 0.0012 | 0.0356 | -0.0030 |
| 6.0 | 103.62 | | | |
| 8.0 | 118.12 | 0.0039 | 0.0631 | 0.0867 |
| 12.0 | 153.28 | | | |
| 16.0 | 192.11 | 0.0016 | 0.1245 | 0.0037 |
| 24.0 | 280.27 | | | |
| 32.0 | 375.68 | 0.0011 | 0.1258 | 0.0000 |
| 48.0 | 590.73 | | | |
| 64.0 | 822.80 | | | |

R.M.S. Observational Error = .0020
R.M.S. Offset Wenner Difference = .0743
R.M.S. Potential Ladder Difference = .0716

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 90.48 |
| 2 | 1.0 | 100.44 |
| 3 | 1.5 | 101.97 |
| 4 | 2.0 | 97.64 |
| 5 | 3.0 | 95.74 |
| 6 | 4.0 | 91.86 |
| 7 | 6.0 | 103.62 |
| 8 | 8.0 | 118.12 |
| 9 | 12.0 | 153.28 |
| 10 | 16.0 | 192.11 |
| 11 | 24.0 | 280.27 |
| 12 | 32.0 | 375.68 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.92 | | 91.9 | |
| | 0.92 | -------- | 0.1256 |
| 1.93 | | 113.3 | |
| | 2.85 | -------- | -0.6239 |
| 1.88 | | 27.4 | |
| | 4.73 | -------- | 0.9477 |
| | | 1021.4 | |
| | | ******** | |

R.M.S. Relative error = 0.0268
Maximum rel. error = -0.0429 at sample 8
Number of trials was 0

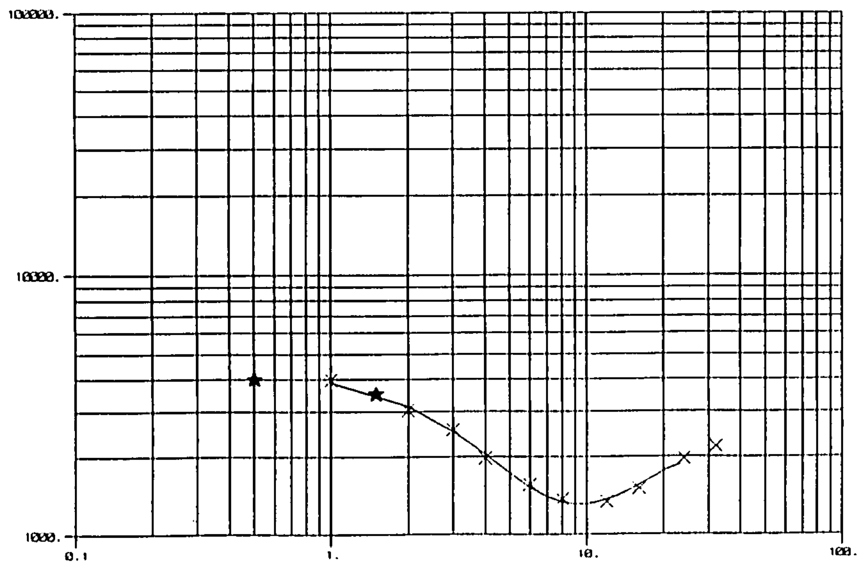
**NO 79 SW R2** **7095 9485** **Crofthead, Banchory** **Block C**

**Azimuth 010°**
**March 1987**

**Bedrock** 7.4m+

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness m | Depth m |
|---|---|---|---|---|
| Dalradian | Psammite and semipelite, with calc-silicate bands (deeply weathered to orange brown silty and clay) | 4143 | 1.3 | 1.3 |
| | | 2119 | 3.0 | 4.3 |
| | | 449 | 3.1 | 7.4 |
| | Psammite and semipelite with calc-silicate bands (unweathered) | 2292 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 711.0000 | 634.0000 | 240.0000 | 339.0000 | 79.8000 |
| 1.0 | 818.0000 | 774.0000 | 649.0000 | 618.0000 | 41.2000 |
| 2.0 | 296.0000 | 280.0000 | 239.0000 | 244.0000 | 16.5100 |
| 4.0 | 93.5000 | 88.5000 | 77.7000 | 79.5000 | 5.0700 |
| 8.0 | 38.0000 | 36.3000 | 24.3000 | 30.3000 | 1.7210 |
| 16.0 | 21.3000 | 19.5100 | 14.9000 | 15.1500 | 1.8430 |
| 32.0 | 14.9100 | 13.8100 | 9.6500 | 12.0800 | 1.1030 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 909.49 | -0.0039 | 0.3420 | 0.0418 |
| 1.0 | 3980.40 | 0.0034 | -0.0189 | 0.0873 |
| 1.5 | 3761.69 | | | |
| 2.0 | 3034.78 | -0.0017 | 0.0307 | -0.0132 |
| 3.0 | 2549.88 | | | |
| 4.0 | 1975.43 | -0.0007 | 0.0229 | -0.1386 |
| 6.0 | 1565.35 | | | |
| 8.0 | 1372.25 | -0.0006 | 0.2198 | 0.0383 |
| 12.0 | 1343.21 | | | |
| 16.0 | 1510.48 | -0.0025 | 0.0166 | -0.0834 |
| 24.0 | 1970.18 | | | |
| 32.0 | 2184.54 | -0.0006 | 0.2237 | 0.0000 |
| 48.0 | 2304.56 | | | |
| 64.0 | 2365.16 | | | |

R.M.S. Observational Error = .0023
R.M.S. Offset Wenner Difference = .1768
R.M.S. Potential Ladder Difference = .0880

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 4000.00 |
| 2 | 1.0 | 3980.40 |
| 3 | 1.5 | 3500.00 |
| 4 | 2.0 | 3034.78 |
| 5 | 3.0 | 2549.88 |
| 6 | 4.0 | 1975.43 |
| 7 | 6.0 | 1565.35 |
| 8 | 8.0 | 1372.25 |
| 9 | 12.0 | 1343.21 |
| 10 | 16.0 | 1510.48 |
| 11 | 24.0 | 1970.18 |
| 12 | 32.0 | 2184.54 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 1.35 | | 4143.2 | |
| | 1.35 | -------- | -0.3233 |
| 3.00 | | 2113.7 | |
| | 4.35 | -------- | -0.6504 |
| 3.07 | | 448.8 | |
| | 7.42 | -------- | 0.7391 |
| | | 2991.5 | |
| | | ******** | |

R.M.S. Relative error = 0.0212
Maximum rel. error = 0.0343 at sample 10
Number of trials was 0

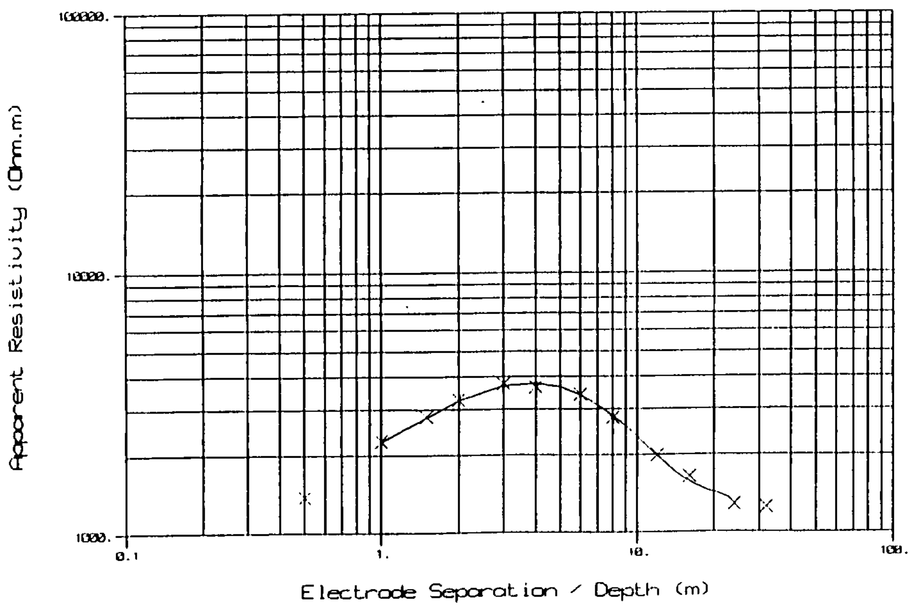
NO 79 SW R3a — 7250 9212 — West Mulloch, Banchory — Block C

Azimuth 088°
March 1987

Overburden 0.2m
Mineral I 5.5m
Bedrock -

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, sandy, pebbly | 513 | 0.2 | 0.2 |
| Fluvioglacial sand and gravel | Gravel, sandy | 3208 | 0.5 | 0.7 |
| | Gravel | 5934 | 3.3 | 4.0 |
| | Sand, gravelly | 731 | 1.7 | 5.7 |
| ?Dalradian | ?Metamorphic rock | 1240 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 654.0000 | 616.0000 | 437.0000 | 438.0000 | 38.0000 |
| 1.0 | 554.0000 | 528.0000 | 373.0000 | 349.0000 | 25.8000 |
| 2.0 | 368.0000 | 345.0000 | 256.0000 | 263.0000 | 22.7000 |
| 4.0 | 186.8000 | 173.7000 | 155.4000 | 133.5000 | 13.1500 |
| 8.0 | 66.9000 | 63.0000 | 59.5000 | 58.5000 | 3.8800 |
| 16.0 | 20.3000 | 19.2500 | 17.9300 | 14.9300 | 1.0640 |
| 32.0 | 8.1000 | 7.4100 | 6.7100 | 5.7300 | 0.7150 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 1374.45 | 0.0000 | 0.0023 | -0.0055 |
| 1.0 | 2268.23 | 0.0004 | -0.0665 | 0.1439 |
| 1.5 | 2809.10 | | | |
| 2.0 | 3260.97 | 0.0008 | 0.0270 | 0.0929 |
| 3.0 | 3748.79 | | | |
| 4.0 | 3630.42 | -0.0003 | -0.1516 | 0.0314 |
| 6.0 | 3399.10 | | | |
| 8.0 | 2764.60 | 0.0003 | -0.1636 | -0.0124 |
| 12.0 | 1993.89 | | | |
| 16.0 | 1651.22 | -0.0312 | -0.1830 | -0.0460 |
| 24.0 | 1282.57 | | | |
| 32.0 | 1250.61 | -0.0031 | -0.1576 | 0.0000 |
| 48.0 | 1188.01 | | | |
| 64.0 | 947.87 | | | |

R.M.S. Observational Error = .0013
R.M.S. Offset Wenner Difference = .1270
R.M.S. Potential Ladder Difference = .0737

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 1374.45 |
| 2 | 1.0 | 2268.23 |
| 3 | 1.5 | 2809.10 |
| 4 | 2.0 | 3260.97 |
| 5 | 3.0 | 3748.79 |
| 6 | 4.0 | 3630.42 |
| 7 | 6.0 | 3399.10 |
| 8 | 8.0 | 2764.60 |
| 9 | 12.0 | 1993.89 |
| 10 | 16.0 | 1651.22 |
| 11 | 24.0 | 1282.57 |
| 12 | 32.0 | 1250.61 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.17 | | 512.7 | |
| | 0.17 | -------- | 0.7244 |
| 0.48 | | 3207.5 | |
| | 0.65 | -------- | 0.2982 |
| 3.31 | | 5933.8 | |
| | 3.96 | -------- | -0.7808 |
| 1.70 | | 730.5 | |
| | 5.66 | -------- | 0.2587 |
| | | 1240.3 | |
| | | ******** | |

R.M.S. Relative error = 0.0217
Maximum rel. error = -0.0465 at sample 10
Number of trials was 0

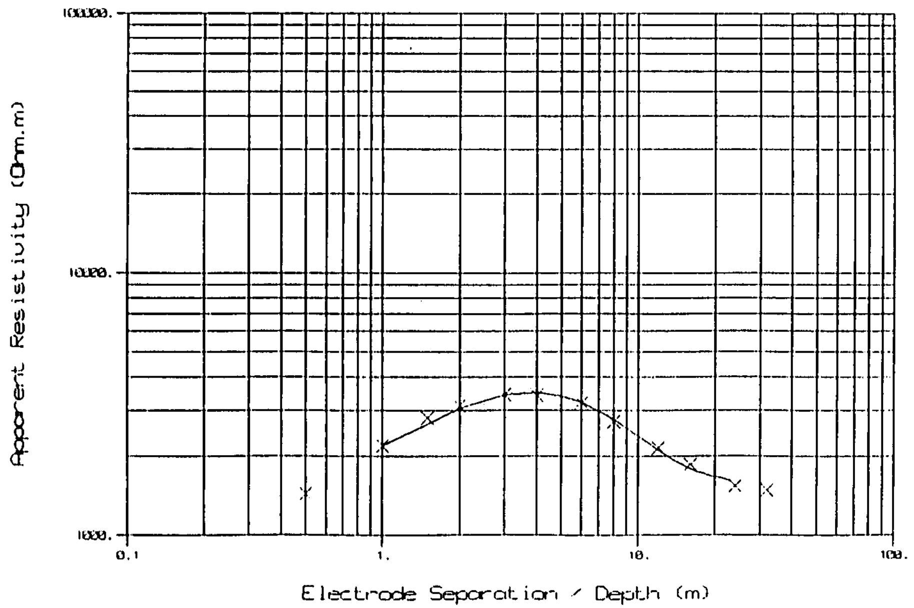
**NO 79 SW R3b** **7250 9212** **West Mulloch, Banchory** **Block C**

**Azimuth 180°**
**March 1987**

| | |
|---|---|
| Overburden | 0.2m |
| Mineral I | 5.7m |
| Bedrock | - |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, sandy, pebbly | 521 | 0.2 | 0.2 |
| Fluvioglacial sand and gravel | Gravel, sandy | 3235 | 0.5 | 0.7 |
| | Gravel | 4991 | 3.5 | 4.2 |
| | Sand, gravelly | 855 | 1.7 | 5.9 |
| ?Dalradian | ?Metamorphic rock | 1514 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 718.0000 | 687.0000 | 472.0000 | 444.0000 | 31.7000 |
| 1.0 | 518.0000 | 487.0000 | 343.0000 | 356.0000 | 30.6000 |
| 2.0 | 350.0000 | 328.0000 | 246.0000 | 248.0000 | 21.2000 |
| 4.0 | 172.1000 | 160.7000 | 127.2000 | 143.4000 | 11.4300 |
| 8.0 | 64.3000 | 60.6000 | 51.2000 | 56.9000 | 3.6400 |
| 16.0 | 23.9000 | 22.9000 | 16.7900 | 20.2000 | 0.9170 |
| 32.0 | 9.9000 | 9.2400 | 6.8400 | 7.9300 | 0.6550 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 1438.85 | -0.0010 | -0.0611 | 0.1543 |
| 1.0 | 2195.97 | 0.0008 | 0.0372 | 0.0574 |
| 1.5 | 2800.83 | | | |
| 2.0 | 3103.89 | 0.0023 | 0.0081 | 0.1014 |
| 3.0 | 3426.14 | | | |
| 4.0 | 3400.46 | -0.0002 | 0.1197 | -0.0303 |
| 6.0 | 3199.89 | | | |
| 8.0 | 2716.85 | 0.0009 | 0.1055 | -0.1443 |
| 12.0 | 2147.73 | | | |
| 16.0 | 1859.32 | 0.0035 | 0.1844 | 0.1019 |
| 24.0 | 1540.67 | | | |
| 32.0 | 1484.84 | 0.0005 | 0.1476 | 0.0000 |
| 48.0 | 1594.34 | | | |
| 64.0 | 1493.76 | | | |

R.M.S. Observational Error = .0017
R.M.S. Offset Wenner Difference = .1111
R.M.S. Potential Ladder Difference = .1076

FIELD CURVE DATA / INTERPRETED MODEL

| | Electrode Separation | Apparent Resistivity | Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|---|---|---|
| 1 | 0.5 | 1438.85 | 0.17 | | 520.5 | |
| 2 | 1.0 | 2195.97 | | | | |
| 3 | 1.5 | 2800.83 | | 0.17 | -------- | 0.7228 |
| 4 | 2.0 | 3103.89 | | | | |
| 5 | 3.0 | 3426.14 | 0.52 | | 3234.5 | |
| 6 | 4.0 | 3400.46 | | | | |
| 7 | 6.0 | 3199.89 | | 0.69 | -------- | 0.2135 |
| 8 | 8.0 | 2716.85 | | | | |
| 9 | 12.0 | 2147.73 | 3.55 | | 4990.6 | |
| 10 | 16.0 | 1859.32 | | | | |
| 11 | 24.0 | 1540.67 | | 4.24 | -------- | -0.7074 |
| 12 | 32.0 | 1484.84 | | | | |
| | | | 1.62 | | 855.4 | |
| | | | | 5.86 | -------- | 0.2780 |
| | | | | | 1514.0 | |
| | | | | | ******** | |

R.M.S. Relative error = 0.0213
Maximum rel. error = -0.0359 at sample 10
Number of trials was 0

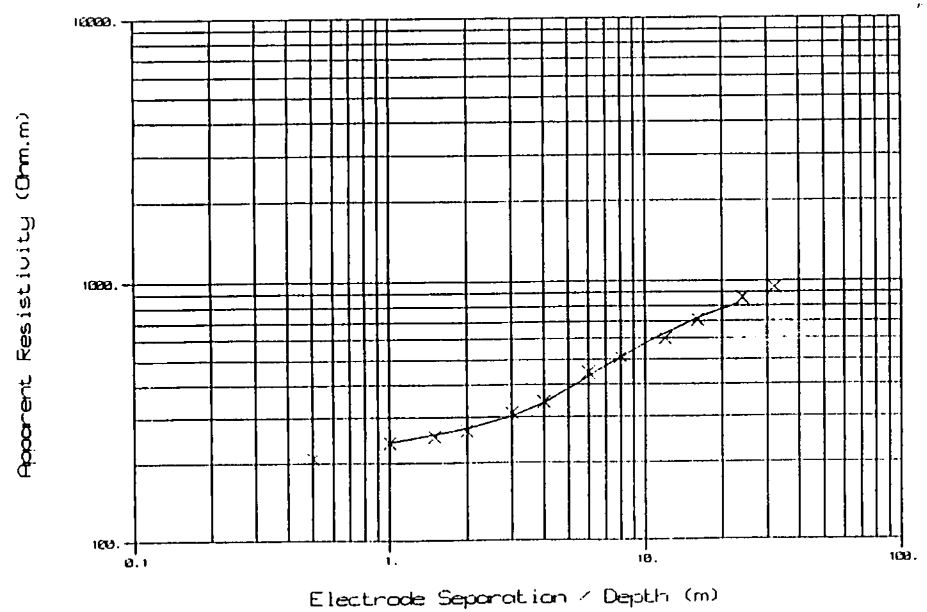
| NO 79 SE R1 | 7804 9054 | Bawd Burn, Durris | Block E |
|---|---|---|---|

Azimuth 152°
March 1987

| | |
|---|---|
| Waste | 2.3m |
| Bedrock | - |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| Peat | Peat | 188 | 0.4 | 0.4 |
| Morainic drift | Clay, sandy, gravelly | 286 | 1.6 | 2.0 |
| Till | Clay, sandy | 53 | 0.3 | 2.3 |
| Caledonian | Granite | 1054 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 93.6000 | 88.3000 | 62.2000 | 70.8000 | 5.2600 |
| 1.0 | 53.8000 | 51.3000 | 38.5000 | 37.7000 | 2.4400 |
| 2.0 | 31.3000 | 29.8000 | 19.8700 | 22.0000 | 1.5270 |
| 4.0 | 19.4600 | 18.0300 | 13.0000 | 14.2400 | 1.3890 |
| 8.0 | 14.5900 | 14.1900 | 9.9000 | 10.4000 | 0.7570 |
| 16.0 | 10.1300 | 9.5500 | 6.4900 | 7.6200 | 0.5810 |
| 32.0 | 6.7900 | 6.4100 | 4.7400 | 4.6300 | 0.3810 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 208.92 | 0.0004 | 0.1293 | 0.0727 |
| 1.0 | 239.39 | 0.0011 | -0.0210 | 0.1230 |
| 1.5 | 253.03 | | | |
| 2.0 | 266.85 | -0.0009 | 0.1236 | 0.1261 |
| 3.0 | 311.63 | | | |
| 4.0 | 343.31 | 0.0006 | 0.0849 | -0.0360 |
| 6.0 | 443.65 | | | |
| 8.0 | 510.19 | 0.0002 | 0.0493 | 0.0733 |
| 12.0 | 600.75 | | | |
| 16.0 | 708.74 | -0.0001 | 0.1617 | 0.0335 |
| 24.0 | 853.24 | | | |
| 32.0 | 941.98 | -0.0001 | -0.0235 | 0.0000 |
| 48.0 | 1166.27 | | | |
| 64.0 | 1386.95 | | | |

R.M.S. Observational Error = .0006
R.M.S. Offset Wenner Difference = .1000
R.M.S. Potential Ladder Difference = .0386

FIELD CURVE DATA / INTERPRETED MODEL

| | Electrode Separation | Apparent Resistivity | Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|---|---|---|
| 1 | 0.5 | 208.92 | 0.45 | | 188.3 | |
| 2 | 1.0 | 239.39 | | | | |
| 3 | 1.5 | 253.03 | | 0.45 | -------- | 0.2063 |
| 4 | 2.0 | 266.85 | | | | |
| 5 | 3.0 | 311.63 | 1.61 | | 286.2 | |
| 6 | 4.0 | 343.31 | | | | |
| 7 | 6.0 | 443.65 | | 2.06 | -------- | -0.6880 |
| 8 | 8.0 | 510.19 | | | | |
| 9 | 12.0 | 600.75 | 0.29 | | 52.9 | |
| 10 | 16.0 | 708.74 | | | | |
| 11 | 24.0 | 853.24 | | 2.35 | -------- | 0.9045 |
| 12 | 32.0 | 941.98 | | | | |
| | | | | | 1054.4 | |
| | | | | | ******** | |

R.M.S. Relative error = 0.0222
Maximum rel. error = 0.0470 at sample 9
Number of trials was 0

NO 79 SE 82a | 7627 9343 | South of Balladrum, Durris | Block C

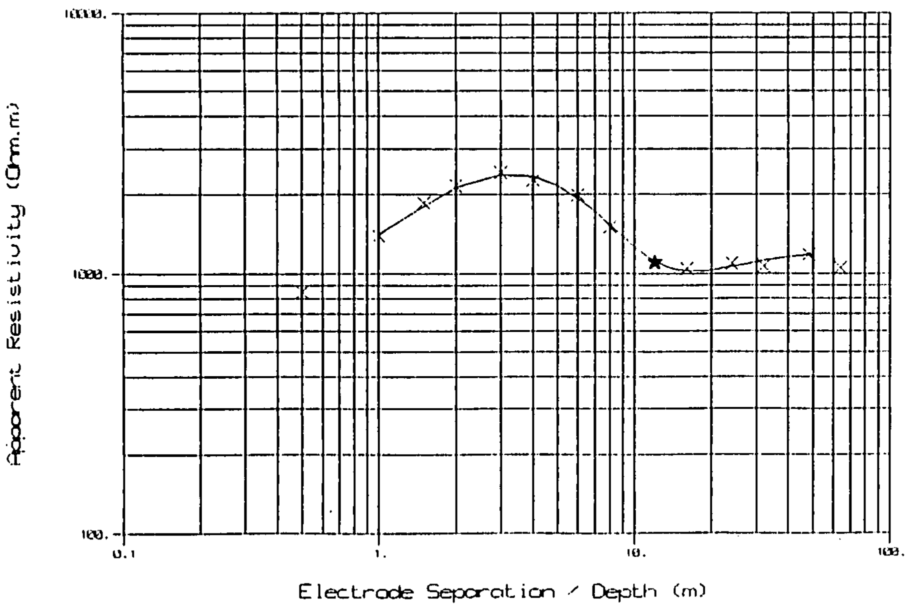
Azimuth 180
March 1987

Waste Bedrock 3.2m
-

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, sandy | 556 | 0.4 | 0.4 |
| ?Sand and gravel (?fill)* | Gravel, sandy | 7600 | 1.5 | 1.9 |
| Till | Clay, sandy, gravelly | 292 | 1.0 | 2.9 |
| | Clay, sandy | 60 | 0.3 | 3.2 |
| ?Caledonian | ?Granite | 1238 | - | - |

* sounding affected by buried pipe-line




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 422.0000 | 402.0000 | 305.0000 | 234.0000 | 19.5800 |
| 1.0 | 333.0000 | 312.0000 | 230.0000 | 210.0000 | 20.2000 |
| 2.0 | 244.0000 | 226.0000 | 177.1000 | 168.1000 | 17.7500 |
| 4.0 | 100.4000 | 89.9000 | 93.7000 | 87.4000 | 10.5000 |
| 8.0 | 34.2000 | 33.1000 | 23.9000 | 30.7000 | 1.0740 |
| 16.0 | 14.9300 | 14.4500 | 9.2100 | 11.5300 | 0.4740 |
| 32.0 | 7.7800 | 7.3700 | 4.9300 | 5.6400 | 0.4180 |
| 64.0 | 3.5700 | 3.3500 | 1.9720 | 3.2800 | 0.2110 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 846.65 | 0.0010 | -0.2635 | 0.1032 |
| 1.0 | 1382.30 | 0.0024 | -0.0909 | 0.0352 |
| 1.5 | 1856.06 | | | |
| 2.0 | 2168.93 | 0.0009 | -0.0521 | 0.0903 |
| 3.0 | 2434.39 | | | |
| 4.0 | 2275.77 | 0.0030 | -0.0556 | -0.5218 |
| 6.0 | 1993.43 | | | |
| 8.0 | 1497.91 | 0.0008 | 0.0604 | -0.1806 |
| 12.0 | 833.70 | | | |
| 16.0 | 1042.51 | 0.0004 | 0.2237 | 0.2704 |
| 24.0 | 1090.97 | | | |
| 32.0 | 1035.63 | -0.0010 | 0.1283 | 0.2838 |
| 48.0 | 1176.72 | | | |
| 64.0 | 1051.96 | 0.0025 | 0.4924 | 0.0000 |
| 96.0 | 1109.69 | | | |
| 128.0 | 1187.44 | | | |

R.M.S. Observational Error = .0014
R.M.S. Offset Wenner Difference = .2230
R.M.S. Potential Ladder Difference = .2624

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 846.66 |
| 2 | 1.0 | 1332.30 |
| 3 | 1.5 | 1856.06 |
| 4 | 2.0 | 2168.96 |
| 5 | 3.0 | 2434.39 |
| 6 | 4.0 | 2275.77 |
| 7 | 6.0 | 1993.43 |
| 8 | 8.0 | 1497.91 |
| 9 | 12.0 | 1100.00 |
| 10 | 16.0 | 1042.51 |
| 11 | 24.0 | 1030.97 |
| 12 | 32.0 | 1035.63 |
| 13 | 48.0 | 1176.72 |
| 14 | 64.0 | 1051.96 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.45 | | 555.9 | |
| | 0.45 | -------- | 0.8637 |
| 1.49 | | 7599.9 | |
| | 1.94 | -------- | -0.9380 |
| 0.95 | | 292.2 | |
| | 2.89 | -------- | -0.6598 |
| 0.30 | | 59.9 | |
| | 3.19 | -------- | 0.9077 |
| | | 1237.9 | |
| | | ******** | |

R.M.S. Relative error = 0.0214
Maximum rel. error = 0.0505 at sample 12
Number of trials was 0

**NO 79 SE R2b** **7627 9343** **South of Balladrum, Durris** **Block C**

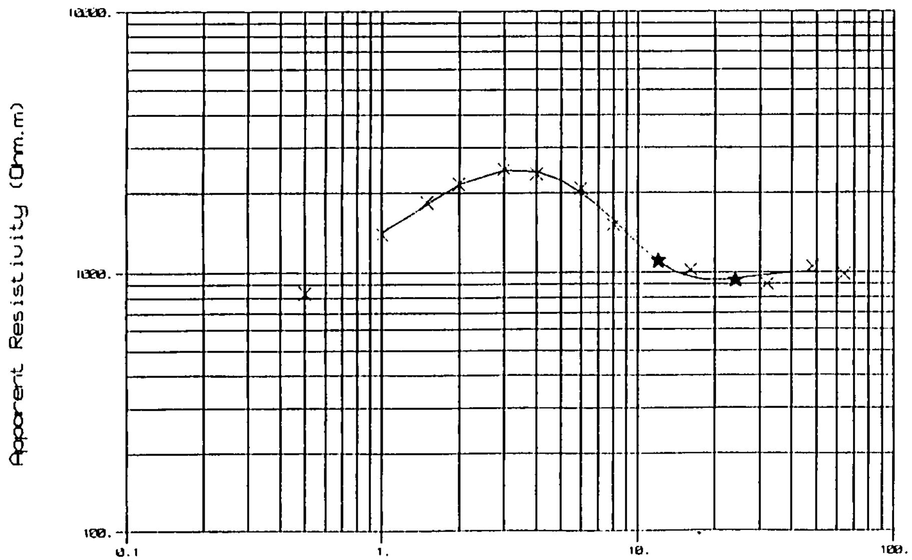
Azimuth 112°
March 1987

Waste 3.1m
Bedrock -

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, sandy | 554 | 0.5 | 0.5 |
| ?sand and gravel (?fill)* | Gravel, sandy | 7932 | 1.5 | 2.0 |
| Till | Clay, sandy, gravelly | 308 | 0.8 | 2.8 |
| | Clay, sandy | 56 | 0.3 | 3.1 |
| ?Caledonian | ?Granite | 1033 | - | - |

* sounding affected by buried pipe-line




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 410.0000 | 388.0000 | 274.0000 | 255.0000 | 21.5000 |
| 1.0 | 338.0000 | 318.0000 | 216.0000 | 229.0000 | 19.8300 |
| 2.0 | 243.0000 | 225.0000 | 181.6000 | 163.6000 | 17.6500 |
| 4.0 | 103.4000 | 97.7000 | 97.4000 | 91.7000 | 10.7100 |
| 8.0 | 33.5000 | 32.3000 | 30.8000 | 29.1000 | 1.1890 |
| 16.0 | 14.3600 | 13.8000 | 9.6800 | 10.6200 | 0.5670 |
| 32.0 | 5.6800 | 5.0300 | 4.2000 | 4.7100 | 0.5930 |
| 64.0 | 3.5300 | 3.3600 | 2.2200 | 2.6500 | 0.1716 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 830.95 | 0.0012 | -0.0718 | 0.0561 |
| 1.0 | 1398.01 | 0.0035 | 0.0534 | 0.0538 |
| 1.5 | 1846.05 | | | |
| 2.0 | 2168.96 | 0.0014 | -0.1043 | 0.0559 |
| 3.0 | 2476.88 | | | |
| 4.0 | 2376.30 | -0.0001 | -0.0303 | -0.3950 |
| 6.0 | 2084.64 | | | |
| 8.0 | 1505.45 | 0.0003 | -0.0568 | -0.2677 |
| 12.0 | 793.54 | | | |
| 16.0 | 1019.38 | -0.0005 | 0.0947 | 0.3208 |
| 24.0 | 1006.59 | | | |
| 32.0 | 835.73 | -0.0004 | 0.1145 | -0.2396 |
| 48.0 | 1046.54 | | | |
| 64.0 | 979.17 | -0.0005 | 0.1766 | 0.0000 |
| 96.0 | 1038.33 | | | |
| 128.0 | 1486.63 | | | |

R.M.S. Observational Error = .0008
R.M.S. Offset Wenner Difference = .0997
R.M.S. Potential Ladder Difference = .2382

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 830.95 |
| 2 | 1.0 | 1398.01 |
| 3 | 1.5 | 1846.05 |
| 4 | 2.0 | 2168.96 |
| 5 | 3.0 | 2476.88 |
| 6 | 4.0 | 2376.30 |
| 7 | 6.0 | 2084.64 |
| 8 | 8.0 | 1505.45 |
| 9 | 12.0 | 1100.00 |
| 10 | 16.0 | 1019.38 |
| 11 | 24.0 | 925.00 |
| 12 | 32.0 | 835.73 |
| 13 | 48.0 | 1046.54 |
| 14 | 64.0 | 979.17 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.45 | | 553.8 | |
| | 0.45 | -------- | 0.8695 |
| 1.51 | | 7931.8 | |
| | 1.96 | -------- | -0.9252 |
| 0.87 | | 308.2 | |
| | 2.83 | -------- | -0.6948 |
| 0.27 | | 55.5 | |
| | 3.10 | -------- | 0.8980 |
| | | 1032.5 | |
| | | ******** | |

R.M.S. Relative error = 0.0331
Maximum rel. error = 0.0778 at sample 12
Number of trials was 0

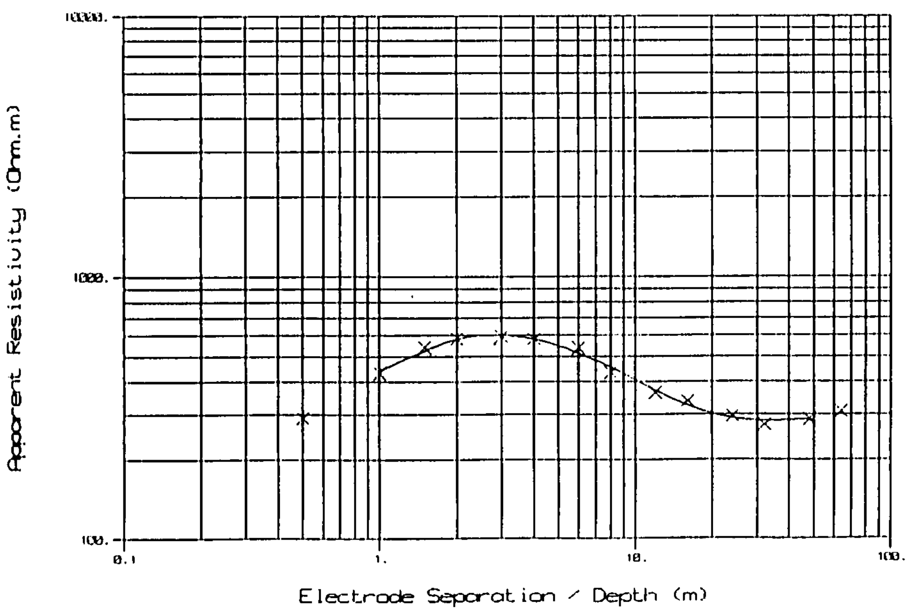
**NO 88 NW R1b** | **8472 8560** | **Fetteresso Castle, Stonehaven** | **Block G**

Azimuth 060°
March 1987

| | |
|---|---|
| Overburden | 0.3m |
| Mineral I | 9.2m |
| Waste | 1.0m |
| Bedrock | - |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness m | Depth m |
|---|---|---|---|---|
| | Soil, clayey | 143 | 0.3 | 0.3 |
| Fluvioglacial sand and gravel (Red Series) | Sand, gravelly | 948 | 1.6 | 1.9 |
| | Sand, silty | 428 | 7.6 | 9.5 |
| Till (Red Series) | Clay, sandy | 54 | 1.0 | 10.5 |
| Devonian | Sandstone, friable | 289 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 143.0000 | 135.0000 | 93.4000 | 91.2000 | 6.9900 |
| 1.0 | 97.8000 | 91.1000 | 66.1000 | 71.0000 | 6.6700 |
| 2.0 | 64.8000 | 61.4000 | 46.8000 | 46.0000 | 3.4000 |
| 4.0 | 29.8000 | 28.0000 | 22.6000 | 23.6000 | 1.8000 |
| 8.0 | 10.7000 | 10.0700 | 8.4700 | 8.7000 | 0.6500 |
| 16.0 | 4.3900 | 4.1400 | 3.1600 | 3.5500 | 0.2470 |
| 32.0 | 1.6380 | 1.5040 | 1.3960 | 1.3120 | 0.1350 |
| 64.0 | 1.1390 | 1.1070 | 0.7580 | 0.7680 | 0.0333 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 289.97 | 0.0001 | -0.0238 | 0.1376 |
| 1.0 | 430.71 | 0.0003 | 0.0715 | -0.0137 |
| 1.5 | 538.68 | | | |
| 2.0 | 583.08 | 0.0000 | -0.0172 | 0.1494 |
| 3.0 | 593.36 | | | |
| 4.0 | 580.57 | 0.0000 | 0.0433 | 0.0708 |
| 6.0 | 536.93 | | | |
| 8.0 | 431.53 | -0.0019 | 0.0268 | -0.0602 |
| 12.0 | 363.37 | | | |
| 16.0 | 337.28 | 0.0037 | 0.1162 | 0.0808 |
| 24.0 | 294.38 | | | |
| 32.0 | 272.24 | -0.0006 | -0.0620 | -0.3040 |
| 48.0 | 285.42 | | | |
| 64.0 | 306.82 | -0.0011 | 0.0131 | 0.0000 |
| 96.0 | 375.90 | | | |
| 128.0 | 552.31 | | | |

R.M.S. Observational Error = .0008
R.M.S. Offset Wenner Difference = .0571
R.M.S. Potential Ladder Difference = .1459

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 289.97 |
| 2 | 1.0 | 430.71 |
| 3 | 1.5 | 538.68 |
| 4 | 2.0 | 583.08 |
| 5 | 3.0 | 593.36 |
| 6 | 4.0 | 580.57 |
| 7 | 6.0 | 536.93 |
| 8 | 8.0 | 431.53 |
| 9 | 12.0 | 353.37 |
| 10 | 16.0 | 337.28 |
| 11 | 24.0 | 294.38 |
| 12 | 32.0 | 272.24 |
| 13 | 48.0 | 285.42 |
| 14 | 64.0 | 306.82 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.27 | | 142.6 | |
| | 0.27 | -------- | 0.7386 |
| 1.58 | | 948.3 | |
| | 1.85 | -------- | -0.3778 |
| 7.64 | | 428.2 | |
| | 9.49 | -------- | -0.7753 |
| 1.05 | | 54.2 | |
| | 10.54 | -------- | 0.6845 |
| | | 289.4 | |
| | | ******** | |

R.M.S. Relative error = 0.0285
Maximum rel. error = 0.0428 at sample 9
Number of trials was 0

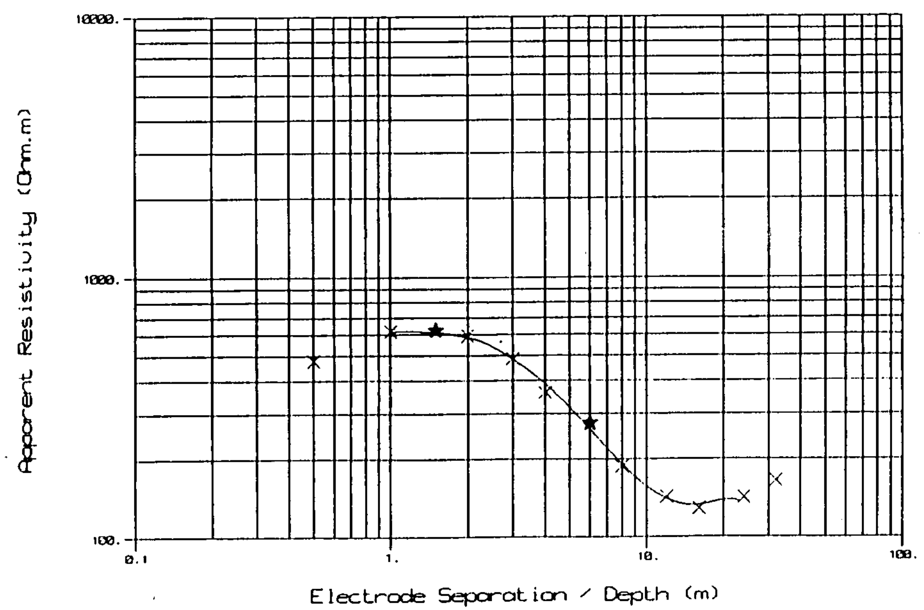
**NO 88 NW R1b** **8446 8539** **Fetteresso Castle, Stonehaven** **Block G**

Azimuth 034°
March 1987

| | |
|---|---|
| Overburden | 0.3m |
| Mineral I | 4.2m |
| Waste | 1.7m |
| Bedrock | - |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness m | Depth m |
|---|---|---|---|---|
| | Soil, clayey | 297 | 0.3 | 0.3 |
| Fluvioglacial sand and gravel (Red Series) | Sand, gravelly | 1038 | 0.8 | 1.1 |
| | Sand, silty | 382 | 3.4 | 4.5 |
| Till (Red Series) | Clay, sandy | 39 | 1.7 | 6.2 |
| Devonian | Sandstone, friable | 147 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 227.0000 | 216.0000 | 161.4000 | 142.4000 | 10.2600 |
| 1.0 | 135.0000 | 126.1000 | 100.3000 | 96.2000 | 8.8200 |
| 2.0 | 59.2000 | 55.5000 | 46.2000 | 48.5000 | 3.7100 |
| 4.0 | 15.4900 | 14.6900 | 13.0400 | 15.5800 | 0.8000 |
| 8.0 | 4.7900 | 4.5600 | 3.9500 | 3.9200 | 0.1882 |
| 16.0 | 1.7900 | 1.7170 | 1.3470 | 1.2120 | 0.0792 |
| 32.0 | 1.2710 | 1.2150 | 0.9470 | 0.6930 | 0.0569 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 477.21 | 0.0033 | -0.1251 | 0.1560 |
| 1.0 | 617.32 | 0.0006 | -0.0417 | 0.0890 |
| 1.5 | 672.42 | | | |
| 2.0 | 595.02 | -0.0032 | 0.0486 | 0.0692 |
| 3.0 | 484.76 | | | |
| 4.0 | 359.65 | 0.0000 | 0.1775 | -0.3983 |
| 6.0 | 230.45 | | | |
| 8.0 | 187.74 | 0.0004 | 0.0991 | 0.1455 |
| 12.0 | 142.92 | | | |
| 16.0 | 128.63 | -0.0031 | -0.1055 | 0.0334 |
| 24.0 | 141.86 | | | |
| 32.0 | 164.87 | -0.0007 | -0.3098 | 0.0000 |
| 48.0 | 235.92 | | | |
| 64.0 | 317.33 | | | |

R.M.S. Observational Error = .0013
R.M.S. Offset Wenner Difference = .1550
R.M.S. Potential Ladder Difference = .1906

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 477.21 |
| 2 | 1.0 | 617.32 |
| 3 | 1.5 | 625.00 |
| 4 | 2.0 | 595.02 |
| 5 | 3.0 | 484.76 |
| 6 | 4.0 | 359.65 |
| 7 | 6.0 | 275.00 |
| 8 | 8.0 | 187.74 |
| 9 | 12.0 | 142.92 |
| 10 | 16.0 | 128.63 |
| 11 | 24.0 | 141.86 |
| 12 | 32.0 | 164.87 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.28 | | 297.3 | |
| | 0.28 | -------- | 0.5546 |
| 0.78 | | 1037.8 | |
| | 1.06 | -------- | -0.4622 |
| 3.43 | | 331.7 | |
| | 4.49 | -------- | -0.8146 |
| 1.70 | | 39.0 | |
| | 6.19 | -------- | 0.5806 |
| | | 147.0 | |
| | | ******** | |

R.M.S. Relative error = 0.0197
Maximum rel. error = 0.0411 at sample 6
Number of trials was 0

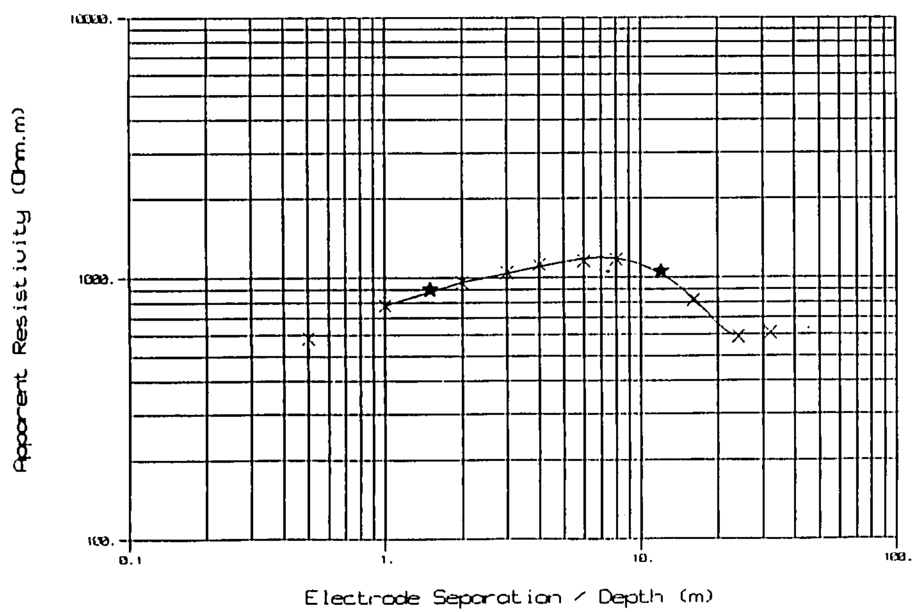
**NO 88 NE R1a** **8556 8898** **Bouff of Ury, Stonehaven** **Block G**

**Azimuth 044°**
**March 1987**

| | |
|---|---|
| **Overburden** | **0.2m** |
| **Mineral I** | **7.3m** |
| **Waste** | **1.9m** |
| **Bedrock** | **-** |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, sandy | 309 | 0.2 | 0.2 |
| Fluvioglacial sand and gravel (Red Series) | Sand, gravelly | 1069 | 4.1 | 4.3 |
| | Gravel, sandy | 3145 | 3.2 | 7.5 |
| Till (Red Series) | Clay, firm | 26 | 1.9 | 9.4 |
| Dalradian | Psammite | 1703 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 285.0000 | 273.0000 | 194.6000 | 188.8000 | 12.3300 |
| 1.0 | 175.6000 | 164.1000 | 126.6000 | 121.3000 | 11.4000 |
| 2.0 | 102.3000 | 95.8000 | 78.8000 | 73.6000 | 6.4000 |
| 4.0 | 62.1000 | 58.9000 | 45.9000 | 42.9000 | 3.1700 |
| 8.0 | 29.1000 | 26.8000 | 23.2000 | 23.1000 | 2.3000 |
| 16.0 | 9.4900 | 8.8400 | 7.8700 | 8.3200 | 0.6490 |
| 32.0 | 3.8400 | 3.5500 | 2.6800 | 3.3900 | 0.2900 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 586.54 | 0.0023 | 0.0225 | 0.1988 |
| 1.0 | 778.80 | 0.0006 | -0.0428 | 0.0275 |
| 1.5 | 934.31 | | | |
| 2.0 | 957.56 | 0.0010 | -0.0582 | -0.0575 |
| 3.0 | 1042.38 | | | |
| 4.0 | 1115.89 | 0.0005 | -0.0576 | 0.1270 |
| 6.0 | 1151.43 | | | |
| 8.0 | 1163.65 | 0.0000 | -0.0043 | -0.0491 |
| 12.0 | 1112.25 | | | |
| 16.0 | 813.80 | 0.0001 | 0.0556 | -0.2544 |
| 24.0 | 590.22 | | | |
| 32.0 | 610.22 | 0.0000 | 0.2339 | 0.0000 |
| 48.0 | 504.71 | | | |
| 64.0 | 414.19 | | | |

R.M.S. Observational Error = .0010
R.M.S. Offset Wenner Difference = .0906
R.M.S. Potential Ladder Difference = .1454

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 593.54 |
| 2 | 1.0 | 778.80 |
| 3 | 1.5 | 900.00 |
| 4 | 2.0 | 957.56 |
| 5 | 3.0 | 1042.38 |
| 6 | 4.0 | 1115.89 |
| 7 | 6.0 | 1151.43 |
| 8 | 8.0 | 1163.65 |
| 9 | 12.0 | 1050.00 |
| 10 | 16.0 | 813.80 |
| 11 | 24.0 | 590.22 |
| 12 | 32.0 | 610.22 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.22 | | 309.0 | |
| | 0.22 | -------- | 0.5514 |
| 4.06 | | 1053.5 | |
| | 4.28 | -------- | 0.4928 |
| 3.25 | | 3144.5 | |
| | 7.53 | -------- | -0.9835 |
| 1.88 | | 26.1 | |
| | 9.41 | -------- | 0.9698 |
| | | 1702.5 | |
| | | ******** | |

R.M.S. Relative error = 0.0125
Maximum rel. error = -0.0238 at sample 9
Number of trials was 0

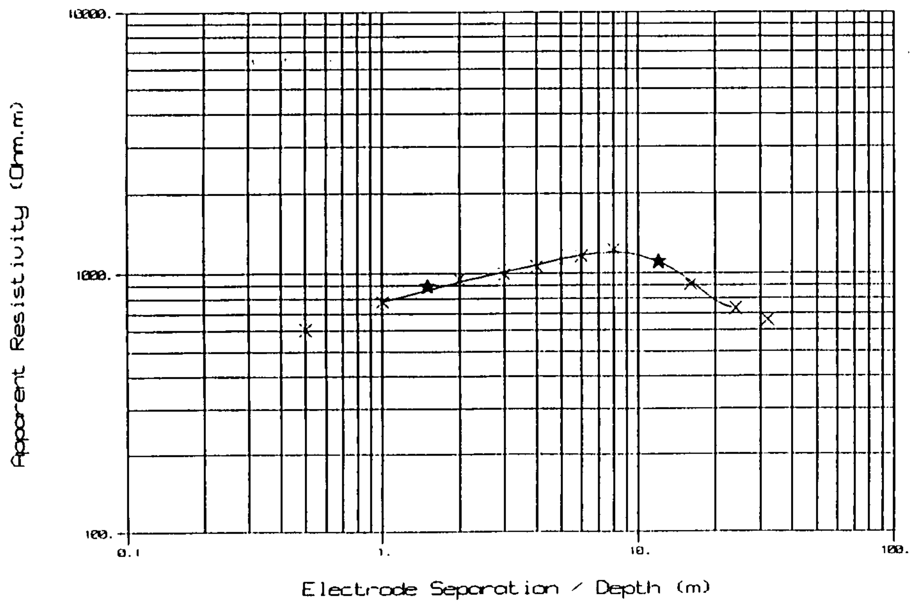
NO 88 NE R1b    8556 8898    Houff of Ury, Stonehaven    Block G

Azimuth 073°
March 1987

| | |
|---|---|
| Overburden | 0.2m |
| Mineral I | 7.3m |
| Waste | 1.6m |
| Bedrock | - |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, sandy | 315 | 0.2 | 0.2 |
| Fluvioglacial sand and gravel | Sand, gravelly | 1002 | 4.0 | 4.2 |
| (Red Series) | Gravel, sandy | 3381 | 3.3 | 7.5 |
| Till (Red Series) | Clay, silty | 32 | 1.6 | 9.1 |
| Dalradian | Psammite | 1822 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 294.0000 | 280.0000 | 185.8000 | 193.7000 | 13.0500 |
| 1.0 | 174.3000 | 162.3000 | 123.5000 | 123.4000 | 11.9100 |
| 2.0 | 103.3000 | 97.5000 | 77.7000 | 72.8000 | 5.8100 |
| 4.0 | 57.5000 | 54.3000 | 42.4000 | 41.8000 | 3.2300 |
| 8.0 | 32.3000 | 33.3000 | 24.2000 | 24.5000 | 1.9980 |
| 16.0 | 10.5400 | 9.8400 | 8.4200 | 9.6400 | 0.7020 |
| 32.0 | 4.2800 | 4.0000 | 2.6400 | 3.9000 | 0.2870 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 605.54 | 0.0032 | 0.0721 | 0.2093 |
| 1.0 | 776.92 | 0.0005 | -0.0040 | 0.0142 |
| 1.5 | 926.38 | | | |
| 2.0 | 945.62 | -0.0001 | -0.0651 | 0.0284 |
| 3.0 | 990.95 | | | |
| 4.0 | 1058.09 | -0.0005 | -0.0143 | 0.0304 |
| 6.0 | 1155.27 | | | |
| 8.0 | 1223.96 | 0.0001 | 0.0123 | 0.1590 |
| 12.0 | 1165.57 | | | |
| 16.0 | 987.79 | -0.0002 | 0.1351 | -0.2526 |
| 24.0 | 731.95 | | | |
| 32.0 | 657.47 | -0.0016 | 0.3853 | 0.0000 |
| 48.0 | 587.07 | | | |
| 64.0 | 584.47 | | | |

R.M.S. Observational Error = .0014
R.M.S. Offset Wenner Difference = .1588
R.M.S. Potential Ladder Difference = .1494

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 605.54 |
| 2 | 1.0 | 776.92 |
| 3 | 1.5 | 830.00 |
| 4 | 2.0 | 945.62 |
| 5 | 3.0 | 990.95 |
| 6 | 4.0 | 1058.09 |
| 7 | 6.0 | 1155.27 |
| 8 | 8.0 | 1223.96 |
| 9 | 12.0 | 1100.00 |
| 10 | 16.0 | 987.79 |
| 11 | 24.0 | 731.95 |
| 12 | 32.0 | 657.47 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.20 | | 315.3 | |
| | 0.20 | -------- | 0.5212 |
| 4.02 | | 1001.7 | |
| | 4.22 | -------- | 0.5428 |
| 3.32 | | 3330.6 | |
| | 7.54 | -------- | -0.9815 |
| 1.57 | | 31.5 | |
| | 9.11 | -------- | 0.9660 |
| | | 1822.4 | |
| | | ******** | |

R.M.S. Relative error = 0.0152
Maximum rel. error = 0.0246 at sample 10
Number of trials was 0

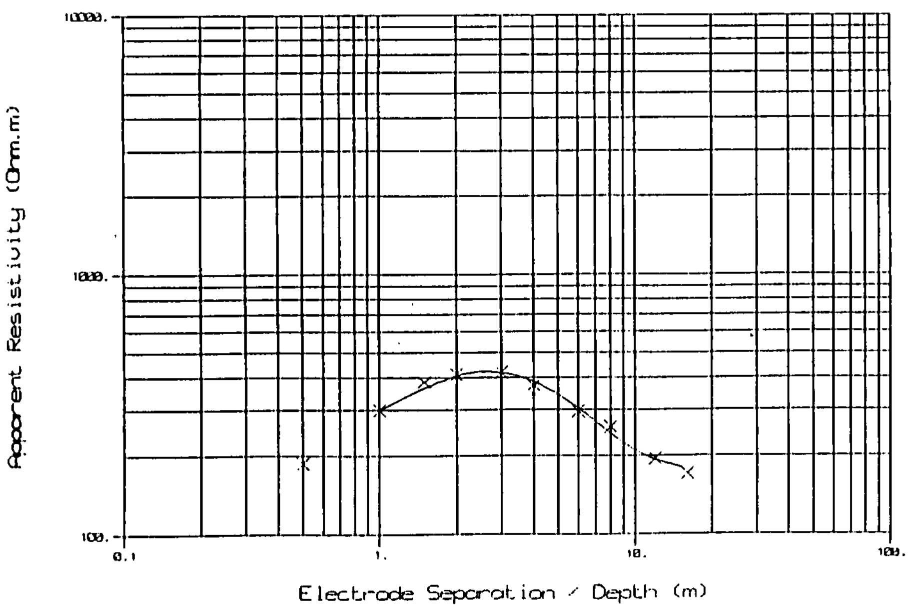
| NO 88 NE R2a | 8895 8762 | Garron Point, Stonehaven | Block G |
|---|---|---|---|

Azimuth 178°
March 1987

Overburden 0.2m
Mineral I 1.5m
Waste -

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, clayey | 60 | 0.2 | 0.2 |
| Raised beach | Sand, pebbly | 873 | 1.5 | 1.7 |
| Glaciolacustrine deposits (Red Series) | Silt, sandy. | 163 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 93.6000 | 89.6000 | 58.9000 | 59.6000 | 4.0400 |
| 1.0 | 70.9000 | 66.2000 | 49.8000 | 45.1000 | 4.6900 |
| 2.0 | 44.7000 | 41.5000 | 33.6000 | 31.7000 | 3.2000 |
| 4.0 | 18.2800 | 17.1200 | 14.3100 | 15.2600 | 1.0910 |
| 8.0 | 6.3400 | 6.0000 | 6.1300 | 4.1000 | 0.2710 |
| 16.0 | 2.3200 | 2.2000 | 1.4300 | 1.9440 | 0.1084 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 186.14 | -0.0004 | 0.0118 | 0.1392 |
| 1.0 | 298.14 | 0.0001 | -0.0991 | 0.0744 |
| 1.5 | 383.60 | | | |
| 2.0 | 410.29 | 0.0000 | -0.0582 | 0.0986 |
| 3.0 | 418.97 | | | |
| 4.0 | 371.59 | 0.0035 | 0.0643 | -0.0309 |
| 6.0 | 295.61 | | | |
| 8.0 | 257.11 | -0.0033 | -0.3959 | 0.0710 |
| 12.0 | 194.66 | | | |
| 16.0 | 169.90 | 0.0050 | 0.3006 | 0.0000 |
| 24.0 | 180.75 | | | |
| 32.0 | 207.30 | | | |

R.M.S. Observational Error = .0025
R.M.S. Offset Wenner Difference = .2103
R.M.S. Potential Ladder Difference = .0901

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 186.14 |
| 2 | 1.0 | 298.14 |
| 3 | 1.5 | 383.60 |
| 4 | 2.0 | 410.29 |
| 5 | 3.0 | 418.97 |
| 6 | 4.0 | 371.59 |
| 7 | 6.0 | 295.61 |
| 8 | 8.0 | 257.11 |
| 9 | 12.0 | 194.66 |
| 10 | 16.0 | 169.90 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.19 | | 60.0 | |
| | 0.19 | -------- | 0.8713 |
| 1.54 | | 872.7 | |
| | 1.73 | -------- | -0.6847 |
| | | 163.3 | |
| | | ******** | |

R.M.S. Relative error = 0.0313
Maximum rel. error = 0.0477 at sample 7
Number of trials was 0

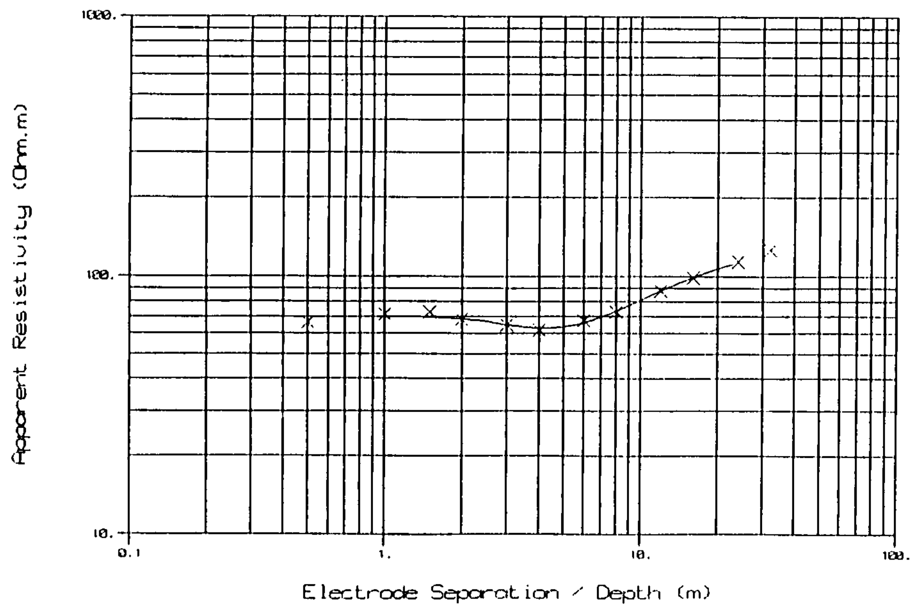
**NO 88 NE R2b** **8902 8763** **Garron Point, Stonehaven** **Block G**

Azimuth 130°
March 1987

Waste 4.3m
Bedrock -

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| | Soil, clayey | 59 | 0.2 | 0.2 |
| ?Raised beach | Silt, clayey | 73 | 2.4 | 2.6 |
| Till (Red Series) | Clay, silty, firm | 28 | 1.7 | 4.3 |
| ?Ordovician | ?Spilites and cherts (Highland Border Complex) | 140 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 30.6000 | 29.1000 | 21.8000 | 20.5000 | 1.5160 |
| 1.0 | 15.2600 | 14.4000 | 11.4400 | 11.2200 | 0.8560 |
| 2.0 | 7.2000 | 6.8400 | 5.3700 | 5.4400 | 0.3560 |
| 4.0 | 3.4000 | 3.2200 | 2.4700 | 2.4500 | 0.1809 |
| 8.0 | 2.0900 | 1.9460 | 1.5010 | 1.3950 | 0.1291 |
| 16.0 | 1.3990 | 1.3200 | 1.0310 | 0.9310 | 0.0792 |
| 32.0 | 0.8840 | 0.8330 | 0.6620 | 0.5890 | 0.0468 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 66.44 | -0.0005 | -0.0615 | 0.2010 |
| 1.0 | 71.19 | 0.0003 | -0.0194 | 0.0683 |
| 1.5 | 72.65 | | | |
| 2.0 | 67.92 | 0.0036 | 0.0130 | 0.0841 |
| 3.0 | 64.70 | | | |
| 4.0 | 61.83 | -0.0003 | -0.0081 | 0.0246 |
| 6.0 | 67.06 | | | |
| 8.0 | 72.78 | 0.0072 | -0.0732 | 0.0147 |
| 12.0 | 87.70 | | | |
| 16.0 | 98.62 | -0.0001 | -0.1019 | 0.0418 |
| 24.0 | 113.53 | | | |
| 32.0 | 125.76 | 0.0048 | -0.1167 | 0.0000 |
| 48.0 | 147.77 | | | |
| 64.0 | 168.48 | | | |

R.M.S. Observational Error = .0033
R.M.S. Offset Wenner Difference = .0694
R.M.S. Potential Ladder Difference = .0955

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 66.44 |
| 2 | 1.0 | 71.19 |
| 3 | 1.5 | 72.65 |
| 4 | 2.0 | 67.92 |
| 5 | 3.0 | 64.70 |
| 6 | 4.0 | 61.83 |
| 7 | 6.0 | 67.06 |
| 8 | 8.0 | 72.78 |
| 9 | 12.0 | 87.70 |
| 10 | 16.0 | 98.62 |
| 11 | 24.0 | 113.53 |
| 12 | 32.0 | 125.76 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.22 | | 58.5 | |
| | 0.22 | -------- | 0.1096 |
| 2.38 | | 72.9 | |
| | 2.60 | -------- | -0.4393 |
| 1.71 | | 28.4 | |
| | 4.31 | -------- | 0.6627 |
| | | 140.0 | |
| | | ******** | |

R.M.S. Relative error = 0.0162
Maximum rel. error = -0.0307 at sample 4
Number of trials was 0

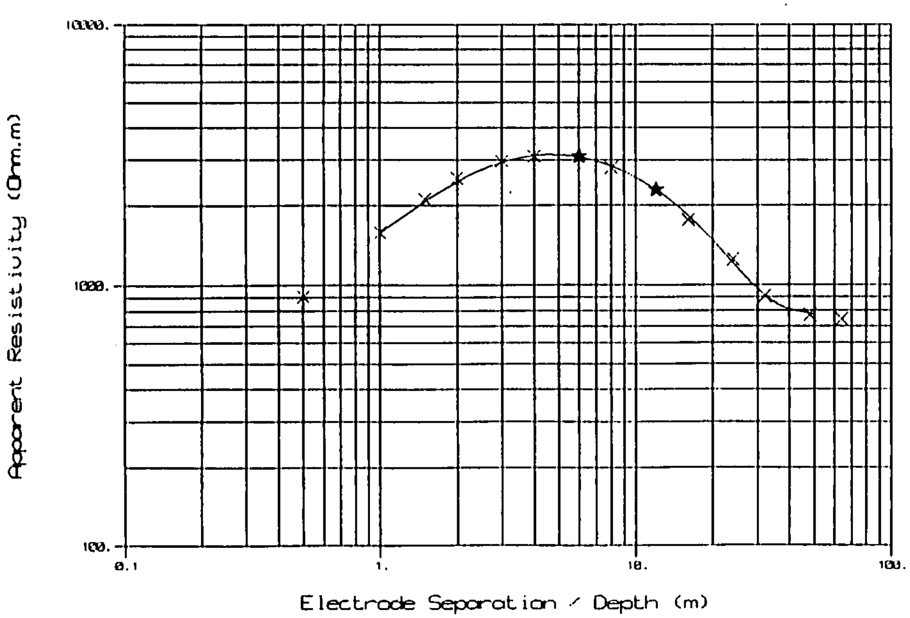
| NO 88 NE R3a | 8511 8973 | Monboys, Stonehaven | Block G |
|---|---|---|---|

Azimuth 138°
March 1987

Overburden 0.4m
Mineral I 14.5m
Waste 1.6m
Bedrock -

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| Peat | Peat, sandy | 625 | 0.4 | 0.4 |
| Glacial sand and gravel | Gravel | 6206 | 2.0 | 2.4 |
| | Gravel, sandy | 2188 | 12.5 | 14.9 |
| Till (Red Series) | Clay, sandy | 42 | 1.6 | 16.5 |
| ?Dalradian | ?Metamorphic rock | 1041 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 446.0000 | 421.0000 | 287.0000 | 287.0000 | 24.6000 |
| 1.0 | 385.0000 | 363.0000 | 252.0000 | 251.0000 | 22.0000 |
| 2.0 | 301.0000 | 284.0000 | 212.0000 | 194.3000 | 16.4200 |
| 4.0 | 153.5000 | 140.4000 | 123.5000 | 122.6000 | 13.0600 |
| 8.0 | 65.1000 | 61.5000 | 57.2000 | 54.1000 | 3.6200 |
| 16.0 | 18.9300 | 18.0600 | 18.4900 | 16.6600 | 0.8640 |
| 32.0 | 5.8100 | 5.5700 | 5.2800 | 3.7200 | 0.2400 |
| 64.0 | 2.6200 | 2.4700 | 1.8480 | 1.8410 | 0.1411 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 901.64 | 0.0000 | 0.0000 | 0.0336 |
| 1.0 | 1580.22 | 0.0000 | -0.0040 | 0.0489 |
| 1.5 | 2117.88 | | | |
| 2.0 | 2552.86 | 0.0019 | -0.0871 | 0.1593 |
| 3.0 | 2969.48 | | | |
| 4.0 | 3092.58 | 0.0003 | -0.0073 | -0.1879 |
| 6.0 | 3241.21 | | | |
| 8.0 | 2797.27 | -0.0003 | -0.0557 | -0.1677 |
| 12.0 | 2048.59 | | | |
| 16.0 | 1766.83 | 0.0003 | -0.1041 | -0.3916 |
| 24.0 | 1248.93 | | | |
| 32.0 | 904.78 | 0.0000 | -0.3467 | 0.0801 |
| 48.0 | 768.49 | | | |
| 64.0 | 741.72 | 0.0034 | -0.0038 | 0.0000 |
| 96.0 | 876.61 | | | |
| 128.0 | 1012.87 | | | |

R.M.S. Observational Error = .0014
R.M.S. Offset Wenner Difference = .1331
R.M.S. Potential Ladder Difference = .1898

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 901.64 |
| 2 | 1.0 | 1580.22 |
| 3 | 1.5 | 2117.88 |
| 4 | 2.0 | 2552.86 |
| 5 | 3.0 | 2969.48 |
| 6 | 4.0 | 3092.58 |
| 7 | 6.0 | 3100.00 |
| 8 | 8.0 | 2797.27 |
| 9 | 12.0 | 2300.00 |
| 10 | 16.0 | 1766.83 |
| 11 | 24.0 | 1248.93 |
| 12 | 32.0 | 904.78 |
| 13 | 48.0 | 768.49 |
| 14 | 64.0 | 741.72 |

INTERPRETED MODEL

| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.43 | | 624.7 | |
| | 0.43 | -------- | 0.8171 |
| 2.03 | | 6205.8 | |
| | 2.46 | -------- | -0.4786 |
| 12.44 | | 2188.4 | |
| | 14.90 | -------- | -0.9622 |
| 1.58 | | 42.2 | |
| | 16.48 | -------- | 0.9221 |
| | | 1041.1 | |
| | | ******** | |

R.M.S. Relative error = 0.0219
Maximum rel. error = 0.0502 at sample 1
Number of trials was 0

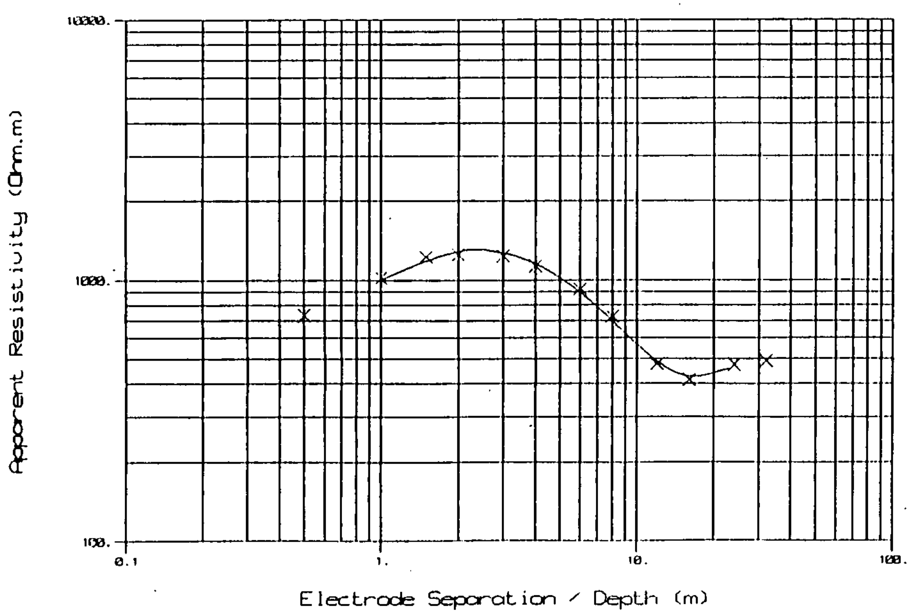
**NO 88 NE R3b** | **8510 8958** | **Monboys, Stonehaven** | **Block G**

Azimuth 138°
March 1987

| | |
|---|---|
| Overburden | 0.6m |
| Mineral I | 6:7m |
| Waste | 1.7m |
| Bedrock | - |

**Interpretation**

| Geological classification | Lithology | Resistivity (ohm m) | Thickness (m) | Depth (m) |
|---|---|---|---|---|
| Peat | Peat, sandy | 616 | 0.6 | 0.6 |
| Morainic drift | Gravel, sandy | 4062 | 0.7 | 1.3 |
| | Sand, pebbly, clayey | 726 | 6.0 | 7.3 |
| Till (Red Series) | Clay, sandy | 38 | 1.7 | 9.0 |
| ?Dalradian | ?Metamorphic rock | 1177 | - | - |




INPUT DATA

| Electrode Spacing | A | C | D1 | D2 | B |
|---|---|---|---|---|---|
| 0.5 | 358.0000 | 342.0000 | 209.0000 | 256.0000 | 16.0700 |
| 1.0 | 228.0000 | 213.0000 | 152.4000 | 170.7000 | 15.3300 |
| 2.0 | 132.2000 | 123.6000 | 89.2000 | 109.3000 | 8.6900 |
| 4.0 | 52.9000 | 49.4000 | 39.6000 | 50.1000 | 3.4400 |
| 8.0 | 18.0000 | 17.5300 | 11.9800 | 16.8300 | 0.4870 |
| 16.0 | 5.6600 | 5.3000 | 3.6100 | 4.6100 | 0.3490 |
| 32.0 | 3.2500 | 2.8900 | 2.2400 | 2.6300 | 0.3650 |

PROCESSING RESULTS

| Electrode Spacing | Wenner Resistivity | Observed Error | Offset Error | Lateral Error |
|---|---|---|---|---|
| 0.5 | 730.42 | -0.0002 | 0.2022 | 0.1776 |
| 1.0 | 1015.05 | -0.0014 | 0.1133 | 0.0168 |
| 1.5 | 1221.93 | | | |
| 2.0 | 1247.21 | -0.0037 | 0.2035 | 0.0420 |
| 3.0 | 1233.10 | | | |
| 4.0 | 1127.20 | 0.0011 | 0.2341 | -0.1322 |
| 6.0 | 919.20 | | | |
| 8.0 | 724.07 | 0.0032 | 0.3367 | 0.2607 |
| 12.0 | 475.20 | | | |
| 16.0 | 413.18 | 0.0019 | 0.2433 | -0.0092 |
| 24.0 | 472.72 | | | |
| 32.0 | 489.59 | -0.0015 | 0.1602 | 0.0000 |
| 48.0 | 508.38 | | | |
| 64.0 | 364.15 | | | |

R.M.S. Observational Error = .0012
R.M.S. Offset Wenner Difference = .2229
R.M.S. Potential Ladder Difference = .1499

FIELD CURVE DATA

| | Electrode Separation | Apparent Resistivity |
|---|---|---|
| 1 | 0.5 | 730.42 |
| 2 | 1.0 | 1015.05 |
| 3 | 1.5 | 1221.93 |
| 4 | 2.0 | 1247.21 |
| 5 | 3.0 | 1233.10 |
| 6 | 4.0 | 1127.20 |
| 7 | 6.0 | 919.20 |
| 8 | 8.0 | 724.07 |
| 9 | 12.0 | 475.20 |
| 10 | 16.0 | 413.18 |
| 11 | 24.0 | 472.72 |
| 12 | 32.0 | 489.59 |

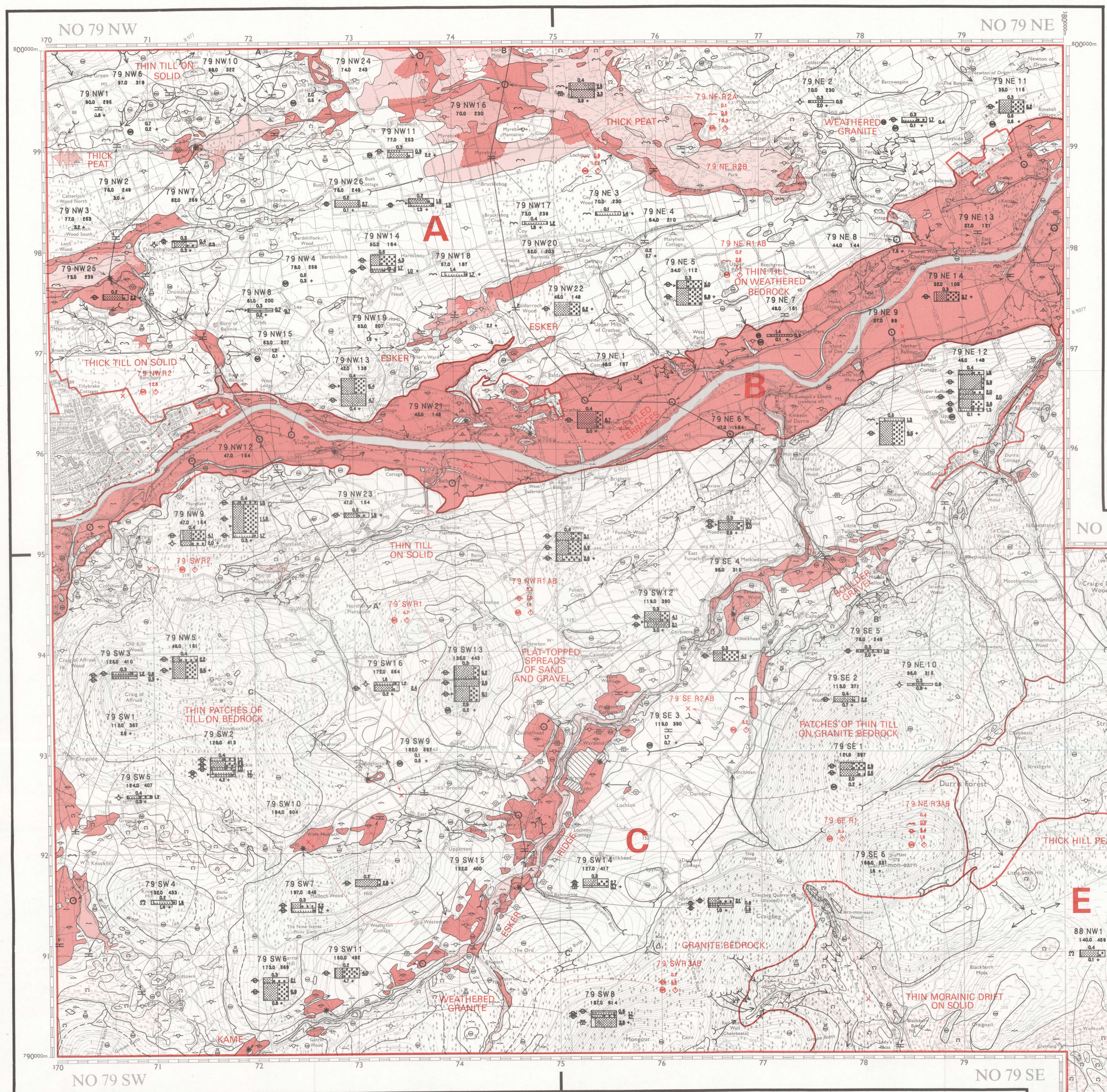
INTERPRETED MODEL

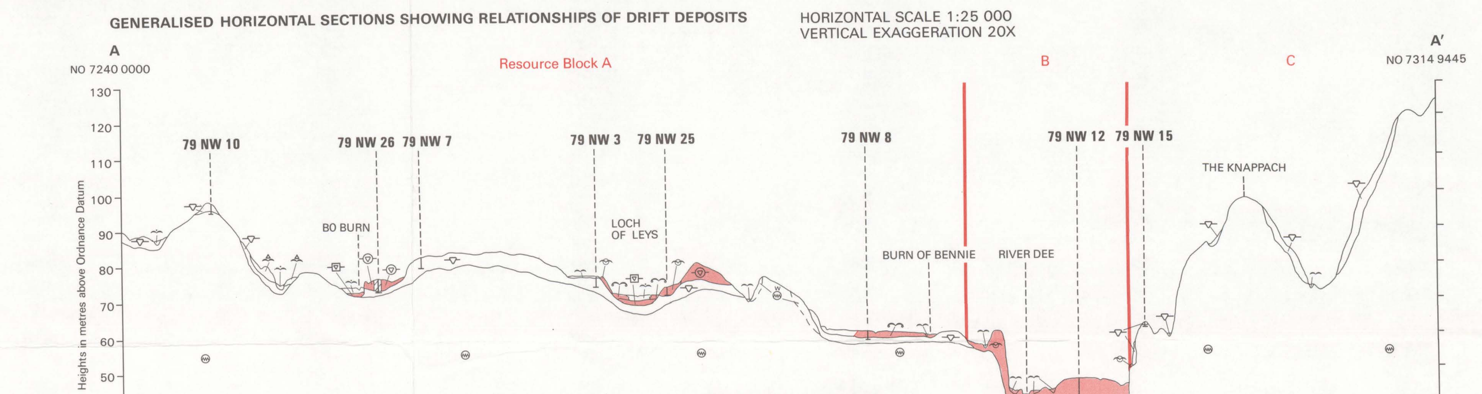
| Thickness | Depth | Rho | Reflection Coeffts. |
|---|---|---|---|
| 0.64 | | 615.5 | |
| | 0.64 | -------- | 0.7368 |
| 0.70 | | 4061.6 | |
| | 1.34 | -------- | -0.6963 |
| 6.01 | | 725.9 | |
| | 7.35 | -------- | -0.8938 |
| 1.62 | | 38.3 | |
| | 8.97 | -------- | 0.9369 |
| | | 1176.6 | |
| | | ******** | |

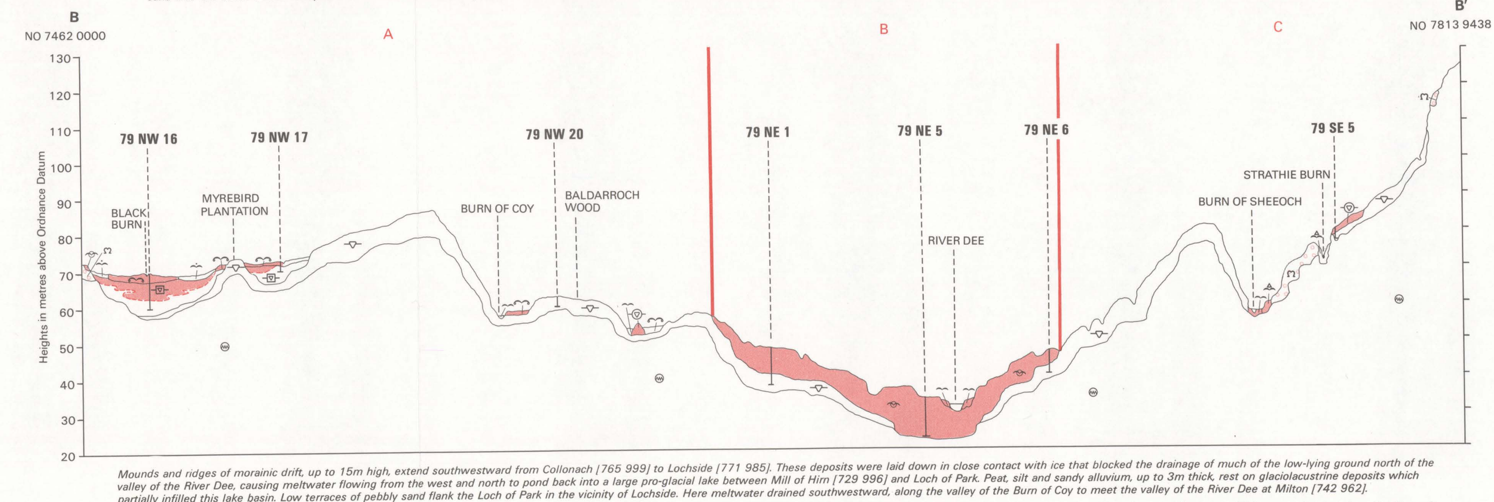
R.M.S. Relative error = 0.0249
Maximum rel. error = -0.042C at sample 8
Number of trials was 0

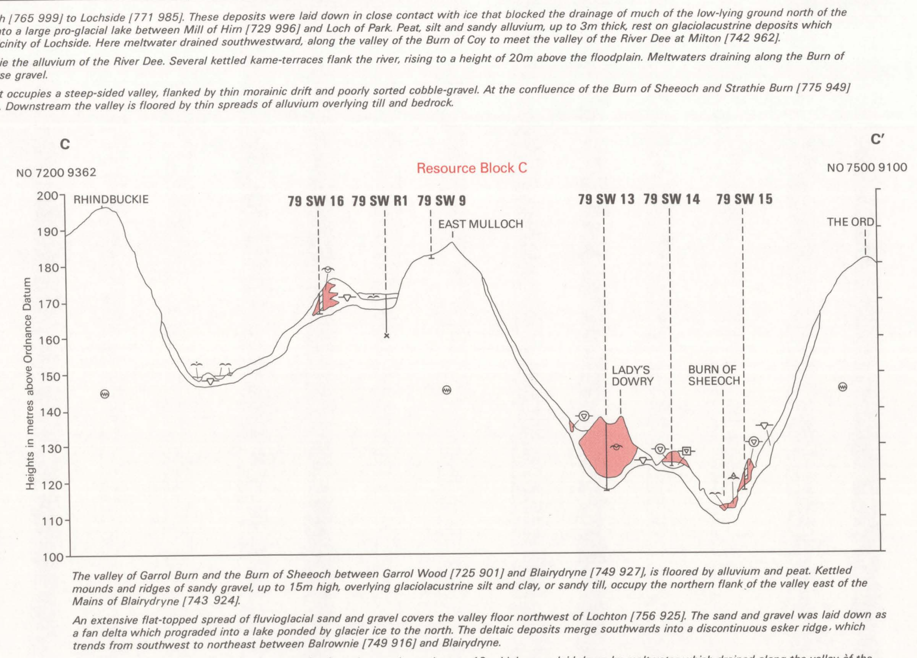
BRITISH GEOLOGICAL SURVEY (SCOTLAND)

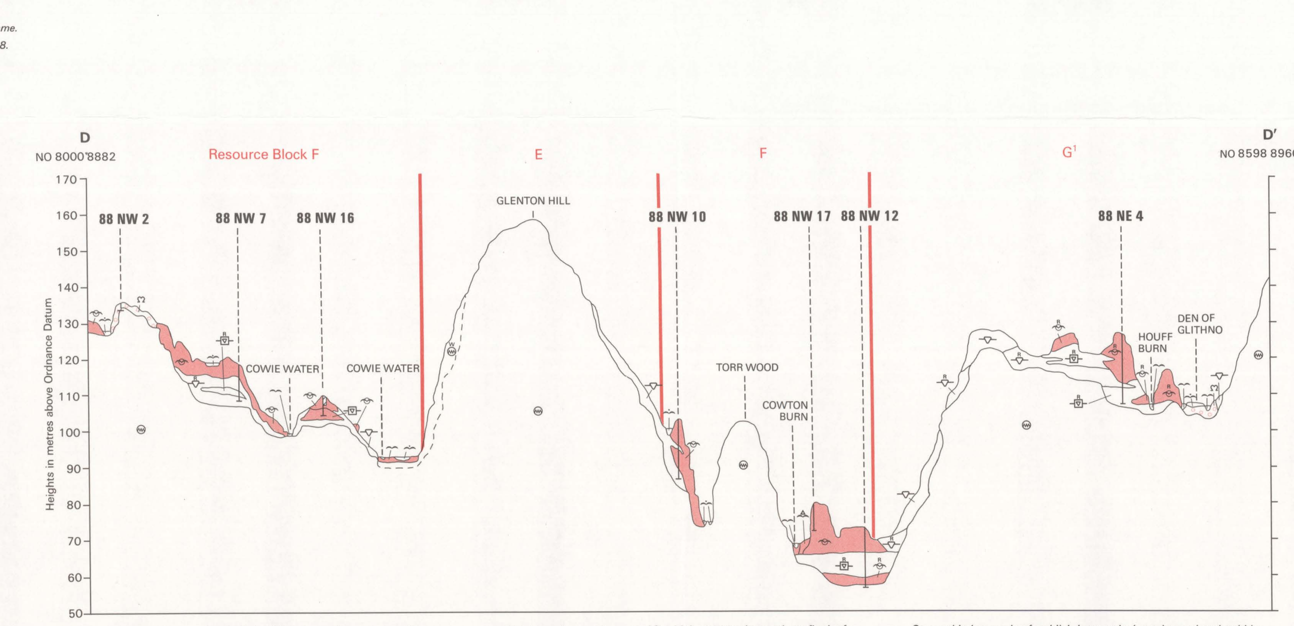
# THE SAND AND GRAVEL RESOURCES OF THE AREA BETWEEN BANCHORY AND STONEHAVEN, GRAMPIAN REGION

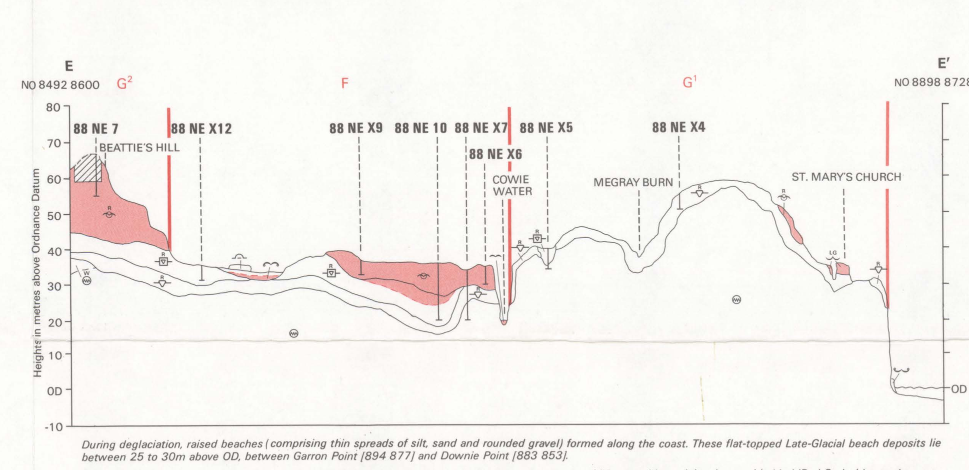


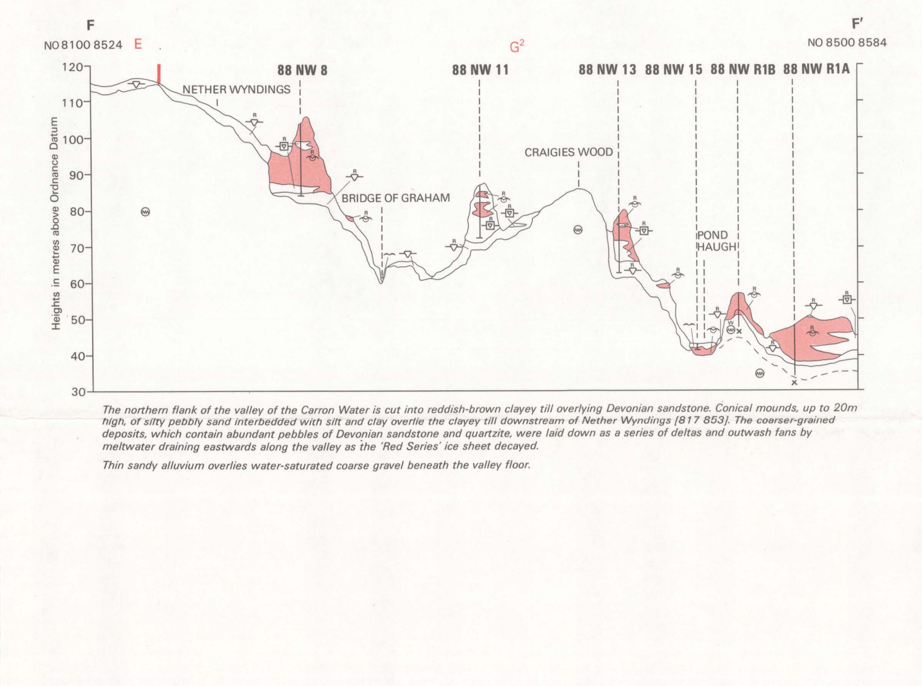












## THE SAND AND GRAVEL RESOURCES OF THE AREA BETWEEN BANCHORY AND STONEHAVEN, GRAMPIAN REGION

*This map should be read in conjunction with the accompanying Report which contains details of the assessment of resources*

### OTHER BOREHOLES

Site investigation boreholes and wells providing ancillary assessment data are located on the map where space permits. These boreholes are identified by serial numbers prefixed by the letter **X**, and indexed by the numbers and letters of the relevant standard quarter sheet e.g. **88 NE X1**

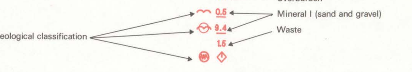
### EXPOSURE RECORDS

Information from the inspection of exposures is shown in the same way as for BGS boreholes. They are registered in the same series as the boreholes, for example, **79 NW 22**

### SHALLOW PITS

Where space permits the locations of shallow pits providing ancillary assessment data are shown by a distinctive symbol. Each pit is identified by serial registration numbers e.g. **79 SE 2.** The surface level for each pit has been extrapolated from the contours on the 1:25 000 and 1:10 000 scale topographic maps.

### GEOPHYSICAL DATA
### RESISTIVITY DEPTH SOUNDINGS




Note:

(i) The depth sounding identification number comprises the alphanumeric code for the quarter sheet e.g. **79 NE** followed by the letter **'R'** denoting a resistivity depth sounding, and the site number e.g. **79 NE R3.** When two or more soundings have been made at the same site, the results have been averaged to produce the values for the thickness of overburden, mineral and waste. The identification number is followed by the letters **'A' 'B' 'C'** etc., which refer to the individual soundings given in the accompanying report ie. the results shown for site **79 NE R3** combine the data from soundings **79 NE R3A** and **79 NE R3B** and are shown as **79 NE R3AB**

(ii) The symbol indicates that the base of the lowest unit (usually bedrock) for which resistivity values have been obtained is below the limit of depth sounding

(iii) Figures underlined denote thicknesses used in the assessment of resources

(iv) Other conventions are as for assessment boreholes

### CATEGORIES OF RESOURCE

**Exposed, potentially workable sand and gravel (mineral I)**

**Continuous or almost continuous spreads of potentially workable sand and gravel beneath overburden**

**Discontinuous spreads of potentially workable sand and gravel exposed or beneath overburden**

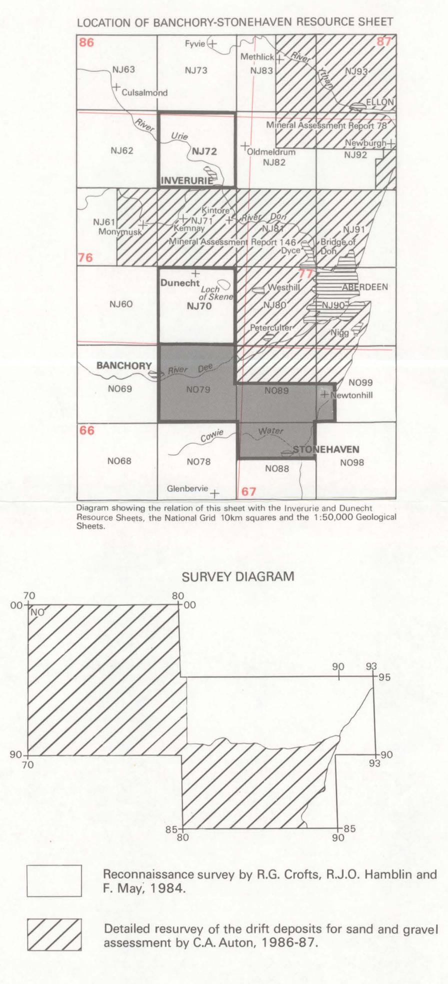
**Sand and gravel not assessed (in built-up areas)**

**Morainic drift—containing potentially workable till (mineral II) and some potentially workable sand and gravel (mineral I).**

**Sand and gravel absent or not potentially workable**

### RESOURCE BLOCKS

For the purpose of assessment, the mineral-bearing land is divided into Resource Blocks (see Report) Each is designated by a letter.



*Detailed records may be consulted on application to the Manager, Highlands and Islands Research Programme, British Geological Survey (Scotland), Murchison House, West Mains Road, Edinburgh EH9 3LA.*

*The British Geological Survey welcomes any revisions or additional geological information known to the user.*

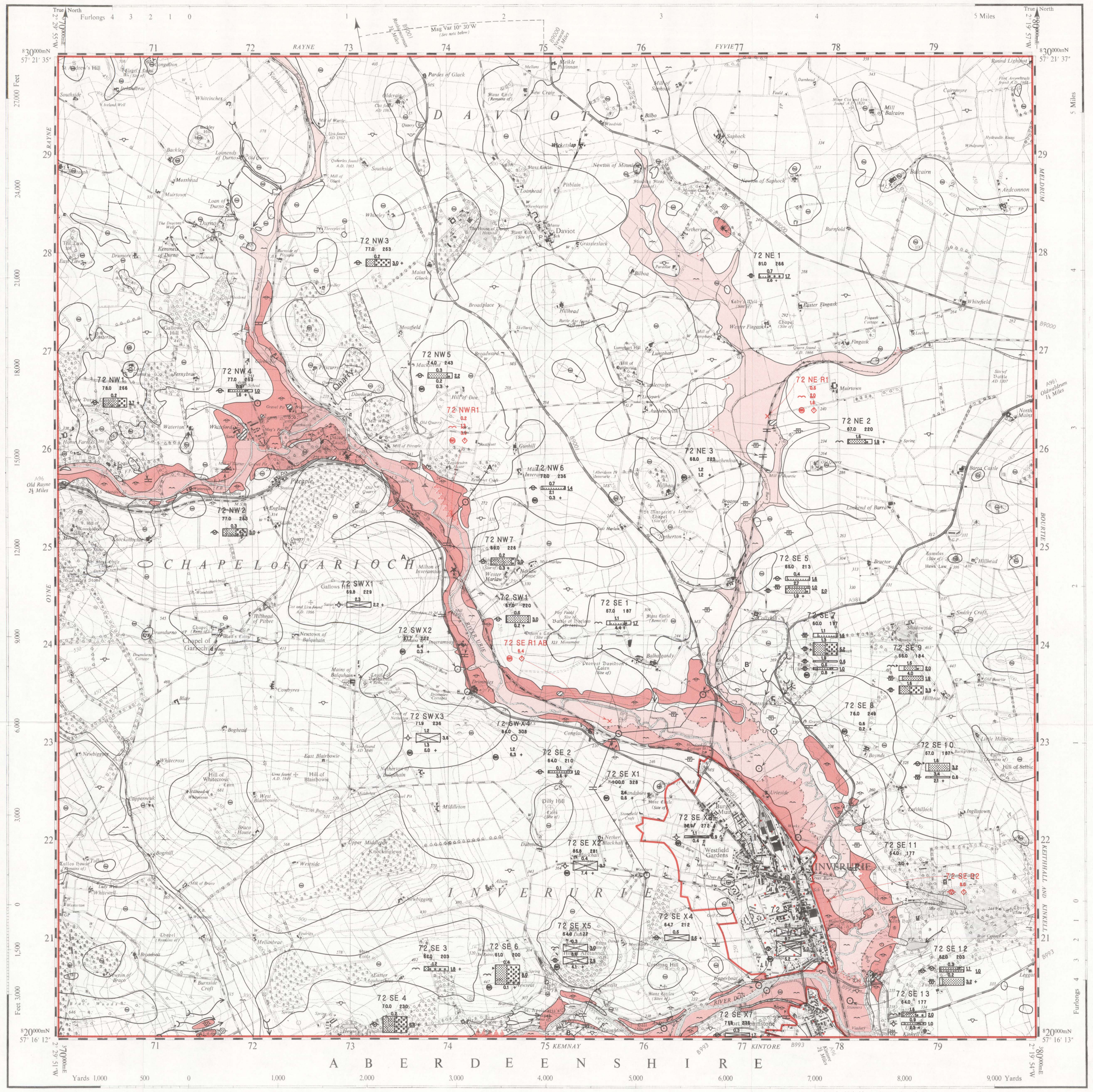

**This Map and the accompanying report were commissioned and financed by the Department of the Environment,** with support from Grampian Regional Council, Gordon District Council and local industry.

BRITISH GEOLOGICAL SURVEY (SCOTLAND)

# THE SAND AND GRAVEL RESOURCES OF THE AREAS AROUND INVERURIE AND DUNECHT, GRAMPIAN REGION

## INVERURIE RESOURCE SHEET

SHEET NJ72



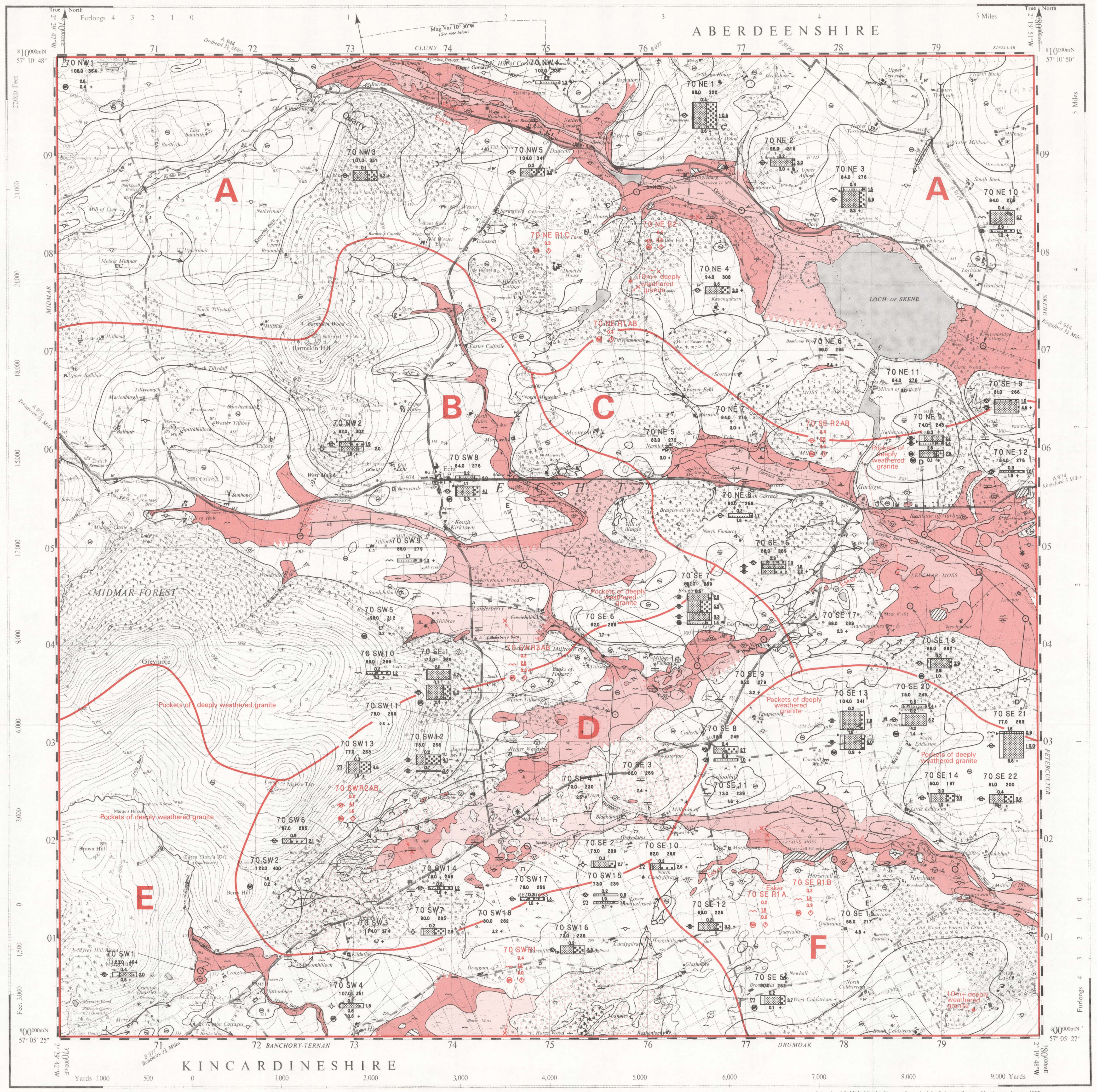

The representation on this map of a Road, Track, or Footpath, is no evidence of the existence of a right of way.

Made and published by the Director General of the Ordnance Survey, Chessington, Surrey, 1957

SHEET NJ72

## DUNECHT RESOURCE SHEET

SHEET NJ70




The representation on this map of a Road, Track, or Footpath, is no evidence of the existence of a right of way.

Printed and Published by the Director General of the Ordnance Survey, Chessington, Surrey, 1957.

SHEET NJ70

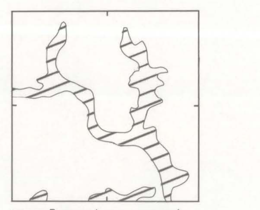
*Original geological survey of NJ 72 on the six-inch scale by D.R. Irvine and L.W. Hinxman, 1880-83*

*Partial resurvey by H.H. Read, 1918*

*Reconnaissance survey of the drift by A. Grout, 1984*

*Resurvey of the drift at a scale of 1:10 000 by J.W. Merritt, 1986*

SURVEY DIAGRAM NJ 72



Reconnaissance survey by A. Grout, 1984

Detailed resurvey (drift) by J.W. Merritt, 1986

yards 1000 0 1 2 Miles

metres 1000 0 1 2 3 Kilometres

*Data quoted for an individual borehole refer strictly to that site: reliable conclusions cannot be drawn about the thickness and grading elsewhere in the deposit, particularly in material as variable as sand and gravel. However, estimates of the volume and mean grading of the mineral as a whole in each Resource Block are given in the Report.*

LOCATION OF THE INVERURIE and DUNECHT RESOURCE SHEETS

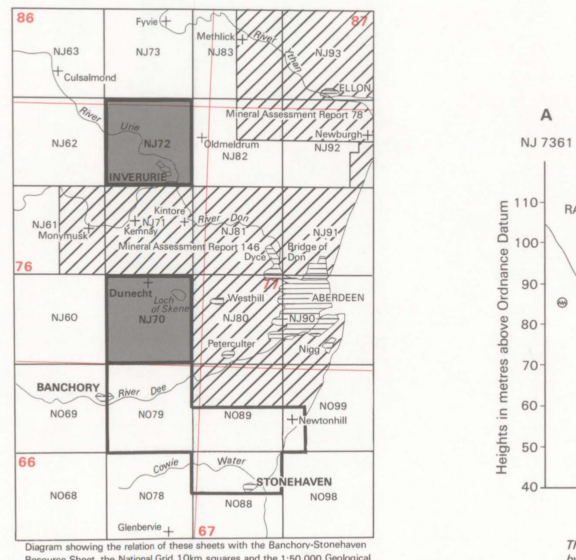



Diagram showing the relation of these sheets with the Banchory-Stonehaven Resource Sheet, the National Grid 10km squares and the 1:50 000 Geological Sheets.



*Original geological survey of NJ 70 on the six-inch scale by D.R. Irvine, L.W. Hinxman and H. Skae, 1881-84*

*Reconnaissance survey of the drift by A. Highton and J.W. Merritt, 1984-86*

*Drift geology re-surveyed at a scale of 1:10 000 by J.W. Merritt, 1986*

*Sand and gravel survey of NJ 70 and NJ 72 by J.W. Merritt, D.L. Ross, C.W. Thomas and C.A. Auton, 1986-87*
*D.J. Fettes, Manager, Highlands and Islands Research Programme.*

*The 1:25 000 sand and gravel resource sheet published 1988*
*F. G. Larminie, O.B.E., Director, British Geological Survey.*

**This Map and the accompanying report were commissioned and financed by the Department of the Environment,** with support from Grampian Regional Council, Gordon District Council and local industry.

SURVEY DIAGRAM NJ70

Reconnaissance survey by A. Highton and J.W. Merritt, 1984-86

Detailed resurvey (drift) by J.W. Merritt, 1986

*Borehole Graphics drawn by computer using programs written by J.L. McInnes, N.E.R.C. Computer Services, Edinburgh.*

*Produced for the British Geological Survey by Baynefield Carto-Graphics (Edinburgh) Limited*
*Printed by John Bartholomew & Son Ltd, Edinburgh 1988*

*Detailed records may be consulted on application to the Manager, Highlands and Islands Research Programme, British Geological Survey (Scotland), Murchison House, West Mains Road, Edinburgh EH9 3LA.*

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### KEY TO SECTIONS

Potentially workable sand and gravel, continuous or almost continuous deposits, exposed or beneath overburden

Bedrock and waste, including overburden, are uncoloured

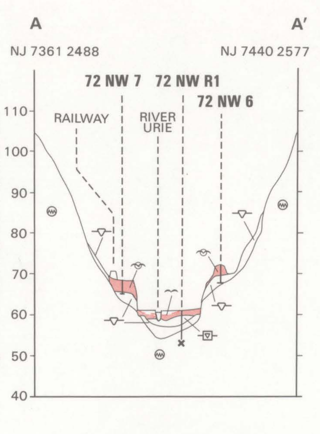
Geological boundary

Inferred boundary limiting the extent of potentially workable material

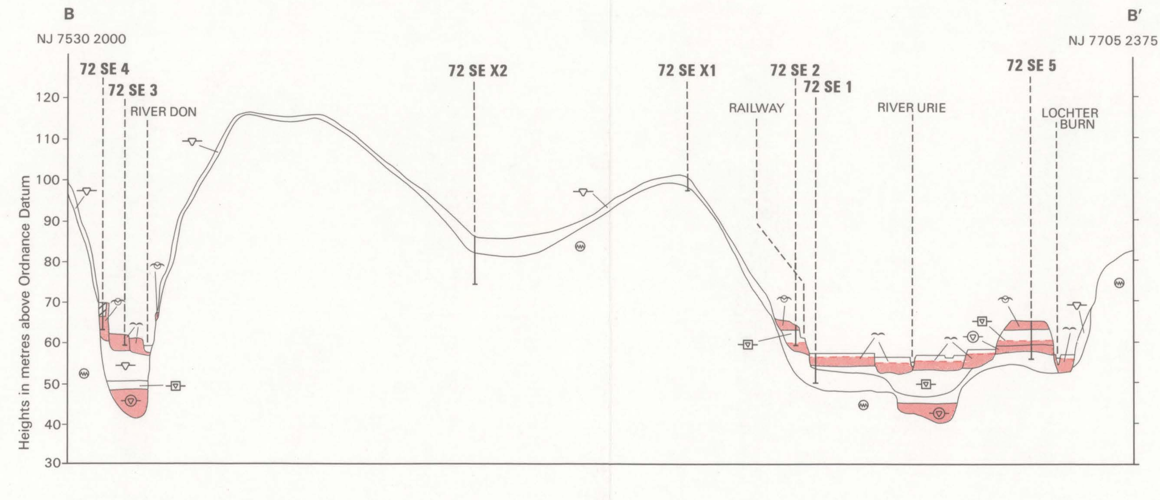
Otherwise symbols and abbreviations as map legend

### GENERALISED HORIZONTAL SECTIONS SHOWING RELATIONSHIPS OF DRIFT DEPOSITS

HORIZONTAL SCALE 1:25 000
VERTICAL EXAGGERATION 20X

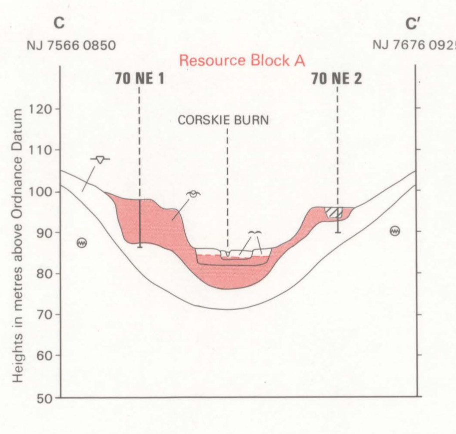



*The valley of the River Urie is flanked by terraced fluvioglacial sand and gravel that tends to fine downwards and also downstream. Fine-grained floodplain alluvium and alluvial gravel rest unconformably on glaciolacustrine silt and clay overlying till filling the bottom of the valley.*

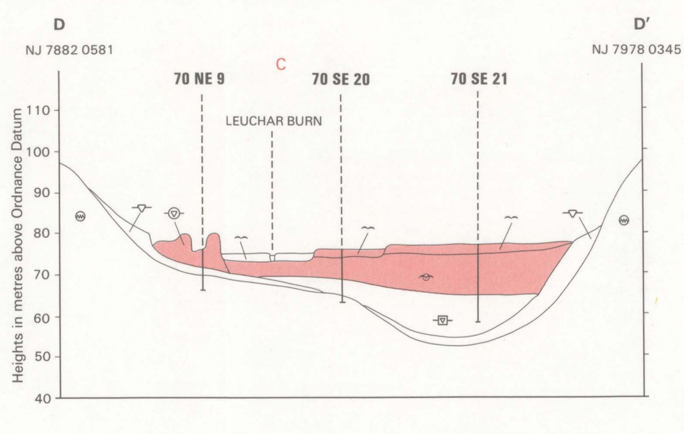



*The deep valley of the River Don is flanked by discontinuous fluvioglacial terraces underlain by coarse, clast-supported gravel. Similar gravel underlies the low-lying alluvial terraces. The bottom of the valley is partly infilled with till, glaciolacustrine deposits and sand and gravel, some of the material almost certainly pre-dating the last glaciation to affect the area.*

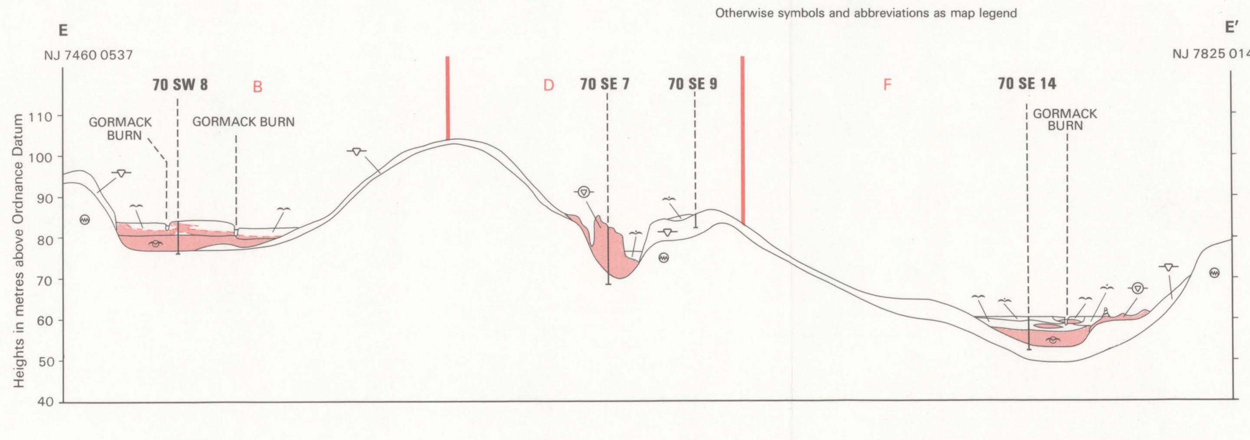
*During deglaciation, the lower reaches of the valleys of the River Urie and the Lochter Burn were occupied by a glacial lake, probably ice-dammed, which stood at about 63m above OD. Glaciolacustrine silt, laminated clay, diamicton and sand and gravel crop out from beneath the fluvioglacial sand and gravel and they also underlie the floodplain alluvium. The fluvioglacial terraces are generally underlain by pebbly sand, probably deltaic in origin.*




*Terraced fluvioglacial sand and gravel flanks the valley of the Corskie Burn, and tends to fine downwards and downstream. Fine-grained floodplain alluvium, peat and alluvial gravel overlie thick deposits of water-saturated, pebbly medium to coarse-grained sand that thicken towards the Loch of Skene. The loch occupies a large kettle-hole.*




*The glacially overdeepened valley of the Leuchar Burn was largely filled with sediment during deglaciation as meltwaters entered by channels from the south-west to form fan-deltas. The terraced deposits lying to the south of the burn typically fine downwards from gravel to finely interlaminated silt and clay. The deposits also fine downstream. The more heterogeneous glacial sand and gravel lying to the north of the burn is moundy, indicating that it was deposited in contact with decaying masses of ice.*




*Peat, fine-grained alluvium and alluvial gravel overlie cleaner, water-saturated pebbly sand of fluvioglacial origin. These deposits accumulated in the glacially scoured depression now traversed by the Gormack Burn.*

*Thick, moundy deposits of glacial sand and gravel choke the north-eastern end of an extensive SW-NE orientated ice-scoured depression that is mainly filled with sediments similar to those described to the left in this cross-section. Meltwaters formerly flowed north-eastwards into the valley of the Leuchar Burn (see section D-D').*

*The glacially overdeepened valley of the Gormack Burn is filled with fluvioglacial deposits, mainly water-saturated, pebbly medium to coarse-grained sand capped by peat and river alluvium. Moundy deposits of glacial sand and gravel bordering the southern edge of the floodplain merge westwards into a sinuous esker (Horsewell Hillocks) that has been largely removed for aggregate.*

## THE SAND AND GRAVEL RESOURCES OF THE AREAS AROUND INVERURIE AND DUNECHT, GRAMPIAN REGION

*This map should be read in conjunction with the accompanying Report which contains details of the assessment of resources*

### EXPLANATION OF SYMBOLS AND ABBREVIATIONS

**Made ground** - waste and/or natural earth materials deposited on the original ground surface

**Made ground** - waste and/or natural earth materials deposited in open-cast workings in bedrock

DRIFT
Recent and Pleistocene

**Peat**

**Alluvium** - silt, clay, sand and gravel

**Alluvial cone** - fan composed of alluvium

**Fluvioglacial sand and gravel** - typically terraced deposits of coarse gravel with medium and coarse sand, moderately to poorly sorted

**Glacial sand and gravel** - typically moundy deposits varying from poorly sorted coarse gravel with coarse and medium sand to well sorted, silty fine sand

**Glaciolacustrine deposits** - fine sand, micaceous silt and clay, often interbedded with clayey till, sometimes laminated, typically olive-brown and olive-grey

**Till** - typically a pale olive grey, firm to stiff, pebbly clayey sand or very sandy clay diamicton with sand and gravel lenses. Local basal grey stony till, very stiff

**Flow-till and mass-flow deposits (not mapped at surface)** - poorly sorted diamictic sand and gravel with a matrix of silty sandy clay

**Morainic drift** - moundy deposits of poorly sorted, angular cobble-gravel with a matrix of clayey sand and silt, interbedded with flow-till and mass-flow deposits.

SOLID

**Bedrock at or near surface** - on sheet **NJ70** bedrock mainly comprises granite or other coarse-grained acid igneous rocks except in the extreme north-east, where metamorphic rocks crop out. The northern half of sheet **NJ 72** is underlain by gabbro, diorite, amphibolite and other coarse-grained basic igneous and metamorphic rocks; metamorphic rocks including schistose grit, psammite and quartzite, mica-schist and quartz-mica-schist, occupy most of the southern half. Both sheets are crossed by felsitic and doleritic dykes.

SAND AND GRAVEL WORKINGS

**Made ground** - waste and/or natural earth materials deposited either on the original ground surface or in man-made workings

**Worked ground** - boundaries as at November 1986

**BOUNDARY LINES**

Geological boundary

Geological boundary coincident with back feature to a terrace

Line marking back feature to a terrace

Inferred boundary between categories of resource

Resource block boundary

Glacial drainage channel, arrow shows direction of water flow

**BOREHOLE AND OTHER DATA SITE LOCATIONS**

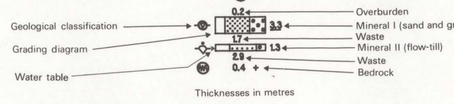
Borehole site

Recorded exposure, sampled

Exposure of decomposed granite potentially workable as sand, not sampled

BGS shallow pit

**BGS BOREHOLES**




**Note:**

(i) Figures underlined denote thicknesses used in the assessment of resources
(ii) The + sign indicates that the base of the deposit was not reached
(iii) The Geological Classification is given only for mineral and bedrock
(iv) When grading data are not sufficiently detailed or are absent the grading diagram is shown without ornament
(v) The surface level of each assessment borehole has been measured, using a surveying aneroid barometer
(vi) A triangle indicates the level in a mineral deposit at which groundwater was first struck; the symbol placed at the top of the grading box may denote that water was encountered in the overlying overburden or waste

**Registration Number**

Each BGS borehole is identified by a registration number, e.g. **70 SE 13**
The first numbers and letters refer to the quarter sheet and the final figures to the BGS serial numbers for that quarter. The unique designation for borehole **70 SE 13,** is **NJ 70 SE 13**

**Grading Diagrams**

Each grading diagram shows the mean particle size distribution of a distinct deposit of mineral

Sand (+1/16–4mm)
Fines (–1/16mm) Gravel (+4mm)

The height of the diagram is proportional to the mineral thickness

The widths of the divisions show the proportions of **Fines**, **Sand** and **Gravel**

**OTHER BOREHOLES**

Site investigation boreholes and wells providing ancillary assessment data are located on the map where space permits. These boreholes are identified by serial numbers prefixed by the letter **X**, and indexed by the numbers and letters of the relevant standard quarter sheet e.g. **72 SE X1**

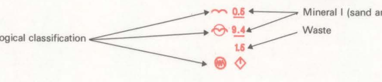
**EXPOSURE RECORDS**

Information from the inspection of exposures is shown in the same way as for BGS boreholes. They are registered in the same series as the boreholes, for example, **70 SW 13**

**SHALLOW PITS**

Where space permits the locations of shallow pits providing ancillary assessment data are shown by a distinctive symbol. Each pit is identified by serial registration numbers e.g. **70 SE 17.** The surface level for each pit has been extrapolated from the contours on the 1:25 000 and 1:10 000 scale topographic maps.

**GEOPHYSICAL DATA**
**RESISTIVITY DEPTH SOUNDINGS**




**Note:**

(i) The depth sounding identification number comprises the alphanumeric code for the quarter sheet e.g. **79 NE** followed by the letter **'R'** denoting a resistivity depth sounding, and the site number e.g. **79 NE R3.** When two or more soundings have been made at the same site, the results have been meaned to produce the values for the thickness of overburden, mineral and waste. The identification number is followed by the letters **'A' 'B' 'C'** etc., which refer to the individual soundings given in the accompanying report ie. the results shown for site **79 NE R3** combine the data from soundings **79 NE R3A** and **79 NE R3B** and are shown as **79 NE R3AB**
(ii) The symbol indicates that the base of the lowest unit (usually bedrock) for which resistivity values have been obtained is below the limit of depth sounding
(iii) Figures underlined denote thicknesses used in the assessment of resources
(iv) Other conventions are as for assessment boreholes

### CATEGORIES OF RESOURCE

**Exposed, potentially workable sand and gravel (mineral I)**

**Continuous or almost continuous spreads of potentially workable sand and gravel beneath overburden**

**Discontinuous spreads of potentially workable sand and gravel exposed or beneath overburden**

**Sand and gravel not assessed**

**Morainic drift containing potentially workable till (mineral II) and some potentially workable sand and gravel (mineral I).**

**Sand and gravel absent or not potentially workable**

**RESOURCE BLOCKS**

For the purpose of assessment, the mineral-bearing land is divided into Resource Blocks (see Report)
Each is designated by a letter.