British Geological Survey

Technical Report WF/90/7

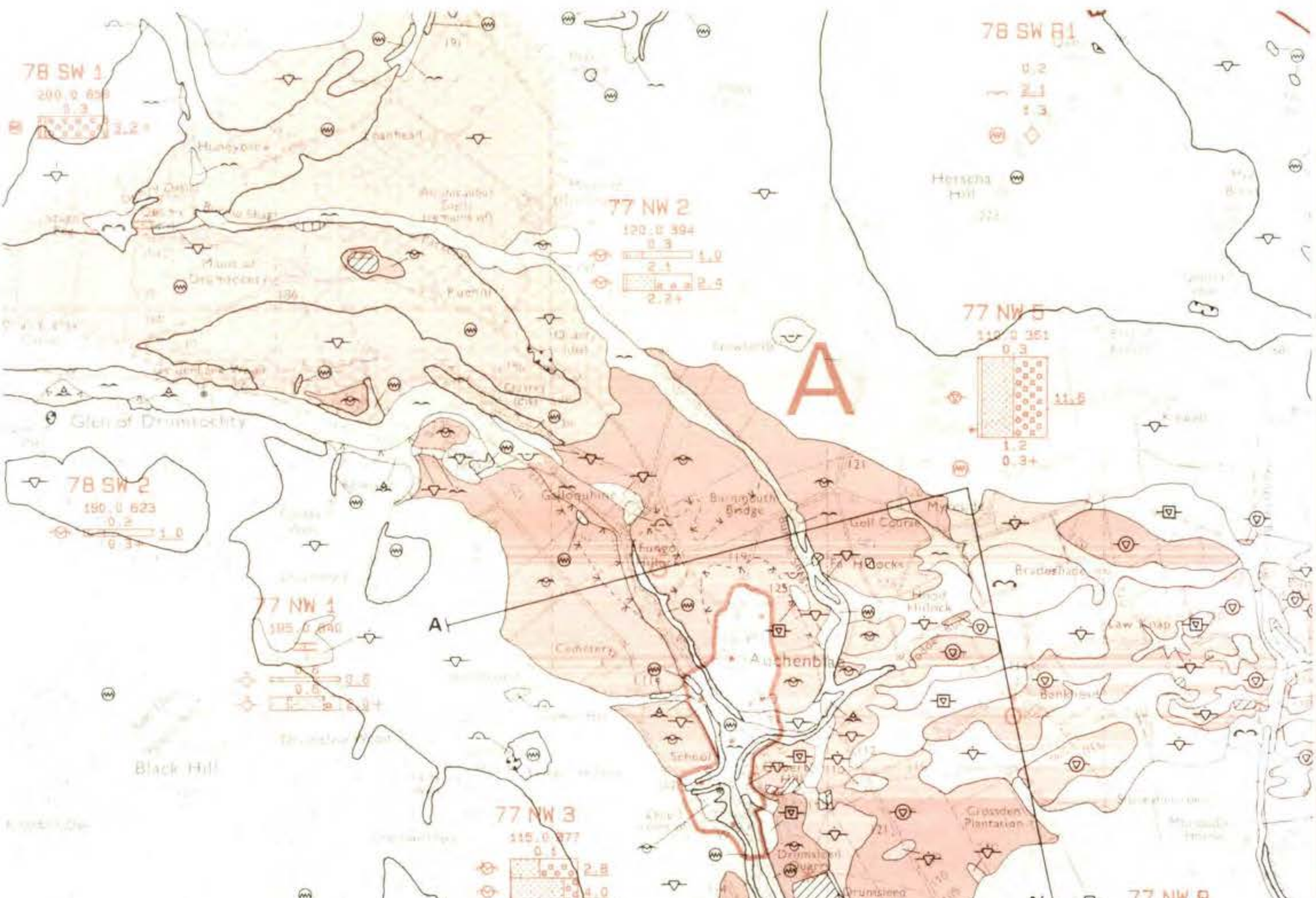
Mineral Resources Series

Sand and Gravel Resources

Parts of NO 68, 69, 77, 78, 87 and 88

Strachan, Auchenblae and Catterline, Grampian Region

Part 1: Report

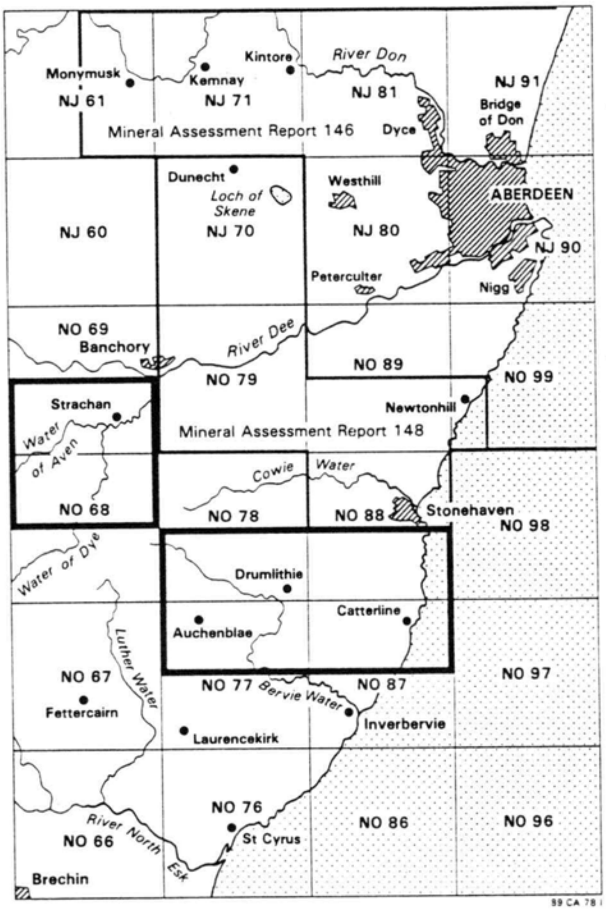


Mineral Assessment Report 149

BRITISH GEOLOGICAL SURVEY

TECHNICAL REPORT WF/90/7

Mineral Resources Series



The sand and gravel resources of the country around Strachan and between Auchenblae and Catterline, Grampian Region

Description of parts of 1:25 000 sheets NO 68, 69, 77, 78, 87 and 88

Part 1: Report

C A Auton, C W Thomas and J W Merritt

Contributor
M G Raines

Mineral Assessment Report 149

Geographical index
UK, NE Scotland, Grampian

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

This report was prepared for the Department of the Environment

Bibliographic reference
Auton, C A, Thomas, C W, and Merritt, J W. 1990. The sand and gravel resources of the country around Strachan and between Auchenblae and Catterline, Grampian Region. *British Geological Survey Technical Report* WF/90/7.

Keyworth, Nottingham British Geological Survey 1990

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Printed in the United Kingdom for the British Geological Survey by Four Point Printing, Chertsey

PREFACE

The extraction of naturally occurring industrial minerals and their use by the building and construction industries are activities that are vital to the UK economy. There is a continuing demand for vast quantities of these materials, and there is a requirement that these non-renewable resources should be available as close to their point of use as practicable in order to minimise transportation costs. The industrial minerals industry provides substantial sums to the exchequer in taxation and it provides jobs, directly and indirectly, for many thousands of people. The extraction of minerals has significant effects on the environment, and calls for sound planning control, which itself requires a knowledge of the distribution of the available resources.

Sand and gravel was identified in the 1960s as the industrial mineral most needing attention and systematic surveys were initiated under the then Ministry of Land and Natural Resources, beginning in south-east England. Since then a total 149 full resource surveys have been carried out by BGS to a standardised model, providing an assessment to a consistent level of confidence.

In the 1980's, the country surrounding Aberdeen was identified as an area of priority planning interest by the Scottish Development Department in discussion with the local authorities. As a consequence BGS was commissioned by the SDD, with funding from the Department of Environment, Grampian Regional Council and local aggregate operators, to undertake sand and gravel resource assessment surveys in the Aberdeen area. This report concerns the third of these surveys, of two areas to the south of Aberdeen. BGS made a substantial financial contribution to this survey because of its own complementary interest in the detailed mapping of the area.

This report describes the resources of sand and gravel of 274 km^2 of country around Strachan, Auchenblae and Catterline 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 1988 and 1989 by C A Auton, J W Merritt and C W Thomas. There was a complementary programme of drilling, trial pit excavation, sampling and aggregate testing in 1989 also involving A J Highton and S Robertson. Geophysical soundings (the measurement of ground resistivity) were taken during the summer of 1989 by C A Auton and M G Raines. The interpretation of the resistivity sounding data was undertaken by M G Raines using a VAX 8600 main-frame computer at BGS Keyworth. The survey was supervised by D I J Mallick, Manager, Highland and Islands Research Group. G C Clarke 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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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 by the British Geological Survey. The style of these reports and their accompanying maps varies 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 also been commissioned recently by the Department of the Environment using universities and the private sector. The resulting 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 Manager, Highlands and Islands Group, British Geological Survey, Murchison House, West Mains Road, Edinburgh EH9 3LA.

Bibliographic reference

AUTON, C.A., THOMAS, C.W. and MERRITT, J.W. 1990. The sand and gravel resources of the country around Strachan and between Auchenblae and Catterline, Grampian Region. Parts of 1:25 000 sheets NO 68, 69, 77, 78, 87 and 88. *Mineral Assessment Report No. 149; British Geological Survey Technical Report* No. WF/90/7.

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Note National Grid references are given in the form [645 887] throughout and relate to places in 100-km square NO.

Typesetting:
Rose Telford, BGS, EDINBURGH

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EXECUTIVE SUMMARY

Detailed geological mapping followed by the drilling of thirty-eight boreholes and the excavation of fifty-five shallow pits by the British Geological Survey, together with the inspection and sampling of thirty-five sand and gravel workings, form the basis of the assessment of sand and gravel resources around Strachan and between Auchenblae and Catterline, Grampian Region. Additional data used include pre-existing site investigation information and the results of twenty-two 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 470 bulk samples of sand and gravel have been collected and graded. Petrological analysis and physical and mechanical testing in the laboratory have been undertaken on representative samples.

A 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 the two accompanying 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 south-east 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 important resources were laid down in close contact with melting ice during the decay of the last ice-sheet to cover the Scottish mainland. They form undulating, kettled spreads together with isolated mounds and ridges. The thickness, lithology and particle size distribution vary considerably and there is often a large proportion of cobbles and boulders, but most of these deposits lie above the water-table and overburden is generally thin. More laterally extensive and lithologically homogeneous deposits of sand and gravel were laid down as terraced spreads within the major valleys, but a larger proportion of these resources are water-saturated and are concealed beneath peat or alluvial overburden. Up to now it has been Scottish practice not to work deposits lying below the water-table.

Less important, but very large resources of potentially workable weathered conglomerate bedrock occur in the Auchenblae-Catterline area. Although some deposits occur *in situ*, most have been glacially re-distributed. The material has limited applications because it is generally very coarse and contains many deeply weathered clasts. In the Strachan area, pockets of weathered, disaggregated granite bedrock are potential sources of clay-bound sand suitable for bedding pipelines and for making unmetalled roads. It was not possible to delineate these resources in detail because of the variability of the weathering they have suffered.

It is concluded that, on the whole, the gravels of the Strachan 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; the latter is predominantly coarse-grained.

In the Strachan resource sheet area, the most extensive resources occur within, and on the southern flanks of the valley of the Water of Feugh; the former are mainly water-saturated, but the latter mainly occur as mounds and ridges lying above the water-table. The total resources of the Strachan sheet are estimated to be 83 million m^3.

There are large resources of gravel in Auchenblae-Catterline area, but the presence of mudstone, friable sandstone and weathered lava could be a serious problem should the material be used in the manufacture of concrete. The sands are not so affected, but many are silty and they would require thorough washing before use. They are predominantly fine to medium-grained and they form potential sources of mortaring, building and asphalting sand.

The sands and gravels in the Auchenblae-Catterline resource sheet area are scattered widely, but the most important resources are concentrated around Auchenblae, Drumlithie and Roadside of Catterline, where they lie mainly above the water-table. The total resources of sand and gravel on the Auchenblae-Catterline sheet are estimated to be 110 million m^3. There are also some 93 million m^3 of weathered conglomerate, but these resources have limited potential.

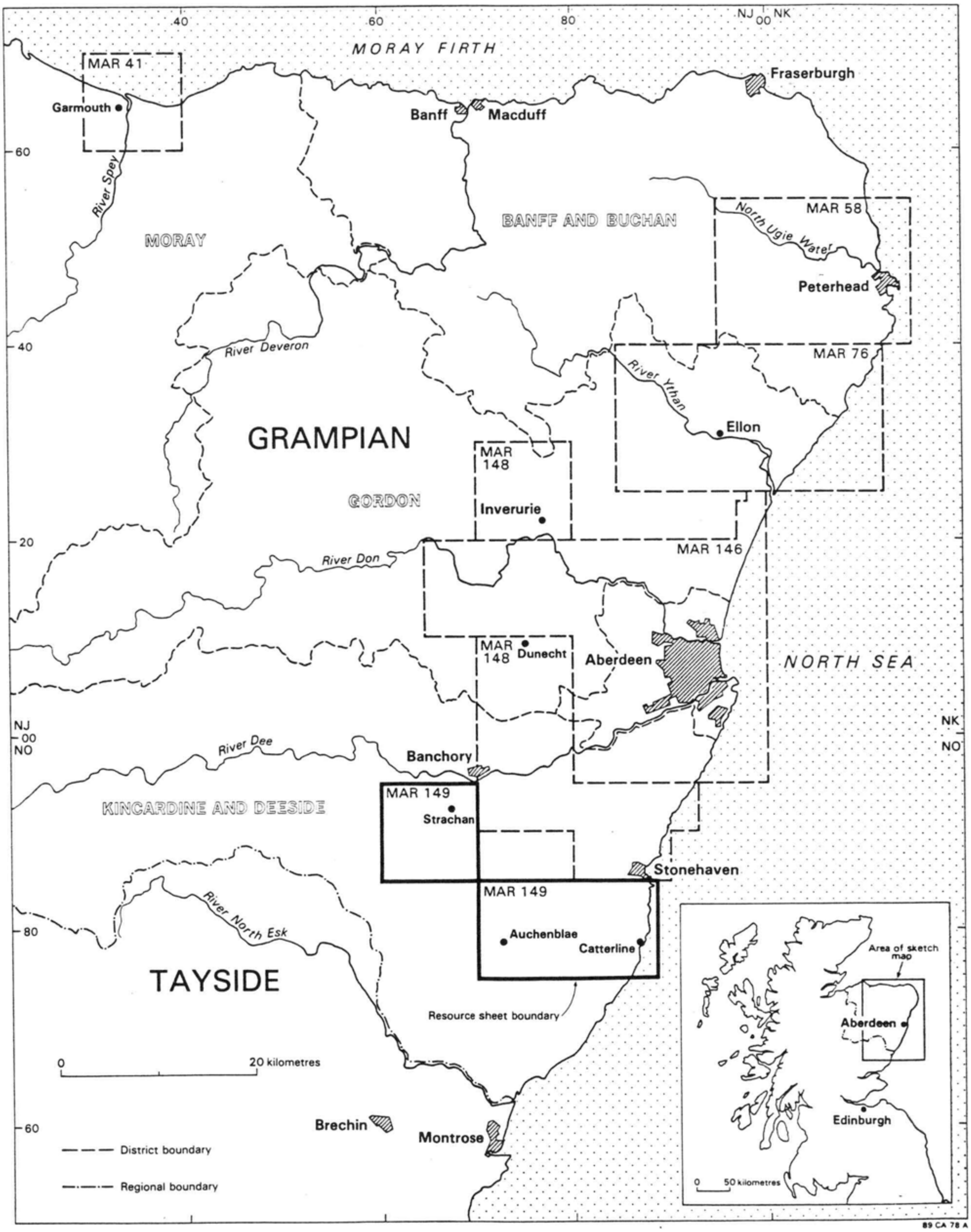


Figure 1. Sketch-map showing the location of the resource sheets

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.

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 (i.e.) particles passing the No.240 mesh BS sieve, about (0.063)mm 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 0.063 mm, 0.25 mm, 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 0.063 mm and 4mm respectively (see Appendix C).

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 in an area of 100 km^2 around Strachan and 174 km^2 between Auchenblae and Catterline (Figure 1) in the Grampian region of North-east Scotland. The sand and gravel resources are shown on two resource sheets, at a scale of 1:25,000. The Strachan resource sheet (Sheet 1) covers 1:10,000

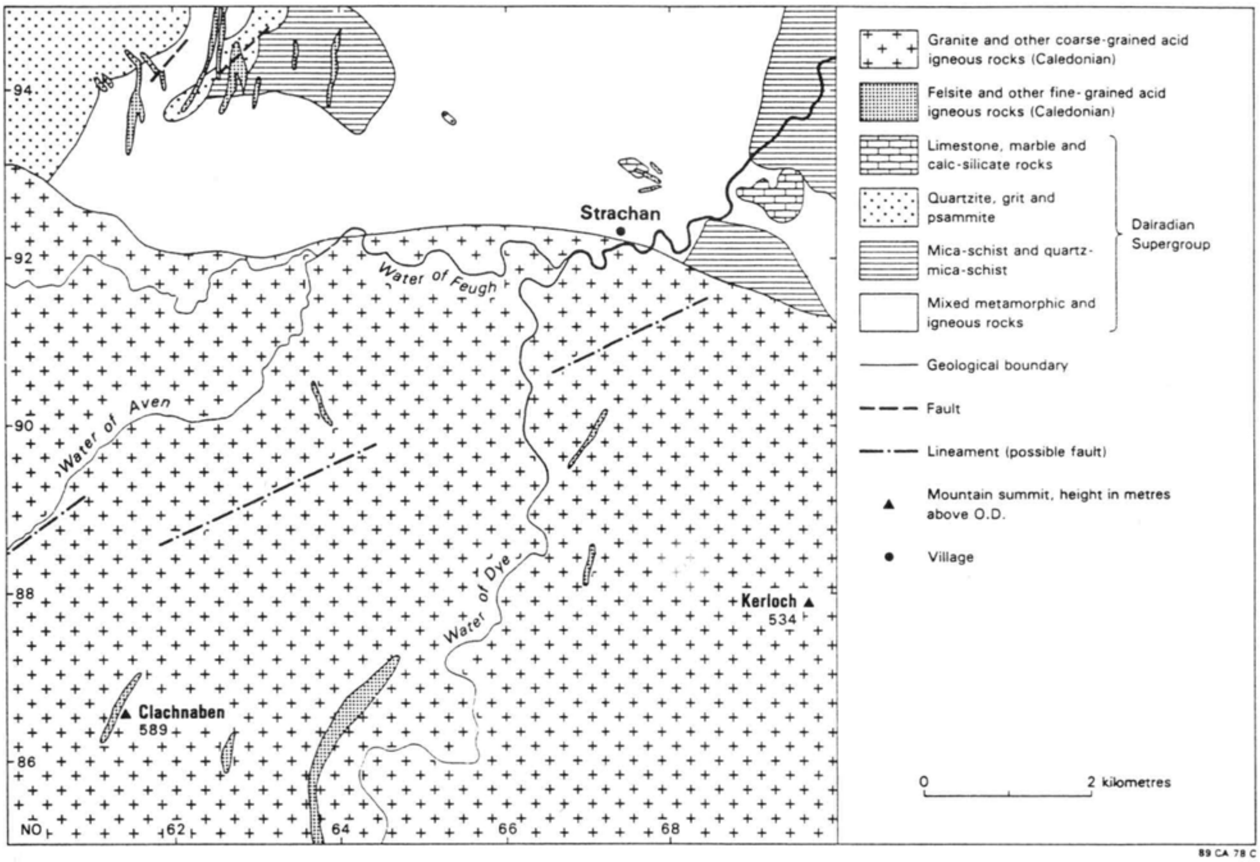


Figure 2. Sketch-map of the solid geology of the Strachan resource sheet

maps NO 68 NW and NE, and NO 69 SW and SE. The Auchenblae-Catterline sheet (Sheet 2) covers 1:10,000 maps NO 77 NW and NE, NO 78 SW and SE, NO 87 NW and NE, and NO 88 SW and SE.

Sheet 1 includes most of the valley of the Water of Feugh and the lower parts of the valleys of its northward flowing tributaries, the Water of Aven and the Water of Dye. The highest point is Clachnaben (+589 m OD) on the interfluve between the valley of the Water of Aven and Glen Dye.

Sheet 2 includes the north-eastern part of Strathmore drained by the Bervie Water and the Carron Water. The ground rises gently north-westwards from the coast towards Leachie Hill (+396 m OD) beyond the northern margin of the survey area. The coastal town of Stonehaven is situated immediately to the north of the area; Inverbervie lies just to the south.

GEOLOGY

Mapping

The ground covered by this survey falls within two 1:50 000 sheets of the Geological Map of Scotland; Sheet 67 (Stonehaven) and Sheet 66 (Banchory). 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 in 1967 and involved only minor further amendment. Only a hand-coloured, solid and drift edition of Sheet 66 (Banchory) dating from 1897 is currently available. Until the present study, the drift geology of the assessment area had not been mapped in detail. A preliminary study of the sand and gravel deposits of Strathmore (Aitken, 1983) collated existing information on the distribution of sand and gravel resources on the Auchenblae-Catterline resource sheet area. This was followed by a rapid reconnaissance survey of 1:10,000 sheets NO 69 SW and SE in 1984-85 (Smith, 1986),during which most of the deposits of potentially workable sand and gravel occurring within the valley of the Water of Feugh were identified. Detailed surveying of the drift deposits at the 1:10,000 scale by C A Auton in 1988 forms the basis of the assessment of the Strachan resource sheet; the drift deposits of the Auchenblae-Catterline resource sheet were surveyed by J W Merritt, C W Thomas and C A Auton in 1988-89.

Publications

There are no Geological Survey memoirs covering the assessment area, but there is one for the adjacent Sheet 77 (Aberdeen) (Munro, 1986). The bedrock geology of much of the ground covered by the Auchenblae-Catterline resource sheet has been described by Campbell (1913) and BGS Report 70/12 describes the Lower Old Red Sandstone of the Strathmore region (Armstrong and Paterson, 1970). An excursion guide to the geology of the Aberdeen area, edited by Trewin and others (1987), provides an up-to-date framework for understanding the solid geology of the remainder of the ground covered in the present study.

The sand and gravel deposits were dealt with by Anderson (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. Mineral Assessment Report No. 148 (Auton, Merritt and Ross, 1988) covers the adjoining area between Banchory and Stonehaven (Figure 1). Other sand and gravel assessment reports in this series are available for the country around Aberdeen (Auton and Crofts, 1986), 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 both districts. A sketch map of the solid geology of the Strachan resource sheet is shown in Figure 2, and one for the Auchenblae-Catterline resource sheet in Figure 3.

The oldest rocks of the district are the Dalradian metamorphic rocks that crop out to the 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 much of the study area. Less resistant metamorphic rocks, such as slate (pelite), schist, gneiss (semipelite) and metamorphosed limestone, are also present; they generally form only a small proportion of the gravel clasts, and they are often deeply weathered. The presence of large amounts of friable metamorphic rock types in sand and gravel can seriously affect the durability of the aggregate.

Table 1 Geological classification of deposits

DRIFT (Quaternary)	Peat
	Scree
	Alluvium
	Alluvial fan
	Lacustrine alluvium
	Present-day beach deposits
	Fluvioglacial sand and gravel
	Glacial sand and gravel
	Glaciolacustrine deposits
	Morainic drift
	Flow-till
	Till
SOLID	
Old Red Sandstone	Conglomerate, sandstone, siltstone, mudstone, basic andesitic lava and tuff
Highland Border Complex	Serpentinised ultrabasic rocks, spilitic lava, chert and mudstone
'Younger Granites' (Caledonian)	Post-tectonic granite
Dalradian Supergroup	Metasedimentary rocks (mainly psammite, pelite, semipelite and calc-silicate rock)

Note: Elements of the drift sequence in the Catterline-Auchenblae area have been subdivided into 'Inland Series' and 'Red Series' on the face of the resource map.

The Dalradian metamorphic rocks have been intruded by coarse- and fine-grained granitic igneous rocks, which are categorised as 'Caledonian', both in Table 1 and in the borehole logs. Kincardine Granite forms most of the bedrock in the southern part of the Strachan resource sheet area and it also crops out in the north-western corner of the Auchenblae-Catterline area. Rounded clasts of this granite are the predominant component of gravels throughout the Strachan assessment area. Granitic rocks have been particularly susceptible to deep weathering, with the result that much of the high ground formed of granite is mantled by several metres of decomposed granitic material.

This deeply weathered rock has been incorporated into the drift deposits throughout the Strachan district and is responsible for their very sandy nature. Most of the coarse- and medium-grained sand in the Strachan resource sheet area is composed of quartz and feldspar derived from granite.

The Highland Boundary Fault crosses the northern part of the Auchenblae-Catterline area and separates the highly deformed Dalradian rocks from the unmetamorphosed rocks that underlie Strathmore. A complex association of rocks, known collectively as the Highland Border Complex, crop out as fault-bounded slices within the fault zone. In the Auchenblae area, the Highland Border Complex includes spilitic pillow lavas, black shales and beds of chert; clasts of these rocks are potentially deleterious, but they form only a minor component of the gravels in the district.

Sedimentary rocks of Silurian and Devonian age form the bedrock to the south-east of the Highland Boundary Fault. These rocks are known informally as the 'Old Red Sandstone' and they occur within a large basin, the Strathmore Syncline. They include conglomerate, sandstone, tuffaceous sandstone, mudstone and thin beds of siltstone. These sedimentary rocks are interstratified with basic andesitic and basaltic lavas and volcanoclastic rocks. Clasts of friable volcanic rocks, derived from the interbedded lavas and tuffs are a major component in many of the conglomerates. Durable clasts of quartzite, psammite, granite and sandstone, derived from conglomerate, form a large component of the gravels in the Auchenblae-Catterline area. Clasts of tuffaceous sandstone, mudstone, siltstone and volcanic rocks may be present in significant amounts, and these rock types often affect the quality of the aggregate adversely.

In places, beds of conglomerate within the Dunnottar, Crawton and Arbuthnott groups of the 'Old Red Sandstone' succession (Figure 3) have been deeply weathered. This weathered conglomerate forms a dense, consolidated gravel, which may be several metres thick and it constitutes a potential source of coarse aggregate. Unfortunately, because these weathered conglomerates can contain a large proportion of unsound clasts of volcanoclastic rocks, the strength of the aggregate is reduced unless they are removed by processing.

Drift (Quaternary) geology

Introduction

The Quaternary history of the study area is given below, together with a systematic description of the drift deposits. A selective glossary of geological terms has been provided. Apart from pockets of deeply weathered granite, which are potential sources of silty coarse-grained sand, and decomposed conglomerate, which is a source of poor quality coarse aggregate, all other known resources of sand and gravel occurring within the area are of Quaternary age. In fact, most of the deposits were formed less than 15,000 years ago at the end of the last glaciation that affected the area. The potentially workable Quaternary deposits include sand and gravel formed by glacial, glaciofluvial and fluvial processes. Glacial deposits such as till and morainic drift, and glaciolacustrine deposits contain some mineral, but most may be regarded as waste. In order to fully understand the nature, form and distribution of the sand and gravel deposits it is important to consider the glacial and post-glacial history of the district in some detail.

The truly '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 consequently more difficult and costly to delineate and to assess than the more extensive spreads of terraced glaciofluvial and fluvial sand and gravel that occur in the major valleys of Scotland, such as the Spey or Dee. In general, the sand and gravel in the Strachan area 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 low-lying terraces, but these deposits are predominantly water-saturated and could only be exploited by dredging, a practice that is not presently favoured in Scotland.

In the Auchenblae-Catterline area, the sand and gravel is more widespread, occurring not only as flat-topped mounds and terraces, but also as linear ridges. Most of these deposits occur above groundwater level, but discontinuous spreads within the alluvium of the rivers are mainly water-saturated.

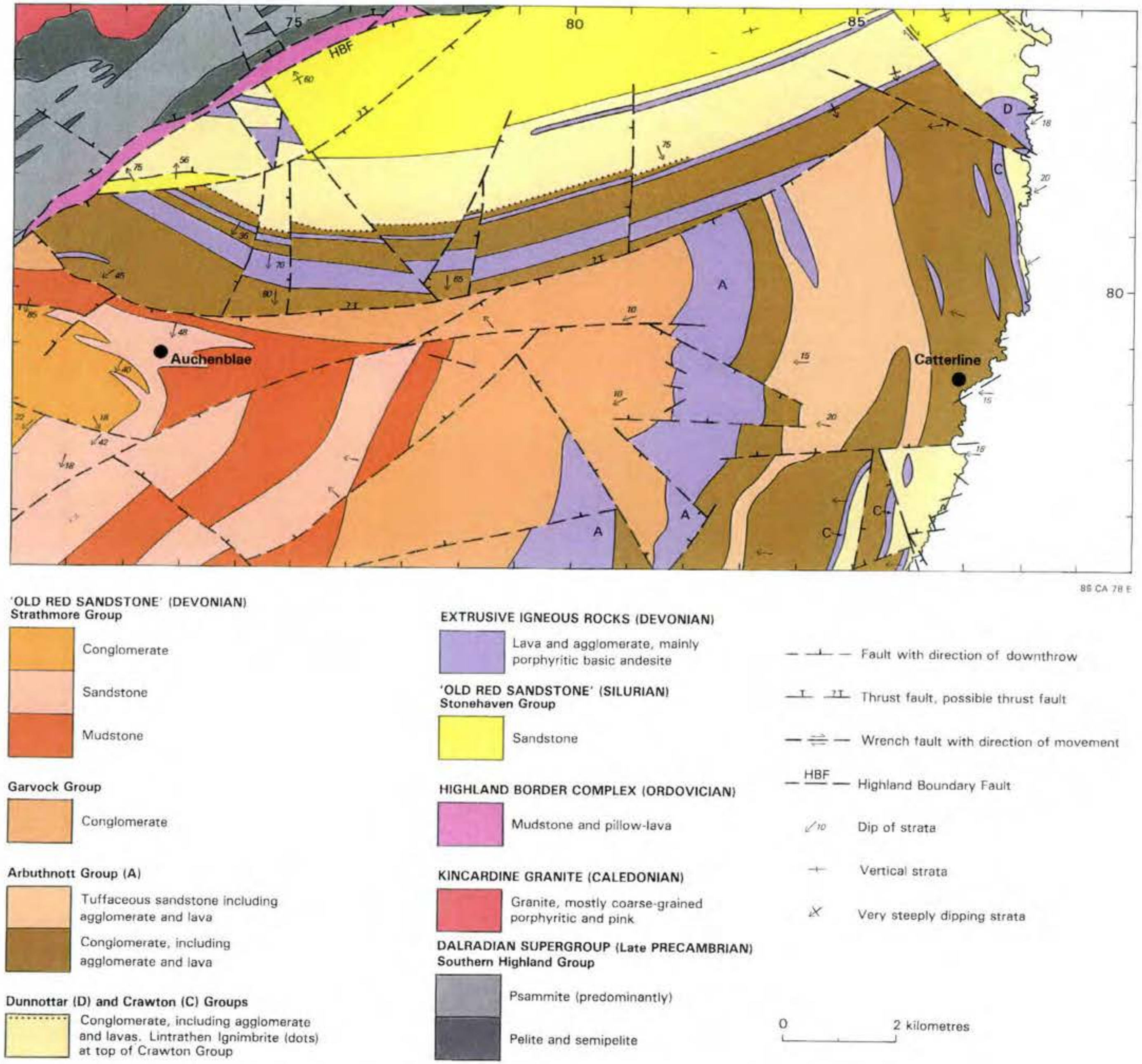


Figure 3. Map showing the solid geology of the Auchenblae – Catterline resource sheet-area

The late-Devensian glaciation

North-east Scotland was glaciated several times during the Pleistocene epoch (1.7 million to 10 000 years ago). These glacial episodes modified the land surface by widening and deepening river valleys, breaching watersheds and polishing and striating outcrops of resistant bedrock. Most of the glacial drift deposits preserved are thought to have formed during the last (Devensian) glacial period, because erosion associated with each successive ice advance largely removed the sediments laid down during previous glaciations.

The late-Devensian ice-sheet reached its maximum extent in north-east Scotland about 18 000 years ago. The Strachan district was covered by ice that flowed eastwards from accumulation centres in the Grampian Highlands. Most of Auchenblae-Catterline district, however, was covered by a separate ice-stream, the Strathmore lobe, which flowed north-eastwards along the south-eastern flank of the Grampian Highlands and then north-north-eastwards along the coast (and off-shore) towards Aberdeen. The former zone of confluence between the Grampian ice-sheet and the Strathmore lobe can be ascertained quite precisely because there are marked differences in the nature of the deposits derived from the two ice masses. Following the practice adopted in Mineral Assessment Report 148, the deposits laid down by the Grampian ice-sheet and those laid down by the Strathmore lobe have been identified as belonging to the 'Inland Series' and 'Red Series' respectively after Hall (1984) and Connell and Hall (1987). The Strathmore lobe produced deposits of till containing abundant erratics of 'Old Red Sandstone' rock-types whereas the Grampian ice-sheet generally yielded deposits containing erratics of metamorphic rocks and granite.

All of the glacial deposits in the Strachan area are of Inland Series type, together with those occurring in the north-western part of the Auchenblae-Catterline assessment area. Most of the glacial deposits in the remainder of the district are of Red Series type. The two suites of deposits are distinguished on the face of the Auchenblae-Catterline resource sheet and the former zone of confluence between the two ice masses can be traced north-eastwards from the vicinity at Saugh Bog [703 805] to Elf Hillock [801 848] at the northern margin of the map.

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. It is clear, however, that after about 18 000 years ago, the higher ground in the district started to become free of ice. The ice-sheet gradually shrank into separate glaciers within valleys that had formed prior to the late-Devensian, especially those that were orientated parallel with the general direction of flow. Continued ice-wastage led to the accumulation of sheets of glacial outwash sand and gravel beyond the margins of the retreating or stagnating ice. Glacial meltwater streams cut complex networks of channels beneath the ice and across the ground that had become deglaciated. Commonly, meltwater became ponded temporarily behind residual masses of ice or barriers of debris left in the main valleys. A large amount of gravel, sand, silt and clay was deposited as fan-deltas in these temporary proglacial lakes.

The Grampian ice-sheet and the 'Inland Series'

The drift deposits of the 'Inland Series' have been derived from the Grampian ice-sheet; they are predominantly yellowish-brown or grey in colour and contain a preponderance of locally derived clasts of igneous and metamorphic bedrock. Although direct evidence for the direction of ice movement, such as glacial striations on exposed bedrock, is scarce, the overall direction of movement appears to have been from west to east, i.e. from the Grampian Highlands and towards the coast. The direction of flow was more variable locally, being governed largely by the local topography.

The 'Inland Series' deposits include stiff, clayey diamicton (boulder clay), friable sandy diamicton, sand, gravel, silt and clay. Moraines formed of very poorly sorted glacial debris were laid down at the ice margins in the valleys during the deglaciation. As the ice melted, morainic material was commonly deposited on top of previously deposited sand and gravel, lodgement till and areas of newly exhumed bedrock. The moundy deposits have been classified as 'morainic drift' and they form ridges that stand up to 20 m above the surrounding ground surface. They are formed of a complex mixture of clayey and sandy diamictons, intercalated with lenses of poorly stratified, often clay-bound, sand and gravel. The material was deposited in contact with glacier-ice with minimal water sorting and it forms both elongate ridges on the flanks of valleys (lateral moraines) and transverse ridges lying across valley-floors (recessional moraines). The latter mark the positions of minor still-stands during the retreat of a valley glacier. Lateral moraines are well-developed on the southern side of the valley of the Water of Feugh in the vicinity of the Moss of Powlair [624 911] and on both sides of the valley of the Burn of Greendams, to the south-west of Rouchan [640 897]; a steep sided recessional moraine, up to 16 m high lies across the valley floor at Rouchanbeg [645 898].

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. Material deposited within subglacial and englacial tunnels now forms sinuous, steep-sided ridges called eskers. The englacial deposits were let down onto the land surface as the ice, in which they were contained, melted. Eskers commonly cut obliquely across the present topography and invariably their internal stratification 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 meltwater streams that flowed between glaciers and ice-free ground on the valley sides. These streams generally deposited coarse outwash material that interdigitates with flow-till. 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 30 m 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 a 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.

Stages of deglaciation in the Strachan area

In the Strachan area, four stages of deglaciation of the Feugh basin have been recognised (Crofts, 1974) based on the distribution of meltwater channels, eskers and kame terraces. The first stage was characterised by active movement of the ice-sheet, which deposited till on the lower-lying ground. Glacial meltwater eroded drainage channels at higher levels on the interfluves; the Slack of Dye and Deil's Oxter drainage channels are good examples (see geomorphology map on the Strachan resource sheet).

The second stage was one of ice stagnation. This was associated with overflow channels and glacial drainage channels that were incised across the lower-lying cols in the area. For example, spreads of fluvioglacial sand and gravel within the valley of the Burn of Brooky were deposited by water derived from melting ice that occupied the upper part of Glen Dye. The meltwater flowed across the col between Craigangower [642 890] and the Ord at Tillyfumerie,towards the centre of the basin, whilst ice blocked drainage along the lower part of the valley of the Water of Dye. The glacial drainage channels within the Den of Tillygarmond were formed at about the same time, and the Tillygarmond and Waulkmill Eskers were laid down by meltwater that drained south-eastwards within ice that covered the adjacent lower-lying ground.

During the third stage of deglaciation, topographic differences were thought to have increasingly influenced the orientation of glacial drainage and the distribution of fluvioglacial deposits in the valley of the Water of Feugh. Most of the eskers that rise above the level of the terraced fluvial deposits in the floor of the valley were formed during this stage, and kame-terraces, such as those at Pitdelphin Wood [654 907], were laid down.

The final stage of deglaciation was accompanied by the melting of blocks of ice buried within fluvioglacial sand and gravel, which produced the characteristic kettled topography of the kame-terraces.

The Strathmore ice-stream and the 'Red Series'

As explained above, there is clear evidence that during the last (Devensian) glaciation at least two ice-streams were confluent in the north-western part of the Auchenblae-Catterline assessment area. The deposits of the Strathmore ice-stream are characteristically of a vivid red-brown colour due to their high content of comminuted sandstone, siltstone and mudstone material derived from the Old Red Sandstone rocks; they 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, sand, gravel, finely-laminated sandy silt and stiff, waxy clay. This suite of deposits was formerly termed the 'Red Clay Series' by Jamieson (1906) and the 'Strathmore Drift' by Bremner (1934a). The term 'Red Series' was introduced by Synge (1956) and adopted by Auton, Merritt and Ross (1988) when they described these deposits in the adjacent Stonehaven area.

The direction of ice-movement, as indicated by glacial striae, erratic trains and ice-moulded bedrock features, was from the south-west towards the north-east. This trend is followed by many of the glacial drainage channels, particularly those crossing the low-lying ground between Drumlithie and the coast. This alignment of drainage channels was first noted by Bremner (1920, 1934b), who postulated that some formed as overflow channels that were eroded during the southward retreat of the Strathmore ice-lobe. Many eskers, such as those at Little Wairds and Fawsyde are also aligned SW-NE (see glacial geomorphology map on the Auchenblae-Catterline resource sheet). The Fawsyde Esker emerges from the Den of Ery drainage channel, indicating lateral change from subglacial erosion to englacial deposition.

The Den of Luckyfeal [813 833] is a particularly fine example of a subglacially formed meltwater channel. It has an undulating longditudinal profile and the meltwater quite clearly was constrained to flow in a north-easterly direction across the interfluve. Site investigation boreholes show that sand and gravel lies at the base of the channel, but that it has been concealed beneath till.

In the western part of the Auchenblae-Catterline area, glacial drainage was directed towards the south and east as the ice that covered the high ground melted and the Strathmore lobe retreated south-westwards and shrank towards the centre of the Strathmore basin. Thick spreads of glacial sand and gravel interbedded with flow-till were laid down close to the margin of the decaying Strathmore ice-lobe; these deposits typically form hummocky topography, as at Candy [704 801], for example, to the east of Drumlithie. Between Auchenblae and Drumlithie, however, the sand and gravel forms a series of E-W trending ridges up to 15 m high. These features are possibly recessional moraines that mark successive retreat positions of the former ice-margin.

Melting of the ice was accompanied by the formation of many temporary lakes, ponded by ice and glacial debris on the low-lying ground. Many of these former lake basins, such as those seen to the south of Auchenblae, are infilled by glaciolacustrine silt and clay capped by thin spreads of alluvial sand and gravel.

The Windermere Interstadial and Loch Lomond Stadial

Deglaciation appears to have been completed in the district by around 12 000 years ago, but glaciers returned to the mountainous areas of Scotland during the subsequent cold period called the Loch Lomond Stadial, which occurred 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 former ice-sheet still blocked drainage in the valleys during this return to a cold climate, but solifluction and mass-wasting certainly caused considerable downslope redistribution of unconsolidated material at this time. This contention is supported by the radiocarbon dating of a bed of peat, intercalated with sandy silt, that was discovered during this survey at Knockhill Wood [7667 8012], on the southern side of the valley of the Bervie Water, south of Glenbervie. The interbedded peat and silt, which is both overlain and underlain by stiff, reddish-brown, clayey diamicton, has yielded ^{14}c ages of 12,460 ± 130BP, 12,305 ±50 BP and 12, 340 ± 50BP. These ages indicate that the peat formed during the comparatively warm Windermere (Lateglacial) Interstadial, as confirmed by pollen analysis (M J C Walker, pers. comm.). This suggests that the diamicton overlying the peat was formed by the mass-movement and resedimentation of till from higher up on the valley side, probably during the Loch Lomond Stadial.

The Holocene

The present warm, interglacial climate commenced at the beginning of the Flandrian Stage (Holocene), around 10 000 BP. Reduction in annual snow melt in the river catchments led to decreased fluvial activity in the valleys. The braided, multi-channel river regime typical of the periglacial climate of the Loch Lomond Stadial changed to the present single-channel, sinuous river regime. As a result of this change the fine-grained floodplain alluvium in the main river valleys commonly conceals gravel deposits

Table 2 Mean gradings of potentially workable deposits; Strachan resource sheet

Deposits	Number of data points* m	Number of samples m	Mean grading percentage (sizes in mm) Fines -.063	Fine sand .063-.25	Medium sand .25-1	Coarse sand 1-4	Fine gravel 4-16	Coarse gravel 16-64	Cobbles and boulders +64
Fluvioglacial sand and gravel	27	101	4	7	24	30	16	11	8
Glacial sand and gravel	14	32	3	3	15	27	15	19	18
Alluvial fan deposits	4	8	6	4	15	22	14	21	18
Alluvium	10	15	6	6	19	25	15	20	9
Morainic drift	5	7	2	2	13	21	15	13	34
Potentially workable till	5	6	16	11	20	24	15	10	4
Decomposed Granite	5	5	9	6	16	35	28	5	1

* Including assessment boreholes, trial pits and measured sections

Table 3 Mean gradings of potentially workable deposits; Auchenblae-Catterline resource sheet

Deposits	Number of data points*	Number of samples	Mean grading percentage (sizes in mm) Fines -.063	Fine sand .063-.25	Medium sand .25-1	Coarse sand 1-4	Fine gravel 4-16	Coarse gravel 16-64	Cobbles and boulders +64
Glacial sand and gravel	43	215	8	25	26	12	13	13	3
Fluvioglacial sand and gravel	8	30	4	7	37	21	17	12	2
Alluvium	7	2	7	6	11	14	22	27	13
Weathered Conglomerate Bedrock	8	14	7	11	14	10	20	27	12

* Including assessment boreholes, trial pits and measured sections

that were deposited earlier by braided-rivers. The youngest superficial deposits include alluvium associated with the present drainage, blanket peat on the high ground, and beach deposits. Spreads of lacustrine alluvium and peat underlie marshy ground within the sites of former lochs. The lacustrine alluvium generally comprises finely interbedded silt, clay and fine-grained sand, and often overlies laminated, silty glaciolacustrine deposits. Shingle beaches occur in the sheltered bays and havens along the coast.

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. 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 4 and 5. 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.

Mean grading data for seven mineral-bearing deposits in the Strachan resource sheet area are given in Table 2 and Figure 4. Mean grading data is included separately for potentially workable till (Mineral II) and morainic drift; the latter is classified as Mineral I.

The mean particle size distributions (gradings) of the four principal mineral-bearing deposits of the Auchenblae-Catterline resource sheet area are given in Table 3 and Figure 5. The mean grading for workable bedrock derived from weathered Old Red Sandstone conglomerate (Mineral II) is also given.

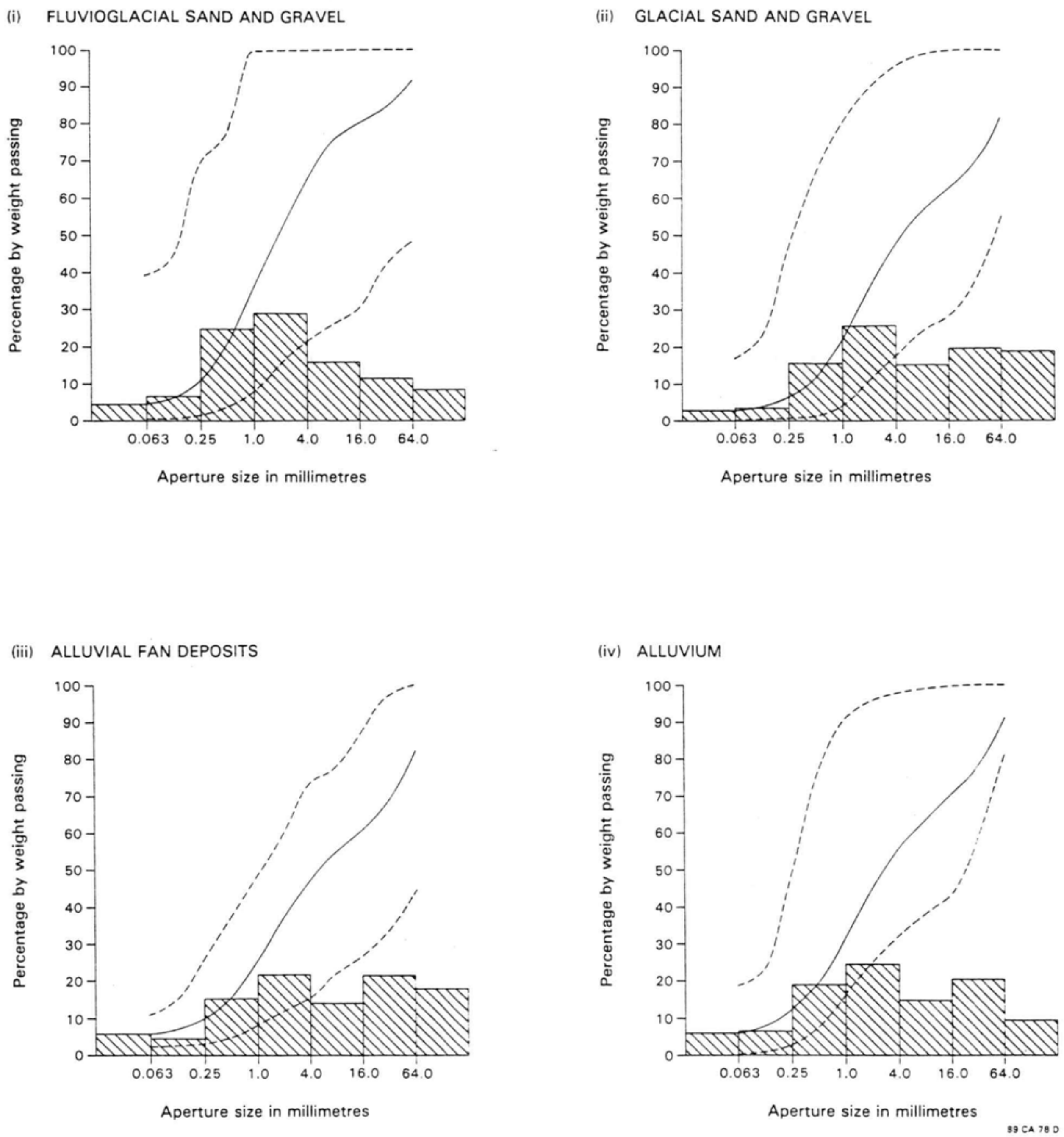
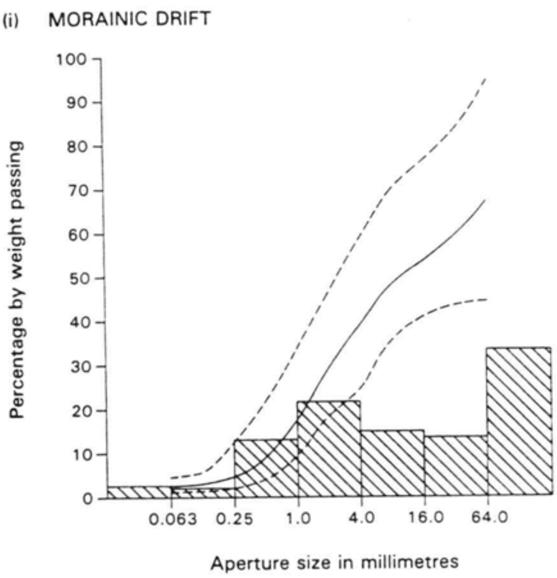
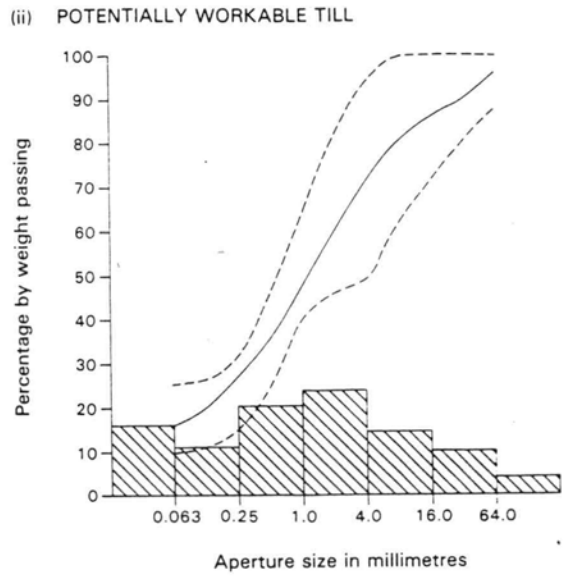


Figure 4a. Mean grading characteristics of potentially workable fluvioglacial sand and gravel, glacial sand and gravel, alluvial fan deposits and alluvium; Strachan resource sheet





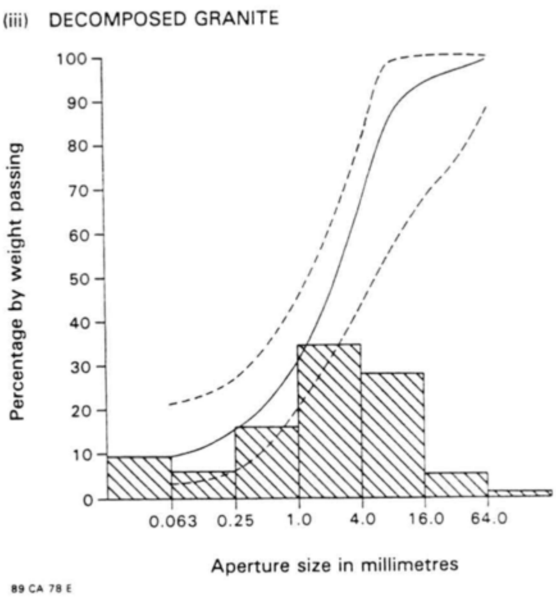


Figure 4b. Mean grading characteristics of potentially workable morainic drift, till and decomposed granite; Strachan resource sheet

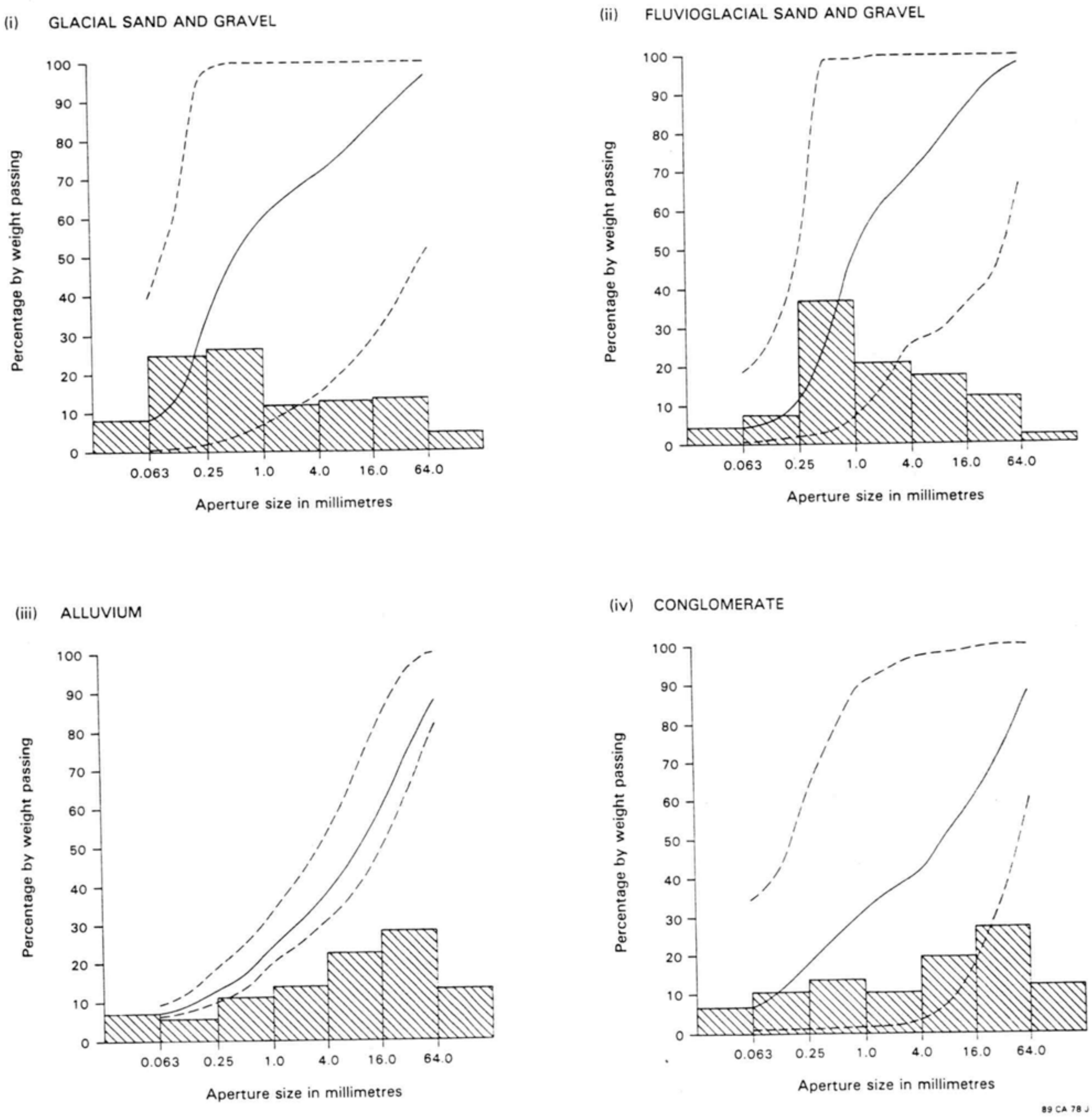


Figure 5. Mean grading characteristics of potentially workable glacial sand and gravel, fluvioglacial sand and gravel, alluvium and decomposed conglomerate; Auchenblae/Catterline resource sheet

In order to have sufficient material for the mechanical and physical tests and lithological analysis, samples from more than one sample point were amalgamated, giving 19 composite samples. The mechanical and physical tests and the lithological analyses were carried out on the 10-14 mm size fraction. The source of each composite sample is shown in Table 4. In general, each composite sample represents a group of deposits that are regarded as being geologically or geomorphologically similar.

The mechanical and physical tests are described in the next section.

Lithological analyses (pebble-counts) were conducted on 13 of the 19 composite samples taken from assessment boreholes, pits and working quarries in the two resource sheet areas. The rock classification scheme used for the pebble-counts is shown in Table 5; it is similar to that used in Mineral Assessment reports 146 and 148 for adjoining assessment areas to the north around Aberdeen, although the names for each group based on a single rock type have been omitted. In using this classification scheme, comparison can be made between the clast lithologies of similar mineral deposits from all the resource sheets in the Aberdeen area. 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, *Group 2* 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 F.

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 samples	Boreholes and pits from which samples were taken	Depth range (m)
STRACHAN RESOURCE SHEET				
Glen Dye	1	Fluvioglacial sand and gravel	NO 68 NW 2	0.1 - 3.1
			NO 68 NW 3	2.5 - 4.8
			NO 68 NW 4	0.3 - 2.4
			NO 68 NE 2	0.0 - 2.7
			NO 68 NE 7	0.3 - 9.1
Bogarn	2	Fluvioglacial sand and gravel	NO 68 NE 1	0.4 - 16.7
			NO 69 SE 5	0.1 - 12.5
			NO 69 SE 8	0.2 - 19.6
			NO 69 SE 24	0.4 - 4.8
Water of Feugh/ Water of Aven (sub-block B1)	3	Alluvial and fluvioglacial sand and gravel	NO 69 SW 1	0.3 - 17.0
			NO 69 SW 9	0.4 - 5.4
			NO 69 SW 13	0.9 - 3.0
			NO 69 SW 15	0.3 - 2.7
			NO 69 SW 19	0.4 - 2.1
			NO 69 SW 20	0.3 - 6.1
Tillygarmond/ Waulkmill/Pitdelphin eskers	4	Glacial sand and gravel with abundant clasts of metamorphic rocks	NO 69 SW 23	0.1 - 1.5
			NO 69 SW 24	0.1 - 4.6
			NO 69 SW 25	0.4 - 3.6
			NO 69 SW 27	0.1 - 2.7
			NO 69 SE 6	0.2 - 5.2
			NO 69 SE 7	3.1 - 4.6
Valley of the Water of Feugh/Rouchan eskers	5	Glacial sand and gravel with abundant clasts of granite	NO 69 SW 6	0.3 - 5.0
			NO 69 SW 8	0.1 - 2.1
			NO 69 SE 9	0.2 - 5.3
			NO 69 SE 11	0.4 - 4.4
			NO 69 SE 14	0.3 - 10.3
			NO 69 SE 16	0.3 - 4.5
Water of Feugh alluvium and terraces (sub-block B2)	6	Alluvial and fluvioglacial sand and gravel	NO 69 SW 21	0.3 - 8.9
			NO 69 SE 2	0.2 - 10.1
			NO 69 SE 3	0.3 - 2.3
			NO 69 SE 10	0.3 - 3.1
			NO 69 SE 13	0.4 - 2.7
Cammie Mill area	7	Glacial and fluvioglacial sand and gravel	NO 69 SE 12	0.2 - 5.8
			NO 69 SE 15	0.4 - 1.5
			NO 69 SE 16	0.0 - 6.5
			NO 69 SE 17	0.1 - 10.0
			NO 69 SE 19	0.0 - 5.0
			NO 69 SE 21	0.0 - 12.8
			NO 69 SE 22	0.0 - 4.5
			NO 69 SE 23	0.2 - 1.1

AUCHENBLAE-CATTERLINE RESOURCE SHEET

Auchenblae	8	Fluvioglacial and alluvial sand and gravel	NO 77 NW 2 NO 77 NW 3 NO 77 NW 4 NO 77 NW 6 NO 77 NW 7	0.3 - 5.8 0.1 - 7.4 1.3 - 9.4 0.4 - 4.7 1.5 - 2.4
Bomershanoe Wood	9	Glacial sand and gravel	NO 77 NW 8	0.3 - 4.5
Bankhead - East Mondynes belt	10	Glacial sand and gravel	NO 77 NW 5 NO 77 NW 9 NO 77 NW 10 NO 77 NE 1 NO 77 NE 5	0.3 - 11.9 0.2 - 6.6 0.9 - 20.6 0.2 - 23.2 0.9 - 2.7
Fordoun - Kair area	11	Fluvioglacial sand and gravel	NO 77 NW 11 NO 77 NE 3	0.3 - 7.1 0.5 - 2.5
Pitdrichie area and Little Wairds Esker (Eastern marginal belt and eskers)	12	Glacial sand and gravel	NO 77 NE 16 NO 77 NE 17 NO 78 SE 6 NO 78 SE 7 NO 78 SW 2	0.3 - 4.2 0.2 - 4.8 0.3 - 3.6 4.5 - 17.3 19.0 - 20.0
Drumlithie area (Central body)	13	Glacial sand and gravel	NO 77 NE 10 NO 78 SE 8 NO 78 SE 9 NO 78 SE 10	1.8 - 3.7 0.0 - 5.4 3.1 - 12.2 1.3 - 12.8
Glenbervie (alluvial deposits)	14	Alluvial sand and gravel	NO 78 SE 1 NO 78 SE 2	0.5 - 3.5 0.3 - 2.3
Greenden	15	Glacial sand and gravel	NO 87 NW 2 NO 87 NW 3	0.2 - 3.3 0.1 - 5.3
Catterline area	16	Glacial sand and gravel	NO 87 NE 1 NO 87 NE 2 NO 87 NE 3 NO 87 NE 4 NO 87 NE 5	0.1 - 2.8 0.3 - 4.5 0.4 - 6.1 0.3 - 4.0 0.2 - 10.4
Auquhirie	17	Glacial sand and gravel	NO 88 SW 1 NO 88 SW 3 NO 88 SW 4 NO 88 SW 5 NO 88 SW 6 NO 88 SW 7	0.9 - 1.9 0.1 - 3.8 0.0 - 3.7 0.2 - 3.8 0.2 - 8.3 6.2 - 11.2
Criggie	18	Glacial sand and gravel	NO 88 SW 8	0.3 - 10.0
Lochburn - Newtonleys	19	Conglomerate, ice-disturbed	NO 88 SE 1 NO 88 SE 2	0.3 - 3.8 0.2 - 3.5

The results of the petrological analyses are given in Table 6. It is quite clear that rocks of *Group 2* predominate in all but one of the samples analysed from the Strachan area, with the bulk of the clasts being made up of granitic lithologies. In contrast, the samples from the Auchenblae-Catterline area are dominated by tough sandstones, grits and psammites, but also contain much higher quantities of highly weathered and other deleterious rocks (*Group 1).*

In both resource sheet areas the main accessory rock types are generally volcanic rocks from *Groups 4* and *5* with schistose rocks (*Group 7*) being abundant locally. Cryptocrystalline siliceous rocks are rare.

Strachan sheet

Fluvioglacial sand and gravel

Much of the potentially workable sand and gravel in the Strachan area occurs within the flat-topped mounds and terraced spreads of fluvioglacial sand and gravel that flank the Water of Feugh and its tributaries; fluvioglacial deposits also commonly underlie floodplain alluvium and form kettled terraces up to 25m high. The fluvioglacial sand and gravel has a mean grading of 4 per cent fines, 61 per cent sand and 35 per cent gravel (sandy gravel). However, there is relatively wide variation in gradings between individual sample points, as is shown by the broad envelope in Figure 4a(i), indicating considerable local variation in the deposits.

The fluvioglacial deposits occur characteristically in multiple coarsening-upwards sequences. Individual units are generally moderately well-sorted and often well-bedded, often with low angle cross-stratification. Overall, the deposit is medium to coarse-grained, with a poorly developed mode in the coarse sand

Table 5 Lithological classification of pebbles used in this report

Toughness	Composition	Fissility	Grain Size	Colour	Group
Friable					1. Mudstone, shale, coal, poorly-cemented sandstone, badly weathered igneous or metamorphic rocks
Tough	Silicate		Coarse to medium-grained rocks	pale	2. Granite, granodiorite, syenite, pegmatite, vein-quartz, quartzite, coarse-grained sandstone, arkose, psammite, gneiss
				dark	3. Gabbro, norite, diorite, coarse-grained greywackes and metagreywackes
		Homogeneous or banded but not fissile	Medium to fine-grained rocks (disregarding phenocrysts or porphyroblasts)	pale	4. porphyries, aplite, felsite, rhyolite, trachyte, pale hornfels, calc-silicate rock, fine-grained sandstones
				dark	5. basalt, andesite, serpentinite, microdiorite, lamprophyre, fine-grained greywackes and metagreywackes, semipelite, dark hornfels, dolerite, amphibolite
			Crypto-crystalline		6. chert/and silicified rocks
		Fissile rocks	Coarse to medium-grained rocks		7. mica-schist, quartz-mica-schist, hornblende-schist
			Fine-grained rocks (disregarding porphyroblasts)		8. Slate, phyllite
	Non-silicate				9. Limestone, dolomite, marble, ironstone
Tough rocks known to be deleterious in concrete					10. Rocks known to shrink in concrete e.g. some greywackes. Rocks which react with cement e.g. those containing pyrite or sulphates

fraction. In the samples graded, fine and coarse gravel constitute, by weight, 16 per cent and 11 per cent of the material respectively; cobbles account for 7 per cent.

The most extensive fluvioglacial deposits occur in the vicinity of Cammie Wood (Table 4, sample 7), forming kettled topography, and in the vicinity of Bogarn (Table 4, sample 2) where kettled outwash mantles the interfluve between the Water of Dye and the Burn of Strathy. The gravel from the Cammie Wood deposits is composed mainly of angular to subangular clasts of granitic rocks with lesser amounts of quartzite, psammite and vein-quartz; clasts of schist, porphyry, felsite and highly weathered rocks, chiefly of volcanic origin, are also common. Granitic material constitutes the bulk of the gravel from the Bogarn area, with a lesser amount of porphyry and felsite.

Significant quantities of fluvioglacial sand and gravel also occur beneath the floodplains and low-lying terraces in the valleys of the Waters of Feugh and Aven (Table 4, samples 3, 6). The clasts in these gravels are dominated by granitic rocks with significant proportions of porphyry and felsite.

Gravel from fluvioglacial deposits in Glen Dye (Table 4, sample 1) has much the same composition as that from deposits in the valley of the Water of Feugh.

Glacial sand and gravel

Deposits classed as glacial sand and gravel are much less extensive than the fluvioglacial deposits on the Strachan sheet. They are generally restricted to esker ridges composed of complex sequences of sand and gravel which vary greatly in composition and grading, both laterally and vertically; for the most part, the deposits are poorly sorted and stratified.

The overall grading of samples of glacial sand and gravel is 3 per cent fines, 52 per cent sand and 49 per cent gravel (Figure 4a(ii)). The

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

		STRACHAN SHEET							AUCHENBLAE-CATTERLINE SHEET					
Composite sample number		1	2	3	4	5	6	7	10	12	13	15	16	17
Lithological Group	Rock Types													
1	Mudstone friable sandstone and highly weathered rocks	-	0	0	7	**	3	15	9	39	29	20	30	41
2	Granite and granodiorite	92	79	77	18	76	69	37	1	**	3	1	1	2
	Vein quart and pegmatite	2	4	2	42	5	2	15	11	9	4	7	9	11
	Psammite, quartzite and non-friable sandstone	1	1	**	7	1	3	6	52	31	46	33	5	7
	Group: undivided	95	84	79	67	82	74	58	64	40	53	41	15	30
3	Norite, diorite and gabbro	-	**	**	7	2	1	4	-	1	1	-	2	-
4	Porphyry and felsite	5	14	20	9	15	21	11	5	1	3	10	25	4
5	Andesite, basalt, dolerite and amphibolite	**	1	1	3	**	1	1	13	14	10	25	25	22
6	Chert and silicified rocks	-	-	-	-	-	-	-	-	2	**	2	2	1
7	Mica-schist, quartz-mica schist and hornblende-schist	-	1	**	7	-	**	11	5	3	4	2	1	2
8	Slate, phyllite	-	-	-	-	-	-	-	-	**	-	-	-	-
10	Rocks known shrink in concrete, eg. some greywackes	-	-	-	-	-	-	-	4	-	-	-	-	-
Number of pebbles counted		815	458	452	267*	477	544	611	420	436	379	368	372	332
Angularity		a-sr	a-sr	a-sr	a-sr	a-sr	a-sr	a-sr	a-sr	a-sr	a-sr	a-sr	a-sr	a-sr

* Total sample counted

** Trace amounts (less than 0.5 per cent)

a = angular sr = subrounded

Results are given as frequency percent

higher proportions of coarse and cobble gravel serve to distinguish the glacial sand and gravel from deposits of fluvioglacial origin.

Based on the lithology of the contained clasts, two suites of eskers are recognised in the Strachan area. Gravel from the Tillygarmond, Waukmill and Pitdelphin eskers (Table 4, sample 4) is characterised by a high proportion of quartzite and psammite. In contrast, gravel from the eskers in the valley of the Water of Feugh and in the vicinity of Rouchan are composed chiefly of granitic clasts with moderately abundant amounts of porphyry and felsite.

Alluvial fan deposits

Most of the alluvial fan deposits on the Strachan sheet are composed of clast-supported sand and gravel with well-developed, subhorizontal stratification. The deposits have a mean grading of 6 per cent fines, 41 per cent sand and 53 per cent gravel (Figure 4a(iii)). The material is moderately well-sorted and is somewhat coarser than other alluvial deposits in the area. No composite samples were prepared specifically to represent the alluvial fan deposits, but some material was included in composite sample 3 (Table 4). The gravel from the alluvial fan deposits in the valley of the Water of Aven is composed predominantly of granite, whereas alluvial fan gravels from the valley of the Water of Feugh contain significant amounts of psammite and quartzite.

Alluvium

Most of the river alluvium on the Strachan sheet comprises thin spreads of sand and gravel overlying coarse fluvioglacial gravel. However, lacustrine alluvium and floodplain alluvium of the smaller tributary streams is composed largely of sand, silt and clay. The mean grading of samples of the alluvium is 6 per cent fines 50 per cent sand and 44 per cent gravel (Figure 4a(iv)). The lithological composition of the gravel in the alluvium is the same as the underlying fluvioglacial deposits (Table 4, samples 3,6); the alluvium is distinguished from the fluvioglacial deposits by being slightly more clayey and pebbly.

Morainic drift and potentially workable till

Large amounts of low grade, heterogeneous sand and gravel in the form of morainic drift occur to the south of the valley of the Water of Feugh on the Strachan resource sheet. The material, which is generally delineated on the basis of landform, is typically very poorly sorted and slightly cohesive. The mean grading is given in Table 2 and the grading curve in Figure 4b(i). It contains a large proportion of subangular cobble and boulder-grade material composed mainly of granite. The deposits are composed mainly of multiple sequences of matrix-supported diamictons that merge locally into clast-supported cobble- and boulder-gravel. 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 are present in places.

Potentially workable till can be regarded as the sandy end-member of the suite of glacially deposited diamictons that blanket the Strachan area. It is generally more compact than morainic drift and contains more fines. It has proved impracticable to delineate potentially workable till, hence no assessment of volume is attempted for this category of mineral.

Grading data for the morainic drift and potentially workable till in the Strachan resource sheet area are shown graphically in Figure 4b(i) and 4b(ii). Both types of deposit are poorly sorted, the former containing 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 more gravelly and less clayey than the till.

Potential sources of coarse gravel within the morainic drift occur on the southern flank of the valley of the Water of Feugh, around Blackhole and Moss of Powlair, and on the eastern side of the Water of Aven, north of Ord of Cuttieshillock. Apart from isolated pockets of workable material, the remaining morainic drift is too clayey or contains too much cobble- or boulder-grade material to be considered as a potential resource.

Weathered granite

The Kincardine Granite underlies most of the southern part of the Strachan resource sheet (see Figure 3). The rock is deeply weathered at the surface locally and, in such a condition, it constitutes potentially a very large resource of sharp, slightly cohesive coarse-grained sand and gravel. The material grades generally as 'clayey' pebbly sand (Table 2, Figure 4b(iii)) and has proved to be ideal for bedding pipe-lines and for constructing footpaths and tracks. The material is best worked intermittently, leaving the rock to become disaggregated by allowing it to weather over winter.

Auchenblae-Catterline sheet

Glacial sand and gravel forms the bulk of the resources on this sheet, though fluvioglacial sand and gravel forms a significant resource in the vicinity of Auchenblae. Fluvioglacial sand and gravel is distinguished from glacial sand and gravel on the basis of geomorphology rather than composition or grading. Alluvium forms minor patchy resources, but these commonly contain much >64mm material, are relatively rich in fines and occur close to, or beneath, the water-table. Weathered conglomerate bedrock occurs over a significant area of the sheet and is a potential resource, particularly of coarse gravel. However, it generally contains appreciable amounts of cobbles and boulders.

Glacial sand and gravel

Important resources of glacial sand and gravel occur in a north-south belt to the east of Drumlithie, in a belt extending north from Temple [8515 7652] to the ground north-west of Denhead [8650 7957] and in a series of ridges and mounds extending eastwards from Auchenblae to the ground around East Mondynes [7785 7950]. The grading characteristics show that the deposits are dominated overall by fine and medium-grained sand with equal amounts of coarse-grained sand and fine and coarse gravel (Table 3, Figure 5(i)). However, data for individual sample points indicate great variation in grading of the deposit, even where sample points are closely spaced.

Lithological analysis shows that the gravel fraction contains a wide range of rock types (Table 6, samples 10-17); most are dominated by quartzite or by volcanic rocks. The majority of the lithologies are derived from the underlying Old Red Sandstone bedrock, though clasts representing the metamorphic rocks to the north of the Highland Boundary Fault are not uncommon; schists and metamorphosed grits are the most abundant. The sand fraction contains quartz, feldspar, rock fragments and mica in varying quantities.

Many of the igneous clasts are severely weathered and these, along with subordinate quantities of other weathered rocks, constitute at least 20 per cent of the gravel in samples 12-17. The presence of the weathered clasts significantly affects the strength of the aggregate; this is discussed further in the section on Mechanical and Physical Properties.

Fluvioglacial sand and gravel

The only extensive deposit of fluvioglacial sand and gravel occurs around Auchenblae, where it flanks the valley of the Luther Water in terraces; the deposit is predominantly medium-grained (Table 3, Figure 5ii). Though not analysed in detail lithologically, gravel examined in the field during the sampling programme reveals that it is similar to that in the glacial sand and gravel, but with more abundant schist and grit from the Dalradian rocks to the north of the Highland Boundary Fault.

Alluvium

Only two bulk samples of alluvium were recovered during the sampling programme due to problems with large cobbles and boulders; coarse gravel is the dominant fraction (Table 3, Figure 5iii). However, the deposit is likely to vary widely in terms of the grading and the data presented should not be considered representative of the deposit as a whole. Examination of the gravel fraction in the field shows that the alluvium has broadly the same lithological composition as the glacial sand and gravel.

Weathered conglomerate

Weathered conglomerate constitutes a potential source of coarse aggregate over a significant area of the resource sheet and it is likely to occur wherever this lithology forms the bedrock (Figure 3). The most extensive spread occurs in the north-eastern quadrant of the resource sheet. Grading data indicates that the aggregate is slightly bimodal, with medium-grained sand and coarse gravel predominating. The grading data indicates that some 12 per cent of the material is comprised of clasts larger than 64 mm. However, this is likely to be a gross underestimate because the very large size of many of the clasts is such that representative sampling is not possible. The weathered conglomerate contains a range of lithologies similar to those in the glacial sand and gravel, though many clasts are noted as being rotten and fractured.

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 9 composite samples. The samples represent the major resources of sand and gravel within the survey area. The material for testing was obtained by sieving the residues of bulk samples taken for particle size analysis from trial pits and boreholes, or it 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 present in the resource sheet areas. 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), the aggregate impact value residue (AIVR), as defined by Ramsay (1965) and Ramsay, Dhir and Spence (1973, 1974), and 10 per cent fines. In addition, relative density (on both an oven-dried and surface-dried basis), apparent relative density and water absorption were also determined. Concrete cubes were made from seven samples of aggregate (samples 2,7,8,10,12,16,17) to determine the drying shrinkage, wetting expansion and moisture absorption of the concrete. The samples contained both sand and gravel.

The test data can be considered in conjunction with the lithological analyses to allow direct comparison between the mechanical and physical properties and the lithological composition of the gravels. The results of the lithological analyses

Table 7 Results of mechanical and physical tests

Composite sample	AIV	AIVR %	10 percent fines (kN)	Relative density (oven-dried basis) kg x $10^3/m^3$	Relative density (surface-dried basis kg x $10^3/m^3$	Apparent relative density kg x $10^3/m^3$	Water absorption %
1	31	26	-	2.51	2.55	2.61	1.56
2	29	28	-	2.54	2.56	2.60	0.90
3	31	27	140	2.49	2.53	2.59	1.48
4	22	41	-	2.59	2.63	2.68	1.34
5	28	37	-	2.52	2.55	2.61	1.28
6	30	33	170	2.57	2.60	2.65	1.18
7	29	28	-	2.55	2.61	2.71	2.25
8	Concrete drying shrinkage data only, see Table 8						
9	27	32	-	-	-	-	-
10	28	28	160	2.52	2.58	2.69	2.45
11	27	36	-	-	-	-	
12	28	28	95	2.61	2.73	2.99	4.84
13	27	31	-	2.44	2.53	2.67	3.49
14	22	36	-	-	-	-	-
15	19	41	-	2.51	2.58	2.69	2.45
16	23	36	240	2.57	2.63	2.73	2.03
17	29	29	110	2.49	2.56	2.69	3.00
18	22	36	-	-	-	-	-
19	26	33	-	-	-	-	-

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. The 10 per cent fines test measures the resistance of an aggregate to crushing under an applied compressive load. It measures the amount of load required to produce 10 per cent (by weight) of material less than 2.36mm in size in 10 minutes. The result is given in kilonewtons (KN). 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 Ramsay introduced the concept of the aggregate impact value residue (AIVR), calculated by measuring the amount of 10 to 14 mm material remaining intact after the AIV test 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 19 to 31 with a median value of 28 (the average is 27). The range of AIV values is quite large, similar to that (22-34) recorded for the adjoining assessment areas (Auton and Crofts, 1986; Auton, Merritt and Ross, 1988). It is well above the average of 19, quoted by Edwards (1970), for a selection of worked Scottish gravels.

With one exception, the samples from the Strachan area have AIV values between 28 and 31; although these samples contain very abundant coarse-grained granitic clasts, many of the clasts are weathered to some extent, resulting in the high AIV values. The other sample from the Strachan area is dominated by quartzite and psammite and has a correspondingly lower AIV of 22.

AIV values in samples from the Auchenblae-Catterline area also tend to high values, though none exceed 29; half have values of 27 or 28. The samples contain abundant quartzite, psammite, well-cemented sandstone and vein-quartz, but the durable properties of these lithologies is offset by the high content of weak and highly weathered rocks.

Broadly, AIVR values vary inversely with AIV. However, the samples from the Auchenblae-Catterline resource sheet area have AIVR values which are slightly, but consistently lower, than those from the Strachan resource sheet area, for equivalent AIV values. This lower resistance to crushing can again be attributed to the high content of weak and highly weathered rocks in the Auchenblae-Catterline samples.

The 10 per cent fines values, determined on only five samples due to limited amounts of material, are inconclusive, ranging from 95 (sample 12) to 240 (sample 16). There is no clear correlation with lithology and it is probable that the results are a complex function of lithology, clast shape and the degree of weathering.

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 characteristics (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 0.90 to 4.84 per cent, with a median value of 2.25 (average 2.17). This is well above the average of 1.48 per cent quoted by Edwards for a selection of Scottish and English gravels.

It is clear that the water absorption values are controlled by the presence of highly weathered clasts, generally of volcanic origin, and porous clasts, such as friable sandstone and mudstone. Samples from the Strachan area have water absorption values below 2.25, the highest value occurring in the sample with the largest amount of highly weathered clasts (sample 7). Thus it appears that although the granite clasts dominating these samples may not be very resistant to crushing, they are at least relatively non-porous. The Auchenblae-Catterline samples have markedly higher water absorption values, ranging from 2.30 to 4.84. This is clearly related to the large content of mudstone, sandstone and weathered clasts; again the sample with the largest water absorption value contains the highest number of weathered clasts (sample 12).

Relative density values were obtained for thirteen composite samples, on both an oven-dried and a saturated surface-dried basis (Table 7). The apparent relative density of the samples has been calculated also.

There is little difference between 'oven-dried' and 'surface-dried' relative densities for the Strachan samples; the differences range from 0.03 to 0.06, the largest difference occurring in sample 7. As noted previously, this sample contains the highest proportion of weathered clasts of any of the Strachan samples. The difference between 'oven-dried' and 'surface-dried' relative densities is more marked in the Auchenblae-Catterline samples, ranging from 0.06 to 0.12. Once again, it is clear that these results are due to the presence of the highly weathered clasts which occur in these samples (samples 10,12,13,15,16,17).

Concrete drying shrinkage, wetting expansion and moisture absorption results are given (Table 8) for seven specially prepared composite samples of aggregate from the study areas. The tests involved the manufacture of concrete prisms (200x50x50mm) using Ordinary Portland cement (BS 12, 1978), <5mm sand and 200mm to 5mm graded gravel from each separate sample provided. The tests were carried out in a commercial laboratory, using the method described in BS 812, part 120, 1989.

The laboratory procedure involves immersing the prisms in water for a period of five days at a temperature of 20°C. 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 days, cooled in a dessicator (containing solid calcium chloride in a saturated solution of calcium chloride) to 20°C and its length measured. 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". A further period of immersion for four days and subsequent measurement allow wetting expansion and water absorption values to be calculated.

The 'drying shrinkage' values obtained for the seven samples are listed in Table 8: they range from 0.040 per cent to 0.073 per cent with an average of 0.055 percent. The results are consistent with all other test results reported above, with samples from the Strachan resource sheet area having significantly lower shrinkage and expansion values (0.040 - 0.044) compared to those from the Auchenblae-Catterline resource sheet area (0.053 - 0.073). The 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 it has not been processed.

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

Composite sample	Source	Geological classification	Drying shrinkage %	Wetting expansion %	Moisture absorption %
Strachan resource sheet					
2	Bogarn	Fluvioglacial sand and gravel	0.044	0.035	6.2
7	Cammie Wood	Fluvioglacial sand and gravel	0.040	0.033	5.8
Auchenblae-Catterline resource sheet					
8	Auchenblae	Fluvioglacial and alluvial	0.053	0.042	6.5
10	Bankhead - East Mondynes belt	Glacial sand and gravel	0.056	0.045	6.8
12	Pitdrichie	Glacial sand and gravel	0.063	0.053	6.8
16	Catterline area	Glacial sand and gravel	0.056	0.044	6.6
17	Auquhirie	Glacial sand and gravel	0.073	0.058	7.2

* Conducted commercially in accordance with BS 812: Part 120 (1989)

The dominating influence of lithology on the test results for the samples from the Strachan and Auchenblae-Catterline resource sheet areas is clear. 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. Although the Strachan samples are slightly less resistant to impact and crushing than the Auchenblae-Catterline samples, they are markedly less porous; this reflects the high content of coarse-grained granitic lithologies in the former, compared to the high content of weathered clasts and mudstone in the latter. However, none of the aggregates tested can be considered to be of high quality. Although the gravels from the Auchenblae-Catterline resource sheet area could be beneficiated by removing the deleterious clasts, probably as much as 50 per cent of the aggregate would be lost. It is unlikely, therefore, that such action would be economic when compared, say, to the production of crushed hard-rock aggregate elsewhere.

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 the 1:10 000 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 red.

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

Mineral resource information

The maps are divided into resource blocks (see Appendix A) 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 this category depends upon the proportion of sample points that 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 Strachan resource sheet by an ornament of open pink circles.

Areas of potentially workable decomposed conglomeratic bedrock on the Auchenblae-Catterline sheet, are shown in a dark shade of red with white open circles.

Areas where sand and gravel is deemed to be not potentially workable, where superficial deposits do not contain mineral, or where bedrock other than decomposed conglomerate 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), 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 Strachan sheet is divided into seven resource blocks for assessment and the Auchenblae/Catterline sheet is divided into three. 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 18. The statistical procedure adopted for the volumetric assessment of the mineral resources is outlined in Appendix B. At the level of sampling allowed for in the present survey, potentially workable deposits are too patchy and diverse in many cases to justify the siting of sufficient sample points on which to base 'statistical' assessments. 'Inferred' or 'speculative' assessments are offered for the other resources.

Resources of potentially workable aggregate occur principally as fluvioglacial, glacial and alluvial sand and gravel. In the Strachan area, minor resources of aggregate occur as morainic drift and where granite bedrock is weathered, it is also potentially workable locally. Weathered conglomerate forms a significant resource of coarse aggregate in the Auchenblae-Catterline area and till is locally potentially workable in both areas, but it is only a marginal resource.

In the borehole records, the deposits of potentially workable sand and gravel are categorised as 'Mineral I', whereas those of potentially workable till, granite and conglomerate are identified as 'Mineral II'.

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 on the Strachan resource sheet as they are considered to be extremely patchy in distribution, and in any case, they are usually of low grade. A volumetric assessment has been made of the potentially workable conglomerate on the Auchenblae-Catterline sheet, however, as the material is known to be extensive and it has been exploited.

Table 9 Summary of the sand and gravel resources of both 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	$m^3 \times 10^6$	$\pm$%	$\pm m^3 \times 10^6$	-.063 mm	+.063 - 4mm	+4mm
STRACHAN SHEET										
Block A	25.4	0.4	0.2	2.8	1.1	54	0.6	5	27	68
Block B	9.6	7.3	0.3	6.6	48.2	30	14.5	4	57	39
Block C	3.8	2.1	0.2	7.0	15.0	60	9.0	4	47	49
Block D	5.0	1.1	0.1	6.4	7.0	41	2.9	4	61	35
Block E	4.2	3.0	0.3	3.0	4.0	38	1.5	2	45	53
Block F	6.8	1.5	0.5	3.4	4.9	39	1.9	5	61	34
Block G	45.1		Too little sand and gravel present to assess							
Whole Sheet	99.9	15.4	0.3	5.4	83.2	19	15.8	4	53	43
AUCHENBLAE-CATTERLINE SHEET										
Block A sand and gravel	46.0	6.2	0.4	6.1	37.9	51	19.3	6	55	39
Block A conglomerate	46.0	2.0	0.3	3.2	6.5	-	-	3	7	90
Block B	54.0	6.9	0.6	5.2	36.0	55	19.8	6	52	42
Block C sand and gravel	73.7	5.5	0.4	6.7	36.9	33	12.2	7	58	35
Block C conglomerate	73.7	19.5	0.5	4.4	85.9	54	46.4	11	40	49
Whole Sheet										
sand and gravel	173.7	18.6	0.5	5.9	109.7	25	27.4	6	55	39
conglomerate	173.7	21.5	0.4	4.3	92.5	48	44.4	10	36	54

Note: Some figures differ slightly form those quoted elsewhere due to rounding and re-calculation

* Excluding built-up areas

$ Only quoted for statistical assessments

Fluvioglacial sand and gravel (mainly gravel forming kame-terraces and underlying floodplain alluvium) is the most extensive potentially workable deposit in the Strachan assessment area. Glacial sand and gravel (deposited as kames, eskers and spreads of glacial outwash) forms the major source of sand and gravel in the Auchenblae/Catterline area. 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 Strachan sheet, is ±30 per cent (Table 9). 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 THE STRACHAN RESOURCE SHEET

Resource block A

This block covers an area of generally barren ground that lies between the northern margin of the resource sheet and the valley of the Water of Feugh. The village of Strachan covers 0.1 km^2 on the southern margin of the block. Most of the high ground is covered by thin spreads of till overlying Dalradian bedrock. Mineral-bearing ground is confined to the Tillygarmond and Waulkmill Eskers (see glacial geomorphology map) and a discontinuous spread of fluvioglacial sand and gravel that extends north-westwards from Castlehill [658 922]. A statistical assessment of the mineral deposits, based on five sample points is given Table 10.

Eskers

Two NW-SE trending, parallel esker ridges (the Tillygarmond Eskers) extend between East Tillygarmond [637 932] and the Feughside Inn [643 924]. The eskers stand up to 10 m above the level of the surrounding ground and they are composed of glacial sand and gravel. They were laid down subglacially or englacially by meltwater streams that also cut a steep-sided drainage channel between Shooting Greens Cottage [635 942] and Cults [640 935]. The esker deposits were formerly worked in a pit that is now a caravan site, north of the Feughside Inn. The deposits have also been worked in a very small pit near East Tillygarmond, where a section and pit (69 SW 27) proved 2.6 m of poorly sorted boulder gravel, not bottomed. The boulder gravel becomes more sandy with depth, but the large proportion of cobbles and boulders detracts from its attractiveness as a potential resource.

Three sample points were sited on the esker ridges north of Waulkmill (the Waulkmill Eskers); only one proved the full thickness of the deposit. A section and pit (69 SW 25) at the northern end of a working in the longest ridge proved 3.2m of cobble gravel with lenses of pebbly sand; the excavation was terminated on a bed of large boulders slightly below the level of the worked face, suggesting that little potentially workable material is present below this depth. Farther to the south, sand and gravel has been worked for fill and for making up farm tracks, at a temporary working in a 4 m high esker ridge. A section and pit (69 SW 24) at the eastern end of this working exposed 4.5m of coarse gravel, not bottomed. The uppermost 2.3 m is a 'clayey' clast-supported gravel

Table 10 Strachan sheet: Data from sample points and the assessment of resources in Block A

Data point	Recorded thickness			Mean grading percentage (sizes in mm)							
Borehole, pit, exposure or resistivity sounding	Total mineral m	Depth of burial m	Intervening waste m	Fines -.063	Fine sand .063-.25	Medium sand .25-1	Coarse sand 1-4	Fine gravel 4-16	Coarse gravel 16-64	Cobbles and boulders +64	Descriptive category (see the diagram in Appendix C)
NO 69 SW 23	1.4	0.1	-	3	2	9	12	15	30	29	G
NO 69 SW 24	4.5+	0.1	-	10	2	8	10	18	37	15	CG
NO 69 SW 25	3.2+	0.4	-	2	2	11	13	13	33	26	G
NO 69 SW 27	2.6+	0.1	-	5	6	13	7	8	41	20	G
NO 69 SE 1	2.3+	0.3	-	1	2	14	26	15	30	12	G
Mean	2.8	0.2	-	5	3	11	13	14	35	19	G

Statistical assessment of the fluvioglacial sand and gravel and glacial sand and gravel north of the valley of the Water of Feugh

Total area (excluding the village of Strachan)	25.43 km^2
Strachan Village (including 0.01 km^2 of sand and gravel, not assessed)	0.08 km^2
Area of discontinuous spreads of mineral	0.40 km^2
Total area of mineral-bearing ground	0.40 km^2*
Area of ground worked for sand and gravel	0.02 km^2
Mean thickness of overburden	0.2m
Mean thickness of mineral	2.8m
Estimated volume of mineral	1.1 million m^3 (± 54% or 0.6 million m^3)
Estimated yield of mineral per hectare	28 thousand m^3 (± 54% or 15 thousand m^3)

*In the calculation of this figure, 50% of the area of discontinuous spreads is assumed to be mineral-bearing containing rounded cobbles of banded psammite, porphyry, felsite and psammite; sparse clasts of granite are also present. A channel, aligned parallel to the ridge-crest and infilled with coarse sand, is cut to a depth of 1.0m into the top of the 'clayey' gravel unit, which rests in turn on 2.2 m of imbricated, open-work gravel which was not bottomed. An assessment pit (69 SW 23) sited on a low esker ridge, 400 m to the south-east, exposed 1.4 m of imbricated cobble gravel resting on light brown till.

Fluvioglacial deposits

Discontinuous spreads of coarse gravel and sand underlie an area of undulating moundy topography north-west of Castlehill. The sand and gravel was laid down as a fluvioglacial fan shortly after the Waulkmill eskers had been formed, and after the immediate area had become free of ice. Mapping indicates that the fan deposits are generally clayey and that they vary considerably in thickness. A pit (69 SE 1) near to the toe of the fan, however, proved 2.3 m of clean, clast-supported gravel, lying above the water-table. The gravel, which showed well developed horizontal stratification, was principally composed of rounded to subrounded clasts of granite, psammite, felsite and semipelite.

Sandy flow-till has been worked in a small pit (69 SW 2) to the west of Drumhead [606 924]. The deposit, which grades as 'clayey' sandy gravel, overlies Dalradian bedrock; it is used for re-surfacing tracks on the Finzean estate.

Resource block B

Resource block B contains the most extensive spreads of workable sand and gravel in the Strachan assessment area. It includes the alluvial, glacial and fluvioglacial deposits within the valley of the Water of Feugh, together with those in the valley of the Water of Aven, downstream of the point at which the river emerges from its steep-sided valley (500m west of Ord of Cuttieshillock [638 902].

Block B is divided into two sub-blocks for assessment purposes. Sub-block B^1 includes the sand and gravel deposits within the valley of the Water of Aven, together with those within the valley of the Water of Feugh lying to the west of an arbitrary line drawn from Whitestone [639 924], on the northern bank of the Water of Feugh, to a point 300m south-east of Balblythe [637 916] on the eastern bank of the Water of Aven. The sub-block corresponds with the lower-lying parts of the Feugh and Aven catchments, upstream of the confluence of both rivers. Sub-block B^2 includes all of the alluvial and terraced fluvioglacial deposits within the valley of the Water of Feugh to the east of the sub-block boundary, together with the glacial sand and gravel forming eskers in the vicinity of Balblythe, Dalbreck [653 917] and Templeton [670 916], and moundy deposits of morainic drift north and east of Cuttieshillock [645 910].

Sub-block B^1

Most of the area is underlain by continuous or almost continuous spreads of alluvial sand and gravel, overlying fluvioglacial sand and gravel and till.

Barren ground is confined to low hillocks, capped by till, in the vicinity of Ordie [617 919], Nether Boghead [617 925] and Dalsack [605 918], and to outcrops of Kincardine Granite near Little Enochie [633 918]. Discontinuous spreads of sand and gravel are present within alluvial fans in the valley of the Water of Aven and the valley of the Water of Feugh, between Wester Powlair [620 913] and Mill of Clinter [612 920], and in the alluvium and low-lying fluvial terraces in the vicinity of Woodside [635 926].

The flat-lying alluvial deposits north of Ordie and Dalsack also contain thin discontinuous deposits of sand and gravel; these occur within a predominantly silty alluvial sequence. Laterally impersistant, thin deposits of gravel also form a small terrace to the south of Balblythe.

A statistical assessment of sub-block B^1, based on ten data points is given in Table 11.

Alluvium and terrace deposits of the Water of Feugh

Two assessment boreholes (69 SW 9 and 69 SW 20) were sited on the ground underlain by continuous spreads of sand and gravel in the valley of the Water of Feugh upstream of the Feugh/Aven confluence. Both proved potentially workable sand and gravel lying close to the water-table. Borehole 69 SW 9, east of Ordie, proved 1.5 m of alluvial gravel overlying 3.5 m of fluvioglacial sand and gravel. The alluvial deposit is very coarse-grained, with 56 per cent, by weight, of the material passing the +16mm sieve. Clasts of granitic rock types predominate. The underlying fluvioglacial

Table 11 Strachan sheet: Data from sample points and the assessment of resources in Block B

Data point	Recorded thickness			Mean grading percentage							
				(sizes in mm)							
Borehole, pit, exposure or resistivity sounding	Total mineral m	Depth of burial m	Intervening waste m	Fines -.063	Fine sand .063-.25	Medium sand .25-1	Coarse sand 1-4	Fine gravel 4-16	Coarse gravel 16-64	Cobbles and boulders +64	Descriptive category (see the diagram in Appendix C)
Sub-block B1	Fluvioglacial sand and gravel, alluvium and alluvial fan deposits in the valleys of the Water of Feugh and the Water of Aven, upstream of their confluence										
NO 69 SW 1	15.9+	0.3	0.8	2	5	23	39	17	10	4	SG
NO 69 SW 5	1.5+	0.5	-	14	11	24	36	13	2	0	CPS
NO 69 SW 9	5.0+	0.4	-	4	4	17	30	16	17	12	SG
NO 69 SW 13	2.1	0.9	-	5	4	19	28	9	26	9	SG
NO 69 SW 15	2.0+	0.3	0.4	6	7	16	25	16	19	11	SG
NO 69 SW 19	1.7*	0.4	-	4	3	12	30	18	25	8	G
NO 69 SW 20	4.9	0.3	1.2	3	4	22	30	12	17	12	SG
NO 69 SW R1	2.2	0.2	-	-	-	-	-	-	-	-	-
NO 69 SW R3	3.9	0.2	-	-	-	-	-	-	-	-	-
NO 69 SW R5	4.1	0.1	-	-	-	-	-	-	-	-	-
Mean	4.3	0.4	0.3	4	5	21	34	15	14	7	SG
Sub-block B2	Fluvioglacial sand and gravel, glacial sand and gravel and alluvium in the valley of the Water of Feugh, downstream of its confluence with the Water of Aven										
NO 69 SW 21	8.1	0.3	0.5	4	6	20	32	17	14	7	SG
NO 69 SW 26	1.5	0.4	-	19	12	23	23	15	8	0	CSG
NO 69 SE 2	8.2+	0.2	1.7	4	7	27	33	16	10	3	SG
NO 69 SE 3	2.0	0.3	-	7	4	14	22	13	27	13	G
NO 69 SE 6	8.2+	0.2	-	2	3	21	27	13	16	18	SG
NO 69 SE 7	4.2+	0.4	-	9	23	26	14	7	10	11	SG
NO 69 SE 9	4.6+	0.2	0.5	4	7	28	23	13	10	15	SG
NO 69 SE 10	14.0+	0.3	1.3	3	8	27	35	21	5	1	SG
NO 69 SE 11	4.0	0.4	-	1	2	16	31	21	21	8	G
NO 69 SE 13	2.4+	0.4	0.1	5	4	15	22	16	16	22	G
NO 69 SE 14	10.0+	0.3	-	1	1	8	25	19	20	26	G
NO 69 SE 15	3.9**	0.4	0.9	18	10	27	17	13	11	4	CSG
NO 69 SE X1	18.0	-	0.9	-	-	-	-	-	-	-	-
NO 69 SE X2	15.0	0.3	-	-	-	-	-	-	-	-	-
NO 69 SE X3	18.9	0.6	3.1	-	-	-	-	-	-	-	-
NO 69 SE X7	8.1	0.2	2.8	4	7	16	27	16	27	3	SG
NO 69 SE R1	1.6	0.1	-	-	-	-	-	-	-	-	-
NO 69 SE R2	1.9	0.2	-	-	-	-	-	-	-	-	-
NO 69 SE R4	8.6	0.1	-	-	-	-	-	-	-	-	-
NO 69 SE R5	12.5	0.1	-	-	-	-	-	-	-	-	-
Mean	7.8	0.3	0.6	4	7	21	29	16	14	9	SG
Overall mean for whole block	6.6	0.3	0.5	4	6	21	30	16	14	9	SG

* Overlies 4.0m of potentially workable till
** Overlies 2.7m of potentially workable till

Statistical assessment of block B

	Sub-block B^1	Sub-block B^2
Total area	4.45 km^2	5.17 km^2
Area of exposed mineral	2.06 km^2	3.88 km^2
Area of concealed mineral	<0.01 km^2	0.39 km^2
Area of discontinuous spreads of mineral	1.57 km^2	0.33 km^2
Total area of mineral-bearing ground	2.86 km^{2*}	0.44 km^{2*}
Area of morainic drift (not assessed)	-	0.28 km^2
Mean thickness of overburden	0.4m	0.3m
Mean thickness of mineral	4.3m	7.8m

Estimated volume of mineral (sub-block B^1) 12.3 million m^3 (± 74% or 9.1 million m^3)
Estimated yield of mineral per hectare 43 thousand m^3 (± 74% or 32 thousand m^3)

Estimated volume of mineral (sub-block B^2) 34.0 million m^3 (± 34% or 12.2 million m^3)
Estimated yield of mineral per hectare 78 thousand m^3 (± 34% or 28 thousand m^3)

* In the calculation of these figures, 50% of the area of discontinuous spreads is assumed to be mineral-bearing

deposit is sandier and contains clasts of more varied lithologies; pebbles and cobbles of felsite, psammite, semipelite, gabbro and vein-quartz are present, together with red and pink granite. Blocks of decomposed granite were present from 4.5 to 4.7 m depth. The fluvioglacial sand and gravel rests on 0.6m of silty diamicton containing abundant angular fragments of granite. The matrix of the diamicton is principally composed of silty granitic sand, characterised by dark flakes of mica; the deposit is either till or decomposed granite. The borehole was terminated at 6.4 m depth in bedrock.

Assessment borehole 69 SW 20, sited on a terrace to the north- east of Little Enochie, proved 3.4 m of alluvial sandy gravel, overlying a 1.2 m thick waste parting on 1.5 m of fluvioglacial sand and gravel. A perched water-table was struck at 3.1 m depth. The borehole was terminated in till, underlying the fluvioglacial deposit, at a depth of 7.5 m. The alluvial and fluvioglacial deposits are comparable in terms of grading and clast-composition, although pebbles of gabbro and fine-grained basic igneous rock were only present in the lower deposit.

In the vicinity of Balblythe, the gravelly alluvial terraces stand 3-5 m above the level of the floodplain, but mapping indicates that granite bedrock is, in places, only a few metres below the surface of the terraces. For instance, granite crops out in a terrace bluff, less than 100 m to the north-east of assessment borehole 69 SW 19, which proved 1.7 m of alluvial gravel resting on 4.0m of flow-till, overlying bedrock. A trial pit (69 SW 5) and a resitivity sounding site (69 SW R4) were located on the flat-lying alluvium to the east of Boghead [614 927]. The pit proved 1.5m of clayey sand, before groundwater prevented further progress. The interpretation of the resistivity soundings, taken 200m south-east of the pit site, indicated that 3.3 m of clayey alluvium rests on till overlying bedrock.

Alluvial deposits of the Water of Aven

Because of access problems caused by waterlogged ground, no pits or boreholes were sited on the floodplain and terraced alluvium of the Water of Aven. Mapping indicates, however, that considerable (albeit water-saturated) deposits of sand and gravel may be present. Three trial pits were sited on alluvial fan deposits, which stand 3-8 m above the floodplain of the Water of Aven. Two of the pits (69 SW 15 and 69 SW 13) proved potentially sand and gravel above groundwater level, the third (69 SW 12) proved stony clay with thin seams of sand to 1.9 m depth; groundwater halted further progress. The alluvial fan deposits are generally more silty than those underlying the floodplain and alluvial terraces, and potentially workable material is only present locally; they are therefore shown as a discontinous resource on the assessment map.

Alluvial fan deposits, eskers and lacustrine alluvium in the valley of the Water of Feugh

Discontinuous spreads of workable sand and gravel are present within the alluvial fan deposits of the valley of the Water of Feugh to the north and to the east of Easter Clune [612 915]. Interpretation of resistivity soundings (69 SW R3) undertaken on the fan deposit to the north of Easter Clune, indicate 1.0 m of dry cobble gravel, overlying 2.9 m of damp sandy gravel resting on sandy till.

The thickest deposits of sand and gravel in sub-block B^1 underlie a spread of lacustrine alluvium to the west of Blackhole [606 915]. An assessment borehole (69 SW 1) drilled in the centre of the spread showed that the alluvium rests on an interbedded sequence of fluvioglacial sand and gravel and laminated silt. The sequence of deposits infills an ice-scoured basin on the southern side of the valley of the Water of Feugh (see cross-section A-A'). The borehole was terminated on an obstruction, possibly bedrock, at a depth of 17.0m. It proved 15.9m of sand and gravel, of which only the uppermost 1.4m lies above groundwater level. A single waste parting, 0.4m thick, was recorded in the borehole, but resistivity soundings (69 SW R1) taken at the borehole site indicate that numerous silty beds may be present within the sequence (the resistivity method used had insufficient resolution to distinguish between the individual sandy and silty layers). A thick deposit of glacial sand and gravel may be present to the west of the borehole site, because the two mounds standing up to 2.0m above the surface of the alluvium hereabout, may represent parts of an esker that is largely concealed beneath the alluvium.

Sub-block B^2

Potentially workable deposits of sand and gravel were proved in each of the five boreholes, two trial pits and five sections excavated during the assessment of sub-block B^2 (Table 11). This data, together with that from three site investigation boreholes, four resistivity sounding sites and a test well for groundwater extraction near Castle Hill [657 921], forms the basis of a statistical assessment of the resources.

Alluvium and terrace deposits on the southern side of the Water of Feugh, upstream from Strachan

Continuous, or almost continuous, surficial spreads of sand and gravel lying closely above the water-table, are present beneath the floodplain and the terraces that extend along both sides of valley of the Water of Feugh between Whitestone and Templeton Croft [674 918]. They are also present on the northern side of the valley, in the vicinity of Heugh-head [687 929]. An assessment borehole (69 SE 10), sited on the floodplain near Haugh of Strachan [662 918], proved 1.0m of alluvial gravel overlying 13.0m of fluvioglacial sand and gravel, intercalated with 1.3 m of laminated clay and silt. The borehole was terminated on an obstruction, having failed to bottom the fluvioglacial deposits at a depth of 15.6m. Groundwater was struck at 1.3m depth.

Thick deposits of water-saturated sand and gravel were recorded from site investigation boreholes (69 SE X1, X2, and X3) sunk for the 'Strachan Bridge' improvement. For example, 18.0m of mineral, overlying 5.4m of waste resting on granite bedrock, was recorded in borehole 69 SE X1; interpretation of resistivity soundings (69 SE R5) taken on the floodplain, 200m south-west of the borehole site indicated 12.5m of sand and gravel overlying glaciolacustrine deposits.

Alluvial deposits of the Burn of Strathy

Low-lying, flat-topped spreads of sand and gravel flank the Burn of Strathy downstream of the ford [6520 9072]. An assessment borehole (69 SE 2) sited on the terraced alluvial deposits south-west of Dalbreck farm [653 917] proved 8.2m of sand and gravel, with a waste parting, 1.7m thick, of glaciolacustrine silt and clay. The borehole was terminated on an obstruction at 10.1m depth; resistivity soundings (69 SE R2) taken at the borehole site suggest that granite bedrock is present at between 9.7 and 11.7m depth. A nearby assessment pit (69 SE 3) proved 2.0m of gravelly alluvium overlying sandy till, indicating that the sand and gravel may thin towards Dalbreck. A borehole (69 SW 21) 500m south-west of the farm, however, proved 8.1m of sand and gravel, resting on till overlying granite bedrock. A waste parting of till was present from 4.5 to 5.0m depth, which suggests that the till at the base of assessment pit 69 SE 3 may merely be a waste parting concealing potentially workable sand and gravel below.

Alluvial and terraced deposits of the Water of Dye

Terraces, underlain by spreads of sand and gravel, are present on both sides of the Water of Dye, downstream from the Bridge of Bogendreep [663 910]. Those in the vicinity of Muiryhaugh [664 914], on the eastern side of the river, stand up to 8m above the level of the floodplain. Field evidence and resistivity soundings (69 SE R4) indicate that up to 8.6m of coarse gravel overlies till and that the gravel lies above the water-table. There are no data points for the low lying terraces to the west of the river, but mapping indicates that several metres of water-saturated sand and gravel are present.

Terraced deposits on the northern side of the Water of Feugh

Terraced alluvial deposits west of the Feughside Inn and south-west of Castlehill proved to be thinner than anticipated. An assessment borehole (69 SW 26), sited on the former deposit, proved 1.5m of 'clayey' sand and gravel with abundant clasts of Dalradian metamorphic rocks overlying stiff, yellowish brown till. Water-extraction borehole (69 SE X7), on the terrace south-west of Castlehill, proved 0.9m of sandy alluvium overlying 2.8m of waste (mainly flow-till). Beneath the waste parting, 7.2m of fluvioglacial sand and gravel was proved, overlying a further 1.4m of till; the borehole was terminated in granite bedrock, at 12.6m depth.

Terraced fluvioglacial deposits, standing 8-10m above river level are present in the vicinity of Heugh-head. An assessment borehole (69 SE 15), sited 200m south-west of the farm, proved 3.9m of clayey sand and gravel, interbedded with flow-till and laminated silt and clay; the grading results recorded in the borehole log may be unrepresentative owing to comminution caused by drilling.

Minor resources of exposed sand and gravel form terraces in the vicinity of Invery House [697 940] and north-east of Mains of Invery [696 942]. Mapping indicates that thin discontinuous spreads of sand and gravel are also present within the alluvial deposits of the Water of Feugh, downstream of Heugh-head.

Alluvial fan deposits

Discontinuous beds of claybound cobble gravel are exposed in 3m-high bluffs at the front of an alluvial fan that has been formed by the Burn of Affrusk where it enters the main valley [693 933]. Similar gravelly deposits are thought to be present within the alluvial fan at the confluence of the Water of Feugh and the small tributary which drains south-eastwards from Ardlair Cottage [673 931], but most of the resource has been built on. Silty cobble gravel is exposed in a 4m-high bluff at the front of an alluvial fan at Avendale [664 923] and up to 2m of unstratified cobble gravel is exposed in the sides of another alluvial fan, north of Mill of Cammie [689 921].

An assessment pit (69 SE 13) dug on the alluvial fan at the mouth of the Burn of Rhoda proved 2.4 m of cobble-gravel, before progress was halted by groundwater. The deposit is moderately well-sorted and contains subrounded clasts of psammite, quartzite and pink granite.

Floodplain alluvium of the Water of Feugh, downstream from Strachan

Potentially workable deposits of sand and gravel are concealed beneath silty alluvium between Templeton Croft [674 918] and Kitnaekit Wood [690 929]; pebbly sand is exposed in the banks of the Water of Feugh, but up to 1.3m of silty alluvium has been augered on the floodplain to the south of the river.

Eskers

The thickest mineral deposits in sub-block B^2 occur as eskers and esker-beads that stand above the surface of the alluvial deposits of the valley floor. Sections were excavated in five of the numerous small-scale workings in the eskers; none proved the full thickness of mineral, which is thought to extend for many metres below the water-table at each site.

The thickest sequence was recorded in a section and pit (69 SE 14) from a working in an esker-bead, 300m east of Gateside [678 924], which proved 10.0 m of sand and gravel. Clast-supported cobble gravel, 7.4m thick, was exposed in the section and 2.6m of iron-stained sandy gravel was exposed in a pit dug at the base of the face. A section and pit (69 SE 9) in a second esker-bead, north of Haugh of Strachan, proved over 4.6m of sand and gravel interbedded with thin waste partings of laminated silt; the deposit coarsens upwards from sandy gravel with tabular cross-bedding into clast-supported cobble gravel.

The Balblythe Eskers rise up to 5m above the surface of the alluvial terraces that lie adjacent to them. No trial pits or boreholes were sited on the eskers, but 2-3m of rounded cobble-gravel, overlying coarse-grained sand, was exposed in a small face [6400 9189], 400m north-east of Balblythe farm.

The Dalbreck Eskers stand 3-10m above the level of the floodplain to the south-east of Dalbreck farm. A section (69 SE 6) excavated in the esker lying closest to the farm, proved 8.2m of sand and gravel, not bottomed. The upper 5.0m of the deposit comprises clast-supported coarse gravel, with poorly developed stratification dipping parallel to the flanks of the ridge. The gravel unit overlies pebbly sand with crude horizontal bedding. Clasts of psammite, semipelite, calc-silicate and quartzite predominate. Clasts of Dalradian metamorphic rocks also constitute most of the gravel component in samples taken from a 3-5m high esker, 500m east-south-east of Dalbreck. A section and pit (69 SE 7), excavated in a small working at the southern end of the ridge, showed 2.7m of trough cross-bedded 'clayey' pebbly sand, overlying cobble gravel with tabular cross bedding; the excavation was abandoned at a depth of 4.6m, without reaching the water-table.

A series of steep-sided, 10m-high eskers, trending SW-NE, are present on the southern flank of the valley of the Water of Feugh, between Muiryhaugh and Templeton Croft. A section (69 SE 11) in a small gravel pit in one of the eskers at Templeton, showed 4.0m of sand and gravel overlying light brown, stiff, silty till. The uppermost 1.6m of the deposit is a clast-supported, well-sorted gravel which coarsens-upwards. Between 2.0 and 3.4m from the top of the section, the deposit is poorly sorted and more sandy, but below 3.4m depth, the sand and gravel is well-sorted and shows sub-horizontal stratification. The predominant gravel clasts are of granitic rock types, although some psammitic and semipelitic rock types are also present.

Table 12 Strachan sheet: Data from sample points and the assessment of resources in Block C

Data point	Recorded thickness			Mean grading percentage (sizes in mm)							
Borehole, pit, exposure or resistivity sounding	Total mineral m	Depth of burial m	Intervening waste m	Fines -.063	Fine sand .063-.25	Medium sand .25-1	Coarse sand 1-4	Fine gravel 4-16	Coarse gravel 16-64	Cobbles and boulders +64	Descriptive category (see the diagram in Appendix C)
NO 68 NW 5	3.2+	0.1	-	3	1	10	11	16	4	55	G
NO 68 NE 1	16.3+	0.4	-	4	3	18	22	17	20	16	G
NO 68 NE 2	2.7	-	-	8	13	29	25	16	5	4	SG
NO 68 NE 7	8.8	0.3	-	4	3	13	18	20	19	23	G
NO 69 SWR6	4.8	0.1	-	-	-	-	-	-	-	-	-
NO 69 SE 4	1.2	0.3	-	3	3	23	22	15	21	13	G
NO 69 SE 5	12.2+	0.1	0.2	4	5	27	27	15	14	8	SG
NO 69 SE 8	14.9+	0.2	4.5	6	10	21	26	17	10	10	SG
NO 69 SE 24	4.4+	0.4	-	1	1	8	18	14	24	34	G
NO 69 SE X6	1.8+	0.4	-	-	-	-	-	-	-	-	-
Mean	7.0	0.2	0.5	4	5	19	23	17	15	17	G

Statistical assessment of the fluvioglacial sand and gravel and glacial sand and gravel of Pitdelphin Wood, and the fluvioglacial sand and gravel, glacial sand and gravel, alluvial deposits and morainic drift of the valley of the Burn of Brooky (Block C)

Total area	3.76 km^2
Area of exposed mineral	1.76 km^2
Area of concealed mineral	<0.01 km^2
Area of discontinuous spreads of mineral	0.26 km^2
Area of morainic drift	0.49 km^2
Total area of mineral-bearing ground	2.14 km^{2}*
Mean thickness of overburden	0.2m
Mean thickness of mineral	7.0m
Estimated volume of mineral	15.0 million m^3 (± 60% or 9.0 million m^3)
Estimated yield of mineral per hectare	70 thousand m^3 (± 60% or 42 thousand m^3)

*In the calculation of this figure, 50% of the area of discontinuous spreads and 50% of the area of morainic drift are assumed to be mineral-bearing

Morainic drift

The morainic deposits in the vicinity of Cuttieshillock constitute a minor, discontinuous resource of sand and gravel. No pits or boreholes were sited on the deposits, but rounded boulder and cobble-gravel is exposed in ridge-ploughing on newly afforested hummocky ground to the north of Cuttieshillock. Individual hummocks may rise to heights of 6 to 8m, but the gravel deposits thin abruptly between the hummocks. The high proportion of cobbles and boulders present suggest that the morainic deposits do not represent an attractive mineral resource.

Resource block C

The boundaries of block C are drawn to include all of the moundy and kettled spreads of fluvioglacial sand and gravel within the valleys of the Burn of Brooky and its tributaries, between Greystane Wood [649 872] and Black Loch [653 904], and those mantling the interfluve between the Burn of Strathy and the Water of Dye, north of Bogarn [657 903]. The block also includes moundy deposits of morainic drift that occur on the western side of the Burn of Brooky, and in the vicinity of Rouchanbeg [648 898]. The thin, discontinuous resources of sand and gravel contained within the alluvium of Burn of Brooky and those underlying the marshy ground south-west of Greendams [649 900] are also included.

A statistical assessment is given for the block as a whole (Table 12), based on 10 data points, but the fluvioglacial, morainic and alluvial deposits will each be described separately.

Fluvioglacial sand and gravel in the valley of the Burn of Brooky

Data from four sample points on the kettled spreads of fluvioglacial sand and gravel that flank the Burn of Brooky, show that the deposits generally lie above the water-table, and that they vary considerably in terms of thickness and grading. The thickest deposits form steep-sided mounds, up to 28m in height, on either side of the B947 road, between Cormech [651 901] and the disused sand and gravel quarry [6513 8865], 800m west of Tillyfumerie [659 886]. A section (68 NE 7) excavated in the quarry showed 8.8m of gravel overlying till. Horizontally bedded sandy gravel, 2.2m thick, at the top of the section, passes down into cross-stratified gravel that becomes more clayey below 4.9m depth. A pit (68 NE 2) excavated in a small sand and gravel working, 200m farther north, proved 2.7m of sandy gravel overlying till, indicating that the sand and gravel thins northwards hereabouts.

Fluvioglacial sand and gravel forming a steep-sided conical mound, 28m high, has been worked at Dunniemore Quarry [6530 8978]; a pit (68 NE 1) excavated at the base of the 15m high worked face, failed to bottom the deposit at an overall depth of 16.7m. The top of the working lies some 10m below the mound summit, suggesting that more than 25m of sand and gravel, lying above the water-table, may be present. Cobble gravel, interbedded with trough cross-bedded pebbly sand, is present at the top of the section; it overlies trough cross-bedded sandy gravel, which rests on gravel interbedded with ripple-laminated fine-grained sand towards the base.

Cobble gravel is thought to underlie moundy, kettled topography that extends 800m southwards from Lady's Dowry [649 897]. The gravel deposits have been dissected by steep-sided drainage channels, up to 10m deep, some of which have till exposed in their floors. No sample points were sited on these fluvioglacial deposits, but 2-3m of clast-supported gravel, composed almost entirely of granite cobbles in a matrix of clayey sand, is exposed in the sides of several of the forestry tracks which cross the area.

Fluvioglacial sand and gravel on the interfluves of the Burn of Strathy and the Water of Dye

Thick deposits of fluvioglacial sand and gravel form kettled terraces in the vicinity of Woodside Cottage [646 905] and Pitdelphin Wood [654 907]. The Pitdelphin Wood terrace stands up to 30m above the level of the adjacent floodplain of the Water of Dye, but mapping shows that the sand and gravel deposits are generally less than 20m thick. They overlie till and glaciolacustrine deposits, particularly towards the southern margin of the terrace, where an assessment borehole (69 SE 8) proved 14.1m of fluvioglacial sand and gravel, beneath negligible overburden. At this borehole, the fluvioglacial deposits fine downwards, from clast-supported cobble gravel into sandy gravel and 'very clayey' pebbly sand; they overlie 4.5m of varved, glaciolacustrine silt resting in turn on sandy gravel interbedded with diamicton. The borehole was terminated at 19.6m depth having failed to bottom the drift sequence or to reach the water-table. An assessment borehole (69 SE 5) near Pitdelphin Farm [654 911] at the north-eastern margin of the fluvioglacial deposits, failed to bottom the sand and gravel at 12.5m depth. Trial pits (69 SE 24 and 69 SE X6) were also terminated in sand and gravel, at depths of 4.8m and 2.2m respectively. The samples taken at each data point indicate that the sand and gravel has been laid down as one, or more, coarsening-upwards units and that most of the resource lies well above groundwater level.

The kettled terrace on the western side of the Burn of Strathy is underlain by thinner fluvioglacial deposits than those forming the Pitdelphin Wood terrace. The sand and gravel is exposed in faces, 2m high, in a small abandoned working at Woodside Cottage; it is seen to comprise clast-supported coarse gravel, interbedded with pebbly sand. An assessment pit (69 SE 4), dug near the north-eastern margin of the terrace proved only 1.2m of poorly stratified gravel, resting on till.

Morainic drift

Four assessment pits (68 NW 5, 6, 7 and 8), show that the hummocky spreads of morainic drift in block C contain little potentially workable sand and gravel. Claybound boulder-gravel, with blocks of granite up to 1.1m, was recorded in pits 68 NW 6 and 68 NW 8; stony diamicton overlying granite bedrock was exposed in pit 68 NW 7. Clast-supported cobble gravel was proved to a depth of 3.2m in pit 68 NW 5, but claybound boulder gravel and diamicton are seen in many small exposures nearby.

Alluvial deposits

Thin, laterally discontinuous deposits of sand and gravel are exposed in the banks of the Burn of Strathy/Burn of Brooky, between the northern margin of the resource block and northing 89. Sand and gravel is also present underlying the marshy ground in the vicinity of

Table 13 Strachan sheet: Data from sample points and the assessment of resources in Block D

Data point	Recorded thickness			Mean grading percentage (sizes in mm)							
Borehole, pit, exposure or resistivity sounding	Total mineral m	Depth of burial m	Intervening waste m	Fines -.063	Fine sand .063-.25	Medium sand .25-1	Coarse sand 1-4	Fine gravel 4-16	Coarse gravel 16-64	Cobbles and boulders +64	Descriptive category (see the diagram in Appendix C)
NO 69 SE 12	5.6	0.2	-	2	1	14	39	16	12	16	SG
NO 69 SE 16	6.5	-	-	1	1	13	35	13	24	13	G
NO 69 SE 17	7.9*	0.1	-	9	13	30	19	8	7	14	SG
NO 69 SE 18	6.9+	0.2	-	2	14	56	26	2	0	0	S
NO 69 SE 19	4.1**	0.2	-	5	3	18	31	23	17	3	SG
NO 69 SE 21	12.8+	-	-	3	8	19	28	17	15	10	SG
NO 69 SE 22	7.3+	-	-	4	4	30	22	12	15	13	SG
NO 69 SE 23	5.3+	0.2	-	2	3	39	33	10	7	6	PS
NO 69 SE R6	1.0	0.1	-	-	-	-	-	-	-	-	-
Mean	6.4	0.1	-	4	6	27	28	13	12	10	SG

* Overlying 2.0m of potentially workable till

** Overlying 0.7m+ of potentially workable till

Statistical assessment of the fluvioglacial sand and gravel, glacial sand and gravel and alluvial deposits between the Slacks of Pitreadie and Affrusk Farm (Block D)

Total area	5.04 km^2
Area of exposed mineral	0.91 km^2
Area of discontinuous spreads of mineral	0.34 km^2
Total area of mineral-bearing ground	1.08 km^2*
Area of ground worked for sand and gravel	0.02 km^2
Area of morainic drift (not assessed)	0.75 km^2
Mean thickness of overburden	0.1m
Mean thickness of mineral	6.4m
Estimated volume of mineral	6.9 million m^3 (± 41% or 2.8 million m^3)
Estimated yield of mineral per hectare	64 thousand m^3 (± 41% or 26 thousand m^3)

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

Greendams. Resistivity soundings (69 SW R6), taken on the alluvial flat 100m north of Greendams, indicate that between 3.7m and 6.0m of pebbly sand may be present, though only the top 0.3m of the resource lies above the water-table.

Resource block D

Block D includes all of the potentially workable sand and gravel, between the eastern margin of the resource sheet and the alluvial deposits of the Water Feugh downstream of Templeton Croft. The southern part of the block includes the lower reaches of the Burn of Melmannoch, but it does not include the morainic ridges to the east of the Coves of Curran [693 896] as mapping indicates that they contain no potentially workable deposits.

Thick resources of sand and gravel are present within moundy fluvioglacial deposits that extend between Moss-side [696 916] and Kitalnaekit Wood. Thick deposits also flank the floodplain of the Water of Feugh between Templeton Croft and Mill of Cammie Farm [688 923]. Thinner resources underlie the kettled topography at the eastern margin of the block; these extend onto ground covered by the adjoining Banchory/Stonehaven resource sheet. Sand and gravel also forms steep-sided mounds in the valley of the Burn at Melmannoch, especially at the confluence of this burn and the Burn of Slacks.

Fluvioglacial deposits are presently being worked at Cammie Wood Gravel Pit [695 920]; similar material has been worked in a pit 300m north-north-west of Blackness [697 929] and glacial sand and gravel, forming an esker, has been worked at Burn of Rhoda Gravel Pit [678 918]. Minor resources of pebbly sand are present as thin, discontinuous spreads within the lacustrine alluvium and alluvium fan deposits to the north of Upper Curran [697 906]; most of this material lies close to the water-table.

The morainic drift deposits in block D have not been assessed, because mapping indicates that they contain little workable material. A single trial pit (69 SE 20) dug into these deposits proved only 0.6m of silty sand overlying 0.4m of sandy diamicton; the latter rests on decomposed granite which grades as 'gravel' and may be workable. A statistical assessment (Table 13), based on 9 sample points, is given for the block as a whole.

Fluvioglacial deposits

The kettled spreads of fluvioglacial sand and gravel north and west of Moss-side constitute the most attractive resources in the area. The records of one assessment borehole (69 SE 17), two measured sections (69 SE 21 and 22) and one trial pit (69 SE 23) sited on these deposits, show that, in general, they fine downwards from clast-supported gravel, into pebble sand, and then into silty sand. The fluvioglacial sand gravel was laid down as a series of fan-deltas which prograded north-westwards into ice-marginal lakes, ponded by ice that occupied the valley of the Water of Feugh. One measured section (69 SE 18) in a small disused pit [6942 9154] south-west of Moss-side, however, recorded only 6.9m of cross-bedded sand, showing that gravelly deposits are absent locally.

The thickest sequence of deltaic sediments was recorded from one of the working faces in Cammie Wood Gravel Pit (69 SE 21) where 12.8m of sand and gravel was recorded lying above the water-table. The surface of the ground underlain by sand and gravel rises in elevation to the east of the present workings, indicating that the thicker deposits may be present in this part of the block. Mapping also indicates that thick sand and gravel deposits may underlie flat-topped mounds that rise 10-15m above the level of the surrounding ground, between Moss-side and Burn of Rhoda farm [682 919], and to the north-east of Mill of Cammie [689 921]. Assessment borehole 69 SE 17, sited to the east of the mill, proved 7.9m of sand and gravel overlying potentially workable flow-till.

Three flat-topped mounds of fluvioglacial sand and gravel on the flanks of the Burn of Affrusk, north of Blackness, constitute a minor resource. A section and pit (69 SE 16), in a small working in one of the mounds, proved 3.4m of horizontally bedded gravel overlying 3.1m of cross-bedded gravel resting on laminated silt and clay; these three units respectively constitute the topset, foreset and bottom set beds of a small fan-delta.

An extensive kettled spread of sand and gravel lies to the east of, and rises 7-8m above the surface of flat-lying ground underlain by lacustrine alluvium to the east of Pitreadie Farm [692 910]. An assessment borehole (69 SE 19), sited on top of a mound near to the southern margin of the spread, proved 4.1m of sandy gravel overlying potentially workable flow-till. The sand and gravel is known to thicken north-eastwards as indicated by an assessment borehole (79 SW 2) drilled during the assessment of the adjoining Stonehaven/Banchory area, which proved 6.6m of fluvioglacial sand and gravel overlying flow-till.

No quantitative information is available on the thickness and quality of the fluvioglacial sand and gravel in the valley of the Burn of Slacks and in the valley of the Burn of Melmannoch. Mapping indicates that workable deposits may be up to 10m in thickness, but their limited extent and isolated location detract from their potential as a resource.

Glacial sand and gravel

Discontinuous steep-sided eskers, trending SW-NE, rise 8-15m above the adjacent ground surface north of Gally Bank [687 911]. No sample points were sited on the eskers, but they are thought to be a potential source of aggregate because clast-supported cobble-gravel and pebbly sand can be seen in numerous small exposures.

Glacial sand and gravel, forming a low E-W trending esker, has been worked in Burn of Rhoda Gravel Pit. A measured section (69 SE 12) at the eastern end of the pit recorded 1.7m of poorly-sorted cobble-gravel, overlying 3.9m of sandy gravel with scattered granite boulders. The sand and gravel rests on till, which forms the floor of the pit.

Lacustrine alluvium

Discontinuous beds of silty sand have been augered beneath the alluvial flat to the east of Pitreadie Farm. The sand, which is interbedded with peat and silt, crops out in the banks of the Burn of Curran and in the sides of ditches which drain the waterlogged ground. The sand is of minor interest, in resource terms, and resistivity soundings (69 SE R5) indicate that the underlying glaciolacustrine deposits are mainly composed of water-saturated silt.

Comparable spreads of sandy lacustrine alluvium

Table 14 Strachan sheet: Data from sample points and the assessment of resources in Block E

Data point	Recorded thickness			Mean grading percentage (sizes in mm)							
Borehole, pit, exposure or resistivity sounding	Total mineral m	Depth of burial m	Intervening waste m	Fines -.063	Fine sand .063-.25	Medium sand .25-1	Coarse sand 1-4	Fine gravel 4-16	Coarse gravel 16-64	Cobbles and boulders +64	Descriptive category (see the diagram in Appendix C)
N0 68 NW 9	2.2+	0.3	-	6	3	11	12	14	26	28	G
N0 69 SW 4	3.1+	0.2	0.1	3	5	19	24	13	14	22	G
N0 69 SW 6	4.7	0.3	-	2	1	10	20	15	20	32	G
N0 69 SW 8	4.5+	0.1	-	1	1	18	39	16	15	10	SG
N0 69 SW 11	2.0+	0.8	-	3	1	18	31	13	19	15	SG
N0 69 SW 14	2.6+	0.2	-	2	1	7	20	14	15	41	G
N0 69 SW 16	4.2+	0.3	-	1	1	22	40	11	10	15	SG
N0 69 SW 18	1.0	0.3	-	2	1	9	32	21	26	9	G
Mean	3.0	0.3	-	2	2	15	28	14	17	22	G

Statistical assessment of Block E (mainly glacial sand and gravel and morainic drift deposits)

Total area	4.17 km^2
Area of exposed mineral	0.27 km^2
Discontinuous spreads of mineral	0.40 km^2
Area of morainic drift	1.72 km^2
Total area of mineral-bearing ground	1.33 km^2*
Mean thickness of overburden	0.3m
Mean thickness of mineral	3.0m
Estimated volume of mineral	4.0 million m^3 (± 38% or 1.5 million m^3)
Estimated yield of mineral per hectare	30 thousand m^3 (± 38% or 11 thousand m^3)

*In the calculation of this figure, 50% of the area of discontinuous spreads and 50% of the area of morainic drift are assumed to be mineral-bearing

have been mapped to the south-east of Blackness, where they are flanked, to the north, by a low-lying terrace composed of fluvioglacial sand and gravel. Although both deposits are shown on the resource map as continuous spreads of exposed sand and gravel, they are only of limited interest, as they are thin and lie at or near groundwater level.

Resource block E

The boundaries of block E are drawn to include most of the morainic drift and glacial sand and gravel deposits on the southern flank of the valley of the Water of Feugh, between the western margin of the resource sheet and the Feugh/Aven confluence. The block also includes most of the morainic drift and alluvial deposits in the valley of the Burn of Greendams to the west of Rouchanbeg and the moraines and eskers between The Drummels [629 897] and Ord of Cuttieshillock.

Morainic drift

Deposits of morainic drift are widespread in block E where they constitute a resource of poor-grade heterogeneous sand and gravel that typically forms very irregular hummocky topography and sandy soils. The deposit has been dug on a very small scale to the south of Blackhole. A section and pit (69 SW 4) in one working, proved 1.5m of poorly sorted cobble gravel overlying 1.6m of poorly stratified sandy gravel, separated by a waste parting 10cm thick. The excavation was abandoned on large boulders of felsitic porphyry at 3.4m depth. A trial pit (69 SW 7) sited 700m to the south-east of the working proved 1.3m of diamicton with angular boulders of coarse-grained granite, resting on granite bedrock, illustrating the highly variable nature of the morainic drift material.

Workable sand and gravel was proved at four of the six trial pits sited on the morainic drift in block E. A pit (69 SW 11) at Moss of Powlair proved 2.0m of sandy gravel beneath sandy diamicton, before the water-table halted further progress. Two pits (69 SW 14 and 18), sited on the morainic drift on the eastern side of the valley of the Water of Aven, proved 2.6m and 1.0m of workable sand and gravel respectively.

No trial pits were dug in the morainic drift in the valley of the Burn of Greendams, but ridge-ploughing in recently planted coniferous forestry plantations, indicates that the deposits contain a high proportion of large boulders, thus making them unattractive as a source of aggregate.

Glacial sand and gravel

Discontinous esker ridges, up to 15m high, composed of poorly sorted glacial sand and gravel, were laid down by englacial meltwater that drained south-eastwards between Blackhole and Rouchan [640 896]. The sand and gravel has been dug in numerous small workings to the south of Midclune farm [607 916]. The face of a small working (69 SW 6), 500m to the south-east of the farm, exposed 4.7m of clast-supported cobble gravel with prominent cross-stratification. The cross-stratification dips parallel to the sides of the esker, which, at its eastern end, stands up to 8m high. A pit excavated at the base of the working face showed that the sand and gravel rests on stiff, clayey diamicton.

Glacial sand and gravel also forms a prominent sinuous esker, 1km long, to the west of Ord of Cuttieshillock. Exposures in the sides of a newly constructed forestry track show the deposit to be composed of poorly stratified coarse gravel, containing many boulders of coarse-grained pink granite. A pit (69 SW 16), excavated mid-way along the esker ridge, proved 4.2m of sand and gravel, unbottomed.

Alluvial deposits

A single trial pit (68 NW 9) was sited on the alluvial deposits in block E. It showed that 2.2m of clast-supported gravel, lying above the water-table, is present beneath the surface of an alluvial fan at Rouchan. Discontinuous potentially workable deposits are present close by, as indicated by exposures of pebbly sand, interbedded with silt and clay, in the banks of the Burn of Greendams. The sand, silt and clay overlie boulder gravel. Up to 5m of cobble gravel is exposed in river cliffs cut into terraced alluvial fan deposits upstream of Rouchan; the gravel is seen to pass laterally into stiff, sandy, stony clay.

Water-saturated silty sand, underlying humic silt, has been augered in places on the alluvial flat to the south of Midclune and similar material is thought to be present beneath waterlogged silty alluvium in the vicinity of Rouchan.

Other mineral deposits

Two kettled mounds of fluvioglacial sand and gravel are present where the Wester Burn and Easter Burn converge to form the Burn of Greendams. No assessment data are available regarding the thickness and grade of these deposits, but clast-supported cobble and boulder gravel is exposed in a degraded river cliff, about 17m high, [6254 8860] on the eastern side of the larger mound.

Assessment data for block E is given in Table 14.

Resource block F

This block includes all of the potentially workable sand and gravel in the valleys of the Water of Dye and its tributaries, between the Bridge of Bogendreep and the southern margin of the resource sheet. The most extensive deposits are found beneath the floodplain of the river but they are generally thin and water-saturated. They are therefore less attractive than thicker, dry deposits of fluvioglacial sand and gravel, which form moundy topography at Black Hillocks [628 862] and Scolly's Cross [652 877], and flat-topped terraces, 8-10m in height, west of Heatheryhaugh [658 869] and east of Miller's Bog [637 861].

Discontinuous resources, of minor importance, underlie low-lying terraces on both sides of the river in the vicinity of Heatheryhaugh, higher terraces near Glen Dye Lodge [645 862] and low terraces on the northern side of Mill Burn. Small amounts of alluvial sand and gravel are present in the valley of Mill Burn and the valley of Builg Burn.

A statistical assessment of block F, based on fourteen data points, is given in Table 15.

Fluvioglacial deposits

The most attractive resources in the block, form steep-sided mounds up to 25m high at Black Hillocks. The mounds, which are densely forested, are the dissected remnants of a fan-delta that was laid down by meltwater that debouched from the south-eastern end of the Slack of Dye drainage channels. Steep topography and inaccessibility meant that the sand and gravel could only be sampled with

Table 15 Strachan sheet: Data from sample points and the assessment of resources in Block F

Data point	Recorded thickness			Mean grading percentage (sizes in mm)							
Borehole, pit, exposure or resistivity sounding	Total mineral m	Depth of burial m	Intervening waste m	Fines -.063	Fine sand .063-.25	Medium sand .25-1	Coarse sand 1-4	Fine gravel 4-16	Coarse gravel 16-64	Cobbles and boulders +64	Descriptive category (see the diagram in Appendix C)
N0 68 NW 2	8.3	0.3	0.7	7	7	33	29	20	4	0	SG
N0 68 NW 3	2.3	2.5	-	5	5	17	34	21	18	0	SG
N0 68 NW 4	2.1+	0.3	-	2	2	11	20	36	25	4	G
N0 68 NE 3	4.9	0.3	0.1	5	11	30	42	12	0	0	PS
N0 68 NE 5	4.9	0.3	-	9	9	27	36	16	3	0	PS
N0 68 NE 6	1.2	0.6	-	16	32	42	7	2	0	0	CS
N0 68 NE X1	2.7+	0.5	-	3	4	22	48	19	4	0	PS
N0 68 NE X3	2.0+	0.2	-	13	9	19	23	21	11	4	CSG
N0 68 NE X4	1.5+	0.2	-	3	4	10	25	27	23	8	G
N0 68 NE R1	2.2	0.1	-	-	-	-	-	-	-	-	-
N0 68 NE R2	1.4	0.1	-	-	-	-	-	-	-	-	-
N0 68 NE R3	4.7	0.1	-	-	-	-	-	-	-	-	-
N0 69 SE X4	6.9	0.6	-	1	3	16	26	15	21	18	G
N0 69 SE X5	2.1	0.7	-	1	8	15	13	11	29	23	G
Mean	3.4	0.5	0.1	5	7	24	30	18	11	5	SG

Statistical assessment of the fluvioglacial sand and gravel, glacial sand and gravel and alluvial deposits at Glen Dye (Block F)

Total area	6.82 km^2
Area of exposed mineral	0.85 km^2
Area of concealed mineral	<0.01 km^2
Area of discontinuous spreads of mineral	1.19 km^2
Total area of mineral-bearing ground	1.45 km^2*
Mean thickness of overburden	0.5m
Mean thickness of mineral	3.4m
Estimated volume of mineral	4.9 million m^3 (± 39% or 1.9 million m^3)
Estimated yield of mineral per hectare	34 thousand m^3 (± 39% or 13 thousand m^3)

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

great difficulty, by means of a mechanical excavator. A single trial pit (68 NW 4) proved 2.1m of clast-supported gravel, becoming finer with depth, before the excavation was abandoned. Exposures in the sides of a deep glacial drainage channel show that fine, angular gravel overlies at least 5m of fine-grained sand towards the base of the sequence, indicating that 20-25m of sand and gravel may be present. The whole of the resource lies above the water-table.

An assessment borehole (68 NE 3) sited on kettled fluvioglacial deposits that form moundy topography at Scolly's Cross proved 4.9m of sand and gravel, which becomes more clayey with depth. The mineral overlies glaciolacustrine silt, which rests on interbedded sandy and clayey diamictons overlying granitic gravel (probably decomposed bedrock). Similar fluvioglacial deposits were thought to underlie an area of undulating topography at Bridge of Dye farm [652 862]. An assessment borehole (68 NE 4) sited 200m north-west of the farmhouse, however, proved only a thinly interbedded sequence of sandy diamicton, clayey gravel, silt and clay, resting on granite bedrock at 3.5m depth. Records of a trial pit (68 NE X1), 100m to the south-west of the borehole site, excavated during the site-investigation for the Bridge of Dye road improvement, show 2.7m of sand and gravel.

A degraded section, about 8m high, in a terrace bluff, indicates that several metres of sand and gravel underlies a flat-topped terrace, 300m west of Heatheryhaugh. The exposure (68 NE 5) was cleaned and sampled by hand, and a pit was dug by mechanical excavator at the base of the cleaned face. The excavations proved 4.9m of pebbly sand overlying 3.3m of glaciolacustrine silt. Comparable flat-topped terraces flank Mill Burn, where sand and gravel has been dug in several workings. A section and pit (68 NW 2) in one of the larger workings proved 2.8m of 'clayey' sandy gravel overlying 0.7m of waste and 4.0m of pebbly sand. The pebbly sand overlies glaciolacustrine deposits. The contrasting nature of the deposits that form terraces in the valley of Mill Burn is illustrated by the sequence recorded from a borehole (68 NW 3) sited on a terrace on the northern side of the burn. This borehole proved 2.3m of sand and gravel concealed beneath 2.5m of overburden, comprising soil, glaciolacustrine deposits and flow till.

Alluvial deposits

Three resistivity sounding sites (68 NE R1, R2 and R3) and one assessment pit (68 NE 6) were located on the floodplain and alluvial terraces of the Water of Dye, upstream of Builg Pot. Data from these sample points, together with the records from a site investigation borehole (68 NE X3) and a trial pit (68 NE X4), show that the mineral deposits in this part of the valley comprise a thin, almost continuous, spread of alluvial sand and gravel, which overlies boulder gravel or Kincardine Granite. The mineral, which has a mean thickness of 2.2m, lies mainly below the water-table.

No sample points were sited on the alluvial deposits in the valley of the Water of Dye downstream of Builg Pot. Mapping suggests that the sand and gravel is generally thin and laterally impersistant, but the records of two site investigation boreholes (68 NE X4 and X5), drilled for the proposed Bogendreep Bridge Improvement, show 6.9m and 2.1m of sand and gravel respectively, underlying the floodplain of the river, immediately upstream of the present bridge.

Resource block G

This block covers most of the southern part of the resource sheet. It comprises generally barren upland covered by thin deposits of granitic sand and thick deposits of peat, overlying Kincardine Granite. No volumetric assessment is given for the limited resources present.

Only one sample point (69 SW 3) was sited in the block. It proved 5.4m of highly decomposed granite, that grades as sandy gravel, overlying fresh coarse-grained Kincardine Granite in a sand pit west of Bogmore [607 903]. Patches of similarly altered bedrock are widespread in the upland area; their presence is noted on the resource map. No attempt has been made to place a boundary between altered and fresh bedrock as it is frequently gradational and it could not be mapped accurately, particularly where it is obscured beneath peat. The only other resources identified in block G, comprise very thin, terraced spreads of cobble gravel in the valley of the Water of Aven. The terraces are preserved upstream and downstream of a deep gorge cut by the river between Creaganducy [601 891] and Meikle Strathvella [616 891].

Total area of block G	45.08km^2
Area of discontinuous spreads of mineral	0.11km^2

DESCRIPTION OF THE AUCHENBLAE-CATTERLINE RESOURCE SHEET

Resource block A

Resource block A is confined to the south-western part of the resource sheet. Its boundary with resource block B is defined by the southern and western margins of the floodplain of the Bervie Water. The major sand and gravel resources in block A are concentrated in two linear belts. The larger of these two belts flanks the valleys of the Luther Water and its tributary, the Burnie Shag, from the area around Galloquhine [7230 7946] to Mains of Fordoun [7325 7694], and south-eastwards to Whiteriggs [7588 7587]. This belt consists entirely of terraced deposits of fluvioglacial sand and gravel. The other belt trends eastwards from Auchenblae to the vicinity of East Mondynes [7785 7950] and it comprises discontinuous ridges and mounds of glacial sand and gravel.

Weathered conglomerate occurs in a triangular area between Glen of Drumtochty, Galloquhine and Denside [7170 8123] and it constitutes a less attractive resource, as do isolated deposits of glacial sand and gravel around Bomershanoe Wood [7332 7534] and an alluvial fan 200m north-east of West Cairnbeg [7016 7620]. Alluvium forms a poor, discontinuous resource in the Glen of Drumtochty, in the upper reaches of the Burnie Shag and in the low-lying ground between Pitrennie Mill [7285 7702] and Redmyre [7500 7536]. The remainder of the resource block is barren, being mapped as exposed bedrock and till with small areas of glaciolacustrine deposits and lake alluvium. Summary assessment statistics and sampling data

Table 16 Auchenblae-Catterline Resource sheet: Data from sample points and the assessment of resources in Block A

Data point	Recorded thickness			Mean grading percentage (sizes in mm)							
Borehole, pit, exposure or resistivity sounding	Total mineral m	Depth of burial m	Intervening waste m	Fines -.063	Fine sand .063-.25	Medium sand .25-1	Coarse sand 1-4	Fine gravel 4-16	Coarse gravel 16-64	Cobbles and boulders +64	Descriptive category (see the diagram in Appendix C)
Fluvioglacial sand and gravel											
NO 77 NE 2*	1.8+	0.3	-	10	trace	15	19	33	23	0	CG
NO 77 NE 3*	2.0	0.5	-	5	8	53	11	15	8	0	PS
NO 77 NW 2	3.4	0.3	2.1	5	5	10	20	36	22	2	G
NO 77 NW 3	7.3+	0.1	-	1	5	37	20	21	15	1	SG
NO 77 NW 4	8.1+	0.3	1.0	6	7	45	16	18	8	0	SG
NO 77 NW 6	5.2	-	-	4	4	48	41	2	1	0	S
NO 77 NW 11	6.8	0.3	-	6	14	51	14	11	4	0	PS
NO 78 SW 2	1.0	0.2	-	7	3	11	11	28	35	5	G
Mean	4.5	0.3	0.4	6	6	32	19	21	15	1	SG
Glacial sand and gravel: Auchenblae - East Mondynes belt											
NO 77 NE 1	23.1+	0.1	0.3	7	24	38	11	12	7	1	PS
NO 77 NE 4	1.8	0.2	-	6	8	22	6	21	33	4	G
NO 77 NE 5	1.8+	0.9	-	2	2	16	15	27	35	3	G
NO 77 NE 8	3.3+	0.3	-	12	17	25	14	18	13	1	CSG
NO 77 NE 9	3.8+	0.2	-	9	19	19	10	12	19	12	SG
NO 77 NW 5	11.6	0.3	-	6	6	18	21	28	17	4	G
NO 77 NW 9	6.4+	0.2	-	4	7	48	23	9	9	0	PS
NO 77 NW 10**	18.1+	0.9	1.6	9	23	26	14	15	11	2	SG
Mean	8.7	0.4	0.2	7	13	27	14	18	18	3	SG
Glacial sand and gravel: Bomershanoe Wood											
NO 77 NW 8	4.2+	0.3	-	5	4	16	15	26	29	5	G
Overall mean for glacial and fluvioglacial sand and gravel	6.5	0.3	0.3	6	9	29	17	20	17	2	PS
Alluvium											
NO 77 NW 7	0.9	1.5	-	9	9	15	20	30	17	0	G
Overall mean for sand and gravel	6.1	0.4	0.3	6	9	29	17	20	17	2	G

* shown incorrectly as glacial sand and gravel in the borehole arrays on the resource map
** includes 1.0m of potentially workable flow-till

Weathered conglomerate											
NO 78 SW 1	3.2+	0.3	-	3	1	2	4	24	49	17	G

Statistical assessment of glacial and fluvioglacial sand and gravel in block A

Area of exposed mineral	3.74 km^2
Area of concealed mineral	1.17 km^2
Area of discontinuous mineral	0.86 km^2
Area of ground worked for mineral	0.21 km^2
Area of sterilised ground	0.25 km^2.
Total area of mineral-bearing ground	5.34 km^{2*}
Mean thickness of overburden	0.3 m
Mean thickness of mineral	6.5 m
Estimated volume of mineral	34.7 million m^3 (±52% or 18.0 million m^3)
Estimated yield of mineral per hectare	65 thousand m^3 (±50% or 34 thousand m^3)

Speculative assessment of weathered conglomerate bedrock in block A

Area of exposed mineral	2.02 km^2
Total area of mineral-bearing ground	2.02 km^2
Estimated mean thickness of overburden	0.3m
Estimated mean thickness of mineral	3.2m
Estimated volume of mineral	6.5 million m^3
Estimated yield of mineral per hectare	32 thousand m^3

Speculative assessment of alluvial deposits in block A

Area of exposed mineral	0.06 km^2
Area of discontinuous mineral	1.62 km^2
Total area of mineral-bearing ground	0.87 km^{2*}
Estimated mean thickness of overburden	0.9m
Estimated mean thickness of mineral	0.9m
Estimated volume of mineral	0.8 million m^3
Estimated yield of mineral per hectare	9 thousand m^3

* In the calculation of these figures, 50 per cent of the area of discontinuous spreads is considered to be mineral bearing.

are presented in Table 16.

Fluvioglacial sand and gravel

The fluvioglacial sand and gravel between Galloquhine [7230 7946] and Whiteriggs [7588 7587] forms a series of dissected terraces and ridges; the highest of these features stand more than 25m above the floodplain of the Luther Water in the ground between Mains of Fordoun [7325 7694] and Auchenblae. This sand and gravel is considered to have been deposited in ice-marginal lakes, ponded between ice occupying low ground and higher ground to the north-west of Auchenblae. Meltwaters entered the lake that occupied the low-lying ground west of Mains of Fordoun from the north-north-east, down the drainage channels now occupied by the Luther Water and Burnie Shag. As ice retreated to the south and south-west, meltwaters dissected the earlier deposits, forming the prominent erosional features seen in the Auchenblae area. The terraced deposits between Mains of Fordoun and Whiteriggs were probably laid down by meltwaters which were constrained by ice to flow south-eastwards, joining the drainage channel of the Bervie Water south-east of Fordoun.

The greatest thickness of mineral occurs in the area between Auchenblae and Mains of Fordoun where sampling in pits and sections has proved thicknesses in excess of 5m. Trial pit/section 77 NW 6 proved 5.2m of sand resting on till, whereas 77 NW 3, in Gilberts Hill Quarry, and 77 NW 4 in Drumsleed Quarry, proved in excess of 7.3m and 8.1m of sandy gravel respectively. The sections show cross-stratified sands and gravels that generally coarsen upwards. A terraced ridge of sand and gravel to the west of the Luther Water, between Cairnton Cottages [7279 7722] and Whinhill [7272 7801] was not sampled. However, sand and gravel is being extracted in a small quarry [7255 7768] 200m north of Black Knaps, where a section showed more than 6m of clast-supported cobble-gravel. Site investigation data confirms that sand and gravel underlies the terraces to the east.

North of Auchenblae, the deposits of sand and gravel appear to thin. Borehole 77 NW 2 proved 3.4m of mineral with a 2.1m waste parting, probably consisting of massive boulder gravel. Geological mapping of the ground around Fa' Hillocks [7320 7923] suggests that several metres of sand and gravel are present, but the ground is currently occupied by the Auchenblae Golf Course. Several metres of mineral are also likely to be present in the ground flanking the south-western side of the valley of the Luther Water north-west of Auchenblae. Parts of Auchenblae, including High Street, Inverurie Street and Glenfarqhuhar Road, are built on the sand and gravel, thus sterilising some of the deposit.

The lower lying, terraced deposits between Mains of Fordoun and Whiteriggs [7588 7587] are considered to be less continuous than the equivalent deposits to the north-west. Borehole 77 NW 11, sited 200m south of Pittengardner, proved 6.8m of pebbly sand resting on till, but geological mapping suggests that the thickness of mineral is much reduced in other places and it is no more than 1 to 1.5m thick to the south-east, near Fordoun. Between Fordoun and Whiteriggs, four dissected, terraced deposits of mineral are present and they are considered to be an extension of the terraces to the north-west of Fordoun. Pits 77 NE 2 and 77 NE 3 proved 1.8m and 2.0m of gravel respectively, the former being unbottomed. Please note that the geological classification of these deposits is shown incorrectly in the borehole graphic arrays on the resource map; the deposits are fluvioglacial and not glacial sand and gravel.

The deposits between Auchenblae and Mains of Fordoun are the most intensively worked of any on the Auchenblae-Catterline resource sheet. Drumsleed Quarry is by far the largest working, with some two-thirds of the ridge between Drumalan [7302 7751] and Gilbert's Hill having been removed.

The mean thickness of the fluvioglacial sand and gravel is 4.5m and the mean grading is 6 per cent fines, 57 per cent sand and 37 per cent gravel; the overall classification is sandy gravel. However, as the data in Table 16 show, these deposits vary considerably in grading and the possibility of higher fines contents occurring in places cannot be discounted.

Glacial sand and gravel

Auchenblae to East Mondynes

Glacial sand and gravel between Auchenblae and East Mondynes [7785 7950] occurs in a linear belt of ridges and mounds. The most extensive spreads of mineral occur at the western end of this belt, between Auchenblae and Hungeral/Nursery Burn; here the ridges exceed 20m in height and the belt is about a kilometre wide. East of Causeywell Brae [7515 7889], the deposits of sand and gravel are less abundant and more widely scattered, but significant resources are present, most notably the 900m long ridge of sand and gravel extending eastwards from Castleton [7600 7870]. In the vicinity of Lafton Knowes [7640 7935], ridges of sand and gravel occur amidst ice-scoured ridges formed of conglomerate; it is likely that the sand and gravel is derived directly from the conglomerate, indeed trial pit 77 NE 4 proved 1.8m of gravel on conglomerate in a ridge 10m high.

Exposures in glacial sand and gravel are not common and in many areas the sand and gravel is blanketted with a thin layer of flow-till up to about 2.5m thick. Exposures in pit 77 NW9 reveal the complex internal structures that can occur in these sands and gravels. Beds are contorted and faulted and, in the upper part of the section, gravels interdigitate with gravelly flow-till. The sands and gravels are considered to have been deposited in temporary, ice-marginal lakes, formed by the ponding of meltwaters between ice on high ground to the north and ice in Strathmore to the south.

The glacial sands and gravels vary considerably in thickness. The thickest proven deposits occur in the ridge between Causeywell Brae [7515 7892] and Spy Hillock [7561 7887]. Boreholes 77 NE 1 and 77 NW 10 proved 23.1m and 18.1m of mineral, respectively; in both boreholes, the mineral was not bottomed and the lowest 4 to 5m of the deposit lies below the water-table. In these two boreholes, the mineral varied from 'clayey' sand and 'clayey' gravel to gravel. In the 'clayey' sand horizons, the fines content reaches 25 per cent and the sand is very fine-grained. The 'clayey' gravel occurs betwen 4.9 and 5.9m in 77 NW 10 and is probably a flow-till. The overall grading classification for 77 NE 1 is pebbly sand and in 77 NW 10, it is sandy gravel. In the central part of the belt of glacial sands and gravel deposits, west of Hungeral/Nursery Burn, borehole 77 NW 5 at Bankhead proved 11.6m of gravel. Trial pit/section 77 NW 9 sited in a small working at [7457 7877] was unbottomed in 6.4m of mineral grading overall as pebbly sand.

It is considered that the glacial sand and gravel east of Castleton [7600 7870] is likely to be thinner generally than that to the west. However, mineral was only bottomed in trial pit 77 NE 4 where, as mentioned previously, gravel rests on conglomerate. The gravel in pit 77 NE 5, which was sited on the ridge extending eastwards from Castleton, lies beneath 0.9m of flow-till, but it is exceptionally clean with a fines content of only 2 per cent. Only 1.8m of mineral was proved at this site, because the poor consolidation of the material caused the sides of the pit to collapse, but it looks to be an attractive resource. In the area around East Mondynes, trial pits 77 NE 8 and 77 NE 9 proved 3.3 and 3.8 of mineral respectively, though both were unbottomed; the mineral here is more fines-rich than material farther west and it also contains some >64mm material.

The mean grading of the glacial sand and gravel in the Auchenblae/East Mondynes area is 7 per cent fines, 54 per cent sand and 39 per cent gravel and the overall classification is 'sandy gravel'. The mean thickness of the resource is 8.7m, but the range is from 1.8m to 23.1m. Because of the likelihood of great variability in grading within the glacial sand and gravel, the mean values given above must be treated with caution; variations in both thickness and grading may occur rapidly over short distances.

Bomershanoe Wood

The glacial sand and gravel deposits in the vicinity of Bomershanoe Wood occur as a series of mounds and arcuate ridges that are considered to have been deposited as eskers. These features are about 5m high and give rise to gravelly soils. Trial pit 77 NW 8 was sited in the central mound and it was unbottomed in 4.2m of gravel. The mineral is relatively clean, though it does contain some cobbles. None of the other mounds were sampled, but 1.8m of gravel resting on till is recorded in a trench in the south-easternmost mound. Based on the one sample point the mean grading is 5 per cent fines, 35 per cent sand and 60 per cent gravel.

The glacial sand and gravel has not been worked extensively in resource block A. The only working that was active in 1989 was at [7450 7877], but this was operated on a very small scale. A mound of what was probably largely glacial sand and gravel has been removed from the area immediately east of Laftan Knowes [7670 7926].

Alluvium and alluvial fans

Deposits of alluvial sand and gravel occurring as alluvial fans only form minor resources. By and large, these deposits are close to, or below, the water-table.

Alluvium Thin discontinuous spreads of mineral are considered to be present beneath the flat, low-lying and poorly-drained ground between Pitrennie Mill [7285 7702] and the area just to the north-west of Redmyre [7500 7536]. This material is considered to have been deposited in ice-scoured basins containing glaciolacustrine deposits and till. Up to 1.5m of clast-supported gravel is seen in the banks of the Luther Water to the south of Pitrennie Mill. However, interpreted resistivity sounding 77 NW R2 suggests that the alluvium to the south-west of the Mains of Fordoun comprises a mixture of clay, silt and sandy gravel and is thus considered to be waste. Furthermore, borehole 77 NW 7 proved only 0.9m of saturated, poorly sorted, dirty gravel at a depth of 1.5m. Alluvial sands and gravels up to 1.9m thick are recorded in a pipeline trench south-east of Auchenzeoch [7379 7610] and site investigation boreholes record that sand and gravel in excess of 3m thick underlies the alluvial flat north-west of Redmyre. Available data thus indicates that the alluvial deposits vary widely in thickness and character and that these variations are likely to occur very rapidly, both laterally and vertically. Please note that resistivity sounding site 77 NW R3 is wrongly positioned on the resource map: the correct site is [7274 7545].

Alluvium forming the narrow floodplains of the Luther Water, north of Cairnton Cottages, together with that of the Burnie Shag, is considered to contain some sand and gravel. However, this is likely to be discontinuous and very variable in thickness and grading.

Alluvial fans The gently undulating ground between Mains of Fordoun [7835 7694] and Drumalan [7302 7751] is considered to be formed largely by an alluvial fan, deposited by water debouching from the gorge of the Luther Water south of Auchenblae. At its highest point, the surface of the fan stands at about 5m above the adjacent floodplain. Although not sampled, the gravelly soil suggests the presence of sand and gravel; any mineral is unlikely to be more than 5m thick. It is not a particularly attractive resource.

An alluvial fan immediately north-east of West Cairnbeg [7020 7620] stands, at its highest, 3m above the level of the surrounding alluvial flat. Sections in drainage ditches reveal up to 1m of fine-grained silty gravels interbedded with sand. The material is water-saturated below 0.5m.

Conglomerate

Conglomerate cropping out to the north of Glen of Drumtochty is weathered and disaggregated and thus constitutes a source of coarse aggregate. Trial pit 77 SW 1, sited immediately to the north of a small working at Den of Dash, was unbottomed in 3.2m of coarse gravel. The mineral here contains only a small amount of sand and it becomes increasingly coarse with depth, with +64mm material constituting at least 40 per cent of the sample between 2.3 and 3.5m. Some of the upper part of the deposit may have been glacially reworked. An exposure in a sileage pit at Denside [7170 8124] exposes in excess of 4.5m of decomposed conglomerate, but the thickness and lateral extent of such material will vary widely; as little as 0.8m is recorded at the top of the section in a disused quarry 400m south-east of Ruehill [7158 8026]. The estimated mean thickness of the decomposed conglomerate resource is 3.2 m and the mean grading is 5 per cent fines, 16 per cent sand and 79 per cent gravel.

Resource block B

The western margin of resource block B is defined by the western boundary of the alluvium of Bervie Water. The eastern margin runs north-south, for the most part, along easting gridline 38000. The eastern margin is defined so that, as far as possible, potentially workable resources of conglomerate are contained within a single resource block for assessment (block C).

Much of block B is barren ground with bedrock

Table 17 Auchenblae-Catterline Resource sheet: Data from sample points and the assessment of resources in Block B

Data point	Recorded thickness			Mean grading percentage (sizes in mm)							
Borehole, pit, exposure or resistivity sounding	Total mineral m	Depth of burial m	Intervening waste m	Fines -.063	Fine sand .063-.25	Medium sand .25-1	Coarse sand 1-4	Fine gravel 4-16	Coarse gravel 16-64	Cobbles and boulders +64	Descriptive category (see the diagram in Appendix C)
DRUMLITHIE COMPLEX (Glacial sand and gravel)											
a) Eastern marginal belt											
N0 78 SE 6	3.5+	0.3	-	6	8	37	20	18	11	0	SG
N0 78 SE 7	18.7+	0.2	1.3	5	16	21	26	16	12	4	SG
N0 87 NW 1	1.9	0.3	-	4	5	10	11	16	33	21	G
N0 88 SW 2	20.4	2.5	-	18	55	22	2	2	1	trace	CG
Mean	11.1	0.9		8	21	23	15	13	14	6	SG
b) Central moundy body											
NE 77 NE 10	1.9+	1.8	-	7	7	31	26	17	12	0	SG
N0 77 NE 15	3.2+	0.7	-	14	58	24	3	1	trace	0	CS
N0 77 SE 9	9.1	3.1	-	10	29	44	10	5	2	0	CPS
N0 78 SE 10	11.3*	1.3	0.2	20	54	24	1	1	trace	0	VCS
Mean	6.4	1.7		13	37	30	10	6	4	0	CPS
c) Eskers											
N0 77 NE 16	3.9+	0.3	-	4	5	12	15	18	35	11	G
N0 77 NE 17	4.6+	0.2	-	6	8	17	13	18	36	2	G
Mean	4.3	0.3		5	7	14	14	18	36	6	G
d) Peripheral spreads											
Discontinuous and isolated sheets and low mounds											
N0 78 SE 4	3.1	0.3	-	13	24	30	15	12	6	0	CPS
N0 78 SE 8	5.4+	0.0	-	2	2	10	15	26			
Mean	4.3	0.2	-	8	13	20	15	19	21	4	SG
Overall mean for glacial sand and gravel	7.3	0.9	-	9	23	24	13	13	15	3	SG
THE VALLEYS OF THE BERVIE WATER AND CARRON WATER											
Alluvium (valley floor)											
N0 77 NE 7	1.8	0.3	-	-	-	-	-	-	-	-	-
N0 78 SE 2	2.0	0.3	-	6	4	10	11	19	32	18	G
N0 77 NE R1	1.2**	0.2	-	-	-	-	-	-	-	-	-
N0 78 SW R1	2.1	0.1	-	-	-	-	-	-	-	-	-
N0 78 SW R2	1.0	0.1	-	-	-	-	-		-	-	-
N0 78 SE R1	0.8	0.1	-	-	-	-	-	-	-	-	-
Mean	1.5	0.2									
Terraces (valley side)											
N0 78 SE 1	2.5+	0.6	0.4	4	5	11	14	16	32	18	G
Fluvioglacial sand and gravel											
N0 78 SE 3	1.6+	0.4	-	1	6	42	43	8	0	0	PS
Overall mean for whole block	5.2	0.7	<0.1	6	13	22	17	14	21	7	SG

* including 1.7m of potentially workable flow-till
** incorrectly sited on the resource map; correct site [7672 7557]

Statistical assessment of glacial sand and gravel resources in block B

Area of exposed mineral	2.03 km^2
Area of concealed mineral	1.48 km^2
Area of discontinuous mineral	0.18 km^2
Area of ground worked for mineral	0.09 km^2
Total area of mineral-bearing ground	3.65 km^{2*}
Mean thickness of overburden	0.9 m
Mean thickness of mineral	7.3 m
Estimated volume of mineral	26.6 million m^3 (±59% or 15.7 million m^3)
Estimated yield of mineral per hectare	73 thousand m^3 (±50% or 43 thousand m^3)

Statistical assessment of alluvial, terrace and fluvioglacial deposits in the valleys of the Bervie Water and Carron Water, block B

Area of exposed mineral	0.31 km^2
Area of discontinuous mineral	3.97 km^2
Total area of mineral-bearing ground	3.29 km^{2*}
Mean thickness of overburden	0.3 m
Mean thickness of mineral	1.6 m
Estimated volume of mineral	5.3 million m^3 (±32% or 1.7 million m^3)
Estimated yield of mineral per hectare	1.6 thousand m^3 (±50% or 0.8 thousand m^3)

* In the calculation of these figures, 75 per cent of the area of discontinuous spreads is considered to be mineral bearing.

at or near the surface. The sand and gravel deposits are concentrated in an area east of Drumlithie [7868 8092], extending from Pitdrichie [7948 8254] and Keabog [8025 8280], in the north, to Mavisbank [7948 7742] in the south. These resources consist entirely of glacial sands and gravels and they comprise a highly complex sequence of deposits. To aid description, these sands and gravels will be referred to collectively as the 'Drumlithie Complex'.

Minor resources of sand and gravel are found in the valleys of the Bervie Water and Carron Water. These comprise river terraces and floodplain deposits with some very small spreads of glacial and fluvioglacial sand and gravel.

The data from the sample points is summarised in Table 17.

Glacial sands and gravels of the Drumlithie Complex

The deposits within the Drumlithie Complex are moundy for the most part, but some are terraced, particularly to the west of the Forthie Water, between Brinzieshill [7985 7920] and Thriepland [8061 8005]. There are also low-lying, undulating spreads and two eskers.

The sand and gravel deposits can be subdivided into four suites, each characterised by specific sediment and landform assemblages and by location and/or spatial association. The four suites are defined below in order of their importance as resources:

a: The eastern marginal belt: elongated mounds and terraces, composed mainly of sandy gravels that form a belt along the eastern margin of the Drumlithie Complex.

b: The central moundy body: This is the central, moundy part of the Complex that is roughly circular in plan and that extends from Drumlithie to the Forthie Water in the south and east, and Pade O'France [7832 7986] in the west; it is mainly underlain by sand that is concealed beneath flow-till up to 3m thick.

c: eskers: closely related to the deposits in '*a*' and composed chiefly of gravels.

d: fringing spreads: isolated, thin spreads and low mounds of gravel which lie to the north and south of the central body; they mainly occur about 300m south of East Kinmonth [7874 8147], where they flank the Drumlithie Burn, and between Gyratsmyre [7861 7917] and Brinzieshill.

a) The eastern marginal belt. The linear mounds which form the belt of sand and gravel deposits along the eastern margin of the Drumlithie Complex are composed, in the main, of relatively clean sands and gravels, though they contain some thin bands of clayey silt in places.

The sands and gravels were deposited by meltwaters in an ice-marginal setting as the ice-sheet retreated to the south-west; they fill, or flank drainage channels that were cut subglacially when ice extended over this area.

The dissected or fragmented character of these deposits indicates that both deposition and erosion was occurring at the same time.

The deposits are predominantly sandy gravels, though the deposit around, and to the north of, Clearymuir [8003 8107] is a major exception. Here, borehole 88 SW 2 proved 20.4m of 'very clayey' to 'clayey' sand beneath 2.5m of cobble and boulder diamicton. Part of this deposit has been worked in a pit [7985 8146] to the north-west of the borehole site. Although the section here is degraded, the upper 4m of the deposit is exposed, showing 1.5m of cobble and boulder diamicton overlying cross-stratified sands with some fine gravels in the upper metre.

The deposits vary in thickness from 2m to 22m, with the thickest deposits occurring in the north-eastern part of the Drumlithie Complex, between Clearymuir [8003 8107] and Pitdrichie [7948 8254]. The best exposure is in Pitdrichie gravel quarry [7988 8191], where piecemeal working has exposed some 17.5m of sand and gravel with some interbedded silt and clay. A trial pit dug at the base of section 78 SE 7 proved that the sand and gravel extends at least 2.7 m below the base of the working face, so that the overall thickness of sand and gravel here is in excess of 18.7m (Table 17).

Low moundy spreads of sand and gravel between Forest Avenue [7944 8164] and Bridge of Fiddes [7997 8057] probably have a composition similar to the deposits lying between Thriepland and the Forthie Water where 1.9m of gravel was proved in borehole 87 NW 1. It is possible that the sands and gravels in the Forest Avenue - Bridge of Fiddes area extend in part under the central moundy body of the Drumlithie Complex (described below); sand and gravel may also underlie the alluvium in the Forthie Water.

The mean grading for deposits of the eastern marginal belt, based on four sample points, is 8 per cent fines, 59 per cent sand and 33 per cent gravel; the mean thickness is 11.2m.

a) The central moundy body. The central moundy body of the Drumlithie Complex is a conspicuous feature when viewed from the A91 and it extends over an area of about 1.5km^2. The moundy nature of the landform is due to the melting out of masses of ice that were buried beneath the sediments as they accumulated in standing water. This water was ponded up between an ice-front that was retreating to the south-west, and higher ground (and possibly stagnant, wasting ice) to the north, east and south. Sediment was deposited mainly from sediment-rich density flows and cohesive mass-flows with little winnowing out of fines. Subsequently, the sands and gravels of the central moundy body were concealed by flow-tills which are 3.1m thick in borehole 78 SE 9.

The kettle-holes resulting from the melting of masses of ice trapped in the sediment are abundant and they affect the thickness of the sands and gravels locally. The large depression between Pade O'France [7832 7986] and Candy [7941 8008] was probably caused by a large mass of wasting ice preventing deposition of sand and gravel; the depression is now occupied by about 3.5m of alluvial silt and clay which sit directly on lodgement till (trial pit 78 SE 5).

Data from the four sample points encountering mineral in the central moundy body show that the deposits are predominantly fine-grained sand and silt with some clay. The level of fines varies widely from a mean of 7 per cent in trial pit 77 NE 10 to 20 per cent in borehole 78 SE 10. Trial pit 77 NE 10 shows that gravel is present locally, but overall the data suggest that gravel is not an abundant component of the deposits. The mean grading is 13 per cent fines, 77 per cent sand and 10 per cent gravel; the mean thickness of mineral is 6.4m. It should be noted, however, that these values may not be representative, because wide variation in grading and thickness is to be expected. The greatest thickness proved is 11.3m in borehole 78 SE 10.

c) The eskers. There are two well-defined eskers within the Drumlithie Complex, namely the Little Wairds Esker and the Bridge of Fiddes Esker (see glacial geomorphology inset map on resource sheet). The Little Wairds Esker, though somewhat discontinuous, extends north-north-east from a point some 200m north-west of Mavisbank [7949 7748] to Little Wairds [7967 7857]. To the north-east of Little Wairds, the esker passes into low moundy spreads of sand and gravel. The Fiddes Esker runs north-north-west from [802 804] to [7990 8098], about 140m south-west of Clearymuir.

The Little Wairds esker has been worked a little by farmers for gravel, but is still largely untouched. The Fiddes Esker, by contrast, has been worked extensively and only about one third of the deposit remains, mainly at the northern end. Because the bulk of this esker has been worked out, it was not sampled during the assessment programme.

Sections in both eskers show the internal structure of the deposits. In the Fiddes Esker, some 7-8m of material is exposed, revealing massive cobble and boulder gravel passing up into cross-stratified and laminated finer gravel and coarse-grained sand. The top metre of the deposit is comprised of coarse gravel with some stratification and lenses of finer gravel with a sandy, clayey matrix in places. These lenses are probably diamictons, deposited as mass flows.

A good section in the Little Wairds Esker occurs at [7968 7790] where a 2-3m face exposes massive to stratified clast-supported gravel, interbedded with finer sandy gravel and lenses of coarse-grained sand. Generally there is a sandy matrix, sometimes bound by silt and clay. As with the Fiddes Esker, the top 0.5m of the deposit comprises coarse, diamictic gravel. Trial pit/section 77 NE 17 proves that the deposit is at least 4.8m thick, as the pit was unbottomed in gravels 2.6m below the base of the 2.2m section; the pit was terminated at the water-table. Trial pit/section 77 NE 16, 280m south of Little Wairds, proved 4.2m of gravel (unbottomed). Samples from the trial pits all grade as 'gravel' with an overall mean of 5 per cent fines, 35 per cent sand and 60 per cent gravel. The mean proven thickness is 4.3m.

d) fringing spreads. These comprise thin, discontinuous and isolated spreads and low mounds; they are considered to be of minor importance as resources compared to those described above. They are not thought to be more than 1-2m in thickness in general. However, Orchard Hill [7837 8066], due south of Drumlithie, is capped by 3.1m of 'clayey' pebbly sand (borehole 78 SE 4) and trial pit/section 78 SE 8 revealed over 5.4m of very coarse gravels with subordinate pebbly sand in a pit [7899 8095] to the east of the village. The pit is at the western end of a 300m long, 3m high linear ridge that is subparallel to the Drumlithie Burn; this ridge may be an esker.

Fluvioglacial sand and gravel

Sand and gravel classified as fluvioglacial in origin is very limited in extent in block B. Three mounds are present in the extreme north-west of the resource sheet, around [706 840], near the confluences of the East and West Burns of Builg and the Bervie Water. Because of their isolation, the deposits have not been examined in detail. However, the largest mound is about 12m high and the other two a little over 5m high. Geological mapping suggests that they are composed of sands with some gravels.

Another two deposits are present immediately to the east of Glenbervie House [7649 8035], where they form low, rounded, elongated mounds. The larger and more westerly of these stretches about 500m and it was investigated by trial pit 78 SE 3. This was unbottomed in 1.6m of medium and coarse-grained sand with a small amount of fine gravel. This deposit is extremely clean, with fines at about 1 per cent.

Alluvial deposits in the Bervie Water

Deposits of sand and gravel in the valley of the Bervie Water are limited, though in the vicinity of Glenbervie, isolated terraces on the flanks of the valley indicate that perhaps more extensive deposits once existed. South of Bridge of Mondynes [7822 7966] only patchy spreads of sand and gravel flank the floodplain of the Bervie Water. These occur east of Fordoun [751 758] and they are probably fluvioglacial in origin; because they are considered to be part of a series of fluvioglacial deposits extending from the Auchenblae area, they are described in the discussion of block A. Please note that these are incorrectly classified as glacial sand and gravel in the borehole log and on the graphical representation of the borehole log on the map.

To aid description, deposits in the valley of the Bervie Water are subdivided into those of the 'valley-floor' and those of the 'valley-side'.

Valley-floor deposits The 'valley-floor' deposits form the floodplain and low-lying alluvial fans; they are considered to be a poor resource and they are almost wholly water-saturated. Borehole and depth-resistivity sounding data, summarised in Table 17, show that the alluvium is generally less than 2m thick, resting on lodgement-till or flow-till. The two boreholes drilled in the alluvium (77 NE 7, 78 SE 2) encountered coarse gravels, those in 77 NE 7 being too coarse to sample. However, the depth-resistivity soundings indicate that the alluvial deposits vary widely and include clays and silts as well as coarse gravels. Please note that resistivity sounding site 77 NE R1 is wrongly positioned on the resource map; the correct site is [7672 7557].

The alluvial fans have not been sampled.

However, geological mapping shows that the deposits forming them are very variable, ranging from cobble-gravel to silty, clayey sand, and that thicknesses range in general from 1 to 2m.

Valley-side deposits The 'valley-side' deposits consist of the higher alluvial terraces. The terraces are developed between Mains of Delavaird [7417 8153] and Mill of Glenbervie [7641 8043] where they stand between 2m and about 6m above the floodplain. The thickest deposit occurs north of Auchtochter [7523 8030] where trial pit 78 SE 1 was unbottomed in 3.5m of coarse gravel with clasts up to 0.5m across. The terraces are degraded somewhat and probably formed fairly soon after deglaciation. The material forming this terrace is well-exposed in a river bluff above the Bervie Water in the vicinity of [7549 8053], where about 6m of somewhat silty and clayey sand and gravel rests on decomposed conglomerate. Across the valley and about 100m to the west of Hawkhill, an exposure [7572 8069] in the edge of a terrace shows about 4m of interbedded clast-supported gravel and sandy gravel with some sand and loam. These terrace deposits rest upon weathered lodgement till.

Alluvial deposits in the valley of Carron Water

The alluvial deposits are likely to be very similar to those occurring in the valley of the Bervie Water, but less extensive. The glacial sands and gravels around Cuttiesouter are thought to be dissected kame-terraces and they consist of clast-supported, but poorly-sorted, angular gravels.

The mean thickness of the deposits in the valleys of the Bervie Water and Carron Water is 1.5m. The mean grading is 4 per cent fines, 49 per cent sand and 47 per cent gravel. The grading characteristics of the fluvioglacial sand and gravel contrasts strongly with those of the alluvial deposits (Table 17).

Resource block C

Block C covers the eastern half of the Auchenblae - Catterline resource sheet. Its western margin with block B is roughly coincident with easting gridline 38000 and its eastern margin is formed by the North Sea coastline. In contrast to the sand and gravel deposits in blocks A and B, which are concentrated in two areas, the deposits in block C are more widely scattered. The block also contains the greatest area of ground identified as containing potentially workable deposits of conglomerate. Glacial sand and gravel is the most abundant of the Drift deposit resources; fluvioglacial sand and gravel and alluvial deposits are much less significant volumetrically. The resources are described below roughly in order of their size. The glacial, fluvioglacial and alluvial sand and gravel deposits are described first, followed by a description of the potentially workable conglomerate. Note is also made of the shingle beaches on the coast. The borehole pit and section data are given in Table 18.

Glacial and fluvioglacial sand and gravel

Denhead - Brigstanes - Bellfield. The most extensive deposit of glacial sand and gravel occurs between Denhead [8650 7957] and the Glasslin Burn, south of Bellfield [8583 7758]. The sand and gravel forms undulating topography with mounds and ridges reaching 2 to 3 m in height, separated by shallow kettle-holes. The deposit was formed by north-eastward flowing meltwaters that debouched into an ice-marginal lake, forming a delta. Borehole 87 NE 5 proved 12.8 m of mineral with an overall grading classification of sandy gravel. However, the deposit fines downwards at a depth of 10.4 m from sandy gravel into fine- and medium-grained sands interdigitating with seams of glaciolacustrine silt and clay up to 0.7 m thick. A fining-downwards sequence also occurs at trial pit 87 NE 1 (6.4 m of mineral, unbottomed) and trial pit/section 87 NE 2 (6.7 m of mineral, unbottomed). Trial pit/section 87 NE 3 proved 5.2 m of mineral with a 0.5 m waste parting comprising silt and fine-grained sand at a depth of 2.6 m. Water was struck at a depth of about 6 m at section 87 NE 3 and at about 5 m in borehole 87 NE 5.

To the east of the A92, a steep slope, interpreted to be a former ice-contact slope, forms the eastern margin of the thicker, more laterally extensive part of the resource. To the east of this slope, the sand and gravel is probably much thinner, discontinuous and interbedded with diamicton.

Based on four sample points, the Denhead-Brigstanes-Bellfield deposit has an overall grading of 4 per cent fines, 72 per cent sand and 23 per cent gravel (Table 18); the grading classification, with a sand:gravel ratio of 3:1, falls at the boundary between 'pebbly sand'

Table 18 Auchenblae-Catterline Resource sheet: Data from sample points and the assessment of resources in Block C

Data point	Recorded thickness			Mean grading percentage (sizes in mm)							
Borehole, pit, exposure or resistivity sounding	Total mineral m	Depth of burial m	Intervening waste m	Fines -.063	Fine sand .063-.25	Medium sand .25-1	Coarse sand 1-4	Fine gravel 4-16	Coarse gravel 16-64	Cobbles and boulders +64	Descriptive category (see the diagram in Appendix C)
Glacial sand and gravel and fluvioglacial sand and gravel											
Denhead-Brigstanes-Bellfield											
NO 87 NE 1	6.4+	0.1	-	7	46	30	4	4	6	3	PS
NO 87 NE 2	6.7+	0.3	-	4	52	37	3	1	3	0	S
NO 87 NE 3	5.2+	0.5	0.5	3	8	40	8	21	18	2	SG
NO 87 NE 5	12.8	0.1	2.0	3	13	29	16	20	18	1	SG
Mean	7.8	0.3	0.4	4	30	33	8	12	11	2	SG
Fernyflatt											
NO 87 NE 4	3.7	0.3	-	8	8	16	14	13	28	13	G
Nether Craighill-Greenden											
NO 87 NW 2	3.1+	0.2	-	2	4	10	8	15	32	29	G
NO 87 NW 3	6.2	0.1	-	8	9	16	13	20	25	9	G
Mean	4.7	0.2	-	5	7	13	11	17	28	19	G
Foggiebrae-Den of Luckyfeal											
NO 88 SW 4	10.7+	-	-	4	4	9	13	24	29	17	G
NO 88 SW 5	6.6+	0.2	-	3	12	24	9	12	19	21	G
NO 88 SW 6	6.3	2.0	-	6	7	34	14	18	19	2	SG
Mean	7.9	1.1	-	4	8	23	12	18	22	13	G
Briggs of Criggie											
NO 88 SW 8	16.5	0.3	-	8	34	31	8	8	10	1	PS
Catterline											
NO 87 NE 6	9.2	2.4	-	17	66	17	trace	trace	0	0	CS
Brucklaywaird											
NO 88 SW 7	13.1	0.4	-	9	21	23	7	11	17	12	SG
Mains of Dunnottar											
NO 88 SE 3	3.4	0.3	-	21	42	11	7	8	11	0	VCPS
East and West Carmont											
NO 88 SW 1	3.8+	0.1	-	12	37	20	11	10	7	3	PS
NO 88 SW 3	3.7+	0.1	-	2	13	38	8	7	21	11	SG
Mean	3.8	0.1	-	7	25	29	9	9	14	7	SG
Uras Knaps											
NO 88 SE 4	2.0	0.3	-	3	7	35	23	19	13	0	SG
Mean for glacial sand and gravel	7.0	0.5	0.2	7	23	25	10	12	16	7	SG
Alluvial deposits											
NO 87 NE R1	1.0	0.1	-	-	-	-	-	-	-	-	-
Overall mean for sand and gravel	6.7	0.4	0.1	7	23	5	10	2	6	7	G
* Includes some glacial sand and gravel and mineral bearing glaciolacustrine deposits											
Weathered conglomerate											
NO 88 SE 1	3.5+	0.3	-	4	10	13	7	14	38	14	G
NO 88 SE 2	3.3+	0.2	-	3	5	12	8	13	34	25	G
NO 88 SE X2	9.7*	0.3	-	13	13	11	15	21	15	12	G
NO 88 SE X3	2.7	0.3	-	16	17	18	8	12	29	0	CSG
NO 85 SE X4	5.0	1.0	-	30	25	21	10	8	5	1	VCPS
NO 88 SW X2	3.1	0.9	-	8	15	24	5	30	15	3	G
NO 88 SW X3	3.5	1.0	-	3	16	17	12	14	31	7	G
Overall mean for conglomerate	4.4	0.5	-	11	15	15	9	16	25	9	G

Statistical assessment of glacial and fluvioglacial sand and gravel in block C

Area of exposed mineral	4.29 km^2
Area of discontinuous mineral	0.65 km^2
Area of worked ground	0.02 km^2
Total area of mineral-bearing ground	4.61 km^2*
Mean thickness of overburden	0.5 m
Mean thickness of mineral	7.0 m
Estimated volume of mineral	32.3 million m^3 (±33% or 10.3 million m^3)
Estimated yield of mineral per hectare	70 thousand m^3 (±50% or 35 thousand m^3)

Statistical assessment of weathered conglomerate bedrock in block C

Area of exposed mineral	19.53 km^2
Area of mineral-bearing ground	19.53 km^2
Estimated mean thickness of overburden	0.5m
Estimated mean thickness of mineral	4.4m
Estimated volume of mineral	85.9 million m^3 (±54% or 46.4 million m^3)
Estimated yield of mineral per hectare	44 thousand m^3 (±54% or 24 thousand m^3)

Speculative assessment of alluvial deposits in block C

Area of exposed mineral	0.30 km^2
Area of concealed mineral	0.54 km^2
Area of discontinuous mineral	0.03 km^2
Total area of mineral-bearing ground	0.86 km^2 *
Estimated mean thickness of overburden	0.1 m
Estimated mean thickness of mineral	1.0 m
Estimated volume of mineral	0.9 million m^3
Estimated yield of mineral per hectare	0.9 thousand m^3

* In the calculation of these figures, 50 per cent of the area of discontinuous spreads is considered to be mineral bearing.

and 'sandy gravel'. However, the deposit is likely to vary in grading, both laterally and vertically. It is probable that the bulk of the gravel occurs in the upper parts of the deposit. The mean proven thickness is 7.8 m.

Fernyflatt. This deposit occurs south of the Glasslin Burn, extending as far south as Temple [8515 7653]. Although mapped as glacial sand and gravel, the form of the topography and the nature of the deposit suggests that at least some of it is glacially redistributed conglomerate. In the absence of data suggesting otherwise, most of the deposit is considered to be a glacial outwash fan with an ice-contact feature present to the east. The latter is shown by a pecked boundary on the resource map. The deposit was sampled in borehole 87 NE 4. This proved 3.7 m of compact sand and gravel resting on hard conglomerate bedrock. The overall grading classification for the samples from the borehole is 'gravel' with 8 per cent fines, 38 per cent sand and 54 per cent gravel (Table 18). The deposit, however, was difficult to sample and the drilling technique used undoubtedly increased the fines content at the expense of gravel.

Nether Craighill-Greenden. The resources in this area lie around, and to the north-east of Nether Craighill [8072 7746]. The largest resource comprises a spread of glacial sand and gravel forming undulating, kettled topography, with mounds up to 5 m high. This spread of sand and gravel is bisected by a glacial drainage channel with a fan of fluvioglacial sand and gravel lying at its north-eastern end.

The glacial sand and gravel was sampled in trial pit 87 NW 2 and borehole 87 NW 3. The pit proved in excess of 3.1 m of gravel. Although the fines content of the samples is very low at 2 per cent, material >64mm is abundant, forming 29 per cent of the sample. Borehole 87 NW 3 proved 6.2 m of gravel resting on flow-till. The samples grade overall as 'gravel' with a fines content of 8 per cent. The deposits will vary widely in grading and thickness, but based on the two sample points, the mean grading for the glacial sand and gravel is 5 per cent fines, 31 per cent sand and 65 per cent gravel; the overall grading classification is 'gravel' and the mean thickness is 4.7 m (Table 18). The fluvioglacial sand and gravel at Nether Craighill was not sampled. Field mapping indicates 0.5 to over 1 m of very pebbly sand and sandy gravel, but it is probable that most of this deposit lies below the water-table.

A thin spread of sand and gravel flanks the Bridgend Burn at the northern end of a glacial meltwater channel that lies to the north-east of Hareden [805 784]. There are no sample points in this deposit, which is probably heterogeneous in lithology. To the south-east of Nether Craighill, isolated patches of sandy and gravelly flow-till deposits may also contain some sand and gravel, though the fines content is likely to be high.

Foggie Brae - Den of Luckyfeal. This is a complex, sinuous deposit which extends from the northern end of the prominent glacial meltwater channel, called Den of Luckyfeal [8167 8356], to Foggie Brae [8274 8448], and then eastwards towards the Seggie Burn [8312 8449]. The latter part of the deposit is dissected by several northwards-trending glacial meltwaters channels, including the one occupied by the Seggie Burn.

At the south-western end of the deposit, the sand and gravel forms a kettled outwash spread that was probably deposited by meltwaters that debouched from the Den of Luckyfeal. In excess of 6.6 m of very dense, clast-supported gravel with abundant cobbles and boulders was proved at pit 88 SW 5. To the north-east of these deposits, and in the ground 150 m south-east of the ruin of Garbertstrypes [8173 8398], the deposit thins and it is considered to be mostly a sandy, gravelly diamicton. Information from a pipeline trench in the area shows that gravel is present in places.

The remainder of the deposit forms a prominent sinuous ridge that lies between the small pit [8185 8409] to the north-east of Garbertstrypes and the Seggie Burn. The ridge probably formed in an ice-marginal environment as a recessional moraine and hence it comprises a greater variety of deposits than if it were an esker. The deposit was sampled in trial pit/section 88 SW 4 and borehole 88 SW 6. The former proved 10.7 m of mineral, unbottomed; the lowermost 0.2 m of the deposit being below the water-table, probably indicating that till is not far beneath the base of the pit. The samples grade as 'gravel'; again, cobbles and boulders are quite abundant at 17 per cent. Borehole 88 SW 6 sited on Foggie Brae proved 6.3 m of sandy gravel beneath 2.0 m of flow-till; the mineral rests on lodgement till at a depth of 8.3 m. The material here is finer grained than that at pit/section 88 SW 4, with +64mm material constituting only 2 per cent of the deposit. A wide variation in grading is likely, but the mean grading for this deposit, based on three sample points, is 4 per cent fines, 43 per cent sand, and 53 per cent gravel; the mean thickness is 7.9 m (Table 18).

Briggs of Criggie and the Muirtown of Barras Esker. These resources comprise glacial sand and gravel and they lie west of Briggs of Criggie [8426 8234]. The main part of the deposit is a deltaic, coarsening upwards sequence, which forms an undulating plateau pitted with kettle-holes. Fine-grained glaciolacustrine deposits crop out on its north-eastern margins. The deposit was sampled in borehole 88 SW 8, about 200 m south of the former Criggie Smithy. This proved 16.5 m of coarsening-upward glacial sand and gravel resting on non-mineral glaciolacustrine silt, flow-till and lodgement till. The uppermost 3.4 m of the deposit is unconsolidated, clean gravel. Beneath this is 6.3 m of pebbly sand resting on 6.8 m of 'clayey' sand. Overall, the deposit grades as 'pebbly sand' with 8 per cent fines, 73 per cent sand and 19 per cent gravel (Table 18). However, this is based on only one sample point and wide variations in grading characteristics are to be expected within this deposit.

Lying to the south of the plateau is the Muirtown of Barras Esker; this stands about 5 m in height and it extends for just over a kilometre from Muirton Wood [8358 8106] to Bridgend [8418 8192]. The esker was not sampled, but it probably comprises unconsolidated coarse gravel. Associated with this esker are three kames which form 3 to 6 m high ridges and mounds to the west of Bridgend [8411 8194].

Catterline. Deposits of glacial sand and gravel form kames around Catterline. The largest deposit occurs south-east of Harvieston [865 782], forming rolling ground immediately west of the gorge cut by the Catterline Burn. Borehole 87 NE 6 proved 9.2 m of 'clayey' sand beneath 2.4 m of overburden. The top 6 m of the sand contains much silt with fines averaging 23 per cent; 67 per cent of the material is in the 'fine sand' fraction. The lowermost 3.2 m is much less clayey, with an average of 7 per cent fines; gravel is present only in trace quantities. Geological mapping indicates that the other, smaller kame deposits in the vicinity are likely to be very similar to the deposits sampled in 87 NE 6. The mean grading of samples from 87 NE 6 is given in Table 18.

Brucklaywaird. This deposit extends southwards from Brucklaywaird [8257 8403] for about 800 m. The southern half of the deposit is an esker standing up to 3 m high. This passes northwards into a plateau that is formed of a coarsening-upwards, deltaic sequence of glacial sand and gravel, and that is fringed by fine-grained glaciolacustrine deposits. The deposit was formed by northward flowing meltwaters that debouched into a temporary ice-dammed lake during the deglaciation of the area. The deposit was sampled in borehole 88 SW 7; this proved 13.1 m of sand and gravel which graded overall as 'sandy gravel'. (Table 18). The deposit at the borehole site comprises three distinct units. The top unit comprises 5.8 m of gravel with 26 per cent of >64 mm material. The middle unit is made up of 5 m of 'clayey' pebbly sand which rests on the lowermost unit, comprising of 2.3 m of 'clayey' sand. The sand and gravel rests on 3.1 m of glaciolacustrine deposits, which include interstratified flow-till, fine sandy silt and clay. The esker forming the southern half of the deposit was not sampled, but geological mapping indicates the presence of pebbly sand and gravel at its southernmost end.

Mains of Dunnottar. The deposits occur in a series of kames and ridges lying adjacent to the coastal cliffs. The two larger deposits lie immediately east of Mains of Dunnottar [8752 8383] and are fringed to the north and east by fine-grained glaciolacustrine deposits. Once again, the deposits reveal coarsening-upward sequences, as shown by data from borehole 88 SE 3, which proved 3.4 m of mineral resting on glaciolacustrine deposits. Although the overall grading is 'very clayey' pebbly sand (Table 18), the uppermost 1.4 m is sandy gravel. This rests on 2.0 m of 'very clayey' sand with a fines content of 30 per cent.

East and West Carmont. Small isolated kames occur around West Carmont [8080 8435] and east of East Carmont [8143 8455]. The sand and gravel forms mounds up to about 10 m high. Trial pit 88 SW 1 at West Carmont was unbottomed in 3.8 m of mineral. The deposit varies from 'very clayey' sand to sandy gravel and it grades overall as 'clayey' pebbly sand. The largest of the kames at East Carmont was sampled in trial pit 88 SW 3. This pit was also unbottomed in mineral, proving 3.7 m of sandy gravel. The mean grading and thickness data are given in Table 18.

Uras Knaps. The largest deposit hereabouts is an 11 m high kame; it is fringed to the east by fine-grained glaciolacustrine deposits which are proved to extend beneath the sandy gravel in borehole 88 SE 4. The deposit has been worked in two small pits on the south-western side of the kame where a section shows 10 m of pebbly sand and sandy gravel. However, only 2 m of sandy gravel was proved in the borehole (Table 18), indicating uneven, complex internal relationships between mineral and non-mineral within the deposit. Little is known about the two smaller deposits of glacial sand and gravel that lie to the south-west of Uras Knaps, but they are not thought to be very thick.

Keabog. Several kames formed of glacial sand and gravel occur east of Keabog [8013 8285]. However, the boundaries of these deposits are difficult to delineate and it is not known for certain whether all of them actually are formed of sand and gravel. The ambiguity is caused by the presence of conglomerate bedrock, which, in the weathered state, can easily be confused with glacial sand and gravel. Field mapping suggests that the deposits consist mainly of silty pebbly sand and sandy gravel. They have not been sampled.

The deposits in the vicinity of Collieston [809 815] and four small isolated deposits around Clochnahill [824 825] are probably similar to those at Keabog. A 1.5 m thick unconsolidated deposit of sand and gravel, overlying a dense, clast-supported till derived almost wholly from weathered conglomerate, was worked in a small borrow pit [8242 8226] to the south of Clochnahill during the improvement of the A94 in 1988.

Dunnottar Square. This deposit occurs north-east of Dunnottar Square [8621 8468] and it is a continuation of the deposit mapped as fluvioglacial sand and gravel on the adjoining resource sheet to the north (Auton, Merritt and Ross, 1988); the classification on this sheet has been revised to glacial sand and gravel. The sand and gravel forms moundy topography, the two principal mounds being between 7 m and 12 m high. Although the deposit was not sampled, data from trial pit/section 88 NE 11 in Auton, Merritt and Ross (1988) indicates that it is likely to consist of several metres of pebbly sand or sandy gravel, with a low fines content.

A site investigation borehole (88 SE X1) sited within the Den of Glaslaw, 1.25 km to the south-west of Dunnotter Square, proved 7.5 m of sand and gravel.

Fawsyde Esker. This esker forms a sinuous 4 to 5 m high ridge extending over about 550 m to the north and west of Fawsyde [8460 7712]. Limited geological information suggests that it is made up of coarse gravel. The sand and gravel was laid down in an ice-walled tunnel by north-eastwardly flowing meltwaters that cut the Den of Ery glacial drainage channel to the south-west (see geomorphology map on the resource sheet).

Largie. Several isolated kames occur around Largie [8356 7600]. The main group flank the Broggie Burn 500 m south-west of Largie, with a smaller group 300 m to the north. The mounds are generally about 3 m high and geological mapping indicates that they consist of silty fine-grained sand and coarse gravel.

Pitcarles Esker. This small 2 m to 3 m high esker lies 400 m to the east of Pitcarles [8061 7538]. Trending north-eastwards over some 250 m, it splits into two ridges about halfway along its length. Geological mapping shows that the esker consists of pebbly sand and coarse gravel, but the deposit is unlikely to be more than a few metres thick.

Alluvial deposits. Apart from the alluvium of the River Carron along the northern margin of the resource sheet, the only alluvial spread considered to contain potentially workable sand and gravel occurs in a shallow, ice-scoured depression to the north of Mill of Barras [8495 7932]. The Lumgair Burn and the Catterline Burn have both formed alluvial fans at the points where they enter the depression. The fans are composed mainly of sand and gravel. The rest of the depression appears to contain silt overlying coarse gravel. Resistivity sounding 87 NE R1 is interpreted as indicating the presence of 1.1 m of dry gravel overlying bedrock. The total thickness of the gravel is not considered to exceed 3 m and most of the deposit is thought to lie beneath the water-table. Downstream of this depression there are fragmentary alluvial terraces in the vicinity of Catterline, but they are unlikely to form significant resources.

Weathered conglomerate. Potentially workable bedrock in the form of deeply weathered Old Red Sandstone conglomerate has been identified over a large area in block C. The largest area occurs in the north of the resource block, with smaller patches in the extreme south. The conglomerate resources are depicted on the Auchenblae-Catterline resource sheet in a distinctive ornamant. Precise delineation of resources of workable conglomerate is not possible, but a zig-zag boundary has been used to define those areas considered most likely to contain potentially workable material.

The resource has been sampled in a series of trial pits and this data supplements records from the BGS data archive. Only the resources in the north have been investigated in this way.

Trial pit/section 88 SE 1 was dug at the base of a section in Lochburn Quarry [8539 8305], where conglomerate is worked intermittantly; it proved weathered conglomerate to a depth of 3.5 m before the deposit became too hard to dig. The samples grade as 'gravel' with cobbles and boulders being abundant, especially in the lower part of the section. The uppermost 1 to 2 m of the conglomerate is glacially disturbed and partially re-sedimented. Original bedding is commonly preserved, however, indicating that much of the rock has been weathered *in situ.* In pit 88 SE 2, 3.3 m of dense, clast-supported gravel was proven, but the pit was unbottomed. This deposit has almost certainly been glacially re-distributed. Again the material grades as 'gravel', with 25 per cent of the material comprising cobbles and boulders. The supplementary data on the map (pits and boreholes 88 SE X2 to 88 SE X4 and 88 SW X2 to 88 SW X3) also show that most of the potentially workable conglomerate is coarse gravel with little sand and that thicknesses reach 6.0 m. Clasts may exceed 200 mm in diameter and most are well-rounded.

A wide range of lithologies is present; some of these, including quartzite, psammite and some granite, are sound, but the deposits also contain a large proportion of potentially deleterious clasts of weathered volcanic rocks and schists. The sand is rich in rock fragments, many of which are volcanic in origin and are badly weathered. Many of the cobbles have been shattered by faulting. The conglomerate material described above is not a very attractive resource, but it is useful for bulk fill. It was exploited in a temporary quarry [8535 8345] as bottoming for the improvement of the A94 road in 1988.

The mean thickness of the weathered, glacially re-distributed conglomerate is 4.4 m and the mean grading is 11 per cent fines, 39 per cent sand and 50 per cent gravel; the overall classification is 'gravel'.

Shingle beaches. Shingle beaches are common at the heads of sheltered bays along the coast. Much of the shingle is derived from the erosion of the conglomerate cliffs. The clasts are well-rounded and consist generally of tough lithologies, the deleterious ones having been destroyed, by wave action. The beach deposits are well-graded with clasts from 'coarse gravel' to 'boulder size'. They have not been sampled or examined in detail. While they represent a potential resource, they are not considered to be important in terms of the overall resources of the sheet, principally because they are very coarse and because any working is likely to be considered undesirable environmentally.

CONCLUSION

Background

The sand and gravel resources of the assessment area have been described systematically and the results of the volumetric calculations summarised in Table 9. The survey concerns the estimation of *resources* rather than *reserves* and 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 per cent; and that it must lie within 25 m 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.

The assessment survey reported here has been undertaken essentially to provide the physical planner with data on the extent and character of the potentially workable sand and gravel resources lying to the south-west of Aberdeen. The hinterland of Aberdeen is an area identified by the Scottish Development Department as having a high priority for investigation on planning grounds because of the large demand for aggregates and the consequent land-use problems around this rapidly expanding city.

The sand and gravel resources in the immediate vicinity of Aberdeen have been exploited for many years and many of them have been either exhausted or sterilised by buildings and infrastructure. Of the remaining resources, few are available for extraction because they lie close to settlements and pipelines or they occur in environmentally sensitive areas. In order to ensure continuity of supply of sand and gravel to the local market, it consequently has been necessary to take stock of the resources lying farther afield, around Strachan, and between Auchenblae and Catterline.

The results of surveys such as this one 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 further sterilisation of potential resources and to rationalise the conflicts which may occur between conservation and mineral exploitation.

Geological mapping

The Drift deposits of the entire area described in this report, 274 km^2, was re-surveyed at the 1:10,000 scale prior to drilling and sampling. This mapping exercise was required because the primary geological survey of the area undertaken in the nineteenth century was not sufficiently detailed for the purposes of resource evaluation at the level of accuracy required here. The mapping involved a thorough walk-over survey (135 man days) following an initial interpretation of the ground using aerial photographs.

Two important resources of sand and gravel have been delineated for the first time in the Strachan area, in the vicinity of Pitdelphin Wood [653 906] and Black Hillocks [627 863]. Neither of these resources were distinguished from the extensive spreads of morainic deposits shown on the maps of the primary survey. Furthermore, the numerous eskers and glacial meltwater channels occurring on both sheets have been located accurately for the first time. This geomorphological information has been summarised in the inset maps on the two resource sheets. Whereas more sand and gravel has been located on the Strachan sheet than was mapped hitherto, less has been found on the Auchenblae-Catterline sheet. The latter has resulted partly from the separate identification in the modern survey of the deposits of weathered and ice-transported conglomerate. Some of this material was shown as glacial sand and gravel on the published one-inch solid-and-drift edition of sheet 67. When the sand, gravel and conglomerate is taken together, however, there is also more mineral-bearing ground on the Auchenblae-Catterline sheet than anticipated before.

Method of investigation

Patchy, heterogeneous deposits of sand and gravel, such as that occur in the study area, are more difficult and costly to assess than widespread deposits. As far as possible pits have been dug to extend nearby sections, in order to avoid drilling expensive boreholes. This has been particularly successful throughout north-east Scotland where deposits are generally thin. Pits and sections 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, reach far below the water-table.

Following the successful application of the Offset-Wenner method of ground resistivity sounding (see Appendix D) to the assessment of sand and gravel resources in the previous survey west of Aberdeen (Auton, Merritt and Ross, 1988), the method was used again here to provide site specific information akin to drilling results. The method is especially useful for estimating the total thickness of sand and gravel at sites (mainly pits) where the mineral deposit has not been bottomed, where drilling has to be abandoned owing to slow progress, and at sites where access is 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 is time-consuming; it also requires sophisticated computer back-up. In conclusion, ground resistivity has been proved again to be a valuable additional tool, allowing improved interpolation between sample points and some decrease in the total number of boreholes required. The method is not, however, a complete substitute for drilling.

Resources

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 the disposition of the material relative to the water-table.

Relation to the water-table

As far as possible, resources have been divided, for the purposes of assessment, into those lying mainly above and those lying mainly below the water-table and they are described in respect to their position relative to the water-table in the detailed notes on the resource blocks. Water-saturated sand and gravel deposits mainly underlie river floodplains, but they also underlie many of the low-lying spreads of peat and alluvium.

Grade and thickness

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 are more numerous, but they 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 may 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 in north-east Scotland form mounds.

Composition and end uses

The results of the limited number of pebble-counts and mechanical and physical tests that were undertaken have been given in Tables 6, 7 and 8. On the whole, the gravels in the Strachan assessment 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. Granite is the most common constituent of the gravel and the sand is formed mainly of comminuted granite (quartz, feldspar and a little mica).

Psammite, quartzite and indurated sandstone are collectively the most abundant constituents of the gravels in the Auchenblae-Catterline area. Whilst these rock-types are potentially stronger and more durable than granite, the relatively large proportion of mudstone, friable sandstone and weathered lava occurring in these aggregates is a major drawback. The presence of these rock-types restricts the range of end-uses to which the gravels are suited and hence it seriously reduces their potential value. The sands occurring in the Auchenblae-Catterline area are composed mostly of quartz with little or no mudstone or weathered lava; hence their potential end-uses are not so restricted. The sands are, however, often very silty and micaceous and they consequently need to be washed thoroughly before they are suitable for most value-added applications.

There are large resources of weathered and ice-transported conglomerate in the Auchenblae-Catterline area, but the large proportion of cobbles and boulders, the common absence of sand, and the abundance of deeply weathered clasts in these deposits, seriously diminishes their potential. The material is useful for bulk fill, and for making unmetalled roads.

Selection of resource targets

Many of the resources identified on the accompanying maps and described in this report will repay further, more detailed, investigation by the industry as potential reserves for future exploitation. 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 are listed below.

Strachan sheet

The largest resources of sand and gravel occur within block B (see Table 9), especially block B^2, but apart from isolated mounds and ridges, most of the mineral lies below the water-table. More attractive resources occur in the form of kame-terraces around Pitdelphin Wood in block C and Cammie Wood, in block D, but the presence of kettle-holes reduces the reserves that might otherwise have been present. An attractive, but geographically remote resource occurs in the vicinity of Black Hillocks in the south-west of block F. Pockets of weathered, disaggregated granite bedrock occur widely. This material has been used successfully for bedding pipelines and for making unmetalled tracks, but the degree of weathering of the material is very variable and it has not been possible to delineate such resources in detail.

Auchenblae-Catterline sheet

The most attractive resources of gravel occur in the vicinity of Auchenblae, in block A, and between Denhead, Brigstanes and Bellfield, in block C. These deposits contain comparatively little mudstone and weathered lava compared with other gravels in the area, but even the presence of small amounts of these potentially deleterious rock-types can reduce their value. Large resources of glacial sand occur in block B, between Drumlithie, Pitdrichie and the Forthie Water; smaller, more isolated resources occur in block C, most notable at Criggie.

The sands occurring in the Auchenblae- Catterline area are generally finer in grain-size than the granitic sands of the Strachan sheet, and consequently they have a better potential for use in asphalt, and in building and mortaring.

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GLOSSARY *

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

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 (GLACIOFLUVIAL). 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

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

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

PROGRADE. To build forward or outward into a body of water

PSAMMITE. A metamorphosed sandstone

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

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

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

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

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

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

APPENDIX A
FIELD AND LABORATORY PROCEDURE

Earlier 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 were 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.

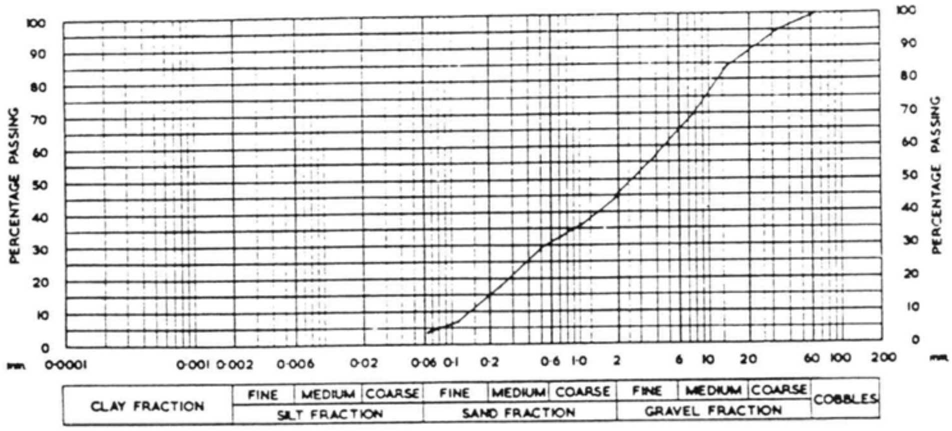
Thin spreads of sand and gravel are sampled by means of shallow trial pits.

A continuous series of bulk samples was taken throughout the sand and gravel. Ideally, samples were composed exclusively of the whole of the material encountered in the borehole or pit, between stated depths. A new sample was 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 6. The grading procedure is based on British Standard 1377 (1975). Random checks on the accuracy of the grading are made by BGS staff.

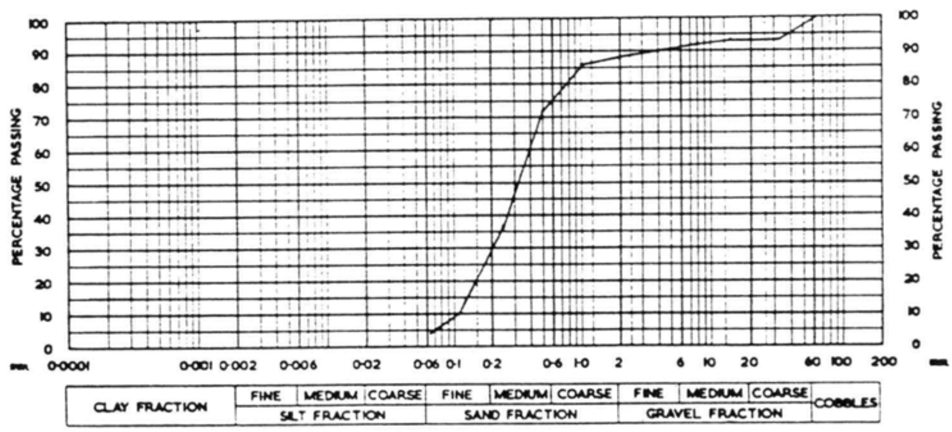
In the current survey, additional data on the thickness and extent of the mineral deposits have been obtained in some areas by measurements of ground resistivity following the methods outlined in Clarke and others (1982). The methods employed and the results obtained are discussed in more detail in Appendix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

All data were coded up for analysis by

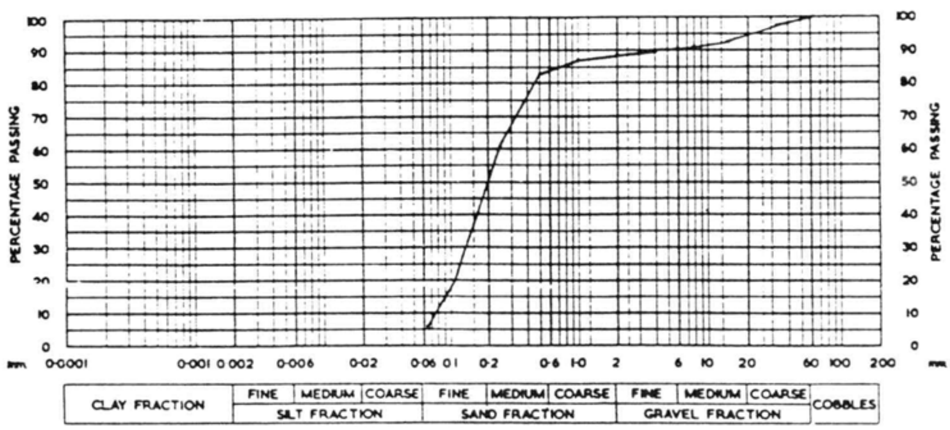
PARTICLE SIZE DISTRIBUTION



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 6. Examples of particle size distribution curves

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 H.

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

APPENDIX B
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

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

From this it can be seen that as $S_A{}^2/S_{\bar{d}}{}^2$ tends to O 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
$\Sigma\,(dm_1 + dm_2 \ldots dm_n)/n.$

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_{dm}, expressed as a proportion of the mean thickness, is given by

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

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

$$S_{\bar{d}_m} \leq S_V \leq 1.05 S_{\bar{d}_m}.$$

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:

Assessment details

Area

Block:	11.08 km^2
Mineral:	8.32 km^2

Mean thickness

Overburden:	2.5 m
Mineral:	6.5 m

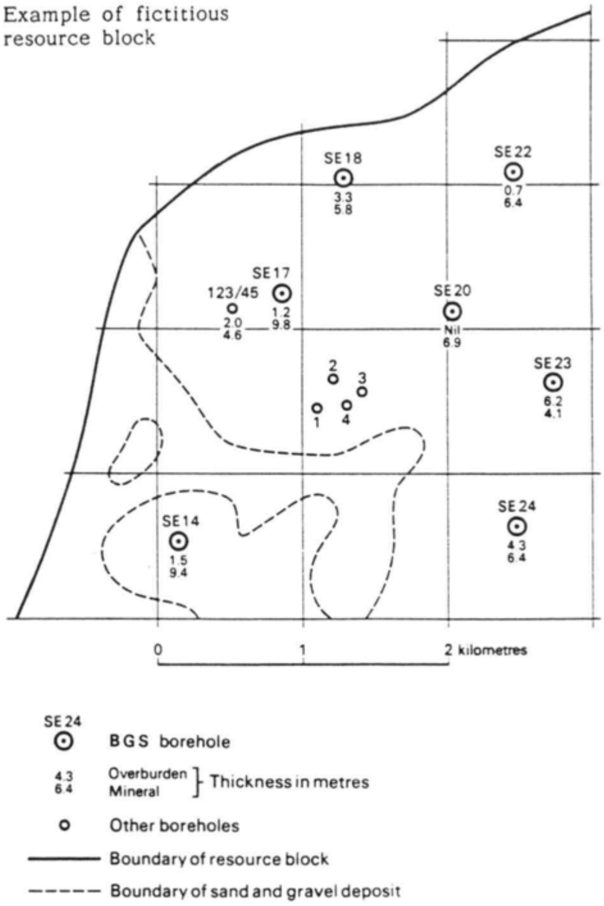
Volume

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 7. Example of a statistical assessment of a fictitious resource block

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:

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

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

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

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

11 The application of this procedure to a fictitious area is illustrated in Figure 7.

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. The value is then shared between the data points within the zone as the weighting factor.

APPENDIX C
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 8.

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

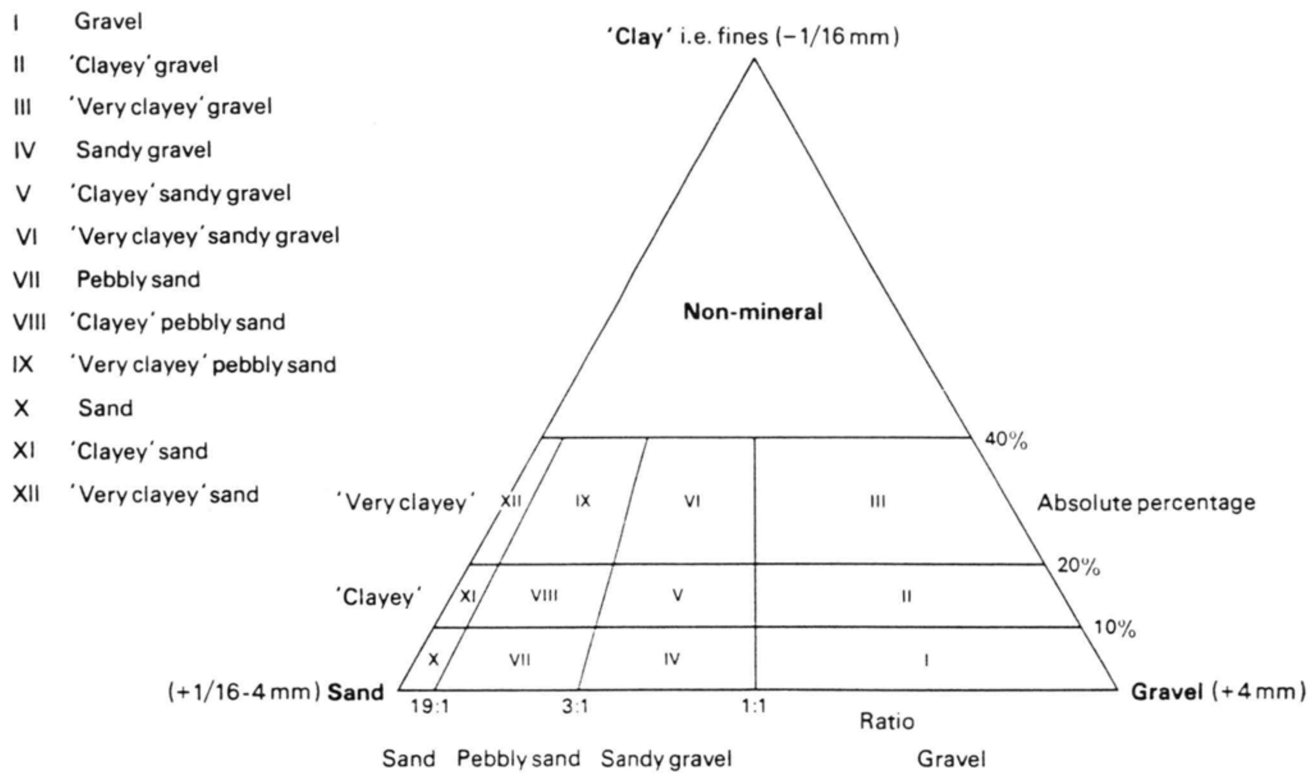


Figure 8. Diagram showing the descriptive categories used in the classification of sand and gravel

Table 19. 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

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 8 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 E).

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 (Table 19).

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. In this report the grading is tabulated in the assessment records (Appendix F), 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 kept in the BGS archives and they may be seen on request.

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 D
GEOPHYSICAL INVESTIGATIONS

Resistivity survey

In order to evaluate various techniques for the assessment of scattered sand and gravel deposits, the former 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 become 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 other parts of England.

Ground resistivity measurements have also proved useful in extrapolating the thickness and extend of sand and gravel deposits between the sites of assessment boreholes and trial pits in north-east Scotland, where the deposits are generally small (but sometimes thick) and scattered. Soundings made, with the Offset Wenner array have been used in previous sand and gravel surveys around Aberdeen (Auton, Merritt and Ross, 1988) and have also been used during this assessment of the Strachan and Auchenblae-Catterline areas.

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 (ΔV) 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 9a) the apparent resistivity (ρa) is given by:-

$$\rho = 2\pi \text{ a } \Delta \text{ V/I}$$

where (a) is the electrode separation.

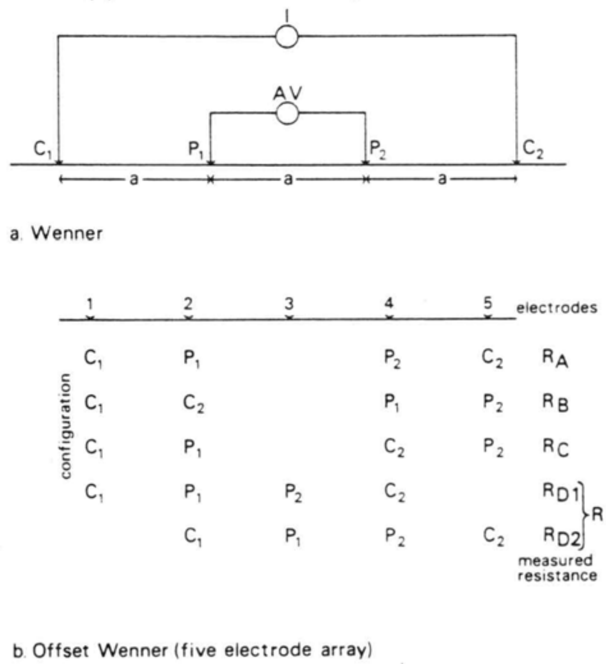


Figure 9. Example of the Wenner and Offset Wenner five electrode array

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 9b, 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 using the Wenner electrode configuration. 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 between 0.11 x 256m = 28.2m (Roy and Apparo, 1971) and 0.17 x 256m = 43.5m (Edwards, 1976), which exceeds the maximum depth (25m) to which assessment boreholes are drilled (see Appendix A). 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 a VAX 8600 main-frame computer. 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 H.

RESULTS

The Offset Wenner sounding system was operated at 22 sites in which 44 resistivity soundings were measured, 26 in the Strachan area and 18 in the Auchenblae-Catterline area. These two areas are underlain by distinctly different suites of bedrock:

a) Strachan: Caledonian (Kincardine) Granite and Dalradian metamorphic rocks.

b) Auchenblae-Catterline: Mainly Old Red Sandstone strata comprising conglomerates, sandstones and mudstones intercalated with basaltic lavas and tuffs.

Previous work from an adjacent area to the north (Auton, Merritt and Ross, 1988) showed that there were likely to be difficulties in determining the nature and thickness of superficial deposits in the assessment area using resistivity soundings, due primarily to a lack of sufficient resistivity contrast between the drift deposits and the bedrock. This problem was expected to emerge in the Strachan area because of the sandy nature of the drift sequence as a whole and the till deposits in particular. In the Auchenblae-Catterline area, however, it was expected that the sand and gravel component of the drift would be more readily identified, because of the greater resistivity contrast between the Red Series clayey tills and glaciolacustrine deposits and the sandy mineral deposits.

As a result of experience gained during the previous assessment, it was decided that resistivity soundings would be restricted to sites located on the alluvium of the river valleys and to terraced deposits of sand and gravel flanking the alluvium, thereby limiting the variety of stratigraphic settings for which interpretations would be required. This restriction in the type of sites investigated made the interpretation of the resistivity data easier than would have otherwise been the case. Distinguishing between the superficial deposits and the underlying bedrock was also aided by the contrast afforded by a low to medium resistivity layer of till or glaciolacustrine deposits, that was found to directly overlie the bedrock, and underlie the alluvial and fluvioglacial deposits at most sounding sites.

Measurements. The level of confidence for any geological interpretation that utilises resistivity data is greatly improved when it can be calibrated against other field evidence. About half of the soundings were therefore positioned in close proximity to either boreholes, trial pits or measured sections. Two series of soundings, taken as near to 90 degrees apart as possible, were measured at each site. Allowance was made for fences, hedges and burns and advantage was taken of the open ground at Strachan Bridge, where a Schlumberger sounding was conducted to compare the cost-effectiveness of this well-established technique to soundings made using the Offset-Wenner array.

A frequency distribution plot displaying ground resistivity values has been constructed from the interpreted values and is shown in Figure 10. Detailed interpreted resistivity values for the types of drift is shown below:

STRACHAN AREA:

a) Mineral: Alluvial and fluvioglacial sand and gravel deposits have an overall interpreted resistivity range of 146-15444 ohm.m, with a mean value of 3750 ohm.m, but most ranged between 5000 and 15000 ohm.m, particularly when coarse gravels and cobbles (in a sandy matrix) were encountered lying above the water-table as at Dalbreck (69 SE R2) and Ordie (69 SW R5). The thickest mineral deposit was recorded in soundings taken near Strachan Bridge, (69 SE R5), where sand and gravel with an interpreted thickness of between 11.7 m and 13.2 m overlies sandy and silty glaciolacustrine deposits.

b) Waste: The glaciolacustrine and till deposits had a similar interpreted range of 147-934 ohm.m, with a mean value of about 500 ohm.m. These values reflect the sandy and gravelly nature of such deposits; the site at Blackhole (69 SW R1) is a good example. These deposits reach a maximum thickness of 20 metres at the Castle Hill site (69 SE R1).

c) Bedrock: The granite bedrock gave interpreted resistivity values of between 842 ohm.m, when decomposed, and up to 14428 ohm.m when fractured. Typically, the values for fresh granite were in the range 2500-6000 ohm.m. The resistivity soundings taken on the flat-lying alluvium at Boghead (69 SW R4) indicated that metamorphic rock produced interpreted values, attributed to semipelite, of 575 and 699 ohm.m. A value of 62 ohm.m was obtained for pelite.

AUCHENBLAE-CATTERLINE AREA

a) Mineral: The interpreted resistivities for the alluvial and fluvioglacial sand and gravel deposits range from 334-4709 ohm.m, with a mean value of 1000 ohm.m. Dry gravelly/cobble deposits lying above the water-table, such as those at Tipperty (78 SW R2) and Hawkshill Farm (78 SE R1), produced values >2000 ohm.m. Values for mineral deposits lying below the water-table were typically around 1000 ohm.m. Where the sand and gravel is predominantly silty, resistivities were much lower, in the range of 350-1000 ohm.m. The interpreted maximum thickness of mineral deposits encountered was 2.3 m at the Mains of Fordoun (77 NW R2B).

b) Waste: The till and glaciolacustrine deposits have an interpreted resistivity range of 134-798 ohm.m, with a mean value of 350 ohm.m. This reflects the more silty/clayey nature of the drift which overlies the Old Red Sandstone in the Auchenblae-Catterline area, as seen in the soundings taken at Pittarrow (77 NW R3) and Pitskelly (77 NE R2). The soundings at Tipperty (78 SW R2) showed the thickest interpreted sequence of 5.0 metres.

c) Bedrock: The Old Red Sandstone sequence gave interpreted resistivity values ranging from 15 ohm.m to 100 ohm.m for lavas and mudstone/siltstone lithologies, and 200-400 ohm.m for sandstone and conglomerate. Soundings at the Tipperty site (78 SW R2) gave

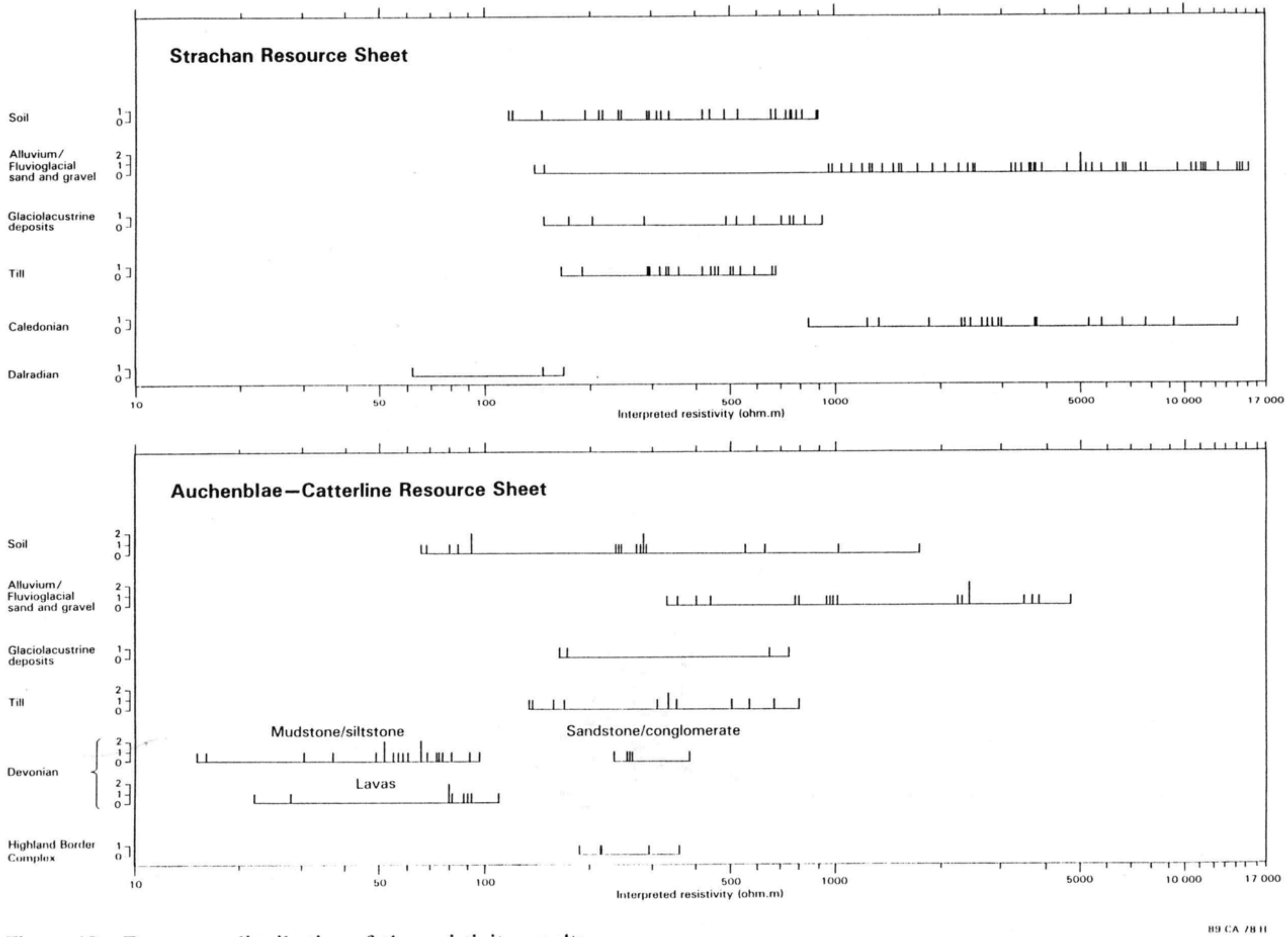


Figure 10. Frequency distribution of the resistivity results

interpreted resistivity values for the Highland Border Complex (interstratified basaltic lava and chert) at between 180 and 400 ohm.m.

General

In the Strachan area, the resistivity results indicated that the sandy nature of the drift proved in the boreholes and pits and seen to be due to derivation from the underlying crystalline bedrock is maintained between the sampling points. The additional information provided by the 'Strachan Bridge' site investigation boreholes helped to calibrate the resistivity and confirm the depth to bedrock. The soundings (69 SE R5A and R5B) were in close agreement with the borehole data, recording a considerable thickness of sand and gravel in the area. However, the borehole logs depicted many thin silty horizons within the sand and gravel that the resistivity method was unable to resolve. This resulted in several broad groupings, with an obvious loss of stratigraphic detail. Resistivity data from the 13 sites in the Strachan area indicated a mean drift thickness of 16.4 m.

The low resistivity of the Old Red Sandstone bedrock in the Auchenblae- Catterline area resulted in moderate resistivity values (mean value of 1000 ohm.m for the sand and gravel derived from it, compared to a mean value of 3750 ohm.m, for sand and gravel derived from Kincardine Granite bedrock in the Strachan area.

In contrast to the Strachan area, resistivity data indicated a thin spread of drift with an average thickness of only 3.8 m. With the comparatively short resistivity range of the sand and gravel, allied to the good bedrock resistivity contrast, interpretation was often quick and simple. The low resistivity layer apparent at the base of the drift in most of the soundings was again attributed to either sandy till or glaciolacustrine deposits. Without borehole control it was difficult to establish which type of deposit formed this layer at individual sites as the respective resistivity ranges of both till and glaciolacustrine deposits (150-900 ohm.m) are almost identical.

Conclusions:

The Wenner array system has proved to be a useful and rapid tool in extending the broad stratigraphy of the glacial drift in the assessment area. It also accurately determined the total thickness of the drift sequence at Strachan Bridge, where there was little lateral variation and confirmation from close borehole control. Overall the system was more successful in the Auchenblae-Catterline area, because the greater resistivity contrast between the bedrock and overlying drift permitted a quicker and more accurate curve matching and interpretation. This differed from the Strachan area, where the contrast was reduced due to the very sandy nature of the whole drift sequence. Overall, the interpretation of the resistivity data proved much slower than expected, due to the very high resistivities of the sand and gravel and the variable sand/clay content of the tills and glaciolacustrine deposits. Certainly this masking and overlapping, coupled to the rapid increases and decreases in resistivity values, made the curve matching process more difficult and ultimately less accurate in the Strachan area. As the sounding at Strachan Bridge proved, good borehole control is always necessary. At some of the other sites where good control was available, however, the resulting resistivity interpretations looked poor. This is probably due to the patchy nature of the mineral deposits and it is assumed that lateral variation had a major effect and, as previously discussed, there is some averaging, with the resistivity failing to discriminate thin layers within an otherwise homogeneous unit.

Resistivity soundings were particularly successful in areas underlain by coarse gravels where shell and auger drilling to bedrock was almost impossible as well as prohibitively expensive. However, the reliability of interpretation of the drift sequence in an area containing rapidly varying deposits decreases with distance away from boreholes, pits or measured sections which provide control.

The results obtained from the Schlumberger sounding near Strachan Bridge are comparable to those obtained using the Wenner array system. Both gave similar interpreted curve shapes, but the Schlumberger method indicated a slightly greater depth to bedrock. Although both systems gave very good results at this site, the Wenner array proved to be the more practicable system. Firstly, once laid out it is a static operation and can be operated by two men very quickly. In comparison, Schlumberger soundings require at least 3 field operators and can take significantly longer as electrodes have to be moved after each reading; secondly, the Wenner system operates on ground where space is limited and it also functions more accurately in areas where sequences are laterally variable.

The Offset-Wenner system can, therefore, be confidently recommended as being cost effective as an additional assessment tool, given reasonable geological control.

Overall, the resistivity survey in the Strachan-Catterline assessment area has been less successful than the earlier survey in the Inverurie-Stonehaven area. This is due mainly to problems in resolving and interpreting the resistivities as well as the pocket-like nature of the drift deposits in some of the higher valley sites of the Strachan area.

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148 The sand and gravel resources of the country around Inverurie and Dunecht, and between Banchory and Stonehaven, Grampian Region: Resource sheets NJ 72, and NJ 70, NO 79, and parts NO 88, 89, 99. C. W. Auton, J. W. Merritt and D. L. Ross. [BGS Technical Report WF/88/1.]

149 The sand and gravel resources of the country around Strachan and between Auchenblae and Catterline, Grampian Region: Resource sheets comprising parts of NO 68, 69, 77, 78, 87 and 88. C A Auton, C W Thomas and J W Merritt. [BGS Technical Report WF/90/7.]

Summary Assessments

Summary assessment of the sand and gravel resources of south-east Strathclyde. J. W. Merritt, J. L. Laxton, J. L. Smellie and C. W. Thomas. IGS open-file report, Edinburgh, 1983. [BGS Technical Report WF/83/6.5.]

Summary assessment of the sand and gravel resources of Stirling, Callander and Strathallan. A. M. Aitken. IGS open-file report, Edinburgh, 1984. [BGS Technical Report WF/84/1.5.]

Summary assessment of the sand and gravel resources of Newport-on-Tay, Glenrothes and Kinross. A. M. Aitken. BGS open-file report, Edinburgh, 1985. [BGS Technical Report WF/85/4.5.]

Summary assessment of the sand and gravel resources of northeast Scotland. J. W. Merritt, C. A. Auton and D. L. Ross. [BGS Technical Report WF/88/2]

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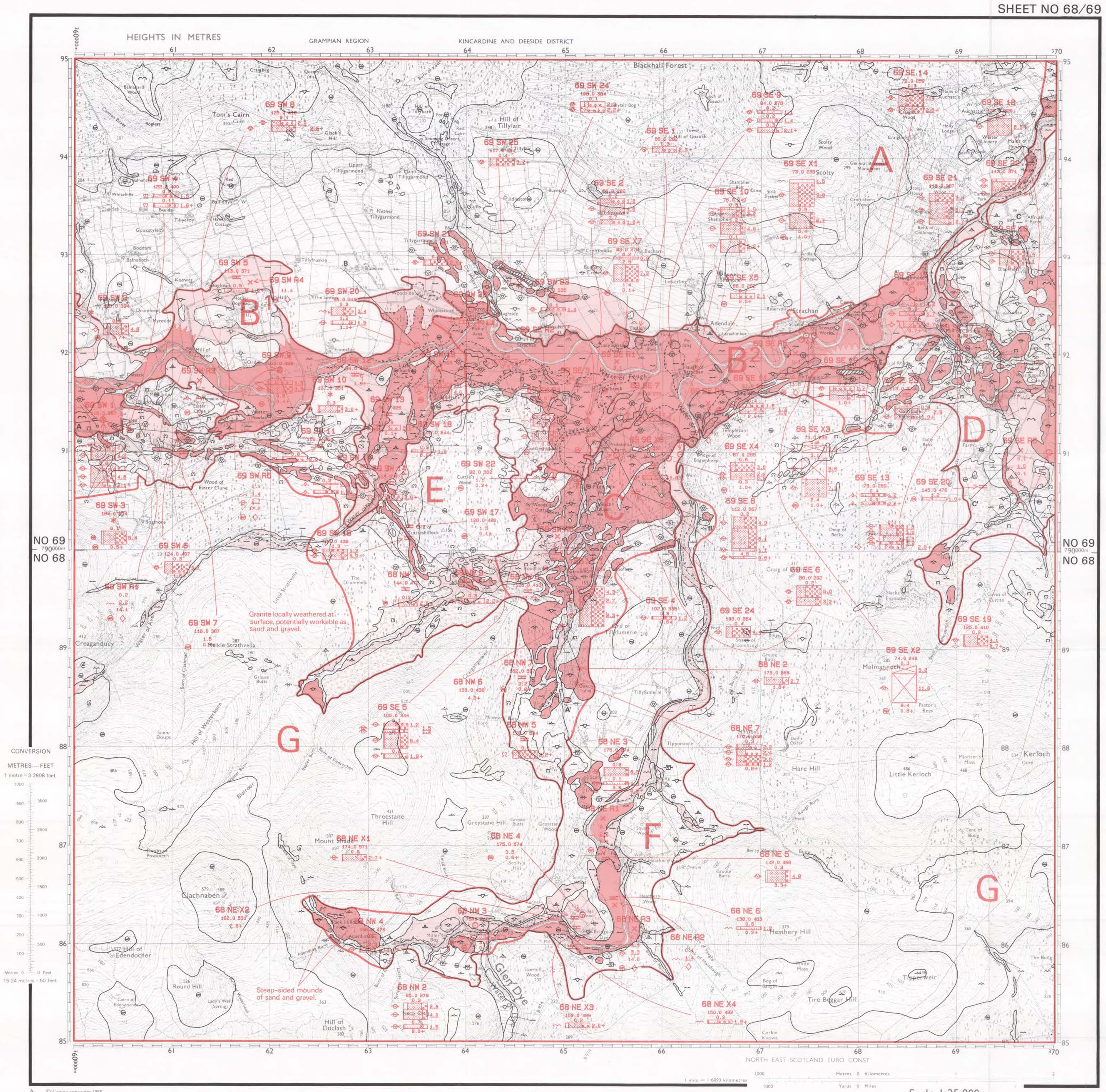
BRITISH GEOLOGICAL SURVEY (SCOTLAND)

THE SAND AND GRAVEL RESOURCES OF THE AREA AROUND STRACHAN, GRAMPIAN REGION

SHEET NO 68/69



Scale 1:25 000

LOCATION OF THE STRACHAN RESOURCE SHEET

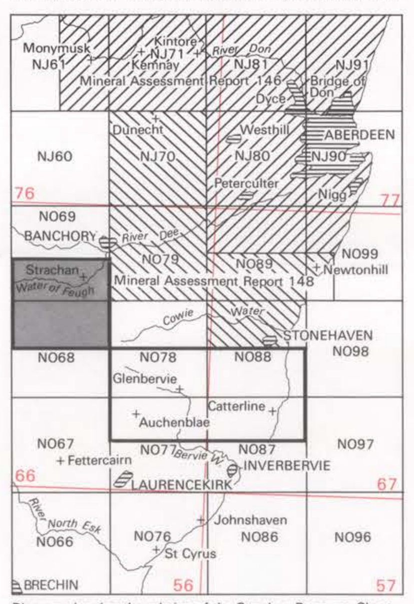
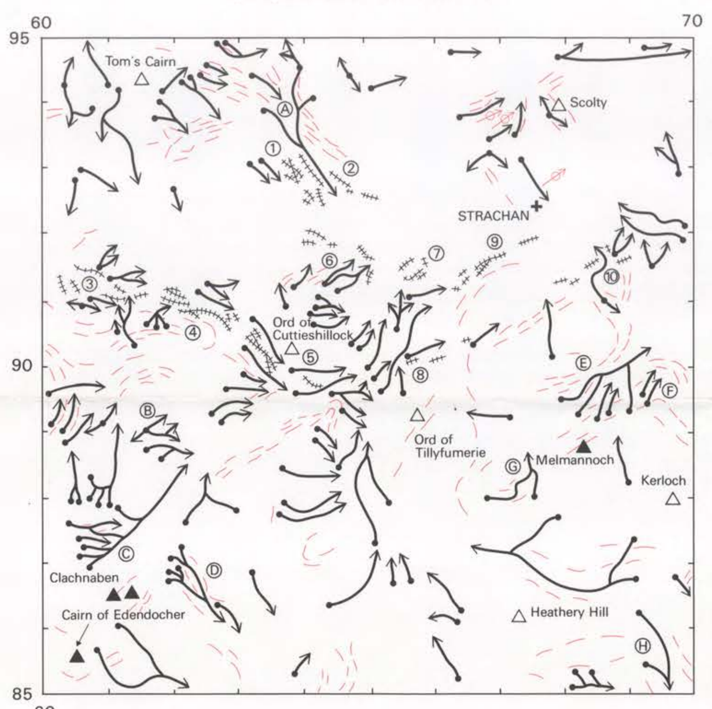


Diagram showing the relation of the Strachan Resource Sheet to the Auchenblae-Catterline Resource Sheet, previously published Resource Sheets, the National Grid 10km squares and the BGS 1:50 000 Geological Sheets (in red).

GLACIAL GEOMORPHOLOGY



Glacial striae, indicating direction of ice-movement

Glacial flutings and ice-moulded features, indicating direction of ice-movement

Granite tor

Esker ridge. The most noteworthy are listed below:

1. Tillygarmond Eskers
2. Waulkmill Eskers
3. Easter Clune Eskers
4. Powlair Eskers
5. Rouchan Eskers
6. Balblythe Eskers
7. Pitdelphin Eskers
8. Bogarn Eskers
9. Templeton Eskers
10. Gallybank Eskers

Glacial drainage channel, showing direction of fall of channel floor. The most noteworthy are listed below:

- (A) Den of Tillygarmond
- (B) Den of Strathvella
- (C) Doups of Powanech
- (D) Slack of Dye
- (E) Slacks of Pitreadie
- (F) Coves of Curran
- (G) Deil's Oxter
- (H) Paton's Den

Principal summit

Village

Original geological survey on the six-inch scale by D.R. Irvine in 1876 and H. Skae in c. 1882 (northern part).
Original geological survey on the one-inch scale by H. Skae in c. 1882 (southern part).
Revision on the six-inch scale by G. Barrow in c. 1896.
Reconnaissance resurvey at a scale of 1:10 000 by D. Gould in 1985.
Drift geology surveyed at a scale of 1:10 000 by C. Auton in 1987-89.
Sand and gravel survey by C.A. Auton, A.J. Highton and M.G. Reiner in 1989.
D.I.J. Mallick, Manager, Highlands and Islands Group.
The 1:25 000 sand and gravel resource sheet published in 1990.
P.J. Cook, Director, British Geological Survey.

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. Tabulated information on the volume and mean grading of mineral in each Resource Block are given in the Report.

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 Bayesfield Carto-Graphics (Edinburgh) Limited
Printed by John Bartholomew & Sons Ltd, Edinburgh 1990

Detailed records may be consulted on application to the Manager, Highlands and Islands Group, 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.

yards 1000 0 1 2 miles
metres 1000 0 1 2 3 kilometres

THE SAND AND GRAVEL RESOURCES OF THE AREA AROUND STRACHAN, GRAMPIAN REGION

This map should be read in conjunction with B.G.S. Technical Report WF/90/3 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 other than in sand and gravel

Landslip

DRIFT

Recent and Pleistocene

Scree

Peat

Alluvium and river terrace deposits - silt, clay, sand and gravel

Lacustrine alluvium - mainly humic silt, clay and fine sand

Alluvial fan - fan composed of alluvium

Fluvioglacial sand and gravel - mounded and terraced deposits varying from coarse gravel with medium and coarse sand to well sorted, silty fine sand

Glacial sand and gravel - typically linear ridges, formed of poorly sorted coarse gravel with coarse and medium 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

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 - mainly comprises coarse-grained Kincardine Granite in the southern part of the sheet. The northern part of the sheet is underlain by Dalradian metamorphic rocks including psammite (slightly gritty in places), pelitic and semipelitic schist and gneiss, and some calc-silicate rock. The granite and metamorphic rocks are both cut by N-S trending felsite dykes

SAND AND GRAVEL WORKINGS

Made ground -waste and/or natural earth materials deposited in man-made workings

Worked ground-boundaries as at November 1989

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

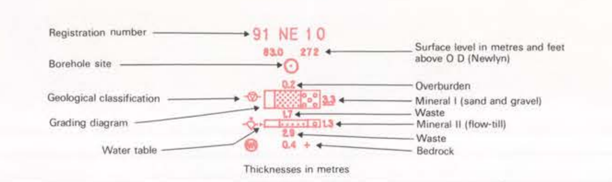
BOREHOLE AND OTHER DATA SITE LOCATIONS

Borehole site

Recorded exposure, 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 estimated from contours on 1:10 000 maps
(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. 68 NW 3
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 68 NW 3 is NO 68 NW 3

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. 69 SE X1

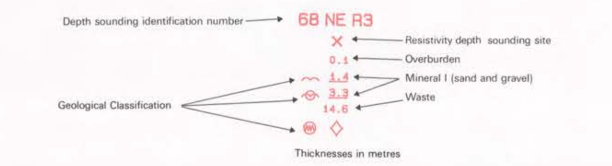
EXPOSURE RECORDS

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, 68 NW 2

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. 68 NW 1. The surface level for each pit has been extrapolated from the contours on the 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. 68 NE followed by the letter 'R' denoting a resistivity depth sounding, and the site number e.g. 68 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. Individual soundings are given in the accompanying report ie. the results shown for site 68 NE R3 combine the data from soundings 68 NE R3A and 68 NE R3B
(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) The Geological Classification is given only for mineral and bedrock

CATEGORIES OF RESOURCE ON MAP

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 some potentially workable sand and gravel

Barren ground: 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.

This Map and the accompanying report were commissioned and financed by the Department of the Environment, with the support from Grampian Regional Council and local industry.

KEY TO SECTIONS

Potentially workable sand and gravel, continuous or almost continuous deposits, exposed or beneath overburden.

Discontinuous spreads of potentially workable sand and gravel exposed or beneath overburden.

Morainic drift, containing potentially workable till (mineral II) and some potentially workable sand and gravel (mineral I).

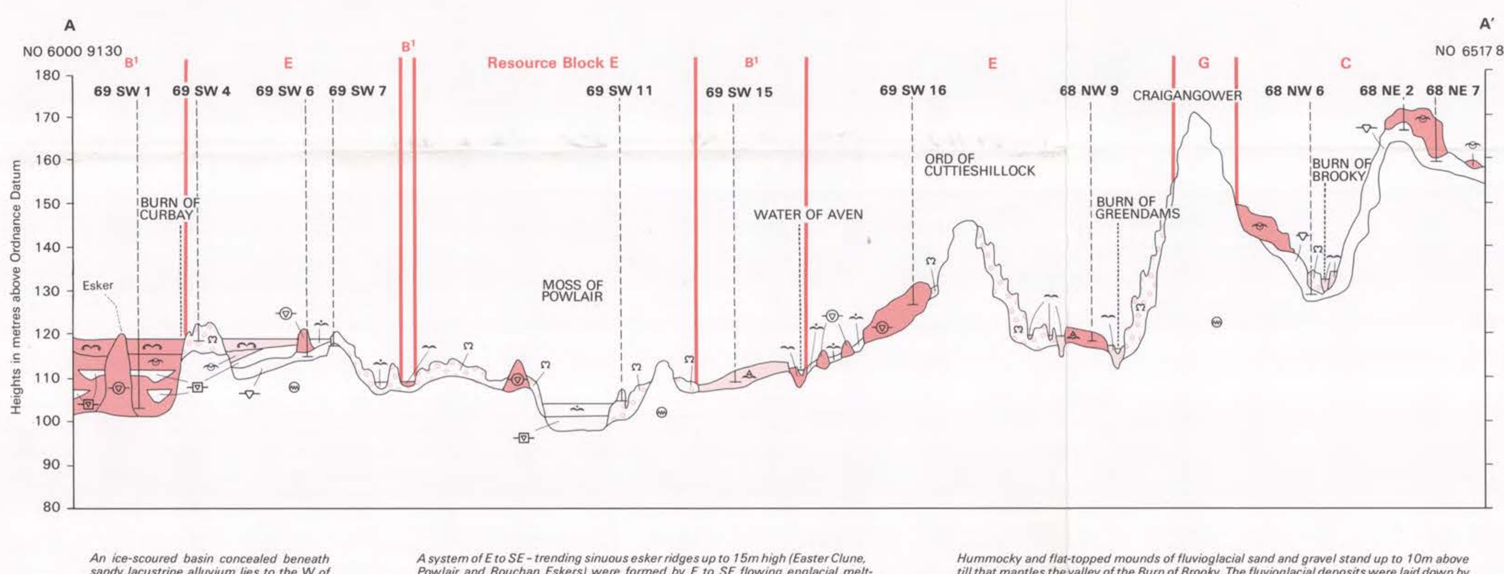
Bedrock and waste, including overburden, are uncoloured.

Geological boundary.

Otherwise symbols and abbreviations as map legend.

GENERALISED HORIZONTAL SECTIONS SHOWING RELATIONSHIPS OF DRIFT DEPOSITS

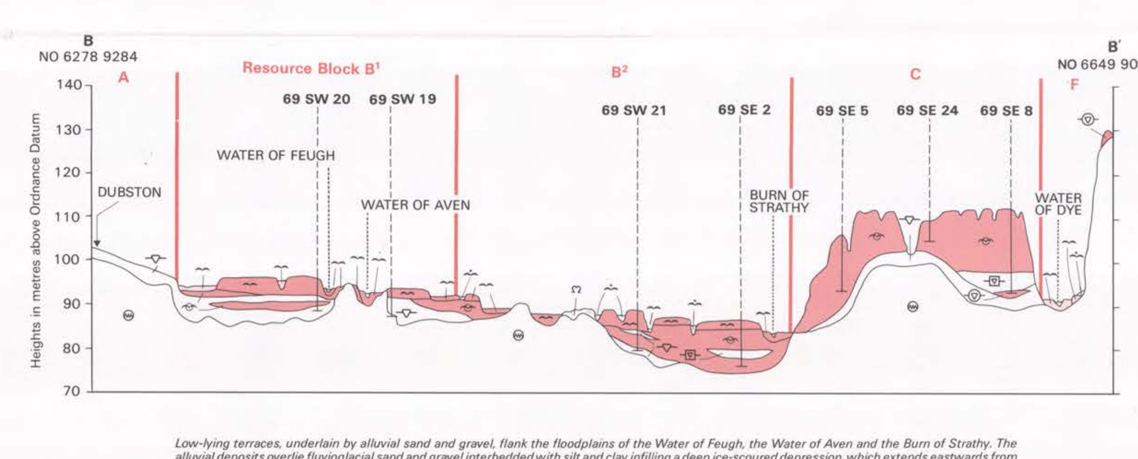
HORIZONTAL SCALE 1:25 000
VERTICAL EXAGGERATION 20X



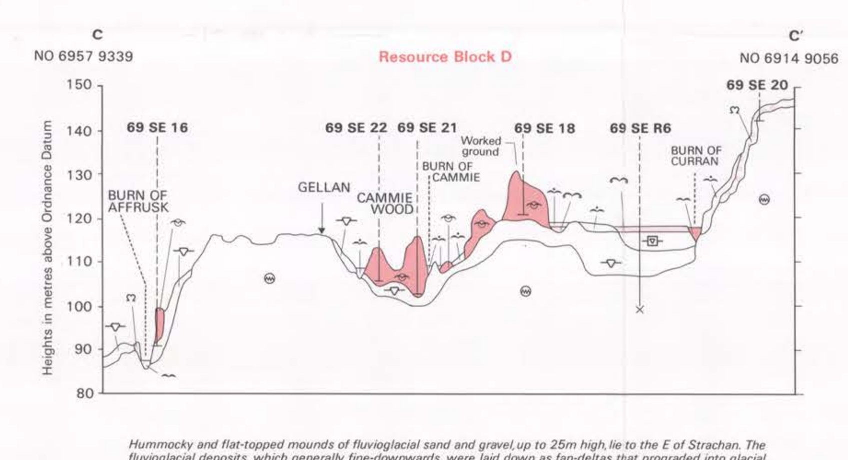
An ice-scoured basin concealed beneath sandy lacustrine alluvium lies to the W of pit 69 SW 7. The alluvial deposits overlie a sequence of sand and gravel interbedded with silt and clay. The basin contained an ice-dammed lake during deglaciation when drainage was blocked to the east.

A system of E to SE - trending sinuous esker ridges up to 15m high (Easter Clune, Powlair and Rouchan Eskers) were formed by E to SE flowing englacial melt-waters. Extensive spreads of hummocky morainic drift were laid down during deglaciation. The Moss of Powlair was formerly a lake occupying a large kettle hole, now infilled by silt and peat.

Hummocky and flat-topped mounds of fluvioglacial sand and gravel stand up to 10m above till that mantles the valley of the Burn of Brooky. The fluvioglacial deposits were laid down by melt water that drained between Craigangower and the Ord of Tillyfumerie, derived from downwasting ice in the upper reaches of Glen Dye.



Low-lying terraces, underlain by alluvial sand and gravel, flank the floodplains of the Water of Feugh, the Water of Aven and the Burn of Strathy. The alluvial deposits overlie fluvioglacial sand and gravel interbedded with silt and clay, infilling a deep ice-scoured depression, which extends eastwards from Ennochie [626 921].
Gravel ridges (Balblythe and Pitdelphin Eskers) stand up to 10m above the level of the floodplain.
The interfluve between the Water of Dye and the Burn of Strathy is mantled by thick, kettled spreads of fluvioglacial sand and gravel N of Bogarn [657 903]. The sand and gravel, which either rests directly on till or passes down into glaciolacustrine silt, was laid down during deglaciation as a fan-delta that prograded into a glacial lake, dammed by ice within the valley of the Water of Feugh.



Hummocky and flat-topped mounds of fluvioglacial sand and gravel, up to 25m high, lie to the E of Strachan. The fluvioglacial deposits, which generally fine-downwards, were laid down as fan-deltas that prograded into glacial lakes, dammed by ice within the valley of the Water of Feugh.
A former lake basin E of Pitreadie Farm [692 910] is infilled with glaciolacustrine silt capped by thin sandy alluvium. Spectacular glacial drainage channels cut into bedrock (the Slack's of Pitreadie and the Coves of Curran) descend steeply towards the southern edge of the basin, which is mantled by thin spreads of morainic drift.

BRITISH GEOLOGICAL SURVEY (SCOTLAND)

THE SAND AND GRAVEL RESOURCES OF THE AREA BETWEEN AUCHENBLAE AND CATTERLINE, GRAMPIAN REGION

LOCATION OF THE AUCHENBLAE - CATTERLINE RESOURCE SHEET

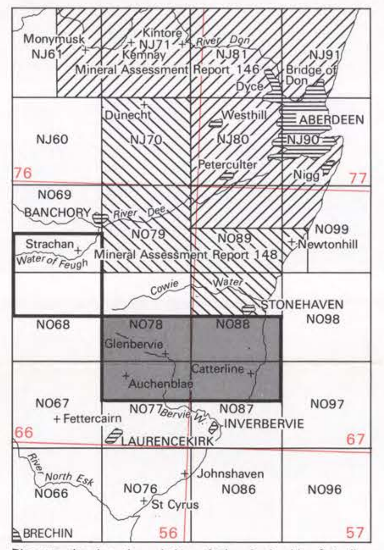
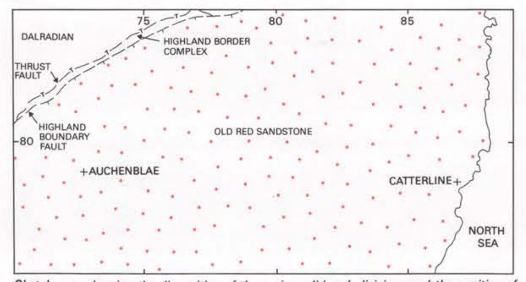


Diagram showing the relation of the Auchenblae-Catterline Resource Sheet to the Strachan Resource Sheet, previously published resource sheets, the National Grid 10 km squares and the 1:50,000 Geological sheets (in red).



Sketch map showing the disposition of the major solid rock divisions and the position of the Highland Boundary Fault

Original surveys on the six-inch scale by D.R. Irvine and G. Barrow in 1876-1879

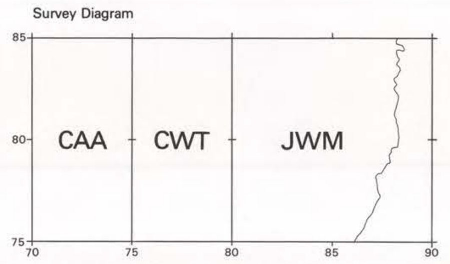
Drift geology resurveyed at a scale of 1:10 000 by C.A. Auton, J.W. Merritt and C.W. Thomas in 1988-1989

Sand and gravel survey by C.A. Auton, J.W. Merritt, M.G. Raines, S. Robertson and C.W. Thomas in 1989

D.I.J. Mallick, Manager, Highlands and Islands Group

The 1:25 000 sand and gravel resource sheet published in 1990
Peter J. Cook, Director, British Geological Survey

Survey Diagram



Detailed resurvey of drift deposits for sand and gravel assessment by C.A. Auton (CAA), J.W. Merritt (JWM) and C.W. Thomas (CWT)

Borehole Graphics drawn by computer using programs written by J.L. McInnes, NERC Computer Services, Edinburgh

Produced for the British Geological Survey by Bartholomew Carto-Graphics (Edinburgh) Limited
Printed by John Bartholomew & Son Ltd, Edinburgh 1990

This Map and the accompanying report were commissioned and financed by the **Department of the Environment**, with support from Grampian Regional Council and local industry.

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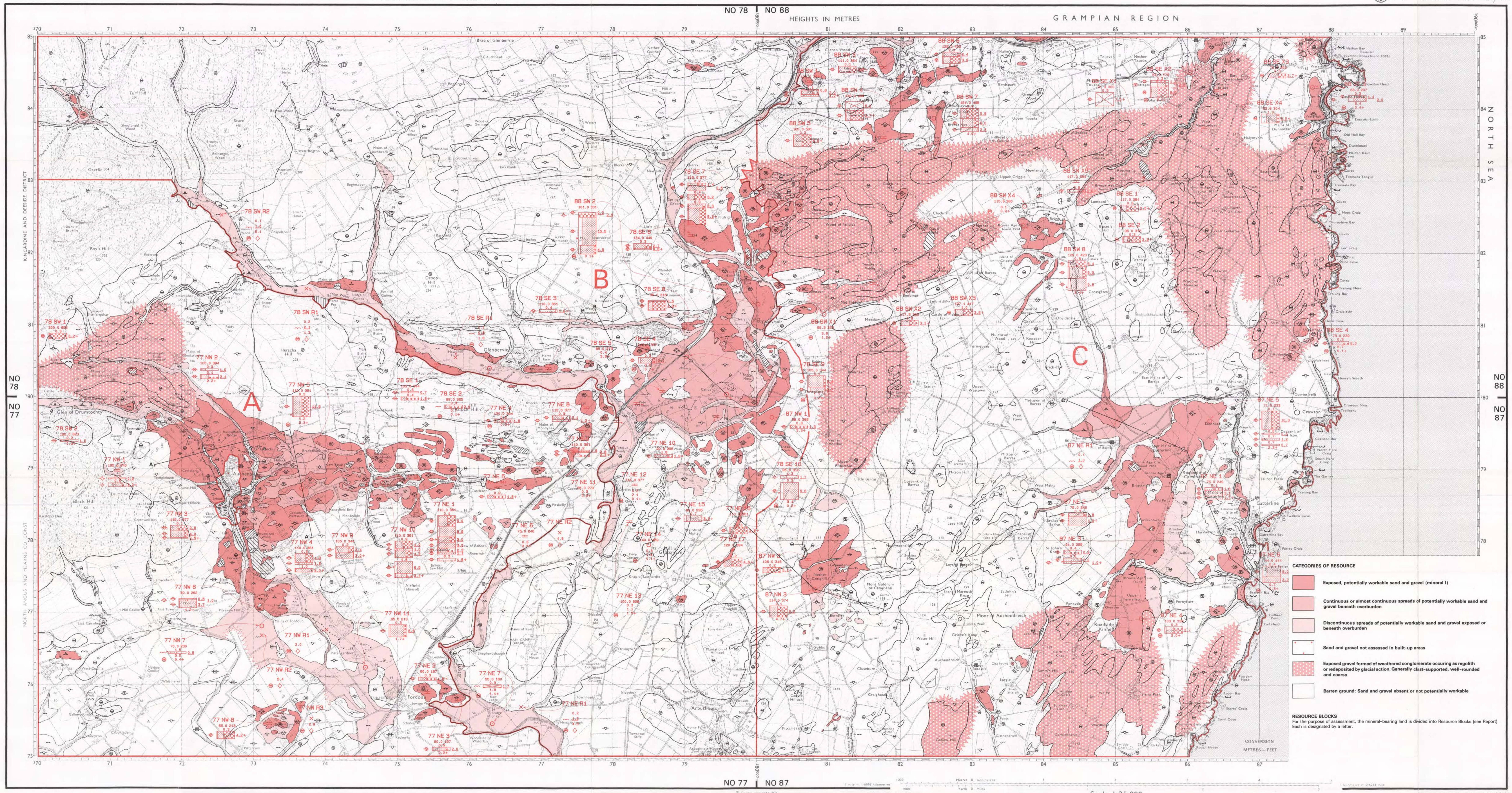
ORDNANCE SURVEY

SHEET NO 87/88



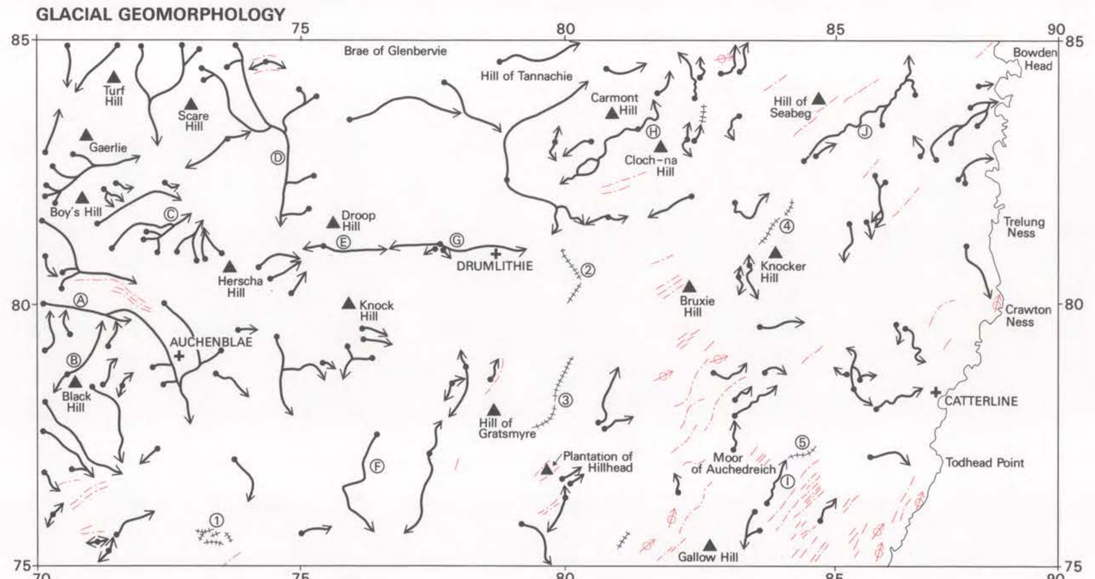
NO 77 | NO 87

Scale 1:25 000

1 mile = 1·6093 kilometres
1 kilometre = 0·6214 mile

SHEET NO 87/88

GLACIAL GEOMORPHOLOGY



Glacial striae, indicating direction of ice movement.

Glacial flutings and ice-moulded features, indicating direction of ice movement

Esker ridge. The most noteworthy are listed below
① Bomershanoe Wood Eskers ② Fiddes Esker ③ Little Wairds Esker
④ Barras Esker ⑤ Fawsyde Esker

Glacial drainage channel, showing direction of fall of channel floor.
The most noteworthy are listed below. Ⓐ Glen of Drumtochty Ⓑ Red Den
Ⓒ Paidyfair Den Ⓓ Den of Guinea Ⓔ Hawkhill Den Ⓕ Shepherdshaugh
Ⓖ Kinmonth Den Ⓗ Den of Luckyfeal Ⓘ Den of Ery Ⓙ Den of Glaslaw

Principal summit

Village

Detailed records may be consulted on application to the Manager, Highlands and Islands Research Group, 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.

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.

Potentially workable sand and gravel, continuous or almost continuous deposits, exposed or beneath overburden.

Discontinuous spreads of potentially workable sand and gravel exposed or beneath overburden.

Bedrock and waste, including overburden, are uncoloured

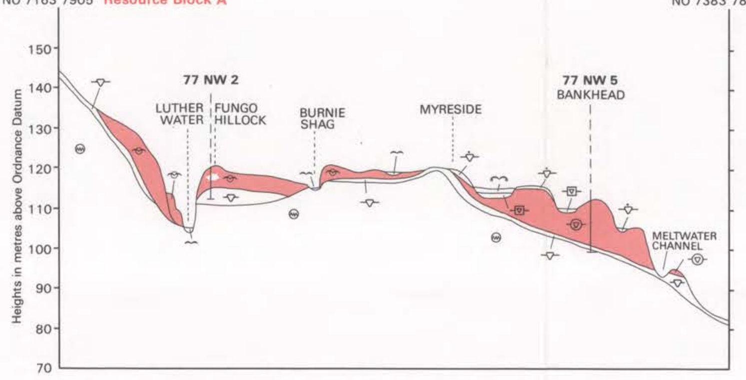
Geological boundary (broken line denotes uncertainty)

Inferred boundary limiting the extent of potentially workable material

Otherwise symbols and abbreviations as map legend

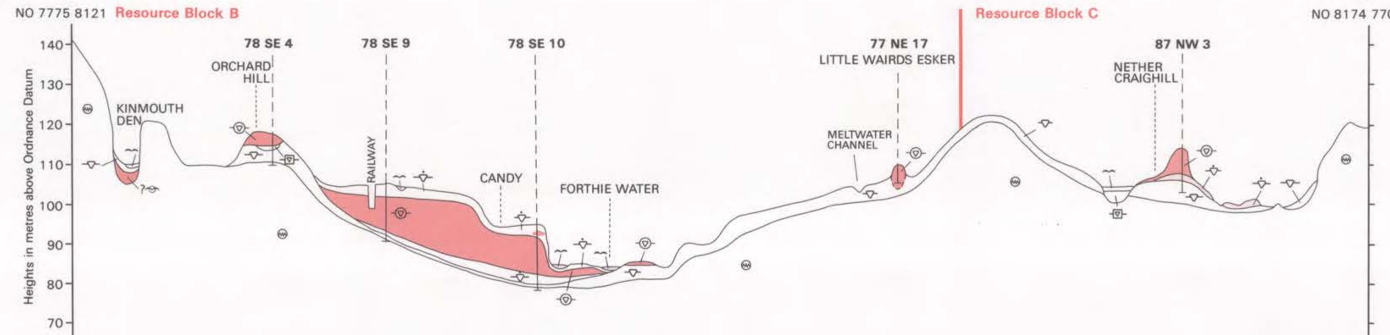
GENERALISED HORIZONTAL SECTIONS SHOWING RELATIONSHIPS OF DRIFT DEPOSITS

HORIZONTAL SCALE 1:25 000
VERTICAL EXAGGERATION 20X



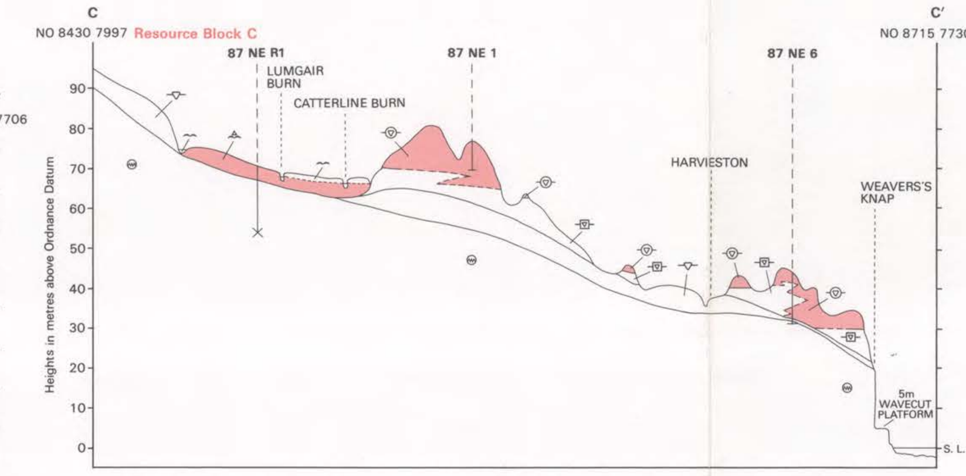
The flat-topped and kettled terraces of fluvioglacial sand and gravel flanking the Luther Water and the Burnie Shag were laid down during the deglaciation by glacial meltwaters that drained south-eastwards. The terraced deposits rest on thin till overlying Old Red Sandstone bedrock.

Glacial sand and gravel south-east of Myreside [736 794] forms east-west trending linear ridges and mounds up to 15m high. The material was laid down during deglaciation, possibly at an E-W trending ice-front by meltwater that flowed into temporary ice-marginal lakes. Thin spreads of glaciolacustrine silt and clay underlie hollows between the ridges of sand and gravel.



Moundy, kettled deposits of glacial sand and gravel lying between Drumlithie [785 808] and the Forthie Water were deposited in an ice-dammed lake by meltwaters during deglaciation and were subsequently covered by an almost continuous layer of flow-till. The sands and gravels vary considerably in lithology, but tend to be fine-grained and silty; they rest on till overlying Old Red Sandstone bedrock.

South-east of the Forthie Water, patchy deposits of glacial sand and gravel overlie an ice-smoothed surface of till resting on Old Red Sandstone bedrock. Immediately east and south of Little Wairds [7976 7858], there is a discontinuous esker that passes northwards into low moundy spreads of ice-proximal glacial outwash sand and gravel.



The Catterline Burn crosses a WSW-ENE trending ice-scoured basin containing alluvial sand and gravel resting directly on conglomerate bedrock.

An undulating spread of glacial sand and gravel lies to the west of Roadside of Catterline [859 792], it overlies glaciolacustrine silt and clay and generally coarsens upwards. The deposits were probably laid down by meltwaters flowing north-east wards along the margin of ice lying along the coast. As the coastal ice decayed, a complex sequence of diamictic mass-flow deposits, sand, gravel, silt and clay were deposited towards the coast at Catterline. All these deposits are shown as glaciolacustrine deposits on the map.

THE SAND AND GRAVEL RESOURCES OF THE AREA BETWEEN AUCHENBLAE AND CATTERLINE, GRAMPIAN REGION

This map should be read in conjunction with B.G.S. Technical Report WF/90/7 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 other than those in sand and gravel

Open-cast working - disused

Landslip

DRIFT
Recent and Pleistocene

Peat

Alluvium - silt, clay, sand and gravel

Alluvial fan - composed of alluvium

Lacustrine alluvium - mainly humic silt, clay and fine sand

River Terrace Deposits - silt, clay, sand and gravel

Present day beach deposits - mainly well-sorted shingle

'Red Series'

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 red

Flow-till and mass-flow deposits - poorly sorted, diamictic/clay, sand and gravel or pebbly, silty, sandy clay, often with abundant mudstone clasts

Till - typically reddish brown, firm to stiff, clayey pebbly sand to sandy, gravelly clay diamicton with sand and gravel lenses

'Inland Series'

Till - typically yellowish to dark brown clayey sand to sandy clay diamicton

SOLID

Bedrock, at or near surface - Old Red Sandstone forms the bedrock beneath most of the area south-east of the Highland Boundary Fault and comprises mudstones, sandstones and conglomerates together with some volcani-clastics and lavas. In the extreme north-west of the area, north-west of the Highland Boundary Fault, the bedrock comprises metamorphosed grits and greywackes of the Dalradian. Within the Highland Boundary Fault zone are tectonic slices of pillow lavas and shales of the Highland Border Complex

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 1989

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

BOREHOLE AND OTHER DATA SITE LOCATIONS

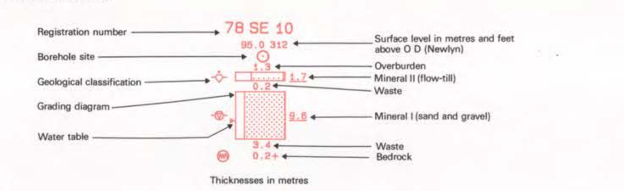
Borehole site

Recorded exposure, sampled

Resistivity depth sounding site

BGS shallow pit

BGS BOREHOLES



Thicknesses in metres

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 estimated from contours on 1:10 000 maps
(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. 78 SE 10
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 78 SE 10 is NO 78 SE 10

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. 88 SE XI

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, 78 SE 7

SHALLOW PITS

Where space permits the locations of shallow pits providing ancillary assessment data are show by a distinctive symbol. Each pit is identified by serial registration numbers e.g. 77 NE 2

GEOPHYSICAL DATA RESISTIVITY DEPTH SOUNDINGS

Depth sounding identification number — 77 NE R1 — Resistivity depth sounding site; Overburden; Mineral I (sand and gravel); Waste

Geological classification

Note:

(i) The depth sounding identification number comprises the alphanumeric code for the quarter sheet e.g. 77 NE followed by the letter R denoting a resistivity depth sounding, and the site number e.g. 77 NE R1. 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. Individual soundings are given in the accompanying report.
(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

British Geological Survey

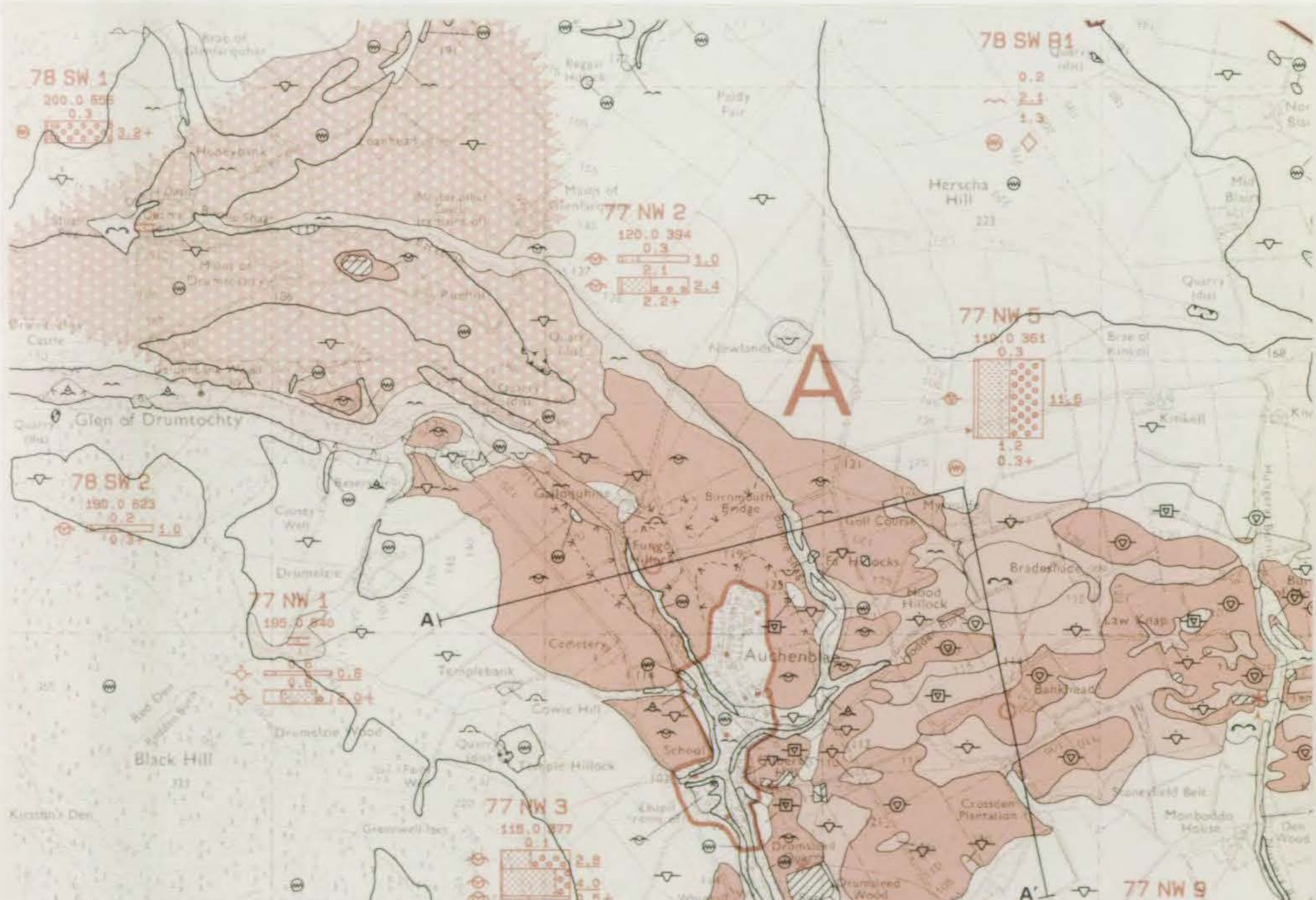
Technical Report WF/90/7

Mineral Resources Series

Sand and Gravel Resources

Parts of NO 68, 69, 77, 78, 87 and 88
Strachan, Auchenblae and Catterline, Grampian Region

Part 2: Borehole and geophysical logs



Natural Environment Research Council

Mineral Assessment Report 149

TECHNICAL REPORT WF/90/7

The sand and gravel resources of the country around Strachan and between Auchenblae and Catterline, Grampian Region

Parts of 1:25 000 sheets NO 68, 69, 77, 78, 87 and 88

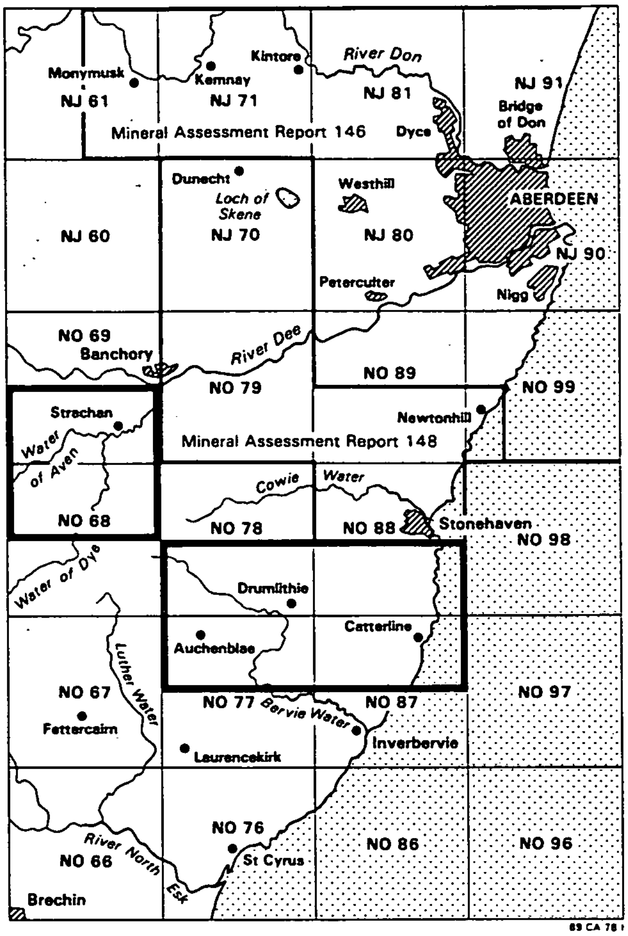
Part 2: Borehole and geophysical logs

C A Auton, C W Thomas and J W Merritt

BRITISH GEOLOGICAL SURVEY

TECHNICAL REPORT WF/90/7

Mineral Resources Series



The sand and gravel resources of the country around Strachan and between Auchenblae and Catterline, Grampian Region

Description of parts of 1:25 000 sheets NO 68, 69, 77, 78, 87 and 88

Part 2: Borehole and geophysical logs

C A Auton, C W Thomas and J W Merritt

Contributor
M G Raines

Mineral Assessment Report 149

Geographical index
UK, NE Scotland, Grampian

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

This report was prepared for the Department of the Environment

Bibliographic reference
Auton, C A, Thomas, C W, and Merritt, J W. 1990. The sand and gravel resources of the country around Strachan and between Auchenblae and Catterline, Grampian Region. *British Geological Survey Technical Report* WF/90/7.

Keyworth, Nottingham British Geological Survey 1990

BRITISH GEOLOGICAL SURVEY

The full range of Survey publications is available through the Sales Desks at Keyworth, at Murchison House, Edinburgh, and at the BGS London Information Office in the Natural History Museum Earth Galleries. The adjacent 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.

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

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Printed in the United Kingdom for the British Geological Survey by Four Point Printing, Chertsey

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* *a full explanation of the sampling and assessment procedures, the grain-size classification and resource criteria, is given in part 1*

Detailed records, including cumulative grading curves, may be obtained on application to:-

Manager
Highlands & Islands Group
British Geological Survey
Murchison House
West Mains Road
EDINBURGH
EH9 3LA

(Tel. 031-667-1000)

APPENDIX E: EXPLANATION OF THE ASSESSMENT RECORDS
ANNOTATED FICTITIOUS EXAMPLE

NO 79 NE 20[1] 7234 9567[2] Valleyside Farm[3]

Surface level c+83m[4]	Overburden 0.2m[7]
Water struck at c+77m[5]	Mineral I 3.3m
250 and 200mm percussion[6]	Waste 1.7m
September 1989	Mineral II 1.3m
	Waste 2.9m
	Bedrock 0.4m+[9]

Geological[10] classification	Lithology[11]	Thickness m	Depth[8] m
	Soil, clayey and sandy, pale brown	0.2	0.2
?Glacial sand and gravel	**a** 'Clayey' sandy gravel *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 *Sand:* medium with coarse and fine, angular quartz and rock *Fines:* silt and clay, loosely binding the deposit; moderate reddish brown (10R 4/6) becoming moderate yellowish brown (10YR 5/3) with depth	3.3	3.5
Glaciolacustrine deposits	Clay, sandy, moderate reddish brown (10R 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, (5Y 5/6) abundant pebbles (?dropstones) of granite, quartz and schist	1.2	5.2
Flow-till	**b** 'Very clayey' pebbly sand, cleaner with depth *Gravel:* fine and coarse, rounded, red quartzite and schist with some granite *Sand:* medium and coarse with fine, angular, quartz and rock *Fines:* silt and clay binding deposit above 6.0m depth, moderate, olive brown (5Y 4/4) to dark yellowish brown (10R 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 (5GY 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	-1/16	+1/16-1/4	+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 NO 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 NO 79 NE 20.

2 The National Grid reference
All National Grid references in this publication lie within the 100-km square 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.

4 Surface level
The surface level at the sample point, given in metres above Ordnance Datum, is estimated from contours on 1:10 000 base maps.

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 C) 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.

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. A grain size category with a mean grading between 0-1% is indicated as 'trace'. The classification used is shown in Table 19. 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 F: BRITISH GEOLOGICAL SURVEY BOREHOLE, SECTION AND SHALLOW PIT LOGS

STRACHAN RESOURCE SHEET

NO 68 NW 1 6338 8961 The Drummels

Surface level c.+144m
Water not struck
Pit
May 1989

Overburden 0.2m
Mineral II 2.6m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil; sandy, humic	0.2	0.2
Caledonian	'Very clayey' sandy gravel (decomposed granite gruss) *Gravel:* fine, angular quartz and decomposed granite *Sand:* coarse with medium, angular quartz and granite *Fines:* silt and clay minerals formed of decomposed feldspar and mica. Moderate red (5R 4/6)	2.6+	2.8

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
21	55	24	0.2- 2.8	21	6	18	31	23	1	0

NO 68 NW 2 | **6386 8601** | **Miller's Bog**

Surface level c.+85m
Water struck at c.+75.7m
Section and Pit
May 1989

Overburden	0.3m
Mineral I	6.8m
Waste	0.7m
Mineral I	1.5m
Waste	2.0m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, pebbly	0.3	0.3
Fluvioglacial sand and gravel (Topset beds)	**a 'Clayey' sandy gravel**, with large scale trough cross-bedding; becoming cleaner below 0.9m depth *Gravel:* fine and coarse, subangular; coarse-grained pink granite, with some felsite, fine-grained basic rock and vein-quartz *Sand:* medium and coarse, angular to subangular granite, quartz and feldspar *Fines:* silt and clay, binding top 0.6m and draping trough cross-bedding; light brown (5YR 6/4)	2.8	3.1
(Foreset beds)	**b Pebbly sand**; well-sorted, in tabular cross-beds up to 10cm thick *Gravel:* fine, subangular, mainly granite *Sand:* coarse and medium, with some fine, angular quartz, feldspar and some mica *Fines:* mainly silt, forming finely laminated partings; light brown (5YR 6/4)	4.0	7.1
Glaciolacustrine deposits (Bottomset beds)	**Sand and silt**, interlaminated with silty clay; forming planar horizontal beds 2-8cm and mottled, light brown (5YR 5/6), yellowish grey (5Y 7/2) and light olive grey (5Y 5/2)	0.7	7.8

Fluvioglacial sand and gravel	**c Sandy gravel**, forming tabular cross-beds *Gravel:* mainly fine, subangular granite *Sand:* mainly medium and coarse; subangular quartz, granite and feldspar; some mica *Fines:* silt and clay, as thin partings; light brown (5YR 5/6)	1.5	9.3
Glaciolacustrine deposits	**Silt and clay**; firm, especially below 9.6m depth. Fine horizontal lamination. Mottled light brown (5YR 5/6) and light olive brown (5Y 5/6) Pit terminated, wet silty clay collapsing in from the sides	2.0+	11.3

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	17	58	25	0.3- 3.1	17	6	29	23	15	10	0
b	2	78	20	3.1- 7.1	2	10	33	35	20	trace	0
c	4	67	29	7.8- 9.3	4	2	36	29	27	2	0
a&b	8	70	22	Mean	8	8	32	30	18	4	0
a-c	7	69	24	Mean	7	7	33	29	20	4	0

NO 68 NW 3 6410 8619 Glendye Lodge

Surface level c.+75m
Water struck at c.+69.2m
250mm percussion
July 1989

Overburden 2.5m
Mineral I 2.3m
Waste 3.1m
Bedrock 0.1m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil; sandy and silty	0.4	0.4
Glaciolacustrine deposits	**Clay**; silty and sandy, stiff, a bed of clay-bound gravel from 1.4 to 1.5m depth. Finely laminated, abundant carbonaceous fragments from 0.4 to 1.3m and below 1.5m depth. Finely-graded laminae (? varves) towards the base, light brown (5YR 5/6) to reddish orange (10YR 6/6), becoming moderate reddish brown (10YR 4/6) and light grey (N7) below the bed of gravel	1.8	2.2
?Flow-till	**Clay-bound gravel**, interbedded with sandy diamicton, stiff. Clasts mainly of pink granite. Moderate reddish brown (10YR 4/6).	0.3	2.5
Fluvioglacial sand and gravel	**Sandy gravel**, with a small lens of fine sand below 4.2m *Gravel:* fine and coarse, well-rounded to subrounded; porphyritic and equigranular white granite, often decomposed to kaolinite below 3.7m, some aplogranite *Sand:* mainly coarse, subangular granite, quartz, and feldspar; some fine quartz and mica *Fines:* silt, disseminated, moderate brown (5YR 4/4) to 3.2m, light brown (5YR 5/6) from 3.2 to 4.1m. Strong iron and manganese stain below 4.4m	2.3	4.8
Till	**Diamicton**, clayey, stiff, angular clasts, mainly of	3.1	7.9

	porphyritic felsite and megacrystic pink granite; some subrounded clasts of quartzite and psammite. Light brown (5YR 5/6) to moderate reddish brown (10R 4/6)		
Caledonian	**Granite;** fresh, coarse to medium-grained, pink to orange pink (10R 7/5)	0.1+	8.0

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
5	56	39	2.5- 3.7	5	5	18	34	19	19	0
			3.7- 4.8	6	5	16	35	22	16	0
			Mean	5	5	17	34	21	18	0

NO 68 NW 4 **6304 8608** **Black Hillocks**

Surface level c+145m
Water not struck
Pit
May 1989

Overburden 0.3m
Mineral I 2.1m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; humic to 0.1m, silty below	0.3	0.3
Fluvioglacial sand and gravel	**Gravel**; clast-supported, becoming coarser with depth *Gravel:* coarse, cobble and fine, mainly angular to subangular coarse and medium-grained pink granite, some tabular felsite and microgranite; sparse metamorphic clasts *Sand:* mainly coarse, angular granite, quartz and feldspar *Fines:* silt, disseminated, moderate brown (5YR 4/4) Pit terminated, bedded gravel collapsing in from the sides	2.1+	2.4

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
2	33	65	0.3- 1.8	3	3	12	19	37	20	6
			1.8- 2.4	1	1	9	23	32	34	0
			Mean	2	2	11	20	36	25	4

NO 68 NW 5 **6457 8871** **Minster's Burn**

Surface level c.+178m
Water not struck
Pit
May, 1989

Soil	0.1m
Mineral I	3.2m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, silty, humic	0.1	0.1
Morainic drift	**Cobble gravel**; angular boulders up to 50cm, between 2.0m and 2.7m. Poorly-sorted, crude cross-bedding; a bed of silty fine sand between 1.5m and 2.0m depth *Gravel:* cobble with some fine, rounded to subrounded; mainly coarse-grained pink granite, with some felsite and microgranite *Sand:* coarse and medium, angular, sharp; mainly granite, quartz and pink feldspar *Fines:* silt, disseminated, light brown (5YR 5/6) Pit terminated, pebbly sand collapsing in from the sides	3.2+	3.3

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
3	22	75	0.1- 3.3	3	1	10	11	16	4	55

NO 68 NW 6 6498 8924 South of Lady's Dowry

Surface level c.+133m
Water not struck
Section and pit
May 1989

Waste 4.3m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil; humic	0.2	0.2
Morainic drift	**Boulder gravel and diamicton**; clast-supported cobbles and boulders up to 1.1m; poorly developed tabular cross-stratification in top metre. Clasts: poorly sorted, rounded to subrounded, coarse and medium-grained pink and red granite; some angular pelitic schist, gneiss, psammite and pegmatite. Silt and clay, disseminated, moderate to light brown (5YR 4/4 - 5/6); binding deposit, especially below 1.5m depth	3.2	3.4
Flow-till	**Diamicton**, firm, sandy clay and silt with tabular and subangular pebbles and cobbles of granite, banded psammite, semipelitic schist and porphyritic felsite. Moderate yellowish brown (10YR 5/4); two thin beds of silt in top 0.2m	0.9+	4.3

NO 68 NW 7 6457 8871 **Craigangower**

Surface level c.+182m
Water not struck
Pit
May 1989

Waste 2.2m
Bedrock 0.2m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, silty	0.1	0.1
Morainic drift	**Pebbly clay** silty and sandy. Strong orange	0.4	0.5
	Diamicton; sandy, with angular boulders and cobbles of coarse-grained pink granite up to 0.8m; scattered pebbles of fine-grained basic igneous rock, felsite, psammite, microgranite and coarse-grained granodiorite. Clay, binding deposit below 1.3m depth	1.7	2.2
Caledonian	**Granite**, fresh, coarse-grained, pale pink	0.2+	2.4

NO 68 NW 8 6463 8959 **Rouchanbeg**

Surface level c.+126m
Water not struck
Pit
May 1989

Waste 2.2m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; sandy, humic	0.1	0.1
Morainic drift	**Boulder gravel**; poorly-sorted, with crude horizontal bedding and a matrix of hard, friable silt and clay binding top 0.5m. Angular to subangular clasts up to 1.2m, chiefly coarse-grained pink granite, some felsite. Well-developed horizontal stratification between 1.0m and 1.3m depth. Moderate brown (5YR 4/4)	2.1+	2.2
	Pit terminated on a layer of large boulders		

NO 68 NW 9 6406 8963 **Rouchan**

Surface level c.+121m
Pit
Water struck at c.+118.5m
May 1989

Overburden 0.3m
Mineral I 2.2m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, sandy and humic	0.3	0.3
Alluvial fan	**Gravel**; silty to 0.9m, becoming cleaner with abundant cobbles and boulders below 1.2m. A bed of interlaminated silt and sand containing charcoal fragments, infilling a shallow channel from 0.9m to 1.2m *Gravel:* cobble and coarse, with some fine, subangular to subrounded; mainly coarse, medium and fine-grained pink and orange granite, some felsite *Sand:* coarse and medium, subangular to angular, quartz and lithic grains, sharp, dirty *Fines:* silt and clay, disseminated, dark orange brown, strong iron stain from 0.3 to 0.9m depth; finely laminated silt and clay, filling channel, light olive grey (5Y 3/2) to black (N1). Patches of clast-supported diamicton below 2.0m depth. Pit abandoned at water table, still in gravel	2.2+	2.5

NO 68 NW 9

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
6	26	68	0.3- 1.7	9	5	14	16	16	29	11
			1.7- 2.5	2	1	5	7	11	17	57
			Mean	6	3	11	12	14	26	28

NO 68 NE 1	6528 8975	Dunniemore Quarry

Surface level c+140m
Water not struck
Section and pit
May 1989

Overburden 0.4m
Mineral I 16.3m+

LOG

Geological classification	**Lithology**	**Thickness**	**Depth**
	Soil; pebbly and sandy	0.4	0.4
Fluvioglacial sand and gravel (Topset beds)	**a Gravel**, interbedded with coarse sand in horizontal units to 1.5m depth. Upper 3.0m cut by channel infilled with fine gravel and cross-bedded sand *Gravel:* cobble with coarse and fine, in beds 0.5 to 1.0m thick. Well-sorted, bedded; claybound from 1.5m to 3.0m depth. Well-rounded to subangular, mainly coarse-grained pink granite, some felsite, banded psammite and fine-grained basic igneous rock. *Sand:* mainly coarse and medium, subangular to subrounded granite, quartz and feldspar *Fines:* silt and clay, disseminated, moderate yellowish brown (10YR 5/4) to light brown (5YR 5/4)	4.3	4.7
	b Sandy gravel, in upward-fining trough cross-bedded units up to 0.7m thick *Gravel:* mainly fine, subrounded to subangular, medium and fine-grained pink and white granite, with felsite, quartzite, porphyry, psammite and fine-grained gabbro *Sand:* medium and coarse, subangular and subrounded, granite, quartz and feldspar *Fines:* silt, disseminated, light brown (5YR 5/4)	2.7	7.4
(Foreset beds)	**c Gravel**: in tabular cross-bedded units, interbedded with trough cross-bedded fine sand with ripple-drift lamination *Gravel:* cobble and fine, with coarse, subrounded to subangular; mainly granite, with some	9.3+	16.7

felsite, gabbro, porphyry and psammite
Sand: mainly coarse and medium, subangular and subrounded quartz, granite and feldspar
Fines: silt, disseminated, draping foresets and as basal lag on trough cross-bedded units; pale yellowish brown (10YR 6/2). Angular and rounded intraclasts, up to 20cm of stiff waxy clay, from 16.3m depth; varigated light brown (5YR 5/6) to yellowish grey (5Y 7/2)

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	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
a	5	28	67	0.4- 4.7	5	2	11	15	14	18	35
b	4	63	33	4.7- 7.4	4	3	30	30	27	6	0
c	3	46	51	7.4-12.2	3	4	17	24	12	31	9
				12.2-16.7	2	3	17	25	20	18	15
				Mean	3	4	17	25	15	24	12
a&b	5	41	54	Mean	5	2	19	20	19	14	21
a-c	4	43	53	Mean	4	3	18	22	17	20	16

NO 68 NE 2 6516 8880 **Ord of Tillyfumerie**

Surface level c.+173m
Water not struck
Pit
May 1989

Mineral I 2.7m
Waste 1.3m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
Fluvioglacial sand and gravel	**Sandy gravel**; interbedded with silty fine sand. Beds 20 to 30cm thick, becoming sandier with depth; some cross-bedded units and lenses of diamicton from 2.2m depth. Gravel in discrete upwardly fining lenses. *Gravel:* mainly fine with some coarse, occasional cobbles, tabular to subrounded; pale pink coarse-grained granite, some vein-quartz, psammite and felsite *Sand:* medium and coarse with fine, subangular quartz and pink feldspar; as thin graded beds. *Fines:* silt and clay, firm, finely laminated; involuted and contorted, especially in top 1.0m; moderate yellowish brown (10YR 5/4)	2.7	2.7
Till	**Diamicton**, clayey and sandy, very stiff; subrounded and subangular boulders, up to 50cm, of coarse-grained pink granite, medium-grained granodiorite, and porphyritic felsite below 3.7m depth; occasional cobbles of aplite and vein-quartz. Moderate yellowish brown (10YR 5/4)	1.3+	4.0
	Pit abandoned in till		

NO 68 NE 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
8	67	25	0.0- 2.7	8	13	29	25	16	5	4

NO 68 NE 3 — 6553 8791 — Scolly's Cross

Surface level c+175m	Overburden 0.3m
Water struck at c+169.5m and c+165.9m	Mineral I 3.5m
250mm percussion	Waste 0.1m
July 1989	Mineral I 1.4m
	Waste 3.4m
	Mineral II 0.2m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil; sandy	0.3	0.3
Fluvioglacial sand and gravel	a **Pebbly sand**; a bed of silty micaceous sand from 2.3m to 2.5m *Gravel:* fine, subangular to angular, granite and sparse felsite *Sand:* coarse with medium, subangular, quartz and feldspar; some granite *Fines:* silt and clay, disseminated; iron stain to 1.0m. Moderate brown (5YR 4/4) to pale yellowish brown (10YR 6/2). Thin beds of laminated silt towards the base	3.5	3.8
	Silt; sandy, micaceous, firm, horizontally laminated. Moderate yellowish brown (10YR 5/4) to light brown (5YR 5/6)	0.1	3.9
	b **'Clayey' pebbly sand** *Gravel:* fine, subangular granite and sparse subrounded semipelite *Sand:* coarse and medium with fine, subangular, quartz, with some feldspar and mica *Fines:* silt and clay, disseminated and as thin discontinous finely laminated beds. A bed of sandy micaceous silt from 5.0m to 5.1m. Moderate brown (5YR 4/4) to moderate yellowish brown (10YR 5/4)	1.4	5.3
Glaciolacustrine deposits	**Silt**, clayey, micaceous, stiff. Prominent lamination; moderate brown (5YR 4/4) to moderate yellowish brown (10YR 4/4)	0.2	5.5

Flow-till	**Diamicton**, sandy and clayey, firm to friable. Fine angular clasts of medium-grained pink granite and felsite; some vein-quartz and fine-grained basic rock. Moderate brown (5YR 4/4)	0.1	5.6
	Sand, silty, medium to fine, quartz and feldspar. Moderate yellowish brown (10YR 5/4)	0.1	5.7
Till	**Diamicton**, clayey and sandy, stiff. Clasts mainly fine, angular, medium-grained orange-pink granite, some felsite, vein-quartz and fine-grained basic rock. A bed of gravelly clay with abundant angular felsite clasts from 7.7m to 8.0m. Moderate reddish brown (10YR 4/6) to 8.0m, strong reddish brown (10R 3/6) towards the base.	3.4	9.1
?Caledonian	**c Sandy gravel** *Gravel:* mainly fine, angular fragments of coarse-grained, pink and grey megacrystic granite *Sand:* coarse with medium, angular, granite, quartz and feldspar *Fines:* silt and clay minerals, formed of decomposed feldspar and mica	0.2+	9.3
	Borehole terminated owing to slow progress; probably in decomposed granitic bedrock		

NO 68 NE 3

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	3	84	13	0.3- 1.5	2	5	25	54	14	0	0
				1.5- 2.5	3	8	29	50	9	1	0
				2.5- 3.8	4	12	38	31	15	0	0
				Mean	3	8	31	45	13	trace	0
b	10	78	12	3.9- 5.0	8	17	31	31	12	1	0
				5.0- 5.3	17	25	21	28	9	0	0 $
				Mean	10	19	29	30	11	1	0
c	6	61	33	9.1- 9.3	6	5	24	32	28	5	0 $
a&b	5	83	12	Mean	5	11	30	42	12	trace	0
a-c	5	81	14	Mean	5	11	30	40	13	1	0

NO 68 NE 4 **6519 8630** **Bridge Wood**

Surface level c+175m
Water not struck
250mm percussion
July 1989

Waste 3.5m
Bedrock 0.6m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil; silty, firm	0.4	0.4
Flow-till	**Diamicton**; silty and sandy; firm, becoming more sandy and friable with depth. Crude subhorizontal lamination and wisps of orange sand. Angular pebbles of granite. Light brown (5YR 5/6)	0.6	1.0
Fluvioglacial sand and gravel	**Clayey gravel** in beds 3-5cm thick, Fine angular gravel clasts, chiefly medium and coarse-grained pink granite. Matrix mainly coarse to fine angular granite, quartz and feldspar sand; some silt and clay binding the deposit. Moderate yellowish brown (10YR 5/4) to light brown (5YR 5/6)	0.5	1.5
Glaciolacustrine deposits	**Clay**; silty, stiff, laminated. Mottled moderate reddish orange (10R 6/6), light brown (5YR 5/6) and yellowish grey (5Y 7/2)	0.2	1.7
Flow-till	**Diamicton**, friable; with a matrix of silty granitic sand. Sparse cobbles of reddish orange granite. Moderate reddish orange (10R 6/6)	0.1	1.8
Glaciolacustrine deposits	**Silt**; firm, finely laminated, interbedded with coarse-grained pebbly granitic sand. Light brown (5YR 6/4)	0.4	2.2
Till	**Diamicton**; clayey, stiff. Angular clasts, chiefly coarse-grained reddish orange, dark grey and pink granite. Moderate reddish brown to moderate reddish orange (10R 4/6-6/6)	1.3	3.5

Caledonian	**Aplogranite**; fresh, fine to medium-grained, saccharoidal texture. Greyish orange pink (5YR 7/2)	0.6+	4.1

NO 68 NE 5 6543 8697 **North East of Smithy Wood**

Surface level c.+142m	Overburden 0.3m
Section and pit	Mineral I 4.9m
Water not struck	Waste 3.3m+
June 1989	

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, sandy	0.3	0.3
Fluvioglacial sand and gravel	**Pebbly sand**; cryoburtated above 0.6m, becoming more silty and sandy with depth *Gravel:* mainly fine, subangular pink granite; some angular felsite and vein-quartz *Sand:* coarse with medium and fine, subangular, quartz and feldspar; some fine mica *Fines:* silt and clay, disseminated; a bed of stiff finely laminated silty clay from 0.6m to 0.9m. Pale yellowish brown (10YR 6/2) to light brown (5YR 5/6)	4.9	5.2
Glaciolacustrine deposits	**Silt and clay**, stiff, waxy, massive; becoming sandy from 6.6m. Mottled, light brown (5YR 5/6) and light olive grey (5Y 6/1)	2.6	7.8
	Clay, sandy and silty, horizontal lamination. Sparse rounded cobbles of granite (dropstones). Light olive grey (5Y 6/1)	0.7+	8.5

NO 68 NE 5

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
9	72	19	0.3- 5.2	9	9	27	36	16	3	0

NO 68 NE 6 **6551 8647** **West of Heathery Wood**

Surface level c.+138m
Water not struck
Pit
June 1989

Overburden 0.6m
Mineral I 1.2m
Waste 0.2m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, silty and sandy	0.1	0.1
Alluvium	**Silt**; sandy, firm, moderate brown (5YR 4/4)	0.5	0.6
	'Clayey' sand *Gravel:* fine, subangular *Sand:* medium and fine, subrounded quartz and mica *Fines:* silt, disseminated, light brown (5YR 5/4); becoming mottled dark yellowish orange (10YR 6/6) and light olive grey (5Y 6/1) below 1.0m depth	1.2	1.8
	Silt, stiff, micaceous, light olive grey (5Y 5/2)	0.1	1.9
	Boulder gravel; well-rounded, clasts of coarse-grained pink granite up to 60cm	0.1+	2.0
	Pit abandoned on large granite 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
16	82	2	0.6- 1.8	16	33	42	7	2	trace	0

NO 68 NE 7 **6513 8865** **East of Tillyfumerie**

Surface level c.+170m
Water not struck
Section and pit
May 1989

Overburden 0.3m
Mineral I 8.8m
Waste 0.8m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, humic, sandy	0.3	0.3
Fluvioglacial sand and gravel	**a Sandy gravel**; crude horizontal stratification *Gravel:* fine and coarse, with some cobble; sparse rounded boulders of coarse-grained pink granite up to 30cm. Well-rounded and tabular clasts of coarse-grained granite with some psammite and quartzite; sparse porphyritic felsite and microgranite *Sand:* mainly coarse and medium, clean, angular quartz and pink feldspar *Fines:* silt, disseminated, moderate yellowish brown (10YR 5/4) to greyish orange (10YR 7/4)	2.2	2.5
	b Gravel, with well-developed tabular cross-stratification; silty at the base *Gravel:* coarse with medium and fine, some cobble; rounded granite, with some psammite and sparse fine-grained gabbro *Sand:* mainly coarse, subangular, granite, quartz and feldspar *Fines:* clay and silt, mainly disseminated; discrete thin beds of clayey silt in basal 0.2m. Light brown (5YR 6/4)	2.4	4.9
	c Gravel, interbedded with sandy silt above 5.9m *Gravel:* cobble, with some coarse and fine, mainly rounded, coarse and medium-grained pink granite *Sand:* mainly coarse and medium,	3.0	7.9

	subangular, granite, quartz and feldspar *Fines:* silt, with fine cross-lamination; light brown (5YR 6/4)		
	d 'Clayey' gravel; prominent cross-stratification *Gravel:* fine, with some coarse and cobble; sparse rounded boulders of porphyritic felsite and pink granite up to 30cm. Mainly subangular to subrounded, coarse-grained pink granite, tabular psammite and porphyritic, felsite *Sand:* coarse with some medium, subangular, granite, quartz and feldspar *Fines:* silt and clay, disseminated, moderate brown (5YR 4/4)	1.2	9.1
Till	**Diamicton**, clayey and sandy, stiff, subangular to subrounded clasts of coarse-grained pink granite and granodiorite; 'flat-iron' clasts of psammite and semipelite and sparse calc-silicate. Moderate brown (5YR 4/4)	0.8+	9.9

NO 68 NE 7

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	48	48	0.3- 2.5	4	5	19	24	24	16	8
b	5	31	64	2.5- 4.9	5	4	13	14	18	37	9
c	2	29	69	4.9- 7.9	2	3	11	15	10	8	51
d	10	31	59	7.9- 9.1	10	2	9	20	35	17	7
a&b	5	38	57	Mean	5	4	16	18	21	28	8
b&c	3	30	67	Mean	3	4	12	14	14	21	32
a-c	3	35	62	Mean	3	4	14	17	17	19	26
a-d	4	34	62	Mean	4	3	13	18	20	19	23

NO 69 SW 1 **6030 9133** **Blackhole**

Surface level c.+118m
Water Struck at c.+116.6m
250 and 200mm percussion
June 1989

Overburden	0.3m
Mineral I	7.1m
Waste	0.8m
Mineral I	8.8m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, sandy and silty	0.3	0.3
Alluvium	**a Sandy gravel** *Gravel:* fine and coarse, subangular to subrounded, mainly granite *Sand:* coarse and medium, angular to subrounded quartz and feldspar; some mica and lithic grains *Fines:* silt, disseminated	2.9	3.2
Fluvioglacial sand and gravel	**b Pebbly sand**, becoming silty below 5.3m *Gravel:* fine, subangular granite and vein-quartz *Sand:* medium and coarse, with some fine, subangular, quartz, feldspar, mica and some lithic grains *Fines:* silt, disseminated, moderate yellowish brown (10YR 5/4)	4.2	7.4
Glaciolacustrine deposits	**Silt**, with thin stringers of gravel, firm, feint lamination and scattered dark carbonaceous specks. Moderate yellowish brown (10YR 5/4) to moderate reddish brown (5YR 4/4)	0.8	8.2
Fluvioglacial sand and gravel	**c Gravel**, with cobbles of megacrystic pink and grey granite up to 20cm, below 10.3m *Gravel:* coarse and fine, subangular, pink and grey granite, aplogranite and some semipelitic gneiss *Sand:* coarse with medium, quartz and feldspar *Fines:* little, disseminated	2.1	10.3
	d Sandy gravel; cobbles towards the top *Gravel:*fine with coarse,	4.6	14.9

subangular to subrounded, medium-grained biotite granite, coarse-grained pink granite, aplite and porphyritic aplogranite
Sand: coarse with medium, subangular, granite, quartz and feldspar
Fines: silt, disseminated, moderate brown to light brown (5YR 4/4-5/6)

e **Gravel**	2.1+	17.0

Gravel: fine with coarse and cobble, subangular to subrounded, medium and coarse-grained granite; sparse aplogranite
Sand: coarse with medium, subangular, granite, quartz and feldspar
Fines: litttle, disseminated, moderate to light brown (5YR 4/4-5/6)

Borehole terminated owing to obstruction, possibly bedrock

NO 69 SW 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	3	67	30	0.3- 1.3	4	7	26	31	17	15	0
				1.3- 3.2	3	5	26	36	19	11	0 $
				Mean	3	6	26	35	18	12	0
b	3	91	6	3.2- 5.3	1	7	51	36	5	0	0 $
				5.3- 7.4	5	15	31	41	8	0	0 $
				Mean	3	11	41	39	6	0	0
c	1	47	52	8.2- 8.9	1	4	13	29	20	33	0 $
				8.9-10.3	1	5	13	30	19	14	18 $
				Mean	1	5	13	29	20	20	12
d	1	64	35	10.3-11.8	2	2	15	39	24	8	10 $
				11.8-13.0	1	2	21	62	8	6	0 $
				13.0-13.5	1	1	9	44	28	17	0 $
				13.5-14.9	0	2	14	40	33	11	0 $
				Mean	1	2	15	47	23	9	3
e	1	49	50	14.9-17.0	1	2	11	36	22	16	12 $
a&b	3	81	16	Mean	3	9	35	37	11	5	0
c&d	1	58	41	Mean	1	3	15	40	22	13	6
c-e	1	55	44	Mean	1	3	14	38	22	14	8
a-e	2	67	31	Mean	2	5	23	39	17	10	4

NO 69 SW 2 | 6018 9242 | **Finzean**

Surface level c.+120m
Water not struck
Section and pit
June 1989

Overburden 0.3m
Mineral II 4.6m
Bedrock 0.7m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, humic clay with large angular clasts	0.3	0.3
Flow-till	**'Clayey'** sandy gravel; very stiff, cryoturbated at the top, traces of cross-stratification below 1.0m depth; passing down into massive sandy diamicton below 2.6m *Gravel:* cobble with fine and coarse; some angular boulders up to 90cm at 2.4m depth. Angular to subrounded, pink granite, felsite, fine-grained amphibolite and porphyritic felsite *Sand:* coarse with medium and fine, angular granite *Fines:* silt and clay, binding deposit. Moderate yellowish brown (10YR 5/4) to 2.6m; light to moderate brown (5YR 5/6-4/4) from 2.6m to 3.8m depth	4.6	4.9
Dalradian	**Semipelitic schist**, decomposed to micaceous, silty clayey sand; iron stain. Moderate olive brown (5Y 4/4)	0.7+	5.6

NO 69 SW 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
16	56	28	0.3- 4.9	16	10	17	29	11	5	12

NO 69 SW 3 6041 9031 **Bogmore Sand Pit**

Surface level c.+184m
Water not struck
Section and pit
June 1989

Overburden 0.1m
Mineral II 5.4m
Bedrock 0.5m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; humic, sandy	0.1	0.1
Caledonian	**Sandy gravel** (granite gruss) *Gravel:* fine with some coarse, angular fragments of coarse-grained, pale pink and white megacrystic granite *Sand:* mainly coarse, angular, granite, quartz and feldspar *Fines:* clay minerals, formed of decomposed feldspar and mica. Several cross-cutting veins of aplite decomposed to grey clay	5.4	5.5
	Granite, hard, fresh, coarse-grained, white and pink granite; patches of decomposed material	0.5+	6.0

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
7	50	43	0.1- 5.5	7	6	14	30	35	8	0

NO 69 SW 4	6056 9124	East of Burn of Curbay

Surface level c.+122m
Water not struck
Section and pit
June 1989

Overburden	0.2m
Mineral I	1.5m
Waste	0.1m
Mineral I	1.6m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; sandy, pebbly and humic	0.2	0.2
Morainic drift	**a Gravel**; poorly sorted, clast-supported, clay-bound at the top *Gravel:* cobble with coarse and fine; some boulders up to 60cm; subrounded to angular, medium and fine-grained pink granite and occasional felsite *Sand:* coarse and medium, in cross-bedded units 0.3m thick; angular, sharp, quartz and feldspar *Fines:* silt and clay, disseminated. Iron stain below 0.4m, dark yellowish orange (10YR 6/6)	1.5	1.7
	Silt, sandy, micaceous, laminated, light brown (5YR 6/4) to pale yellowish brown (10YR 6/2)	0.1	1.8
	b Sandy gravel; poorly stratified to massive below 2.5m *Gravel:* fine and coarse with cobble, boulders up to 90cm; angular, coarse, medium and fine-grained pink granite *Sand:* coarse and medium, angular to subangular quartz, feldspar and granite *Fines:* silt, disseminated, light brown (5YR 5/4)	1.6+	3.4
	Pit abandoned owing to obstruction. Large boulders of felsitic porphyry at bottom of pit		

NO 69 SW 4

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	2	41	57	0.2- 1.7	2	1	18	22	8	11	38
b	4	55	41	1.8- 3.4	4	9	21	25	18	17	6
a&b	3	48	49	Mean	3	5	19	24	13	14	22

NO 69 SW 5 6166 9278 **Boghead**

Surface level c.+113m
Water struck at c.+111.3m
Pit
June 1989

Overburden 0.5m
Mineral I 1.5m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Made ground, silty loam	0.5	0.5
Alluvium	**'Clayey' pebbly sand**, with horizontal stratification *Gravel:* fine, subrounded to subangular, granite, schist and psammite; some vein-quartz and semipelite *Sand:* coarse, with medium and some fine, angular to subangular, quartz and feldspar, with some lithic grains *Fines:* silt and clay, disseminated; light olive grey (5Y 5/2) to light olive brown (5Y 5/5) Pit collapsing below the water table, still in sand and gravel	1.5+	2.0

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
14	71	15	0.5- 2.0	14	11	24	36	13	2	0

NO 69 SW 6	6105 9120	South West of Easter Clune

Surface level c.+124m
Water not struck
Section and pit
June 1989

Overburden	0.3m
Mineral I	4.7m
Waste	1.6m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy and pebbly; scattered granite boulders	0.3	0.3
Glacial sand and gravel (Esker)	**Cobble gravel**; clast-supported, cross-stratification dipping at high angles towards the flanks of the ridge *Gravel:* cobble, coarse and fine, poorly sorted; boulders of granite up to 60cm. Mainly rounded to well-rounded with some subangular; coarse, medium and fine-grained pink, white and red granite, sparse quartzite. A bed of manganese stained gravel below 4.6m *Sand:* coarse with some medium, angular to subangular, quartz, feldspar and granite; mainly clean and sharp *Fines:* silt and clay, disseminated; binding the deposit, especially in the top 1.0m. Greyish orange (10YR 7/4) to 2.2m, yellowish brown (10YR 5/2) towards the base	4.7	5.0
Till	**Diamicton**, clayey, firm, poorly stratified. Abundant angular blocks and subangular boulders of granite. Mottled light brown (5YR 5/6) and pale yellowish brown (10YR 6/2)	1.6+	6.6

NO 69 SW 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
2	31	67	0.3- 2.2	2	1	5	26	14	25	27
			2.2- 4.0	1	2	17	15	15	18	32
			4.0- 5.0	3	1	6	18	15	15	42
			Mean	2	1	10	20	15	20	32

NO 69 SW 7 **6118 9121** **South of Easter Clune**

Surface level c.+118m
Water not struck
Pit
June 1989

Waste 1.5m
?Bedrock 0.1m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; humic, sandy; angular blocks of granite up to 1.0m	0.2	0.2
Morainic drift	**Diamicton**; sandy and silty, unstratified. Abundant angular blocks, boulders and cobbles of coarse-grained granite. Light brown (5YR 5/6)	1.3	1.5
? Caledonian	**Granite**; fresh, angular blocks of coarse-grained, pegmatic grey-pink granite	0.1+	1.6
	Pit abandoned on large angular granite blocks		

NO 69 SW 8 | **6113 9100** | **Wood of Easter Clune**

Surface level c.+125m
Water not struck
Pit
June 1989

Overburden 0.1m
Mineral I 4.5m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, humic	0.1	0.1
Glacial sand and gravel (Esker)	a **Gravel**, clast-supported, becoming more sandy below 1.5m *Gravel:* coarse and cobble, with some fine; some subangular boulders up to 50cm. Mainly subangular; coarse, medium and fine-grained red and pink granite, sparse felsite *Sand:* mainly coarse, subangular to angular, quartz, feldspar and granite *Fines:* silt and iron stain, disseminated, dark yellowish orange (10YR 6/6)	2.0	2.1
	b **Pebbly sand** *Gravel:* fine with some coarse, rounded to subangular, medium and fine-grained red, pink and white granite, some felsite and sparse fine-grained basic rock *Sand:* coarse with medium, subangular quartz and feldspar, with some granite *Fines:* silt, disseminated, light brown (5YR 6/4)	2.5+	4.6
	Pit abandoned, sand and gravel collapsing in from the sides		

NO 69 SW 8

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	37	62	0.1- 2.1	1	1	12	24	14	25	23
b	2	74	24	2.1- 4.6	2	trace	24	50	17	7	0
a&b	1	58	41	Mean	1	1	18	39	16	15	10

NO 69 SW 9 **6210 9184** **East of Ordie**

Surface level c.+103m	Overburden 0.4m
Water struck at c.+100.8m	Mineral I 5.0m
250mm percussion	Waste 0.6m
June 1989	Bedrock 0.4m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, humic and clayey	0.4	0.4
Alluvium	**a Gravel** *Gravel:* coarse with cobble and fine, subrounded to subangular, medium and fine-grained red and pink granite *Sand:* coarse with medium, angular to subangular, quartz and feldspar *Fines:* silt and iron stain, disseminated, binding the top of the deposit, orange brown	1.5	1.9
Fluvioglacial sand and gravel	**b Sandy gravel**; thin beds of cobbles at 2.9m and 3.6m *Gravel:* fine with coarse and cobble, rounded to angular, coarse, medium and fine-grained red and pink granite, with some felsite, grey psammite and vein-quartz; sparse gabbro and semipelite. Abundant fragments of decomposed granite from 4.5m to 4.7m *Sand:* coarse with medium, angular to subangular quartz, some feldspar, lithic grains and hydrolyzed mica *Fines:* silt and clay, disseminated, moderate reddish brown (10YR 4/6) to moderate reddish orange (10R 5/6) above 4.5m; moderate yellowish brown (10YR 5/4); binding deposit from 4.5m to 5.4m	3.5	5.4
? Till	**Diamicton**, with a matrix of silty and clayey granite sand. Angular clasts, mainly of granite; abundant grains of hydrolyzed mica. Dark yellowish brown (10YR 4/2)	0.6	6.0

Caledonian	**Granite**, decomposed to clayey angular granite sand. Mainly pinkish grey (5YR 8/1) to white (N9); becoming moderate yellowish brown (10YR 5/4) with depth	0.4+	6.4

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	3	30	67	0.4- 1.9	3	3	10	17	11	37	19
b	4	60	36	1.9- 2.9	6	6	19	32	18	12	7 $
				2.9- 4.5	4	4	24	39	19	10	0 $
				4.5- 5.4	3	4	15	34	17	2	25 $
				Mean	4	5	20	35	18	9	9
a&b	4	51	45	Mean	4	4	17	30	16	17	12

NO 69 SW 10 6261 9159 South of Ennochie

Surface level c+107m
Water struck at c+104.1m
Section and pit
June 1989

Overburden 0.3m
Mineral II 3.0m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, with angular granite fragments	0.3	0.3
Caledonian	**a Pebbly sand** (granite gruss) *Gravel:* fine angular fragments of coarse-grained granite *Sand:* mainly coarse, angular, granite, quartz and feldspar *Fines:* silt and clay minerals formed of decomposed feldspar and mica. Greyish red (10R 4/2) to moderate brown (5YR 3/4) Pit collapsing below water table	3.0+	3.3

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
5	74	21	0.3- 3.3	5	7	17	50	21	trace	0

NO 69 SW 11 **6250 9107** **Moss of Powlair**

Surface level c+108m
Water struck at c+105.2m
Pit
June 1989

Overburden 0.8m
Mineral I 2.0m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; humic and sandy; scattered angular boulders up to 60cm	0.3	0.3
Morainic drift	**Diamicton**; sandy, poorly developed stratification. Abundant rounded to subangular cobbles and boulders, mainly granite. Moderate yellowish brown to greyish orange (10YR 5/4-7/4)	0.5	0.8
	Sandy gravel; well developed subhorizontal bedding, iron and manganese stained above 1.2m *Gravel:* coarse with fine and cobble, some boulders up to 20cm below 1.9m; rounded to subrounded, medium to coarse-grained white and pink granite, with some psammite, quartzite, vein-quartz; sparse acid volcanic rock and pegmatite *Sand:* coarse with medium, subangular to angular, quartz and some feldspar; clean, sharp *Fines:* iron and manganese staining towards the top. Silt and clay, disseminated, pale yellowish brown (10YR 6/2) below 1.9m depth	2.0+	2.8
	Pit collapsing below the water table, still in sand and gravel		

NO 69 SW 11

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
3	50	47	0.8- 1.9	1	1	19	33	12	20	14
			1.9- 2.8	4	1	16	34	13	17	15
			Mean	3	1	18	31	13	19	15

NO 69 SW 12	6286 9179	South East of Ennochie

Surface level c+98m
Water struck at c+96.3m
Pit
June 1989

Waste 1.9m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, humic	0.3	0.3
Alluvial fan	**Clay**: silty, stiff, sparse boulders; sandy below 0.6m depth. Mottled light olive grey (5Y 6/1) and light brown (5YR 5/6)	0.6	0.9
	Clay; gravelly and silty, horizontally bedded. Rounded to well-rounded clasts, chiefly of medium-grained red granite; some psammite. Olive grey (5Y 3/2) to greyish green (10GY 5/2)	1.0+	1.9
	Pit collapsing below water table; still in gravelly clay alluvial deposit		

NO 69 SW 13 | 6320 9139 | South West of Balblythe

Surface level c+99m	Overburden 0.9m
Water struck at c+96.3m	Mineral I 2.1m
Pit	Waste 0.1m+
June 1989	

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, sandy and humic	0.4	0.4
Alluvial fan	**Silty loam**; sandy and clayey, soft, friable. Moderate yellowish brown (10YR 5/4). Scattered subangular boulders of granite	0.5	0.9
	Sandy gravel, becoming more sandy with depth to 2.5m; subhorizontal stratification marked by iron and manganese pans at 1.1m and 1.3m depth *Gravel:* coarse with cobble and fine, rounded to well-rounded, coarse and medium-grained pink, red and white granite. Abundant rounded boulders up to 20cm *Sand:* mainly coarse, subangular quartz and felspar *Fines:* silt and clay, disseminated, binding top of deposit and as thin beds of silty clay from 2.9m. Light brown (5YR 5/6) to moderate yellowish brown (10YR 5/4) to 2.5m, pale yellowish brown (10YR 6/2) below	2.1	3.0
? Flow-till	**Clay**, sandy, silty, stiff, pale yellowish brown (10YR 6/2)	0.1+	3.1
	Pit collapsing below water table		

NO 69 SW 13

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
5	51	44	0.9- 2.5	4	4	18	25	9	28	12
			2.5- 3.0	11	7	20	35	10	17	0 S
			Mean	5	4	19	28	9	26	9

NO 69 SW 14	6322 9069	West of Cuttie's Wood

Surface level c.+113m
Water not struck
Pit
May 1989

Overburden 0.2m
Mineral I 2.6m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, humic	0.2	0.2
Morainic drift	**Boulder and cobble gravel**, horizontally bedded *Gravel:* cobble with fine and coarse; abundant subangular and well-rounded boulders of coarse-grained pink granite up to 70cm. Mainly rounded to well-rounded granite, occasional felsite *Sand:* mainly coarse, binding clasts, angular to subangular; quartz, feldspar and granite *Fines:* iron stain to 1.2m; silt, disseminated, moderate brown (5YR 4/4) Pit terminated, gravel collapsing in from the sides	2.6+	2.8

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
2	28	70	0.2- 2.8	2	1	7	20	14	15	41

NO 69 SW 15 **6294 9080** **N.W. of Ord of Cuttieshillock**

Surface level c.+112m
Water not struck
Pit
June 1989

Overburden 0.3m
Mineral I 0.6m
Waste 0.4m
Mineral I 1.4m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, sandy	0.3	0.3
Alluvial fan	a **'Clayey' sandy gravel**, becoming less pebbly with depth *Gravel:* fine with coarse, rounded to subangular, mainly medium-grained pink granite, some coarse-grained granite *Sand:* medium and coarse with fine, quartz with feldspar and some granite *Fines:* silt, disseminated, dark yellowish orange (10YR 6/6)	0.6	0.9
	Silt, sandy, firm; pale yellowish brown (10YR 6/2) to light brown (5YR 6/4); passing down into olive grey and light olive grey (5Y 3/2- 5/2) clayey silt with carbonaceous grains. Scattered pebbles and charcoal fragments (? palaeosol) from 1.2m to 1.3m	0.4	1.3
	b **Gravel**, silty, firm; horizontally bedded, in units up to 50cm thick *Gravel:* coarse with cobble and fine, well-rounded to rounded, medium and fine-grained pink granite, with some felsite, semipelite and pegmatite *Sand:* coarse with medium, subangular to angular, mainly quartz and feldspar, some coarse granite *Fines:* silt and clay, disseminated, pale yellowish brown (10YR 6/2) to light olive grey (5Y 6/1). Thin partings of olive grey silt with charcoal grains above 2.1m; beds of varigated light brown (5YR 6/4), strong orange and yellowish grey (5Y 7/2) sandy silt, below 2.3m	1.4+	2.7

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	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
a	10	60	30	0.3- 0.9	10	16	23	21	18	12	0
b	4	43	53	1.3- 2.7	4	3	14	26	15	22	16
a&b	6	48	46	Mean	6	7	16	25	16	19	11

NO 69 SW 16 | 6341 9013 | Ord of Cuttieshillock

Surface level c.+133m
Water not struck
Pit
May 1989

Overburden 0.3m
Mineral I 4.2m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, humic, pebbly	0.3	0.3
Glacial sand and gravel (Esker)	**a Gravel**; clay-bound to 0.7m; cleaner, iron stained, with well-developed low-angle tabular cross-bedding dipping towards the flanks of the ridge from 0.7m to 1.5m *Gravel:* cobble, with some coarse and fine, fines downwards; subrounded, mainly coarse-grained pink granite, with some felsite, felsitic porphyry and psammite, sparse amphibolite *Sand:* mainly coarse, subangular, granite, quartz and feldspar *Fines:* iron stain, moderate brown (5YR 3/4)	1.2	1.5
	b Sandy gravel, becoming more pebbly below 3.9m *Gravel:* fine with coarse and some cobble, subrounded coarse-grained pink granite, sparse grey granite and felsite *Sand:* coarse with medium, subangular feldspar and quartz; clean, sharp *Fines:* silt, little, diesseminated, light brown (5YR 5/6)	3.0+	4.5

Pit terminated, sand and gravel collapsing in from the sides

NO 69 SW 16

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	33	66	0.3- 1.5	1	trace	9	24	9	13	44
b	2	73	25	1.5- 3.9	2	1	30	50	11	6	0
				3.9- 4.5	1	1	15	25	17	21	20
				Mean	2	1	27	45	12	9	4
a&b	1	63	36	Mean	1	1	22	40	11	10	15

NO 69 SW 17 6342 9025 **W. of Ord of Cuttieshillock**

Surface level c.+128m
Water not struck
Pit
May 1989

Waste 1.5m
Bedrock 0.1m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; humic, large subangular boulders of granite	0.3	0.3
Morainic drift	**Diamicton**, clayey and silty, friable. Abundant angular and rounded cobbles and boulders of coarse-grained pink granite, grey granite and felsite, up to 80cm; passing down into clay-bound sandy boulder gravel with fewer cobbles below 1.3m; occasional tabular metamorphic clasts. Greyish orange to moderate yellowish brown (10YR 7/4-5/4)	1.2	1.5
Caledonian	**Granite**, boulders and angular blocks	0.1+	1.6

Digger scraping on interlocking blocks of granite in base of pit

NO 69 SW 18 | **6356 9114** | **South of Balblythe**

Surface level c.+105m	Overburden 0.3m
Water not struck	Mineral I 1.0m
Pit	Waste 0.9m+
May 1989	

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, sandy and humic	0.3	0.3
Morainic drift	**Gravel**; becoming cleaner with depth, well sorted, bedded *Gravel:* coarse and fine, some cobble up to 30cm; subrounded to subangular, coarse and fine-grained pink granite, with some felsite, semipelite and psammite *Sand:* mainly coarse, subangular quartz and feldspar *Fines:* silt, disseminated, moderate brown (5YR 3/4)	1.0	1.3
	Diamicton, passing laterally into boulder gravel; clasts mainly subangular to subrounded boulders of coarse and fine-grained pink granite up to 60cm; some felsite and sparse amphibolite. Matrix of silty, clayey, coarse sand; moderate yellowish brown (10YR 5/4)	0.9+	2.2
	Digger scraping on boulders or bedrock, no sample recovery		

NO 69 SW 18

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
2	42	56	0.3- 1.3	2	1	9	32	21	26	9

NO 69 SW 19 **6372 9185** **Balblythe**

Surface level c+93m
Water struck at c+89.6m
250mm percussion
June 1989

Overburden 0.4m
Mineral I 1.7m
Mineral II 4.0m
Bedrock 0.5m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, loamy	0.4	0.4
Alluvium (Terrace)	**a Gravel** *Gravel:* coarse and fine, with some cobble, mainly granite, psammite and semipelite *Sand:* mainly coarse, subangular quartz and feldspar *Fines:* silt, disseminated and as parting of silty clay at 1.7m depth; moderate brown (5YR 4/4)	1.7	2.1
Flow-till	**b 'Clayey' pebbly sand**, with a bed of silty sand from 3.0m to 3.5m *Gravel:* fine, subrounded, mainly decomposed granite *Sand:* medium and coarse, with fine, angular granite, quartz and feldspar *Fines:* silt and clay, binding deposit, greyish orange pink (5YR 7/2)	4.0	6.1
Caledonian	**Granite**, decomposed to coarse angular sand; partly kaolinised below 6.3m	0.2	6.3
	Granite, fresh, pale pink and grey mesogranite	0.3+	6.6

NO 69 SW 19

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	45	51	0.4- 2.1	4	3	12	30	18	25	8	
b	13	80	7	2.1- 3.5	12	17	29	34	8	0	0	$
				3.5- 6.1	14	17	33	30	6	0	0	$
				Mean	13	17	32	31	7	trace	0	
a&b	11	68	21	Mean	11	13	26	29	10	8	3	

NO 69 SW 20	6349 9209	Little Ennochie

Surface level c.+96m
Water struck at c.+92.9m
250mm percussion
June 1989

Overburden	0.3m
Mineral I	3.4m
Waste	1.2m
Mineral I	1.5m
Waste	1.1m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, pebbly and sandy	0.3	0.3
Alluvium (Terrace)	**a Sandy gravel**; more pebbly below 2.0m *Gravel:* coarse with cobble and fine, well-rounded to subangular, medium and coarse-grained red and pink granite, sparse psammite, semipelite and gneiss *Sand:* coarse and medium, angular to subangular, quartz and feldspar, some granite *Fines:* silt, disseminated, light brown (5YR 5/6) to moderate yellowish brown (10YR 5/4)	3.4	3.7
Flow-till	**Diamicton**, silty and sandy; angular clasts of porphyritic red granite, psammite and felsite. Light brown (5YR 5/6) to moderate yellowish brown (10YR 5/4)	1.2	4.9
Fluvioglacial sand and gravel	**b Sandy gravel**; less pebbly below 5.4m *Gravel:* fine with coarse, angular medium-grained pink and red granite, psammite, psammitic grit and felsite; some semipelite, vein-quartz, gabbro and fine-grained basic rock *Sand:* coarse with medium, angular to subangular, sharp, quartz, with some feldspar and granite *Fines:* silt and clay, disseminated, pale yellowish brown (10YR 6/2)	1.5	6.4
? Till	**Silty clay**, firm. Scattered angular clasts of granite, felsite and fine-grained basic rock. Moderate yellowish brown (10YR 5/4)	1.1+	7.5

Borehole terminated, owing to slow progress

Grading

	Mean for Deposit percentages			Depth below surface (m)	percentages						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
				from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
a	2	50	48	0.3- 2.4	2	3	26	22	11	18	18
				2.4- 3.7	2	2	17	27	12	23	17 $
				Mean	2	3	22	25	11	20	17
b	6	70	24	4.9- 6.1	6	5	22	42	14	11	0 $
				6.1- 6.4	6	7	27	40	18	2	0 $
				Mean	6	5	23	42	15	9	0
a&b	3	56	41	Mean	3	4	22	30	12	17	12

NO 69 SW 21 | **6480 9149** | **West of Dalbreck**

Surface level c+89m	Overburden	0.3m
Water struck at c+87.2m	Mineral I	4.2m
250mm percussion	Waste	0.5m
June 1989	Mineral I	3.9m
	Waste	0.3m
	Bedrock	0.6m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, loam with granite cobbles	0.3	0.3
Alluvium (Terrace)	**a Sandy gravel**, in two fining-downwards cycles; a layer of boulders at 3.0m *Gravel:* coarse with fine and some cobble, pink and grey granite, with some hornblende schist, marble, aplogranite and psammite *Sand:* mainly coarse, quartz, feldspar and granite *Fines:* silt, disseminated, light brown (5YR 5/6)	4.2	4.5
? Till	**Clay**, silty; with fine angular clasts. Greyish orange pink (5YR 7/2)	0.5	5.0
Fluvioglacial sand and gravel	**b Sandy gravel**, with a bed of sandy clay from 8.5m to 8.7m *Gravel:* fine, with coarse and some cobble, subrounded; mainly coarse-grained megacrystic pink granite, some porphyritic aplogranite; angular clasts of lamprophyre from 5.0m to 6.7m *Sand:* coarse with medium, quartz and feldspar *Fines:* silt and clay, with some mica, mainly disseminated; several thin beds of silty clay from 5.0m to 5.4m. Light brown (5YR 5/6)	3.9	8.9
Till	**Clay**, gritty, moderate brown (5YR 4/4)	0.3	9.2
Caledonian	**Granite**, decomposed	0.5	9.7
	Granite, megacrystic, fresh	0.1+	9.8

NO 69 SW 21

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	2	51	47	0.3- 1.2	4	4	15	23	14	24	16	
				1.2- 1.8	2	3	20	37	15	23	0	
				1.8- 3.9	0	3	16	28	19	20	14	$
				3.9- 4.5	7	9	18	37	20	9	0	$
				Mean	2	4	17	30	17	20	10	
b	6	65	29	5.0- 6.7	6	8	19	34	16	9	8	$
				6.7- 7.7	5	7	26	32	18	12	0	$
				7.7- 8.9	6	9	28	38	16	3	0	$
				Mean	6	8	23	34	17	8	4	
a&b	4	58	38	Mean	4	6	20	32	17	14	7	

NO 69 SW 22 6488 9074 N.E. of Woodside Cottage

Surface level c.+92m
Water not struck
Pit
May 1989

Waste 1.0m
Bedrock 0.2m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil; silty, humic	0.3	0.3
Till	**Diamicton**: sandy; firm in top 0.3m, friable below. Rounded to subangular clasts, chiefly cobbles of medium and fine-grained granite, some psammite. Iron stained, becoming pale yellowish brown (10YR 6/2) with depth	0.8	1.1
Caledonian	**Granite**, decomposed. Angular fragments of medium-grained pale pink granite in a matrix of light brown (5YR 6/4) to moderate orange pink (5YR 8/4) clayey gruss	0.2+	1.3

NO 69 SW 23 | 6488 9259 | North of Waulkmill

Surface level c.+102m
Water not struck
Pit
May 1989

Overburden 0.1m
Mineral I 1.4m
Waste 1.1m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, with abundant boulders	0.1	0.1
Glacial sand and gravel (Esker)	**Cobble gravel**; imbricated, clast-supported; abundant subangular boulders of banded psammite and psammitic gneiss up to 1.2m *Gravel:* coarse and cobble with fine, subangular, banded psammite, gneiss, medium-grained aplogranite and porphyry; some felsite and pink granite *Sand:* coarse with medium, dirty, angular to subangular, quartz, feldspar and pelite *Fines:* silt, disseminated, binding deposit, moderate yellowish brown (10YR 5/4). Iron pan in the top 1.0m	1.4	1.5
Till	**Diamicton**, clayey and sandy, stiff. Subangular and subrounded clasts of metabasic rock, psammite, felsite and semipelite. Light brown (5YR 6/4)	1.1+	2.6

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
3	23	74	0.1- 1.5	3	2	9	12	15	30	29

NO 69 SW 24 6453 9270 **Waulkmill**

Surface level c.+108m
Water not struck
Section and pit
May 1989

Overburden 0.1m
Mineral I 4.5m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, sandy and pebbly	0.1	0.1
Glacial sand and gravel (Esker)	**a 'Clayey' gravel**, cut by a channel 1.0m deep, filled with coarse sand *Gravel:* coarse with fine and cobble, clast-supported, rounded to well-rounded, banded psammite, porphyry, felsite and semipelite, sparse pink granite *Sand:* coarse and medium, angular, quartz, feldspar and metamorphic rock *Fines:* clay and silt, binding the top 1.5m. Moderate yellowish brown (10YR 5/4)	2.3	2.4
	b Gravel; imbricated, open-work *Gravel:* coarse with fine and cobble, rounded, psammite, with felsite; granite and schist *Sand:* coarse with medium, angular, quartz, feldspar and metamorphic rock *Fines:* silt, disseminated, pale brown (5YR 5/2)	2.2+	4.6
	Pit terminated, gravel collapsing in from the sides		

NO 69 SW 24

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	17	17	66	0.1- 2.4	17	2	7	8	17	33	16
b	2	24	74	2.4- 4.6	2	2	9	13	20	40	14
a&b	10	20	70	Mean	10	2	8	10	18	37	15

NO 69 SW 25 **6436 9287** **North of Feughside Inn**

Surface level c.+117m
Water not struck
Section and pit
May 1989

Overburden 0.4m
Mineral I 3.2m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, sandy, pebbly	0.4	0.4
Glacial sand and gravel (Esker)	**Gravel**, interbedded with lenses of pebbly sand up to 0.3m thick, to 1.9m depth *Gravel:* coarse and cobble, with fine, well-rounded to subangular, psammite, psammitic grit and felsite; some fine and medium-grained pink granite, granodiorite and decomposed semipelitic schist *Sand:* coarse and medium, subangular, quartz, feldspar and metamorphic rock *Fines:* silt and clay, disseminated, binding top 1.0m. Moderate yellowish brown (10YR 5/4) to 1.9m, dark yellowish brown (10YR 4/3) towards the base Digger scraping on large boulders at the base of the pit	3.2+	3.6

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
2	26	72	0.4- 1.9	1	1	6	9	13	34	36
			1.9- 3.6	2	2	15	16	13	34	18
			Mean	2	2	11	13	13	33	26

NO 69 SW 26	6405 9246	West of Feughside Inn

Surface level c+93m
Water not struck
250mm percussion
June 1989

Overburden 0.4m
Mineral I 1.5m
Waste 2.3m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, pebbly and silty	0.4	0.4
Alluvium (Terrace)	**'Clayey' sandy gravel** *Gravel:* fine and coarse, some large cobbles (not sampled), subangular, psammitic grit, calc-silicate and hornblende schist, sparse granite *Sand:* coarse and medium, quartz and feldspar *Fines:* silt and clay, disseminated, moderate brown (5YR 4/4)	1.5	1.9
Till	**Diamicton**, sandy, stiff. Angular to subangular clasts of psammite, semipelite, hornblende schist and some red granite. Moderate yellowish brown (10YR 5/4)	2.3+	4.2
	Borehole abandoned owing to slow progress		

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
19	58	23	0.4- 1.9	19	12	23	23	15	8	0

NO 69 SW 27 **6368 9308** **East Tillygarmond**

Surface level c+116m
Water not struck
Section and pit
June 1989

Overburden 0.1m
Mineral I 2.6m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, with abundant boulders	0.1	0.1
Glacial sand and gravel (Esker)	**Boulder gravel**; poorly sorted, clast-supported, becoming more sandy below 1.5m *Gravel:* coarse with cobble and some fine, rounded to angular; psammite, semipelite, semipelitic gneiss, decomposed semipelitic schist; some pink microgranite and felsitic porphyry *Sand:* medium, with coarse, and fine, subangular quartz and lithic grains *Fines:* silt and clay, disseminated; moderate yellowish brown (10YR 5/4)	2.6+	2.7

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
5	26	69	0.1- 2.7	5	6	13	7	8	41	20

NO 69 SE 1 **6576 9224** **Castlehill**

Surface level c.+86m
Water struck at c.+83.7m
Pit
June 1989

Overburden 0.3m
Mineral I 2.3m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, pebbly	0.3	0.3
Fluvioglacial sand and gravel	**Gravel**; well-developed horizontal stratification *Gravel:* coarse with cobble and fine, rounded to well-rounded, medium and fine-grained pink and white granite, some psammite, felsite, quartzite and semipelite *Sand:* mainly coarse, angular to subangular, quartz and feldspar *Fines:* silt and clay, disseminated, light brown (5YR 5/6)	2.3+	2.6
	Pit abandoned, in sand and gravel below the water table		

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	42	57	0.3- 1.7	2	3	14	26	14	28	13
			1.7- 2.6	0	1	13	28	17	29	12
			Mean	1	2	14	26	15	30	12

NO 69 SE 2 **6523 9133** **S.S.W. of Dalbreck**

Surface level c.+86m
Water struck at c.+83.9m
250 and 200mm percussion
May 1989

Overburden	0.2m
Mineral I	6.4m
Waste	1.7m
Mineral I	1.8m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; silty, humic	0.2	0.2
Alluvium (Terrace)	**a Gravel** *Gravel:* coarse and fine, rounded to subrounded, coarse-grained red granite; some psammite, hornblende schist and semipelite *Sand:* coarse and medium, subangular and subrounded, quartz and feldspar *Fines:* silt and clay, disseminated, moderate brown (5YR 4/4)	1.8	2.0
Fluvioglacial sand and gravel	**b Pebbly sand** *Gravel:* mainly fine, subangular, granite and metamorphic rocks *Sand:* coarse and medium, subangular, quartz and feldspar; some fine mica *Fines:* silt, disseminated, moderate to light brown (5YR 4/4-5/6)	4.6	6.6
Glaciolacustrine deposits	**Clay**, silty, finely laminated. Dark yellowish brown (10YR 4/2); light brown (5YR 5/6) and light grey (5Y 5/2) layers	0.2	6.8
	Silty sand; interbedded with silty clay; moderate brown (5YR 4/4)	0.4	7.2
	Clay, silty, interlaminated with thin stringers of sand and fine gravel. Light brown (5YR 5/6) and light olive grey (5Y 5/2)	0.8	8.0
	Pebbly sand, with some cobbles of granite and metamorphic rocks	0.2	8.2
	Clay, silty, laminated, light brown (5YR 5/6)	0.1	8.3

Fluvioglacial sand and gravel	c **Gravel**, becoming cleaner with depth *Gravel:* fine with coarse, subangular; mainly medium-grained red granite *Sand:* coarse and medium, subangular granite, quartz and feldspar *Fines:* silt and clay, disseminated and as thin laminated partings; especially above 8.5m Borehole terminated owing to obstruction	1.8+	10.1

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	44	52	0.2- 1.5	4	4	20	24	27	21	0
				1.5- 2.0	3	3	14	19	18	43	0
				Mean	4	3	18	23	25	27	0
b	4	86	10	2.0- 4.0	4	9	45	35	6	1	0 S
				4.0- 6.6	4	7	27	49	13	0	0 S
				Mean	4	8	35	43	10	trace	0
c	5	44	51	8.3- 8.5	14	9	23	24	26	4	0 S
				8.5-10.1	4	7	16	19	22	17	15 S
				Mean	5	7	17	20	21	16	14
a&b	4	74	22	Mean	4	6	30	38	14	8	0
a-c	4	67	29	Mean	4	7	27	33	16	10	3

NO 69 SE 3	6514 9169	Dalbreck

Surface level c+85m
Water struck at c+81.9m
Pit
May 1989

Overburden 0.3m
Mineral I 2.0m
Waste 0.8m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, sandy	0.3	0.3
Alluvium (Terrace)	**Gravel**, with crude bedding; rounded granite boulders up to 30cm *Gravel:* coarse with fine and cobble, rounded to subrounded; mainly coarse-grained pink granite, some felsite and granodiorite *Sand:* medium and coarse, angular granite, subangular quartz and feldspar *Fines:* silt, disseminated; iron stain from 0.3 to 0.7m. Orange brown	2.0	2.3
Till	**Diamicton**, clayey and sandy, stiff. Angular to subrounded clasts of semipelite, coarse-grained pink granite, fine-grained basic rock and red granite. Damp below 2.6m. Light grey (5Y 5/2) to light olive brown (5Y 5/6)	0.8+	3.1
	Pit terminated at water table		

NO 69 SE 3

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
7	40	53	0.3- 2.3	7	4	14	22	13	27	13

NO 69 SE 4 | 6514 9070 | South West of Pitdelphin Farm

Surface level c.+102m
Water not struck
Pit
May 1989

Overburden 0.3m
Mineral I 1.2m
Waste 0.6m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, sandy and pebbly	0.3	0.3
Fluvioglacial sand and gravel	**Gravel**; crude horizontal stratification, iron pan from 0.3m to 0.5m *Gravel:* coarse, with fine, some cobbles up to 30cm; rounded to subrounded, coarse-grained pink granite and some medium-grained granodiorite *Sand:* medium and coarse, subangular, granite, quartz and feldspar *Fines:* iron stain, disseminated, orange brown	1.2	1.5
Till	**Diamicton**, clayey and sandy, stiff. Abundant cobbles and boulders of medium and fine-grained pink granite in a matrix of clay-bound granite sand. Pale yellowish brown (10YR 6/2)	0.6+	2.1

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
3	48	49	0.3- 1.5	3	3	23	22	15	21	13

NO 69 SE 5 **6553 9098** **Pitdelphin Farm**

Surface level c.+105m
Water not struck
250 and 200mm percussion
May 1989

Overburden 0.1m
Mineral I 10.3m
Waste 0.2m
Mineral I 1.9m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, sandy	0.1	0.1
Fluvioglacial sand and gravel	**a Gravel**, with cobbles up to 30cm *Gravel:* cobble, fine and coarse, subrounded to subangular, coarse-grained granite, psammite, amphibolite and semipelite *Sand:* coarse with some medium, subrounded, quartz and feldspar *Fines:* clay, disseminated, moderate brown (5YR 4/5)	1.2	1.3
	b Sandy gravel, interbedded with laminated silt at the top *Gravel:* fine, with coarse and cobble, rounded to tabular, coarse-grained red granite *Sand:* medium with coarse and some fine, subangular quartz, feldspar and mica *Fines:* silt, mainly disseminated, light brown (5YR 5/6)	1.5	2.8
	c Gravel *Gravel:* mainly coarse and fine, some cobble below 3.2m, rounded, red porphyritic granite, aplogranite and grey granite *Sand:* coarse with medium, angular to subrounded, quartz and feldspar *Fines:* silt, disseminated, moderate brown (5YR 4/4)	1.2	4.0
	d Sandy gravel; some cobbles up to 8cm *Gravel:* coarse and fine, rounded to subangular coarse-grained pink and red granite, porphyritic aplogranite and microgranite *Sand:* medium and coarse, angular, granite, quartz and feldspar *Fines:* silt and mica, disseminated, light brown (5YR 5/6)	6.4	10.4

Silty sand, laminated, light olive grey (10Y 6/2)	0.2	10.6
e Sandy gravel *Gravel:* mainly fine, rounded, red granite *Sand:* medium and coarse, with some fine, subrounded quartz, with some feldspar *Fines:* silt and mica, disseminated, moderate yellowish brown (10YR 5/4)	1.9+	12.5

Borehole terminated owing to slow progress.

Grading

	Mean for Deposit percentages			Depth below surface (m)	percentages						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
				from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
a	5	45	50	0.1- 1.3	5	1	15	29	17	16	17
b	5	56	39	1.3- 2.8	5	8	29	19	15	12	12
c	2	35	63	2.8- 3.2	2	3	18	19	25	33	0
				3.2- 4.0	2	1	10	22	19	32	14
				Mean	2	2	12	21	21	33	9
d	3	67	30	4.0- 5.0	2	4	25	33	12	16	8
				5.0- 6.2	5	5	28	26	13	16	7
				6.2- 7.6	3	6	51	22	7	11	0
				7.6- 9.0	3	4	31	28	10	6	18
				9.0-10.4	3	4	23	43	13	14	0
				Mean	3	4	32	31	11	12	7
e	4	63	33	10.6-12.5	4	11	28	24	24	9	0
a&b	5	50	45	Mean	5	5	23	22	16	14	15
a-c	4	47	49	Mean	4	4	20	23	17	19	13
a-d	4	59	37	Mean	4	4	28	27	13	15	9
a-e	4	59	37	Mean	4	5	27	27	15	14	8

NO 69 SE 6 6549 9152 North of Pitdelphin Farm

Surface level c.+89m
Water not struck
Section and pit
May 1989

Overburden 0.2m
Mineral I 8.2m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy and pebbly	0.2	0.2
Glacial sand and gravel (Esker)	**a Gravel**; poorly stratified units 30cm thick, dipping off flanks of ridge. A bed of subrounded boulders of granodiorite from 3.0m to 3.2m *Gravel:* cobble and coarse with some fine, subrounded to subangular, semipelite, psammite, calc-silicate, felsitic porphyry, quartzite and purple lava; sparse bleached medium-grained granite *Sand:* medium and coarse, angular, quartz, with some feldspar *Fines:* silt and clay, disseminated, concentrated in sandy units. Manganese staining from 0.4m to 0.6m. Moderate brown (5YR 4/4), becoming dusky yellow (5Y 6/4) below 3.0m	5.0	5.2
	b Pebbly sand; crude horizontal stratification *Gravel:* mainly fine, subangular to tabular, semipelite, psammite and quartzite *Sand:* coarse with medium, angular quartz, with some feldspar *Fines:* silt, disseminated, moderate to dark yellowish brown (10YR 5/4-4/2)	3.2+	8.4

Pit terminated, sand and gravel collapsing in from the sides

NO 69 SE 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	1	36	63	0.2- 3.0	2	2	20	18	10	24	24
				3.0- 5.2	1	2	14	14	12	21	36
				Mean	1	2	18	16	11	23	29
b	2	77	21	5.2- 8.4	2	4	25	48	17	4	0
a&b	2	51	47	Mean	2	3	21	27	13	16	18

NO 69 SE 7 **6585 9154** **North East of Pitdelphin Farm**

Surface level c.+85m
Water not struck
Section and pit
June 1989

Overburden 0.4m
Mineral I 4.2m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy	0.4	0.4
Glacial sand and gravel (Esker)	a **'Clayey' pebbly sand**, in trough cross-bedded units 50cm thick, a granite boulder near the base *Gravel:* fine, angular, metamorphic rocks *Sand:* fine and medium with some coarse, angular, quartz, feldspar and granite *Fines:* silt and clay, as finely laminated partings dipping off flanks of ridge; light brown (5YR 5/5)	2.7	3.1
	b **Gravel**, with tabular cross-bedding, dipping at high angles of flanks of ridge *Gravel:* cobble and coarse, with some fine, rounded to well-rounded, semipelite, semipelitic gneiss, psammite and quartzite; sparse pink and white granite, vein-quartz and gabbro; some angular boulders of felsite and semipelite *Sand:* coarse and medium, angular, sharp; lithic grains and quartz, some feldspar *Fines:* silt and clay, disseminated, moderate brown (5YR 4/4); iron stained below 4.4m	1.5+	4.6
	Pit terminated, sand and gravel collapsing in from the sides		

NO 69 SE 7

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	13	82	5	0.4- 3.1	13	33	33	16	5	trace	0
b	3	28	69	3.1- 4.6	3	5	11	12	11	28	30
a&b	9	63	28	Mean	9	23	26	14	7	10	11

NO 69 SE 8 | 6605 9047 | North East of Bogarn

Surface level c.+112m
Water struck at c.+97.7m
250 and 200mm percussion
June 1989

Overburden 0.2m
Mineral I 14.1m
Waste 4.5m
Mineral I 0.8m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, with abundant boulders	0.2	0.2
Fluvioglacial sand and gravel (Topset beds)	**a Cobble gravel** (unrepresentative grading owing to comminution by drilling) *Gravel:* cobble, coarse and fine, subangular to rounded, mainly coarse-grained pink granite, some felsite, red granite and granodiorite *Sand:* coarse and medium, angular to subangular, granite, quartz and feldspar *Fines:* silt and clay, disseminated, binding deposit to 3.4m; light brown (5YR 3/4). A thin diamicton between 3.0m and 3.1m	4.9	5.1
(Foreset beds)	**b Sandy gravel**, in several fining-downwards units; abundant cobbles of coarse-grained dark pink granite from 8.0m to 10.1m *Gravel:* fine with coarse and cobble, angular to subangular, coarse-grained pink granite, with some fine-grained red granite, psammite and semipelite; sparse vein-quartz and purple volcanic rock *Sand:* coarse and medium, angular to subangular, clean, sharp, mainly quartz and feldspar, some coarse granite *Fines:* silt, disseminated, light brown (5YR 5/4). A thin bed of diamicton containing granite clasts at 12.3m depth	8.1	13.2
(Bottomset beds)	**c 'Very clayey' pebbly sand** *Gravel:* fine, angular, mainly granite *Sand:* mainly fine, with some medium and coarse, subangular to subrounded, quartz and mica	1.1	14.3

	Fines: silt and clay, as finely laminated discontinuous beds 5cm thick from 13.7m to 13.9m, light brown (5YR 5/4)		
Glaciolactustrine deposits	**Silt**, sandy; becoming clayey, stiff below 16.0m. Finely laminated and graded (?varved) from 16.0m to 16.5m. Dark grey layers 50mm thick (possibly organic) from 18.0m to 18.3m. Moderate yellowish brown (10YR 5/4) with some light brown (5YR 5/6) laminae	4.5	18.8
Glacial sand and gravel	**d Sandy gravel**; interbedded with diamicton in top 0.3m *Gravel:* fine with coarse and cobble, angular, dark pink megocrystic granite, medium and fine-grained pale pink and red granite, some amphibolite, vein-quartz, felsite, and granodiorite *Sand:* mainly coarse angular granite, some medium quartz and feldspar *Fines:* silt, disseminated, moderate yellowish brown (10YR 5/4) Borehole terminated on obstruction, probably on large boulders	0.8+	19.6

NO 69 SE 8

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	7	44	49	0.2- 1.9	7	7	13	16	15	18	24
				1.9- 3.4	12	10	20	25	14	15	4
				3.4- 5.1	1	3	15	24	21	22	14
				Mean	7	6	16	22	17	18	14
b	2	67	31	5.1- 7.2	1	8	27	36	22	6	0
				7.2-10.1	1	5	23	28	15	5	23
				10.1-13.2	4	15	29	28	19	5	0
				Mean	2	9	26	32	18	5	8
c	32	60	8	13.2-14.3	32	37	12	11	7	1	0
d	2	49	49	18.8-19.6	2	4	13	32	24	13	12
a&b	4	58	38	Mean	4	8	22	28	18	10	10
a-c	6	58	36	Mean	6	10	22	26	17	9	10
a-d	6	57	37	Mean	6	10	21	26	17	10	10

NO 69 SE 9	6608 9211	North of Haugh of Strachan

Surface level c.+84m
Water not struck
Section and pit
May 1989

Overburden	0.2m
Mineral I	1.1m
Waste	0.2m
Mineral I	1.4m
Waste	0.3m
Mineral I	2.1m

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, pebbly	0.2	0.2
Glacial sand and gravel (Esker bead)	**a Gravel**, clast-supported, crude horizontal bedding *Gravel:* cobble with coarse and some fine, well-rounded to subangular; coarse-grained pink granite, some banded psammite, porphyry, felsite and aplite *Sand:* coarse, angular granite, quartz and feldspar *Fines:* little, silt, disseminated, moderate brown (5YR 4/4)	1.1	1.3
	Silt, sandy, firm, with fine horizontal lamination; moderate yellowish brown (10YR 5/4)	0.2	1.5
	b Sandy gravel, interbedded with thin beds of laminated sandy silt in the top 0.3m *Gravel:* cobble with fine and some coarse, subangular and subrounded; mainly medium and fine-grained pink and grey granite *Sand:* medium with some coarse, clean, subangular; quartz and feldspar, some granite *Fines:* silt, disseminated and as discrete beds up to 20mm thick; light brown (5YR 6/4)	1.4	2.9
	Silt, sandy, laminated, micaceous. Moderate yellowish brown (10YR 5/4)	0.3	3.2
	c Sandy gravel, in low-angle, tabular cross-bedded units between 30mm and 50mm thick; passing laterally into silty fine and medium-grained sand between 4.0m and 5.0m. A bed of manganese stained gravel at 5.0m	2.1+	5.3

Gravel: mainly fine, medium-grained pink granite, microgranite and sparse psammite
Sand: medium and coarse, subangular to subrounded, quartz, feldspar and mica; clean, soft
Fines: silt and clay, disseminated within sand units and as partings along cosets; moderate yellowish brown (10YR 5/4)

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	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
a	trace	19	81	0.2- 1.3	trace	trace	3	16	10	25	46
b	6	66	28	1.5- 2.9	6	5	40	21	9	5	14
c	5	71	24	3.2- 5.3	5	12	31	28	18	6	0
a&b	4	46	50	Mean	4	3	24	19	10	14	26
a-c	4	58	38	Mean	4	7	28	23	13	10	15

NO 69 SE 10	6633 9187	Haugh of Strachan

Surface level c+76m
Water struck at c+74.7m
250 and 200mm percussion
May 1989

Overburden	0.3m
Mineral I	4.0m
Waste	1.2m
Mineral I	4.8m
Waste	0.1m
Mineral I	5.2m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, silty	0.3	0.3
Alluvium	**a Gravel**, with subrounded cobbles of megacrystic granite up to 30cm *Gravel:* coarse with fine and cobble, rounded, granite *Sand:* mainly coarse, rounded, quartz with some feldspar *Fines:* silt and iron stain, disseminated, moderate to greyish brown (5YR 3/4-3/2)	1.0	1.3
Fluvioglacial sand and gravel	**b Sandy gravel**, becoming more sandy with depth *Gravel:* mainly fine, rounded, granite, with some psammite and hornblende schist *Sand:* coarse with medium, rounded to subrounded, quartz and feldspar *Fines:* silt and mica, disseminated, light to moderate brown (5YR 5/6-4/4)	3.0	4.3
Glaciolacustrine deposits	Clay, firm, feintly laminated, dark organic fragments; becoming sandy towards the base. Medium light grey (N6) to light brown (5YR 5/6)	1.2	5.5
Fluvioglacial sand and gravel	**c Pebbly sand** *Gravel:* fine, mainly granite *Sand:* coarse and medium, quartz and feldspar *Fines:* silt, light brown (5YR 5/6)	4.8	10.3
	Silt and sand, light brown (5YR 6/4)	0.1	10.4
	d Pebbly sand *Gravel:* mainly fine, felsite and coarse-grained pink granite *Sand:* coarse and medium, quartz,	5.2+	15.6

feldspar and some mica
Fines: silt, disseminated, light brown (5YR 5/4)

Borehole terminated on obstruction

Grading

	Mean for Deposit percentages: Fines	Sand	Gravel	Depth below surface (m): from to	percentages: Fines -1/16	Sand +1/16-1/4	+1/4-1	+1-4	Gravel +4-16	+16-64	+64 mm
a	2	35	63	0.3- 1.3	2	4	11	20	18	33	12
b	3	63	34	1.3- 3.1	3	4	17	31	31	14	0 $
				3.1- 3.5	2	2	27	43	24	2	0 $
				3.5- 4.3	6	16	35	33	10	0	0 $
				Mean	3	7	23	33	25	9	0
c	2	80	18	5.5- 6.7	4	15	34	33	14	0	0 $
				6.7- 9.6	1	7	30	41	20	1	0 $
				9.6-10.3	5	12	36	32	15	0	0 $
				Mean	2	9	32	39	18	trace	0
d	3	74	23	10.4-12.0	3	4	22	49	22	0	0 $
				12.0-14.2	3	9	30	33	23	2	0 $
				14.2-15.6	3	14	35	29	16	3	0 $
				Mean	3	9	29	36	21	2	0
a&b	3	56	41	Mean	3	6	20	30	23	15	3
a-c	3	69	28	Mean	3	8	26	35	20	7	1
a-d	3	70	27	Mean	3	8	27	35	21	5	1

NO 69 SE 11 **6690 9162** **Templeton**

Surface level c+87m
Water struck at c+81.2m
Section and Pit
June 1989

Overburden 0.4m
Mineral I 4.0m
Waste 2.0m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, pebbly	0.4	0.4
Glacial sand and gravel (Esker)	**a Gravel**, clast-supported, well-sorted, fining-downwards *Gravel:* fine and coarse with scattered cobbles, well-rounded, medium and coarse-grained, pink and white granite; some psammite, semipelite and felsite *Sand:* mainly coarse, subangular quartz, granite, felsite and feldspar *Fines:* iron and manganese staining; cementing top 1.0m	1.6	2.0
	b Sandy gravel, unstratified, very poorly sorted *Gravel:* fine and coarse with some cobble, rounded to subangular, granite, psammite, semipelitic gneiss and felsite; some decomposed granodiorite *Sand:* coarse and medium, clean, sharp, subangular feldspar and quartz *Fines:* little, silt, disseminated, light brown (5YR 5/6)	1.4	3.4
	c Gravel, with abundant cobbles; subhorizontal stratification *Gravel:* coarse and fine, mainly rounded, granite, psammite, semipelite and felsite *Sand:* mainly coarse, subangular, feldspar and quartz *Fines:* little, disseminated	1.0	4.4
Till	**Diamicton**, silty and sandy, very stiff, faint lamination. Subrounded and subangular clasts, mainly of coarse-grained pink granite; some pegmatite, felsite and psammite	2.0+	6.4

Pit terminated in till, below the water table

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	45	54	0.4- 2.0	1	1	10	34	26	21	7
b	1	61	38	2.0- 3.4	1	3	25	33	16	13	9
c	trace	39	61	3.4- 4.4	trace	1	12	26	21	32	8
a&b	1	53	46	Mean	1	2	17	34	21	17	8
a-c	1	49	50	Mean	1	2	16	31	21	21	8

NO 69 SE 12 | 6782 9180 | Burn of Rhoda Gravel Pit

Surface level c.+89m
Water struck at c.+82.3m
Section and pit
May 1989

Overburden 0.2m
Mineral I 5.6m
Waste 1.0m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly	0.2	0.2
Glacial sand and gravel (Esker)	**a Gravel**; cryoturbated in top 0.5m *Gravel:* cobble and coarse with some fine, rounded; mainly granite, some felsite, gabbro and quartzite *Sand:* mainly coarse, angular to subangular, lithic grains, quartz and feldspar *Fines:* silt, disseminated, binding top of deposit; moderate brown (5YR 4/4)	1.7	1.9
	b Sandy gravel, with scattered cobbles, well-bedded *Gravel:* mainly fine, granite, felsite, gabbro and quartzite *Sand:* mainly coarse, subangular quartz and feldspar *Fines:* silt, disseminated, moderate brown (5YR 4/4)	3.9	5.8
Till	**Diamicton**, silty and clayey, stiff. Boulders of psammite and coarse-grained pink and grey granite. Pale yellowish brown (10YR 6/2)	1.0+	6.8
	Pit terminated in till, below the water table		

NO 69 SE 12

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	17	82	0.2- 1.9	1	trace	5	12	11	34	37
b	2	72	26	1.9- 5.8	2	1	18	53	18	2	6
a&b	2	54	44	Mean	2	trace	14	40	16	12	16

NO 69 SE 13 6814 9196 **Burn of Rhoda**

Surface level c+79m	Overburden 0.4m
Water struck at c+76.2m	Mineral I 1.2m
Pit	Waste 0.1m
May 1989	Mineral I 1.2m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; sandy, humic	0.4	0.4
Alluvial fan	**a Cobble gravel**, with crude horizontal bedding *Gravel:* cobble, coarse and fine, moderately sorted, clast-supported; subangular to subrounded, coarse-grained pink granite, dark pink microgranite and banded psammite; some quartzite *Sand:* coarse with medium, angular, quartz and feldspar *Fines:* silt and clay, disseminated, moderate brown (5YR 4/6)	1.2	1.6
	Silt; sandy, finely laminated, moderate yellowish brown (10YR 5/4)	0.1	1.7
	b Gravel *Gravel:* cobble with coarse and fine, subangular to subrounded; mainly granite with some psammite and quartzite *Sand:* coarse with medium, subangular, quartz and feldspar *Fines:* silt and clay, disseminated, moderate brown (5YR 4/6)	1.2+	2.9

Pit abandoned at the water table

NO 69 SE 13

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	5	42	53	0.4- 1.6	5	6	16	20	16	15	22
b	5	41	54	1.7- 2.9	5	2	15	24	15	17	22
a&b	5	41	54	Mean	5	4	15	22	16	16	22

NO 69 SE 14 | 6814 9234 | **East of Gateside**

Surface level c.+79m
Water not struck
Section and pit
May 1989

Overburden 0.3m
Mineral I 10.0m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, sandy	0.3	0.3
Glacial sand and gravel (Esker bead)	**a Cobble gravel**; clast-supported *Gravel:* cobble with coarse and fine; scattered boulders of porphyritic felsite up to 60cm; subangular to subrounded, mainly pale pink megacrystic granite, some felsite; sparse psammitic grit and basic porphyry *Sand:* mainly coarse, angular, clean, sharp, granite, quartz and feldspar *Fines:* little, disseminated, light brown (5YR 6/4)	7.4	7.7
	b Sandy gravel; iron stained, especially below 9.7m *Gravel:* fine and coarse, rounded, mainly granite and psammite. Forms lags at the base of fining-upwards tabular cross-beds *Sand:* coarse with medium, subangular to angular granite, quartz and feldspar *Fines:* silt and iron stain, disseminated; dark yellowish orange (10YR 6/6)	2.6+	10.3
	Pit terminated, sand and gravel collapsing in from the sides		

NO 69 SE 14

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	trace	29	71	0.3- 3.9	0	1	5	21	20	16	37
				3.9- 7.7	1	1	4	26	14	25	29
				Mean	trace	1	4	24	17	21	33
b	3	50	47	7.7- 9.7	3	2	19	34	24	18	0
				9.7-10.3	1	1	11	26	22	22	17
				Mean	3	2	17	31	24	19	4
a&b	1	34	65	Mean	1	1	8	25	19	20	26

NO 69 SE 15 **6853 9267** **Heugh-head**

Surface level c.+78m
Water struck at c.+70.6m
250mm percussion
June 1989

Overburden	0.4m
Mineral I	2.2m
Waste	0.9m
Mineral I	1.7m
Waste	1.3m
Mineral II	2.7m
Waste	0.7m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, sandy and pebbly	0.4	0.4
Fluvioglacial sand and gravel	**a 'Clayey' sandy gravel** (unrepresentative grading owing to comminution by drilling) *Gravel:* fine and coarse with cobble; rounded boulders up to 30cm. Mainly rounded to well-rounded coarse-grained pink granite, some quartzite, schist, semipelite, calc-silicate and amphibolite *Sand:* coarse with medium, angular to subangular, quartz, feldspar and lithic grains *Fines:* silt and clay, disseminated; pale yellowish brown (10YR 5/2) to 1.5m, moderate yellowish brown (10YR 5/4) towards the base	2.2	2.6
? Flow-till	**Diamicton,** silty and sandy, moderately firm. Fine angular clasts. Moderate yellowish brown (10YR 5/4)	0.8	3.4
	Silt, clayey, laminated, with partings of medium to fine sand. Moderate yellowish brown (10YR 5/4) to moderate reddish brown (10R 4/6)	0.1	3.5
?Fluvioglacial sand and gravel	**b 'Very clayey' pebbly sand** (unrepresentative grading owing to comminution by drilling) *Gravel:* fine and coarse, subangular to subrounded, granite and psammitic grit. No gravel below 4.6m depth *Sand:* mainly medium, subangular to subrounded; quartz, with some feldspar and lithic grains	1.7	5.2

	Fines: silt and clay, disseminated, binding top of unit and as thin beds interlaminated with graded beds of sand from 4.6m to 4.7m. A trace of organic material. Moderate yellowish brown (10YR 5/4) to moderate reddish brown (10R 4/6)		
Glaciolacustrine deposits	**Silt**, sandy and clayey, laminated; firm, becoming soft below 5.8m. Sparse subangular and subrounded cobbles (? dropstones) from 5.8m to 6.0m. Mainly moderate yellowish brown (10YR 5/4) but some light grey banding	1.3	6.5
Flow-till	**c 'Clayey' gravel**, very firm *Gravel:* coarse with fine, angular to subangular, psammitic grit and granite, some vein-quartz *Sand:* coarse and medium with some fine, angular to subrounded, quartz and feldspar *Fines:* clay and silt, binding the deposit	2.7	9.2
Till	**Diamicton**, clayey, stiff. Angular to subangular clasts of psammite and granite. Moderate yellowish brown (10YR 5/4)	0.7+	9.9
	Borehole terminated on obstruction, possibly bedrock, no sample recovery		

NO 69 SE 15

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	13	48	39	0.4- 1.5	9	5	11	22	13	25	15
				1.5- 2.6	17	12	20	25	21	5	0
				Mean	13	9	15	24	17	15	7
b	25	62	13	3.5- 4.6	17	18	32	13	12	8	0
				4.6- 5.2	39	3	58	0	0	0	0
				Mean	25	12	41	9	8	5	0
c	14	41	45	6.5- 9.2	14	11	15	15	16	29	0 $
a&b	18	54	28	Mean	18	10	27	17	13	11	4
a-c	17	48	35	Mean	17	10	22	16	14	18	3

NO 69 SE 16 6955 9315 Blackness

Surface level c.+100m
Water not struck
Section and pit
May 1989

Mineral I 6.5m
Waste 0.8m+

LOG

Geological classification	Lithology	Thickness m	Depth m
Fluvioglacial sand and gravel (Topset beds)	**a Gravel**; clast-supported, horizontal stratification, some poorly developed fining-upwards grading *Gravel:* mainly coarse with some fine and cobble, subangular to subrounded; medium-grained pink granite with psammite, felsite, quartzite and aplogranite *Sand:* mainly coarse, angular, clean, sharp; quartz, feldspar and granite *Fines:* silt, binding top 0.5m of deposit and as partings on prominent bedding planes; light to brown moderate (5YR 5/6-4/4)	3.4	3.4
(Foreset beds)	**b Gravel**, in large scale (>3m) tabular cross-bedded units *Gravel:* cobble and coarse, with fine, subangular, medium and fine-grained pink granite, vein-quartz, granodiorite and felsite *Sand:* mainly coarse, well-sorted, angular to subangular quartz, feldspar and some granite; clean, sharp *Fines:* silt, disseminated, light brown (5YR 5/6)	3.1	6.5
Glaciolacustrine deposits	**Silt and clay**, interlaminated with micaceous silty fine sand; horizontal stratification and fine (? varved) graded bedding. Firm, rubbery; light brown (5YR 5/6) and moderate yellowish brown (10YR 5/4)	0.6	7.1
Till	**Diamicton**, clayey, firm, with wisps of fine sand. Scattered subangular clasts of coarse-grained pink granite and grey granodiorite. Dark yellowish brown (10YR 3/3)	0.2+	7.3

NO 69 SE 16

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	48	51	0.0- 3.4	1	1	13	34	13	30	8
b	1	48	51	3.4- 6.5	1	1	12	35	14	18	19
a&b	1	49	50	Mean	1	1	13	35	13	24	13

NO 69 SE 17 6900 9214 **Mill of Cammie**

Surface level c.+101m
Water struck at c.+94.2m
250mm percussion
May 1989

Overburden 0.1m
Mineral I 7.9m
Mineral II 2.0m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, sandy and silty	0.1	0.1
Fluvioglacial	**a Gravel** *Gravel:* cobble with fine and coarse, rounded to subrounded megacrystic pink and red granite; some tabular psammite, semipelitic gneiss, quartzite, marble, aplite, porphyry and pegmatite *Sand:* medium and coarse, mainly angular quartz and feldspar *Fines:* silt, clay and some mica, disseminated, light brown (5YR 5/6)	1.3	1.4
	b Sandy gravel, becoming less pebbly towards the base, thin beds of silt towards the top *Gravel:* cobble, fine and coarse; some cobbles (up to 20cm) of megacrystic pink granite towards the top. Mainly rounded to subrounded pink granite, some psammite and quartzite *Sand:* medium and coarse, angular to subrounded, quartz, feldspar and granite, sparse biotite mica *Fines:* silt and clay, disseminated and as thin partings; light brown (5YR 5/6)	3.1	4.5
	c 'Clayey' sand, finely laminated; scattered faceted dropstone cobbles of psammite, aplogranite and marble *Sand:* mainly medium and fine, subrounded, quartz *Fines:* silt and clay, disseminated and as thin interlaminated beds, moderate brown (5YR 4/4)	2.3	6.8
	d Gravel, silty in top 0.1m *Gravel:* cobble, with fine and coarse, subrounded to subangular, pink granite, aplogranite,	1.2	8.0

	psammite and marble *Sand:* coarse and medium, angular to subangular, granite, quartz and feldspar *Fines:* silt, disseminated, light brown (5YR 5/6)		
Flow-till	e **'Very clayey' gravel**, stiff *Gravel:* fine with coarse, angular to subangular, psammite, semipelitic gneiss and sparse granite. Many faceted pebbles *Sand:* medium with coarse and some fine, angular, lithic grains, quartz and feldspar *Fines:* clay and silt, binding deposit and coating clasts, dark yellowish brown (10YR 4/2)	2.0+	10.0

Borehole terminated on obstruction

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	5	39	56	0.1- 1.4	5	3	19	17	14	11	31	
b	4	66	30	1.4- 3.0	3	5	28	27	12	15	10	
				3.0- 4.5	6	9	36	26	8	3	12	
				Mean	4	7	33	26	10	9	11	
c	18	80	2	4.5- 6.8	18	32	38	10	2	trace	0	
d	5	41	54	6.8- 6.9	14	8	19	19	16	24	0	$
				6.9- 8.0	5	4	17	20	11	7	36	$
				Mean	5	4	17	20	11	8	35	
e	25	24	51	8.0-10.0	25	4	12	8	34	17	0	$
a&b	5	57	38	Mean	5	6	27	24	11	10	17	
a-c	9	66	25	Mean	9	15	32	19	8	6	11	
a-d	9	62	29	Mean	9	13	30	19	8	7	14	
a-e	12	54	34	Mean	12	11	26	17	13	9	12	

NO 69 SE 18 6942 9154 **Moss-side**

Surface level c.+128m
Water not struck
Section and pit
May 1989

Overburden 0.2m
Mineral I 6.9m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, humic and sandy	0.2	0.2
Fluvioglacial sand and gravel	**Sand, well-sorted, in tabular cross-stratified units** *Gravel:* fine, subangular granite *Sand:* medium, with coarse and some fine, subangular to subrounded, quartz with feldspar and grains of black decomposed pyrite *Fines :* silt, disseminated, light brown (5YR 5/6) Pit abandoned, fine sand collapsing in from the sides	6.9+	7.1

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
2	96	2	0.2- 2.4	2	4	70	24	0	0	0
			2.4- 5.1	2	15	46	34	3	0	0
			5.1- 7.1	2	25	51	19	3	0	0
			Mean	2	14	56	26	2	trace	0

NO 69 SE 19 | 6994 9102 | East of Pitreadie Farm

Surface level c.+125m
Water not struck
250mm percussion
May 1989

Overburden 0.2m
Mineral I 4.1m
Mineral II 0.7m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, sandy	0.2	0.2
Fluvioglacial sand and gravel	a **Sandy gravel**, with a bed of large boulders of coarse-grained granite at 2.9m depth *Gravel:* fine with coarse, sparse cobbles of coarse-grained granite from 0.8m to 1.2m; rounded, subrounded and tabular, pale pink granite, psammite and quartzite; sparse felsite *Sand:* coarse and medium, angular to subangular, granite, quartz and feldspar; sparse mica *Fines:* silt, disseminated, light brown (5YR 5/6)	4.1	4.3
Flow-till	b **Sandy gravel**, very compact, clay-bound *Gravel:* fine with some coarse, subangular, coarse-grained granite, microgranite and sparse fine-grained basic rock *Sand:* mainly coarse and medium, angular, granite, quartz and feldspar *Fines:* silt and rock-flour, disseminated, and coating clasts; moderate brown (5YR 4/4) to moderate yellowish brown (10YR 5/4)	0.7+	5.0
	Borehole abandoned owing to slow progress		

NO 69 SE 19

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	5	52	43	0.2- 2.2	6	2	18	33	21	14	6
				2.2- 4.3	4	4	17	31	24	20	0
				Mean	5	3	18	31	23	17	3
b	9	62	29	4.3- 5.0	9	6	26	30	23	6	0
a&b	6	53	41	Mean	6	3	19	31	23	16	2

NO 69 SE 20 | 6926 9067 | **Pitreadie Farm**

Surface level c.+145m
Water not struck
Pit
May 1989

Overburden 1.2m
Mineral II 1.0m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, humic and sandy	0.2	0.2
Morainic drift	**Silty sand,** with rounded pebbles and cobbles of coarse-grained pink granite; scattered angular granite boulders up to 60cm. Moderate brown (5YR 4/4)	0.6	0.8
	Diamicton, very sandy, stiff. Angular clasts of decomposed coarse-grained pink and grey granite, in a matrix of clayey granite sand. Light brown (5YR 6/4)	0.4	1.2
Caledonian	**Gravel** (granite gruss) *Gravel:* fine and coarse with cobble, angular, decomposed coarse-grained pale pink granite *Sand:* mainly coarse, angular, granite, quartz and feldspar *Fines:* clay minerals, formed of decomposed feldspar and mica. Moderate reddish orange (10R 6/6) to light brown (5YR 6/4)	1.0+	2.2

NO 69 SE 20

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
3	40	57	1.2- 2.2	3	3	14	23	24	20	13

NO 69 SE 21 | 6945 9202 | Cammie Wood Gravel Pit

Surface level c.+118m
Water struck at c.+106m
Section and pit
May 1989

Mineral I 12.8m+

LOG

Geological classification	Lithology	Thickness m	Depth m
Fluvioglacial sand and gravel (Topset beds)	**a Gravel**; in subhorizontal beds from 0.3m to 1.0m thick *Gravel:* coarse, with fine and some cobble; well-rounded, tabular and subrounded; mainly coarse-grained pink granite with fine-grained basic rock, felsite and grey psammite; some felsitic porphyry, semipelite and vein-quartz *Sand:* coarse and medium, with some fine, clean, sharp, subangular quartz and feldspar *Fines:* silt, disseminated, moderate yellowish brown (10YR 5/4)	3.4	3.4
(Foreset beds)	**b Sandy gravel**, in fining-upwards graded units from 0.2m to 1.0m thick *Gravel:* fine and cobble with some coarse, as lags at the base of foresets; subrounded to tabular, mainly granite with felsite, psammite, semipelite and vein-quartz *Sand:* coarse with medium and fine, subangular quartz and feldspar. In silty beds with ripple lamination; some small-scale channels and normal faulting *Fines:* silt and clay, disseminated, especially in sandy units; moderate yellowish brown (10YR 5/4)	6.7	10.1
(Bottomset beds)	**c Pebbly sand** *Gravel:* mainly fine, subangular to subrounded, granite and felsite; some psammite and vein-quartz	2.7+	12.8

Sand: coarse with medium, clean, subangular; quartz, feldspar and granite
Fines: silt and clay, disseminated and as thin beds interlaminated with pebbly sand below 12.0m; moderate brown (5YR 4/4)

Pit collapsing below water table, still in sand and gravel

At least 5m of poorly exposed sand and gravel present overlying sampled face

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	28	71	0.0- 3.4	1	6	11	11	22	41	8
b	5	59	36	3.4-10.1	5	11	19	29	15	6	15
c	3	79	18	10.1-12.8	3	4	27	48	15	3	0
a&b	3	49	48	Mean	3	9	16	24	18	18	12
a-c	3	55	42	Mean	3	8	19	28	17	15	10

NO 69 SE 22 | 6934 9217 | Cammie Wood

Surface level c.+113m
Water not struck
Section and pit
May 1989

Mineral I 7.3m+

LOG

Geological classification	Lithology	Thickness m	Depth m
Fluvioglacial sand and gravel (Topset beds)	a **Gravel**; clast-supported, horizontally bedded *Gravel:* coarse with cobble and some fine, well-sorted, rounded to tabular; coarse-grained pink and red granite, psammite and quartzite; some gabbro, felsite, porphyry and granodiorite *Sand:* coarse and medium, lithic grains, quartz and feldspar *Fines:* iron stain, dark orange	1.1	1.1
(Foreset beds)	b **Gravel**, in tabular cross-bedded, fining-downwards units; some small-scale normal faulting *Gravel:* cobble, coarse and fine, rounded; microgranite, felsite, granite and quartzite *Sand:* mainly coarse, angular to subangular, granite, quartz and feldspar *Fines:* silt, disseminated, moderate brown (5YR 4/4)	3.4	4.5
(Bottomset beds)	c **Pebbly sand**, with out-of-phase ripple drift; a disrupted and faulted bed of laminated silt, from 4.7m to 4.9m *Gravel:* fine, subangular granite *Sand:* mainly medium, subrounded to subangular, quartz and feldspar, clean and soft *Fines:* silt, mainly disseminated, dark yellowish brown (10YR 4/2)	2.8+	7.3

Pit terminated, sand collapsing in from the sides

NO 69 SE 22

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	20	79	0.0- 1.1	1	2	8	10	9	45	25
b	5	38	57	1.1- 4.5	5	1	9	28	18	18	21
c	3	90	7	4.5- 7.3	3	8	63	19	7	trace	0
a&b	4	34	62	Mean	4	1	9	24	16	24	22
a-c	4	56	40	Mean	4	4	30	22	12	15	13

NO 69 SE 23 | 6848 9160 | **Gallybank Plantation**

Surface level c.+113m
Water not struck
Pit
May 1989

Overburden 0.2m
Mineral I 5.3m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil; sandy, humic	0.2	0.2
Fluvioglacial sand and gravel	**a Gravel**; clast-supported, poorly developed horizontal stratification *Gravel:* coarse with cobble and fine, rounded to well-rounded; coarse-grained pink granite, with some quartzite, psammite and felsite *Sand:* medium and coarse, mainly quartz and feldspar *Fines:* silt and iron stain, disseminated; dark yellowish orange (10YR 6/5)	0.9	1.1
	b Pebbly sand, with tabular cross-bedding *Gravel:* sparse rounded granite cobbles, up to 10cm *Sand:* mainly medium, subangular quartz and feldspar, some coarse lithic grains; clean, sharp *Fines:*silt, disseminated; light brown (5YR 6/4) to greyish orange (10YR 7/4)	2.5	3.6
	c Sandy gravel, with tabular cross-bedding *Gravel:* fine with some coarse, rounded to subrounded, pink and grey granite, vein-quartz, felsite and occasional psammite *Sand:* coarse with medium, clean, sharp, subangular, quartz, feldspar and granite *Fines:* little, disseminated, light brown (5YR 4/6)	1.9+	5.5
	Pit terminated, sand and gravel collapsing in from the sides		

NO 69 SE 23

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	47	49	0.2- 1.1	4	1	24	22	13	22	14
b	2	90	8	1.1- 3.6	2	3	59	28	1	trace	7
c	1	71	28	3.6- 5.5	1	3	23	45	20	8	0
a&b	3	78	19	Mean	3	3	48	27	4	6	9
a-c	2	75	23	Mean	2	3	39	33	10	7	6

NO 69 SE 24 | 6572 9060 | **Pitdelphin Wood**

Surface level c.+108m
Water not struck
Pit
May 1989

Overburden 0.4m
Mineral I 4.4m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, sandy; abundant large rounded cobbles of granite	0.4	0.4
Fluvioglacial sand and gravel	**Gravel**, with abundant cobbles and boulders, up to 1.0m of coarse and medium-grained pale and dark pink granite; poorly developed horizontal stratification *Gravel:* cobble with coarse and fine, well-rounded to rounded, mainly granite, some granodiorite, porphyritic felsite and fine-grained basic rock *Sand:* mainly coarse, angular, granite, quartz and feldspar *Fines:* silt and clay, disseminated, binding deposit above 1.8m; some iron stain at the top. Moderate brown (5YR 4/4), becoming light brown (5YR 6/4) below 4.1m	4.4+	4.8

Pit terminated, sand and gravel collapsing in from the sides

NO 69 SE 24

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	27	72	0.4- 3.0	1	1	6	17	12	25	38
			3.0- 4.1	1	2	6	15	15	27	34
			4.1- 4.8	2	2	17	26	16	18	19
			Mean	1	1	8	18	14	24	34

AUCHENBLAE - CATTERLINE RESOURCE SHEET

NO 77 NW 1	**7110 7897**	**Drumelzie**

Surface level c.+195m	Overburden	0.6
Water not struck	Mineral II	0.6
Pit	Waste	0.6
August 1989	Mineral II	2.0+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, dark brown, clayey, stony	0.3	0.3
Flow-till	**Diamicton**; firm, fine, sandy silt and fine sand, very clayey and cohesive, micaceous. Moderate reddish brown (10R 4/6). Some gravel clasts in places	0.3	0.6
	a 'Clayey' sandy gravel; gravel in silty clayey matrix, but deposit is clast-supported *Gravel:* coarse and fine with some cobble, angular to well-rounded, quartzite and metasediments including grits and schists *Sand:* medium with fine and coarse, angular to subrounded quartz, rock fragments, feldspar and mica *Fines:* disseminated silt and clay, binding deposit in places	0.6	1.2
	Diamicton; weakly stratified, clay-bound deposit, sandy and silty, with some clasts up to cobble size, angular to well-rounded. Firm, moderate reddish brown (10R 4/6)	0.6	1.8
	b 'Very clayey' sandy gravel; diamictic deposit, clay-bound in places, poorly sorted *Gravel:* fine and coarse with cobble; subangular to subrounded quartzite, grits and schists *Sand:* fine with medium and coarse, subangular to subrounded, quartz, rock	2.0+	3.8

fragments, mica and feldspar
Fines: silt and clay binding deposit and coating grains and clasts

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	16	50	34	0.6- 1.2	16	21	17	12	15	14	5
b	26	50	24	1.8- 2.8	27	30	16	10	11	6	0
				2.8- 3.8	24	21	14	10	9	8	14
				Mean	26	25	15	10	10	7	7
a&b	23	52	25	Mean	23	26	15	11	11	8	6

NO 77 NW 2	7239 7925	Fungo Hillick, Auchenblae

Surface level c.+120m
Water struck at +114m
250mm percussion
August 1989

Overburden	0.3
Mineral I	1.0
Waste	2.1
Mineral I	2.4
Waste	2.2+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; light sandy silty soil with some gravel at the base	0.3	0.3
Fluvioglacial sand and gravel	**a Gravel**; dirty and 'silty' near top with clayey coats on clasts and a cohesive sandy silty matrix *Gravel:* coarse and fine with some cobble, subangular to well-rounded, quartzite, quartz- and mica-schist, vein-quartz, with rare sandstone, granitic material and volcanics *Sand:* fine, medium and coarse, angular to subangular, quartz, rock fragments, feldspar and mica *Fines:* disseminated silt and clay, coating grains and clasts	1.0	1.3
	No recovery. Very hard compact ground, possibly boulder gravel	2.1	3.4
	b Gravel; slightly claybound to about 3.8m, where a 10cm band of flow till is developed. Cleaner from 4.0m, moderate yellowish brown (10YR 5/4) *Gravel:* fine with coarse and a little cobble, angular to well-rounded, quartz- and mica-schist, quartzite, vein-quartz, and some volcanics *Sand:* coarse with medium and some fine angular to subrounded, quartz, feldspar, rock fragments *Fines:* disseminated silt and clay, coating grains and clasts and binding deposit in places	2.4	5.8
Till	**Diamicton**; moderate reddish	2.2+	8.0

brown (10R 4/6), massive, matrix
supported, silty sandy; firm but
plastic

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	23	71	0.3- 1.3	6	7	8	8	26	39	6
b	5	41	54	3.4- 4.4	6	7	15	24	33	15	0
				4.4- 5.8	4	3	8	26	45	14	0
				Mean	5	5	11	25	40	14	0
a&b	5	35	60	Mean	5	5	10	20	36	22	2

NO 77 NW 3 | 7282 7844 | Gilbert's Hill, Auchenblae

Surface level c.+115m
Water not struck
Section and pit
August 1989

Overburden 0.1
Mineral I 7.3+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil; stony, thin	0.1	0.1
Fluvioglacial sand and gravel	**a Gravel**; poorly stratified, but tending to coarsen upwards, generally massive. Some weak imbrication in places below 0.9m. Some schist clasts are deeply weathered. Sandy silt layer between 0.8 and 0.9m *Gravel:* coarse and fine with some cobble, angular to subrounded, quartzite, grits, schist and some volcanics *Sand:* coarse with medium and a little fine, angular to subrounded, quartz, rock fragments and feldspar *Fines:* low, disseminated silt and clay	2.8	2.9
	b Pebbly sand; poorly sorted and weakly stratified, chiefly gravel clasts in a sand matrix. Becomes increasingly sandy with depth *Gravel:* fine with some coarse and rare cobbles, subangular to rounded quartzite, vein-quartz, grits and schist *Sand:* medium with coarse and some fine, angular to subrounded quartz, rock fragments, feldspar and mica *Fines:* low, disseminated silt and clay	4.0	6.9
	c Gravel; sharp transition from pebbly sands above into gravel. Gravels appear well sorted with some sand matrix *Gravel:* fine with coarse and trace cobble, angular to rounded quartzite, vein-quartz, grits, schists and some volcanics and granitic material	0.5+	7.4

Sand: coarse with medium and trace fine, angular to subrounded quartz, feldspar and rock fragments
Fines: low, disseminated silt and clay

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	43	56	0.1- 0.8	1	1	12	26	25	35	0
				0.8- 1.9	1	5	22	17	24	31	0
				1.9- 2.9	1	1	19	24	28	18	9
				Mean	1	3	18	22	26	27	3
b	1	79	20	2.9- 3.9	1	5	49	21	18	6	0
				3.9- 4.9	1	4	41	25	18	11	0
				4.9- 5.9	1	7	57	17	12	6	0
				5.9- 6.9	2	15	57	13	10	3	0
				Mean	1	8	52	19	14	6	0
c	1	39	60	6.9- 7.4	1	1	14	24	49	11	0
a-c	1	62	37	Mean	1	5	37	20	21	15	1

NO 77 NW 4 | 7293 7815 | **Drumsleed, Auchenblae**

Surface level c.+110m	Overburden 0.3
Water not struck	Mineral I 6.1
Section and pit	Waste 1.0
August 1989	Mineral I 2.0+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil; gravelly	0.3	0.3
Fluvioglacial sand and gravel	**a Sandy gravel**; weakly cross-stratified gravels in upper metre, passing down into cross stratified open framework gravels with silty sandy layers. Deposit becomes much less gravel rich from 3.7m below a 0.4m silty sand layer *Gravel:* fine with coarse, subangular to rounded quartzite, vein quartz, some schist, granitic material, andesite and grits *Sand:* medium with coarse and a little fine, angular to subrounded, quartz, feldspar and rock fragments *Fines:* generally low, disseminated silt and clay	4.9	5.2
	b 'Clayey' sand; silty fine sand, lacking clear cross-stratification of above deposit. Moderate reddish brown (10R 4/6) *Sand:* Medium with fine and a little coarse, subangular to subrounded quartz, feldspar, mica and rock fragments *Fines:* chiefly disseminated silt and clay, though some clayey silty bands are present in places	1.2	6.4
	Silt; sandy, micaceous, moderate reddish brown	1.0	7.4
	c Pebbly sand; appears to fine downwards, becoming more silty below 8.4m *Gravel:* fine and coarse, subangular to subrounded quartzite, vein quartz and	2.0+	9.4

grits
Sand: medium with some coarse and a little fine angular to subrounded quartz, feldspar, mica and rock fragments
Fines: low, disseminated silt and clay

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	5	55	40	0.3- 1.3	No grading data available						
				1.3- 3.3	1	1	5	20	53	20	0
				3.3- 5.2	8	5	60	22	2	3	0
				Mean	5	3	31	21	28	12	0
b	19	81	0	5.2- 6.4	19	31	49	1	trace	0	0
c	3	90	7	7.4- 9.4	3	4	71	15	4	3	0
a-c	6	68	26	Mean	6	7	45	16	18	8	0

NO 77 NW 5 | 7367 7872 | **Bankhead**

Surface level c.+110m
Water struck at +99m
250mm percussion
September 1989

Overburden	0.3
Mineral I	11.6
Waste	1.2
Bedrock	0.3+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; sandy, slightly clayey and stony soil	0.3	0.3
Glacial sand and gravel	**Gravel**; *Gravel:* fine with coarse and some cobble, angular to well-rounded, quartzite, vein quartz, grits, psammite, some sandstone and lava (andesitic) *Sand:* coarse and medium with some fine, angular to subangular quartz, rock fragments and feldspar *Fines:* disseminated and as coats on grains	11.6	11.9
Till	**Diamicton**; firm to hard, moderate reddish brown (10R 4/6) with clasts up to cobble size	1.2	13.1
Old Red Sandstone	**Mudstone**; moderate reddish brown (10R 4/6), silty sandy mudstone, weathered, micaceous	0.3+	13.4

NO 77 NW 5

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
6	45	49	0.3- 1.3	5	6	20	25	24	20	0
			1.3- 2.3	2	7	11	18	27	11	24
			2.3- 3.3	9	8	18	24	28	13	0
			3.3- 4.4	8	7	20	18	24	23	0
			4.4- 5.7	7	7	25	18	26	17	0
			5.7- 6.7	5	5	19	21	27	19	4
			6.7- 8.1	6	6	17	23	27	17	4
			8.1- 9.1	5	5	12	18	18	25	17
			9.1-10.1	8	4	10	20	30	28	0
			10.1-10.8	7	6	15	27	35	10	0
			10.8-11.9	8	9	24	26	25	8	0 S
			Mean	6	6	18	21	28	17	4

NO 77 NW 6 | 7309 7705 | **Mains of Fordoun**

Surface level c.+80m
Water not struck
Section and pit
August 1989

Mineral I	5.2
Waste	1.2+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
Fluvioglacial sand and gravel	**Sand**; stratified, with silty top inaccessible and not sampled	0.5	0.5
	Gravel; cross-stratified with thin silty, sandy laminae on top of the stratified units. Becomes finer upwards; moderately well-sorted *Gravel:* fine with coarse subangular to subrounded quartzite, vein quartz, schists and some sandstone *Sand:* coarse with medium and a little fine, subangular to rounded quartz, feldspar, rock fragments and mica *Fines:* low, disseminated, silt and clay	1.0	1.5
	Sand; moderate reddish brown; laminated in places, with some fine and coarse gravel clasts. *Sand:* medium and coarse with some fine, angular to subrounded quartz, feldspar, rock fragments and some mica *Fines:* disseminated silt and clay, becoming more abundant with depth	3.7	5.2
	Silt; sandy, laminated and clayey; moderate reddish brown	1.0	6.2
Till	**Diamicton**; stiff, massive, moderate reddish brown (10R 4/6) with clasts up to boulder size	0.2+	6.4

NO 77 NW 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					No grading data available for this deposit						
b	3	47	50	0.5- 1.5	3	3	21	23	31	19	0
c	4	93	3	1.5- 3.5	2	1	38	56	3	0	0
				3.5- 5.2	7	9	57	22	2	3	0
				Mean	4	4	48	41	2	1	0

NO 77 NW 7 | 7312 7681 | **Mains of Fordoun**

Surface level c.+70m	Overburden 1.5
Water not struck	Mineral I 0.9
250mm percussion	Waste 5.2
August 1989	Bedrock 0.4+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; silty, clayey and stony	0.3	0.3
Alluvium	**Clay**; variable sequence of very stiff medium reddish brown micaceous silty clays with layers of fine sand and gravel up to 10cm thick. Thin c.20mm thick layers of blue green (5BG 7/2) clay adjacent to sandy horizons	1.2	1.5
	Gravel; poorly sorted 'dirty' gravels, sandy and silty in part *Gravel:* fine with coarse and trace cobble, angular to subrounded vein-quartz, quartz-schist, mica schist, volcanics including ignimbrite, quartz porphyry and andesite *Sand:* coarse with medium and some fine, angular to subrounded quartz, rock fragments and some mica *Fines:* disseminated silt and clay, binding deposit in places	0.9	2.4
Till	**Diamicton**; moderate reddish brown (10R 4/6) silty clay. Angular to subrounded clasts up to coarse gravel size with some cobbles	5.2	7.6
Old Red Sandstone	**Sandstone**; soft, weathered, fine, micaceous sandstone; moderate reddish brown (10R 4/6)	0.4+	8.0

NO 77 NW 7

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
9	44	47	1.5- 2.4	9	9	15	20	30	17	0 $

NO 77 NW 8 | 7322 7546 | **Bomershanoe Wood**

Surface level c.+65m
Water not struck
Pit
August 1989

Overburden 0.3
Mineral I 4.2+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil; sandy, gravelly	0.3	0.3
Glacial sand and gravel	Gravel; moderate reddish brown (10R 4/6) with clay coats on grains and clasts; 'dirty' and somewhat diamictic in appareance, becoming cleaner with depth. Poorly sorted and stratified *Gravel:* coarse and fine with some cobble, angular to well-rounded *Sand:* medium and coarse with some fine, subangular to subrounded quartz, rock fragments and feldspar *Fines:* disseminated silt and clay, coating grains and binding deposit in places	4.2+	4.5

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
5	35	60	0.3- 1.3	5	4	11	17	31	32	0
			1.3- 2.3	4	4	11	7	22	37	15
			2.3- 3.5	4	3	25	16	23	29	0
			3.5- 4.5	5	3	14	18	30	23	7
			Mean	5	4	16	15	26	29	5

NO 77 NW 9 | 7457 7877 | **Monboddo House**

Surface level c.+105m
Water struck at +99m
Section and pit
August 1989

Overburden 0.2
Mineral I 6.4+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; gravelly	0.2	0.2
Glacial sand and gravel	**a Sandy gravel**; generally moderately well stratified, becoming more gravel rich with depth; moderately well-sorted. Sand bands with silty tops occur in the upper part of the deposit *Gravel:* coarse and fine with trace cobble angular to rounded quartzite, vein-quartz, schist and volcanics, chiefly andesite. Volcanic material is quite abundant *Sand:* medium and coarse with a little fine angular to subrounded quartz, feldspar and rock fragments *Fines:* disseminated silt and clay	3.4	3.6
	b Sand; variable with cross-stratified coarse sands and more silty fine sands; pebbles present in places, but not abundant *Sand:* medium with coarse and some fine, angular to rounded quartz, feldspar, rock fragments and mica *Fines:* silt and clay in thin laminae in places and disseminated	3.0+	6.6

NO 77 NW 9

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	2	68	30	0.2- 0.6	4	10	40	13	12	21	0
				0.6- 2.1	2	4	35	37	15	7	0
				2.1- 3.6	2	4	27	29	14	24	0
				Mean	2	4	33	31	14	16	0
b	5	92	3	3.6- 4.6	5	16	63	11	3	2	0
				4.6- 5.6	4	7	57	28	3	1	0
				5.6- 6.6	8	7	81	4	0	0	0
				Mean	5	10	67	15	2	1	0
a&b	4	78	18	Mean	4	7	48	23	9	9	0

NO 77 NW 10 | 7479 7880 | **Temple Fauchs**

Surface level c.+110m
Water struck at +95m
250mm percussion
August 1989

Overburden	0.9
Mineral I	9.2
Waste	1.6
Mineral	8.9+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; medium brown (5YR 4/4), silty loam, pebbly	0.3	0.3
Flow-till	**Diamicton**; moderate reddish brown (10R 4/6), stiff silty clay with clasts of quartz-schist, schistose grit, vein-quartz and, notably, Lintrathan-type porphyry material	0.6	0.9
Glacial sand and gravel	a **Gravel**; poorly sorted with silt and clay which binds the deposit in places; silt and clay give a moderate reddish brown (10R 4/6) to the deposit *Gravel:* fine and coarse with some cobble, angular to subrounded quartzite, vein-quartz, schistose grit, decomposed volcanics and sandstone with some porphyry *Sand:* coarse with medium and some fine, angular to subrounded quartzite, rock fragments and some mica *Fines:* disseminated silt and clay, sufficient to bind the deposit in places	4.0	4.9
Flow-till	b **'Clayey'** gravel; very hard clay bound deposit, but compositionally as above *Gravel:* fine with coarse and cobble, lithologies as above *Sand:* coarse with medium and some fine, lithologies as above *Fines:* silt and clay binding the deposit	1.0	5.9
Glacial sand and gravel	c **Gravel**; unit becomes less gravel-rich with depth to 10.1m *Gravel:* fine with coarse and a little cobble, angular to	4.2	10.1

	subrounded quartzite, vein-quartz, schistose grit, fresh to decomposed volcanics, decomposed sandstone and some porphyry *Sand:* medium with fine and some coarse angular, to subrounded quartz, rock fragments and some mica *Fines:* disseminated silt and clay		
Glaciolacustrine deposits	**Silt**; laminated, micaceous, moderate reddish brown (10R 4/6). Laminated on the scale of a few millimetres with clayey silt and silty-fine sand laminae. A single c.70mm layer of clay-bound sand and gravel occurs at about 10.4m	1.6	11.7
Glacial sand and gravel	**d 'Clayey' sand**; moderate reddish brown (10R 4/6) with silty and clayey horizons in places and rare fine-gravel sized clasts *Sand:* fine with medium and trace coarse, angular to subrounded quartz, rock fragments and mica *Fines:* silt and clay, concentrated in laminae and disseminated	6.5	18.2
	e Sandy gravel; coarsening downwards *Gravel:* fine with coarse and trace cobble, angular to subrounded mudstones, porphyry, non-porphyritic volcanics and quartzite *Sand:* medium with coarse and some fine, angular to subrounded quartz and rock fragments *Fines:* disseminated silt and clay	2.4+	20.6

Borehole terminated at 20.6m in mineral due to very slow progress

NO 77 NW 10

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	41	55	0.9- 2.1	6	5	15	19	26	23	6
				2.1- 3.5	4	3	14	20	23	25	11
				3.5- 4.9	3	4	15	26	26	26	0
				Mean	4	4	15	22	25	24	6
b	12	40	48	4.9- 5.9	12	6	13	21	23	13	12
c	4	60	36	5.9- 7.1	4	4	14	25	27	19	7
				7.1- 8.4	5	9	31	19	23	13	0
				8.4-10.1	4	8	43	20	13	12	0
				Mean	4	7	32	21	20	14	2
d	17	83	0	11.7-13.4	25	56	19	0	0	0	0
				13.4-14.7	15	37	47	1	0	0	0
				14.7-16.6	15	55	30	0	0	0	0 $
				16.6-18.2	14	62	24	0	0	0	0 $
				Mean	17	54	29	trace	trace	trace	0
e	4	61	35	18.2-19.6	5	14	40	19	11	11	0 $
				19.6-20.6	2	3	15	28	37	15	0 $
				Mean	4	10	28	23	22	13	0
a-e	9	63	28	Mean	9	23	26	14	15	11	2

NO 77 NW 11 | 7456 7624 | Pittengardner

Surface level c.+65m
Water not struck
250mm percussion
August 1989

Overburden 0.3
Mineral I 6.8
Waste 1.7+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, sandy and silty, light medium brown	0.3	0.3
Fluvioglacial sand and gravel	**Pebbly sand**; clean, moderate reddish brown (10R 4/6); deposit fines down in general, though it becomes more gravel rich from 6.2 to 7.1m *Gravel:* fine with coarse, quartzite, volcanics, sandstone, gritty breccia, and quartz-schist *Sand:* medium with some coarse and fine, subangular to subrounded quartz, feldspar, rock fragments and mica *Fines:* chiefly disseminated silt and clay, but also concentrated in occasional clay-bound layers	6.8	7.1
Till	**Diamicton**; moderate reddish brown, stiff clay wth abundant subangular to subrounded clasts up to 120mm, chiefly quartzite and red siltstone	1.7+	8.8

NO 77 NW 11

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
6	79	15	0.3- 0.8	4	6	34	23	25	8	0
			0.8- 2.1	5	13	51	13	12	6	0
			2.1- 3.4	7	23	41	13	10	6	0
			3.4- 4.7	7	10	55	14	10	4	0
			4.7- 6.2	7	14	58	11	8	2	0
			6.2- 7.1	7	17	45	15	13	3	0
			Mean	6	14	51	14	11	4	0

NO 77 NE 1 | 7526 7888 | **Causeywell Brae**

Surface level c.+110m
Water struck at +97m
250mm percussion
August 1989

Overburden	0.1
Mineral I	21.5
Waste	0.3
Mineral I	1.6+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; light brown, silty, sandy with gravel	0.1	0.1
Glacial sand and Gravel	a **Sandy gravel**; moderate reddish brown (10R 4/6) to moderate brown (5R 4/4); clayey in places with clayey matrix binding the deposit. Lowermost 0.6m is more sandy *Gravel:* fine with coarse and a little cobble, quartzite schistose grit, andesite, silty sandstone, vein-quartz and quartz-feldspar porphyry *Sand:* medium with fine and some coarse, subangular to subrounded quartz and rock fragments *Fines:* chiefly as disseminated silt and clay, but also concentrated in clayey silt lenses	6.0	6.1
	b **'Clayey' sand**; becoming finer with depth. Moderate reddish brown and cohesive. Contains some rare subangular to subrounded fine gravel clasts *Sand:* fine with medium and a little coarse, subangular to subrounded quartz, rock fragments and mica *Fines:* disseminated silt and clay	5.9	12.0
	c **Sandy gravel**; clayey from 12.0 to 13.4m, thence much cleaner *Gravel:* fine with coarse, angular to subrounded with some (rare) cobbles to 100mm in size, red granite, volcanics, some sandstone, quartz-feldspar porphyry, vein-quartz and mica schist *Sand:* medium with coarse and fine, subangular to subrounded,	3.0	15.0

	quartz, rock fragments and mica *Fines:* disseminated silt and clay		
Glacial sand and gravel	**d Sand**; becoming gravel-free with depth to 18.2m, but containing a small percentage of gravel from 15.0 to 16.7m *Gravel:* fine with some coarse, subangular to subrounded; lithologies as above *Sand:* medium with fine and a little coarse, subangular to subrounded quartz, rock fragments and mica *Fines:* disseminated silt and clay	3.2	18.2
	e Sandy gravel; deposit coarsens downwards with cobbles up to 100mm, though rare *Gravel:* fine with coarse, and rare cobble, subangular to subrounded, quartzite, vein-quartz, red granite, porphyry, mica schist, sandstone and volcanics *Sand:* coarse with medium and some fine, subangular to subrounded quartz, rock fragments and mica *Fines:* disseminated silt and clay	2.3	20.5
	f Sand; *Sand:* medium with some fine and a little coarse, subangular to subrounded quartz and rock fragments *Fines:* disseminated silt and clay	1.1	21.6
	Silt; laminated micaceous silt and clay, cohesive	0.3	21.9
	g 'Clayey' sand; becoming slightly pebbly with some fine and trace coarse gravel from 23.2m *Sand:* medium with some fine and a little coarse, quartz, rock fragments and mica *Fines:* disseminated silt and clay, decreasing with depth	1.6+	23.5
	Borehole terminated in mineral at 23.5m due to very slow progress		

NO 77 NE 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	5	53	42	0.1- 2.1	8	10	29	18	19	16	0
				2.1- 3.1	4	4	22	20	23	22	5
				3.1- 4.4	3	4	16	20	26	19	12
				4.4- 5.5	3	6	27	17	31	16	0
				5.5- 6.1	7	30	45	4	4	10	0
				Mean	5	9	27	17	22	17	3
b	10	90	0	6.1- 8.3	10	38	49	2	1	0	0
				8.3- 9.7	9	42	48	1	0	0	0
				9.7-10.9	10	67	23	0	0	0	0
				10.9-12.0	14	76	9	1	0	0	0
				Mean	10	53	36	1	trace	trace	0
c	6	64	30	12.0-13.4	10	30	34	6	9	11	0
				13.4-15.0	2	5	23	30	26	14	0 $
				Mean	6	16	28	20	18	12	0
d	6	93	1	15.0-16.7	7	29	54	6	3	1	0 $
				16.7-18.2	5	19	73	3	0	0	0 $
				Mean	6	24	65	4	1	trace	0
e	2	53	45	18.2-19.5	2	5	18	30	36	9	0 $
				19.5-20.5	2	3	14	36	32	13	0 $
				Mean	2	4	16	33	34	11	0
f	5	95	0	20.5-21.6	5	19	75	1	trace	0	0 $
g	10	89	1	21.9-23.5	10	27	60	2	1	trace	0 $
a-g	7	73	20	Mean	7	24	38	11	12	7	1

NO 77 NE 2 | 7542 7589 | **Rob's Hillock, Fordoun**

Surface level c.+60m
Water not struck
Pit
August 1989

Overburden 0.3
Mineral I 1.8+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; sandy, gravelly	0.3	0.3
Fluvioglacial sand and gravel	'Clayey' gravel; moderately well-stratified, open framework, clast-supported gravels; some clay binds deposit in top 0.3m but cleaner and well-sorted with depth, fines content drops markedly below 1.3m *Gravel:* fine with coarse, subangular to well-rounded, quartzite, vein-quartz, schists, some volcanics and mudstone *Sand:* coarse with medium and trace fine, angular to subrounded quartz, feldspar and rock fragments *Fines:* disseminated silt and clay, but with sufficent in top 0.3m of deposit to give a 'clayey' classification	1.8+	2.1

Terminated at 2.1m in mineral due to badly collapsing pit sides

NO 77 NE 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	34	56	0.3- 1.3	17	1	8	15	35	24	0
			1.3- 2.1	2	0	24	23	29	22	0
			Mean	10	trace	15	19	33	23	0

NO 77 NE 3 | 7584 7579 | Whiteriggs, Fordoun

Surface level c.+60m
Water not struck
Pit
August 1989

Overburden 0.5
Mineral I 2.0
Waste 0.2+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil; sandy, slightly clayey	0.5	0.5
Fluvioglacial sand and gravel	**Pebbly sand;** moderately well-stratified, moderate reddish brown (10R 4/6); clean, but slightly cohesive *Gravel:* fine with coarse, subangular to well-rounded schists, grits, quartzite, vein-quartz, volcanics and red mudstone *Sand:* medium with some coarse and fine, subangular to subrounded, quartz, feldspar, rock fragments and mica *Fines:* disseminated silt and clay	2.0	2.5
Till	**Diamicton;** moderate reddish brown (10R 4/6), firm clay with clasts up to boulder-size. Bleached in top 10-15cm	0.2+	2.7

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
5	72	23	0.5- 1.5	4	5	54	10	15	12	0
			1.5- 2.5	7	11	50	13	14	5	0
			Mean	5	8	53	11	15	8	0

NO 77 NE 4 | 7647 7930 | **Laftan Knowes, Castleton**

Surface level c.+120m
Water not struck
Pit
August 1989

Overburden 0.2
Mineral I 1.8
Bedrock 0.3+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; turf and sandy, gravelly soil	0.2	0.2
Glacial sand and gravel (?)	**Gravel**; 'dirty' gravel, massive, poorly to moderately stratified with clasts up to 300mm. Deposit probably derived locally from ORS conglomerate bedrock *Gravel:* coarse with fine and some cobble, rounded to well-rounded, chiefly quartzite *Sand:* medium with some fine and coarse, subangular to subrounded quartz, feldspar, rock fragments and mica *Fines:* disseminated silt and clay coating grains and clasts, sufficient to bind the deposit in places	1.8	2.0
Old Red Sandstone	**Conglomerate**; well-rounded cobbles and coarse-gravel sized clasts in a sandy volcaniclastic matrix	0.3+	2.3

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
6	36	58	0.2- 1.2	6	11	27	6	19	31	0
			1.2- 2.0	6	4	17	6	24	35	8
			Mean	6	8	22	6	21	33	4

NO 77 NE 5 | 7638 7874 | **Castleton**

Surface level c.+105m	Overburden 0.9
Water not struck	Mineral I 1.8+
Pit	
August 1989	

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil; moderate reddish brown (10R 4/6) clayey stony soil	0.3	0.3
Flow-till	**Diamicton**; moderate reddish brown (10R 4/6) stiff, hard. Matrix supported; clasts of rotted schist and siltstone in clay matrix; massive, structureless	0.6	0.9
Glacial sand and gravel	**Gravel**; massive, apparently poorly stratified 'loose' clean gravels with clasts up to 100mm *Gravel:* coarse with fine and a little cobble, subangular to well-rounded schists, grits, quartzite, volcanics and mudstone *Sand:* medium and coarse with a little fine, angular to subrounded quartz, feldspar and rock fragments *Fines:* low, disseminated silt and clay	1.8+	2.7

Pit terminated at 2.7m due to badly collapsing pit sides

NO 77 NE 5

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
2	33	65	0.9- 1.9	2	1	17	17	26	37	0
			1.9- 2.7	2	4	14	12	29	32	7
			Mean	2	2	16	15	27	35	3

NO 77 NE 6 **7677 7806** **Abbeyton**

Surface level c.+75m
Water not struck
Pit
August 1989

Waste 3.8+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; dark reddish brown stony clay soil	0.3	0.3
Flow-till sequence	**Diamicton**; bright red, very clast-rich till. Clasts chiefly of red mudstone with some of rotted schist in upper 2m of deposit. Weakly stratified and more sandy and silty in places. Also wet in places with fine gravels in a wet sticky clay matrix	3.5+	3.8

NO 77 NE 7 | 7632 7546 | Bridge of Kair

Surface level c.+55m
Water struck at c.+51m
250mm percussion
August 1989

Waste 3.8
Bedrock 1.1+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; moderate yellowish brown silty clay soil	0.3	0.3
Alluvium	**Cobble and boulder gravel**; massive, very hard and compact, clay-bound in part. (Insufficient material recovered for a sample for grading)	1.7	2.0
Till	**Diamicton**; very hard, moderate reddish brown, very poor recovery	1.5	3.5
	Gravel; coarse, angular to subrounded schist, grit, quartzite, vein-quartz and red mudstone	0.3	3.8
? Old Red Sandstone	**? Siltstone**; red, soft and weathered (much broken up by drilling method and retrieved as slurry)	0.4	4.2
Old Red Sandstone	**Conglomerate**; weathered gravelly conglomerate; clasts up to 64mm quartzite, vein-quartz, schist and grit together with clasts of lithified sand matrix with moulds of cobble clasts	0.7+	4.9

NO 77 NE 8 | 7763 7985 | **East Mondynes**

Surface level c.+115m
Water not struck
Pit
August 1989

Overburden 0.3
Mineral I 3.3+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil; sandy stony clay soil	0.3	0.3
Glacial sand and gravel	a **Sandy gravel**; diamictic poorly sorted and stratified, becomes damp with depth from 2.0m *Gravel:* fine with coarse and a little cobble, subangular to well-rounded, quartzite, vein-quartz and grit *Sand:* fine with medium and some coarse, subangular to rounded, quartz, feldspar, mica and rock fragments *Fines:* silt and clay, disseminated in general, but also binding the deposit in places	2.1	2.4
	b **'Very clayey' pebbly sand**; some pebbly bands in top 0.5m or so, thereafter passes down into silty clayey sand. Micaceous, moderate reddish brown *Gravel:* fine with a little coarse, composition as above *Sand:* fine with medium and some coarse, angular to rounded quartz, feldspar, rock fragments and mica *Fines:* disseminated silt and clay, building the deposit locally	1.2	3.6+

NO 77 NE 8

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	50	46	0.3- 1.3	4	6	30	17	23	20	0
				1.3- 2.4	3	7	21	19	26	20	4
				Mean	4	7	25	18	24	20	2
b	27	66	7	2.4- 3.6	27	36	24	6	6	1	0
a&b	12	56	32	Mean	12	17	25	14	18	13	1

NO 77 NE 9 | 7755 7952 | East Mondynes

Surface level c.+110m
Water not struck
Pit
August 1989

Overburden 0.2
Mineral I 3.8+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil; dark yellowish brown, sandy, silty, with some gravel clasts	0.2	0.2
Glacial sand and gravel	a **Sandy gravel**; 'dirty' diamictic gravel; poorly sorted and stratified *Gravel:* coarse with fine and cobble, subangular to rounded quartzite, schist, vein-quartz and volcanics *Sand:* medium with fine and coarse, angular to subrounded quartz, rock fragments and feldspar *Fines:* disseminated silt and clay, coating grains and clasts	0.6	0.8
	b **Pebbly sand**; gravel clasts are contamination from above deposit incurred during sampling *Gravel:* fine and coarse, details as above *Sand:* fine with medium and a little coarse, angular to subrounded quartz, feldspar, mica and rock fragments *Fines:* disseminated silt and clay	0.8	1.6
	c **Gravel**; diamictic and 'clayey' from 1.6 to 2.6m with cohesive sandy, clayey matrix. Some clasts are in excess of 200mm in size, massive, poorly sorted *Gravel:* coarse with cobble and fine, angular to well-rounded conglomerate, schist, grit, mudstone, decomposed volcanics (including andesite and basalt), quartzite and vein-quartz *Sand:* medium with coarse and fine, angular to subrounded quartz, feldspar, and rock	2.4+	4.0

fragments
Fines: disseminated silt and clay, also binding deposit in places

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	8	48	44	0.2- 0.8	8	17	22	9	14	20	10
b	9	85	6	0.8- 1.6	9	47	35	3	3	3	0
c	9	38	53	1.6- 2.6	11	9	14	10	15	33	8
				2.6- 4.0	7	11	17	13	13	17	22
				Mean	9	10	16	12	14	23	16
a-c	9	48	43	Mean	9	19	19	10	12	19	12

NO 77 NE 10 | 7833 7991 | Pade O'France

Surface level c.+90m
Water not struck
Pit
August 1989

Overburden 1.8
Mineral I 1.9+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil; dark reddish brown sandy loam	0.3	0.3
Flow-till	**Diamicton**; sandy clay, firm, with some clasts, massive structureless	0.7	1.0
	Diamicton; bright reddish brown stiff stony clay; clasts of angular red mudstone/micaceous siltstone	0.8	1.8
Glacial sand and gravel	**Sandy gravel**; becomes more gravel-rich with depth; clasts up to cobble size, though rare; becomes cleaner with depth *Gravel:* fine with coarse and rare cobble, angular to well-rounded quartzite, vein-quartz, mudstone and siltstone *Sand:* medium with coarse and some fine, angular to subrounded quartz, feldspar and rock fragments *Fines:* disseminated silt and clay	1.9+	3.7

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
7	64	29	1.8- 3.7	7	7	31	26	17	12	0

NO 77 NE 11 **7805 7966** **East Mondynes**

Surface level c.+85m
Water not struck
Pit
August 1989

Waste 3.2+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil; sandy, clayey, stony	0.3	0.3
Flow-till	**Diamicton;** sandy and gravelly diamicton, matrix-supported and weakly stratified, moderate reddish brown, hard	0.9	1.2
	Very clayey gravel or gravelly diamicton with clay-bound masses. Moderate reddish brown with clasts up to cobble-size. Deemed non-mineral; not sampled	0.9	2.1
Till	**Diamicton;** massive, firm, with angular to well-rounded clasts up to boulder-size, chiefly quartzite and red mudstone derived from Old Red Sandstone	1.1+	3.2

NO 77 NE 12 | 7830 7877 | **Gyratsmyre**

Surface level c.115m
Water not struck
Pit
August 1989

Waste 2.3
Bedrock 0.1+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil;	0.2	0.2
Flow-till	**Diamicton**; ? cryoturbated, sandy, moderate reddish brown	0.7	0.9
	Gravel; diamictic, part matrix-, part-clast supported; clasts up to cobble size, well-rounded	0.4	1.3
	Diamicton; soft, sandy in places and with some laminated silty material. Clasts up to boulder-size, some of decomposed schist	1.0	2.3
Old Red Sandstone	**Sandstone**; decomposed, blocky, dark reddish brown, medium grained	0.1+	2.4

NO 77 NE 13 7823 7826 Deep

Surface level c.100m
Water not struck
Pit
August 1989

Waste 1.4
Bedrock 1.5+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil; stony, sandy	0.3	0.3
Till	**Diamicton**; sandy, massive, matrix supported and structureless. Clasts up to boulder-size, moderate reddish brown	1.1	1.4
Old Red Sandstone	**Conglomerate**; deeply weathered to about 1.5m+ and possibly moved slightly; weathered sandy matrix binds the deposit. Clasts very abundant, well-rounded, up to boulder-size. Becomes more solid from 2.5m where fragments of sandstone matrix appear	1.5+	2.9

NO 77 NE 14 | 7850 7794 | **Deep**

Surface level c.+140m
Water not struck
250mm percussion
August 1989

Waste 2.1
Bedrock 1.1+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; sandy, stony	0.3	0.3
Till	**Diamicton**; moderate reddish brown 10R 4/6) firm to stiff stony clay; matrix-supported clasts up to cobble-size, angular to subangular	1.8	2.1
Old Red Sandstone	**Sandstone**; deeply weathered soft clayey sandstone-micaceous, medium reddish brown (10R 4/4) with some light greenish grey (5GY 8/1) flecks (?reduction spots). Angular fragments appear from 2.4m	1.1+	3.2

NO 77 NE 15 | 7944 7973 | **Candy**

Surface level c.+90m
Water not struck
Pit
August 1989

Overburden 0.7
Mineral I 3.2+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; dark reddish brown, silty, clayey, stony	0.3	0.3
Flow-till	**Diamicton**; sandy, moderate reddish brown, firm, cohesive, few coarse-gravel sized clasts	0.4	0.7
Glacial sand and gravel	**'Clayey' sand**; cohesive, silty, micaceous, moderate reddish brown; rare subrounded to rounded pebbles. Occasional coarse sand and clay laminae *Sand:* fine with medium and a little coarse, angular to subrounded quartz, feldspar and mica *Fines:* disseminated, silt and clay	3.2+	3.9

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
14	85	1	0.7- 1.7	14	53	29	3	1	0	0
			1.7- 2.7	15	60	21	3	1	0	0
			2.7- 3.9	15	56	23	5	1	0	0
			Mean	14	58	24	3	1	trace	0

NO 77 NE 16 | 7975 7830 | **Little Wairds**

Surface level c.+110m
Water not struck
Section and pit
August 1989

Overburden 0.3
Mineral I 3.9+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; sandy, gravelly	0.3	0.3
Glacial sand and gravel	**Gravel; massive, poorly stratified and structured** *Gravel:* coarse with fine and cobble, subrounded to well-rounded, chiefly quartzite, vein-quartz, schists, grits, andesite and some red friable mudstone *Sand:* coarse with medium and some fine, subangular to rounded quartz, feldspar, rock fragments and some mica *Fines:* silt and clay, disseminated and binding deposit in places	3.9+	4.2

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
4	32	64	0.3- 1.5	5	6	18	11	16	29	15
			1.5- 2.5	4	4	10	16	28	27	11
			2.5- 4.2	2	5	10	16	13	46	8
			Mean	4	5	12	15	18	35	11

NO 77 NE 17 | 7967 7787 | **Wairds of Alpity**

Surface level c.+120m
Water struck at +115m
Section and pit
August 1989

Overburden 0.2
Mineral I 4.6+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; gravelly	0.2	0.2
Glacial sand and gravel	**Gravel;** 'clayey' in upper 1.1m to 1.3m with the appearance of a mass-flow deposit, thereafter weakly stratified gravels with a sandy matrix *Gravel:* coarse with fine and a little cobble, subangular to well-rounded quartzite, vein quartz, schists, grits, andesite and some red mudstone *Sand:* medium and coarse with some fine, subangular to well-rounded quartz, feldspar, rock fragments and some mica *Fines:* disseminated silt and clay	4.6+	4.8

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
6	38	56	0.2- 1.3	10	11	12	8	17	42	0
			1.3- 2.2	7	8	13	9	23	40	0
			2.2- 3.2	6	8	35	20	8	12	11
			3.2- 4.2	3	5	11	17	23	41	0
			4.2- 4.8	4	5	11	12	18	50	0
			Mean	6	8	17	13	18	36	2

NO 78 SW 1 | 7053 8049 | Den of Dash

Surface level c.+200m
Water not struck
Pit
August 1989

Overburden 0.3
Mineral II 3.2+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Old Red Sandstone	**Conglomerate**; massive weathered conglomerate with clasts up to 500mm; disaggregated and grading as gravel *Gravel:* coarse with fine and cobbles and some boulders, subangular to well-rounded, chiefly quartzite, but with some schist *Sand:* coarse with fine and medium, subangular to subrounded quartz, feldspar and rock fragments *Fines:* low, some clayey coats on clasts	3.2+	3.5

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
3	7	90	0.3- 1.3	7	3	5	7	20	58	0
			1.3- 2.3	3	0	1	5	36	49	6
			2.3- 3.5	1	0	1	2	16	40	40
			Mean	3	1	2	4	24	49	17

NO 78 SW 2 | 7131 8038 | Ruehill

Surface level c.+190m	Overburden 0.2m
Water not struck	Mineral 1.0m
Pit	Waste 0.3m+
August 1989	

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil; gravelly, sandy	0.2	0.2
Fluvioglacial sand and gravel	**Gravel**, dirty in top 0.3m with clayey coats on clasts. Becomes cleaner with depth, passing down into open framework gravel *Gravel:* coarse and fine with some cobbles and rare boulders, angular to well-rounded quartzite, schist and metasediments *Sand:* coarse and medium with some fine, angular to subrounded quartz, rock fragments and feldspar *Fines:* some disseminated silt and clay and coatings on grains and clasts in upper part of the deposit	1.0	1.2
Till	**Diamicton**; large cobbles and boulders in clay matrix, probably clast supported and very hard, massive. Clay matrix is moderate reddish brown (5R 4/6)	0.3+	1.5

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
7	25	68	0.2- 1.2	7	3	11	11	28	35	5

NO 78 SE 1 | 7555 8046 | Auchtochter

Surface level c.+105m	Overburden 0.6
Water not struck	Mineral I 0.7
Pit	Waste 0.4
August 1989	Mineral I 1.8+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; dark yellowish brown (10YR 5/4), silty, stony and clayey. Becomes increasingly stony with depth	0.6	0.6
Fluvioglacial sand and gravel	**a Gravel**; dirty, poorly sorted gravels with clasts up to 0.3m across *Gravel:* coarse and fine with some cobble and rare small boulders up to 0.3m, subangular to well-rounded quartzite, vein-quartz, schist, grits, psammite and volcanics *Sand:* coarse with medium and some fine, subangular to subrounded quartz, rock fragments and feldspar *Fines:* disseminated silt and clay, coating grains and clasts	0.7	1.3
	Diamicton; moderate reddish brown (10R 4/6), red sandstone clasts in a clay matrix	0.4	1.7
	b Gravel; massive, very coarse gravels with clasts up to 0.5m across in a coarse sand matrix *Gravel:* coarse with cobble and fine, subangular to well-rounded quartzite, vein-quartz, schist, grits, psammite and volcanics *Sand:* coarse with medium and some fine, subangular to subrounded quartz, rock fragments and feldspar *Fines:* disseminated silt and clay, coating grains and clasts	1.8+	3.5

NO 78 SE 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	2	40	58	0.6- 1.3	2	3	17	20	26	27	5
b	5	25	70	1.7- 2.7	5	7	7	6	10	31	34
				2.7- 3.5	5	5	10	17	15	36	12
				Mean	5	6	8	11	12	34	24
a&b	4	30	66	Mean	4	5	11	14	16	32	18

NO 78 SE 2 | 7628 8040 | **Mill of Glenbervie**

Surface level c +99m
Water not struck
250mm percussion
August 1989

Overburden	0.3
Mineral I	2.0
Waste	0.7
Bedrock	0.1+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; gravelly	0.3	0.3
Alluvium	**Gravel**; clast supported cobble gravel *Gravel:* coarse with fine and cobble, angular to subrounded with some well-rounded quartzite, mica schist, green sandstone, red porphyry, red and flesh coloured granite and andesitic lava *Sand:* coarse and medium with some fine, angular to subangular quartz, feldspar and rock fragments *Fines:* silt, disseminated, becoming clayey towards base	2.0	2.3
Till	**Diamicton**; clayey slurry retrieved	0.7	3.0
Old Red Sandstone	**Tuff**; greenish grey, with clasts of maroon lava less than 15mm in size; thoroughly decomposed	0.1+	3.1

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
6	25	69	0.3- 2.3	6	4	10	11	19	32	18

NO 78 SE 3 | 7710 8040 | Glenbervie Home Farm

Surface level c.+110m
Water not struck
Pit
August 1989

Overburden 0.4
Mineral I 1.6+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil; sandy loam with a few fine gravel sized clasts	0.4	0.4
Fluvioglacial sand and gravel	**Pebbly sand;** moderately well-stratified and well-sorted, clean, loose material. A band of very well-sorted fine gravel occurs between 1.8 and 2.0m *Gravel:* fine, angular to subrounded quartzite and vein-quartz with some mudstone and schist *Sand:* coarse and medium with a little fine, angular to subrounded quartz, rock fragments and feldspar *Fines:* very low, disseminated silt and clay Pit terminated at 2m due to bad collapsing of pit sides	1.6+	2.0

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
1	91	8	0.4- 1.4	1	6	54	37	2	0	0
			1.4- 2.0	1	6	22	52	19	0	0
			Mean	1	6	42	43	8	0	0

NO 78 SE 4 | 7848 8066 | **Orchard Hill, Drumlithie**

Surface level c.+118m
Water not struck
250mm percussion
August 1989

Overburden	0.3
Mineral I	3.1
Waste	3.8
Bedrock	0.7+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil; dark yellowish brown (10YR 5/4) silty, clayey loam	0.3	0.3
Glacial sand and gravel	**'Clayey' pebbly sand**; moderate reddish brown (10R 5/4), very 'clayey' in the top metre, but becoming cleaner with depth beyond 1.3m *Gravel:* fine with coarse, angular to subrounded vein-quartz, schist, mudstone, some volcanics and rare amphibolite *Sand:* medium with fine and some coarse, angular to subrounded, quartz, feldspar and rock fragments *Fines:* chiefly as disseminated silt and clay, but with some clay-bound masses in places	3.1	3.4
	Silt; moderate reddish brown (10R 5/4), with fine sand, laminated	0.8	4.2
Till	**Diamicton**; cohesive, sandy and gravelly matrix supported deposit with clasts up to 0.2m. Clasts are angular to subrounded, chiefly vein-quartz, decomposed red sandstone, volcanics and green chloritic material. Colour varies from moderate reddish brown (10R4/6) to moderate brown (5YR 3/4)	3.0	7.2
Old Red Sandstone	**Lava**; porphyritic andesite, greyish red-purple, fresh	0.7+	7.9

NO 78 SE 4

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
13	69	18	0.3- 1.3	21	42	22	8	6	1	0
			1.3- 2.5	9	15	31	19	15	11	0
			2.5- 3.4	9	14	35	20	16	6	0
			Mean	13	24	30	15	12	6	0

NO 78 SE 5 | 7869 8008 | **Pade O'France**

Surface level c. +85m
Water not struck
Pit
August 1989

Waste 4.2+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil; clayey, silty, smooth, pale brown (5YR 6/2)	0.4	0.4
Lacustrine alluvium	**Silt**; laminated clayey and fine-sandy silt, becoming less clayey with depth, grading into discrete laminated fine sand, clayey silt and clay. Colour varies from light brown (5YR 5/6) to moderate greyish reddish brown (10R 5/6). Whole deposit cut by rootlets.	1.3	1.7
	'Very clayey' sand/silt; non-mineral deposit of alternating silty clay and fine sand beds about 10mm thick. Moderate brown (5YR 4/4) to moderate greyish reddish brown (10R 5/6), becoming paler with depth. The thickness of the beds also increases with depth to a few centimeters	1.2	3.9
Till	**Diamicton**; moderate reddish brown (10R 4/6) stiff, sandy, stony clay with clasts up to large cobble and small-boulder size	0.3+	4.2

NO 78 SE 6	7909 8224	Pitdrichie

Surface level c.+134m	Overburden 0.3
Water not struck	Mineral I 3.5+
Pit	
August 1989	

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil; dark reddish brown, silty sandy loam	0.3	0.3
Glacial sand and gravel	**a Sandy gravel;** poorly sorted and stratified, with fines content increasing with depth *Gravel:* fine with coarse, subangular to rounded quartzite, vein-quartz and schist *Sand:* medium with coarse and some fine *Fines:* disseminated silt and clay, sufficient to bind the deposit in places below 0.8m	2.7	3.0
	b Pebbly sand; generally cleaner than above *Gravel:* fine with coarse, subangular to rounded, quartzite, vein-quartz and schist *Sand:* medium with coarse and some fine *Fines:* disseminated silt and clay	0.8+	3.8

NO 78 SE 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	7	58	35	0.3- 0.8	4	6	26	18	30	16	0
				0.8- 1.8	8	11	39	13	16	13	0
				1.8- 3.0	6	6	29	23	24	12	0
				Mean	7	8	32	18	22	13	0
b	5	88	7	3.0- 3.8	5	8	53	27	5	2	0
a&b	6	65	29	Mean	6	8	37	20	18	11	0

NO 78 SE 7	7987 8195	Pitdrichie Gravel Pit

Surface level c.+115m
Water not struck
Section and pit
August 1989

Overburden	0.2
Mineral I	3.9
Waste	0.4
Mineral I	3.2
Waste	0.9
Mineral I	11.6+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil;	0.2	0.2
Glacial sand and gravel	**a Sandy gravel**; cross-stratified, clast-supported and well-sorted gravel, reddish brown, with some interbeds of silty fine sand and sandy silt; interbeds are less than 30cm thick *Gravel:* fine with coarse *Sand:* coarse with some medium and a little fine *Fines:* disseminated silt and clay and in interbeds described above	1.4	1.6
	b 'Clayey'sand; ripple cross-laminated, with a trace of fine gravel, micaceous, moderate reddish brown *Sand:* fine with medium and a little coarse *Fines:* disseminated and in thin seams	2.5	4.1
	Silt; diamictic, micaceous, firm, moderate reddish brown with clasts, chiefly of red mudstone and some thin lenses of gravel	0.4	4.5
	c Gravel; clast supported *Gravel:* fine, coarse and cobble, angular to subrounded with well-rounded green-spotted red mudstone, quartzite, decomposed schist, vein-quartz, red gritstone and sandstone, schistose grit, basalt and granite gneiss *Sand:* coarse with some medium	3.2	7.7

	and fine, angular to subrounded quartz *Fines:* disseminated silt and clay		
	Clay; silty and stiff with fine to coarse sand, reddish brown, micaceous	0.9	8.6
Glacial sand and gravel	**d Pebbly sand**; cross-stratified with an 0.6m thick band of silty fine sand from 9.3 to 9.8m, crudely laminated *Gravel:* fine and coarse, angular to subrounded, composition as above *Sand:* coarse with medium and fine *Fines:* disseminated and concentrated in seams of micaceous fine sand and silt, less than 50mm thick	2.3	10.9
	e Sandy gravel; clast-supported, becoming less gravel-rich from 17.3m *Gravel:* fine with coarse and a little cobble, angular to subrounded, composition as above *Sand:* coarse and medium, with fine, angular to subrounded quartz and rock fragments *Fines:* disseminated silt and clay	9.3+	20.2

NO 78 SE 7

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	52	47	0.2- 1.6	1	4	15	33	30	17	0
b	13	87	0	1.6- 4.1	13	56	30	1	trace	0	0
c	3	35	62	4.5- 5.7	6	12	8	12	19	25	18
				5.7- 7.7	0	1	8	28	22	18	23
				Mean	3	5	8	22	21	20	21
d	5	79	16	8.6- 9.3	2	5	26	46	12	9	0
				9.3- 9.8	15	78	7	0	0	0	0
				9.8-10.9	2	5	26	46	12	9	0
				Mean	5	21	22	36	9	7	0
e	4	63	33	10.9-12.0	1	3	13	32	22	29	0
				12.0-13.5	4	6	15	28	22	19	6
				13.5-14.5	5	11	15	22	23	18	6
				14.5-15.5	6	21	18	22	21	12	0
				15.5-17.3	7	19	22	22	19	11	0
				17.3-18.6	2	7	57	22	9	3	0
				18.6-20.2	1	5	30	46	15	3	0
				Mean	4	10	25	28	18	13	2
a-e	5	63	32	Mean	5	16	21	26	16	12	4

NO 78 SE 8 | 7899 8095 | **Drumlithie**

Surface level c.+96m
Water struck at +90m
Section and pit
August 1989

Mineral I 5.4+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
Glacial sand and gravel	a **Pebbly sand**; cross-stratified, well-sorted *Gravel:* fine with a little coarse, angular to subangular quartzite, vein-quartz, schist, grit and some granitic and volcanic clasts *Sand:* medium with coarse and some fine, angular to subangular quartz, feldspar and rock fragments *Fines:* disseminated silt and clay	0.5	0.5
	b **Gravel**; massive, poorly-stratified cobble gravels with clasts in excess of 0.2m in size *Gravel:* coarse with fine and some cobble, angular to subrounded quartzite, vein-quartz, schist and grit *Sand:* coarse with medium and a little fine, angular to subrounded quartz, feldspar and rock fragments *Fines:* clay coats on clasts and grains, yellowish brown Pit terminated in wet, collapsing gravels	4.9+	5.4

NO 78 SE 8

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	81	15	0.0- 0.5	4	7	41	33	14	1	0
b	2	22	76	0.5- 2.2	1	3	10	17	29	29	11
				2.2- 3.2	3	1	9	15	24	34	14
				3.2- 4.2	3	1	4	11	30	38	13
				4.2- 5.4	2	1	4	8	23	62	0
				Mean	2	2	7	13	27	40	9
a&b	2	27	71	Mean	2	2	10	15	26	37	8

NO 78 SE 9	7903 8056	**Drumlithie**

Surface level c.+105m
Water not struck
250mm percussion
August 1989

Overburden	3.1
Mineral	9.1
Waste	1.1
Bedrock	0.2+

LOG

Geological classification	**Lithology**	**Thickness**	**Depth**
	Soil; dark reddish brown, sandy, clayey with some fine-gravel sized clasts, chiefly of red mudstone	0.3	0.3
Flow-till	**Diamicton**; clay, moderate reddish brown (10R 5/4), with disturbed, contorted sandy and gravelly bands throughout. Clasts abundant, chiefly red mudstone with some quartzite and weathered schist. Deposit becomes more gravel-rich from 1.7m, but gravels alternate with clay-rich horizons.	2.9	3.1
Glacial sand and gravel	**Pebbly sand**; clayey in top 0.3m with abundant red mudstone clasts; becomes cleaner from 3.4m. Gravelly from 8.5m to 9.5m *Gravel:* fine with a little coarse, subangular to subrounded vein-quartz, quartzite, some granitic fragments, schist, grits and red mudstone with some andesite *Sand:* medium with fine and some coarse, subangular to subrounded quartz, feldspar and rock fragments *Fines:* disseminated silt and clay for most part, but concentrated in bands in places between 3.1 and 5.3m and between 8.5 and 9.5m	6.4	9.5
	'Clayey' sand; contains a very small amount of gravel, composition as above; characterised by alternating silty and sandy laminae; fines content increases with depth.	2.7	12.2

?Flow-till	**Diamicton**; contorted clay-bound coarse sand with dark grey to black flecking; stiff, with clasts up to coarse-gravel size	0.1	12.3
	Gravel; large cobbles in a silty sand matrix	0.2	12.5
	Silt; sandy, clayey, firm and micaceous; moderate reddish brown (10R 5/4)	0.2	12.7
Till	**Diamicton**; clay, moderate reddish brown (10R 5/4) with sandy bands and fragments of rotted andesite	0.6	13.3
Old Red Sandstone	Lava; rotted, dark grey-green, porphyritic	0.2+	13.5

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	7	84	9	3.1- 4.3	6	21	59	7	5	2	0
				4.3- 5.3	8	35	40	13	4	0	0
				5.3- 6.7	5	25	59	7	3	1	0
				6.7- 7.2	No grading data available						
				7.2- 8.5	9	14	50	16	7	4	0
				8.5- 9.5	7	15	30	25	18	5	0
				Mean	7	22	49	13	7	2	0
b	16	83	1	9.5-10.7	14	51	29	5	1	0	0
				10.7-11.7	14	39	42	4	1	0	0
				11.7-12.2	26	52	17	3	1	1	0
				Mean	16	47	32	4	1	trace	0
a&b	10	83	7	Mean	10	29	44	10	5	2	0

NO 78 SE 10 7958 8004 Candy

Surface level c.+95m
Water struck at +86m
250mm percussion
August 1989

Overburden	1.3
Mineral II	1.7
Waste	0.2
Mineral I	9.6
Waste	3.4
Bedrock	0.2+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil;	0.3	0.3
Flow-till	**Diamicton;** moderate reddish brown (10R 4/6) micaceous sandy clay, stiff, becoming softer with depth and with a crudely laminated sandy silt horizon from 1.0-1.2m. Clasts angular to well-rounded, up to large-boulder size	1.0	1.3
	a 'Very clayey'sand; thinly interbedded sequence of silty sands, micaceous silts, pebbly sands and massive silts with 10 to 30mm seams of sandy clay diamicton. Chiefly reddish brown, but yellowish brown in places *Sand:* fine with some medium and a little coarse *Fines:* disseminated silt and clay and concentrated in thin diamicton and silt beds	1.7	3.0
	Silt; massive, reddish brown	0.2	3.2
Glacial sand and gravel	**b 'Clayey' sand;** mixed silty and clayey sequence of micaceous sands, particularly silty and clayey between 7.1 and 9.1m. Cleaner again from 9.1 to 12.8m, with a trace of gravel. Reddish brown *Sand:* fine with medium and a little coarse *Fines:* disseminated silt and clay and concentrated in silty seams and laminae	9.6	12.8

Flow-till	**Silt**; micaceous, crudely laminated, reddish brown	0.1	12.9
	Diamicton; sandy clay, clayey silt, sand and gravel. Individual beds less than 150mm thick with crude lamination and discrete seam of diamicton. Moderate reddish brown, micaceous	1.1	14.0
	Gravel; cobbles with coarse and fine, chiefly well-rounded (derived from Old Red Sandstone Conglomerate) with red mudstone	0.4	14.0
	Pebbly fine sandy silt with gravelly seams	0.7	15.8
Till	**Diamicton**; firm to stiff, with silty sandy clay matrix. Subangular to subrounded clasts up to 100mm, chiefly quartzite, decomposed coarse-grained sandstone and clasts from the Old Red Sandstone conglomerate	0.4	16.2
Old Red Sandstone	**Sandstone**; medium grained, micaceous, quartzo-feldspathic, light grey (N7) with thin seams of moderate reddish brown clay (? penetration fissures)	0.2+	16.4

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	32	65	3	1.3- 3.0	32	47	14	4	3	0	0
b	18	81	1	3.2- 4.2	12	61	26	1	0	0	0
				4.2- 5.7	12	60	27	1	0	0	0
				5.7- 7.1	16	68	16	0	0	0	0
				7.1- 9.1	39	58	3	0	0	0	0
				9.1-10.7	13	48	39	0	0	0	0 $
				10.7-12.8	10	40	46	2	2	0	0 $
				Mean	18	54	26	1	1	trace	0
a&b	20	79	1	Mean	20	54	24	1	1	trace	0

NO 87 NW 1 | **8021 7972** | **Thriepland**

Surface level c.+88m
Water not struck
250mm percussion
August 1989

Overburden 0.3m
Mineral I 1.9m
Waste 3.3m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly	0.3	0.3
Glacial sand and gravel	**Gravel**, clast-supported, dense *Gravel:* cobbles, coarse and fine, some boulders crushed, either subangular to subrounded or well rounded, quartzite and andesite lava with schist and gritstone *Sand:* medium to coarse with fine, subangular to subrounded rock chips and quartz. Little mica. *Fines:* silt, disseminated, moderate reddish brown	1.9	2.2
Glaciolacustrine deposit	**Silt**, with some fine sand, micaceous, massive, moderate reddish brown	2.0	4.2
Till	**Diamicton**; stiff sandy silty clay matrix, micaceous, with subangular to subrounded clasts <500mm of quartzite, lava, sandstone and some rotten gneiss, moderate reddish brown	1.3+	5.5

NO 87 NW 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
4	26	70	0.3- 1.1	2	3	13	14	20	33	15
			1.1- 2.2	5	6	9	10	12	32	26
			Mean	4	5	10	11	16	33	21

NO 87 NW 2 | 8071 7774 | Nether Craighill

Surface level c.+106m
Water not struck
Pit
August 1989

Overburden 0.2m
Mineral I 3.1m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Glacial sand and gravel	**Gravel**, clast-supported, dense, poorly sorted, crude horizontal stratification *Gravel:* cobbles, coarse and fine, boulders <300mm, either subangular to subrounded or well-rounded, quartzites, vein-quartz, gneiss, basalt, porphyritic andesite, red silty sandstone, red mudstone and granite *Sand:* medium and coarse with fine, angular to subrounded rock chips and quartz, reddish brown *Fines:* silt, disseminated	3.1+	3.3

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
2	22	76	0.2- 1.7	2	4	5	5	12	23	49
			1.7- 3.3	1	4	14	12	17	40	12
			Mean	2	4	10	8	15	32	29

NO 87 NW 3 | 8080 7733 | Nether Craighill

Surface level c.+114m	Overburden 0.1m
Water not struck	Mineral I 6.2m
250mm percussion	Waste 4.7m+
August 1989	

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil	0.1	0.1
Glacial sand and gravel	**Gravel**, no recovery below 5.3m *Gravel:* coarse and fine with cobbles and boulders, especially above 1.0m and below 5.3m, angular to well-rounded, quartzite, gritty psammite, lava (andesite), tuff, vein-quartz, schist and some amphibolite, diorite, red mudstone and red volcanoclastics *Sand:* medium to coarse with fine, angular to subangular quartz, feldspar, rock chips and some ferromagnesian minerals *Fines:* silt and clay, disseminated and as coatings, also rarely in seams of silty fine sand. Moderate reddish brown. Discrete seam of moderate reddish brown (10R 5/4) diamicton between 1.0 and 1.2m	6.2	6.3
Flow-till	**Diamictic sand and gravel?**, poor recovery. Retrieved as angular to subangular fragments of quartzite, andesite, basalt, gritty psammite and vein-quartz in a moderate reddish brown sandy silty clay slurry	1.7	8.0
Till	**Diamicton**; sandy clay matrix, moderate reddish brown (10R 5/4), possibly partially clast-supported	3.0+	11.0

NO 87 NW 3

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
8	38	54	0.1- 1.0	7	7	14	11	16	25	20
			1.0- 1.2	No grading data available						
			1.2- 2.5	9	10	23	16	22	20	0
			2.5- 3.7	12	14	19	14	21	20	0
			3.7- 4.6	7	5	11	11	19	29	18
			4.6- 5.3	6	4	11	12	17	35	15
			5.3- 6.3	No grading data available						
			Mean	8	9	16	13	20	25	9

NO 87 NE 1	8598 7925	Upper Mains of Catterline

Surface level c.+76m
Water not struck
Pit
August 1989

Overburden 0.1m
Mineral 6.4m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.1	0.1
Glacial sand and gravel	**a Gravel**, fining downwards but gravel lag at base *Gravel:* cobbles, coarse and fine, either well rounded or subangular to subrounded, lava, red mudstone, granite, gneiss, quartzite, vein-quartz and schist *Sand:* medium with fine and some coarse, quartz and feldspar, reddish brown *Fines:* silt, disseminated and as discrete seams	1.6	1.7
	b Sand, fine horizontal stratification *Gravel:* rare pebbles *Sand:* medium with fine above 2.8m, fine with medium below, laminae of coarse, soft, buff coloured. Sharp break at 2.8m *Fines:* clean above 2.8m, some seams of reddish brown micaceous silt below	3.1	4.8
	c 'Clayey' sand, unstratified *Sand:* mainly fine with some medium, soft, buff coloured *Fines* silt, disseminated	1.7+	6.5

NO 87 NE 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	2	48	50	0.1- 1.7	2	15	25	8	14	22	14
b	5	93	2	1.7- 2.8	1	24	67	6	1	1	0
				2.8- 4.8	7	59	30	3	1	0	0
				Mean	5	46	43	4	1	1	0
c	14	86	0	4.8- 5.8	10	70	18	1	1	0	0
				5.8- 6.5	19	78	3	0	0	0	0
				Mean	14	73	12	1	trace	0	0
a-c	7	80	13	Mean	7	46	30	4	4	6	3

NO 87 NE 2 | 8521 7907 | **Brigstanes**

Surface level c.+75m
Water not struck
Section and pit
August 1989

Overburden 0.3m
Mineral I 6.7m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, sandy	0.3	0.3
Glacial sand and gravel	**a Pebbly sand**, well stratified with gravel lag at base, loose *Gravel:* coarse and fine, subangular to well rounded lava, red mudstone, granite, gneiss, quartzite, vein-quartz and schist *Sand:* chiefly medium with some fine and coarse, angular to subangular rock chips, quartz and feldspar, buff-coloured *Fines:* very little	1.8	2.1
	b Sand, fining downwards, loose *Sand:* chiefly fine with some medium, some laminae of rock grains above 4.5m, otherwise quartzose, soft, some mica below 4.5m *Fines:* clean above 4.5m, disseminated silt below, buff coloured	4.9+	7.0

NO 87 NE 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
a	1	84	15	0.3- 2.1	1	11	64	9	5	10	0
b	5	95	0	2.1- 4.5	4	63	33	0	0	0	0
				4.5- 7.0	5	75	20	0	0	0	0
				Mean	5	68	27	trace	trace	0	0
a&b	4	92	4	Mean	4	52	37	3	1	3	0

NO 87 NE 3 | 8552 7818 | **Purlieknowe**

Surface level c.+91m
Water struck at c+85.9m
Section and pit
August 1989

Overburden	0.4m
Mineral I	2.2m
Waste	0.5m
Mineral I	3.0m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, gravelly	0.4	0.4
Glacial sand and gravel	**a Gravel**, clast-supported *Gravel:* fine and coarse, rare cobbles <200mm, either angular to subangular or well rounded, purple porphyritic andesite/basalt lava (some rotten), pink porphyry, gneiss, quartzite, fragments of lithified conglomerate and rare mudstone *Sand:* medium with fine and coarse, angular to subangular rock, quartz and feldspar *Fines:* silt disseminated. Rare clay drapes	2.2	2.6
	Fine sandy silt, firm, massive, micaceous, reddish brown	0.5	3.1
	b Pebbly sand, cross-stratified *Gravel:* some fine pebbles, as above *Sand:* chiefly medium with some coarse and fine, as above with a little mica *Fines:* quite clean	2.0	5.1
	c Gravel *Gravel:* cobbles, coarse and fine, as above *Sand:* medium with coarse and some fine, sharp, rusty brown, otherwise as above *Fines:* silt, disseminated	1.0+	6.1
	Pit caving in below water-table		

NO 87 NE 3

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	5	30	65	0.4- 2.6	5	7	16	7	35	30	0
b	2	90	8	3.1- 5.1	2	9	73	8	6	2	0
c	1	46	53	5.1- 6.1	1	8	25	13	22	22	9 S
a-c	3	56	41	Mean	3	8	40	8	21	18	2

NO 87 NE 4 | 8535 7692 | **Fernyflatt**

Surface level c.+103m	Overburden 0.3m
Water not struck	Mineral ?I 3.7m
250mm percussion	Bedrock 2.0m+
September 1989	

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, gravelly	0.3	0.3
Glacial sand and gravel (? ice-disturbed conglomerate)	**Gravel**, clast-supported, dense, poor recovery *Gravel:* cobbles, coarse and fine, some boulders crushed, subangular to well rounded, quartzite, vein-quartz, lava, grit and schist *Sand:* medium to coarse with fine, angular to subrounded, quartz and rock chips *Fines:* silt and clay disseminated and coating grains, loosely binding deposit. Some fines produced by chiselling weak clasts.	3.7	4.0
Old Red Sandstone	**Conglomerate**, possibly weathered above 5.5, and more lithified below, very poor recovery owing to continuous chiselling Borehole abandoned in bedrock	2.0+	6.0+

NO 87 NE 4

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
8	38	54	0.3- 2.0	7	8	21	18	13	25	8
			2.0- 4.0	10	8	12	11	14	27	18
			Mean	8	8	16	14	13	28	13

NO 87 NE 5 | 8630 7967 | **Denhead**

Surface level c.+71m	Overburden 0.2m
Water struck at c.+66.2m	Mineral I 10.2m
250mm percussion	Waste 0.6m
September 1989	Mineral I 0.6m
	Waste 0.7m
	Mineral I 1.2m
	Waste 0.7m
	Mineral I 0.7m
	Waste 2.3m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil	0.2	0.2
Glacial sand and gravel	**a Sandy gravel** *Gravel:* fine and coarse with some cobbles and small boulders, subangular to well rounded, psammite, gritstone, lava (andesite) and some vein-quartz *Sand:* medium with coarse and some fine, angular to subrounded quartz, feldspar and rock chips *Fines:* some silt, disseminated and as coatings, becoming cleaner below 2.2m, dark reddish brown (10R 3/4) to moderate reddish brown (10R 5/6)	10.2	10.4
Glaciolacustrine deposit	Clay, plastic, firm, moderate reddish brown (10R 5/6), some well rounded pebbles	0.6	11.0
Glacial sand and gravel	**b Sandy gravel** *Gravel:* cobbles, coarse and fine, as above *Sand:* fine to coarse, poorly sorted *Fines:* silt and clay slurry	0.6	11.6
Glaciolacustrine deposit	Clay, fissile, very firm, moderate reddish brown	0.7	12.3
Glacial sand and gravel	**c Sand** *Sand:* fine with some medium, as above *Fines:* silt, disseminated, moderate reddish brown	1.2	13.5

Glaciolacustrine deposit	Clay, silty, stiff, moderate reddish brown to yellowish brown in siltier parts	0.7	14.2
Glacial sand and gravel	**d Sand** *Sand:* fine with medium, as above *Fines:* silt, disseminated, moderate reddish brown	0.7	14.9
Glaciolacustrine deposit	Silty clay with some fine sand, firm, moderate reddish brown	0.4	15.3
Till	Diamicton; very stiff silty sandy clay matrix, subangular to subrounded clasts, especially maroon lava	1.9+	17.2

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	
a	2	52	46	0.2- 1.2	3	5	28	15	24	25	0	
				1.2- 2.2	3	6	26	18	21	26	0	
				2.2- 3.4	3	5	28	13	21	23	7	
				3.4- 4.8	3	6	36	10	23	22	0	
				4.8- 5.8	1	4	24	14	30	27	0	S
				5.8- 6.8	1	4	21	19	31	18	6	S
				6.8- 7.8	1	3	24	23	29	20	0	S
				7.8- 8.8	1	3	26	24	25	21	0	S
				8.8-10.4	1	4	37	29	19	10	0	S
				Mean	2	5	28	19	24	21	1	
b	9	48	43	11.0-11.6	9	15	17	16	17	22	4	S
c	6	94	0	12.3-13.5	6	64	29	1	trace	0	0	S
d	3	97	0	14.2-14.9	3	53	44	trace	trace	0	0	S
a-d	3	58	39	Mean	3	13	29	16	20	18	1	

NO 87 NE 6 **8659 7776** **Harvieston**

Surface level c.+44m
Water not struck
250 and 200mm percussion
September 1989

Overburden 2.4m
Mineral I 9.2m
Waste 0.7m
Bedrock 0.3m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Glacial sand and gravel	**Fine sandy silt** with laminae of clay, finely laminated, greyish orange (10YR 7/4) to moderate reddish brown (10R 4/6)	2.0	2.4
	a 'Very clayey' sand *Sand:* chiefly fine with some medium, soft, angular to subrounded quartz, feldspar and lithic grains, quite micaceous *Fines:* silt, disseminated and in discrete seams, moderate brown (5YR 5/4)	6.0	8.4
	b Sand *Sand:* fine with medium, otherwise as above *Fines:* silt, disseminated, but less than above	3.2	11.6
Till	**Diamicton;** firm sandy clay matrix with clasts up to cobble size, greyish red (10R 4/2), to dark reddish brown (10R 3/4)	0.7	12.3
Old Red Sandstone	**Sandstone,** tuffaceous, badly weathered, greyish purple (5P 4/2) to very dusky red purple (5RP 2/2)	0.3+	12.6

NO 87 NE 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	23	77	0	2.4- 4.3	26	71	3	0	0	0	0
				4.3- 6.3	18	69	13	0	0	0	0
				6.3- 8.4	25	60	14	1	0	0	0
				Mean	23	67	10	trace	0	0	0
b	7	93	0	8.4-10.4	7	62	30	1	0	0	0
				10.4-11.6	7	66	27	0	0	0	0
				Mean	7	64	29	trace	trace	0	0
a&b	17	83	0	Mean	17	66	17	trace	trace	0	0

NO 88 SW 1	8074 8438	West Carmont

Surface level c.+120m
Water not struck
Pit
August 1989

Overburden 0.1m
Mineral I 3.8m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil	0.1	0.1
Glacial sand and gravel	**a 'Very clayey'sand** *Sand:* fine, micaceous, finely laminated, reddish brown, firm *Fines:* silt	0.8	0.9
	b Sandy gravel, well bedded *Gravel:* fine and coarse with some cobbles, either well rounded or subangular to subrounded quartzites, vein-quartz, porphyry, granite and schist *Sand:* medium with coarse and fine, angular to subangular rock chips, quartz and feldspar *Fines:* little	2.0	2.9
	c, **'Clayey' sand**, massive *Gravel:* rare pebbles *Sand:* mainly fine, micaceous, reddish brown *Fines:* silt	1.0+	3.9

NO 88 SW 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	28	71	1	0.1- 0.9	28	65	4	2	1	trace	0
b	3	63	34	0.9- 1.9	5	10	24	21	15	14	11
				1.9- 2.9	2	10	41	17	19	11	0
				Mean	3	10	34	19	17	12	5
c	16	80	4	2.9- 3.9	16	69	8	3	2	2	0
a-c	12	68	20	Mean	12	37	20	11	10	7	3

NO 88 SW 2 | **8002 8129** | **Clearymuir**

Surface level c.+101m
Water struck at c.+86.3m
250mm and 200mm percussion
July 1989

Overburden 2.5m
Mineral I 20.4m
Bedrock 0.1m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.1	0.1
Glacial sand and gravel	**Boulder-gravel**, clast-supported, no sample recovered	2.0	2.1
Flow-till	**Gravel**, very silty, partially matrix-supported	0.4	2.5
Glacial sand and gravel	**a 'Very clayey' sand** *Sand:* mainly fine with some medium, several fining-downwards sequences, angular to subangular quartz, feldspar and lithic grains, quite micaceous in siltier parts. *Fines:* silt and clay, disseminated, moderate reddish brown (10R 5/6). Thin seams (50-100mm) of diamictic pebbly clay between 3.0 and 3.6m. Some thin seams of silty clay and micaceous silt below 6.5m	15.5	18.0
	b 'Clayey' pebbly sand *Gravel:* fine with coarse and scattered cobbles, angular to subangular quartzite, vein-quartz, schist and gritty psammite with red weathered lava/agglomerate and some granite *Sand:* medium to fine with trace of coarse, quite variable, angular to subangular quartz, feldspar and rock chips with some mica and ferro-magnesian minerals *Fines:* silt and clay, disseminated and in some silty seams. Greyish red (10R 4/2)	4.9	22.9
Old Red Sandstone	**Tuffaceous sandstone**, clay-matrix, weak, dark reddish brown (10R 3/4)	0.1+	23.0

NO 88 SW 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	
a	20	80	0	2.5- 3.6	12	47	38	1	1	1	0	
				3.6- 4.8	19	66	15	0	0	0	0	
				4.8- 6.5	18	77	5	0	0	0	0	
				6.5- 7.5	14	83	3	0	0	0	0	
				7.5- 8.7	35	51	14	0	0	0	0	
				8.7- 9.7	20	45	35	0	0	0	0	
				9.7-12.0	15	75	10	0	0	0	0	
				12.0-13.3	19	72	9	0	0	0	0	
				13.3-14.2	16	60	24	0	0	0	0	
				14.2-16.0	30	59	11	0	0	0	0	$
				16.0-17.0	31	64	5	0	0	0	0	$
				17.0-18.0	14	47	39	0	0	0	0	$
				Mean	20	64	16	trace	trace	trace	0	
b	11	77	12	18.0-19.0	10	26	60	2	1	1	0	$
				19.0-20.0	4	11	39	21	20	5	0	$
				20.0-21.0	9	28	58	2	1	2	0	$
				21.0-22.0	18	45	36	1	0	0	0	$
				22.0-22.9	15	39	13	4	11	8	10	$
				Mean	11	30	41	6	7	3	2	
a&b	18	79	3	Mean	18	55	22	2	2	1	**	

NO 88 SW 3 | 8176 8458 | East Carmont

Surface level c.+111m
Water not struck
Pit
August 1989

Overburden 0.1m
Mineral I 3.7m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.1	0.1
Glacial sand and gravel	**Sandy gravel**, coarsening downwards *Gravel:* cobbles, coarse and fine, some boulders <250mm, subangular to well rounded quartzites, granite, schist, basalt, red porphyry, vein-quartz, gneiss and some red mudstone. Some schists rotten *Sand:* medium with fine becoming mostly medium below 2.0m, angular to subangular, rock chips and quartz, a little mica, reddish brown *Fines:* silt, disseminated	3.7+	3.8

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
2	59	39	0.1- 2.0	3	20	53	9	7	8	0
			2.0- 3.8	1	6	20	8	7	36	22
			Mean	2	13	38	8	7	21	11

NO 88 SW 4	8186 8409	Garbertstrypes

Surface level c.+142m
Water struck at c.+131.5m
Section and pit
August 1989

Mineral I 10.7m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
Glacial sand and gravel	**a Degraded face in sand and gravel**, not sampled	5.0	5.0
	b Gravel, clast-supported, dense, poorly sorted, crude sub-horizontal bedding *Gravel:* cobbles, coarse and fine, some boulders <300mm, generally angular to subangular with well rounded, grey sandstone, quartzites, vein-quartz, andesite, schist, red porphyry with some basalt and rotten tuff *Sand:* coarse with medium and some fine, angular to subangular rock chips with quartz and feldspar *Fines:* silt and clay, disseminated and forming some clay-bound seams. Some micaceous clayey silt-rich seams. Moderate reddish brown	5.7+	10.7
	Surface of underlying till thought to be close to bottom of pit.		

NO 88 SW 4

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					No grading data available for this deposit						
b	4	26	70	5.0- 7.0	5	6	13	13	19	26	18
				7.0- 8.8	4	3	7	14	23	21	28
				8.8-10.7	3	2	6	13	30	41	5
				Mean	4	4	9	13	24	29	17

NO 88 SW 5 | 8176 8360 | Den of Luckyfeal/Witch Pots

Surface level c.+180m
Water not struck
Amalgamated log of two pits
August 1989

Overburden 0.2m
Mineral I 6.6m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Glacial sand and gravel	Gravel, clast-supported, very dense *Gravel:* cobbles, coarse and fine with boulders <400mm, either well rounded or angular to subrounded, quartzites, porphyritic andesite/basalt, vein-quartz, gneiss, schist with some red mudstone and tuffaceous sandstone *Sand:* medium with fine and coarse, angular to subangular rock chips, quartz and feldspar, very little mica, quite variable in grade and sorting *Fines:* silt, disseminated. Rare thin seams of reddish brown micaceous silt.	6.6+	6.8

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
3	45	52	0.2- 1.4	6	17	25	10	10	9	23
			1.4- 3.5	2	4	9	7	12	31	35
			3.5- 5.0	3	19	46	11	10	11	0
			5.0- 6.8	3	12	19	10	16	19	21
			Mean	3	12	24	9	12	19	21

NO 88 SW 6 | 8233 8440 | Foggie Brae

Surface level c.+129m	Overburden 2.0m
Water not struck	Mineral I 6.3m
250mm and 200mm percussion	Waste 2.1m+
July 1989	

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil	0.2	0.2
Flow-till	**Diamicton;** firm to stiff sandy clay matrix, cohesive, with angular to well rounded clasts <150mm of andesitic lava, quartzite and some rotten green schist. Stratified. Moderate reddish brown. Micaceous	1.8	2.0
Glacial sand and gravel	**a Sand,** clay-bound and gravelly in top 0.9m, becoming sandy downwards. Moderate reddish brown (10R 4/6) to moderate brown (5YR 4/4) *Gravel:* coarse and fine, cobbles <100mm, as below *Sand:* medium with some fine and coarse, angular to subangular, quartz and rock chips with a little mica *Fines:* some silt, disseminated	2.4	4.4
	b Gravel, bedded *Gravel:* coarse and fine with cobbles <150mm, either well rounded or subangular to sub rounded, porphyritic lava, quartzite, psammite, vein-quartz with some micaceous red sandstone and rotten schist. Fine gravel more angular than coarse *Sand:* medium to coarse with some fine, quite variably sorted, subangular to subrounded quartz and rock chips with some mica *Fines:* 20mm-seam of cohesive diamictic sandy clay at 6.3m, otherwise disseminated silt and clay, reddish brown	3.9	8.3

Flow-till	**Diamicton**; sandy clay to clayey fine to coarse-grained sand matrix recovered as slurry. Angular to well rounded clasts of andesite and quartzite with some flesh-coloured granite. ?clast-supported in part. Moderate reddish brown (10R 4/6)	2.1+	10.4

Borehole terminated owing to slow progress

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	8	78	14	2.0- 2.9	12	9	30	16	16	17	0
				2.9- 4.4	5	10	75	8	1	1	0
				Mean	8	9	58	11	7	7	0
b	5	41	54	4.4- 5.6	5	4	25	13	19	28	6
				5.6- 7.0	5	7	16	16	34	22	0
				7.0- 8.3	6	6	18	18	21	27	4
				Mean	5	6	19	16	25	26	3
a&b	6	55	39	Mean	6	7	34	14	18	19	2

NO 88 SW 7 | **8246 8387** | **Brucklaywaird**

Surface level c.+151m
Water not struck
250mm and 200mm percussion
July 1989

Overburden 0.4m
Mineral I 13.1m
Waste 4.0m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, gravelly	0.4	0.4
Glacial sand and gravel	**a Gravel, probably** clast-supported *Gravel:* cobbles, coarse and fine, some boulders >250mm, rounded to well rounded quartzite, purple andesite, vein-quartz and some acid volcanics *Sand:* fine to coarse, poorly sorted, angular to subrounded rock chips and quartz with some mica *Fines:* silt, disseminated, moderate brown (5YR 4/4)	5.8	6.2
	b 'Clayey' sandy gravel, stratified with some clast-supported seams *Gravel:* coarse and fine with scattered cobbles <100mm, well-rounded quartzites and psammites and angular andesite. Some red mudstone *Sand:* fine to medium with some coarse, variable sorting but generally fining downwards, micaceous, otherwise as above *Fines:* silt, disseminated and as seams (<15mm) of fine sandy silt and clayey silt. Rare seams of plastic clay towards base. Moderate reddish brown	5.0	11.2
	c 'Clayey' sand, finely stratified *Gravel:* scattered coarse and fine pebbles, as above *Sand:* fine to medium with a trace of coarse, micaceous, otherwise as above	2.3	13.5

	Fines: silt, disseminated and in seams, becoming more abundant downwards		
Glaciolacustrine deposit	**Interstratified diamictic silty fine sand, fine sandy silt and plastic silty clay.** Gravelly at base. Quite micaceous and laminated in parts. Moderate reddish brown (10R 4/6). Scattered angular to subangular clasts up to cobble size, especially of biotite-chlorite schist	3.1	16.6
Till	**Diamicton;** very stiff, sandy silty clay matrix, moderate reddish brown, with clasts <64mm of angular andesite and well-rounded quartzite, psammite, jasper and schist	0.9+	17.5
	Borehole terminated owing to slow progress		

Grading

	Mean for Deposit percentages			Depth below surface (m)	percentages						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
				from to	-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
a	7	27	66	0.4- 2.5	No grading data available						
				2.5- 6.2	7	7	11	9	16	24	26
				Mean	7	7	11	9	16	24	26
b	10	64	26	6.2- 7.5	12	25	36	5	7	8	7
				7.5- 8.6	15	47	28	4	3	3	0
				8.6- 9.6	9	22	21	8	13	27	0
				9.6-11.2	5	22	32	9	11	21	0
				Mean	10	28	29	7	9	15	2
c	13	83	4	11.2-12.5	10	41	35	7	5	2	0
				12.5-13.5	18	41	37	3	1	0	0
				Mean	13	42	36	5	3	1	0
a-c	9	51	40	Mean	9	21	23	7	11	17	12

NO 88 SW 8 | 8371 8238 | Criggie Smithy (Former)

Surface level c.+129m
Water struck at c.+113.8m
250mm and 200mm percussion
July 1989

Overburden 0.3m
Mineral I 16.5m
Waste 2.4m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly	0.3	0.3
Glacial sand and gravel	a **Gravel**, well bedded, part clast-supported *Gravel:* coarse and fine with some cobbles <150mm, subangular to subrounded andesite with some red sandstone and mudstone. Well rounded quartzite, psammite, vein-quartz and flesh-coloured granite *Sand:* medium with coarse and some fine, angular to subangular quartz and rock chips *Fines:* some disseminated silt. Reddish brown	3.4	3.7
	b **Pebbly sand**, well bedded and sorted *Gravel:* coarse and fine, as above *Sand:* fine to medium with coarse, quite variable, soft, micaceous, otherwise as above *Fines:* silt, disseminated and in seams, especially at 4m and 7.9m, moderate reddish brown	6.3	10.0
	c **'Clayey' sand** *Gravel:* scattered pebbles above 11m *Sand:* fine with medium, well sorted, angular to subrounded clear and red-stained quartz with lithic grains. A little mica *Fines:* silt, disseminated and in crudely laminated seams (<150mm) above 12m and below 15m. Reddish brown above 13.6m, orangey brown below	6.8	16.8

Glaciolacustrine deposit	**Interstratified silty fine sand and fine sandy silt,** crudely laminated, micaceous, some graded beds	0.3	17.1
Flow-till	**Diamictic fine sandy silt to silty clay**	0.2	17.3
Till	**Diamicton;** firm to stiff sandy clay matrix, becoming stiffer downwards, with clasts <150mm of A tuffaceous sandstone and well-rounded quartzites, psammite and vein-quartz. Moderate reddish brown (10R 4/6)	1.9+	19.2

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
a	4	40	56	0.3- 1.5	3	10	21	14	16	28	8
				1.5- 2.5	5	7	22	14	19	25	8
				2.5- 3.7	5	8	16	12	24	35	0
				Mean	4	8	19	13	20	31	5
b	7	73	20	3.7- 5.1	12	28	35	10	6	9	0
				5.1- 6.4	6	17	29	25	12	11	0
				6.4- 7.6	5	33	40	7	9	6	0
				7.6- 8.7	8	24	30	14	11	13	0
				8.7-10.0	5	29	31	15	11	9	0
				Mean	7	26	33	14	10	10	0
c	11	89	0	10.0-12.0	12	46	38	2	1	1	0
				12.0-13.6	9	55	36	0	0	0	0
				13.6-15.0	10	57	33	0	0	0	0
				15.0-16.8	13	57	30	0	0	0	0
				Mean	11	54	34	1	trace	trace	0
a-c	8	73	19	Mean	8	34	31	8	8	10	1

NO 88 SE 1 | 8539 8305 | **Lochburn Quarry**

Surface level c.+117m
Water not struck
Section and pit
August 1989

Overburden 0.3
Mineral II 3.5m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, very gravelly, well rounded clasts	0.3	0.3
Conglomerate (Old Red sandstone)	**Gravel**, ice-disturbed conglomerate, very dense, becoming lithified downwards. *Gravel:* cobbles, coarse and fine, few clasts >200mm, well rounded psammite, granite, pink porphyry, quartzite, felsite, epidiorite, porphyritic andesite and basalt, aphyric basalt and rotten schist. Many clasts rotten, many broken along shatter-belts. Generally well sorted and clast-supported. Bedding dipping at 50° to the south. *Sand:* medium with fine and coarse, tuffaceous, orangey brown, either occurring as a matrix or as discrete beds. Becoming lithified downwards. *Fines:* a little silt and clay.	3.5+	3.8

Pit abandoned at 1.5m beneath quarry floor, too hard to dig deeper

NO 88 SE 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
4	30	66	0.3- 2.3	5	11	13	5	15	51	0
			2.3- 3.8	4	9	13	9	13	19	33
			Mean	4	10	13	7	14	38	14

NO 88 SE 2 | 8622 8374 | West Newtonleys

Surface level c.+96m
Water not struck
Pit
August 1989

Overburden 0.2m
Mineral II 3.3m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, very gravelly	0.2	0.2
Till (ice-disturbed conglomerate)	**Gravel**, clast-supported, very dense *Gravel:* cobbles, coarse and fine, boulders <350mm, chiefly well rounded quartzites, granite, porphyry, gneiss, porphyritic andesite and fragments of lithified conglomerate *Sand:* medium with coarse and fine, tuffaceous, reddish-brown *Fines:* silt, disseminated Deposit still unconsolidated at base, no lithification	3.3+	3.5

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
3	25	72	0.2- 1.8	5	7	18	10	12	21	27
			1.8- 3.5	2	3	7	5	14	46	23
			Mean	3	5	12	8	13	34	25

NO 88 SE 3 | 8773 8430 | **Mains of Dunnottar**

Surface level c.+63m
Water struck at c.+58.6m
250mm percussion
July 1989

Overburden	0.3m
Mineral I	3.4m
Waste	6.4m
Bedrock	0.4m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, sandy with cobbles	0.3	0.3
Glacial sand and gravel	**a Sandy gravel** *Gravel:* coarse and fine, some cobbles, subangular to well rounded gritty psammite, quartzite and lava *Sand:* medium with coarse and fine, angular to subrounded quartz, feldspar and rock chips. Some mica *Fines:* silt and clay, disseminated and coating grains, moderate brown (5YR 5/4)	1.4	1.7
	b 'Very clayey' sand, crudely laminated *Sand:* fine, soft, quartz, lithic grains and mica *Fines:* very silty, especially between 1.7-2.0m and 3.2-3.7m, disseminated and in seams. Some 2mm ?organic spots. Light brown (5YR 5/6) to moderate reddish brown (10R 4/6)	2.0	3.7
	Fine sandy silt, firm, moderate reddish brown (10R 4/6)	0.7	4.4
Glaciolacustrine deposit	**Finely interstratified fine sandy silt, silt, silty clay and clay**, becoming more clayey and more stiff downwards, moderate reddish brown (10R 4/6)	3.6	8.0
Flow-till	**Diamictic sandy clay** with scattered clasts <64mm, crudely laminated, moderate reddish brown	1.1	9.1
Till	**Diamicton**; firm, plastic sandy	1.0	10.1

	clay matrix with angular to rounded clasts up to cobble size of quartzite, sandstone, rotten schist and lava. Moderate reddish brown (10R 4/6)		
Old Red Sandstone	Conglomerate, very hard. Fragments of quartzite, lava and vein-quartz retrieved	0.4+	10.5

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	8	50	42	0.3- 1.7	8	10	25	15	17	25	0
b	30	68	2	1.7- 3.7	30	66	1	1	1	1	0
a&b	21	60	19	Mean	21	42	11	7	8	11	0

NO 88 SE 4 **8761 8089** **Uras Knaps**

Surface level c.+73m	Overburden 0.3m
Water not struck	Mineral I 2.0m
250mm percussion	Waste 8.7m
July 1989	Bedrock 0.1m+

LOG

Geological classification	**Lithology**	**Thickness** m	**Depth** m
	Soil, gravelly, sandy	0.3	0.3
Glacial sand and gravel	**Sandy gravel** *Gravel:* fine and coarse, angular to well rounded quartzite, vein-quartz, lavas and some rotten schist *Sand:* medium with coarse and some fine, angular to well rounded, quartz, feldspar, rock chips and some mica *Fines:* a little disseminated silt and clay	2.0	2.3
Glaciolacustrine deposit	**Silt**, sandy and clayey, laminated with laminae of clay and fine-grained sand. Rare fine pebbles. Moderate reddish brown (10R 4/6)	3.8	6.1
Till	**Diamicton**; firm, sandy clay matrix with subrounded to well-rounded clasts up to cobble size of quartzite and gritty psammite with porphyritic andesite lava	4.9	11.0
Old Red Sandstone	**Conglomerate**, hard, little retrieved	0.1+	11.1

NO 88 SE 4

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
3	65	32	0.3- 2.3	3	7	35	23	19	13	0

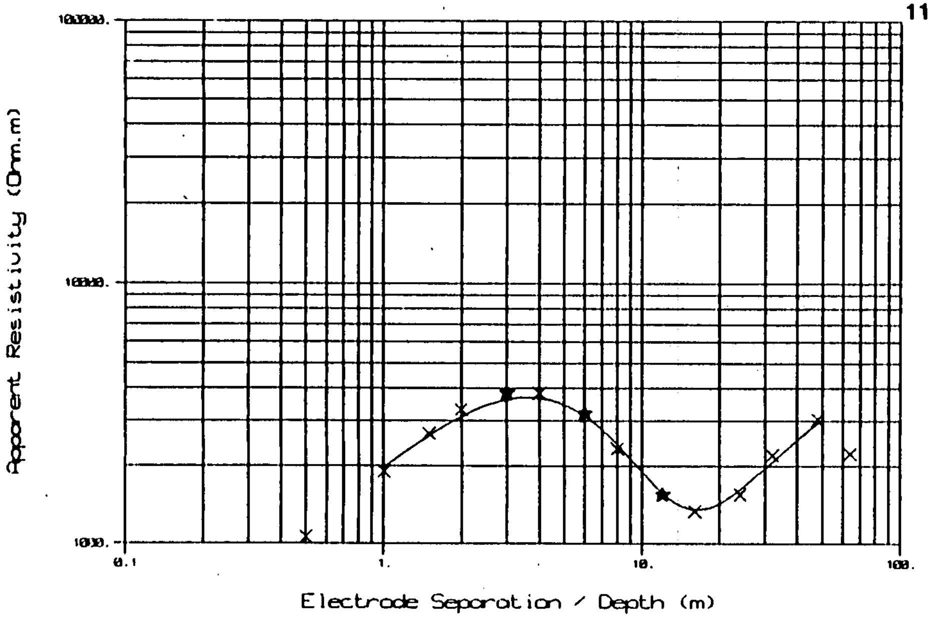
NO 68 NE R1A 1 **6540 8728** 2 **Heatheryhaugh**

Azimuth 080° 3
August 1989 4

		6
Overburden	0.1m	
Mineral I	2.2m	
Waste	7.7m	
Bedrock	-	

Interpretation 7

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, silty	243	0.1	0.1
Alluvium	Sand	2583	0.2	0.3
	Cobble gravel	9989	2.0	2.3
?Till/Decomposed bedrock	Clay, gravelly and sandy	419	7.7	10.0
Caledonian	Granite, fresh	14428	-	-



INPUT DATA 5

Electrode Spacing	A	C	D1	D2	B
0.5	536.0000	513.0000	334.0000	342.0000	22.4000
1.0	478.0000	455.0000	284.0000	320.0000	23.1000
2.0	388.0000	362.0000	266.0000	280.0000	25.7000
4.0	182.1000	164.9000	135.8000	168.0000	17.0900
8.0	54.8000	51.5000	47.0000	46.1000	3.1000
16.0	19.6400	15.6900	11.9300	14.7200	1.1900
32.0	12.2800	11.6400	11.9000	10.0800	3.3700
64.0	6.3000	6.7200	6.0700	5.0500	0.7680

PROCESSING RESULTS 8

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	1061.86	0.0011	0.0237	0.0804
1.0	1897.52	-0.0002	0.1192	0.0816
1.5	2668.96			
2.0	3304.96	0.0008	-0.0228	0.1527
3.0	3969.58			
4.0	3817.66	0.0006	0.2120	-0.2197
6.0	3415.93			
8.0	2339.86	0.0037	-0.0193	-0.1215
12.0	1282.45			
16.0	1339.58	0.1520	0.2094	-0.1769
24.0	1957.99			
32.0	2209.67	-0.2021	-0.1656	-0.5925
48.0	3024.36			
64.0	2235.81	-0.1736	-0.1835	0.0000

R.M.S. Observational Error = .1085
R.M.S. Offset Wenner Difference = .1438
R.M.S. Potential Ladder Difference = .2624

FIELD CURVE DATA 9 INTERPRETED MODEL 10

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	1061.86	0.12		242.7	
2	1.0	1897.52				
3	1.5	2668.96		0.12	--------	0.8255
4	2.0	3304.96				
5	3.0	3830.00	0.18		2538.4	
6	4.0	3817.66				
7	6.0	3200.00		0.30	--------	0.5947
8	8.0	2339.86				
9	12.0	1550.00	1.97		9988.7	
10	16.0	1339.58				
11	24.0	1957.99		2.28	--------	-0.9196
12	32.0	2209.67				
13	48.0	3024.36	7.71		418.5	
14	64.0	2235.81				
				9.99	--------	0.9436
					14428.0	
					********	

R.M.S. Relative error = 0.0445
Maximum rel. error = -0.0815 at sample 12
Number of trials was 30

Resistivity records of each of the depth soundings used in the assessment are given in Appendix H

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, etc.

2 National Grid Reference
All National Grid references fall in the 100km square 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 base map.

3 Azimuth
Azimuth refers to the compass bearing, in degrees from Grid North, along 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.

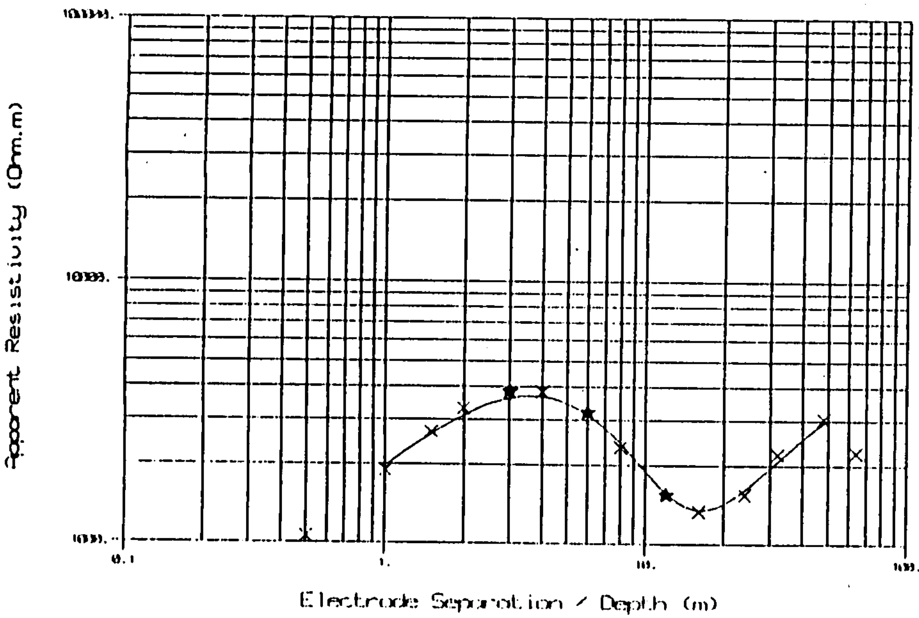
NO 68 NE R1A | 6540 8728 | **Heatheryhaugh**

Azimuth 080°
August 1989

Overburden	0.1m
Mineral I	2.2m
Waste	7.7m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, silty	243	0.1	0.1
Alluvium	Sand	2583	0.2	0.3
	Cobble gravel	9989	2.0	2.3
?Till/Decomposed bedrock	Clay, gravelly and sandy	419	7.7	10.0
Caledonian	Granite, fresh	14428	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	536.0000	513.0000	334.0000	342.0000	22.4000
1.0	478.0000	455.0000	284.0000	320.0000	23.1000
2.0	388.0000	362.0000	266.0000	260.0000	25.7000
4.0	182.1000	164.9000	135.8000	168.0000	17.0900
8.0	54.8000	51.5000	47.0000	46.1000	3.1000
16.0	19.6400	15.6900	11.9300	14.7200	1.1900
32.0	12.2800	11.6400	11.9000	10.0800	3.3700
64.0	6.3000	6.7200	6.0700	5.0900	0.7680

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	1061.86	0.0011	0.0237	0.0804
1.0	1897.52	-0.0002	0.1192	0.0816
1.5	2668.96			
2.0	3304.96	0.0008	-0.0228	0.1527
3.0	3959.58			
4.0	3817.66	0.0006	0.2120	-0.2197
6.0	3415.93			
8.0	2339.86	0.0037	-0.0193	-0.1215
12.0	1202.45			
16.0	1339.58	0.1520	0.2094	-0.1769
24.0	1557.99			
32.0	2209.67	-0.2021	-0.1656	-0.5925
48.0	3024.36			
64.0	2235.81	-0.1736	-0.1835	0.0000

R.M.S. Observational Error = .1085
R.M.S. Offset Wenner Difference = .1438
R.M.S. Potential Ladder Difference = .2624

FIELD CURVE DATA | INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	1061.86	0.12		242.7	
2	1.0	1897.52				
3	1.5	2668.96		0.12	--------	0.8255
4	2.0	3304.96				
5	3.0	3830.00	0.18		2538.4	
6	4.0	3817.66				
7	6.0	3200.00		0.30	--------	0.5947
8	8.0	2339.86				
9	12.0	1550.00	1.97		9988.7	
10	16.0	1339.58				
11	24.0	1957.99		2.28	--------	-0.9196
12	32.0	2209.67				
13	48.0	3024.36	7.71		418.5	
14	64.0	2235.81				
				9.99	--------	0.9436
					14428.0	
					********	

R.M.S. Relative error = 0.0445
Maximum rel. error = -0.0815 at sample 12
Number of trials was 30

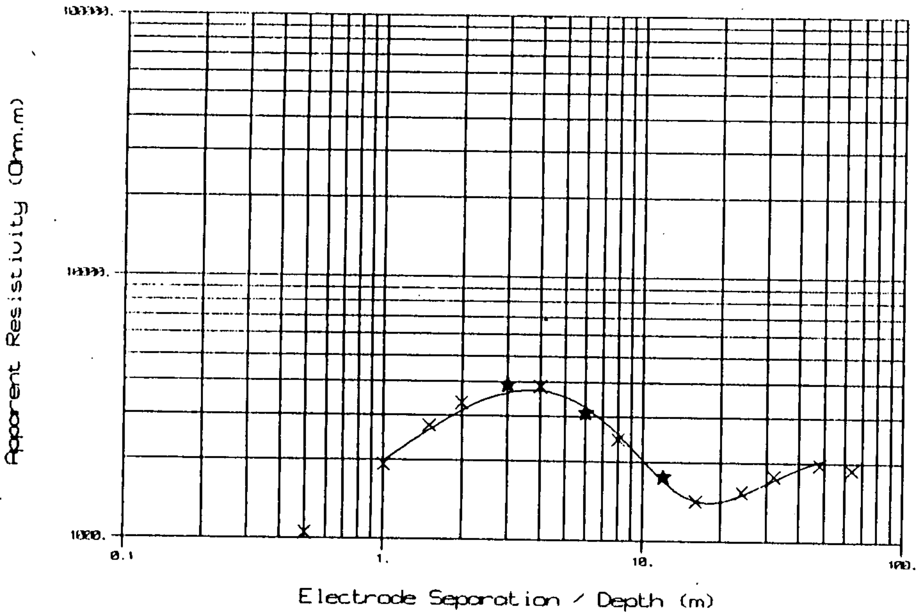
NO68 NE R1B 6540 8728 **Heatheryhaugh**

Azimuth 030°
August 1989

Oveburden	0.1m
Mineral I	2.2m
Waste	6.1m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, silty	216	0.1	0.1
Alluvium	Sand	2506	0.2	0.3
	Cobble gravel	10328	2.0	2.3
?Till/Decomposed bedrock	Clay, gravelly and sandy	504	6.1	8.4
Caledonian	Granite	2729	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	538.0000	517.0000	325.0000	348.0000	20.7000
1.0	486.0000	462.0000	306.0000	308.0000	24.1000
2.0	388.0000	359.0000	264.0000	267.0000	29.7000
4.0	194.7000	177.8000	136.9000	170.6000	16.3300
8.0	62.4000	59.5000	51.8000	45.2000	3.5100
16.0	16.4100	15.6400	12.8500	15.3500	2.3800
32.0	11.1600	9.9500	9.4500	8.1600	2.1000
64.0	10.2000	8.7000	4.6900	4.6400	0.9600

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	1057.15	0.0006	0.0684	0.0884
1.0	1928.94	-0.0002	0.0065	0.0836
1.5	2729.81			
2.0	3336.37	-0.0018	0.0113	0.1060
3.0	4056.44			
4.0	3864.16	0.0029	0.2192	0.0013
6.0	3310.20			
8.0	2437.88	-0.0097	-0.1361	0.2596
12.0	1390.27			
16.0	1417.49	-0.0937	0.1773	-0.4082
24.0	1542.39			
32.0	1770.35	-0.0430	-0.1465	-0.3843
48.0	1966.74			
64.0	1875.91	0.0544	-0.0107	0.0000

R.M.S. Observational Error = .0414
R.M.S. Offset Wenner Difference = .1247
R.M.S. Potential Ladder Difference = .2413

FIELD CURVE DATA

	Electrode Separation	Apparent Resistivity
1	0.5	1057.15
2	1.0	1928.94
3	1.5	2729.81
4	2.0	3336.37
5	3.0	3900.00
6	4.0	3864.16
7	6.0	3085.00
8	8.0	2437.88
9	12.0	1750.00
10	16.0	1417.49
11	24.0	1542.39
12	32.0	1770.35
13	48.0	1966.74
14	64.0	1875.91

INTERPRETED MODEL

Thickness	Depth	Rho	Reflection Coeffts.
0.11		216.3	
	0.11	--------	0.8411
0.18		2506.3	
	0.29	--------	0.6095
1.95		10328.3	
	2.24	--------	-0.9070
6.12		503.9	
	8.35	--------	0.6882
		2728.6	
		********	

R.M.S. Relative error = 0.0401
Maximum rel. error = -0.0686 at sample 5
Number of trials was 30

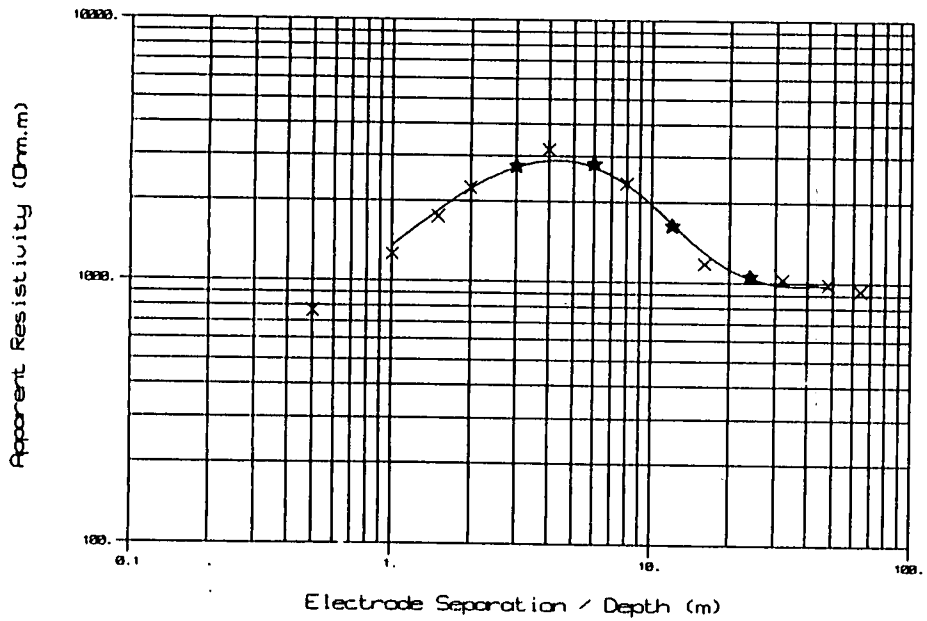
NO68 NE R2A | 6552 8640 | Heathery Wood

Azimuth 005°
August 1989

Overburden	0.1m
Mineral I	1.2m
Waste	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, silty	117	0.1	0.1
Alluvium	Sand	5447	0.2	0.3
	Sand and cobbles, dry	14367	1.0	1.3
?Glaciolacustrine deposits	Silt, sandy, damp	934	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	370.0000	353.0000	254.0000	232.0000	17.6500
1.0	319.0000	305.0000	198.2000	204.0000	12.9000
2.0	277.0000	262.0000	186.9000	172.0000	14.9000
4.0	164.3000	150.3000	135.3000	117.0000	13.5100
8.0	53.6000	50.6000	43.1000	50.5000	3.0400
16.0	14.1600	13.3400	11.7000	11.7100	0.8370
32.0	6.0200	5.6300	5.1400	5.0700	0.3860
64.0	2.8600	2.6300	2.3000	2.3300	0.2470

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	763.41	-0.0018	-0.0905	0.0455
1.0	1263.95	0.0035	0.0288	0.0826
1.5	1747.95			
2.0	2252.52	0.0004	-0.0809	0.1563
3.0	2915.66			
4.0	3170.50	0.0030	-0.1451	0.0208
6.0	3208.29			
8.0	2352.42	-0.0007	0.1581	-0.1770
12.0	1414.56			
16.0	1176.71	-0.0012	0.0009	-0.1813
24.0	935.33			
32.0	1026.42	0.0007	-0.0137	-0.7724
48.0	983.08			
64.0	930.92	-0.0059	0.0130	0.0000

R.M.S. Observational Error = .0028
R.M.S. Offset Wenner Difference = .0880
R.M.S. Potential Ladder Difference = .1568

FIELD CURVE DATA | INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	763.41	0.10		116.8	
2	1.0	1263.55				
3	1.5	1747.95		0.10	--------	0.9580
4	2.0	2252.52				
5	3.0	2740.00	0.18		5447.1	
6	4.0	3170.50				
7	6.0	2800.00		0.28	--------	0.4502
8	8.0	2352.42				
9	12.0	1635.00	1.03		14367.4	
10	16.0	1176.71				
11	24.0	1050.00		1.31	--------	-0.8779
12	32.0	1026.42				
13	48.0	983.08			933.9	
14	64.0	930.92				

R.M.S. Relative error = 0.0501
Maximum rel. error = 0.1036 at sample 10 ********
Number of trials was 10

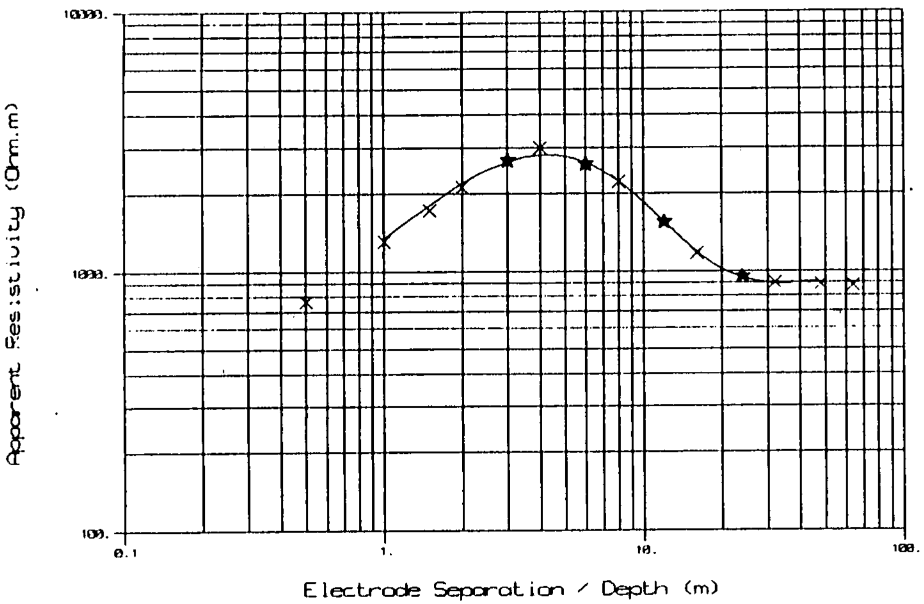
NO68 NE R2B 6552 8640 Heathery Wood

Azimuth 150°
August 1989

Overburden	0.1m
Mineral I	1.6m
Waste	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, silty	119	0.1	0.1
Alluvium	Sand	3983	0.3	0.4
	Sand and cobbles, dry	10823	1.3	1.7
?Glaciolacustrine deposits	?Silt, damp	829	19.5	21.2
	?Silt	895	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	367.0000	349.0000	244.0000	241.0000	16.9700
1.0	330.0000	320.0000	216.0000	200.0000	12.0000
2.0	245.0000	227.0000	182.0000	155.8000	17.9900
4.0	151.8000	139.6000	139.0000	99.5000	12.1600
8.0	50.9000	47.8000	49.1000	39.5000	2.8400
16.0	15.3300	14.5800	11.6400	11.6600	0.7630
32.0	5.6000	5.2200	4.5800	4.3600	0.3790
64.0	2.9800	2.6800	2.3200	2.0400	0.2380

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	761.84	0.0028	-0.0124	0.0144
1.0	1306.90	-0.0060	-0.0769	0.1574
1.5	1728.69			
2.0	2122.46	0.0000	-0.1551	-0.0127
3.0	2829.35			
4.0	2997.08	0.0003	-0.3312	-0.0402
6.0	2863.11			
8.0	2226.76	-0.0028	-0.2167	-0.2053
12.0	1406.14			
16.0	1171.19	-0.0008	0.0017	0.1541
24.0	902.76			
32.0	898.75	0.0002	-0.0492	-0.1557
48.0	887.09			
64.0	876.63	0.0014	-0.1284	0.0000

R.M.S. Observational Error = .0026
R.M.S. Offset Wenner Difference = .1604
R.M.S. Potential Ladder Difference = .1292

FIELD CURVE DATA / INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	761.84	0.10		118.7	
2	1.0	1306.90				
3	1.5	1728.69		0.10	--------	0.9421
4	2.0	2122.46				
5	3.0	2685.00	0.27		3983.4	
6	4.0	2997.08				
7	6.0	2600.00		0.37	--------	0.4619
8	8.0	2226.76				
9	12.0	1550.00	1.34		10823.1	
10	16.0	1171.19				
11	24.0	950.00		1.71	--------	-0.8576
12	32.0	898.75				
13	48.0	887.09	19.49		829.4	
14	64.0	876.63				
				21.20	--------	0.0378
					894.6	
					********	

R.M.S. Relative error = 0.0280
Maximum rel. error = 0.0565 at sample 4
Number of trials was 24

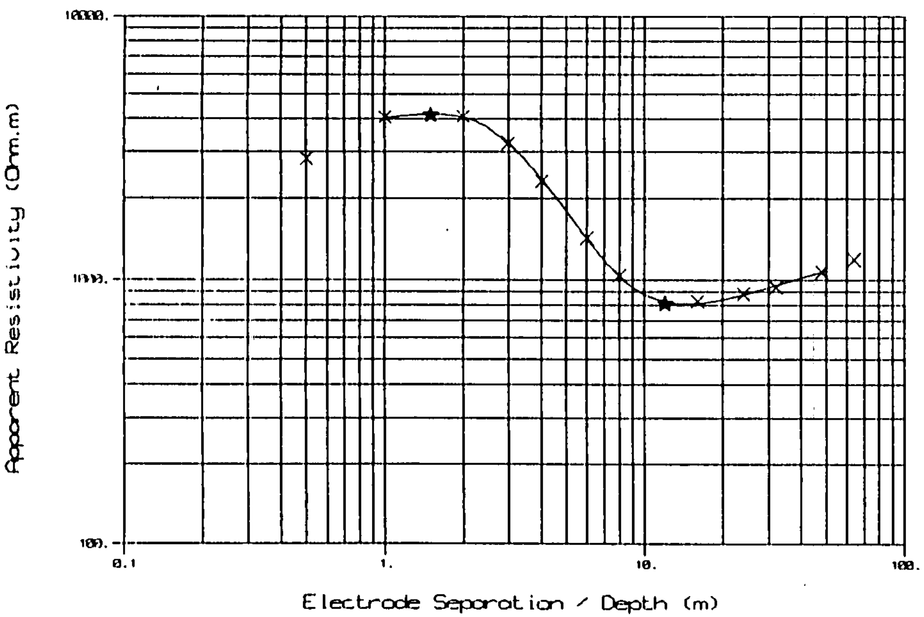
NO 68 NE R3A | 6572 8616 | Burn of Mainhaugh

Azimuth 160°
August 1989

Overburden 0.1m
Mineral I 4.3m
Waste 13.7m
Bedrock -

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, pebbly	681	0.1	0.1
Alluvium	Cobble, gravel	6784	1.4	1.5
?Fluvioglacial sand and gravel	Sand, pebbly	1114	2.9	4.4
?Till/Decomposed bedrock	Clay, gravelly and sandy	665	13.7	18.1
Caledonian	Granite	1321	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	1375.0000	1295.0000	952.0000	851.0000	79.2000
1.0	995.0000	844.0000	666.0000	632.0000	60.7000
2.0	406.0000	383.0000	348.0000	305.0000	23.0000
4.0	107.0000	102.7000	98.8000	86.9000	4.1000
8.0	26.4000	25.2000	19.1800	22.1000	1.2080
16.0	11.4500	10.8400	8.4800	8.0000	0.6040
32.0	6.7300	6.4000	4.2800	5.0100	0.3540
64.0	4.3800	4.1000	2.6000	3.3000	0.2630

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	2832.15	0.0006	-0.1120	0.1069
1.0	4077.79	0.0003	-0.0524	0.0977
1.5	4422.45			
2.0	4102.92	0.0000	-0.1317	0.1085
3.0	3241.46			
4.0	2333.58	0.0019	-0.1282	-0.0181
6.0	1426.87			
8.0	1037.48	-0.0003	0.1415	0.0529
12.0	870.40			
16.0	828.38	0.0005	-0.0583	0.0604
24.0	880.48			
32.0	933.93	-0.0036	0.1572	0.0911
48.0	1069.66			
64.0	1186.27	0.0039	0.2373	0.0000

R.M.S. Observational Error = .0020
R.M.S. Offset Wenner Difference = .1385
R.M.S. Potential Ladder Difference = .0826

FIELD CURVE DATA | INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	2832.15	0.10		681.1	
2	1.0	4077.79				
3	1.5	4150.00		0.10	--------	0.8175
4	2.0	4102.92				
5	3.0	3241.46	1.36		6783.7	
6	4.0	2333.58				
7	6.0	1426.87		1.46	--------	-0.7179
8	8.0	1037.48				
9	12.0	810.00	2.95		1113.8	
10	16.0	828.38				
11	24.0	880.48		4.41	--------	-0.2522
12	32.0	933.93				
13	48.0	1069.66	13.65		665.2	
14	64.0	1186.27				
				18.06	--------	0.3302
					1320.9	
					********	

R.M.S. Relative error = 0.0217
Maximum rel. error = -0.0482 at sample 2
Number of trials was 17

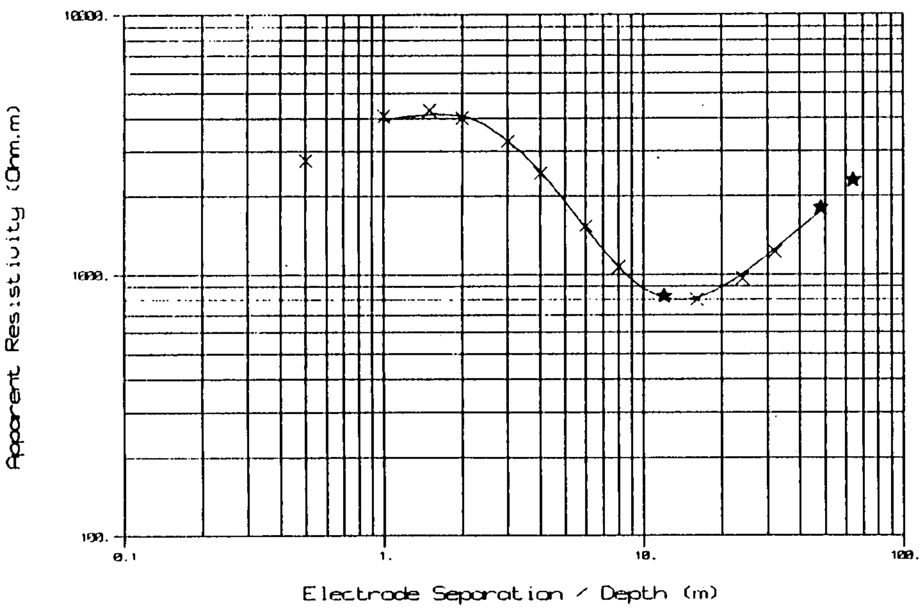
NO 68 R3B 6572 8616 Burn of Mainhaugh

Azimuth 110°
August 1989

Overburden	0.1m
Mineral I	5.0m
Waste	15.5m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, pebbly	658	0.1	0.1
Alluvium	Cobble gravel	6736	1.4	1.5
?Fluvioglacial sand and gravel	Sand, pebbly	1203	3.6	5.1
?Till/Decomposed bedrock	Clay, gravelly and sandy	542	15.5	20.6
Caledonian	Granite, fresh	7863	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	1305.0000	1218.0000	922.0000	828.0000	86.9000
1.0	911.0000	853.0000	679.0000	621.0000	57.9000
2.0	391.0000	368.0000	330.0000	330.0000	22.7000
4.0	116.0000	111.9000	103.9000	90.9000	4.0800
8.0	28.0000	26.8000	19.6400	22.7000	1.2030
16.0	10.2900	9.6500	8.7200	7.1800	0.6030
32.0	6.6600	6.3400	7.6900	4.4500	0.3020

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	2748.89	0.0001	-0.1074	0.0278
1.0	4084.07	0.0001	-0.0892	0.1345
1.5	4297.70			
2.0	4021.24	0.0008	0.0000	-0.0057
3.0	3270.50			
4.0	2447.93	0.0002	-0.1335	0.1854
6.0	1532.72			
8.0	1064.12	-0.0001	0.1445	0.2080
12.0	880.85			
16.0	799.22	0.0036	-0.1937	-0.2171
24.0	966.78			
32.0	1220.45	0.0027	-0.5338	0.0000
48.0	908.37			
64.0	224.05			

R.M.S. Observational Error = .0017
R.M.S. Offset Wenner Difference = .2332
R.M.S. Potential Ladder Difference = .1547

FIELD CURVE DATA / INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	2748.89	0.10		658.3	
2	1.0	4084.07				
3	1.5	4297.70		0.10	--------	0.8219
4	2.0	4021.24				
5	3.0	3270.50	1.38		6735.6	
6	4.0	2447.93				
7	6.0	1532.72		1.48	--------	-0.6970
8	8.0	1064.12				
9	12.0	825.00	3.59		1202.7	
10	16.0	799.22				
11	24.0	966.78		5.08	--------	-0.3786
12	32.0	1220.45				
13	48.0	1800.00	15.49		542.1	
14	64.0	2300.00				
				20.57	--------	0.8710
					7863.2	
					********	

R.M.S. Relative error = 0.0227
Maximum rel. error = -0.0422 at sample 13
Number of trials was 30

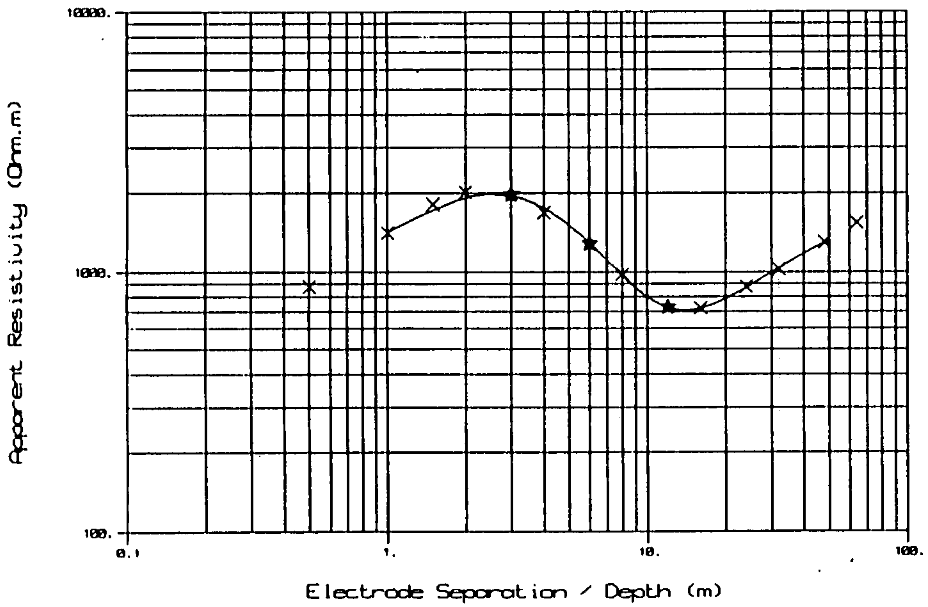
NO 69 SW R1A   6030 9133   Blackhole

Azimuth 130°
August 1989

Overburden	0.2m
Mineral I	2.4m
Waste	13.5m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, sandy	421	0.2	0.2
Alluvium	Sand, pebbly, dry	2095	0.5	0.7
	Gravel, sandy, dry	5099	0.9	1.6
	Gravel, sandy, wet	1535	1.0	2.6
Glaciolacustrine deposits	Silt, clay and pebbly sand, wet	495	13.5	16.1
Caledonian	Granite	2358	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	425.0000	400.0000	282.0000	277.0000	25.3000
1.0	315.0000	290.0000	254.0000	196.4000	25.3000
2.0	236.0000	228.0000	168.7000	152.7000	7.9300
4.0	77.4000	71.9000	73.4000	61.3000	5.5000
8.0	22.1000	21.2000	23.0000	15.8700	0.9440
16.0	10.1000	9.5100	7.6900	6.6900	0.5970
32.0	7.5100	7.0800	5.4400	4.7600	0.4260
64.0	5.5400	5.1700	3.9000	3.8000	0.3870

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	878.08	-0.0007	-0.0179	0.0345
1.0	1414.97	-0.0010	-0.2558	-0.0976
1.5	1818.48			
2.0	2019.42	0.0003	-0.0996	0.4998
3.0	1821.97			
4.0	1692.69	0.0000	-0.1797	-0.2659
6.0	1544.58			
8.0	976.91	-0.0080	-0.3669	-0.2575
12.0	660.15			
16.0	722.82	-0.0007	-0.1391	-0.0457
24.0	874.43			
32.0	1025.42	0.0005	-0.1333	0.0148
48.0	1298.15			
64.0	1548.18	-0.0031	-0.0360	0.0000

R.M.S. Observational Error = .0014
R.M.S. Offset Wenner Difference = .1872
R.M.S. Potential Ladder Difference = .2390

FIELD CURVE DATA

	Electrode Separation	Apparent Resistivity
1	0.5	878.08
2	1.0	1414.97
3	1.5	1818.48
4	2.0	2019.42
5	3.0	1980.00
6	4.0	1692.69
7	6.0	1285.00
8	8.0	976.91
9	12.0	727.00
10	16.0	722.82
11	24.0	874.43
12	32.0	1025.42
13	48.0	1298.15
14	64.0	1548.18

INTERPRETED MODEL

Thickness	Depth	Rho	Reflection Coeffts.
0.24		421.2	
	0.24	--------	0.6652
0.42		2094.9	
	0.66	--------	0.4176
0.93		5098.9	
	1.58	--------	-0.5373
1.02		1534.8	
	2.60	--------	-0.5127
13.53		494.5	
	16.13	--------	0.6533
		2357.7	
		********	

R.M.S. Relative error = 0.0215
Maximum rel. error = -0.0424 at sample 5
Number of trials was 20

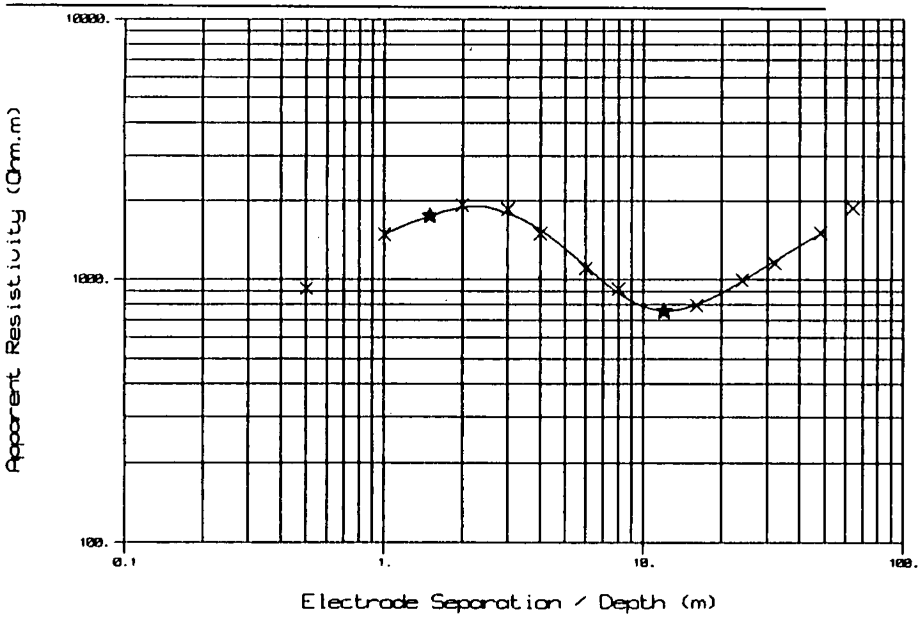
NO 69 SW R1B **6030 9133** **Blackhole**

Azimuth 070°
August 1989

Overburden	0.2m
Mineral I	2.0m
Waste	14.7m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, sandy	436	0.2	0.2
Alluvium	Sand, pebbly, dry	1504	0.2	0.4
	Gravel, sandy, dry	5095	0.8	1.2
	Gravel, sandy, wet	1269	1.0	2.2
Glaciolacustrine deposits	Silt, clay and pebbly sand, wet	584	14.7	16.9
Caledonian	Granite	2965	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	473.0000	453.0000	344.0000	241.0000	19.7300
1.0	349.0000	326.0000	267.0000	207.0000	22.6000
2.0	203.0000	188.6000	170.8000	136.6000	14.4600
4.0	68.4000	63.7000	68.3000	90.9000	4.7300
8.0	25.3000	24.4000	18.7200	17.8100	0.8470
16.0	10.7000	10.0700	7.2700	8.5100	0.6250
32.0	8.4600	8.0200	4.8600	6.5800	0.4380
64.0	6.7900	6.4200	3.6800	5.6900	0.3710

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	918.92	0.0006	-0.3521	0.1778
1.0	1489.11	0.0011	-0.2532	0.0803
1.5	1868.25			
2.0	1931.45	-0.0003	-0.2225	0.0851
3.0	1856.59			
4.0	1497.91	-0.0004	-0.2919	-0.2763
6.0	1100.95			
8.0	918.10	0.0021	-0.0498	0.2808
12.0	693.39			
16.0	793.19	0.0005	0.1572	-0.1185
24.0	992.58			
32.0	1150.07	0.0002	0.3007	-0.0089
48.0	1512.61			
64.0	1883.95	-0.0001	0.4290	0.0000

R.M.S. Observational Error = .0009
R.M.S. Offset Wenner Difference = .2794
R.M.S. Potential Ladder Difference = .1751

FIELD CURVE DATA — INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	918.92	0.22		436.4	
2	1.0	1489.11				
3	1.5	1755.00		0.22	--------	0.5502
4	2.0	1931.45				
5	3.0	1856.59	0.22		1504.0	
6	4.0	1497.91				
7	6.0	1100.95		0.44	--------	0.5442
8	8.0	918.10				
9	12.0	755.00	0.81		5095.1	
10	16.0	793.19				
11	24.0	992.58		1.25	--------	-0.6012
12	32.0	1150.07				
13	48.0	1512.61	0.98		1269.1	
14	64.0	1883.95				
				2.23	--------	-0.3696
			14.72		584.1	
				16.95	--------	0.6709
					2965.3	
					********	

R.M.S. Relative error = 0.0226
Maximum rel. error = 0.0154 at sample 7
Number of trials was 30

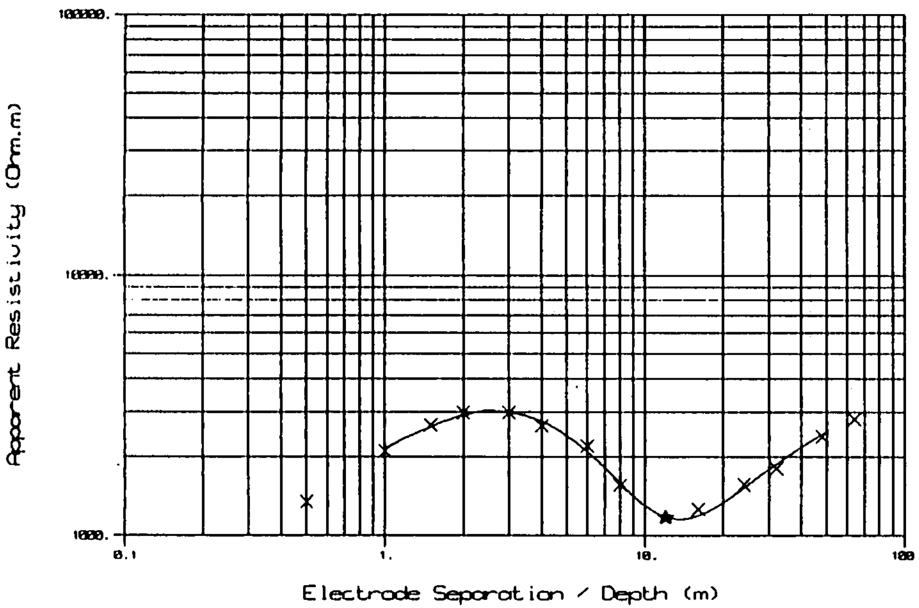
NO 69 SW R3A   6128 9173   Mill of Clinter

Azimuth 075°
August 1989

Overburden	0.2m
Mineral I	3.8m
Waste	7.1m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, silty	337	0.2	0.2
Alluvial fan	Cobble, gravel, dry	7479	0.9	1.1
	Sandy gravel, damp	2279	2.9	4.0
Till	Clay, sandy and gravelly	469	7.1	11.1
Caledonian	Granite, fresh	5376	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	657.0000	622.0000	364.0000	494.0000	33.3000
1.0	494.0000	464.0000	297.0000	374.0000	30.4000
2.0	335.0000	318.0000	218.0000	254.0000	17.8400
4.0	124.9000	116.4000	104.8000	105.2000	8.2200
8.0	39.3000	38.0000	31.3000	30.8000	1.3610
16.0	19.4400	18.4700	15.3900	9.8000	0.9450
32.0	13.3300	12.4100	11.0600	6.8900	0.9210
64.0	10.9000	10.4900	9.3500	4.5700	0.4040

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	1347.74	0.0086	0.3030	0.0777
1.0	2108.01	-0.0008	0.2295	0.0437
1.5	2665.28			
2.0	2965.66	-0.0025	0.1525	0.2772
3.0	2976.91			
4.0	2638.94	0.0022	0.0038	-0.1286
6.0	2203.01			
8.0	1560.74	-0.0016	-0.0161	0.0495
12.0	1127.45			
16.0	1266.19	0.0013	-0.4438	0.1559
24.0	1563.86			
32.0	1804.53	-0.0001	-0.4646	-0.0065
48.0	2395.51			
64.0	2798.78	0.0006	-0.6868	0.0000

R.M.S. Observational Error = .0017
R.M.S. Offset Wenner Difference = .3627
R.M.S. Potential Ladder Difference = .1353

FIELD CURVE DATA / INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	1347.74	0.15		337.2	
2	1.0	2108.01				
3	1.5	2665.28		0.15	--------	0.9137
4	2.0	2965.66				
5	3.0	2976.91	0.93		7479.4	
6	4.0	2638.94				
7	6.0	2203.01		1.08	--------	-0.5330
8	8.0	1560.74				
9	12.0	1175.00	2.94		2278.5	
10	16.0	1266.19				
11	24.0	1563.86		4.02	--------	-0.6588
12	32.0	1804.53				
13	48.0	2395.51	7.13		468.7	
14	64.0	2798.78				
				11.15	--------	0.8396
					5375.5	
					********	

R.M.S. Relative error = 0.0287
Maximum rel. error = -0.0950 at sample 10
Number of trials was 10

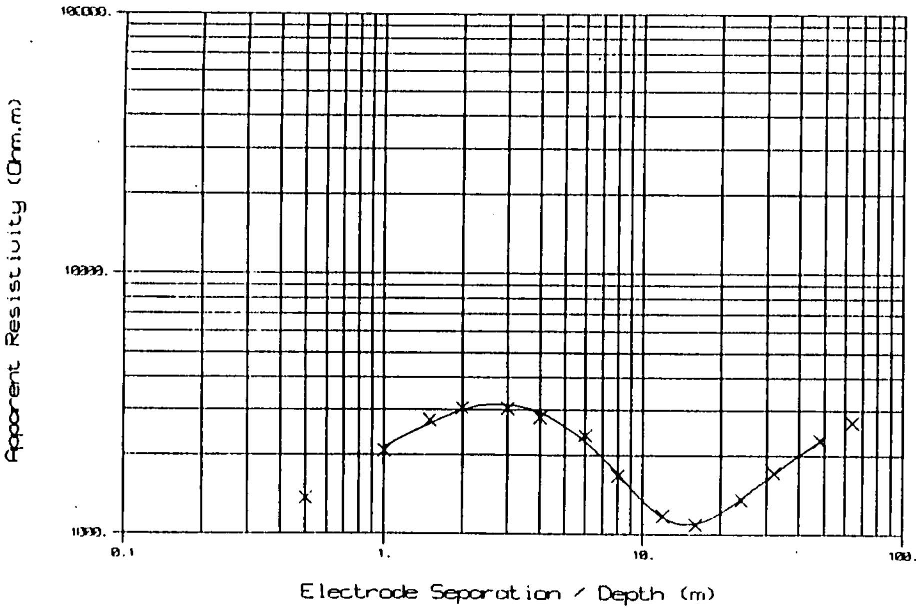
NO 69 SW R3B 6128 9173 Mill of Clinter

Azimuth 150°
August 1989

Overburden	0.2m
Mineral I	4.0m
Waste	8.2m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, silty	335	0.2	0.2
Alluvial fan	Cobble gravel, dry	7828	1.0	1.2
	Sandy gravel, damp	2411	3.0	4.2
Till	Clay, sandy and gravelly	451	8.2	12.4
Caledonian	Granite, fresh	5837	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	687.0000	658.0000	475.0000	398.0000	28.9000
1.0	481.0000	449.0000	328.0000	334.0000	32.7000
2.0	350.0000	333.0000	220.0000	264.0000	16.9000
4.0	139.6000	131.5000	106.3000	117.1000	7.8900
8.0	40.7000	39.2000	33.0000	33.5000	1.4900
16.0	16.1400	15.3300	11.0400	10.6700	0.8100
32.0	13.0700	12.2100	8.7900	8.2700	0.8120
64.0	9.7800	9.1500	6.6200	6.8000	0.6540

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	1371.31	0.0001	-0.1764	0.1693
1.0	2079.73	-0.0015	0.0181	-0.0137
1.5	2735.77			
2.0	3041.06	0.0003	0.1818	0.3151
3.0	3036.21			
4.0	2807.33	0.0015	0.0967	0.0985
6.0	2392.71			
8.0	1671.33	0.0002	0.0150	0.0486
12.0	1179.74			
16.0	1091.26	0.0000	-0.0341	0.0246
24.0	1359.03			
32.0	1715.06	0.0037	-0.0610	0.0518
48.0	2299.19			
64.0	2698.25	-0.0025	0.0268	0.0000

R.M.S. Observational Error = .0017
R.M.S. Offset Wenner Difference = .0998
R.M.S. Potential Ladder Difference = .1432

FIELD CURVE DATA / INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	1371.31	0.15		335.2	
2	1.0	2079.73				
3	1.5	2735.77		0.15	--------	0.9179
4	2.0	3041.06				
5	3.0	3036.21	0.99		7828.0	
6	4.0	2807.33				
7	6.0	2392.71		1.14	--------	-0.5291
8	8.0	1671.33				
9	12.0	1179.74	3.03		2410.9	
10	16.0	1091.26				
11	24.0	1359.03		4.17	--------	-0.6850
12	32.0	1715.06				
13	48.0	2299.19	8.21		450.7	
14	64.0	2698.25				
				12.38	--------	0.8567
					5837.1	
					********	

R.M.S. Relative error = 0.0291
Maximum rel. error = -0.0669 at sample 1
Number of trials was 30

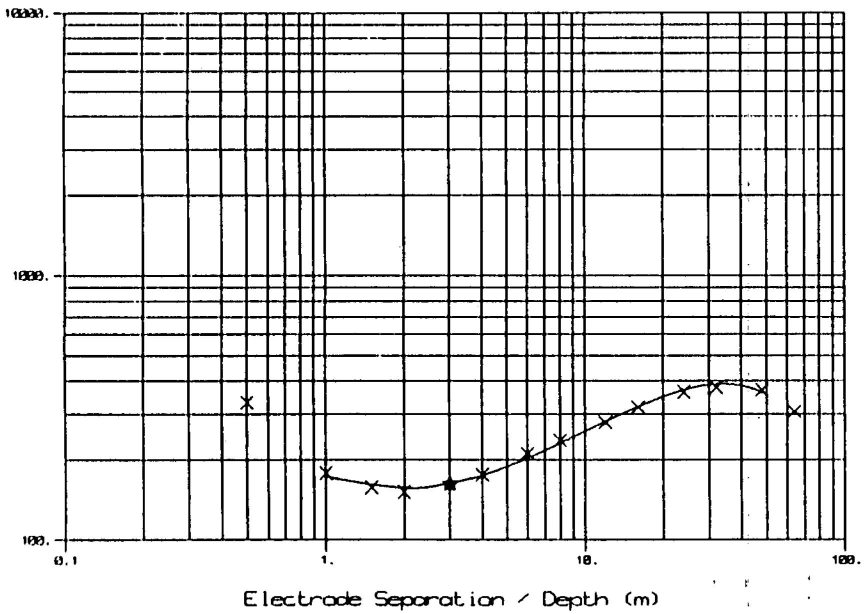
NO 69 SW R4A **6180 9273** **Boghead**

Azimuth 035°
August 1989

Waste 10.8m
Bedrock -

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, sandy	780	0.3	0.3
Alluvium	Clay, silty, damp	147	3.5	3.8
Till	Clay, sandy, damp	298	7.0	10.8
Dalradian	Metamorphic rock (? semipelite)	699	26.1	36.9
	? Metamorphic rock (? pelite)	62	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	155.8000	150.8000	111.9000	100.2000	4.8700
1.0	39.2000	37.8000	24.1000	32.7000	1.3780
2.0	17.4800	16.5600	12.1300	11.9900	0.9150
4.0	9.6800	9.0000	7.1100	6.8700	0.6650
8.0	6.8600	6.4500	4.8800	4.5700	0.4050
16.0	4.4600	4.1700	3.3000	3.0300	0.2940
32.0	2.4600	2.2600	1.8490	1.9140	0.1960

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	332.54	0.0008	-0.1068	1.0890
1.0	178.44	0.0006	0.3028	0.2803
1.5	157.74			
2.0	151.55	0.0003	-0.0116	0.1441
3.0	170.81			
4.0	175.68	0.0016	-0.0343	-0.0731
6.0	211.41			
8.0	237.50	0.0007	-0.0656	0.0458
12.0	277.81			
16.0	318.18	-0.0009	-0.0853	0.0332
24.0	363.72			
32.0	378.30	0.0016	0.0345	0.0000
48.0	368.96			
64.0	305.89			

R.M.S. Observational Error = .0010
R.M.S. Offset Wenner Difference = .1294
R.M.S. Potential Ladder Difference = .4628

FIELD CURVE DATA

	Electrode Separation	Apparent Resistivity
1	0.5	332.54
2	1.0	178.44
3	1.5	157.74
4	2.0	151.55
5	3.0	162.50
6	4.0	175.68
7	6.0	211.41
8	8.0	237.50
9	12.0	277.81
10	16.0	318.18
11	24.0	363.72
12	32.0	378.30
13	48.0	368.96
14	64.0	305.89

INTERPRETED MODEL

Thickness	Depth	Rho	Reflection Coeffts.
0.26		779.5	
	0.26	--------	-0.6833
3.49		146.7	
	3.76	--------	0.3406
7.03		298.2	
	10.79	--------	0.4021
26.14		699.3	
	36.92	--------	-0.8366
		62.2	
		********	

R.M.S. Relative error = 0.0190
Maximum rel. error = 0.0329 at sample 5
Number of trials was 30

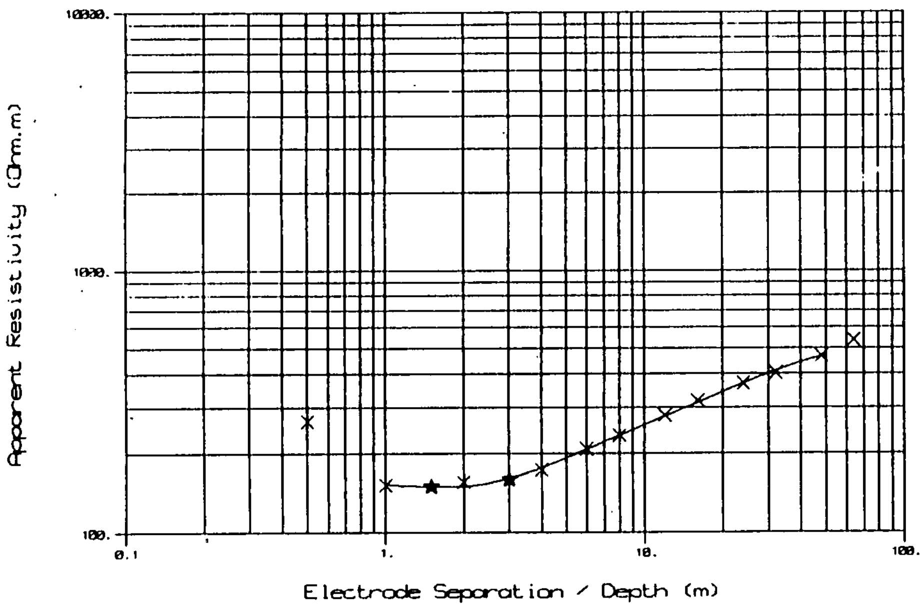
NO 69 SW R4B | 6180 9273 | Boghead

Azimuth 130°
August 1989

Waste 12.0m
Bedrock -

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, sandy	759	0.2	0.2
Alluvium	Clay, damp	137	2.9	3.1
Till	Clay, sandy, damp	298	8.9	12.0
Dalradian	Metamorhic rock	575	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	105.9000	100.3000	82.6000	86.0000	5.4700
1.0	33.4000	32.0000	26.4000	21.9000	1.3810
2.0	18.2300	17.3400	13.1900	11.6400	0.8860
4.0	9.7300	9.1000	7.2300	6.6000	0.6230
8.0	6.7000	6.2800	4.9700	4.3200	0.4160
16.0	4.5200	4.2400	3.3800	2.9900	0.2760
32.0	2.8300	2.6700	1.9540	2.0000	0.1508

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	264.84	0.0012	0.0403	0.1651
1.0	151.74	0.0006	-0.1863	0.1330
1.5	133.74			
2.0	156.01	0.0002	-0.1248	0.2125
3.0	172.84			
4.0	173.79	0.0007	-0.0911	-0.0289
6.0	207.99			
8.0	233.48	0.0006	-0.1399	0.0172
12.0	278.82			
16.0	318.18	0.0009	-0.1359	0.0366
24.0	368.85			
32.0	403.53	0.0033	0.0528	0.0000
48.0	466.19			
64.0	536.71			

R.M.S. Observational Error = .0014
R.M.S. Offset Wenner Difference = .1202
R.M.S. Potential Ladder Difference = .1242

FIELD CURVE DATA | INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	264.84	0.22		758.6	
2	1.0	151.74				
3	1.5	150.00		0.22	--------	-0.6940
4	2.0	156.01				
5	3.0	160.00	2.89		137.0	
6	4.0	173.79				
7	6.0	207.99		3.12	--------	0.3695
8	8.0	233.48				
9	12.0	278.82	8.93		297.7	
10	16.0	318.18				
11	24.0	368.85		12.05	--------	0.3178
12	32.0	403.53				
13	48.0	466.19			575.0	
14	64.0	536.71				

R.M.S. Relative error = 0.0155
Maximum rel. error = -0.0253 at sample 5
Number of trials was 30

****

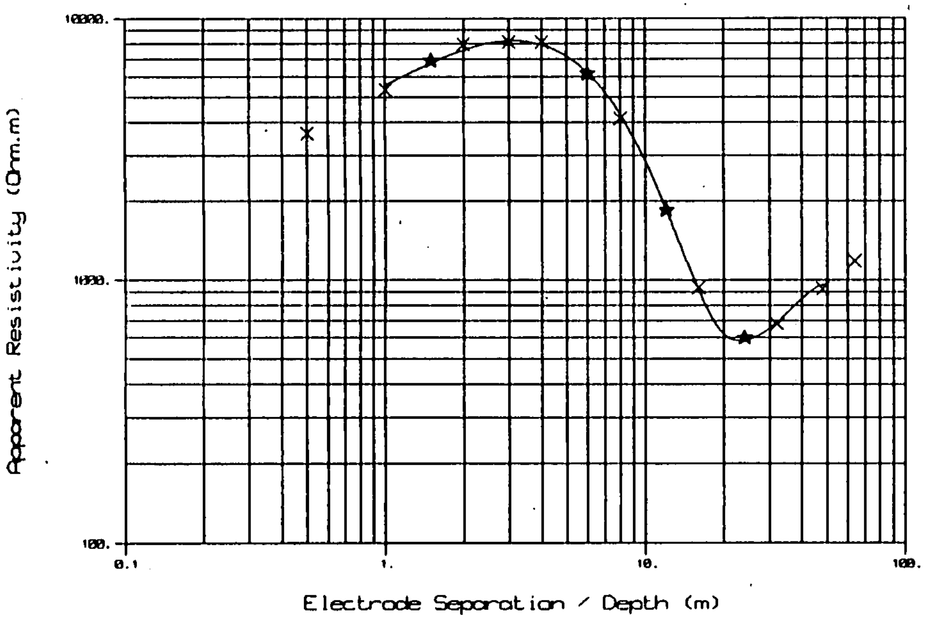
NO 69 SW R5A 6210 9184 Ordie

Azimuth 095°
August 1989

Overburden	0.1m
Mineral I	4.5m
Waste	16.5m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, humic, dry	890	0.1	0.1
Alluvium	Cobble gravel, sandy, dry	11179	1.6	1.7
Fluvioglacial sand and gravel	Cobble gravel, dry	14139	1.7	3.4
	Gravel, sandy, wet	3469	1.2	4.6
Till/Decomposed bedrock	Clay, sandy and gravelly, wet	318	16.5	21.1
Caledonian	Granite	2693	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	1856.0000	1806.0000	1119.0000	1193.0000	49.3000
1.0	1166.0000	1084.0000	738.0000	960.0000	87.2000
2.0	918.0000	877.0000	559.0000	708.0000	40.2000
4.0	365.0000	331.0000	349.0000	296.0000	34.5000
8.0	93.2000	90.5000	72.7000	92.4000	2.6700
16.0	10.2300	9.7600	8.4000	10.1700	0.4540
32.0	4.1200	3.7700	3.3300	3.4200	0.3650
64.0	4.0100	3.9300	2.2800	3.5800	0.9000

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	3631.68	0.0004	0.0640	0.2660
1.0	5334.42	-0.0044	0.2615	-0.1329
1.5	7341.40			
2.0	7960.80	0.0009	0.2352	0.2562
3.0	8128.15			
4.0	8105.31	-0.0014	-0.1643	-0.3998
6.0	7418.58			
8.0	4149.42	0.0003	0.2386	0.3578
12.0	1063.99			
16.0	933.43	0.0006	0.1906	-0.3584
24.0	620.33			
32.0	678.58	-0.0036	0.0267	-0.3675
48.0	923.69			
64.0	1178.22	-0.1871	0.4437	0.0000
96.0	1539.71			
128.0	1022.12			

R.M.S. Observational Error = .0062
R.M.S. Offset Wenner Difference = .2360
R.M.S. Potential Ladder Difference = .3175

FIELD CURVE DATA / INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	3631.68	0.13		889.8	
2	1.0	5334.42				
3	1.5	6900.00		0.13	--------	0.8526
4	2.0	7960.80				
5	3.0	8128.15	1.58		11179.3	
6	4.0	8105.31				
7	6.0	6150.00		1.71	--------	0.1169
8	8.0	4149.42				
9	12.0	1850.00	1.67		14139.3	
10	16.0	933.43				
11	24.0	600.00		3.38	--------	-0.6060
12	32.0	678.58				
13	48.0	923.69	1.23		3469.0	
14	64.0	1178.22				
				4.61	--------	-0.8319
			16.45		318.4	
				21.06	--------	0.7886
					2693.4	

R.M.S. Relative error = 0.0259
Maximum rel. error = 0.0406 at sample 2
Number of trials was 8

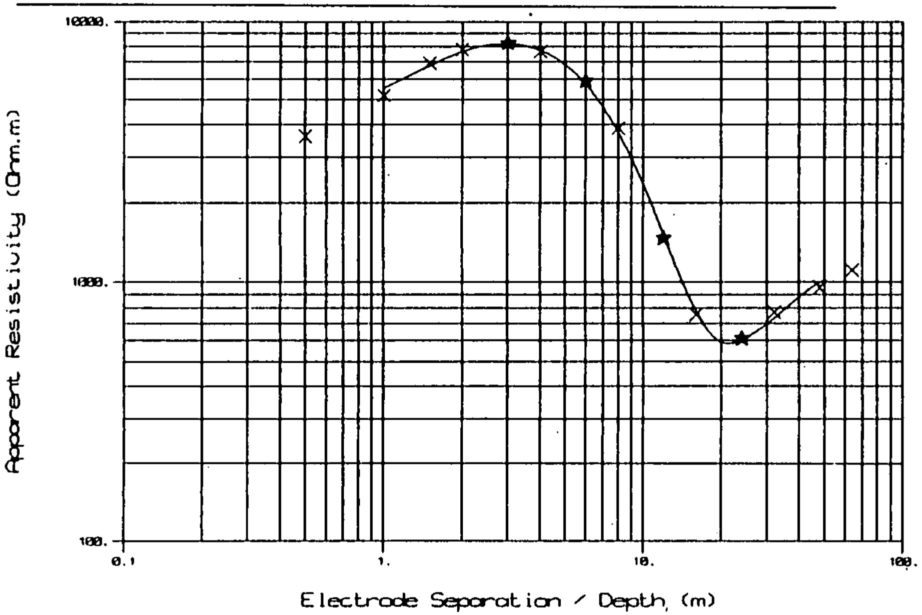
NO 69SW R5B | 6210 9184 | Ordie

Azimuth 180°
August 1989

Overburden	0.1m
Mineral I	3.7m
Waste	17.9m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, humic, dry	808	0.1	0.1
Alluvium	Cobble gravel, sandy, dry	12633	1.2	1.3
Fluvioglacial sand and gravel	Cobble gravel, dry	15444	1.5	2.8
	Gravel, sandy, wet	3226	1.0	3.8
Till/Decomposed bedrock	Clay, sandy and gravelly, wet	360	17.9	21.7
Caledonian	Granite	2866	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	1817.0000	1733.0000	973.0000	1327.0000	82.3000
1.0	1151.0000	1061.0000	808.0000	841.0000	90.0000
2.0	982.0000	958.0000	553.0000	692.0000	23.7000
4.0	350.0000	320.0000	265.0000	346.0000	29.4000
8.0	68.5000	65.0000	76.7000	77.8000	3.5300
16.0	8.6700	8.2300	7.4400	7.6000	0.4310
32.0	4.9800	4.6700	3.6300	4.0100	0.3140
64.0	3.3600	3.1100	2.5900	2.9000	0.2130

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	3612.83	0.0009	0.3078	0.2081
1.0	5180.49	0.0000	0.0400	-0.1201
1.5	6891.03			
2.0	7822.57	0.0003	0.2233	0.5987
3.0	7496.54			
4.0	7678.05	0.0017	0.2651	-0.3087
6.0	7430.37			
8.0	3883.01	-0.0004	0.0142	-2.1309
12.0	1243.24			
16.0	795.99	0.0010	0.0213	-0.3130
24.0	387.85			
32.0	768.06	-0.0008	0.0995	-0.1910
48.0	954.59			
64.0	1103.83	0.0111	0.1129	0.0000

R.M.S. Observational Error = .0040
R.M.S. Offset Wenner Difference = .1731
R.M.S. Potential Ladder Difference = .8608

FIELD CURVE DATA | INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	3612.83	0.13		807.7	
2	1.0	5180.49				
3	1.5	6891.03		0.13	--------	0.8798
4	2.0	7822.57				
5	3.0	8250.00	1.20		12632.7	
6	4.0	7678.05				
7	6.0	5875.00		1.33	--------	0.1001
8	8.0	3883.01				
9	12.0	1470.00	1.49		15444.4	
10	16.0	795.99				
11	24.0	610.00		2:82	--------	-0.6544
12	32.0	768.06				
13	48.0	954.59	0.98		3226.1	
14	64.0	1103.83				
				3.80	--------	-0.7994
			17.87		359.7	
				21.67	--------	0.7770
					2866.3	

R.M.S. Relative error = 0.0387
Maximum rel. error = 0.0767 at sample 2
Number of trials was 20

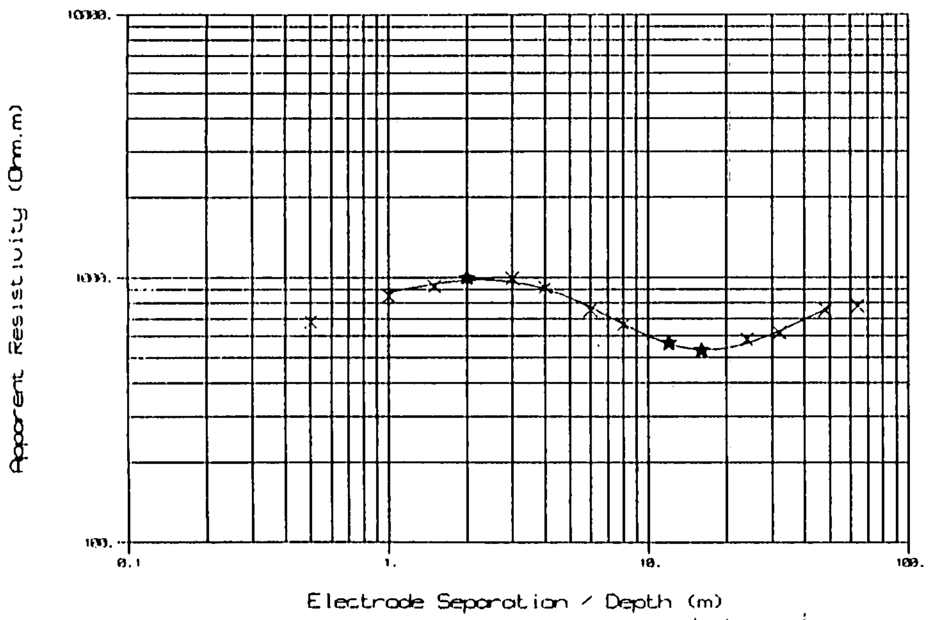
NO 69 SW R6A   6493 9015   Greendams

Azimuth 160°
August 1989

Overburden	0.1m
Mineral I	3.7m
Waste	20.6m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, silty, dry	211	0.1	0.1
Alluvium	Sand, pebbly, dry	1495	0.3	0.4
	Sand, pebbly, damp	1044	3.4	3.8
Till/Decomposed bedrock	Clay, sandy and gravelly, wet	444	20.6	24.4
Caledonian	Granite	1267	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	320.0000	306.0000	238.0000	194.7000	14.1000
1.0	198.4000	189.5000	151.7000	118.4000	8.8000
2.0	92.2000	84.9000	74.2000	69.2000	7.2600
4.0	50.7000	48.1000	37.4000	35.3000	2.5200
8.0	14.1200	12.6300	13.3400	13.0800	1.4480
16.0	10.7700	10.5000	5.3600	8.6600	0.2680
32.0	3.9700	3.7000	3.4100	2.7300	0.2680
64.0	2.8800	2.7500	1.7040	2.1800	0.1300

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	679.68	-0.0003	-0.2001	0.1635
1.0	848.54	0.0005	-0.2466	0.2601
1.5	924.38			
2.0	901.01	0.0004	-0.0697	-0.1364
3.0	989.31			
4.0	913.58	0.0016	-0.0578	0.3924
6.0	755.51			
8.0	664.01	0.0030	-0.0197	-0.5801
12.0	681.46			
16.0	704.72	0.0002	0.4708	0.6371
24.0	581.75			
32.0	617.26	0.0005	-0.2215	-0.1751
48.0	755.80			
64.0	780.92	0.0000	0.2451	0.0000

R.M.S. Observational Error = .0012
R.M.S. Offset Wenner Difference = .2346
R.M.S. Potential Ladder Difference = .3854

FIELD CURVE DATA / INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	679.68	0.13		211.3	
2	1.0	848.54				
3	1.5	924.38		0.13	--------	0.7524
4	2.0	955.00				
5	3.0	989.31	0.32		1495.4	
6	4.0	913.58				
7	6.0	755.51		0.45	--------	-0.1777
8	8.0	664.01				
9	12.0	565.00	3.35		1044.2	
10	16.0	530.00				
11	24.0	581.75		3.80	--------	-0.4031
12	32.0	617.26				
13	48.0	755.80	20.61		444.3	
14	64.0	780.92				
				24.41	--------	0.4807
					1266.8	
					********	

R.M.S. Relative error = 0.0222
Maximum rel. error = 0.0407 at sample 3
Number of trials was 30

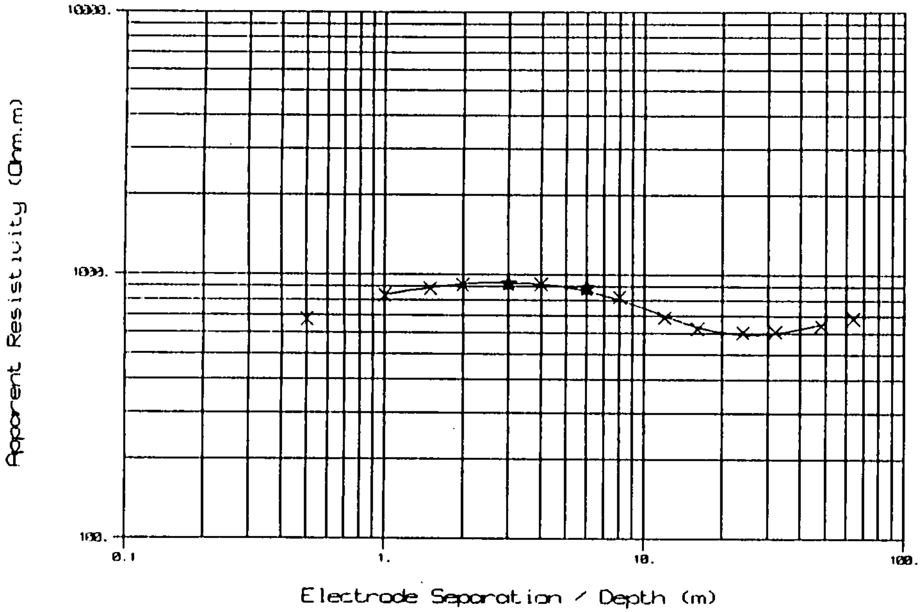
NO 69 SW R6B   6493 9015   **Greendams**

Azimuth 100°
August 1989

Overburden	0.1m
Mineral I	6.0m
Waste	24.1m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, silty, dry	241	0.1	0.1
Alluvium	Sand, pebbly, dry	1284	0.2	0.3
	Sand, silty, wet	961	5.8	6.1
Till/Decomposed bedrock	Clay, sandy and gravelly, wet	514	24.1	30.2
Caledonian	Granite, decomposed	842	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	316.0000	299.0000	231.0000	200.0000	16.9000
1.0	195.9000	187.6000	133.3000	130.8000	8.2600
2.0	99.8000	94.1000	74.0000	70.8000	5.6600
4.0	47.7000	44.5000	40.4000	32.4000	3.2400
8.0	21.3000	20.2000	17.2500	15.3600	1.1000
16.0	7.8800	7.3900	5.9100	6.5100	0.4890
32.0	4.1500	3.8800	3.1100	2.9600	0.2530

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	677.01	0.0003	-0.1439	0.1327
1.0	829.69	0.0002	-0.0189	0.2675
1.5	882.00			
2.0	909.81	0.0004	-0.0442	0.0967
3.0	976.41			
4.0	914.83	-0.0008	-0.2198	-0.0044
6.0	902.14			
8.0	819.58	0.0000	-0.1159	0.1272
12.0	687.55			
16.0	624.30	0.0001	0.0966	-0.1110
24.0	604.92			
32.0	610.22	0.0041	-0.0494	0.0000
48.0	643.89			
64.0	685.99			

R.M.S. Observational Error = .0016
R.M.S. Offset Wenner Difference = .1174
R.M.S. Potential Ladder Difference = .1455

FIELD CURVE DATA   INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	677.01	0.13		241.4	
2	1.0	829.69				
3	1.5	882.00		0.13	--------	0.6834
4	2.0	909.81				
5	3.0	920.00	0.20		1283.8	
6	4.0	914.83				
7	6.0	885.00		0.33	--------	-0.1440
8	8.0	819.58				
9	12.0	687.55	5.79		960.7	
10	16.0	624.30				
11	24.0	604.92		6.12	--------	-0.3031
12	32.0	610.22				
13	48.0	643.89	24.08		513.7	
14	64.0	685.99				
				30.20	--------	0.2424
					842.4	
					********	

R.M.S. Relative error = 0.0123
Maximum rel. error = -0.0236 at sample 8
Number of trials was 7

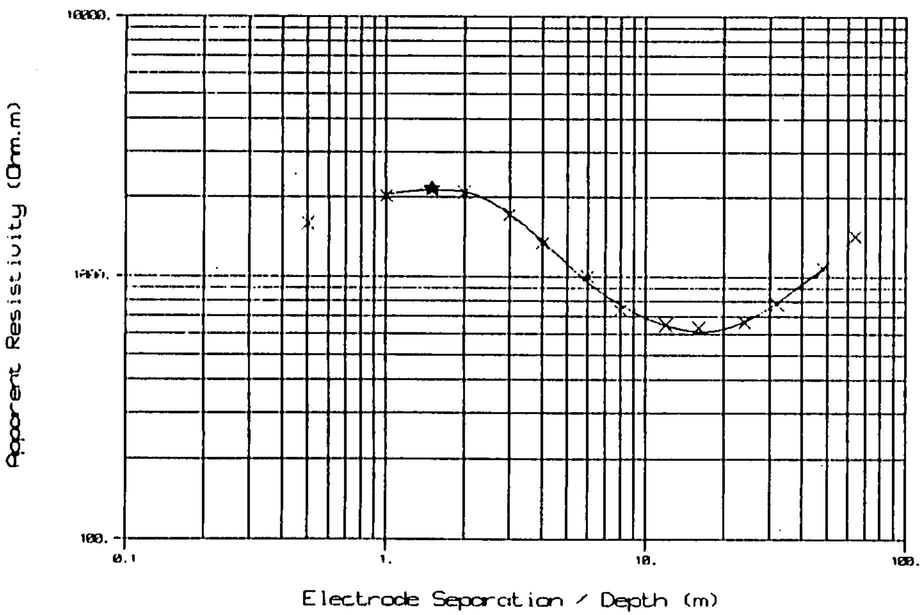
NO 69 SE R1A 6553 9193 Castlehill

Azimuth 100°
August 1989

Overburden	0.1m
Mineral I	1.5m
Waste	20.5m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, silty and sandy, dry	516	0.1	0.1
Alluvium	Sand, gravelly, dry	1809	0.3	0.4
	Gravel, sandy	3321	1.2	1.6
Glaciolacustrine deposits	Silt, clayey and sandy, wet	708	8.1	9.7
Till	Clay, silty and sandy, wet	339	12.4	22.1
Caledonian	Granite	3737	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	795.0000	767.0000	499.0000	510.0000	29.0000
1.0	455.0000	426.0000	338.0000	307.0000	28.8000
2.0	219.0000	209.0000	173.2000	158.0000	10.5300
4.0	63.9000	60.9000	58.7000	47.8000	2.9600
8.0	18.3500	17.2400	16.2600	13.0900	1.1050
16.0	8.8400	8.4200	6.4200	6.2000	0.4240
32.0	5.9100	5.6400	3.8400	3.9100	0.2690

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	1584.93	-0.0013	0.0218	0.3125
1.0	2026.33	0.0004	-0.0961	0.1256
1.5	2298.46			
2.0	2080.99	-0.0024	-0.0918	0.3104
3.0	1717.69			
4.0	1338.32	0.0006	-0.2047	0.0226
6.0	995.86			
8.0	737.65	0.0003	-0.2160	-0.0931
12.0	651.19			
16.0	634.35	-0.0005	-0.0349	0.0440
24.0	665.20			
32.0	779.11	0.0002	0.0181	0.0000
48.0	1070.08			
64.0	1419.88			

R.M.S. Observational Error = .0011
R.M.S. Offset Wenner Difference = .1244
R.M.S. Potential Ladder Difference = .1919

FIELD CURVE DATA — INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	1584.93	0.09		515.6	
2	1.0	2026.33				
3	1.5	2160.00		0.09	--------	0.5563
4	2.0	2080.99				
5	3.0	1717.69	0.27		1808.5	
6	4.0	1338.32				
7	6.0	995.86		0.37	--------	0.2948
8	8.0	737.65				
9	12.0	651.19	1.24		3320.8	
10	16.0	634.35				
11	24.0	665.20		1.61	--------	-0.6484
12	32.0	779.11				
13	48.0	1070.08	8.06		708.2	
14	64.0	1419.88				
				9.68	--------	-0.3526
			12.41		339.0	
				22.09	--------	0.8336
					3736.7	
					********	

R.M.S. Relative error = 0.0179
Maximum rel. error = -0.0322 at sample 7
Number of trials was 30

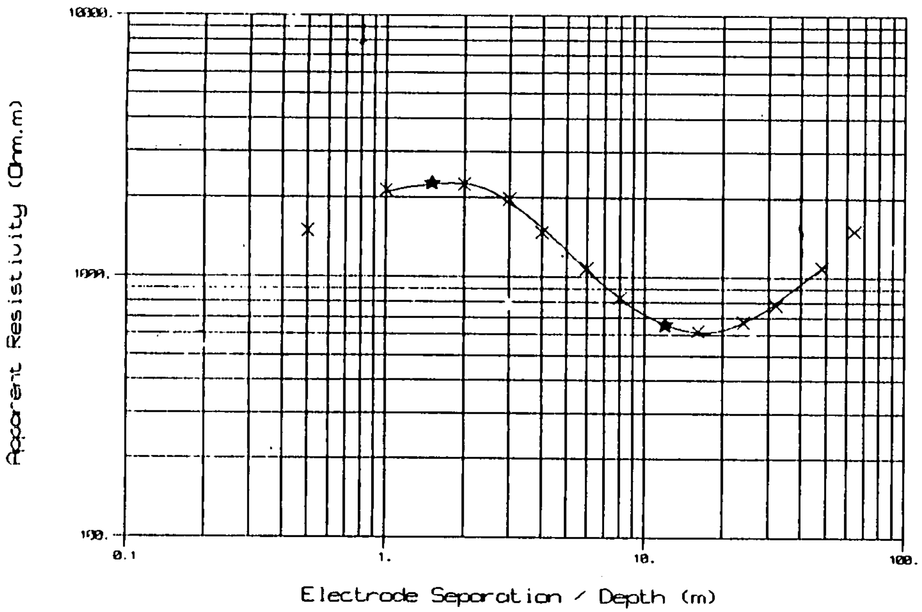
NO 69 SE R1B 6553 9193 Castlehill

Azimuth 005°
August 1989

Overburden	0.1m
Mineral I	1.6m
Waste	19.8m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, silty, dry	485	0.1	0.1
Alluvium	Sand, gravelly, dry	1744	0.3	0.4
	Gravel, sandy	3667	1.3	1.7
Glaciolacustrine deposits	Silt, clayey and sandy, wet	744	7.4	9.1
Till	Clay, silty and sandy, wet	332	12.4	21.5
Caledonian	Granite	3749	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	718.0000	687.0000	465.0000	489.0000	30.3000
1.0	475.0000	449.0000	349.0000	331.0000	26.0000
2.0	227.0000	215.0000	196.3000	162.8000	11.8700
4.0	73.7000	70.9000	61.8000	56.1000	2.8000
8.0	21.1000	20.1000	16.6600	16.3900	1.0280
16.0	8.2600	7.8100	6.5500	5.7800	0.4590
32.0	6.0100	5.7500	3.9700	3.8100	0.2400

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral. Error
0.5	1498.54	0.0010	0.0903	0.1186
1.0	2136.28	0.0000	-0.0529	0.1071
1.5	2407.66			
2.0	2256.29	0.0006	-0.1866	0.1024
3.0	1981.53			
4.0	1481.58	0.0000	-0.0967	0.2240
6.0	1080.23			
8.0	829.63	-0.0013	-0.0188	0.0810
12.0	720.98			
16.0	619.77	-0.0011	-0.1249	-0.0782
24.0	672.39			
32.0	782.13	0.0033	-0.0411	0.0000
48.0	1084.60			
64.0	1903.61			

R.M.S. Observational Error = .0015
R.M.S. Offset Wenner Difference = .0979
R.M.S. Potential Ladder Difference = .1284

FIELD CURVE DATA / INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	1498.54	0.09		485.2	
2	1.0	2136.28				
3	1.5	2275.00		0.09	--------	0.5647
4	2.0	2256.29				
5	3.0	1981.53	0.27		1743.8	
6	4.0	1481.58				
7	6.0	1080.23		0.36	--------	0.3554
8	8.0	829.63				
9	12.0	655.00	1.32		3666.9	
10	16.0	619.77				
11	24.0	672.39		1.68	--------	-0.6626
12	32.0	782.13				
13	48.0	1084.60	7.39		744.2	
14	64.0	1503.61				
				9.07	--------	-0.3834
			12.40		331.6	
				21.47	--------	0.8375
					3749.2	
					********	

R.M.S. Relative error = 0.0195
Maximum rel. error = 0.0268 at sample 1
Number of trials was 20

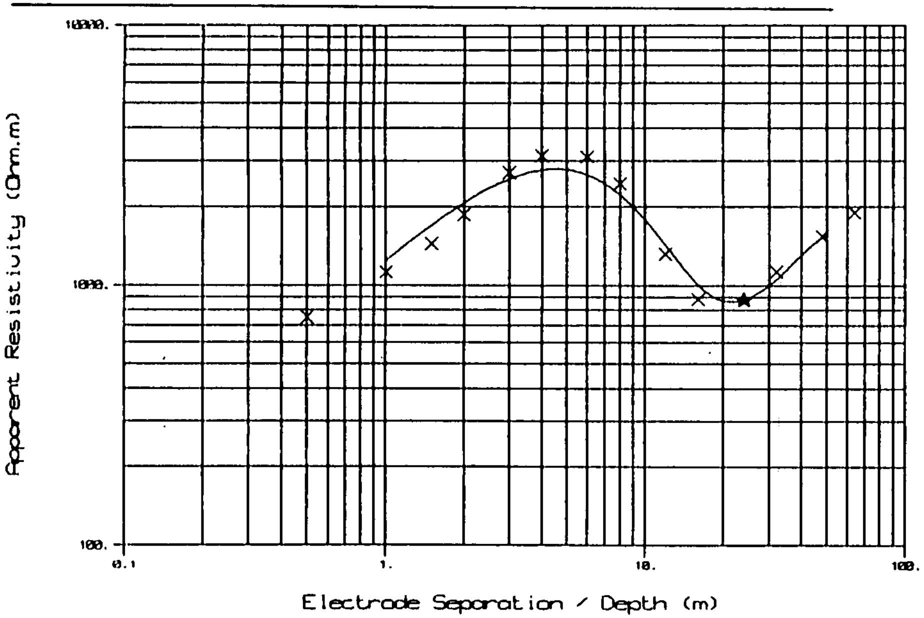
NO 69 SE R2A **6523 9133** **Dalbreck**

Azimuth 060°
August 1989

Overburden	0.1m
Mineral I	2.0m
Waste	7.6m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, silty	146	0.1	0.1
Alluvium (Terrace)	Gravel, dry	5885	1.0	1.1
	Cobble, gravel, dry	14492	1.0	2.1
?Glaciolacustrine deposits	Silt, sandy and clayey, wet	202	7.6	9.7
Caledonian	Granite, fresh	9408	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	362.0000	339.0000	291.0000	187.0000	22.0000
1.0	265.0000	253.0000	202.0000	195.9000	11.6400
2.0	234.0000	216.0000	164.9000	131.7000	18.4600
4.0	176.8000	162.6000	133.2000	116.1000	14.1100
8.0	60.3000	57.5000	45.6000	52.0000	2.8300
16.0	11.5400	10.9200	8.9900	8.5800	0.6140
32.0	8.5800	8.0300	5.6500	5.5700	0.5480
64.0	6.9400	6.4800	4.7800	4.6900	0.4580

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	750.84	0.0028	-0.4351	0.0614
1.0	1124.38	0.0014	-0.2576	0.0005
1.5	1444.28			
2.0	1863.59	-0.0080	-0.2239	0.0414
3.0	2700.56			
4.0	3132.80	0.0005	-0.1372	0.2785
6.0	3106.28			
8.0	2452.96	-0.0005	0.1311	0.4887
12.0	1320.09			
16.0	883.16	0.0005	-0.0467	-0.1189
24.0	751.32			
32.0	1127.96	0.0014	-0.0143	0.0102
48.0	1540.15			
64.0	1904.06	0.0003	-0.0190	0.0000

R.M.S. Observational Error = .0014
R.M.S. Offset Wenner Difference = .2075
R.M.S. Potential Ladder Difference = .2191

FIELD CURVE DATA

	Electrode Separation	Apparent Resistivity
1	0.5	750.84
2	1.0	1124.38
3	1.5	1444.28
4	2.0	1863.59
5	3.0	2700.56
6	4.0	3132.80
7	6.0	3106.28
8	8.0	2452.96
9	12.0	1320.09
10	16.0	883.16
11	24.0	875.00
12	32.0	1127.96
13	48.0	1540.15
14	64.0	1904.06

INTERPRETED MODEL

Thickness	Depth	Rho	Reflection Coeffts.
0.13		145.7	
	0.13	--------	0.9517
0.98		5884.6	
	1.11	--------	0.4224
0.95		14492.1	
	2.07	--------	-0.9725
7.67		202.0	
	9.74	--------	0.9580
		9408.1	
		********	

R.M.S. Relative error = 0.0996
Maximum rel. error = 0.1789 at sample 4
Number of trials was 30

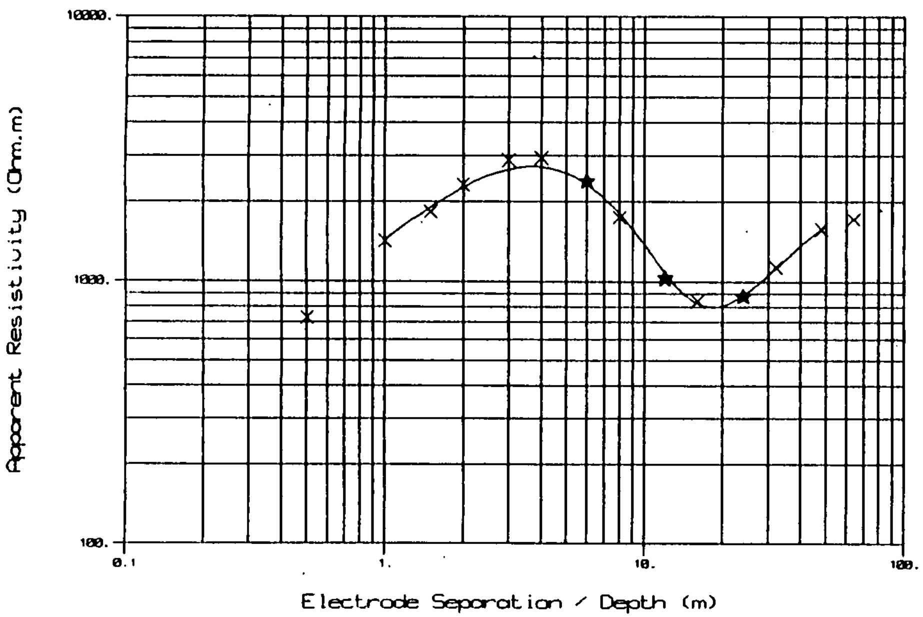
NO 69 SE R2B | 6523 9133 | Dalbreck

Azimuth 150°
August 1989

Overburden	0.2m
Mineral I	1.8m
Waste	9.7m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, silty	193	0.2	0.2
Alluvium (Terrace)	Gravel, dry	5375	0.5	0.7
	Cobble gravel, sandy, dry	9655	1.3	2.0
?Glaciolacustrine deposits	Silt, sandy and clayey, wet	287	9.7	11.7
Caledonian	Granite	6610	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	333.0000	317.0000	197.6000	265.0000	16.7400
1.0	363.0000	358.0000	272.0000	178.9000	5.5300
2.0	307.0000	300.0000	262.0000	108.6000	7.1700
4.0	135.7000	119.5000	185.0000	49.2000	16.1700
8.0	30.2000	27.9000	54.1000	15.0900	2.3800
16.0	12.8800	12.5400	9.0700	7.6800	0.3470
32.0	8.3400	7.7000	5.8100	5.4000	0.6300
64.0	5.8500	5.3200	4.4900	4.0800	0.5300

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	726.65	-0.0022	0.2914	-0.1214
1.0	1416.54	-0.0015	-0.4130	0.2139
1.5	1830.10			
2.0	2328.95	-0.0006	-0.8278	0.4788
3.0	2881.00			
4.0	2943.04	0.0002	-1.1597	-0.4302
6.0	3198.82			
8.0	1738.93	-0.0036	-1.1276	-1.3038
12.0	579.82			
16.0	841.95	-0.0005	-0.1680	0.2425
24.0	747.96			
32.0	1126.95	0.0012	-0.0731	-0.0066
48.0	1572.35			
64.0	1711.04	0.0000	-0.1105	0.0000

R.M.S. Observational Error = .0014
R.M.S. Offset Wenner Difference = .6710
R.M.S. Potential Ladder Difference = .5649

FIELD CURVE DATA | INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	726.65	0.15		193.2	
2	1.0	1416.54				
3	1.5	1830.10		0.15	--------	0.9306
4	2.0	2328.55				
5	3.0	2881.00	0.95		5375.0	
6	4.0	2943.04				
7	6.0	2400.00		0.70	--------	0.2848
8	8.0	1738.93				
9	12.0	1025.00	1.30		9655.1	
10	16.0	841.95				
11	24.0	875.00		1.99	--------	-0.9423
12	32.0	1126.95				
13	48.0	1572.35	9.73		287.1	
14	64.0	1711.04				
				11.72	--------	0.9168
					6610.3	
					********	

R.M.S. Relative error = 0.0471
Maximum rel. error = 0.0924 at sample 1
Number of trials was 8

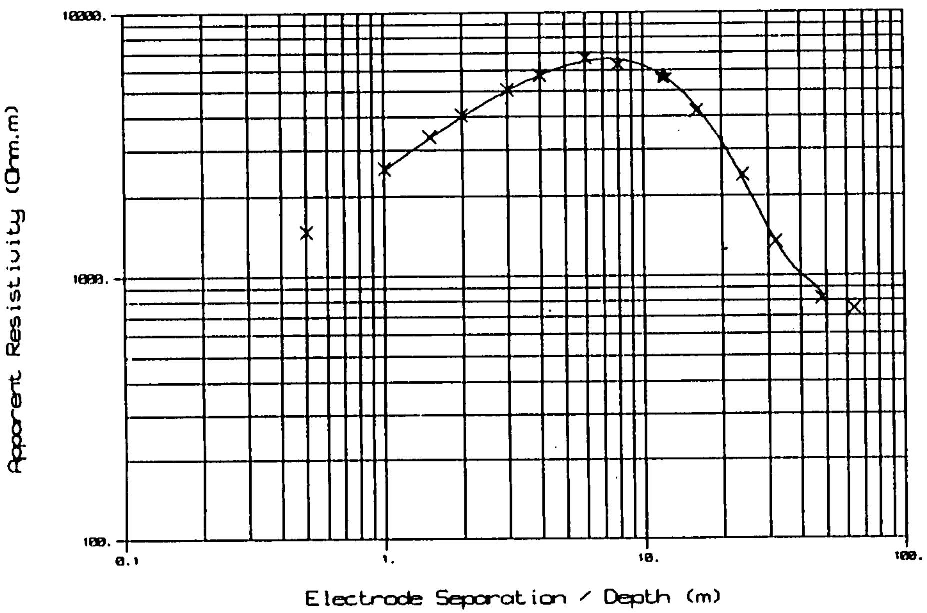
NO 69 SE R4A | 6646 9151 | Muiryhaugh

Azimuth 045°
August 1989

Overburden 0.1m
Mineral I 8.8m
Waste -

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, silty	321	0.1	0.1
Fluvioglacial sand and gravel	Gravel, sandy, dry	6439	1.4	1.5
	Cobble gravel, dry	11349	5.7	7.2
	Gravel, sandy, damp	3798	1.7	8.9
Till	Clay, gravelly and sandy	680	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	720.0000	683.0000	443.0000	494.0000	36.9000
1.0	611.0000	582.0000	420.0000	390.0000	31.0000
2.0	488.0000	463.0000	341.0000	304.0000	24.2000
4.0	304.0000	278.0000	266.0000	188.7000	25.4000
8.0	195.4000	145.3000	135.4000	114.9000	10.0800
16.0	49.9000	48.1000	43.1000	40.5000	1.8140
32.0	7.9400	7.6900	7.4000	5.9800	0.2490
64.0	2.6300	2.4200	1.9220	1.7880	0.1950

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	1471.84	0.0001	0.1089	0.0297
1.0	2544.69	-0.0033	-0.0741	0.0459
1.5	3372.16			
2.0	4052.65	0.0016	-0.1147	0.1197
3.0	5055.37			
4.0	5713.93	0.0080	-0.3400	-0.0931
6.0	6689.91			
8:0	6290.73	0.0001	-0.1638	-0.0177
12.0	5136.92			
16.0	4202.19	-0.0003	-0.0622	0.4407
24.0	2409.44			
32.0	1345.10	0.0001	-0.2123	0.0393
48.0	816.64			
64.0	745.94	0.0057	-0.0722	0.0000
96.0	872.18			
128.0	919.93			

R.M.S. Observational Error = .0025
R.M.S. Offset Wenner Difference = .1685
R.M.S. Potential Ladder Difference = .1781

FIELD CURVE DATA

	Electrode Separation	Apparent Resistivity
1	0.5	1471.84
2	1.0	2544.69
3	1.5	3372.16
4	2.0	4052.65
5	3.0	5055.37
6	4.0	5713.93
7	6.0	6689.91
8	8.0	6290.73
9	12.0	5650.00
10	16.0	4202.19
11	24.0	2409.44
12	32.0	1345.10
13	48.0	816.64
14	64.0	745.94

R.M.S. Relative error = 0.0206
Maximum rel. error = -0.0367 at sample 11
Number of trials was 30

INTERPRETED MODEL

Thickness	Depth	Rho	Reflection Coeffts.
0.12		320.8	
	0.12	--------	0.9051
1.39		6438.7	
	1.51	--------	0.2761
5.70		11349.1	
	7.21	--------	-0.4985
1.64		3797.9	
	8.85	--------	-0.6963
		680.0	
		********	

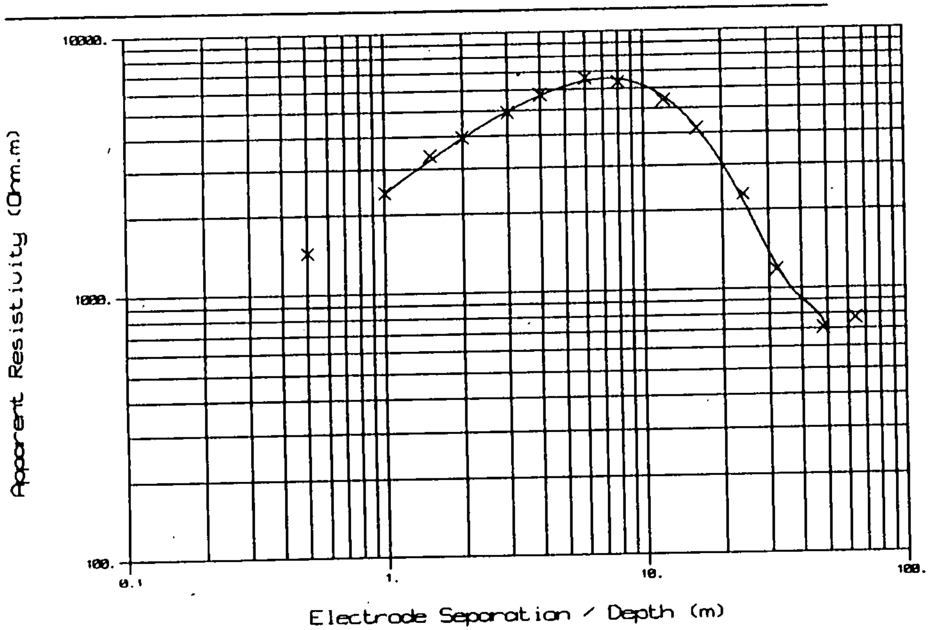
NO69 SE R4B | **6646 9151** | **Muiryhaugh**

Azimuth 070°
August 1989

Overburden	0.1m
Mineral I	8.5m
Waste	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, silty	309	0.1	0.1
Fluvioglacial sand and gravel	Gravel, sandy, dry	6806	1.4	1.5
	Cobble gravel, dry	11416	5.5	7.0
	Gravel, sandy, damp	3786	1.6	8.6
Till	Clay, gravelly and sandy	599	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	721.0000	690.0000	419.0000	496.0000	31.5000
1.0	574.0000	538.0000	392.0000	384.0000	36.1000
2.0	476.0000	451.0000	325.0000	306.0000	24.8000
4.0	316.0000	294.0000	234.0000	222.0000	22.6000
8.0	158.1000	148.0000	116.4000	136.2000	10.1400
16.0	46.1000	44.3000	46.2000	36.6000	1.7910
32.0	6.3300	6.0900	6.1000	5.6600	0.2370
64.0	2.7800	2.6000	1.8680	1.9510	0.1695

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	1437.28	-0.0007	0.1683	0.0986
1.0	2437.88	-0.0002	-0.0206	-0.0247
1.5	3358.59			
2.0	3964.69	0.0004	-0.0002	0.0947
3.0	4909.52			
4.0	5730.27	-0.0019	-0.0526	0.0204
6.0	6594.46			
8.0	6348.53	-0.0003	0.1568	0.0237
12.0	5384.20			
16.0	4161.98	0.0002	-0.2319	-0.0061
24.0	2306.05			
32.0	1182.24	0.0005	-0.0748	-0.3893
48.0	705.92			
64.0	767.86	0.0038	0.0435	0.0000

R.M.S. Observational Error = .0015
R.M.S. Offset Wenner Difference = .1230
R.M.S. Potential Ladder Difference = .1567

FIELD CURVE DATA

	Electrode Separation	Apparent Resistivity
1	0.5	1437.28
2	1.0	2437.88
3	1.5	3358.59
4	2.0	3964.69
5	3.0	4909.52
6	4.0	5730.27
7	6.0	6594.46
8	8.0	6348.53
9	12.0	5384.20
10	16.0	4161.98
11	24.0	2306.05
12	32.0	1182.24
13	48.0	705.92
14	64.0	767.86

R.M.S. Relative error = 0.0291
Maximum rel. error = -0.0603 at sample 11
Number of trials was 16

INTERPRETED MODEL

Thickness	Depth	Rho	Reflection Coeffts.
0.12		308.8	
	0.12	--------	0.9132
1.35		6806.3	
	1.47	--------	0.2530
5.51		11416.0	
	6.98	--------	-0.5019
1.63		3786.2	
	8.61	--------	-0.7266
		599.4	
		********	

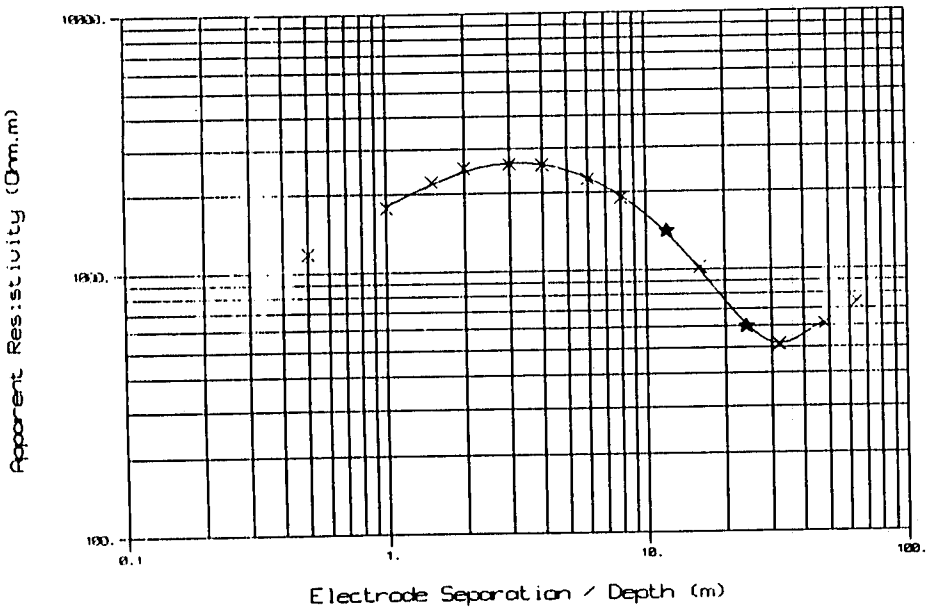
N069 SE R5A   6735 9202   Strachan Bridge

Azimuth 040°
August 1989

Overburden	0.1m
Mineral I	11.7m
Waste	12.2m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, silty	292	0.1	0.1
Alluvium	Gravel, sandy, dry	3633	2.7	2.8
Fluvioglacial sand and gravel	Sand, gravelly, wet	1558	9.0	11.8
Glaciolacustrine deposits	Silt and clay, sandy, wet	149	12.2	24.0
Caledonian	Granite	2313	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	573.0000	539.0000	336.0000	415.0000	33.0000
1.0	403.0000	376.0000	286.0000	279.0000	27.9000
2.0	277.0000	262.0000	,178.2000	222.0000	14.8800
4.0	132.0000	127.3000	86.8000	118.2000	4.6900
8.0	49.9000	48.9000	31.2000	44.6000	1.0110
16.0	13.5300	13.1500	7.5400	12.6700	0.3720
32.0	3.6300	3.4200	2.5200	2.5700	0.2060
64.0	2.8200	2.6500	2.0700	1.6100	0.1720

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	1179.67	0.0017	0.2104	0.0804
1.0	1775.00	-0.0022	-0.0248	-0.0348
1.5	2225.57			
2.0	2514.53	0.0004	0.2189	0.1045
3.0	2607.16			
4.0	2576.11	0.0001	0.3063	0.1545
6.0	2262.21			
8.0	1905.06	-0.0002	0.3536	0.5880
12.0	1532.33			
16.0	1015.87	0.0006	0.5077	0.6980
24.0	857.46			
32.0	511.70	0.0011	0.0196	-0.0234
48.0	611.18			
64.0	739.91	-0.0007	-0.2500	0.0000
96.0	1022.33			
128.0	1301.37			

R.M.S. Observational Error = .0011
R.M.S. Offset Wenner Difference = .2811
R.M.S. Potential Ladder Difference = .3538

FIELD CURVE DATA   INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	1179.67	0.13		291.7	
2	1.0	1775.00				
3	1.5	2225.57		0.13	--------	0.8513
4	2.0	2514.53				
5	3.0	2607.16	2.70		3632.8	
6	4.0	2576.11				
7	6.0	2262.21		2.83	--------	-0.3997
8	8.0	1905.06				
9	12.0	1410.00	8.95		1557.9	
10	16.0	1015.87				
11	24.0	600.00		11.78	--------	-0.8259
12	32.0	511.70				
13	48.0	611.18	12.20		148.5	
14	64.0	739.91				
				23.98	--------	0.8793
					2312.9	
					********	

R.M.S. Relative error = 0.0159
Maximum rel. error = -0.0240 at sample 10
Number of trials was 20

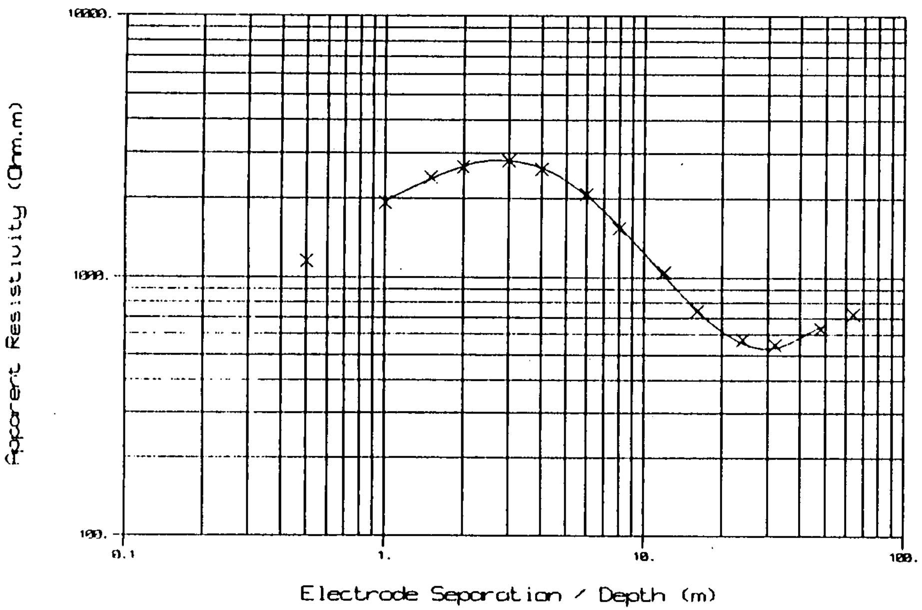
NO 69SE R5B   6735 9202   **Strachan Bridge**

Azimuth 110°
August 1989

Overburden	0.1m
Mineral I	13.2m
Waste	11.5m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, silty	290	0.1	0.1
Alluvium	Gravel, sandy, dry	4670	2.3	2.4
Fluvioglacial sand and gravel	Sand, wet	910	10.9	13.3
Glaciolacustrine deposits	Silt and clay, sandy, wet	175	11.5	24.8
Caledonian	Granite	1875	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	575.0000	546.0000	363.0000	370.0000	28.8000
1.0	456.0000	429.0000	301.0000	313.0000	26.5000
2.0	288.0000	270.0000	208.0000	213.0000	18.2000
4.0	131.5000	124.8000	101.9000	104.6000	6.7000
8.0	35.8000	34.2000	29.4000	31.7000	1.5620
16.0	9.8500	9.5200	6.5400	8.1700	0.3260
32.0	4.2000	4.0200	2.5200	2.9100	0.1758
64.0	2.6000	2.3900	1.7340	1.8500	0.2080

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	1151.39	0.0003	0.0191	0.0850
1.0	1928.94	0.0011	0.0391	0.0807
1.5	2417.07			
2.0	2645.22	-0.0007	0.0238	0.0754
3.0	2800.18			
4.0	2594.96	0.0000	0.0362	0.2054
6.0	2088.77			
8.0	1536.61	0.0011	0.0753	-0.0013
12.0	1041.65			
16.0	739.41	0.0004	0.2216	0.2981
24.0	572.76			
32.0	545.88	0.0010	0.1436	0.2294
48.0	634.35			
64.0	720.61	0.0008	0.0647	0.0000
96.0	921.13			
128.0	963.36			

R.M.S. Observational Error = .0008
R.M.S. Offset Wenner Difference = .1017
R.M.S. Potential Ladder Difference = .1703

FIELD CURVE DATA   INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	1151.39	0.13		290.0	
2	1.0	1928.94				
3	1.5	2417.07		0.13	--------	0.8831
4	2.0	2645.22				
5	3.0	2800.18	2.30		4670.0	
6	4.0	2594.96				
7	6.0	2088.77		2.43	--------	-0.6738
8	8.0	1536.61				
9	12.0	1041.65	10.87		910.0	
10	16.0	739.41				
11	24.0	572.76		13.30	--------	-0.6774
12	32.0	545.88				
13	48.0	634.35	11.45		175.0	
14	64.0	720.61				
				24.75	--------	0.8293
					1875.0	
					********	

R.M.S. Relative error = 0.0219
Maximum rel. error = 0.0495 at sample 1
Number of trials was 0

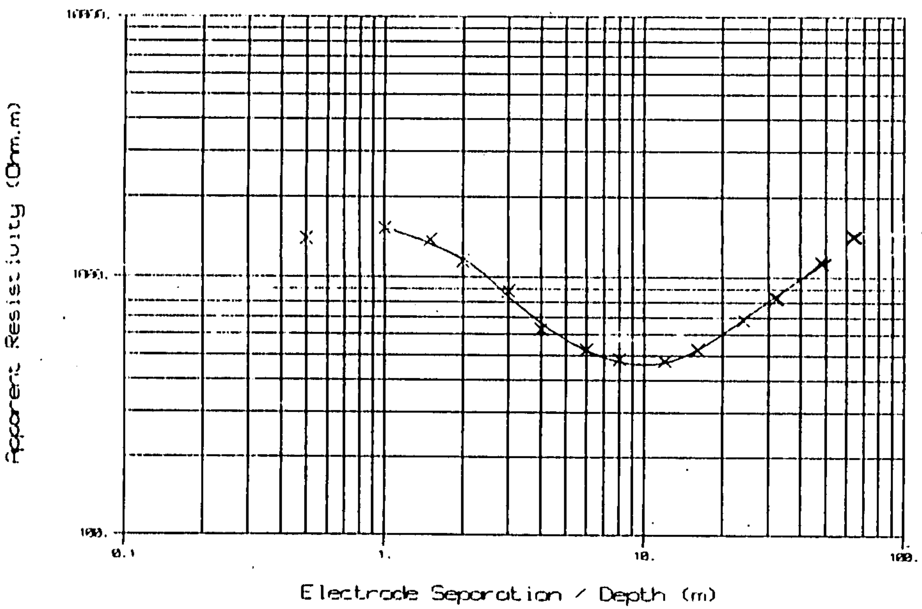
NO 69SE R6A **6965 9104** **Burn of Curran**

Azimuth 050°
August 1989

Overburden	0.1m
Mineral I	1.1m
Waste	10.6m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, sandy	730	0.1	0.1
Alluvium	Sand	1918	1.1	1.2
Glaciolacustrine deposits	Silt, damp	513	5.5	6.7
Till	Clay, sandy, wet	190	5.1	11.8
Caledonian	Granite	2478	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	672.0000	633.0000	456.0000	433.0000	37.7000
1.0	337.0000	321.0000	221.0000	266.0000	16.4800
2.0	122.9000	117.4000	81.9000	100.2000	5.0800
4.0	30.4000	28.8000	24.5000	25.6000	1.6610
8.0	13.1200	12.5700	8.4500	10.0200	0.5410
16.0	7.7100	7.2900	5.1900	5.2500	0.4170
32.0	6.3200	5.9600	4.2300	3.9800	0.3460
64.0	5.4000	5.0700	3.5600	3.4800	0.3260

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	1396.44	0.0019	-0.0517	0.2766
1.0	1529.96	-0.0014	0.1848	0.3487
1.5	1376.08			
2.0	1144.17	0.0002	0.2010	0.5523
3.0	879.56			
4.0	629.58	-0.0020	0.0439	-0.0971
6.0	517.29			
8.0	464.20	0.0007	0.1700	0.1397
12.0	460.63			
16.0	524.77	0.0004	0.0115	0.0046
24.0	684.37			
32.0	825.36	0.0022	-0.0609	0.0289
48.0	1128.50			
64.0	1415.48	0.0007	-0.0227	0.0000

R.M.S. Observational Error = .0014
R.M.S. Offset Wenner Difference = .1185
R.M.S. Potential Ladder Difference = .2759

FIELD O.P.E DATA / INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	1396.44	0.14		729.8	
2	1.0	1529.96				
3	1.5	1376.08		0.14	--------	0.4487
4	2.0	1144.17				
5	3.0	879.56	1.08		1918.0	
6	4.0	629.58				
7	6.0	524.68		1.22	--------	-0.5781
8	8.0	483.93				
9	12.0	475.43	5.54		512.7	
10	16.0	524.77				
11	24.0	684.37		6.76	--------	-0.4599
12	32.0	825.36				
13	48.0	1128.50	5.05		189.7	
14	64.0	1415.48				
				11.81	--------	0.8578
					2477.8	
					********	

R.M.S. Relative error = 0.0186
Maximum rel. error = 0.0421 at sample 7
Number of trials was 30

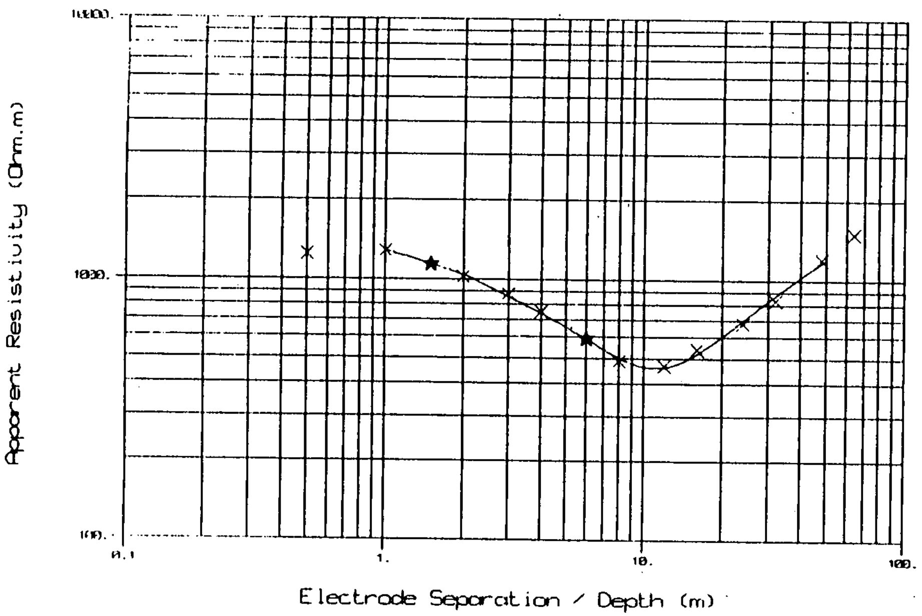
NO 69SE R6B 6965 9104 **Burn of Curran**

Azimuth 140°
August 1989

Overburden	0.1m
Mineral I	0.9m
Waste	9.5m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, sandy	758	0.1	0.1
Alluvium	Sand	1489	0.9	1.0
Glaciolacustrine deposits	Silt	761	4.1	5.2
Till	Clay, sandy, wet	164	5.3	10.5
Caledonian	Granite	2949	-	-



252

INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	569.0000	526.0000	362.0000	430.0000	42.9000
1.0	269.0000	256.0000	203.0000	204.0000	13.6200
2.0	110.1000	105.4000	74.6000	87.8000	4.7600
4.0	37.5000	35.7000	24.7000	34.9000	1.8530
8.0	13.8100	13.2700	8.9400	10.4500	0.5390
16.0	8.2800	7.9800	4.7700	5.9500	0.2890
32.0	6.2800	5.9400	3.4100	4.8700	0.3200
64.0	5.5900	5.1900	3.5300	3.9300	0.3790

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	1244.07	0.0002	0.1717	0.1390
1.0	1278.63	-0.0023	0.0049	0.1429
1.5	1065.48			
2.0	1020.39	-0.0005	0.1626	0.3111
3.0	879.41			
4.0	748.96	-0.0014	0.3423	0.1060
6.0	634.87			
8.0	487.32	0.0001	0.1558	0.1671
12.0	468.59			
16.0	538.85	0.0013	0.2201	0.1341
24.0	678.6f			
32.0	832.40	0.0032	0.3527	-0.0149
48.0	1196.21			
64.0	1499.92	0.0038	0.1072	0.0000

R.M.S. Observational Error = .0021
R.M.S. Offset Wenner Difference = .2184
R.M.S. Potential Ladder Difference = .1664

FIELD CURVE DATA / INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	1244.07	0.12		758.1	
2	1.0	1278.63				
3	1.5	1135.00		0.12	--------	0.3251
4	2.0	1020.39				
5	3.0	879.41	0.90		1488.6	
6	4.0	748.96				
7	6.0	590.00		1.02	--------	-0.3233
8	8.0	487.32				
9	12.0	468.59	4.14		761.2	
10	16.0	538.85				
11	24.0	678.61		5.16	--------	-0.6459
12	32.0	832.40				
13	48.0	1196.21	5.36		163.8	
14	64.0	1499.92				
				10.52	--------	0.8948
					2948.9	
					********	

R.M.S. Relative error = 0.0223
Maximum rel. error = 0.0419 at sample 12
Number of trials was 30

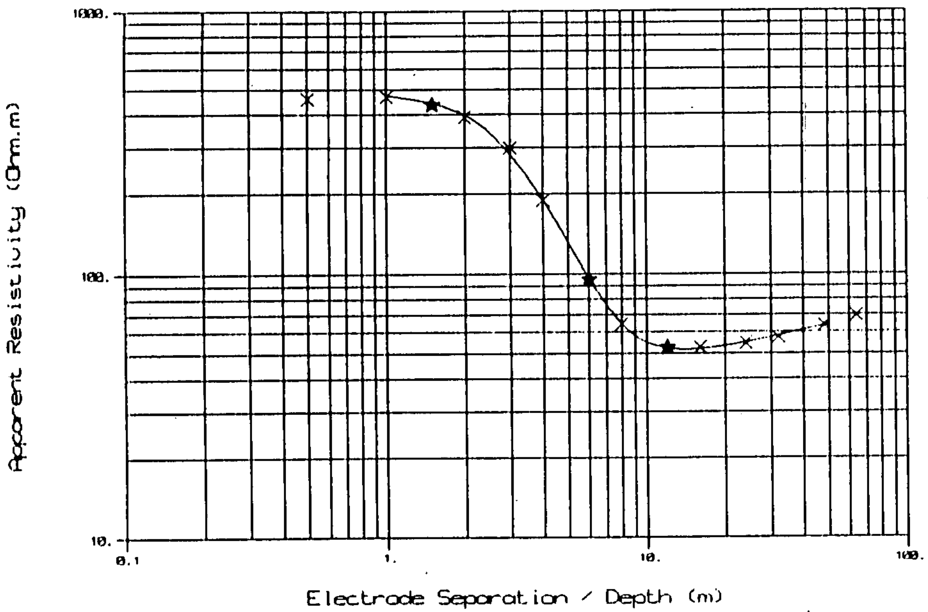
NO 77 NW R1A 7402 7676 **Brownmuir**

Azimuth 105°
August 1989

Waste 2.2m
Bedrock -

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, silty and pebbly, dry	236	0.1	0.1
?Flow-till	Clay, gravelly	514	2.1	2.2
Old Red Sandstone	Siltstone, clayey	52	6.9	9.1
	Mudstone	37	6.7	15.8
	Siltstone	73	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	212.0000	204.0000	133.4000	159.8000	7.7600
1.0	96.3000	91.3000	82.6000	66.6000	5.0000
2.0	36.5000	35.0000	30.0000	32.3000	1.5330
4.0	8.5100	8.2400	8.2100	6.8400	0.2700
8.0	1.6250	1.5400	1.2830	1.2940	0.0828
16.0	0.7140	0.6680	0.5300	0.5240	0.0420
32.0	0.3930	0.3700	0.2810	0.2890	0.0253
64.0	0.2430	0.2280	0.1730	0.1720	0.0150

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	460.56	0.0011	0.1801	0.2710
1.0	468.73	-0.0002	-0.2145	0.0358
1.5	472.46			
2.0	391.44	-0.0009	0.0738	0.0095
3.0	298.77			
4.0	189.12	0.0000	-0.1821	0.0549
6.0	118.54			
8.0	64.77	0.0014	0.0085	-0.0162
12.0	54.14			
16.0	52.48	0.0056	0.0077	0.0189
24.0	54.70			
32.0	57.30	-0.0058	0.0281	-0.0135
48.0	63.89			
64.0	69.37	0.0083	-0.0058	0.0000

R.M.S. Observational Error = .0042
R.M.S. Offset Wenner Difference = .1214
R.M.S. Potential Ladder Difference = .1080

FIELD CURVE DATA

	Electrode Separation	Apparent Resistivity
1	0.5	460.56
2	1.0	468.73
3	1.5	436.00
4	2.0	391.44
5	3.0	298.77
6	4.0	189.12
7	6.0	95.00
8	8.0	64.77
9	12.0	52.50
10	16.0	52.48
11	24.0	54.70
12	32.0	57.30
13	48.0	63.89
14	64.0	69.37

INTERPRETED MODEL

Thickness	Depth	Rho	Reflection Coeffts.
0.09		235.7	
	0.09	--------	0.3716
2.07		514.3	
	2.16	--------	-0.8173
6.96		51.7	
	9.12	--------	-0.1669
6.72		36.9	
	15.83	--------	0.3276
		72.9	
		********	

R.M.S. Relative error = 0.0172
Maximum rel. error = -0.0348 at sample 6
Number of trials was 10

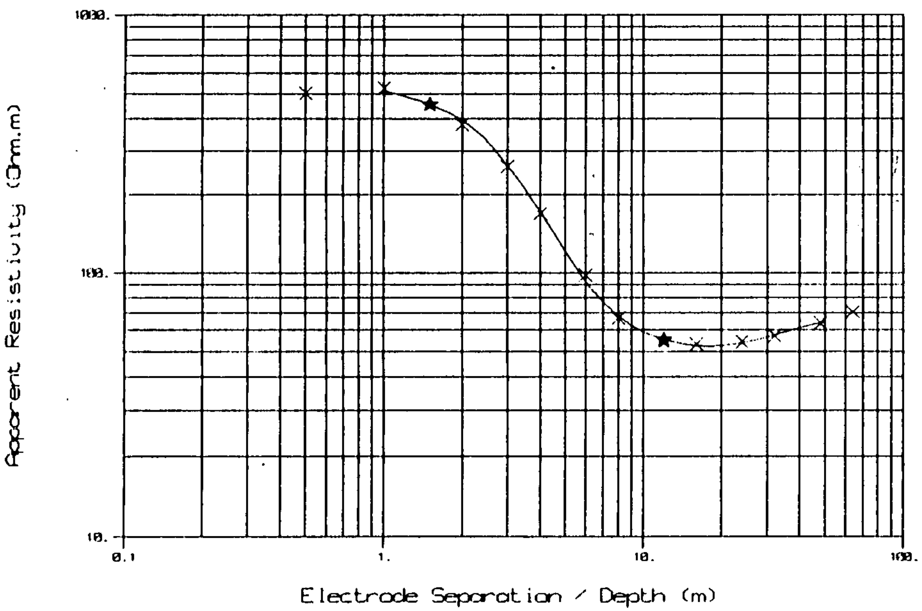
NO 77 NW R1B 7402 7676 **Brownmuir**

Azimuth 160°
August 1989

Waste 1.9m
Bedrock -

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, silty and pebbly, dry	272	0.1	0.1
?Flow-till	Clay, sandy and gravelly	556	1.8	1.9
Old Red Sandstone	Siltstone	69	6.4	8.3
	Mudstone	31	7.0	15.3
	Siltstone	74	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	238.0000	228.0000	170.8000	150.0000	9.7300
1.0	112.3000	105.7000	80.5000	87.4000	6.3500
2.0	36.3000	34.6000	26.3000	34.2000	1.6860
4.0	7.8800	7.6300	5.6600	7.7700	0.2560
8.0	1.7130	1.6240	1.2670	1.3920	0.0875
16.0	0.7260	0.6800	0.5090	0.5470	0.0430
32.0	0.3880	0.3720	0.2800	0.2880	0.0237
64.0	0.2530	0.2340	0.1780	0.1727	0.0141

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	503.91	0.0011	-0.1297	0.3068
1.0	527.47	0.0022	0.0822	0.2229
1.5	506.31			
2.0	380.13	0.0004	0.2612	0.1488
3.0	260.35			
4.0	168.77	-0.0008	0.3142	0.1860
6.0	97.71			
8.0	66.83	0.0009	0.0940	0.0591
12.0	57.33			
16.0	53.08	0.0095	0.0720	0.0418
24.0	54.37			
32.0	57.10	-0.0197	0.0282	-0.0190
48.0	63.64			
64.0	70.51	0.0196	-0.0302	0.0000

R.M.S. Observational Error = .0100
R.M.S. Offset Wenner Difference = .1606
R.M.S. Potential Ladder Difference = .1716

FIELD CURVE DATA | INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	503.91	0.07		272.0	
2	1.0	527.47				
3	1.5	455.00		0.07	--------	0.3432
4	2.0	380.13				
5	3.0	260.35	1.79		556.2	
6	4.0	168.77				
7	6.0	97.71		1.86	--------	-0.7808
8	8.0	66.83				
9	12.0	55.00	6.41		68.5	
10	16.0	53.08				
11	24.0	54.37		8.27	--------	-0.3801
12	32.0	57.10				
13	48.0	63.64	7.06		30.8	
14	64.0	70.51				
				15.33	--------	0.4151
					74.4	
					********	

R.M.S. Relative error = 0.0204
Maximum rel. error = -0.0372 at sample 2
Number of trials was 17

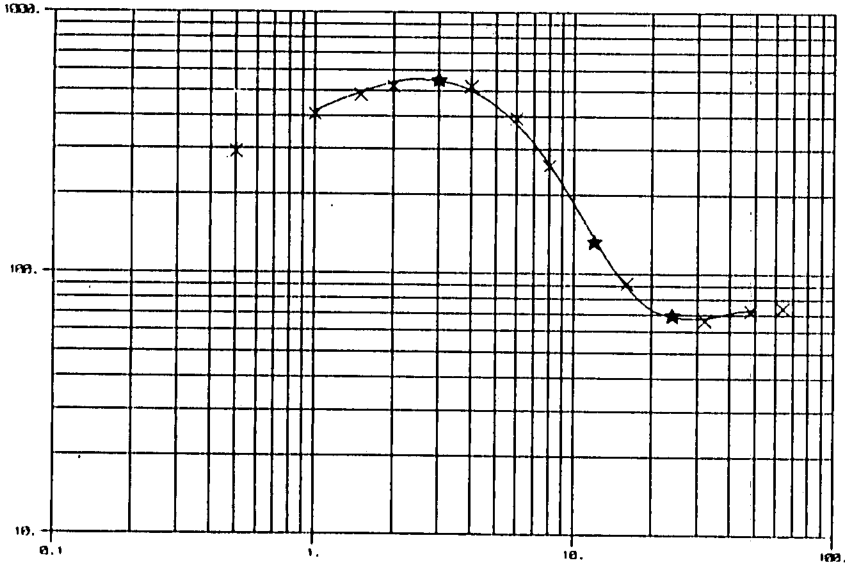
NO 77 NW R2A 7312 7668 **Mains of Fordoun**

Azimuth 105°
August 1989

Waste 5.3m
Bedrock -

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, clayey, dry	84	0.2	0.2
Alluvium	Clayey, silt and sandy gravel	799	2.1	2.3
Till	Clay, sandy and pebbly, wet	334	3.0	5.3
Old Red Sandstone	Siltstone	59	21.7	27.0
	Siltstone, sandy	81	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	144.1000	138.5000	95.0000	90.6000	5.7500
1.0	99.8000	95.8000	60.9000	68.9000	4.0200
2.0	55.8000	51.6000	42.9000	40.0000	4.1700
4.0	25.1000	23.4000	20.7000	20.6000	1.7000
8.0	5.9200	5.6700	4.8900	5.3900	0.2330
16.0	1.1630	1.1070	0.8990	0.9200	0.0500
32.0	0.4990	0.4260	0.3470	0.3140	0.0300
64.0	0.2560	0.2380	0.1820	0.1867	0.0160

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	291.54	-0.0010	-0.0474	0.2030
1.0	407.78	-0.0002	0.1233	0.2452
1.5	484.88			
2.0	520.88	0.0005	-0.0700	-0.0078
3.0	588.13			
4.0	518.99	0.0000	-0.0048	0.0350
6.0	392.97			
8.0	258.36	0.0029	0.0973	0.0917
12.0	117.48			
16.0	91.43	0.0052	0.0231	0.1062
24.0	65.87			
32.0	66.45	0.0902	-0.0998	0.1221
48.0	71.97			
64.0	74.13	0.0157	0.0255	0.0000

R.M.S. Observational Error = .0325
R.M.S. Offset Wenner Difference = .0733
R.M.S. Potential Ladder Difference = .1400

FIELD CURVE DATA / INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	291.54	0.15		83.5	
2	1.0	407.78				
3	1.5	484.88		0.15	--------	0.8108
4	2.0	520.88				
5	3.0	550.00	2.19		799.2	
6	4.0	518.99				
7	6.0	392.97		2.34	--------	-0.4106
8	8.0	258.36				
9	12.0	132.00	2.95		333.9	
10	16.0	91.43				
11	24.0	69.00		5.29	--------	-0.7012
12	32.0	66.45				
13	48.0	71.97	21.68		58.7	
14	64.0	74.13				
				26.97	--------	0.1578
					80.6	

R.M.S. Relative error = 0.0318
Maximum rel. error = -0.0581 at sample 1
Number of trials was 30

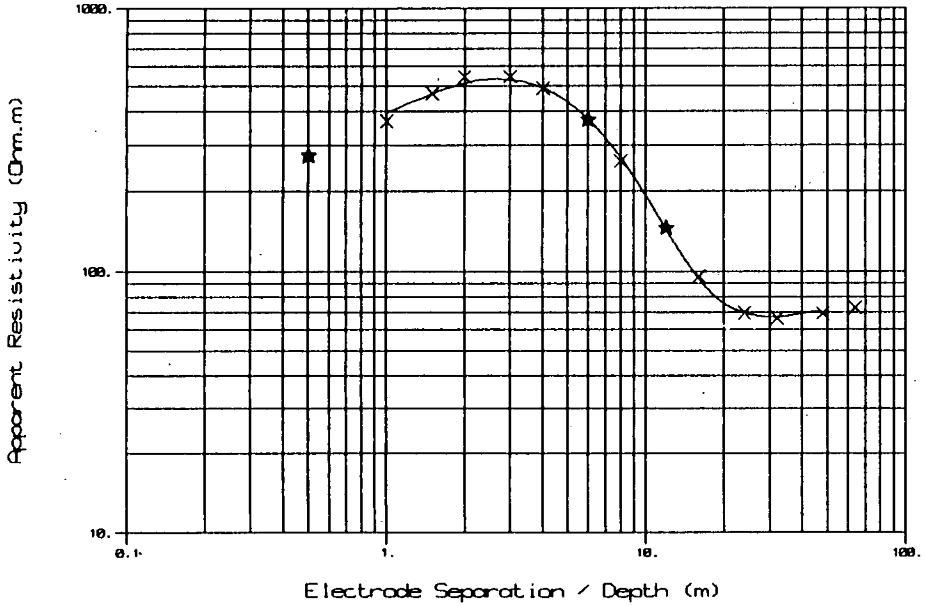
****

NO 77 NW R2B   7312 7668   **Mains of Fordoun**

Azimuth 030°   Waste 5.5m
August 1989   Bedrock -

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, clayey, dry	79	0.2	0.2
Alluvium	Clayey silt and sand gravel	772	2.3	2.5
Till	Clay, sandy and pebbly, wet	313	3.0	5.5
Old Red Sandstone	Siltstone	61	26.7	32.2
	Siltstone, sandy	76	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	123.5000	116.6000	105.7000	79.7000	6.4900
1.0	83.4000	78.2000	60.7000	56.6000	5.1900
2.0	64.8000	62.1000	48.1000	38.6000	2.6200
4.0	22.4000	20.6000	19.8300	19.1800	1.7770
8.0	5.9400	5.7000	5.2700	5.0500	0.2320
16.0	1.1840	1.1350	0.9130	0.9840	0.0530
32.0	0.4480	0.4200	0.3250	0.3340	0.0270
64.0	0.2520	0.2350	0.1830	0.1782	0.0160

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	291.23	0.0033	-0.2805	-0.0892
1.0	368.51	0.0001	-0.0699	-0.0489
1.5	468.31			
2.0	544.75	0.0012	-0.2191	0.4633
3.0	543.98			
4.0	490.21	0.0010	-0.0333	-0.2857
6.0	433.12			
8.0	259.37	0.0013	-0.0426	0.0734
12.0	113.74			
16.0	95.35	-0.0034	0.0749	0.0602
24.0	69.33			
32.0	66.25	0.0022	0.0273	0.0037
48.0	69.12			
64.0	72.62	0.0040	-0.0266	0.0000

R.M.S. Observational Error = .0024
R.M.S. Offset Wenner Difference = .1330
R.M.S. Potential Ladder Difference = .2123

FIELD CURVE DATA   INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	272.00	0.16		79.0	
2	1.0	368.51				
3	1.5	468.31		0.16	--------	0.8145
4	2.0	544.75				
5	3.0	543.98	2.30		772.4	
6	4.0	490.21				
7	6.0	373.00		2.45	--------	-0.4238
8	8.0	259.37				
9	12.0	145.00	3.01		312.6	
10	16.0	95.35				
11	24.0	69.33		5.47	--------	-0.6743
12	32.0	66.25				
13	48.0	69.12	26.73		60.8	
14	64.0	72.62				
				32.20	--------	0.1129
					76.3	
					********	

R.M.S. Relative error = 0.0350
Maximum rel. error = 0.0672 at sample 3
Number of trials was 28

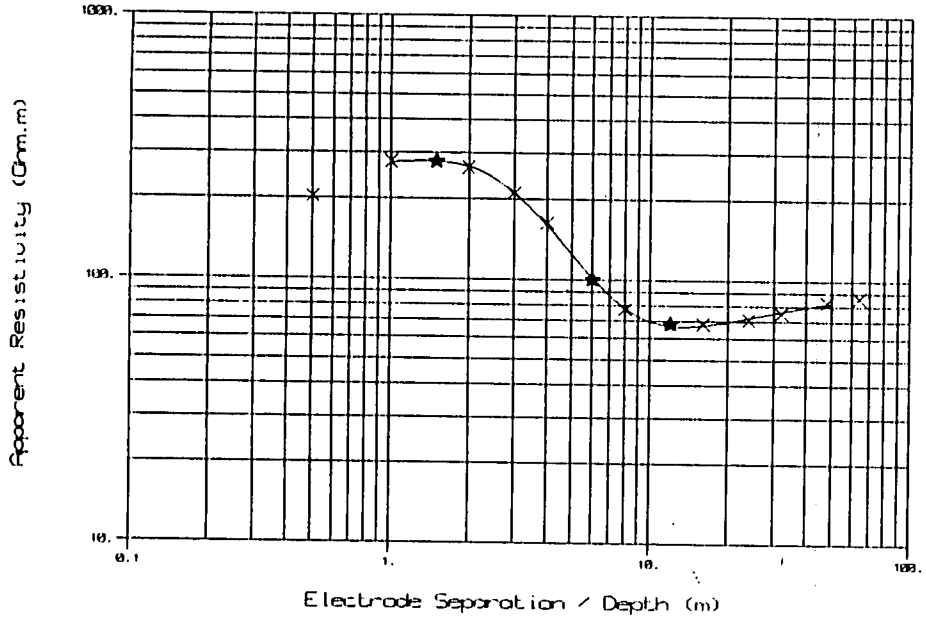
NO 77 NW R3A 7381 7553 **Pittarrow**

Azimuth 140°
August 1989

Waste 2.7m
Bedrock -

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, clayey, dry	66	0.1	0.1
Alluvium	Silt, sandy and clayey	442	1.0	1.1
Glaciolacustrine deposits	Clay, silty, damp	165	1.6	2.7
Old Red Sandstone	Siltstone	57	12.7	15.4
	Siltstone, sandy	91	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	97.2000	91.7000	70.0000	59:7000	5.5600
1.0	61.2000	57.3000	46.2000	41.9000	3.8500
2.0	26.7000	25.3000	20.5000	21.6000	1.3300
4.0	8.2900	8.0200	6.2300	6.7300	0.2750
8.0	2.0000	1.8660	1.5110	1.5620	0.1087
16.0	0.9460	0.8890	0.6690	0.6820	0.0543
32.0	0.5130	0.4740	0.3800	0.3670	0.0350
64.0	0.2900	0.2710	0.2140	0.2140	0.0190

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	203.73	-0.0006	-0.1588	0.1089
1.0	276.77	0.0008	-0.0976	0.1306
1.5	290.69			
2.0	264.52	0.0086	0.0523	0.1610
3.0	211.97			
4.0	162.86	-0.0006	0.0772	0.5007
6.0	111.27			
8.0	77.23	0.0127	0.0332	0.0054
12.0	70.91			
16.0	67.91	0.0029	0.0192	0.0750
24.0	70.80			
32.0	75.10	0.0078	-0.0348	-0.0217
48.0	82.79			
64.0	86.05	0.0000	0.0000	0.0000

R.M.S. Observational Error = .0055
R.M.S. Offset Wenner Difference = .0759
R.M.S. Potential Ladder Difference = .2110

FIELD CURVE DATA / INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	203.73	0.13		65.5	
2	1.0	276.77				
3	1.5	278.00		0.13	--------	0.7419
4	2.0	264.52				
5	3.0	211.97	1.03		442.0	
6	4.0	162.86				
7	6.0	100.00		1.16	--------	-0.4554
8	8.0	77.23				
9	12.0	68.00	1.56		165.4	
10	16.0	67.91				
11	24.0	70.80		2.72	--------	-0.4847
12	32.0	75.10				
13	48.0	82.79	12.71		57.4	
14	64.0	86.05				
				15.43	--------	0.2277
					91.2	
					********	

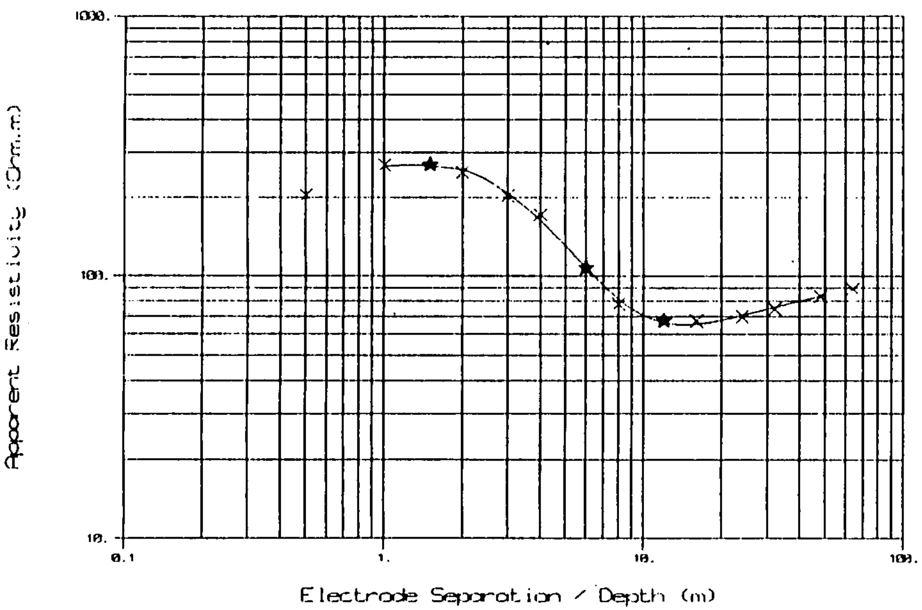
R.M.S. Relative error = 0.0148
Maximum rel. error = -0.0284 at sample 2
Number of trials was 9

NO 77 NW R3B **7381 7553** **Pittarrow**

Azimuth 100° **Waste 3.2m**
August 1989 **Bedrock -**

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, clayey, dry	68	0.1	0.1
Alluvium	Silt, sandy and clayey	400	1.0	1.1
Glaciolacustrine deposits	Clay, silty, damp	172	2.1	3.2
Old Red Sandstone	Siltstone	55	13.8	17.0
	Siltstone, sandy	97	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	99.9000	95.0000	63.9000	66.3000	5.0700
1.0	58.5000	54.6000	45.9000	39.5000	3.8700
2.0	25.3000	24.1000	20.2000	19.9200	1.2320
4.0	9.1700	8.9100	5.8700	7.7600	0.2600
8.0	2.0000	1.8880	1.6000	1.5080	0.1114
16.0	0.9180	0.8610	0.6700	0.6690	0.0548
32.0	0.5040	0.4780	0.3850	0.3580	0.0352
64.0	0.3010	0.2820	0.2240	0.2190	0.0194

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	204.52	-0.0017	0.0369	0.1983
1.0	268.29	0.0005	-0.1499	0.0939
1.5	284.49			
2.0	252.08	-0.0013	-0.0140	0.0906
3.0	203.53			
4.0	171.28	0.0000	0.2773	0.8481
6.0	121.14			
8.0	78.11	0.0003	-0.0592	-0.0007
12.0	72.62			
16.0	67.31	0.0024	-0.0015	0.0183
24.0	69.96			
32.0	74.69	-0.0181	-0.0727	-0.0387
48.0	83.40			
64.0	89.07	-0.0013	-0.0236	0.0000

R.M.S. Observational Error = .0065
R.M.S. Offset Wenner Difference = .1174
R.M.S. Potential Ladder Difference = .3333

FIELD CURVE DATA — INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	204.52	0.13		67.7	
2	1.0	268.29				
3	1.5	270.00		0.13	--------	0.7101
4	2.0	252.08				
5	3.0	203.53	1.01		399.6	
6	4.0	171.28				
7	6.0	107.00		1.14	--------	-0.3978
8	8.0	78.11				
9	12.0	67.90	2.04		172.2	
10	16.0	67.31				
11	24.0	69.96		3.18	--------	-0.5169
12	32.0	74.69				
13	48.0	83.40	13.77		54.8	
14	64.0	89.07				
				16.95	--------	0.2795
					97.4	
					********	

R.M.S. Relative error = 0.0203
Maximum rel. error = 0.0408 at sample 8
Number of trials was 8

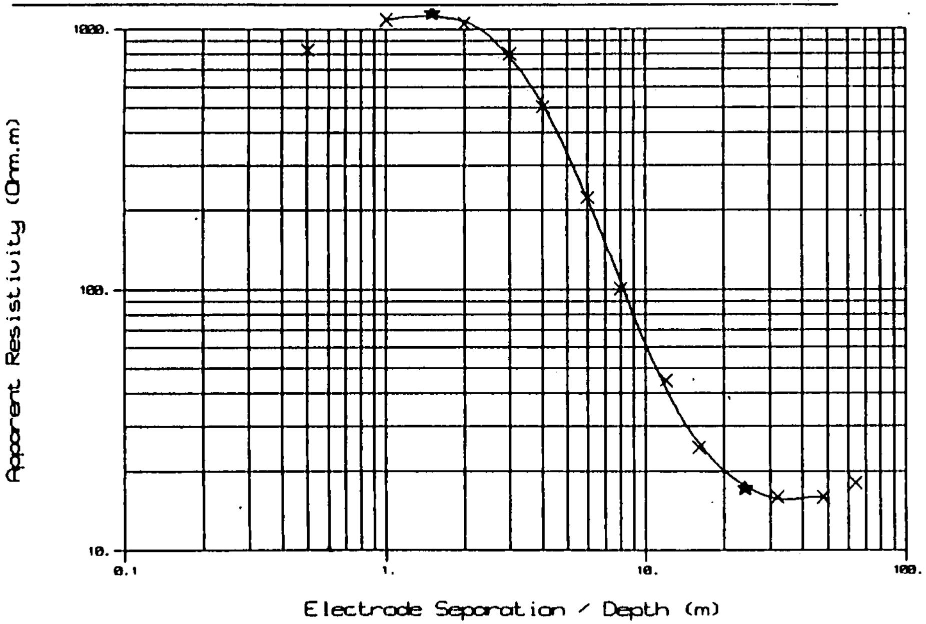
NO 77 NE R1A **7672 7557** **Bridge of Kair**

Azimuth 110°
August 1989

Overburden	0.2m
Mineral I	1.3m
Waste	4.8m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, silty, dry	280	0.2	0.2
Alluvium	Cobble gravel, dry	1964	1.3	1.5
Till/Decomposed bedrock	Clay with boulders	134	4.8	6.3
Old Red Sandstone	Mudstone	16	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	396.0000	377.0000	271.0000	258.0000	19.0800
1.0	242.0000	227.0000	180.3000	185.6000	15.0100
2.0	102.9000	97.3000	86.2000	81.2000	5.6100
4.0	22.2000	21.6000	18.6300	21.3000	0.5830
8.0	2.4000	2.3000	1.9020	2.1000	0.0520
16.0	0.3230	0.3070	0.2500	0.2430	0.0156
32.0	0.1080	0.1020	0.0850	0.0740	0.0063
64.0	0.0710	0.0685	0.0440	0.0460	0.0030

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	830.95	-0.0002	-0.0491	0.1503
1.0	1086.68	0.0000	0.1463	0.1457
1.5	1171.09			
2.0	1051.81	-0.0001	-0.0597	0.1810
3.0	799.83			
4.0	501.78	0.0008	0.1337	0.3212
6.0	224.95			
8.0	100.58	0.0002	0.0990	0.8072
12.0	44.72			
16.0	24.78	0.0012	-0.0284	0.2634
24.0	19.01			
32.0	15.98	-0.0028	-0.1384	-0.0031
48.0	15.96			
64.0	18.10	-0.0070	0.0444	0.0000

R.M.S. Observational Error = .0076
R.M.S. Offset Wenner Difference = .0981
R.M.S. Potential Ladder Difference = .3587

FIELD CURVE DATA / INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	830.95	0.16		279.7	
2	1.0	1086.68				
3	1.5	1150.00		0.16	--------	0.7507
4	2.0	1051.81				
5	3.0	799.83	1.32		1964.3	
6	4.0	501.78				
7	6.0	224.55		1.48	--------	-0.8720
8	8.0	100.58				
9	12.0	44.72	4.82		134.3	
10	16.0	24.78				
11	24.0	17.20		6.30	--------	-0.7986
12	32.0	15.98				
13	48.0	15.96			15.5	
14	64.0	18.10				

R.M.S. Relative error = 0.0303
Maximum rel. error = -0.0559 at sample 9
Number of trials was 30

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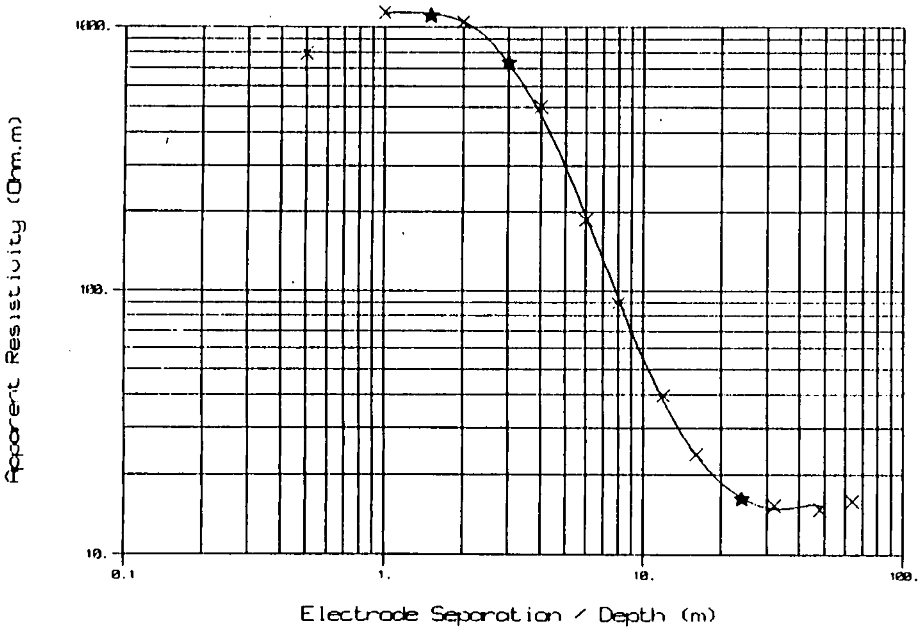
NO 77 NE R1B 7672 7557 **Bridge of Kair**

Azimuth 050°
August 1989

Overburden	0.2m
Mineral I	1.2m
Waste	4.7m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, silty, dry	285	0.2	0.2
Alluvium	Cobble gravel, dry	1946	1.2	1.4
Till/Decomposed bedrock	Clay with boulders	135	4.7	6.1
Old Red Sandstone	Mudstone	15	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	372.0000	353.0000	262.0000	245.0000	18.5000
1.0	261.0000	249.0000	175.1000	185.3000	12.3000
2.0	96.2000	89.7000	82.4000	83.4000	6.4700
4.0	23.1000	22.5000	19.9600	20.0000	0.5350
8.0	1.9470	1.8870	1.8940	1.6590	0.0547
16.0	0.2990	0.2820	0.2420	0.2340	0.0146
32.0	0.1040	0.1000	0.0750	0.0770	0.0060
64.0	0.0585	0.0562	0.0410	0.0380	0.0012

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	796.39	0.0013	-0.0671	0.0535
1.0	1132.23	-0.0012	0.0566	0.3281
1.5	1181.40			
2.0	1041.75	0.0003	0.0121	-0.1590
3.0	859.51			
4.0	502.15	0.0028	0.0000	0.9364
6.0	186.35			
8.0	89.30	0.0027	-0.1323	-0.0249
12.0	39.68			
16.0	23.93	0.0081	-0.0336	0.0939
24.0	17.63			
32.0	15.28	-0.0377	0.0863	0.1095
48.0	14.77			
64.0	15.88	0.0190	-0.0759	0.0000

R.M.S. Observational Error = .0153
R.M.S. Offset Wenner Difference = .0642
R.M.S. Potential Ladder Difference = .3843

FIELD CURVE DATA / INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	796.39	0.15		285.0	
2	1.0	1132.23				
3	1.5	1100.00		0.15	--------	0.7445
4	2.0	1041.75				
5	3.0	735.00	1.27		1945.8	
6	4.0	502.15				
7	6.0	186.35		1.42	--------	-0.8705
8	8.0	89.30				
9	12.0	39.68	4.69		134.8	
10	16.0	23.93				
11	24.0	16.15		6.11	--------	-0.8319
12	32.0	15.28				
13	48.0	14.77			14.8	
14	64.0	15.88				

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R.M.S. Relative error = 0.0355
Maximum rel. error = 0.0646 at sample 8
Number of trials was 20

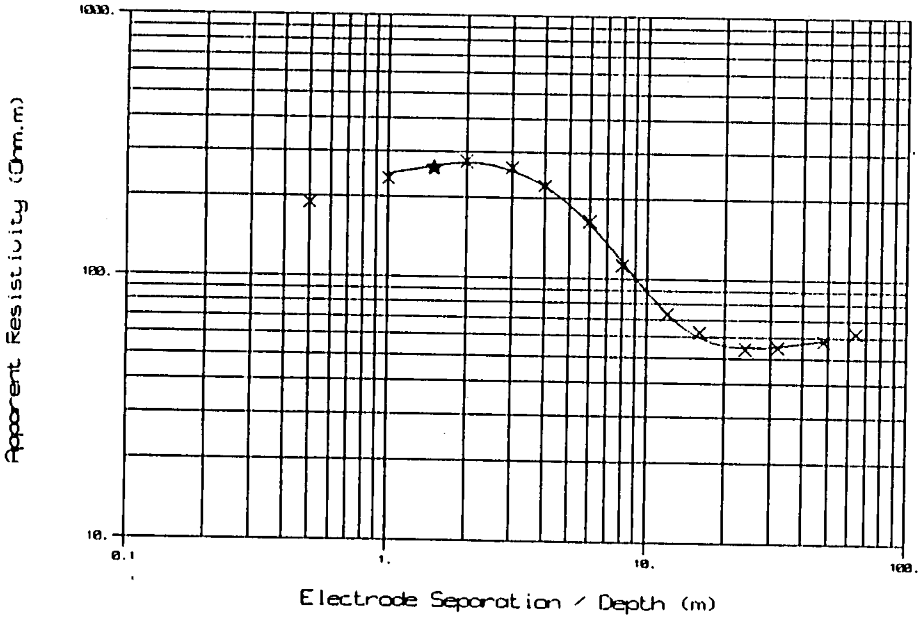
NO 77 NE R2A — 7726 7811 — **Pitskelly**

Azimuth 090°
August 1989

Waste 4.8m
Bedrock -

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, clayey, dry	91	0.2	0.2
Alluvium	Silt, clayey	334	2.1	2.3
Till	Clay, sandy	170	2.5	4.8
Old Red Sandstone	Siltstone, clayey	49	21.8	26.6
	Siltstone	66	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	R
0.5	91.5000	88.1000	70.0000	50.9000	3.5100
1.0	52.4000	49.1000	32.1000	42.9000	3.3300
2.0	29.8000	27.9000	23.1000	20.8000	1.7880
4.0	10.7100	10.1200	8.6800	9.0700	0.5840
8.0	2.6700	2.5500	2.0800	2.3900	0.1330
16.0	0.8240	0.7990	0.6150	0.6270	0.0455
32.0	0.3630	0.3420	0.2750	0.2730	0.0240
64.0	0.2170	0.2050	0.1950	0.1950	0.0120

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	189.91	-0.0012	-0.3160	0.2359
1.0	235.62	-0.0006	0.2880	0.0278
1.5	278.47			
2.0	275.83	0.0038	-0.1048	0.1763
3.0	261.53			
4.0	223.05	0.0006	0.0439	0.0608
6.0	163.72			
8.0	111.84	-0.0049	0.1483	0.0134
12.0	73.25			
16.0	62.43	-0.0246	0.0193	0.1138
24.0	54.25			
32.0	55.09	-0.0082	-0.0073	-0.0704
48.0	58.35			
64.0	62.33	0.0000	0.0000	0.0000

R.M.S. Observational Error = .0094
R.M.S. Offset Wenner Difference = .1651
R.M.S. Potential Ladder Difference = .1250

FIELD CURVE DATA — INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	189.91	0.20		91.2	
2	1.0	235.62				
3	1.5	260.00		0.20	--------	0.5711
4	2.0	275.83				
5	3.0	261.53	2.11		333.9	
6	4.0	223.05				
7	6.0	163.72		2.31	--------	-0.3248
8	8.0	111.84				
9	12.0	73.25	2.47		170.2	
10	16.0	62.43				
11	24.0	54.25		4.78	--------	-0.5529
12	32.0	55.09				
13	48.0	58.35	21.79		49.0	
14	64.0	62.33				
				26.56	--------	0.1461
					65.8	
					********	

R.M.S. Relative error = 0.0240
Maximum rel. error = 0.0411 at sample 3
Number of trials was 21

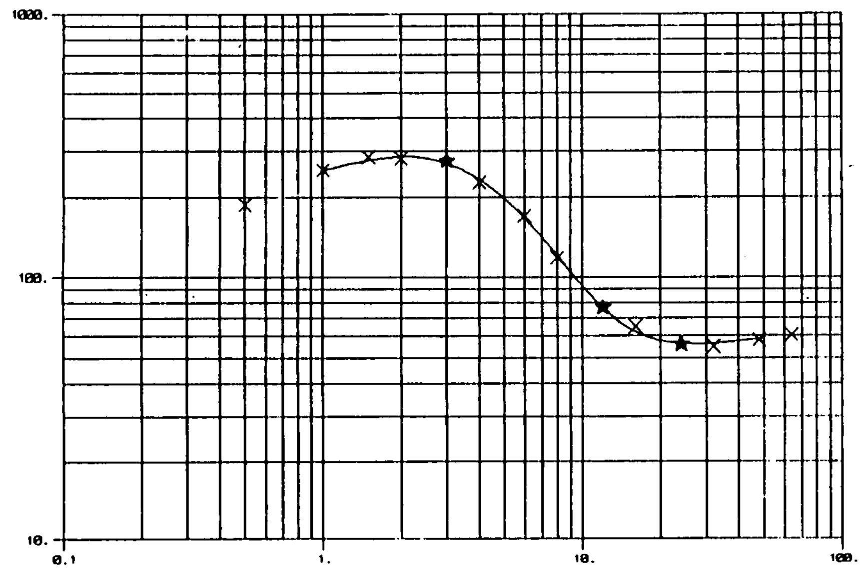
NO 77 NE R2B **7726 7811** **Pitskelly**

Azimuth 010°
August 1989

Waste 4.9m
Bedrock -

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, clayey, dry	91	0.2	0.2
Alluvium	Silt, clayey	358	2.2	2.4
Till	Clay, sandy	157	2.5	4.9
Old Red Sandstone	Siltstone, clayey	52	26.6	31.5
	Silstone	66	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	92.6000	89.3000	65.3000	54.5000	3.2300
1.0	61.4000	59.3000	47.2000	33.7000	2.0900
2.0	29.4000	27.5000	20.6000	24.2000	1.8920
4.0	10.1000	9.4300	9.5200	8.6900	0.6810
8.0	2.8600	2.7400	2.3800	2.3200	0.1064
16.0	0.8660	0.8190	0.7010	0.5910	0.0443
32.0	0.3620	0.3220	0.2770	0.2690	0.0243
64.0	0.2030	0.1963	0.1561	0.1459	0.0124

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	188.18	0.0002	-0.1803	0.2271
1.0	254.15	0.0002	-0.3337	0.3417
1.5	284.96			
2.0	281.49	0.0003	0.1607	0.0605
3.0	293.20			
4.0	228.83	-0.0011	-0.0912	-0.3639
6.0	170.24			
8.0	118.12	0.0048	-0.0255	0.1138
12.0	69.67			
16.0	64.94	0.0031	-0.1703	0.1384
24.0	59.90			
32.0	54.89	0.0444	-0.0293	-0.1282
48.0	58.05			
64.0	60.72	-0.0277	-0.0675	0.0000

R.M.S. Observational Error = .0186
R.M.S. Offset Wenner Difference = .1632
R.M.S. Potential Ladder Difference = .2246

FIELD CURVE DATA

	Electrode Separation	Apparent Resistivity
1	0.5	188.18
2	1.0	254.15
3	1.5	284.96
4	2.0	281.49
5	3.0	275.00
6	4.0	228.83
7	6.0	170.24
8	8.0	118.12
9	12.0	76.50
10	16.0	64.94
11	24.0	56.00
12	32.0	54.89
13	48.0	58.05
14	64.0	60.72

INTERPRETED MODEL

Thickness	Depth	Rho	Reflection Coeffts.
0.20		90.6	
	0.20	--------	0.5963
2.21		358.4	
	2.41	--------	-0.3895
2.46		157.4	
	4.86	--------	-0.5065
26.63		51.6	
	31.49	--------	0.1220
		65.9	
		********	

R.M.S. Relative error = 0.0179
Maximum rel. error = -0.0420 at sample 10
Number of trials was 10

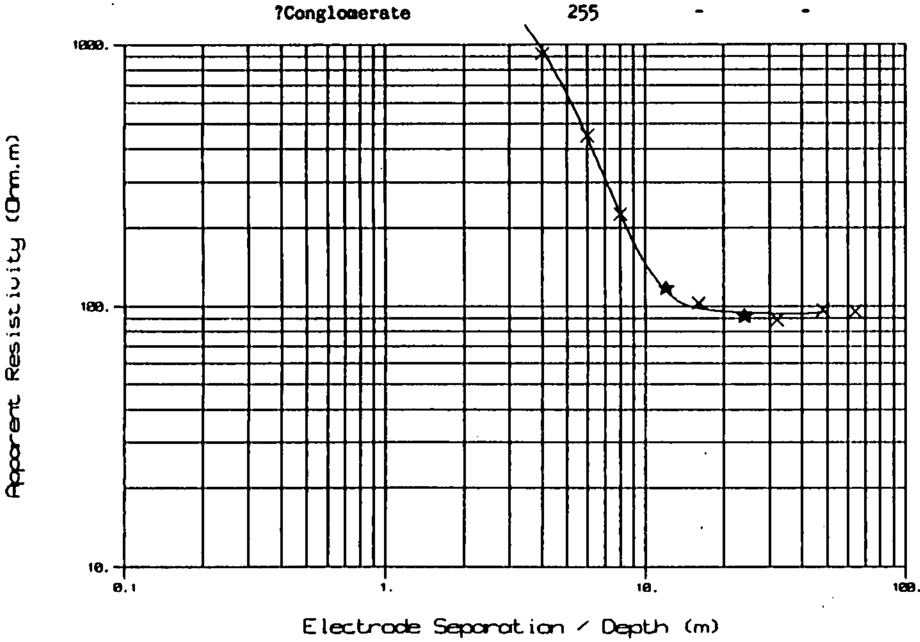
NO 78 SW R1A 7374 8150 Milton of Dellavaird

Azimuth 115°
August 1989

Overburden	0.1m
Mineral I	2.2m
Waste	1.4m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, gravelly, dry	559	0.1	0.1
Alluvium	Cobble gravel, dry	3687	1.0	1.1
	Cobble gravel, sandy wet	1017	1.2	2.3
?Glaciolacustrine deposits	?Silt, sandy	737	1.4	3.7
Old Red Sandstone	?Lava, decomposed	90	85.2	88.9
	?Conglomerate	255	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	725.0000	673.0000	509.0000	523.0000	51.6000
1.0	480.0000	453.0000	369.0000	319.0000	26.1000
2.0	185.0000	175.0000	147.7000	157.8000	9.7800
4.0	41.0000	39.8000	35.2000	38.1000	1.1400
8.0	5.3100	5.1900	3.9500	5.0800	0.1740
16.0	1.4400	1.3540	1.0990	0.9420	0.0600
32.0	0.5640	0.5300	0.4030	0.4800	0.0408
64.0	0.3500	0.3250	0.2300	0.2450	0.0153

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	1621.06	0.0006	0.0271	-0.0431
1.0	2161.42	0.0019	-0.1453	0.2164
1.5	2100.64			
2.0	1919.51	0.0012	0.0661	0.1099
3.0	1477.08			
4.0	921.12	0.0015	0.0791	0.2041
6.0	450.03			
8.0	226.95	-0.0026	0.2503	0.1156
12.0	135.77			
16.0	102.59	0.0182	-0.1538	0.2833
24.0	93.16			
32.0	88.77	-0.0120	0.1744	-0.1407
48.0	96.36			
64.0	95.50	0.0281	0.0632	0.0000

R.M.S. Observational Error = .0126
R.M.S. Offset Wenner Difference = .1384
R.M.S. Potential Ladder Difference = .1756

FIELD CURVE DATA

	Electrode Separation	Apparent Resistivity
1	0.5	1621.06
2	1.0	2161.42
3	1.5	2100.64
4	2.0	1919.51
5	3.0	1477.08
6	4.0	921.12
7	6.0	450.03
8	8.0	226.95
9	12.0	117.00
10	16.0	102.59
11	24.0	91.50
12	32.0	88.77
13	48.0	96.36
14	64.0	95.50

INTERPRETED MODEL

Thickness	Depth	Rho	Reflection Coeffts.
0.14		557.9	
	0.14	--------	0.7371
0.92		3686.5	
	1.07	--------	-0.5675
1.24		1017.1	
	2.31	--------	-0.1597
1.39		736.9	
	3.70	--------	-0.7823
85.15		90.0	
	88.85	--------	0.4780
		254.9	

R.M.S. Relative error = 0.0238
Maximum rel. error = -0.0458 at sample 10
Number of trials was 10

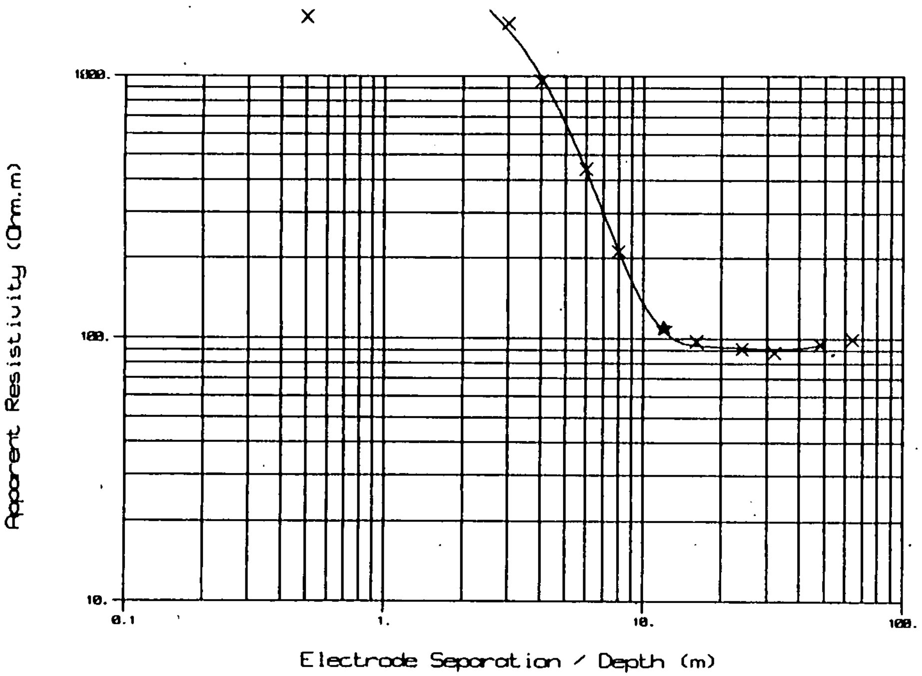
NO 78 SW R1B | 7374 8150 | Milton of Dellavaird

Azimuth 070°
August 1989

Overburden	0.2m
Mineral I	2.2m
Waste	1.2m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, gravelly, dry	638	0.2	0.2
Alluvium	Cobble gravel, dry	3839	1.0	1.2
	Gravel, sandy, wet	990	1.2	2.4
?Glaciolacustrine deposits	?Silt, sandy	650	1.2	3.6
Old Red Sandstone	?Lava, decomposed	87	69.8	73.4
	?Conglomerate	262	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	792.0000	752.0000	535.0000	530.0000	40.0000
1.0	480.0000	454.0000	347.0000	342.0000	26.1000
2.0	197.5000	186.8000	165.7000	156.5000	10.6100
4.0	42.2000	41.0000	37.2000	38.8000	1.2160
8.0	5.1900	4.9800	4.6500	3.8100	0.1654
16.0	1.2750	1.2000	0.9790	0.9540	0.0670
32.0	0.5960	0.5650	0.4330	0.4440	0.0383

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	1672.90	0.0000	-0.0094	0.1372
1.0	2164.56	-0.0002	-0.0145	0.1794
1.5	2251.55			
2.0	2024.44	0.0005	-0.0571	0.1774
3.0	1584.59			
4.0	955.04	-0.0004	0.0421	0.2074
6.0	441.77			
8.0	212.62	0.0009	-0.1986	0.2783
12.0	116.71			
16.0	97.16	0.0063	-0.0259	0.0411
24.0	91.12			
32.0	88.17	-0.0122	0.0251	0.0000

R.M.S. Observational Error = .0052
R.M.S. Offset Wenner Difference = .0811
R.M.S. Potential Ladder Difference = .1847

FIELD CURVE DATA

	Electrode Separation	Apparent Resistivity
1	0.5	1672.90
2	1.0	2164.56
3	1.5	2251.55
4	2.0	2024.44
5	3.0	1584.59
6	4.0	955.04
7	6.0	441.77
8	8.0	212.62
9	12.0	109.00
10	16.0	97.16
11	24.0	91.12
12	32.0	88.17
13	48.0	94.45
14	64.0	98.97

INTERPRETED MODEL

Thickness	Depth	Rho	Reflection Coeffts.
0.17		637.7	
	0.17	--------	0.7151
0.99		3838.6	
	1.16	--------	-0.5901
1.27		989.5	
	2.43	--------	-0.2074
1.20		649.6	
	3.62	--------	-0.7646
69.81		86.7	
	73.43	--------	0.5023
		261.6	
		********	

R.M.S. Relative error = 0.0221
Maximum rel. error = 0.0472 at sample 2
Number of trials was 10

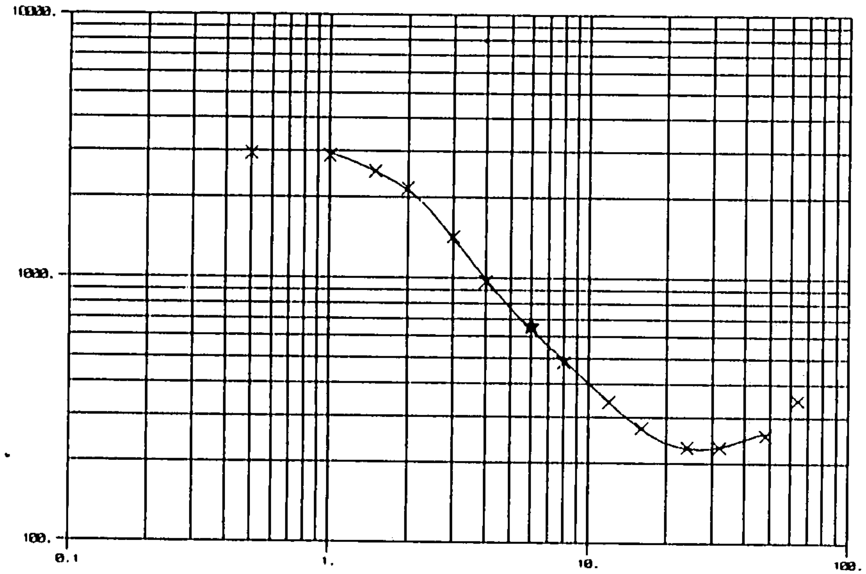
NO 78 SW R2A	7256 8252	Tipperty

Azimuth
August 1989

Overburden	0.1m
Mineral I	1.3m
Waste	5.5m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, with large cobbles	1760	0.1	0.1
Alluvium	Cobble gravel, dry	3451	1.3	1.4
?Flow-till	?Clay, gravel and sand	666	5.5	6.9
?Highland Border Complex	?Siltstone and spilites	187	24.8	31.7
	?Spilites	359	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	1283.0000	1199.0000	1002.0000	866.0000	84.1000
1.0	566.0000	530.0000	412.0000	505.0000	36.0000
2.0	236.0000	230.0000	210.0000	134.4000	6.1200
4.0	45.2000	42.9000	38.0000	38.7000	2.2000
8.0	11.5200	10.8900	9.1100	10.0500	0.6100
16.0	3.3300	3.1100	2.5400	2.8800	0.2090
32.0	1.5800	1.5250	1.0060	1.2840	0.0501
64.0	1.4530	1.4200	0.8100	0.9210	0.0365

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	2934.25	-0.0001	-0.1456	0.0779
1.0	2880.84	0.0000	0.2028	-0.0848
1.5	2518.80			
2.0	2163.93	-0.0005	-0.4390	1.0056
3.0	1421.13			
4.0	963.84	0.0022	0.0183	-0.0201
6.0	795.83			
8.0	481.54	0.0017	0.0981	-0.0131
12.0	343.30			
16.0	272.44	0.0033	0.1295	-0.1462
24.0	230.16			
32.0	230.22	0.0031	0.2428	-0.0582
48.0	255.17			
64.0	348.04	-0.0024	0.1282	0.0000

R.M.S. Observational Error = .0021
R.M.S. Offset Wenner Difference = .2110
R.M.S. Potential Ladder Difference = .3873

FIELD CURVE DATA / INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	2934.25	0.13		1759.5	
2	1.0	2880.84				
3	1.5	2518.80		0.13	--------	0.3246
4	2.0	2163.93				
5	3.0	1421.13	1.31		3450.8	
6	4.0	963.84				
7	6.0	655.00		1.44	--------	-0.6767
8	8.0	481.54				
9	12.0	343.30	5.46		665.5	
10	16.0	272.44				
11	24.0	230.16		6.90	--------	-0.5605
12	32.0	230.22				
13	48.0	255.17	24.83		187.4	
14	64.0	348.04				
				31.72	--------	0.3138
					358.9	
					********	

R.M.S. Relative error = 0.0155
Maximum rel. error = 0.0312 at sample 3
Number of trials was 22

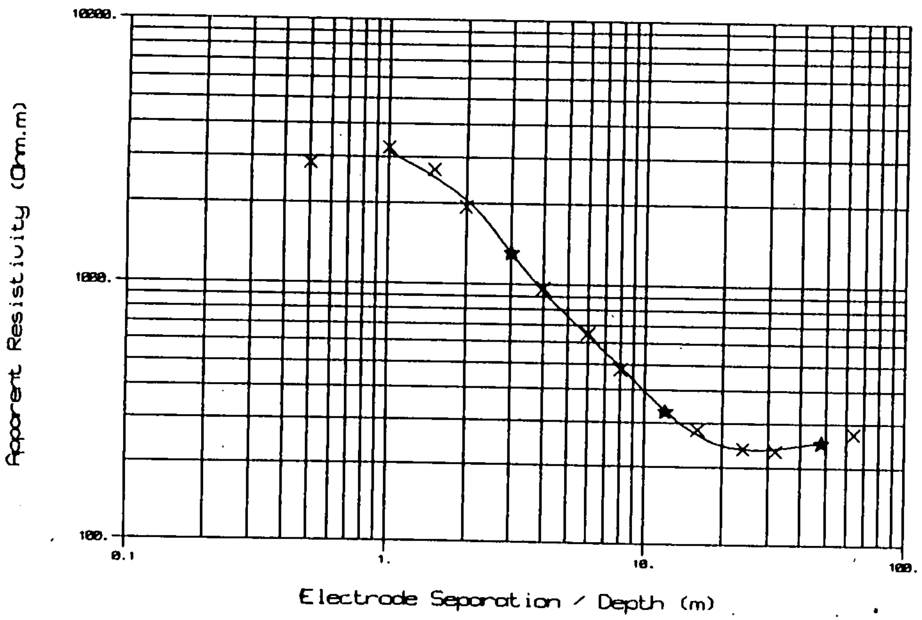
NO 78 SW R2B   7256 8252   Tipperty

Azimuth 120°
August 1989

Overburden	0.1m
Mineral I	0.8m
Waste	4.6m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, with cobbles	1026	0.1	0.1
Alluvium	Cobble gravel, dry	4709	0.8	0.9
?Flow-till	?Clay, gravel and sand	798	4.6	5.5
?Highland Border Complex	?Siltstone and pillow lava	212	24.1	29.6
	?Spilites	281	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	1232.0000	1156.0000	966.0000	840.0000	76.4000
1.0	708.0000	682.0000	456.0000	579.0000	25.8000
2.0	167.8000	159.1000	179.4000	130.2000	8.6800
4.0	48.8000	46.8000	39.6000	37.3000	1.9270
8.0	11.1000	10.5000	9.8700	9.0500	0.6160
16.0	3.5600	3.3300	2.9800	2.6600	0.2090
32.0	1.5670	1.5120	1.0040	1.3130	0.0567
64.0	1.0380	1.0080	0.6150	0.7380	0.0240

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	2836.86	-0.0003	-0.1395	-0.0115
1.0	3251.95	0.0003	0.2377	0.5633
1.5	2691.40			
2.0	1945.27	0.0001	-0.3178	-0.3879
3.0	1498.58			
4.0	966.35	0.0015	-0.0598	0.3864
6.0	648.53			
8.0	475.51	-0.0014	-0.0867	-0.1300
12.0	362.82			
16.0	280.48	.0.0087	-0.0932	-0.0300
24.0	236.54			
32.0	232.93	-0.0011	0.2667	0.0213
48.0	230.49			
64.0	272.04	0.0058	0.1818	0.0000

R.M.S. Observational Error = .0038
R.M.S. Offset Wenner Difference = .1940
R.M.S. Potential Ladder Difference = .3013

FIELD CURVE DATA   INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	2836.86	0.11		1026.4	
2	1.0	3251.95				
3	1.5	2691.40		0.11	--------	0.6421
4	2.0	1945.27				
5	3.0	1300.00	0.83		4709.1	
6	4.0	966.35				
7	6.0	648.53		0.94	--------	-0.7102
8	8.0	475.51				
9	12.0	329.00	4.61		797.9	
10	16.0	280.48				
11	24.0	236.54		5.55	--------	-0.5798
12	32.0	232.93				
13	48.0	250.00	24.03		212.2	
14	64.0	272.04				
				29.58	--------	0.1391
					280.8	
					********	

R.M.S. Relative error = 0.0283
Maximum rel. error = 0.0957 at sample 5
Number of trials was 10

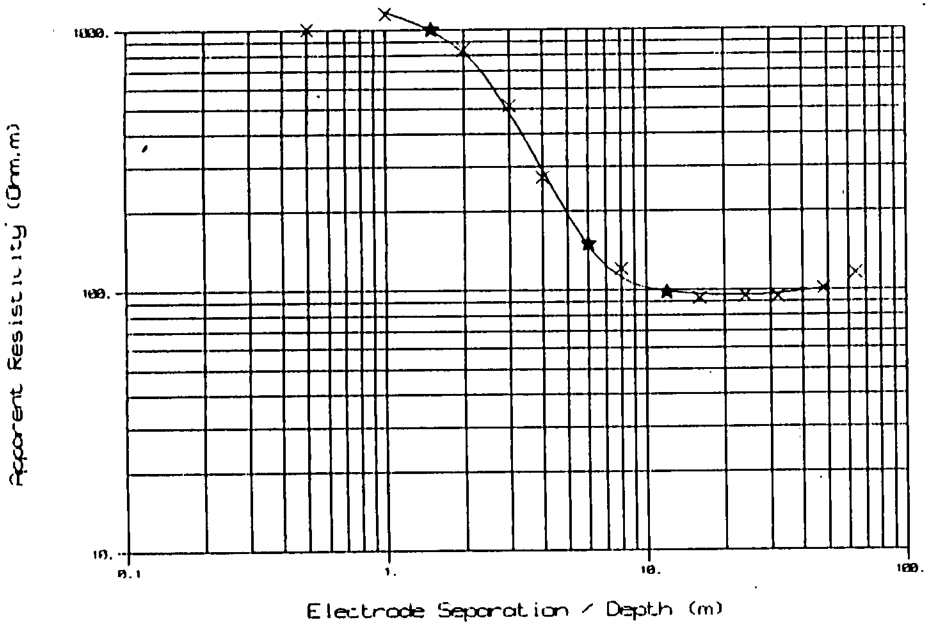
NO 78 SE R1A | 7581 8055 | **Hawkhill Farm**

Azimuth 075°
August 1989

Overburden	0.1m
Mineral I	0.8m
Waste	1.6m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, silty, dry	286	0.1	0.1
Alluvium	Cobble, gravel, dry	2043	0.8	0.9
Till	Clay, sandy and gravelly, damp	333	1.6	2.5
Old Red Sandstone	Tuff	92	27.6	30.1
	Tuff	110	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	446.0000	417.0000	318.0000	323.0000	25.6000
1.0	239.0000	224.0000	163.9000	202.0000	15.2000
2.0	71.8000	68.1000	63.6000	69.6000	3.6800
4.0	11.4300	11.0400	10.2900	11.3700	0.3640
8.0	3.4400	3.2700	2.5200	2.2800	0.1480
16.0	1.1690	1.0840	0.8800	0.9620	0.0830
32.0	0.6460	0.6000	0.4350	0.5020	0.0400
64.0	0.4000	0.3780	0.2700	0.3050	0.0220

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	1006.88	0.0077	0.0156	0.0362
1.0	1149.51	-0.0008	0.2083	0.1150
1.5	1076.98			
2.0	836.92	0.0003	0.0901	-0.3606
3.0	512.74			
4.0	272.19	0.0023	0.0997	-0.4073
6.0	124.37			
8.0	120.64	0.0064	-0.1000	0.4560
12.0	108.92			
16.0	92.59	0.0017	0.0890	-0.1501
24.0	94.90			
32.0	94.20	-0.0031	0.1430	-0.0181
48.0	100.99			
64.0	115.61	0.0000	0.1217	0.0000

R.M.S. Observational Error = .0038
R.M.S. Offset Wenner Difference = .1198
R.M.S. Potential Ladder Difference = .2781

FIELD CURVE DATA | INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	1006.88	0.11		286.1	
2	1.0	1149.51				
3	1.5	1000.00		0.11	--------	0.7543
4	2.0	836.92				
5	3.0	512.74	0.76		2043.0	
6	4.0	272.19				
7	6.0	150.00		0.87	--------	-0.7198
8	8.0	120.64				
9	12.0	98.00	1.68		332.9	
10	16.0	92.59				
11	24.0	94.90		2.54	--------	-0.5676
12	32.0	94.20				
13	48.0	100.99	27.64		91.8	
14	64.0	115.61				
				30.18	--------	0.0915
					110.3	
					********	

R.M.S. Relative error = 0.0341
Maximum rel. error = -0.0640 at sample 8
Number of trials was 9

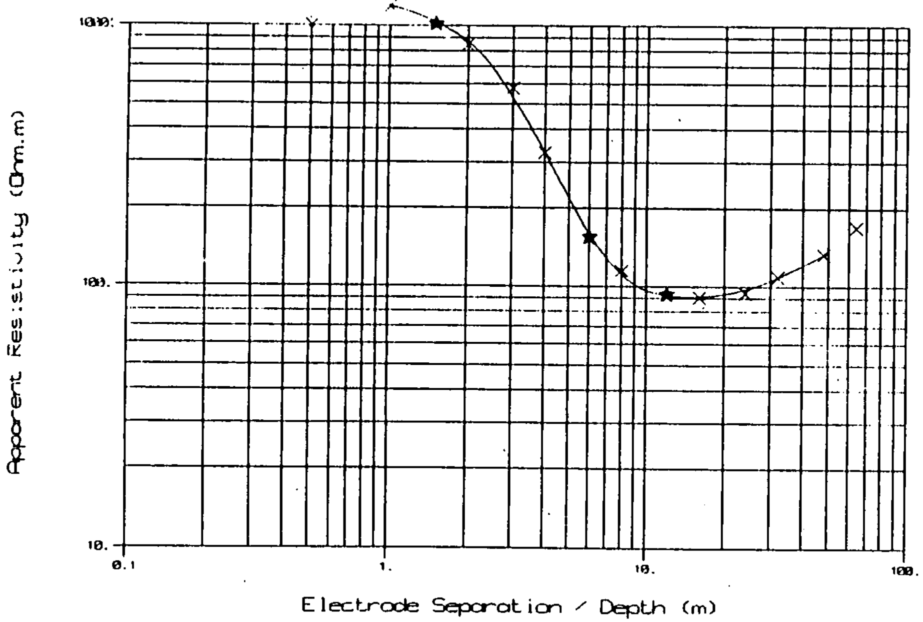
NO 78 SE R1B 7581 8055 **Hawkhill Farm**

Azimuth 140°
August 1989

Overburden	0.1m
Mineral I	0.8m
Waste	2.0m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil	282	0.1	0.1
Alluvium	Cobble, gravel, dry	2043	0.8	0.9
Till	Clay, sandy and gravelly, damp	354	2.0	2.9
Old Red Sandstone	Tuff	81	26.1	29.0
	?Tuff	260	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	483.0000	468.0000	363.0000	275.0000	15.7800
1.0	248.0000	234.0000	197.6000	180.1000	13.8000
2.0	67.3000	63.1000	63.9000	71.1000	4.1000
4.0	14.3600	14.0300	12.4200	13.4600	0.3400
8.0	2.9600	2.7900	2.4300	2.1300	0.1756
16.0	1.1640	1.0820	0.9880	0.8150	0.0792
32.0	0.6970	0.6540	0.5590	0.5220	0.0389
64.0	0.4760	0.4380	0.3930	0.4500	0.0260

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	1002.17	-0.0016	-0.2759	0.2870
1.0	1186.58	0.0008	-0.0927	0.1703
1.5	1189.72			
2.0	848.23	0.0015	0.1067	-0.8364
3.0	575.24			
4.0	325.22	-0.0007	0.0804	-0.0241
6.0	145.02			
8.0	114.61	-0.0019	-0.1316	0.0628
12.0	107.54			
16.0	90.63	0.0024	-0.1919	-0.1636
24.0	94.23			
32.0	108.67	0.0059	-0.0685	-0.2261
48.0	132.92			
64.0	169.50	0.0255	0.1352	0.0000

R.M.S. Observational Error = .0094
R.M.S. Offset Wenner Difference = .1498
R.M.S. Potential Ladder Difference = .3573

FIELD CURVE DATA / INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	1002.17	0.11		287.7	
2	1.0	1186.58				
3	1.5	1015.00		0.11	--------	0.7531
4	2.0	848.23				
5	3.0	575.24	0.79		2042.6	
6	4.0	325.22				
7	6.0	155.00		0.90	--------	-0.7050
8	8.0	114.61				
9	12.0	93.00	1.96		353.5	
10	16.0	90.63				
11	24.0	94.23		2.86	--------	-0.6255
12	32.0	108.67				
13	48.0	132.92	26.13		81.4	
14	64.0	169.50				
				28.99	--------	0.5233
					280.2	
					********	

R.M.S. Relative error = 0.0306
Maximum rel. error = 0.0951 at sample 4
Number of trials was 30

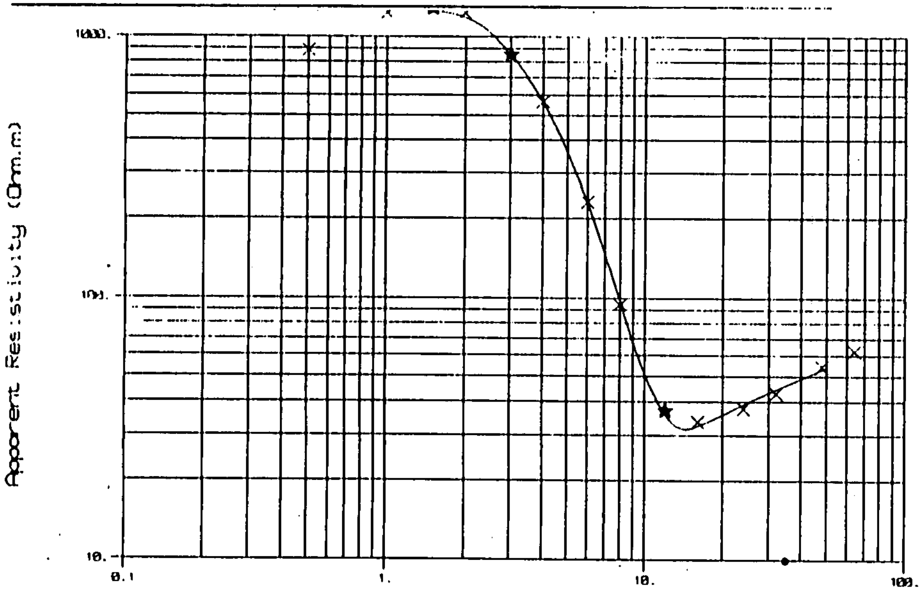
NO 87NE R1A **8501 7968** **Mill of Barras**

Azimuth 180°
August 1989

Overburden 0.1m
Mineral I 1.1m
Bedrock -

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, silty, dry	240	0.1	0.1
Alluvium	Gravel, dry	2257	1.1	1.2
?Old Red Sandstone	?Conglomerate, decomposed	386	2.4	3.6
	?Lava, decomposed	22	12.6	16.2
	?Lava	79	-	-



Electrode Separation / Depth (m)

INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	435.0000	414.0000	299.0000	265.0000	20.8000
1.0	273.0000	256.0000	208.0000	185.2000	17.2800
2.0	119.2000	112.5000	109.5000	86.6000	6.6400
4.0	23.4000	22.8000	22.8000	22.2000	0.5950
8.0	2.1500	2.0900	2.2400	1.5130	0.0487
16.0	0.4770	0.4510	0.3460	0.3210	0.0257
32.0	0.3050	0.2930	0.2190	0.2090	0.0210
64.0	0.2180	0.2020	0.1515	0.1590	0.0195

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	885.93	0.0005	-0.1206	0.1719
1.0	1235.27	-0.0010	-0.1160	0.1045
1.5	1395.20			
2.0	1232.13	0.0005	-0.2336	0.1435
3.0	935.80			
4.0	565.49	0.0002	-0.0067	-0.3388
6.0	231.53			
8.0	94.32	0.0053	-0.3874	0.1567
12.0	42.13			
16.0	33.53	0.0006	-0.0750	0.0497
24.0	37.79			
32.0	43.03	-0.0291	-0.0467	-0.0186
48.0	54.17			
64.0	62.43	0.0023	0.0483	0.0000

R.M.S. Observational Error = .0105
R.M.S. Offset Wenner Difference = .1745
R.M.S. Potential Lateral Difference = .1704

FIELD CURVE DATA / INTERPRETED MODEL

	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	885.93	0.12		240.3	
2	1.0	1235.27				
3	1.5	1285.00		0.12	--------	0.8075
4	2.0	1232.13				
5	3.0	850.00	1.10		2256.6	
6	4.0	565.49				
7	6.0	231.53		1.21	--------	-0.7078
8	8.0	94.32				
9	12.0	37.00	2.43		386.1	
10	16.0	33.53				
11	24.0	37.79		3.65	--------	-0.8914
12	32.0	43.03				
13	48.0	54.17	12.58		22.2	
14	64.0	62.43				
				16.23	--------	0.5631
					79.3	
					********	

R.M.S. Relative error = 0.0244
Maximum rel. error = -0.0345 at sample 10
Number of trials was . 11

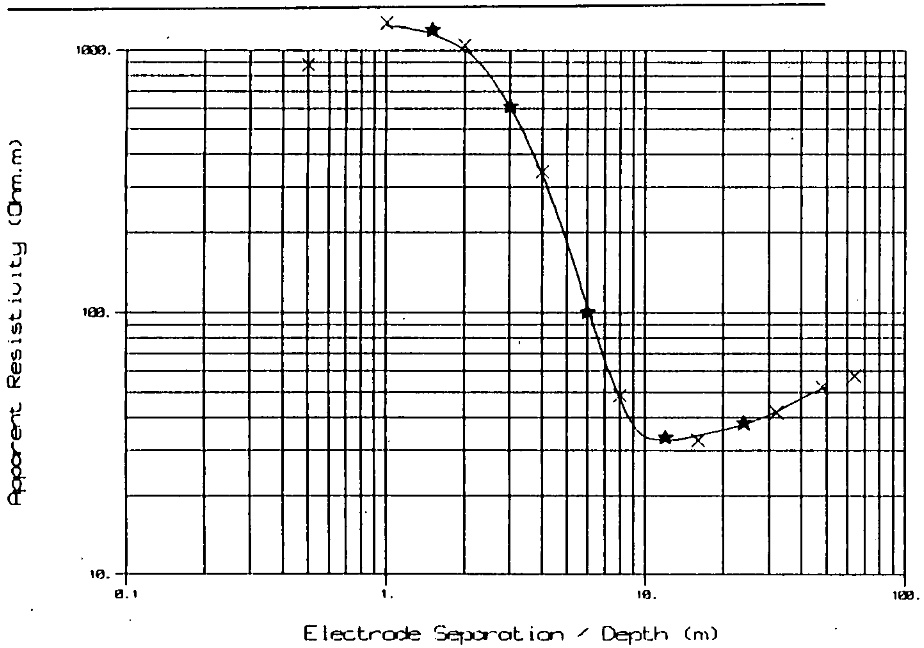
NO 87 NE R1B　　8501　7968　　**Mill of Barras**

Azimuth 120°
August 1989

Overburden	0.1m
Mineral I	0.9m
Bedrock	-

Interpretation

Geological classification	Lithology	Resistivity (ohm m)	Thickness (m)	Depth (m)
	Soil, silty, dry	244	0.1	0.1
Alluvium	Gravel, dry	2306	0.9	1.0
?Old Red Sandstone	?Conglomerate, decomposed	236	1.8	2.8
	?Lava, decomposed	28	17.9	20.7
	?Lava	79	-	-



INPUT DATA

Electrode Spacing	A	C	D1	D2	B
0.5	423.0000	400.0000	272.0000	290.0000	23.6000
1.0	284.0000	267.0000	211.0000	192.1000	16.1400
2.0	86.9000	80.0000	80.3000	85.9000	6.9600
4.0	10.2800	9.8900	12.5000	14.8700	0.3880
8.0	0.9170	0.8630	1.1090	0.8210	0.0570
16.0	0.4730	0.4490	0.3290	0.3220	0.0245
32.0	0.2940	0.2710	0.2110	0.2050	0.0216
64.0	0.1990	0.1870	0.1390	0.1470	0.0152

PROCESSING RESULTS

Electrode Spacing	Wenner Resistivity	Observed Error	Offset Error	Lateral Error
0.5	882.79	-0.0014	0.0641	0.0890
1.0	1266.38	0.0030	-0.0938	0.2925
1.5	1271.46			
2.0	1044.27	-0.0007	0.0674	-0.7285
3.0	738.63			
4.0	343.94	0.0002	0.1732	-4.4316
6.0	28.48			
8.0	48.51	-0.0033	-0.2984	-0.8177
12.0	23.68			
16.0	32.72	-0.0011	-0.0215	0.0926
32.0	41.82	0.0048	-0.0288	-0.0549
48.0	52.07			
64.0	57.50	-0.0160	0.0559	0.0000

R.M.S. Observational Error = .0061
R.M.S. Offset Wenner Difference = .1327
R.M.S. Potential Ladder Difference = *****

FIELD CURVE DATA　　　　INTERPRETED MODEL

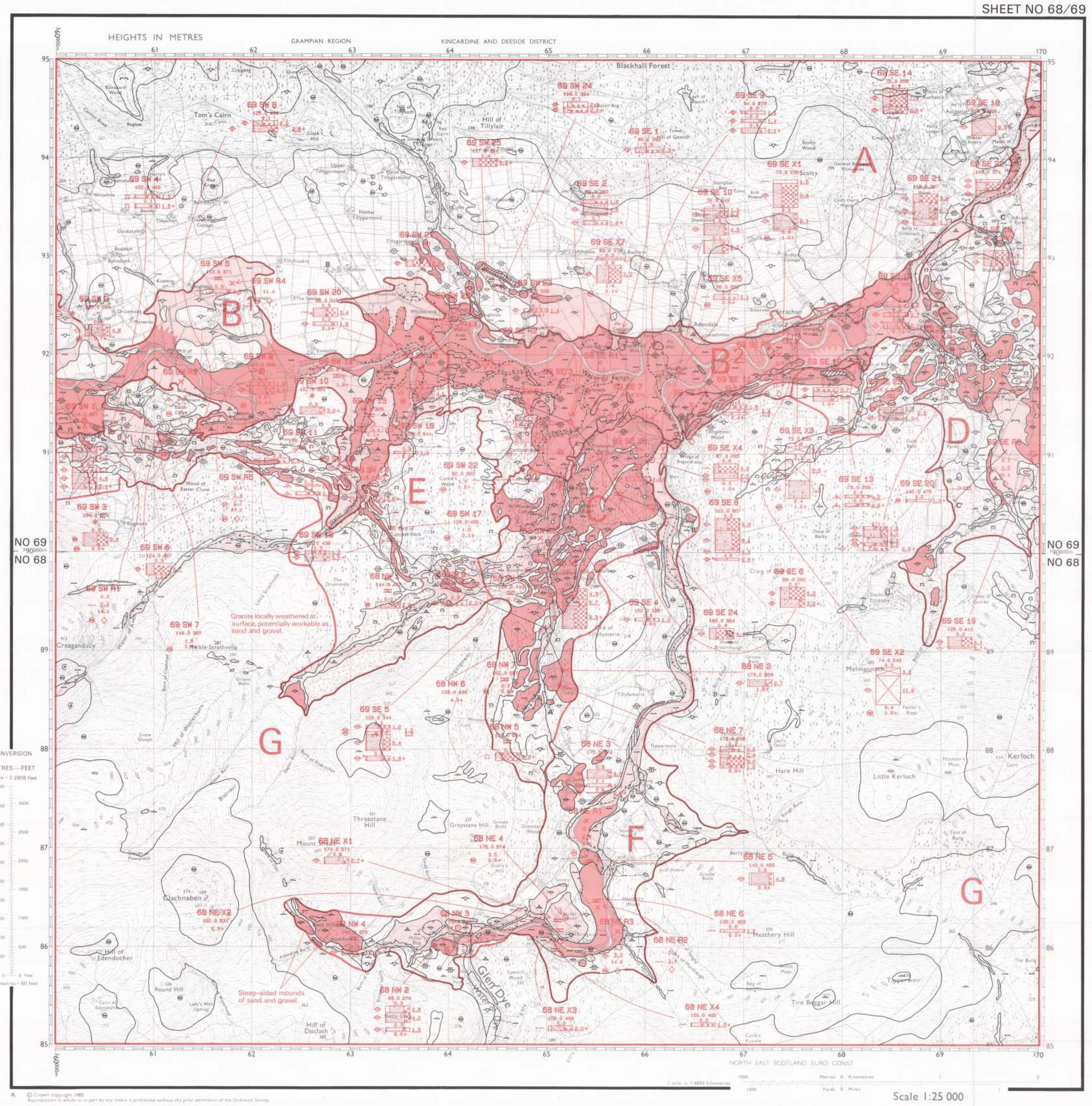
	Electrode Separation	Apparent Resistivity	Thickness	Depth	Rho	Reflection Coeffts.
1	0.5	882.79	0.11		244.3	
2	1.0	1266.38				
3	1.5	1190.00		0.11	--------	0.8084
4	2.0	1044.27				
5	3.0	610.00	0.93		2305.6	
6	4.0	343.94				
7	6.0	100.00		1.04	--------	-0.8141
8	8.0	48.51				
9	12.0	33.50	1.78		236.2	
10	16.0	32.72				
11	24.0	38.00		2.82	--------	-0.7893
12	32.0	41.82				
13	48.0	52.07	17.88		27.7	
14	64.0	57.50				
				20.69	--------	0.4798
					78.9	
					********	

R.M.S. Relative error = 0.0369
Maximum rel. error = 0.0899 at sample 1
Number of trials was 30

BRITISH GEOLOGICAL SURVEY (SCOTLAND)

THE SAND AND GRAVEL RESOURCES OF THE AREA AROUND STRACHAN, GRAMPIAN REGION

SHEET NO 68/69



LOCATION OF THE STRACHAN RESOURCE SHEET

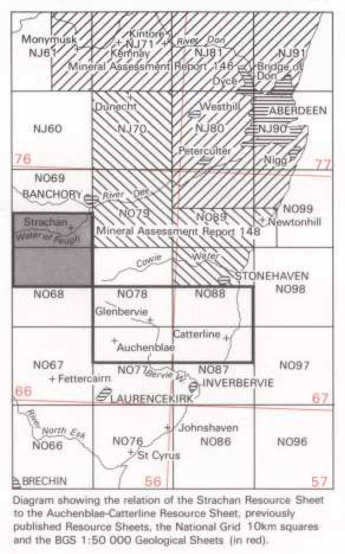
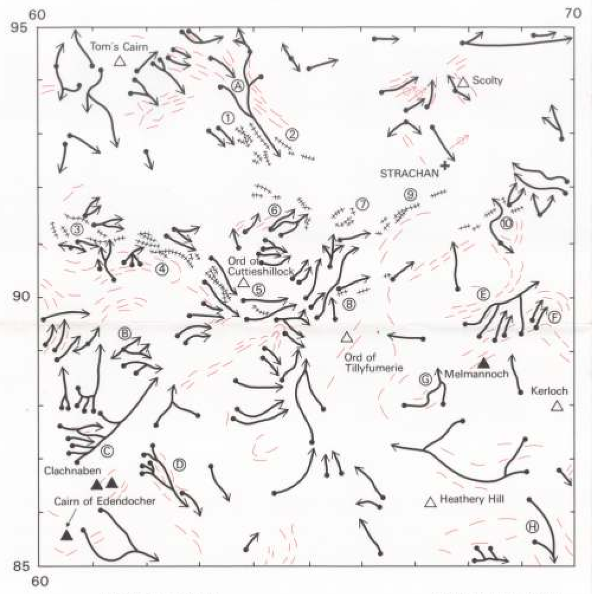


Diagram showing the relation of the Strachan Resource Sheet to the Auchenblae-Catterline Resource Sheet, previously published Resource Sheets, the National Grid 10km squares and the BGS 1:50 000 Geological Sheets (in red).

GLACIAL GEOMORPHOLOGY



Glacial striae, indicating direction of ice-movement

Glacial drainage channel, showing direction of fall of channel floor. The most noteworthy are listed below

Glacial flutings and ice-moulded features, indicating direction of ice-movement

Granite tor

Esker ridge. The most noteworthy are listed below

A Den of Tillygarmond
B Den of Strathvella
C Douple of Pheasanch
D Slack of Dye
E Slacks of Pitreadie
F Coves of Curran
G Deil's Gate
H Peter's Den

1 Tillygarmond Eskers
2 Waulkmill Eskers
3 Easter Clune Eskers
4 Powlair Eskers
5 Rouchan Eskers
6 Balblythe Eskers
7 Pitdelphin Eskers
8 Bogarn Eskers
9 Templeton Eskers
10 Gallybank Eskers

Principal summit

Village

Original geological survey on the six-inch scale by D.R. Irvine in 1878 and H. Skae in c. 1882 (northern part).
Original geological survey on the one-inch scale by H. Skae in c. 1882 (southern part).
Revision on the six-inch scale by G. Barrow in c. 1896.
Reconnaissance resurvey at a scale of 1:10 000 by D. Gould in 1985.
Drift geology surveyed at a scale of 1:10 000 by C. Auton in 1987-89.
Sand and gravel survey by C.A. Auton, A.J. Highton and M.G. Raines in 1989.
D.I.J. Mallick, Manager, Highlands and Islands Group.
The 1:25 000 sand and gravel resource sheet published in 1990.
P.J. Cook, Director, British Geological Survey.

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.

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 & Sons Ltd, Edinburgh 1990

Detailed records may be consulted on application to the Manager, Highlands and Islands Group, 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.

yards 1000 0 1 2 miles
metres 1000 0 1 2 3 kilometres

KEY TO SECTIONS

Potentially workable sand and gravel, continuous or almost continuous deposits, exposed or beneath overburden.

Discontinuous spreads of potentially workable sand and gravel exposed or beneath overburden.

Morainic drift, containing potentially workable till (mineral II) and some potentially workable sand and gravel (mineral I).

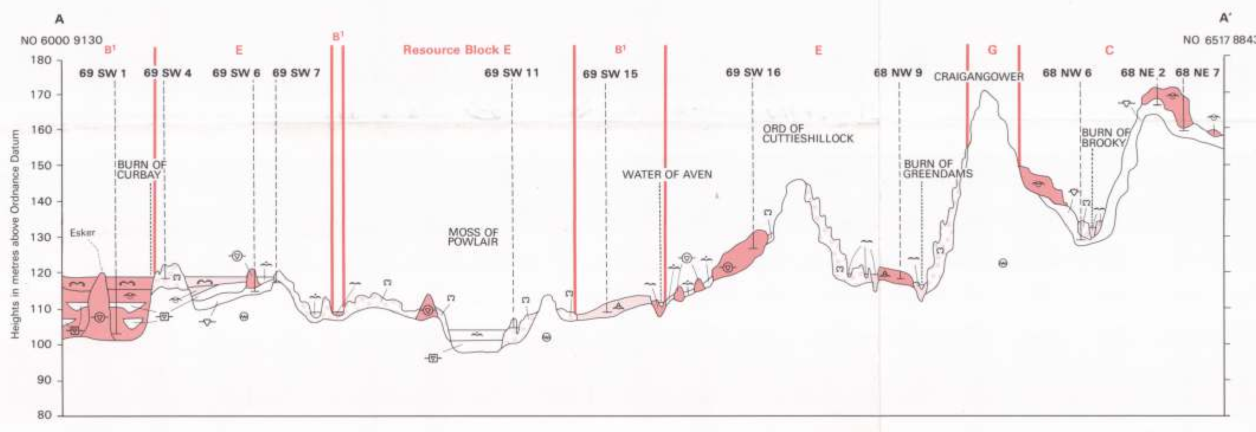
Bedrock and waste, including overburden, are uncoloured.

Geological boundary.

Otherwise symbols and abbreviations as map legend.

GENERALISED HORIZONTAL SECTIONS SHOWING RELATIONSHIPS OF DRIFT DEPOSITS

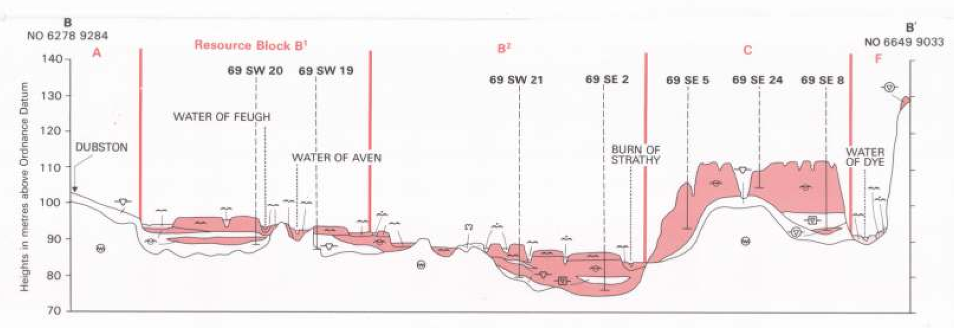
HORIZONTAL SCALE 1:25 000
VERTICAL EXAGGERATION 20X



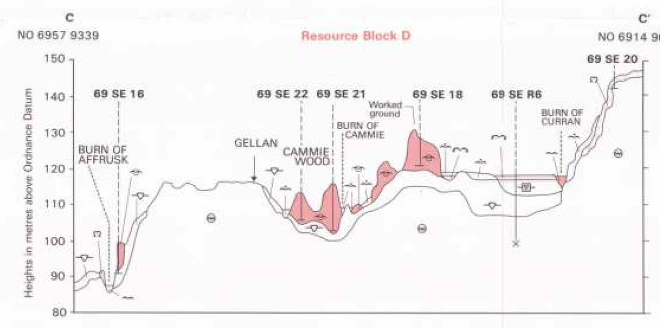
An ice-scoured basin concealed beneath sandy lacustrine alluvium lies to the W of pit 69 SW 7. The alluvial deposits overlie a sequence of sand and gravel interbedded with silt and clay. The basin contained an ice-dammed lake during deglaciation when drainage was blocked to the east.

A system of E to SE-trending sinuous esker ridges up to 15m high (Easter Clune, Powlair and Rouchan Eskers) were formed by E to SE flowing englacial meltwaters. Extensive spreads of hummocky morainic drift were laid down during deglaciation. The Moss of Powlair was formerly a lake occupying a large kettle hole, now infilled by silt and peat.

Hummocky and flat-topped mounds of fluvioglacial sand and gravel stand up to 10m above till that mantles the valley of the Burn of Brooky. The fluvioglacial deposits were laid down by meltwater that drained between Craigangower and the Ord of Tillyfumerie, derived from downwasting ice in the upper reaches of Glen Dye.



Low-lying terraces, underlain by alluvial sand and gravel, flank the floodplains of the Water of Feugh, the Water of Aven and the Burn of Strathy. The alluvial deposits overlie fluvioglacial sand and gravel interbedded with silt and clay, infilling a deep ice-scoured depression, which extends eastwards from Ennochie [626 921].
Gravel ridges (Balblythe and Pitdelphin Eskers) stand up to 10m above the level of the floodplain.
The interfluve between the Water of Dye and the Burn of Strathy is mantled by thick, kettled spreads of fluvioglacial sand and gravel N of Bogarn [657 903]. The sand and gravel, which either rests directly on till or passes down into glaciolacustrine silt, was laid down during deglaciation as a fan-delta that prograded into a glacial lake, dammed by ice within the valley of the Water of Feugh.



Hummocky and flat-topped mounds of fluvioglacial sand and gravel up to 25m high lie to the E of Strachan. The fluvioglacial deposits, which generally fine-downwards, were laid down as fan-deltas that prograded into glacial lakes, dammed by ice within the valley of the Water of Feugh.
A former lake basin E of Pitreadie Farm [692 910] is infilled with glaciolacustrine silt capped by thin sandy alluvium.
Spectacular glacial drainage channels cut into bedrock (the Slack's of Pitreadie and the Coves of Curran) descend steeply towards the southern edge of the basin, which is mantled by thin spreads of morainic drift.

THE SAND AND GRAVEL RESOURCES OF THE AREA AROUND STRACHAN, GRAMPIAN REGION

This map should be read in conjunction with B.G.S. Technical Report WF/90/7 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 other than in sand and gravel

Landslip

DRIFT

Recent and Pleistocene

Scree

Peat

Alluvium and river terrace deposits - silt, clay, sand and gravel

Lacustrine alluvium - mainly humic silt, clay and fine sand

Alluvial fan - fan composed of alluvium

Fluvioglacial sand and gravel - moundy and terraced deposits varying from coarse gravel with medium and coarse sand, to well sorted, silty fine sand

Glacial sand and gravel - typically linear ridges, formed of poorly sorted coarse gravel with coarse and medium 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

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 - mainly comprises coarse-grained Kincardine Granite in the southern part of the sheet. The northern part of the sheet is underlain by Dalradian metamorphic rocks including psammite (slightly gritty in places), pelitic and semipelitic schist and gneiss, and some calc-silicate rock. The granite and metamorphic rocks are both cut by N-S trending felsite dykes

SAND AND GRAVEL WORKINGS

Made ground -waste and/or natural earth materials deposited in man-made workings

Worked ground -boundaries as at November 1989

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

BOREHOLE AND OTHER DATA SITE LOCATIONS

Borehole site

Recorded exposure, sampled

BGS shallow pit

BGS BOREHOLES

Registration Number

Each BGS borehole is identified by a registration number, e.g. 68 NW 3. 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 68 NW 3 is NO 68 NW 3.

Grading Diagrams

Each grading diagram shows the mean particle size distribution of a distinct deposit of mineral

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. 69 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, 69 NW 2.

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. 68 NW 1. The surface level for each pit has been extrapolated from the contours on the 1:10 000 scale topographic maps.

GEOPHYSICAL DATA RESISTIVITY DEPTH SOUNDINGS

CATEGORIES OF RESOURCE ON MAP

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 some potentially workable sand and gravel

Barren ground: 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.

This Map and the accompanying report were commissioned and financed by the Department of the Environment, with the support from Grampian Regional Council and local industry.

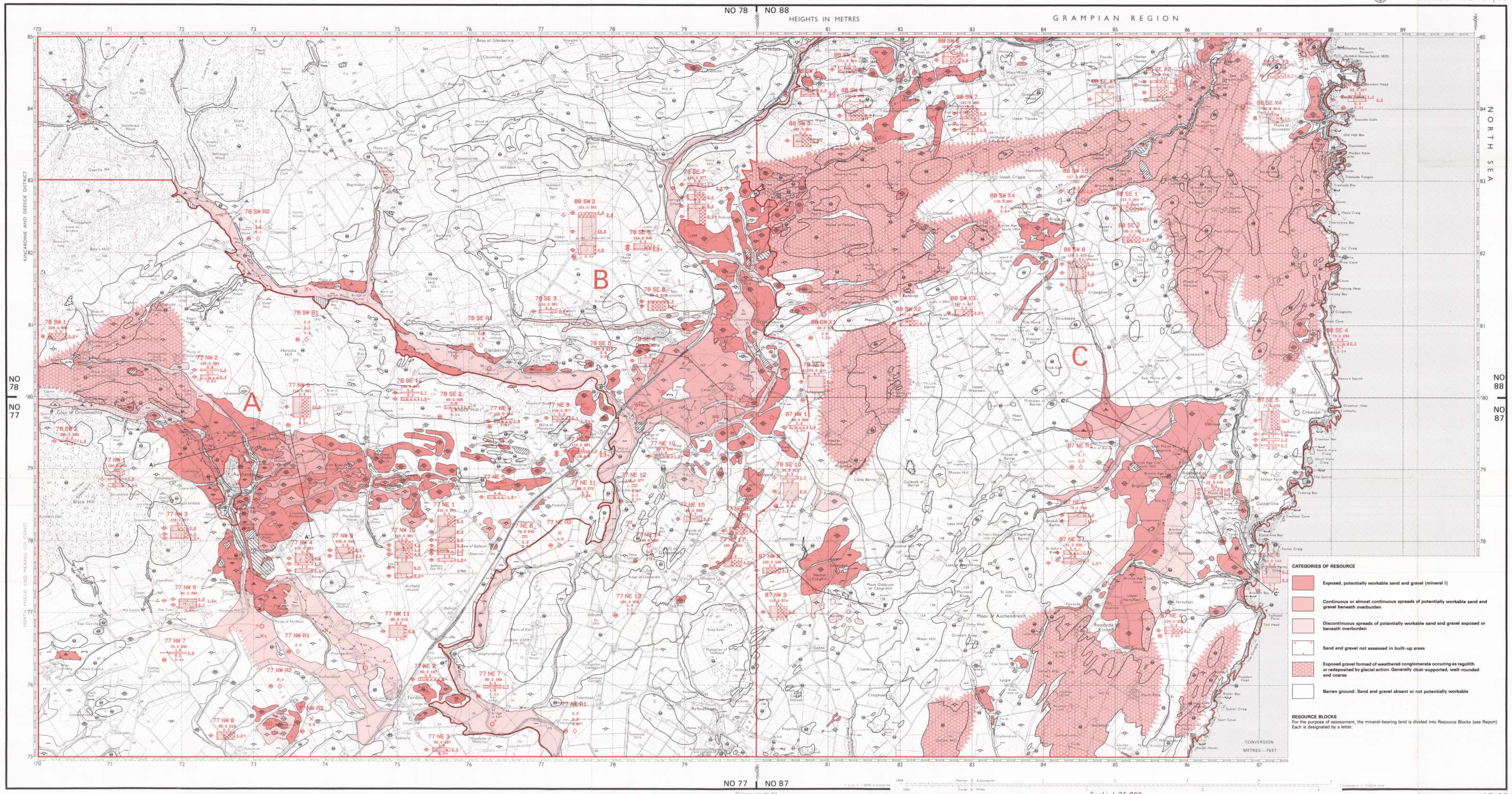
BRITISH GEOLOGICAL SURVEY (SCOTLAND)

THE SAND AND GRAVEL RESOURCES OF THE AREA BETWEEN AUCHENBLAE AND CATTERLINE, GRAMPIAN REGION

Outline Edition Pathfinder Series

ORDNANCE SURVEY

SHEET NO 87/88



Scale 1:25 000

SHEET NO 87/88

LOCATION OF THE AUCHENBLAE - CATTERLINE RESOURCE SHEET

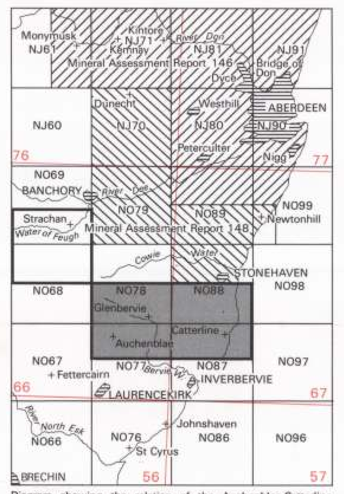
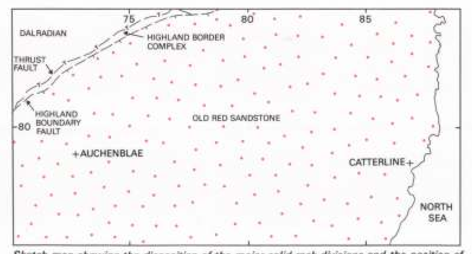


Diagram showing the relation of the Auchenblae-Catterline Resource Sheet to the Strachan Resource Sheet, previously published resource sheets, the National Grid 10 km squares and the 1:50,000 Geological sheets (in red).



Sketch map showing the disposition of the major solid rock divisions and the position of the Highland Boundary Fault

Original survey on the six-inch scale by D.R. Irvine and G. Barrow in 1876–1878

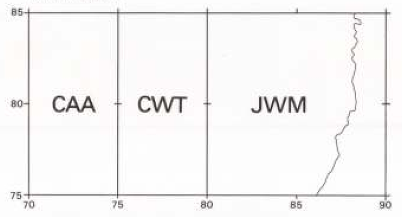
Drift geology resurveyed at a scale of 1:10 000 by C.A. Auton, J.W. Merritt and C.W. Thomas in 1988–1989

Sand and gravel survey by C.A. Auton, J.W. Merritt, M.G. Relaxe, S. Robertson and C.W. Thomas in 1989

D.I.J. Mallick, Manager, Highlands and Islands Group

The 1:25 000 sand and gravel resource sheet published in 1990. Peter J. Cook, Director, British Geological Survey

Survey Diagram



Detailed resurvey of drift deposits for sand and gravel assessment by C.A. Auton (CAA), J.W. Merritt (JWM) and C.W. Thomas (CWT)

Borehole Graphics drawn by computer using programs written by J.L. McInnes, NERC Computer Services, Edinburgh

Produced for the British Geological Survey by Bartholomew Carto-Graphics (Edinburgh) Limited. Printed by John Bartholomew & Son Ltd, Edinburgh 1990

This Map and the accompanying report were commissioned and financed by the Department of the Environment, with support from Grampian Regional Council and local industry.

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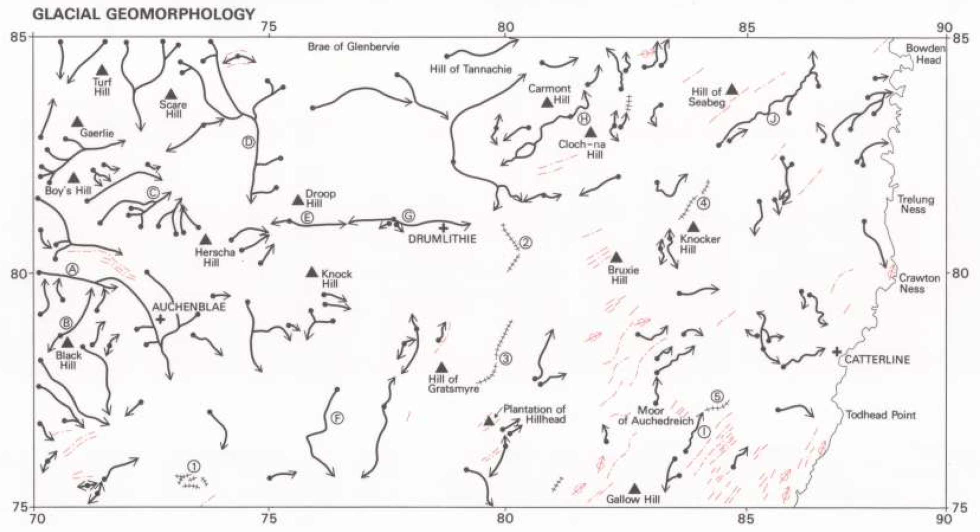
The British Geological Survey welcomes any revisions or additional geological information known to the user.

yards 1000 0 1 2 miles
metres 1000 0 1 2 3 kilometres

GLACIAL GEOMORPHOLOGY



Glacial striae, indicating direction of ice movement.

Glacial flutings and ice-moulded features, indicating direction of ice movement

Esker ridge. The most noteworthy are listed below
① Bomershanoe Wood Eskers ② Fiddes Esker ③ Little Wairds Esker
④ Barras Esker ⑤ Fawsyde Esker

Glacial drainage channel, showing direction of fall of channel floor. The most noteworthy are listed below. Ⓐ Glen of Drumtochty Ⓑ Red Den Ⓒ Paidyfair Den Ⓓ Den of Guinea Ⓔ Hawkhill Den Ⓕ Shepherdshaugh Ⓖ Kinmonth Den Ⓗ Den of Luckyfeal Ⓘ Den of Ery Ⓙ Den of Glaslaw

Principal summit

Village

GENERALISED HORIZONTAL SECTIONS SHOWING RELATIONSHIPS OF DRIFT DEPOSITS

HORIZONTAL SCALE 1:25 000
VERTICAL EXAGGERATION 20X

Potentially workable sand and gravel, continuous or almost continuous deposits, exposed or beneath overburden.

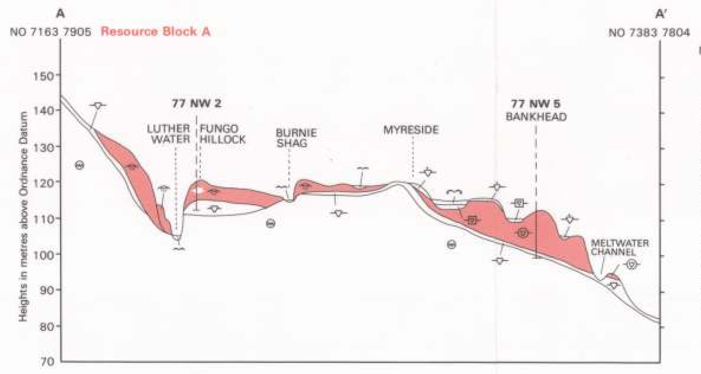
Discontinuous spreads of potentially workable sand and gravel exposed or beneath overburden.

Bedrock and waste, including overburden, are uncoloured

Geological boundary (broken line denotes uncertainty)

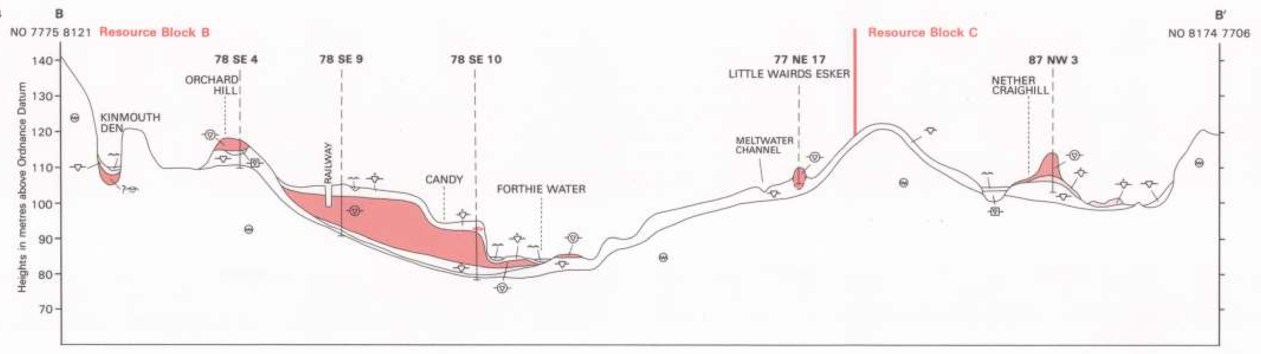
Inferred boundary limiting the extent of potentially workable material

Otherwise symbols and abbreviations as map legend



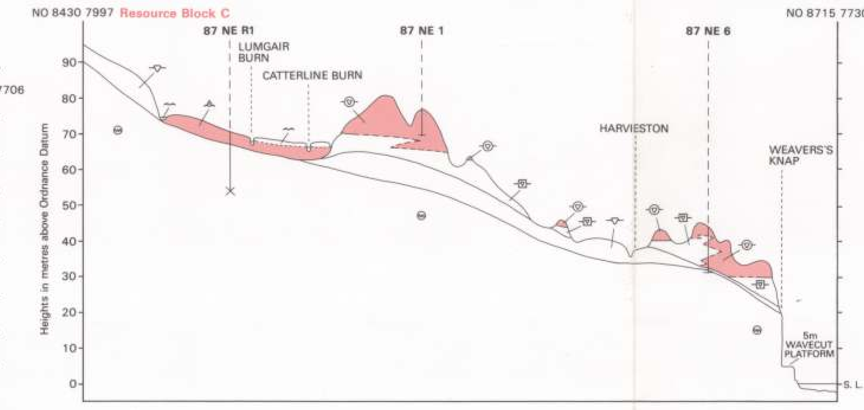
The flat-topped and kettled terraces of fluvioglacial sand and gravel flanking the Luther Water and the Burnie Shag were laid down during the deglaciation by glacial meltwaters that drained south-eastwards. The terraced deposits rest on thin till overlying Old Red Sandstone bedrock.

Glacial sand and gravel south-east of Myreside [736 794] forms east-west trending linear ridges and mounds up to 15m high. The material was laid down during deglaciation, possibly at an E-W trending ice-front by meltwater that flowed into temporary ice-marginal lakes. Thin spreads of glaciolacustrine silt and clay underlie hollows between the ridges of sand and gravel.



Moundy, kettled deposits of glacial sand and gravel lying between Drumlithie [785 808] and the Forthie Water were deposited in an ice-dammed lake by meltwaters during deglaciation and were subsequently covered by an almost continuous layer of flow-till. The sands and gravels vary considerably in lithology, but tend to be fine-grained and silty; they rest on till overlying Old Red Sandstone bedrock.

South-east of the Forthie Water, patchy deposits of glacial sand and gravel overlie an ice-smoothed surface of till resting on Old Red Sandstone bedrock. Immediately east and south of Little Wairds [7976 7858], there is a discontinuous esker that passes northwards into low moundy spreads of ice-proximal glacial outwash sand and gravel.



The Catterline Burn crosses a WSW-ENE trending ice-scoured basin containing alluvial sand and gravel resting directly on conglomerate bedrock.

An undulating spread of glacial sand and gravel lies to the west of Roadside of Catterline [859 792], it overlies glaciolacustrine silt and clay and generally coarsens upwards. The deposits were probably laid down by meltwaters flowing north-east wards along the margin of ice lying along the coast. As the coastal ice decayed, a complex sequence of diamictic mass-flow deposits, sand, gravel, silt and clay were deposited towards the coast at Catterline. All these deposits are shown as glaciolacustrine deposits on the map.

THE SAND AND GRAVEL RESOURCES OF THE AREA BETWEEN AUCHENBLAE AND CATTERLINE, GRAMPIAN REGION

This map should be used in conjunction with B.G.S. Technical Report WF/90/7 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 other than those in sand and gravel

Open-cast working - disused

Landslip

DRIFT
Recent and Pleistocene

Peat

Alluvium - silt, clay, sand and gravel

Alluvial fan - composed of alluvium

Lacustrine alluvium - mainly humic silt, clay and fine sand

River Terrace Deposits - silt, clay, sand and gravel

Present day beach deposits - mainly well-sorted shingle

'Red Series'

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 red

Flow-till and mass-flow deposits - poorly sorted, diamictic/clay, sand and gravel or pebbly, silty, sandy clay, often with abundant mudstone clasts

Till - typically reddish brown, firm to stiff, clayey pebbly sand to sandy, gravelly clay diamicton with sand and gravel lenses

'Inland Series'

Till - typically yellowish to dark brown clayey sand to sandy clay diamicton

SOLID

Bedrock, at or near surface - Old Red Sandstone forms the bedrock beneath most of the area south-east of the Highland Boundary Fault and comprises mudstones, sandstones and conglomerates together with some volcaniclastics and lavas. In the extreme north-west of the area, north-west of the Highland Boundary Fault, the bedrock comprises metamorphosed grits and greywackes of the Dalradian. Within the Highland Boundary Fault zone are tectonic slices of pillow lavas and shales of the Highland Border Complex

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 1989

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

BOREHOLE AND OTHER DATA
SITE LOCATIONS

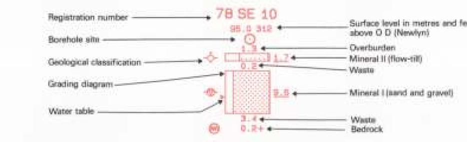
Borehole site

Recorded exposure, sampled

Resistivity depth sounding site

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 to show the grading diagram is omitted
(v) The surface level of each assessment borehole has been estimated from contours on 1:10 000 maps
(vi) A triangle indicates the level to 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. 78 SE 10. 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 boreholes 78 SE 10 is NO 78 SE 10

Grading Diagrams

Each grading diagram shows the mean particle size distribution of a distinct deposit of mineral

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 S, and indexed by the numbers and letters of the relevant standard quarter sheet e.g. 88 SE S1

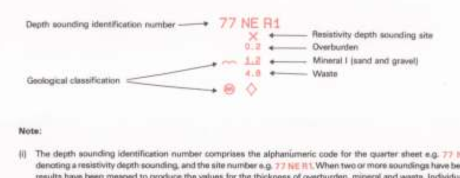
EXPOSURE RECORDS

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, 78 SE 7

SHALLOW PITS

Where space permits the locations of shallow pits providing ancillary assessment data are show by a distinctive symbol. Each pit is identified by serial registration numbers e.g. 77 NE 2

GEOPHYSICAL DATA
RESISTIVITY DEPTH SOUNDINGS



Note:

(i) The depth sounding identification number comprises the alphanumeric code for the quarter sheet e.g. 77 NE followed by the letter 'R' denoting a resistivity depth sounding, and the site number e.g. 77 NE R1. 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. Individual soundings are given in the accompanying report; the results shown for each site (e.g. 77 NE R1) combine data from soundings 77 NE R1A and 77 NE R1B
(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