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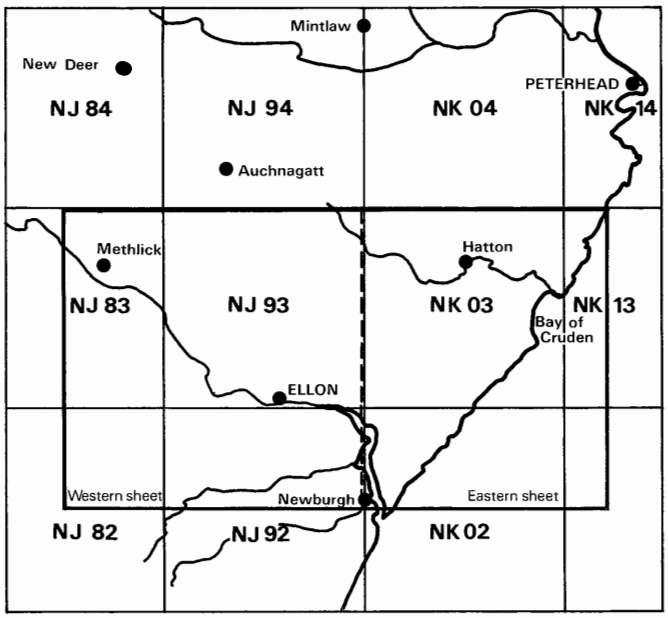

The sand and gravel resources of the country around Ellon, Grampian Region

Description of 1:25 000 resource sheets NJ 93 with parts of NJ 82, 83 and 92, and NK 03 with parts of NK 02 and 13

J. W. Merritt

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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 appear as Mineral Assessment Reports of the Institute.

Details of published reports appear at the end of this report.

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The asterisks on the cover indicate that parts of sheets adjacent to the ones cited are described in this report.

PREFACE

National resources of many industrial minerals may seem so large that stocktaking appears unnecessary, but the demand for minerals and for land for all purposes is intensifying and it has become increasingly clear in recent years that regional assessments of these mineral resources should be undertaken. Publication of information about the quantity and quality of deposits over large areas is intended to provide a comprehensive factual background against which planning decisions can be made.

Sand and gravel, considered together as naturally occurring aggregate, was selected as the bulk mineral demanding most urgent attention, initially in the south-east of England, where about half the national output is won and very few sources of alternative aggregates are available. In 1968, following a short feasibility study initiated in 1966 by the Ministry of Land and National Resources, the Industrial Minerals Assessment Unit (formerly the Mineral Assessment Unit) began systematic surveys which have been extended progressively through Central and Northern England. Work in Scotland, which began in 1975 is being financed by the Department of the Environment, acting through the Scottish Development Department, and is being undertaken with the cooperation of the Sand and Gravel Association of Great Britain.

This report describes the resources of sand and gravel of 343 km^2 of country around Ellon, Grampian Region, shown on the accompanying resource maps. The survey was conducted by J. W. Merritt and the work was controlled from the sub-unit in Edinburgh (E. F. P. Nickless, Officer-in-Charge).

The geological lines now presented at the 1:25 000 scale are based on the one-inch geological survey of Sheet 87 published in 1885 and the six-inch to one mile resurvey of the drift conducted by D. L. Ross in 1977–78. The section of the report on the geology of the area was prepared with the assistance of D. L. Ross.

J. D. Burnell, ISO, FRICS (Land Agent), has been responsible for negotiating access to land for drilling. The ready cooperation of land owners and tenants and the assistance of officials of Banff and Buchan, and Gordon districts is gratefully acknowledged.

G. M. Brown
Director
17 January 1981

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Plate 1 The Kippet Hills Esker and Meikle Loch, Slains: view looking north from Broom Hill [NK 0332 3058].

The sinuous ridge of sand and gravel links in the north with a plateau, probably a kame terrace, in which a small pit is intermittently worked near Whitefields Farm (far right). The fresh-looking features are typical of country underlain by the red drift. Meikle Loch probably occupies the site of a former kettle-hole. (D2791)

Plate 2 Flooded gravel workings in the valley of the River Ythan near Upper Ardlethen [NJ 916 316].

The sheep at the water's edge provide a useful scale to judge the coarseness of the fluvioglacial terrace gravel in this vicinity. The boulders are chiefly composed of gneissose, coarse-grained metagreywacke. (TS1678)

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J. W. MERRITT

SUMMARY

The geological maps of the Institute of Geological Sciences, sixty-one boreholes and thirty-nine shallow pits sunk for the Industrial Minerals Assessment Unit, pre-existing borehole and trench information, together with data from the inspection of fifteen sand and gravel workings form the basis of the assessment of sand and gravel resources in the Ellon area, Grampian Region.

All deposits in the area which might be potentially workable for sand and gravel have been investigated and a simple statistical method used to estimate the volume. The reliability of the volume estimates is given at the symmetrical 95 per cent probability level.

The 1:25 000 map is divided into four resource blocks containing between 2.9 and 5.8 km^2 of potentially workable sand and gravel. The geology of the deposits is described and the mineral-bearing area, the mean thickness of overburden and mineral, and the mean grading of the various types of deposit are stated. Detailed borehole and section data are given. The geology and the outlines of the resource blocks, the position of boreholes, shallow pits and sections used in the assessment are shown on the accompanying maps.

Bibliographic reference

MERRITT, J. W. 1981 The sand and gravel resources of the country around Ellon, Grampian Region. Description of 1:25 000 resource sheets NJ93 with parts of NJ 82, 83 and 92, and NK 03 and parts of NK 02 and 13. *Miner. Assess. Rep. Inst. Geol. Sci.*, No. 76.

Note

National Grid References are given in the form [999 253] throughout. Figures with eastings between 5000 and 9999 relate to places in 100-km square NJ, those with eastings between 0000 and 1400 to places in 100-km square NK.

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INTRODUCTION

The survey is concerned with the estimation of resources, which include deposits that are not currently exploitable but have a foreseeable use, rather than reserves, which can only be assessed in the light of current, locally prevailing, economic considerations. Clearly, both the economic and the social factors used to decide 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; 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 geological evidence. The sites available for inspection, measurement, and sampling are too widely spaced to permit the mineral bodies to be outlined completely or the grade established throughout" (Bureau of Mines and Geological Sciences, 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 arbitrary physical criteria have been adopted:

a The deposit should average at least one metre in thickness.
b The ratio of overburden to sand and gravel should be no more than 3:1.
c The proportion of fines (particles passing the No. 240 mesh BS sieve, about $\frac{1}{16}$ mm) should not exceed 40 per cent.
d The deposit must lie within 25 m 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 18 m 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. As

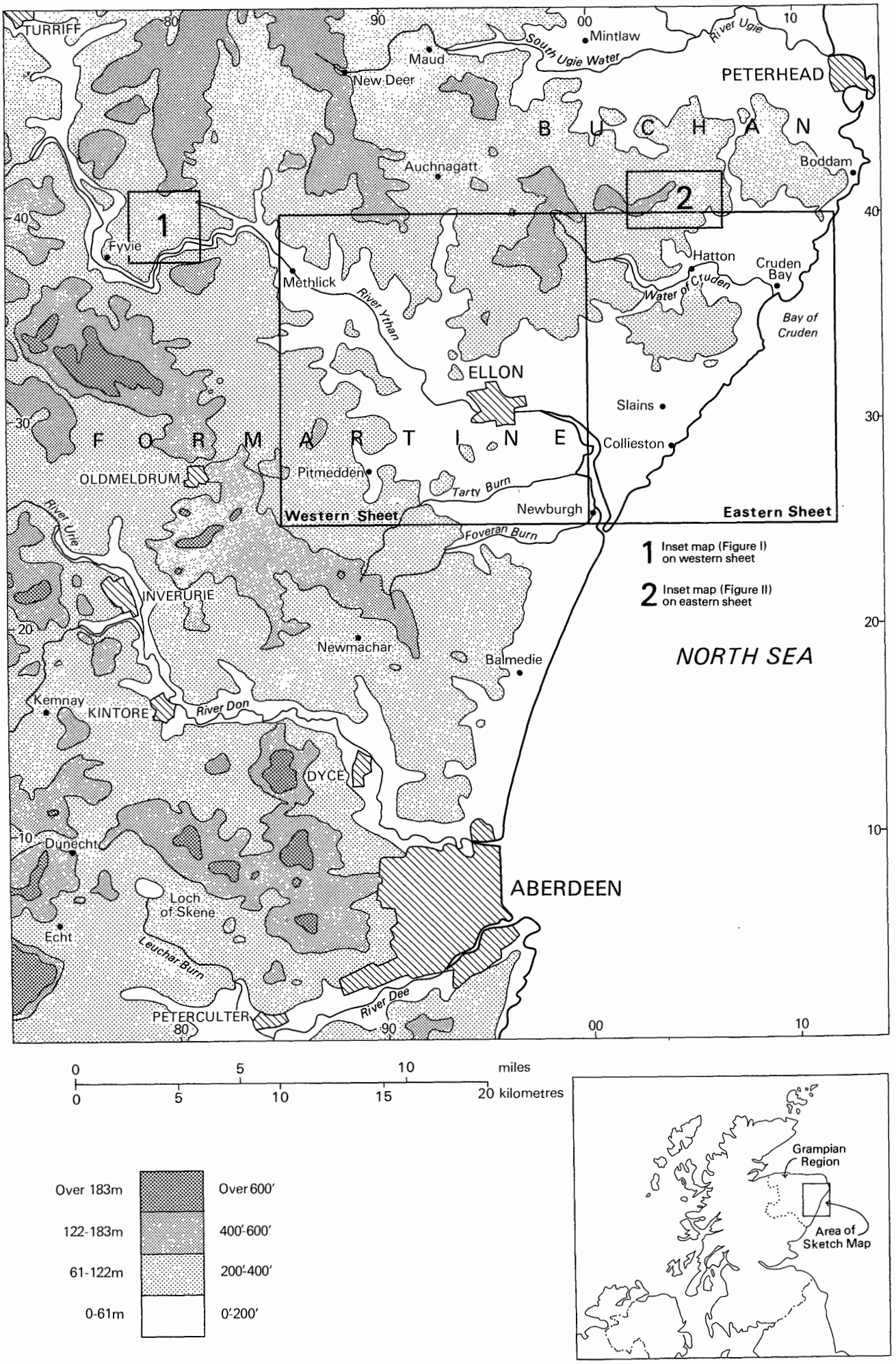


Figure 1 Sketch-map showing the location of the survey area.

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 $\frac{1}{16}$ mm, $\frac{1}{4}$ mm, 1 mm, 4 mm, 16 mm has been adopted. The boundaries between fines (that is, the clay and silt fractions) and sand, and between sand and gravel grade material, are placed at $\frac{1}{16}$ mm and 4 mm respectively (see Appendix C).

The volume and other characteristics are assessed within resource blocks, each of which, ideally, contains approximately 10 km^2 of sand and gravel. No account is taken of any factors, for example, roads, villages and high agricultural or landscape value, which might stand in the way of sand and gravel being exploited, although towns are excluded. The estimated total volume therefore bears no simple relationship to the amount that could be extracted in practice.

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

DESCRIPTION OF THE RESOURCE SHEETS

GENERAL

The survey area is in two parts (Figure 1): it includes 331.8 km^2 of gently undulating agricultural land stretching from Methlick [856 374] in the west to the coast, and 10.8 km^2 to the north-east of Fyvie [765 380] where distinctive quartzite gravels of ?Pliocene age occur at Windyhills [799 398]. Ellon, once a small market town but now a rapidly expanding dormitory town for Aberdeen, some 26 km (16 miles) to the south, is the principal settlement.

Working sand and gravel pits are mainly on the fluvioglacial terraces associated with the present course of the River Ythan between Ellon and Methlick, and within a former course of the river downstream of Ellon. Many isolated deposits of sand and gravel are worked intermittently, especially to the north-east and east of Ellon.

Previous literature on the sand and gravel resources of North-East Scotland includes a systematic brief account of the principal known deposits and workings (Anderson, 1943). More recently Peacock and others (1977) summarised published and unpublished data for Grampian Region as a whole. Chester (1978) investigated reconnaissance techniques for sand and gravel resource evaluation with particular application to the North-East of Scotland. A detailed account of the sand and gravel resources of the country to the west of Peterhead is given in McMillan and Aitken (1981).

TOPOGRAPHY

Local topography is described in some detail in the resource block descriptions. The regional setting may be appreciated from Figure 1 which shows the drainage of the survey area to be dominated by the River Ythan and its tributaries. Along much of its course the river occupies a relatively confined and often steep-sided valley, reaching the North Sea at Newburgh [999 253] where the long and wide estuary includes a considerable area of intertidal flats which form an important wildfowl sanctuary. The Water of Cruden occupies a smaller drainage basin in the north-east of the survey area and flows into the Bay of Cruden [09 34].

Predominantly heather- and grass-covered sand dunes are extensively developed north of the estuary of the River Ythan to Collieston [039 285] and occupy 6.2 km^2 of ground largely sanctioned as the Sands of Forvie Nature Reserve. Dunes also back the sandy beach fringing the Bay of Cruden where they form part of Cruden Bay Golf Course. Elsewhere the coastline comprises high, rugged cliffs indented by small, sheltered havens. A dramatic coastline has developed in granite to the north of the Bay of Cruden where high sea stacks occur at the Bullers O' Buchan [111 380].

The topography of North-East Scotland, in essence, comprises a series of dissected erosion surfaces developed during the Tertiary which repeated glaciation during the Pleistocene has in general only slightly modified. The lowest of these surfaces, the 'Buchan plateau', which lies between 100 and 150 m above Ordnance Datum, is prominent to the north of Ellon. Only at the Hill of Dudwick (174 m) [978 377] and Whitestone Hill (161 m) [978 391] does ground rise substantially above the generally treeless and wind-swept plateau.

GEOLOGY

The assessment area, which is included in the Peterhead (87), Aberdeen (77) and Huntly (86) sheets of the one-inch Geological Map of Scotland published respectively in 1885, 1885 and 1923, was originally geologically surveyed at a scale of six inches to one mile by J. S. Grant Wilson, D. R. Irvine and J. Horne. Only Sheets 87 and 86 have explanatory memoirs, the former edited by Grant Wilson dating from 1886, the latter, by H. H. Read, being published in 1923. In connection with the present survey the drift geology was re-appraised by D. L. Ross during 1977 and 1978.

The geological sequence is summarised in Table 1, where the deposits are listed as far as possible in order of increasing age.

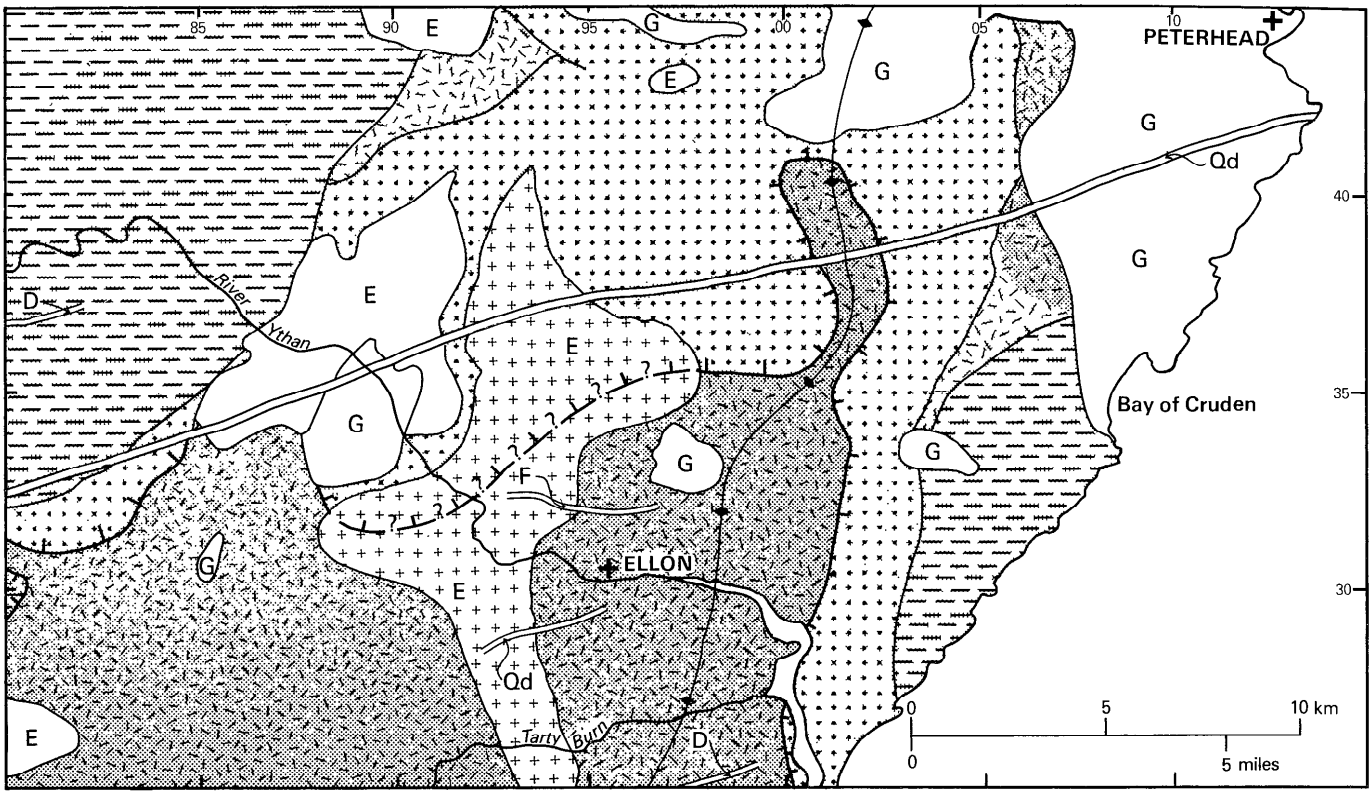
SOLID

With the exception of the ?Pliocene deposits bedrock is not differentiated on the resource maps. However, the distribution and classification of the older solid rocks which range in age from ? Late Precambrian to Permo-Carboniferous are summarised in Figure 2, on which the solid geological boundaries are for the most part highly generalised on account of the paucity of exposures and the severely weathered condition of many of the rocks.

As the solid geology of the area is complex only a résumé is given below. For general information the reader is referred to the British Regional Geology for the Grampian Highlands (Johnstone, 1966), to the Moray–Buchan (57N 04W) sheet of the New Series 1:250 000 Solid Geological Map of Scotland published in 1977, and to Harris and Pitcher (1975).

Rocks older than the Tertiary

Metasediments belonging to the Dalradian Supergroup form bedrock over much of the area and are the predominant constituent of the glacial and fluvioglacial gravels. Strata are essentially in correct stratigraphic order as determined by way-up structures and probably form part of the upper limb of an immense



METAMORPHIC

	MAIN ORIGINAL LITHOLOGY	MAIN PRESENT ROCK-TYPE	LITHOSTRATIGRAPHIC DIVISION.
	Mixed group of greywacke and mudstone (turbidites)	Slate (often 'knotted'), schistose psammite and metagreywacke, mica schist	Upper Dalradian
	Quartzitic sandstone	Metaquartzite, quartz-schist	Middle Dalradian
	Mixed group, predominantly sandy siltstone and mudstone with subordinate sandstone and calcareous beds. Some basic igneous intrusives	Gneiss, mica-schist, hornblende-schist, metadolerite, schistose grit	Middle Dalradian above the Boyne Lag. Mainly ?Pre-Cambrian basement below the Boyne Lag

IGNEOUS

Qd	Quartz - dolerite	Permo - Carboniferous
F	Felsite	Caledonian (mainly pre - Lower Old Red Sandstone)
G	Granite, Granodiorite	
E	Gabbro and Norite ('Haddo Mass')	
E	Gabbro and Norite contaminated by the partial melting of pelitic country-rock ('Arnage Mass')	

KEY TO METAMORPHIC GRADES.

- Low pressure: greenschist facies
- Low pressure: amphibolite facies
- As above, sillimanite zone, approximately equal to areas with migmatite development

- Geological boundary
- Dyke
- Axial trace of the Buchan Antiform (approximate)
- The Boyne Lag: a complicated zone of thrust faulting and crustal attenuation. Pecks indicate the upper surface

Figure 2 Sketch-map showing the solid geology of the Ellon area (excluding the Buchan Ridge and Windyhills gravels) (based on Johnson and Stewart (1960) and 1:250 000 Geological Moray–Buchan (57N 04W) Sheet).

Table 1 Geological classification of deposits

DRIFT	
Recent and Pleistocene	Blown sand Peat Alluvium (undifferentiated) Present day beach and estuarine deposits Post-Glacial beach and estuarine deposits Fluvioglacial sand and gravel (usually flat or terraced at surface) Glacial sand and gravel (usually moundy at surface) Glaciolacustrine deposits Till
SOLID	
?Pliocene	Buchan Ridge Gravels, Windyhills Gravels
Permo-Carboniferous	Igneous (intrusive) rocks
Caledonian (mainly pre-Lower Old Red Sandstone)	'Newer Igneous Intrusions': late- to post-tectonic basic, granitic or complex plutons and hypabyssal rocks
Dalradian (? Late Precambrian to Cambrian)	Metamorphic rocks of the Grampian Caledonides

early-Caledonian anticlinal gravity nappe (the Banff Nappe of Read and Farquhar, 1956) which closes towards the south-east. In the survey area the rocks are disposed about a broad late-Caledonian anticline trending north-north-east (the Buchan Anticline of Read and Farquhar, 1956), the axis of which is located about 3 km east of Ellon. With the exception of local steepening, dips are generally shallow, between 20° and 30°, and slightly higher to the north-west of the anticlinal axis.

Owing to the structural complexity there is uncertainty about stratigraphic relationships but it is likely (Ramsay and Sturt, 1979) that rocks belonging to the Middle (Argyll) and Upper (Southern Highlands) Groups of the Dalradian rest unconformably upon a 'tectonic-slice' of pre-Caledonian basement which is exposed within the core of the Buchan Anticline. The unconformity is in reality a complex zone of thrusting and severe crustal attenuation known as the Boyne Lag or Line (Read and Farquhar, 1956).

The 'Ellon Gneiss', which occurs beneath the Boyne Lag and for which a Precambrian age has been proposed (Sturt and others, 1977) has experienced polyphase metamorphism involving migmitisation and has also been extensively sheared and mylonised. It is generally purplish in colour, massive, siliceous and contains subordinate, more siliceous bands: locally it is strongly foliated and micaceous. The chief rock type is cordierite-biotite-gneiss which often contains garnet and sillimanite. Thin bands of sillimanite-cordierite-biotite-schist are common as are hornblende-schists and granulites.

Dalradian rocks cropping out in the area have been divided on the basis of original lithology into three groups (Harris and Pitcher, 1975). The first two lie at the top of the Middle Dalradian; the third forms the Upper Dalradian. The oldest group were once predominantly siltstone and mudstone with subordinate quartzitic sandstone and calcareous beds. The second group, stratigraphically higher, were predominantly quartzitic sandstone. The youngest group comprised a thick sequence of turbidites, chiefly greywacke with subordinate siltstone and mudstone. The middle group is best developed in the north of the area, where it forms the Mormond Hill Quartzite but is much thinned in the western limb of the Buchan Anticline.

The Dalradian sediments have generally been regionally metamorphosed up to the low-pressure amphibolite facies of Turner (1968). The mudstone has been altered to mica-schist or to dark grey slate, often 'knotted' with porphyroblasts of andalusite. Siltstone and greywacke has become quartz-mica-schist or dark grey to black, very tough, siliceous schistose semipelite and psammite. Quartzitic sandstone has become metaquartzite or pale greenish-grey quartz-schist and the rare calcareous beds have generally become fine-grained massive blue-green calcsilicate rocks. Various basic igneous rocks which were intruded into the sedimentary pile before the onset of the main episode of regional metamorphism have become hornblende-schist or epidiorite.

Two large bodies of basic magma related to the Insch and Huntly gabbros to the west and north-west of the area have been injected into the metasediments (Read, 1923, 1935). Four kilometres downstream of Methlick the valley of River Ythan cuts the western intrusion known as the 'Haddo Mass' which comprises quartz- and olivine-norite (Gribble 1967). The eastern and larger of the two intrusions, the 'Arnage Mass', forms a north–south linear body exposed in the valley of the River Ythan 4 km upstream of Ellon. To a greater extent than in the Haddo Mass the basic magma of the 'Arnage Mass' reacted with the predominantly pelitic country rocks to form a complex series of contaminated, cordierite- and garnet-bearing quartz-norites with abundant xenoliths of gneissose metasediment. Rock from the basic igneous masses and from their surrounding extensive thermal aureoles (Gribble, 1966) has been incorporated in the gravel deposits within the valley of the River Ythan and commonly occurs as boulders displaying onion-weathering.

In addition to the basic complexes, late- to post-tectonic Caledonian granites also occur within the area. The country to the north of Cruden Bay is underlain by pink, coarse-grained biotite-granite forming the southern part of the Peterhead pluton. Smaller bosses of granite occur adjacent to the Haddo Mass and beneath the Hill of Bearnie, 4 km north-north-east of Ellon. Grey granodiorite occurs beneath Lochlundie Moss, 4 km south of Hatton.

Dykes cut both the Dalradian metasediments and the Caledonian igneous masses: only the thicker and more extensive are shown in Figure 2. The majority are of late-Caledonian age and are represented by aplite, pegmatite, felsite, quartz-porphyry and microgranite. Permo-Carboniferous quartz-dolerite dykes also occur: the most extensive is traceable for 64 km and crosses the valley of the River Ythan [897 355] near Schivas. Quartz-dolerite is an important constituent of the fluvioglacial gravels immediately downstream of Schivas: it is very hard and difficult to crush when fresh but weathers within a few years of exposure.

Tertiary gravel and pre-Glacial weathering

Fragments of a presumed formerly extensive spread of ?Pliocene gravel occur beneath the Moss of Auquharney [026 397] (Figure II) and at Windyhills (Figure I). McMillan and Merritt (1980) discussed the origin of these distinctive, well rounded quartzite and flint gravels and recognised two units: the predominantly vein-quartz and quartzite 'Windyhills gravels' were considered to be of fluviatile origin, whereas the deposit composed chiefly of flint, quartzite, and vein-quartz at the Moss of Auquharney, part of the 'Buchan Ridge gravels' which extend south-westwards from the Peterhead survey area (McMillan and Aitken, 1981), was considered to represent a former beach. Both deposits, but particularly the latter, have a kaolinitic silty clay matrix.

Numerous pockets of decomposed bedrock and the remnants of ?Pliocene gravels are thought to be features of a pre-glacial landscape that has survived glacial erosion (Flett and Read, 1921). Both the gravels and the decomposed rock have experienced prolonged subaerial weathering, probably in a warm humid climate such as is thought to have existed in Scotland during the mid- to late-Tertiary (Basham, 1974). The weathering may have been accelerated by warm groundwater (Peacock and Michie, 1975).

Examples of deeply weathered bedrock include pelitic schist decomposed to a silty clay, commonly displaying relict banding and knotting, and quartz-mica-schist, gabbro and granite disaggregated to sand. Disaggregated granite was worked in a pit [083 424] on the Hill of Longhaven in 1979 as bedding for gas and oil pipes. Several commercial boreholes sited on the high ground to the north of Ellon revealed bedrock, particularly granite, gabbro and schist, thoroughly weathered to depths in excess of 20 m. Exceptionally, decomposition is to a kaolinitic silty clay, as, for example, at pit 03 NW P1 near the Moss of Auquharney.

DRIFT

Jamieson (1858, 1860, 1862, 1865, 1874, 1882a, 1882b, 1906 and 1910) provides some of the earliest descriptions of the Quarternary deposits of North-East Scotland and many of his interpretations and theories of glaciation have, in essence, only been modified by later workers. The account which follows mainly draws on the latest published researches, principally those of Clapperton and Sugden (1977), Murdoch (1977) and McLean (1977).

North-East Scotland was glaciated on several occasions during the Pleistocene, but it remains unclear if the entire area was ice-covered during each cold phase or whether parts were polar desert. Apart from a few deposits proved at depth which may be older, the bulk of the drift relates to the maximum of the last (Devensian) glaciation. The present distribution of glacial deposits and landforms broadly reflects the pattern of ice retreat and decay which probably was complete by about 13 000 BP (Sissons and Walker, 1974). A short return to arctic conditions occurred during the Loch Lomond Stadial, 10 800 to 10 300 BP (Sissons, 1974).

As Buchan is generally considered to have been peripheral to the major centres of the late-Devensian ice-sheet (see Figure 3) the ice cover was probably relatively thin in the survey area and decayed rapidly. Clapperton and Sugden (1977) concluded that during a period of about 2000 years at the end of the late-Glacial Period and again during the Loch Lomond Stadial the area was subjected to permafrost. These conditions caused considerable downslope re-distribution of material through the agency of soli-fluxion, giving the present landscape its smoothed and generally rather featureless appearance. Ice wedge casts were recognised by the present author in fluvio-glacial gravels in several of the pits in the valley of the River Ythan: conspicuous vertical orientation of pebbles has been noted at Windyhills (Fitzpatrick, 1975).

The survey area contains contrasting landscapes which broadly coincide with differences in geology. Relatively hummocky terrain towards the coast is characterised by kettles and mounds, kame terraces, esker ridges and narrow steep-sided valleys, all of which are well displayed in the area around Meikle Loch, Slains [027 308]. Inland the landscape is gently undulating and comparatively featureless. The coastal region is generally underlain by a thick sequence (at least 25 m at several borehole sites) of red-coloured clayey till, glaciolacustrine deposits and glacial sand and gravel: the present topography bears little relationship to the sub-drift bedrock surface. In contrast, the drift cover inland, chiefly sandy gravelly till, is generally only a few metres thick and in consequence the land-surface broadly mirrors the sub-drift topography.

Deposits of glacial sand and gravel within the survey area can generally be related to one of three till units recognised by Clapperton and Sugden (1977). The first and generally basal till unit is clay-rich, typically dark blue-grey and very stiff, containing many angular stones of local origin. It was positively identified at eighteen IMAU borehole sites scattered across the survey area and rarely included any sand and gravel. At boreholes 03 NE 3, 03 NE 9 and 92 NE 2 it overlay sand and gravel containing an unusually high proportion of well-rounded quartzite, vein-quartz and flint, possibly derived from the ?Pliocene gravels.

The second till unit is more widespread than the first: it is generally sandier and less stiff, usually a yellow-brown or brown-grey colour, either overlies the first unit or rests directly upon bedrock, and commonly contains pockets of sand and gravel which in the main are too restricted to be delineated separately on the resource map. However, deposits of glacial sand and gravel, typically fining with depth into brown laminated silt, apparently occur between the two till units at a number of localities. The more extensive of these glacial sand and gravel deposits form sizable hillocks to the north and west of Hatton where boreholes 03 NW 4, 03 NW 5, 03 NE 2 and 03 NE 3 proved respectively 13.6 m, 10.9 m, 9.1 m and 4.0 m: in addition 8.5 m was penetrated in borehole 03 NW 1 on the Hill of Auchleuchries. Several other deposits of glacial sand and gravel are not clearly related genetically to any till unit but nonetheless have compositional similarities with the deposits listed above, for example, at Tillybrex [002 349], at borehole 03 NW 2 near Oldtown and at the sand pit in Hatton [054 371] where 11.6 m, 6.8 m and 17.3 m respectively of sand and gravel was recorded.

The third till unit is in reality a complex sequence of clay, silt, sand and gravel in which till as such forms only a part: it is referred to in this report as the 'red drift' (in part, the Red Clay Series of Jamieson, 1906). The sequence is characteristically a vivid red-brown

colour and is essentially restricted to the coastal region, being well exposed along the coast between Collieston and Cruden Bay. It either overlies till units one and two and their associated deposits of sand and gravel, or rests directly on bedrock. Unlike the other units the red drift contains many rock-types, for example limestone and calcareous siltstone, that may crop out beneath the North Sea adjacent to the coastline between Aberdeen and Peterhead (Glentworth and others, 1964).

Borehole evidence shows that the lithology of the red drift changes rapidly, both laterally and vertically. In general, it comprises firm-to-stiff pebbly silty clayey till which passes downwards into a complex sequence including silty clay, silt, fine-grained sand, sand and gravel and clay-rich pebbly till. The sequence sometimes overlies a basal buff-coloured pebbly sand and is typified by the records of boreholes 03 NE 7, 03 SE 2 and 03 SE 3 (Appendix F).

Some of the more sandy beds within the red drift are potentially workable: that is, they meet the arbitrary physical criteria adopted for this survey (see Appendix C). An attempt has been made in the borehole logs to distinguish glaciolacustrine deposits characterised by fine sand, silt and clay from those dominated by till. This procedure allows a convenient classification for these sandy deposits which, although potentially workable by definition, nevertheless have little foreseeable commercial value.

The red drift appears to fill hollows in the sub-drift surface and consequently has an irregular thickness. The two areas within block D identified on the resource map as 'discontinuous spreads of mineral, exposed or beneath overburden' are where the sequence is thought to be thickest and to include potentially workable material, chiefly glaciolacustrine deposits. Towards the centre of block D, and to the north of Cruden Bay, the red drift thins against bedrock and mainly comprises a stiff stony clayey till.

In addition to the generally thin (less than 1 m) and laterally impersistent beds of sand and gravel which form an integral part of the red drift sequence, several larger deposits of glacial sand and gravel have compositional similarities with this unit. A more-or-less continuous sinuous gravel ridge (Kippet Hills Esker) runs northward from Cotehill Loch [028 294] near Collieston, past Meikle Loch to Ladie's Brig [029 318] where it widens north-eastwards into a flat-topped mound (?kame terrace) beneath Knapsleask [032 325]. Boreholes 03 SW 9 and 03 SW 10 sited on this feature proved 22.3 m and 21.0 m respectively of sand and gravel, and both demonstrate that the base of the deposit lies several metres below the level of the surrounding countryside. A small pit [006 266] in the Forvie Esker near Newburgh exposed 10.3 m of sand and gravel at the time of the survey.

Several mounds and low eskers constructed of glacial sand and gravel which are thought to be genetically related to the red drift lie to the south of Ellon, notably at Cross-stone Wood [952 283] and Target Wood [947 285].

Recent studies by McLean (1977) and Murdoch (1977) in the Aberdeen area and Clapperton and Sugden (1977) in North-East Scotland as a whole, involving till fabric analysis, petrographic analysis and the detailed mapping of meltwater channels allows generalised lines of ice-flowage to be inferred for the late-Devensian ice sheet (Figure 3) which probably

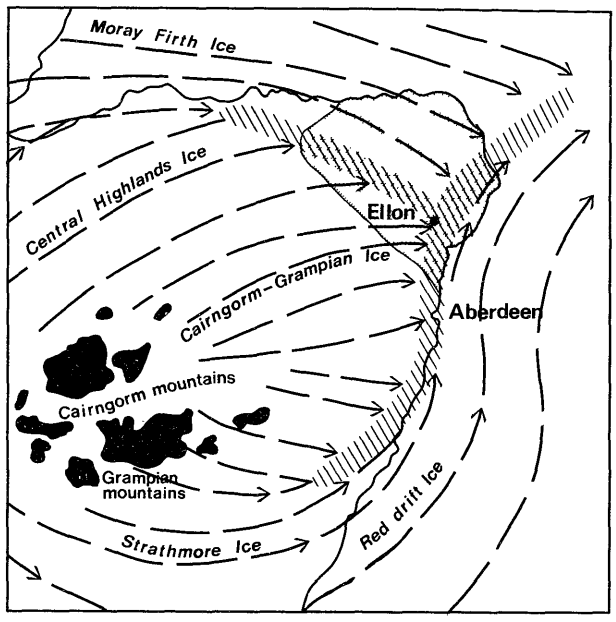


Figure 3 Generalised flow-lines for the late-Devensian ice-sheet in North-East Scotland (after Clapperton and Sugden, 1977). Hatching denotes a confluence zone of locally fluctuating flow strength and direction through time during the late-Devensian. The shaded area depicts a zone of low glacial erosion that possibly became ice-free relatively early during the decay of the late-Devensian ice sheet.

reached its maximum extent at about 17 000 BP. It is apparent that three streams of ice converged in the survey area depositing debris from diverse localities. Fluctuating strengths of flow probably caused some lateral movements of the ice-streams which explains some local interdigitation of tills containing clasts of different provenance.

The results of the present survey generally support the views of McLean (1977) and Murdoch (1977) concerning the mode of deposition of the different tills. The first till unit is probably entirely a lodgement till whereas the second unit is predominantly melt-out and flow till, the included bodies of sand and gravel having formed in supraglacial lakes or from meltwater streams and ponds within a stagnant decaying ice-sheet. The red drift is probably derived from heavily sediment-laden ice which advanced from offshore: it includes lodgement till (common over high ground), and a complex of melt-out till, flow till and waterlain till with glaciolacustrine (perhaps glaciomarine) deposits and sand and gravel.

Red waterlain till interbedded with finely laminated glaciolacustrine sediment including dropstones has been tentatively identified in the brick-pit at Errolston [089 368] (Peacock, personal communication): it seems probable that much of the red drift may have been deposited either from floating ice, or within large water-filled cavities within the decaying ice-sheet. Although late-Glacial, red-coloured, marine clay, silt and sand are widespread offshore southwards from Aberdeen (Peacock, 1975), no glaciomarine deposits have been positively identified in the survey area. During initial phases of ice-sheet decay, meltwaters emanating from inland were probably ponded back against ice occupying the North Sea Basin. A complex system of temporary freshwater lakes would have formed with surface levels gradually falling with time as the ice decayed. Deposits of red laminated clay at Tipperty [969 267] are thought to have formed in a

small pro-glacial lake (Murdoch, 1977): the material has long been used for brick-making.

Murdoch (1977) argued that ice-sheet conditions were favourable for sub-glacial meltwater activity during much of the late Devensian. Several boreholes downstream of Ardlethen Bridge [925 307] proved deeply buried sand and gravel presumably confined to a buried gorge underlying the terraces and floodplain of the River Ythan (see cross-sections B–B′ to D–D′), and 2 km east of Hatton, borehole evidence suggests that a drift-filled gorge lies beneath the floodplain of the Water of Cruden. A seismic traverse across the mouth of the River Ythan at the Snub [002 282] indicated a buried gorge cut into bedrock bottoming at some 40 m below OD (Quaternary Research Association, 1975). These buried features may be attributable to former sub-glacial meltwater streams that deepened pre-Devensian valleys.

The fluvioglacial terraces of the valley of the River Ythan illustrated in geological cross-sections A–A′ to D–D′ broadly form a descending series. Deposits underlying the fragmentary higher terraces, for example at Bellmuir [875 365] and [918 318] near Upper Ardlethen, are generally very poorly sorted and contain boulders up to 3 m in diameter, suggesting deposition in close proximity to melting ice. These terraces were probably formed ice-marginally or subglacially as the ice-sheet decayed and receded up the valley.

The lower terraces were probably formed by braided meltwater streams which initially flowed towards extensive lakes east of the present coastline. In response both to wasting of the ice-sheet and to a general lowering of relative sea level in the North Sea Basin, the surface levels of these lakes fell intermittently during the late-Glacial Period, probably from over 30 m above OD to more than 10 m below OD. Downstream of Ardlethen Bridge the fluvioglacial terrace deposits rest upon, and are incised into a thick sequence of laminated silt and clay likely to have been deposited during a period of high relative sea-level which caused ponding-back in the valley.

The lowermost terraces of the River Ythan lying at a few metres above OD, merge downstream into post-Glacial raised-beach deposits, sometimes gravelly, that border the estuary (Ritchie and others, 1978): the relationship between the deposits is not clear but the raised-beach material probably overlies the terraces. Jamieson (1865) recorded a section 'at the estuary of the River Ythan' in which peat containing tree remains separated terrace gravels from younger shelly 'carse' clay forming a low raised beach.

Ritchie and others (1978) describe series of raised-beaches at two levels at the estuary of the River Ythan, one between 3 and 6 m above OD and the other between 10 and 12 m above OD. In the Sands of Forvie, borehole 02 NW 4 proved 2.0 m of possible beach material based at 4 m above OD and at Cruden Bay Golf Course, borehole 03 NE 14 proved 8.1 m of shelly sand and gravel based at 9.5 m below OD resting upon red drift. The lower series of raised beaches, if not that at Cruden Bay Golf Course, relates to the last major post-Glacial (Flandrian) marine transgression about 7000 BP.

Alluvium occurs within many valleys but only the deposits associated with the River Ythan and Water of Cruden have been investigated. The deposits are mainly gravelly.

Peat occurs either within shallow basins, where it generally overlies ice-scoured bedrock, or in upland areas where the ground is poorly drained. Examples of basin peat occur beneath Lochlundie Moss [045 335] and the Moss of Auchleuchries [010 370]: upland peat spreads across the Moss of Auquharney [022 396] underlain by impervious Buchan Ridge gravels. In both situations peat has been removed extensively for domestic fuel.

Dunes of blown sand fringe the Bay of Cruden and form the 'Sands of Forvie', which lie between Collieston and the estuary of the River Ythan. Most are grass covered but some towards the southern end of the Forvie Reserve are bare and active. The dunes, commonly 10 to 12 m in height, are composed of pale yellow fine- to medium-grained sand. The Sands of Forvie are described in detail by Ritchie and others (1978).

COMPOSITION OF THE SAND AND GRAVEL

Particle-size distribution and petrography

Detailed mean grading data (particle size distributions) for the mineral deposits within each resource block are presented in Tables 5 to 10, and a summary is included in Table 4. Where there is sufficient information, grading characteristics are represented graphically. Figures 4 to 6 show cumulative mean grading curves with envelopes within which the cumulative mean grading curves of the mineral deposits proved at individual sample points fall. In the bar graph illustrating frequency distribution, the length of each bar represents the percentage by weight of material which passes the sieve of the indicated aperture and is retained on the next finest sieve: the percentage of material exceeding 64 mm is not represented as there is insufficient control over this size range.

Composition analyses (pebble-counts) were conducted on five samples of gravel collected either from working faces or from stockpiles at sand and gravel pits. The number of samples examined is a compromise to provide background data on petrography, the physical and mechanical properties of the material consistent with a regional assessment. The 10- to 14-mm fraction was inspected because this size range is specified in BS812.3:1975 for mechanical and physical testing. The fraction analysed may not be representative of the gravel as a whole; indeed, the petrographic composition of deposits comprising coarse-grained rocks such as granite varies greatly with clast size. However, three of the samples contain a proportion of crushed coarse-grade material which probably makes them more truly representative than they would be otherwise.

The classification scheme adopted for the pebble-counting is based upon the British Standard Petrological groups (trade groups) defined in BS812.1:1975 but modified to accommodate vein-quartz and deleterious or weathered rock-types, which, as they are not normally quarried, are not embraced by the standard. Much of the glacial and alluvial gravel in the Ellon area is composed of Dalradian quartzose metasediments which are assigned to the quartzite trade group: to allow more subtlety four subgroups have been recognised, namely vein-quartz, metaquartzite, fine-grained metagreywacke, and medium- to coarse-grained metagreywacke. The metaquartzites are typically pale yellow or pale grey, quartz-rich, fine to medium grained and durable.

Table 2 Composition analyses (pebble-counts) of samples taken from five sand and gravel workings (10- to 14-mm fraction)

British Standard Trade Group	Rock type (Modified after BS 812)	Waulkmill Hill*		Upper Ardlethen*		Deepheather*		Whitefields		Windyhills†§	
		Angularity‡	Weight %	Angularity	Weight %	Angularity	Weight %	Angularity	Weight %	Angularity	Weight %
Basalt	Dolerite, epidiorite	a–sr	3		—		—		—		—
Flint	Flint, chert	wr	trace		—	sa	trace	sa–wr	1	sa–sr	trace
Gabbro	Basic diorite, gabbro and basic gneiss	a–sa	2	a–sr	21	a–sr	12	sa–sr	2		—
Granite	Granite and acid gneiss	a–wr	5	a–sa	11	sa–sr	13	sa–sr	10		—
Gritstone	Fine- to medium-grained sandstone, often red		—	a–wr	3		—	sr–wr	2		—
Limestone	Fine-grained limestone		—		—		—	sr–wr	25		—
	Calcareous or dolomitic siltstone		—		—		—	sa–wr	16		—
	(Group total)		—		—		—		(41)		—
Porphyry	Porphyry, felsite	sa–wr	3	a–sr	2	sa–sr	1		—		—
Quartzite	Metaquartzite	sa–wr	22	a–sr	21	sa–wr	21	sa–wr	12	wr	14
	Fine-grained metagreywacke	sr–wr	28	a–sr	8	sa–wr	9	sa–sr	3		—
	Medium- to coarse-grained metagreywacke	a–sr	23	a–sr	20	sa–sr	20	sa–sr	8		—
	Vein-quartz	a–wr	6	a–sr	6	a–wr	13	sa–wr	14	wr	83
	(Group total)		(79)		(55)		(63)		(37)		(83)
Schist	Quartz-mica-schist and foliated gneiss		—	a–sr	5	sa–wr	7	sa–sr	2		—
	Slate, often knotted	sr–wr	8	sr–wr	3	sr–wr	4	sr–wr	5		—
	(Group total)		(8)		(8)		(11)		(7)		—
Others	Friable, decomposed psammite		—		—		—		—	sr–wr	3
Total number of clasts counted			303		337		326		315		412

* Includes a proportion of crushed gravel.
† Approximately 10 per cent of clasts disintegrated with sieving and were disregarded.
‡ Terms describing the degree of roundness are defined in Appendix C: a – angular, sa – subangular, sr – subrounded, r – rounded, and wr – well rounded.
§ The locations of these and other workings are given in Appendix G.

Metagreywacke is typically dark grey to black and, in addition to quartz, contains up to about 20 per cent of feldspar together with recrystallised aluminium silicates such as andalusite. The medium- to coarse-grained metagreywacke, which is sometimes alternatively referred to as schistose psammite or semipelite in the borehole logs is commonly conglomeratic, containing pebbles up to 5 mm in diameter. There is little distinction between the fine-grained metagreywacke and slate excepting that the metagreywacke is slightly coarser grained, is generally massive and forms tabular or spherical pebbles, whereas the slate is very fine grained, is often knotted, is cleaved and characteristically forms plate-shaped pebbles that break easily when hammered. For brevity, slate and fine metagreywacke are sometimes alternatively described here and in the literature as schistose pelite.

Fluvioglacial sand and gravel (of the valley of the River Ythan) Drilling the fluvioglacial terraces of the River Ythan proved exceptionally difficult because the gravels are generally very coarse, especially in the upper few metres where the material is often bound by iron-pan or by cuticles of clay adhering to the clasts. Boulders a metre or more in diameter are widespread but are most noticeable resting on the higher terraces which are often uncultivated, for example, at Bellmuir. The lower terraces have generally been cleared of boulders but the exceptionally wide dry-stone walls (consumption dykes) testify to the coarseness of the underlying gravels.

In any circumstances, determination of particle-size distribution in material as coarse as the terrace gravels poses considerable technical difficulties. In this survey, bulk samples obtained by drilling are not fully representative, firstly because a chisel bit was often employed which comminuted the coarse gravel and tended to push aside particularly hard cobbles or boulders, and secondly because the borehole diameter of 250 mm obviously limited the maximum size of clast recovered.

A photographic procedure for estimating the weight percentage of material larger than 64 mm exposed in pit sections might have been employed in combination with conventional grading data to allow an overall particle size distribution to be calculated. Such a method is described by Laxton (1980) and was used successfully elsewhere (Laxton and Nickless, 1980), but

unfortunately too few accessible exposures were available in the present survey area for such a technique to be employed. However, a photographic method was used to estimate roughly the proportion of cobble- and boulder-sized clasts in vertical pit faces in gravel workings [8851 3576] at Tangland and [9115 3311] at Waulkmill Hill. After sampling sites had been selected as randomly as practically possible, a 1-m quadrat was placed against the exposed face and photographed from the normal using a polaroid camera. By the use of a circular scale 64 mm in diameter positioned within the field of view of each photograph, the areal percentage of the quadrat covered by material larger than 64 mm was estimated using a transparent grid overlay. The technique assumes a direct relationship between areal and weight percentage which is probably justifiable in most circumstances.

The results of five determinations of material from Tangland Pit suggest that up to 38 per cent by weight of the gravel comprised material exceeding 64 mm whereas at Waulkmill Hill Pit the estimate based upon four determinations is 10 per cent. These determinations are not representative of all the gravel exposed at either locality because it was only practicable to photograph the coarser (and higher) parts of the sections: nevertheless, they may usefully be compared with the grading data obtained from boreholes and trenches for which the amount of material exceeding 64 mm generally ranges up to about 15 per cent, the maximum recorded value being 23 per cent at 92 NE P1. The estimate that at the Tangland Pit 38 per cent of material exceeds 64 mm is probably not extraordinary, as even coarser deposits are exposed elsewhere, for example, in the old workings [9205 3200] at Upper Ardlethen and at Bellmuir. It must be concluded, therefore, that there is a significant underestimate of oversize material in many gradings of terrace gravel and a note to this effect has been added to those borehole logs (Appendix F) most likely to be affected.

The fluvioglacial sand and gravel at most sample points graded as 'gravel' (see Figure 12). The sandiest development was at borehole 83 SE 1 where 4.1 m of gravel fined downwards into 5.1 m of pebbly sand: less pronounced fining-downwards sequences occurred at several other sites. Cumulative mean grading curves, Figures 4 and 5, illustrate the general coarseness and relative lack of sorting of the terrace gravel and indicate increasing sorting downstream. The frequency distribution graph for block A shows very poor sorting whereas for block B it reveals bimodality with peaks in the fine to medium sand and in the coarse gravel (16 to 64 mm) fractions. The mean grading of the terrace gravels is: fines 5 per cent, sand 39 per cent and gravel 56 per cent (gravel).

The composition of the gravel varies both downstream and between the higher and lower terraces. Pebble-counts (Table 2) based on samples collected from sand and gravel workings at Waulkmill Hill [9115 3311], Upper Ardlethen [9180 3185] and Deepheather [9787 2902] show that although rock-types of the quartzite trade group predominate there are nevertheless subtle compositional differences between the sites which reflect the distribution of the solid rock (see Figure 2). Thus at Upper Ardlethen Pit gabbroic rocks derived from the 'Arnage Mass' form a significant proportion of the gravel whereas at

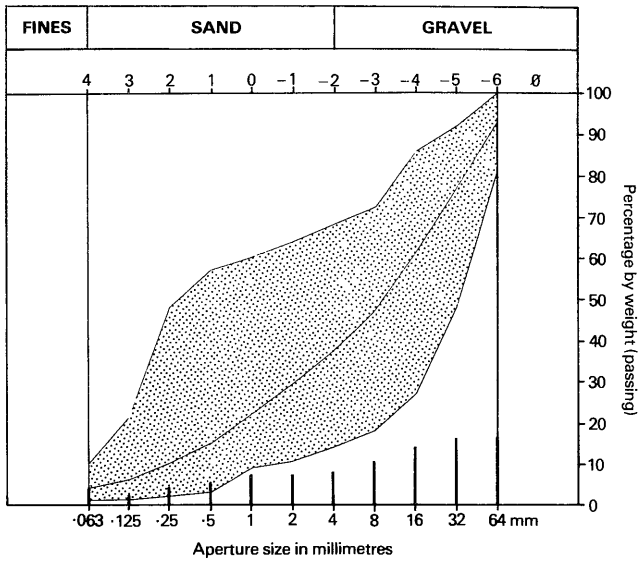


Figure 4 Grading characteristics of resources in the fluvioglacial sand and gravel (block A). The stippled area defines the envelope within which the cumulative mean gradings of the mineral proved at individual sample points fall, the centre line representing the cumulative mean; the frequency distribution of the mean grading (0.063 to 64 mm) is represented by the bar graph.

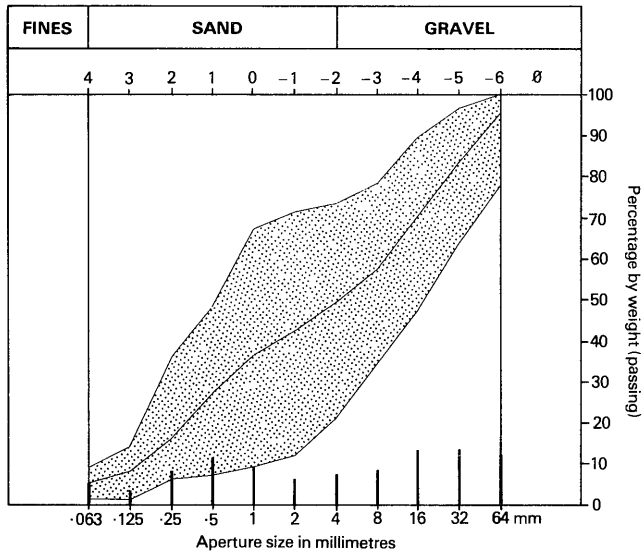


Figure 5 Grading characteristics of resources in the fluvioglacial sand and gravel (block B) (for explanation see Figure 4).

Waulkmill Hill Pit there is relatively more fine-grained greywacke and slate probably derived upstream of Methlick where similar rocks are exposed in a gorge [820 393].

Although there is no quantitative data, significant compositional changes have been observed between terraces at different elevations. Higher terraces are generally more poorly sorted and comprise a greater proportion of very local rock-types, often as large angular blocks. Lower terraces are generally better sorted, probably contain much reworked terrace gravel and possess a greater diversity of rock-types. There is also a concomitant increase in the roundness of clasts in the lower terraces.

As the higher older terraces have experienced a longer period of weathering than the lower they are more likely to comprise weathered, and hence deleterious, rock-types. In the higher pit at Upper Ardlethen [9180 3185] there is considerably more 'rotten' gabbroic rock, for example, than in the lower pit [9205 3200]. At Tangland Pit large boulders of hard ultrabasic rock derived from the 'Haddo Mass' weather relatively quickly on exposure.

At working pits in the valley of the River Ythan (see Appendix G) some of the boulders are crushed, and at Waulkmill Hill Pit crushed rock from a nearby quarry is added to the natural gravel to upgrade its durability for use in blacktop surfacing. Many of the boulders, however, are too hard to crush economically and at the pits near Upper Ardlethen, for example, there is much spoil, chiefly gritty metagreywacke and quartz-dolerite boulders derived from a thick dyke which crosses the valley of the River Ythan at Schivas (see Figure 2).

The coarse-gravel fractions of the terrace deposits are generally well rounded and the clasts typically cuboid or spherical in shape. The fine gravel and coarse sand tends to be more angular, especially if coarse-grained igneous rocks are dominant. These two fractions generally contain much subrounded to well-rounded platy clasts of slate whereas the medium and fine sand is predominantly quartz with some feldspar and rare mica.

Glacial sand and gravel As glacial sand and gravel displays considerable variability both in composition and grading, few generalisations are possible. On the whole the deposits are better sorted than the terrace gravels of the River Ythan as indicated by the graphs of mean grading in Figure 6 which reveal bimodality with modes in the fine-sand and coarse-gravel fractions. The deposits range from well-sorted sand such as exposed in Hatton Pit (section 03 NW 15), to very poorly sorted gravel exposed, for example, at Oldtown Pit (section 03 NW 7) and on Lochlundie Moss (section 03 SW 13). The poorly sorted deposits generally contain much angular rock derived locally whereas the composition of other deposits is more varied. Gravels associated with the grey or brown till units comprise much metagreywacke and metaquartzite, for example, the deposit at Tillybrex Pit [0005 3489]: those associated with the red drift include a large proportion of sedimentary rock, for example, a pebble-count (Table 2) on 10- to 14-mm gravel taken from section 03 SW 12 in Whitefields Pit revealed 41 per cent of ?Jurassic limestone and calcareous siltstone. The content of limestone was sufficient here for the deposit once to have been worked for lime. Pebbles of yellow shelly sandstone, possibly of Pliocene age, were found at Whitefields Pit, confirming observations of older workers, most notably Jamieson (1858, 1882a and 1906).

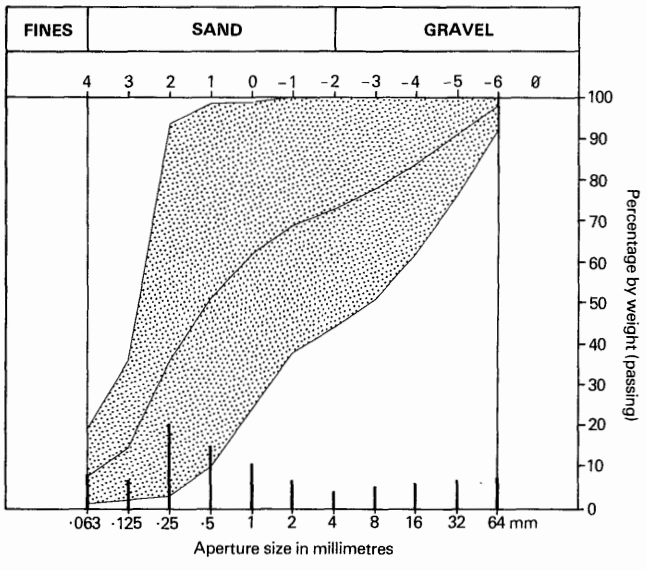


Figure 6 Grading characteristics of resources in the glacial sand and gravel deposits (block C) (for explanation see Figure 4).

The scattered glacial sand and gravel deposits in the north-east of the survey area are generally sandy, often are silty and micaceous, sometimes include seams of finely interlaminated clay, silt and sand, and generally fine with depth into silt and clay.

The mean grading of the glacial sand and gravel is fines 7 per cent, sand 60 per cent and gravel 32 per cent (sandy gravel).

Fluvioglacial terrace deposits of the Water of Cruden On the basis of sample points 03 NW 8 and 03 NE 11 (see Table 8) the terrace gravels have a mean grading of fines 2 percent, sand 41 per cent and gravel 57 per cent (gravel). At section 03 NW 8 the deposit was poorly sorted and the fine gravel and coarse sand particularly angular: downstream at borehole 03 NE 11 the material was better sorted. The gravel, which includes some cobbles and boulders, and also the coarse sand mainly comprise durable metaquartzite and metagreywacke with subordinate amounts of mica-schist, gneiss, vein-quartz and granite. The fine and medium sand fractions are predominantly composed of quartz and feldspar: the fines are chiefly silt.

Red drift Potentially workable sand and gravel within the red drift of block D is either identified as *glaciolacustrine deposits* or as *(buried) glacial sand and gravel.* Graphic mean frequency distributions for both deposits are presented in Figure 7.

The glaciolacustrine deposits are the more widespread, typically comprising red-brown fine- to medium-grained micaceous sand which is generally very silty and often clayey and cohesive. The material is interbedded with red-brown clayey till, and typically includes thin, laterally impersistent seams of yellow-brown, medium-grained sand (often with comminuted shell) and rare stringers of fine gravel. The mean grading based on five sample points (see Table 8) is fines 19 per cent, sand 80 per cent and gravel 1 per cent ('clayey' sand).

Buried glacial sand and gravel was proved in boreholes 03 SW 7, 03 SE 2 and 03 SE 3 where it underlay interbedded glaciolacustrine deposits and red till. The deposit, which has a mean grading of fines 8 per cent, sand 75 per cent and gravel 17 per cent (pebbly sand), typically comprises well-sorted, yellow-brown sand and gravel, often with some comminuted shells. The gravel, mainly fine, is similar in composition to the limestone-rich glacial sand and gravel exposed in Whitefields Pit which has been described above. The sand is chiefly of medium grade with fine and some coarse.

Additional information on the composition of parts of the red drift is given in Jamieson (1882b).

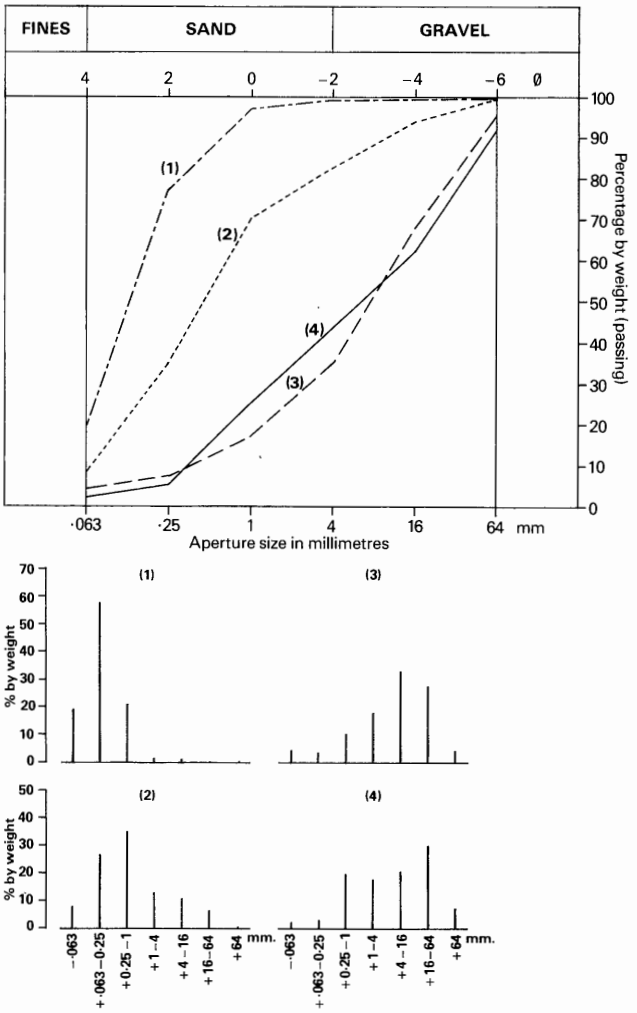


Figure 7 Grading characteristics of resources for which inferred assessments are offered.

1 Glaciolacustrine deposits within the red drift
2 Glacial sand and gravel within the red drift
3 Isolated deposits of glacial sand and gravel in block D
4 Fluvioglacial terrace gravels of the Water of Cruden

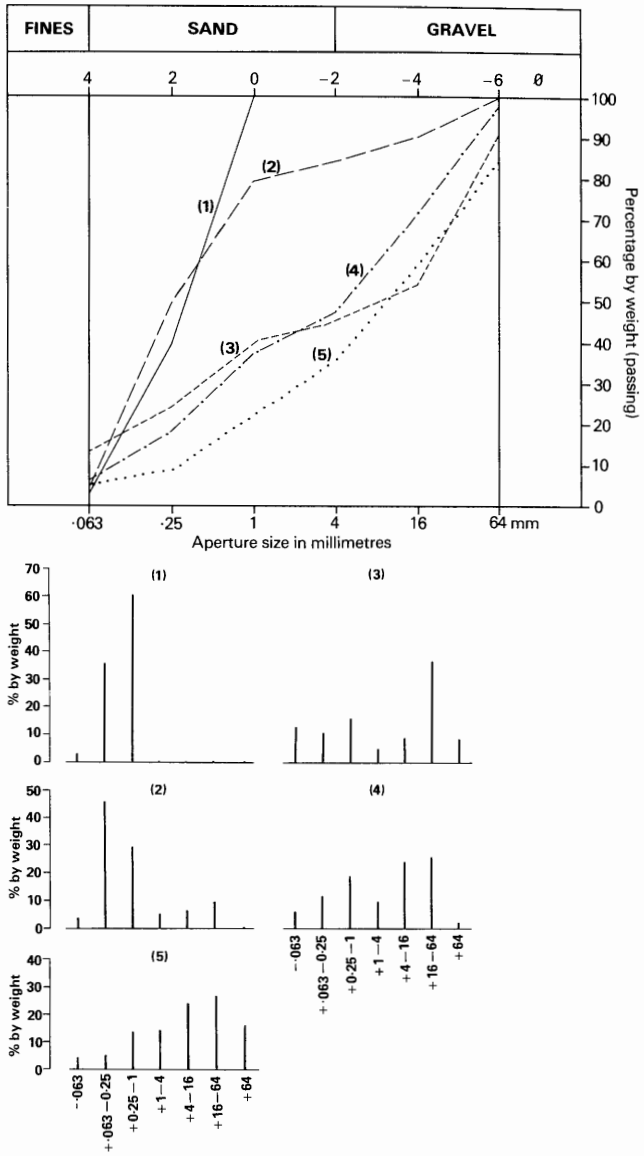


Figure 8 Grading characteristics of resources for which inferred assessments are offered.

1 Blown sand
2 Post-glacial beach deposits
3 Buchan Ridge gravels
4 Windyhills gravels
5 Alluvium of the River Ythan

Blown sand and beach deposits Blown sand forms dunes at Cruden Bay and the Sands of Forvie and is typically a pale yellow quartzose sand which is unconsolidated, very well sorted and medium to fine grained. The mean grading based on six sample points is fines 3 per cent and sand 97 per cent. At boreholes 02 NW 4 and 03 NE 14, blown sand passes down into medium to dark grey sand and gravel interpreted as deposits of a post-Glacial raised beach. The frequency distribution for the latter (Figure 8) shows bimodality with peaks in the fine to medium sand and in the coarse gravel fractions, and contrasts strongly with the frequency distribution for blown sand shown in the same figure. Predictably, the composition of the beach gravel is varied, but durable metagreywacke and metaquartzite predominate.

Alluvium Although the alluvium of several of the larger streams is probably gravelly only that of the River Ythan has been assessed. Based on IMAU boreholes 83 NE 5 and 93 SW 6 the mean grading is fines 4 per cent, sand 32 per cent and gravel 64 per cent (gravel). The frequency distribution and cumulative mean grading curve in Figure 8 shows that the deposit is poorly sorted and 15 per cent of the material exceeds 64 mm in diameter. In composition, the alluvial gravel is broadly similar to that of the fluvioglacial gravel which has been described above.

?Pliocene gravels The ?Pliocene deposits are more fully described in the additional notes on the resource blocks. The clay-bound *Buchan Ridge gravels* proved by borehole 03 NW 3 on the Moss of Auquharney (see Figure II) were so coarse that only one sample was retrieved from the deposit, which is 9.4 m thick: during drilling, cobbles and boulders were generally pushed aside and were not recovered. The principal deposit straddles the boundary with the adjacent resource sheet and a mean grading of fines 13 per cent, sand 32 per cent and gravel 55 per cent ('clayey' gravel) has been obtained by amalgamating data with that quoted in McMillan and Aitken (1981). The mean frequency distribution is given in Figure 8. The gravel comprises

well-rounded flint and white quartzite with subordinate amounts of friable quartzite and soft, deeply weathered granite, gneiss and schist. The matrix is predominantly a stiff, sandy, micaceous kaolinitic clay.

In contrast to the Buchan Ridge gravels the *Windyhills gravels* are generally not clay-bound. The mean grading, based on two sample points (see Table 9), is fines 6 per cent, sand 41 per cent and gravel 53 per cent (gravel). The mean frequency distribution (Figure 8) illustrates that the deposit is moderately well sorted and shows modes in the medium sand and coarse gravel fractions. The predominantly well-rounded gravel is composed of vein-quartz with some white quartzite. Friable weathered quartzite and soft decomposed quartzofeldspathic clasts constitute about 12 per cent of the deposit. Flint is rare. A pebble-count on 10- to 14-mm gravel is given in Table 2. The deposit is very micaceous and the fines principally comprise silty clay composed almost wholly of kaolinite (R. I. Lawson, personal communication).

Mechanical and physical properties

Aggregate Impact Value (AIV), '10 per cent fines', relative density and water absorption were determined in accordance with BS 812.2 and 3:1975 for the 10- to 14-mm fraction of five representative samples collected from sand and gravel workings in the assessment area: the results are listed in Table 3.

AIV and 10 per cent fines are tests of the strength of an aggregate: the former gives a measure of the resistance of rock to sudden impact, the latter measures resistance to an applied compressive load that is gradually increased until a given degree of compaction is achieved in a standard time. Both measurements vary chiefly as a function of the petrology of the gravel but also of clast size, surface texture, flakiness, elongation, and degree of weathering. For example, subrounded to well-rounded pebbles of finely crystalline metaquartzite and psammite might be expected to show a greater resistance to impact than less well-rounded, coarsely crystalline granite and gabbro or platy clasts, such as mica-schist and slate. The behaviour of crushed rock aggregates in response to mechanical testing has been studied exhaustively, for example Ramsay (1965), Dhir and others (1971), Ramsay and others (1973, 1974), allowing predictions about mechanical properties to be made which with caution may be extended to natural aggregates.

Although few results are presented here, the mechanical and physical properties generally correlate with composition in a predictable manner. The sample from Waulkmill Hill Pit in which 79 per cent of the clasts are assigned to the quartzite trade group and 7 per cent to the coarse-grained igneous groups, yielded a low AIV of 14. In contrast, samples from the pits at Upper Ardlethen and Deepheather which respectively comprised 32 per cent and 25 per cent of coarse-grained igneous material gave AIVs of 21 and 19: that is, these samples showed less resistance to impact than the Waulkmill material.

Apart from the sample of ?Pliocene gravel from Windyhills with an AIV of 31 the results are reasonably close to the average of 19 for worked gravel cited in Edwards (1970), and fall well within the normally recommended maximum test value of 30 quoted in BS 812.3:1975. The weathering history and exceptional composition of the Windyhills material (83 per cent of it is vein-quartz) probably explains the high AIV obtained for this sample: in comparison, a value of 25 is cited by Edwards (1970) for a fresh, disaggregated quartz-conglomerate from Central Scotland.

In general the 10 per cent fines value correlates inversely with AIV suggesting that a similar lithological control applies. The results for the sample from Windyhills are exceptional as the 10 per cent fines value is greater than expected probably because vein-quartz, essentially non-granular, does not easily crumble.

The water absorption value of an aggregate is a measure of the absorption after 24 hours of immersion in distilled water, expressed as a percentage of the oven-dry weight. This test is particularly important because there is a broad linear relationship between water absorption and drying shrinkage, both of the

Table 3 Results of mechanical and physical testing*

Sample locality	Deposit type	AIV	10% fines	Relative density (oven dried)	Relative density (surface dried)	Apparent relative density	Water absorption %	Inferred shrinkage† %
Waulkmill Hill Pit‡	Fluvioglacial terrace	14	280	2.63	2.66	2.71	1.3	0.056
Upper Ardlethen Pit‡	Fluvioglacial terrace	21	130	2.59	2.65	2.75	2.2	0.075
Deepheather Pit‡	Fluvioglacial terrace	19	180	2.62	2.66	2.73	1.6	0.063
Whitefields Pit	Esker/kame terrace (Glacial sand and gravel)	24	120	2.51	2.58	2.70	2.9	0.088
Windyhills§	?Pliocene fluvial terrace (Windyhills gravels)	31	150	2.59	2.60	2.64	0.9	0.048

* Conducted in accordance with BS 812; 2 and 3:1975
† For explanation, see text.
‡ Includes a proportion of crushed gravel.
§ Approximately 10 per cent of clasts disintegrated with sieving and were disregarded.

aggregate itself and of any concrete prepared from it. 'Moisture movement' which includes drying shrinkage and wetting expansion is a key factor in determining the stress-carrying ability of concrete and its susceptibility to weathering.

The water absorption values given in Table 3, which range from 0.9 to 2.9 per cent (average 1.78 per cent), are high compared with the range of average values (0.27 to 1.36 per cent) for various groups of crushed rock listed by Edwards (1966, 1970) and compare only a little more favourably with the average of 1.48 per cent and the range of 0.09 to 2.77 per cent quoted for natural aggregates (Edwards, 1970). The sample from Windyhills with a large proportion of non-absorbent vein-quartz predictably yields the lowest value.

The inferred shrinkage values listed in Table 3 have been extrapolated from the graph drawn by Edwards (1970) plotting water absorption against concrete drying shrinkage. With the exception of the sample from Whitefields Pit, the inferred values do not exceed 0.085 per cent, the shrinkage value quoted in the Building Research Station Digest 35 (1968) as defining the lower limit of a category in which 'greatest care' need be exercised when the material is used in concrete manufacture. However, it must be emphasised that derived shrinkage values should be interpreted cautiously as accurate results can only be obtained by laboratory testing of concrete blocks made from the various aggregates. The high water absorption (2.9 per cent) and inferred shrinkage value (0.088 per cent) for the Whitefields sample undoubtedly reflect the exceptional composition: 41 per cent of the sample comprised calcareous siltstone and limestone, much of which was honeycombed. Concrete made from this deposit, may, however, be less affected by shrinkage than might at first be thought as limestone aggregates usually produce concretes of low shrinkage independent of absorption level (Edwards, 1970).

It is widely known that the greywacke-rich gravels of the Midland Valley and Southern Uplands of Scotland make concretes prone to volume change and to rapid deterioration on exposure to the weather. Although the gravels of the Ellon area contain much material of similar appearance to these greywackes, the Dalradian rocks are generally at a higher metamorphic grade and are far less prone to changes in volume: metagreywacke must not be thought necessarily to be a deleterious constituent.

The fluvioglacial terrace deposits with up to 51 per cent metagreywacke and up to 21 per cent of basic igneous rocks have a relative density (oven dried) in the range 2.59 to 2.63, a little higher than the mean of 2.58 for worked gravels cited by Edwards (1970): the determinations on material from Whitefields and Windyhills are less than the mean owing respectively to the high contents of limestone and vein-quartz.

THE MAP

The sand and gravel resource maps are folded into the pocket at the end of this report. The base map is the Ordnance Survey 1:25000 Outline Edition which together with the contours is printed in grey. The geological lines and symbols are in black. Mineral resource information is in red.

Geological data

The geological boundary lines are taken from the geological maps of the area, which were surveyed on the scale of 1:10560 or 1:10000. The boundaries are the best interpretation of information available at the time of survey. However, it is inevitable, particularly with variable superficial deposits, that locally the accuracy of the map will be improved as new evidence from boreholes and excavations becomes available.

Borehole data, which include the stratigraphical relations and mean particle-size analysis of the sand and gravel samples collected during the assessment, are also shown on the map.

Mineral resource information

The map is divided into resource blocks (see Appendix A), within which the extent of mineral-bearing ground is shown in red. The dark shade denotes where mineral is exposed, that is, the overburden averages less than 1.0 m in thickness: a lighter tone is used to identify where it is present in relatively continuous spreads beneath overburden averaging more than 1.0 m in thickness. Within these areas, however, there may be small patches where sand and gravel is absent or not potentially workable, as for example, around borehole 83 NE 2.

A further category which is shown on the resource map in the lightest tone of red, is recognised where mineral is considered discontinuous. The recognition of categories is subjective, depending on the proportion of boreholes which did not find potentially workable sand and gravel, and the distribution of these barren boreholes within a block. The mineral is described as 'almost continuous' if it is present in 75 per cent or more of the boreholes in a resource block, and as 'discontinuous' if present in more than 25 per cent but less than 75 per cent of the boreholes in a resource block.

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

For the most part the distribution of categories of deposits is based on the mapped geological boundaries. Where there is a transition from one category to another which cannot be related to the geological maps and which could not be accurately delineated during this survey, inferred boundaries have been inserted. Such boundaries are shown by a distinctive symbol, 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.

RESULTS

The results are summarised in Table 4. Further particulars are shown in Tables 5 to 10. The mean gradings and the grading 'envelope' for resources assessed statistically are given in Figures 4 to 6, the mean gradings for other mineral deposits are given in Figures 7 and 8.

Accuracy of results

For the resources assessed statistically the accuracy of the results at the symmetrical 95 per cent probability

Table 4 The sand and gravel resources: summary of statistical and inferred assessments

Resource block and mineral-bearing deposits		Area		Mean thickness		Volume of sand and gravel			Mean grading percentage		
		Block	Mineral	Over-burden	Mineral		Limits at the 95% probability level		Fines	Sand $+\frac{1}{16}$	Gravel
		km^2	km^2	m	m	$m^3 \times 10^6$	± %	$\pm m^3 \times 10^6$	$-\frac{1}{16}$ mm	−4 mm	+4 mm
SUMMARY OF STATISTICAL ASSESSMENTS											
A	Valley-side deposits	7.1	4.2	0.1	5.5	23	31	7	4	37	59
B	Valley-side deposits	6.2	2.9	0.3	5.0	14	37	5	5	42	53
C	Glacial sand and gravel	237.8	5.8	1.4	10.5	60	40	24	8	65	27
	Total	251.1	12.9			97					
SUMMARY OF INFERRED ASSESSMENTS											
A	Valley-floor deposits	7.1	1.8	0.8	4.6	8	speculative		5	42	53
B	Valley-floor deposits	6.2	0.8	1.2	3.7	3	speculative		4	26	70
C	Buchan Ridge gravels	237.8	0.5	1.6	9.4	5	speculative		10	25	65
D	Fluvioglacial terrace deposits (Water of Cruden)	78.3	0.5	0.3	4.6	2	speculative		2	41	57
D	Glacial sand and gravel (isolated spreads)	78.3	1.1	0.9	4.2	4	speculative		4	31	65
D	Interstratified sand and gravel (red drift)	78.3	26.0	3.8	3.4	89	speculative		14	78	8
D	Blown sand and beach deposits	78.3	7.0	0.0	6.4	45	speculative		4	91	5
	Windyhills gravels	–	1.6	0.1	12.7	20	speculative		6	41	53
	Total	329.4	39.3			176					
	Combined total	342.7*	52.2			273					

* Including Windyhills and the built up area of Ellon.

level ranges from 31 to 40 per cent. However, the true values are more likely to be nearer the figure estimated than the limits. Moreover it is probable that in each block roughly the same percentage limits would apply for the estimate of volume of a very much smaller parcel of ground (say 100 hectares) containing similar sand and gravel deposits if 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 of part of a block it can be expected that data from more than ten samples points will be required, even if the area is quite small.

However, it must be emphasised that the quoted volume of sand and gravel has no simple relationship with the amount that could be extracted in practice, as no allowance has been made in the calculations for any restraints (such as existing buildings and roads) on the use of land for mineral working.

NOTES ON THE RESOURCE BLOCKS

Block A

The block encompasses the fluvial and fluvioglacial terraces of the River Ythan from west of Methlick downstream to 500 m of Ardlethen Bridge [925 307]. Towards both ends of the block the River Ythan flows within a gorge, usually less than 500 m wide, incised in bedrock capped by thin till: the middle part is 1000 to 1500 m in width and fragmentary fluvioglacial terraces border the floodplain. The boundary separating blocks A and B roughly coincides with a buried knick-point: upstream fluvial and fluvioglacial deposits, locally underlain by till, rest on bedrock, whereas downstream a deep buried channel is filled with glaciolacustrine deposits, till, and sand and gravel.

Characteristically, the gravels within the block are very coarse and boulders of over a metre in diameter are common. Drilling such deposits with a shell and auger rig posed considerable technical difficulties and consequently a greater proportion of boreholes than is normally acceptable was abandoned owing to rock obstruction. Although it has been possible to assess the volume statistically by augmenting borehole data with records obtained from pit sections and trenches dug by mechanical excavator, it must be emphasised that the estimate is probably a minimum. Furthermore, because of the intrinsic difficulties in sampling cobble and boulder gravels much of the grading data slightly underestimates the gravel fraction (see the section on composition).

Potentially workable sand and gravel underlies both fluvial and fluvioglacial terraces. For assessment

Table 5 Block A: data from sample points and the assessment of resources

Sample point	Recorded thickness			Mean grading percentage							Descriptive category (see Figure 11)
Borehole, section*, or pit	Assessed mineral	Overburden	Waste partings	Fines	Fine sand	Medium sand	Coarse sand	Fine gravel	Coarse gravel	Cobbles and boulders	
	m	m	m	$-\frac{1}{16}$ mm	$+\frac{1}{16}$ $-\frac{1}{4}$ mm	$+\frac{1}{4}$ -1 mm	$+1$ -4 mm	$+4$ -16 mm	$+16$ -64 mm	$+64$ mm	
VALLEY-SIDE DEPOSITS (fluvioglacial sand and gravel)											
83 NE 2	–	0.9	–	–	–	–	–	–	–	–	–
83 NE 3	2.4	0.3	–	10	38	12	8	10	15	7	CSG
83 NE 4	7.0+	0.3	–	6	5	14	18	24	25	8	G
83 NE 6*	5.0+	0.0	–	1	3	6	8	20	50	12	G
83 NE 7*	6.2	0.0	–	1	4	4	5	13	56	17	G
83 NE 8*	5.9+	0.0	–	1	1	8	21	39	30	0	G
83 SE 1	9.2	0.2	–	6	13	30	18	18	13	2	SG
93 SW 2	6.2	0.1	–	3	3	9	14	21	35	15	G
93 SW 3*	5.9+	0.0	–	1	2	6	13	27	43	8	G
93 SW 4	7.5	0.2	–	8	24	27	22	14	3	2	G
93 SW 5	5.8+	0.2	–	7	5	10	18	28	30	2	G
93 SW P1	4.3	0.2	–	No grading information available							–
Mean	5.5	0.1	–	4	9	14	15	22	29	7	G
VALLEY-FLOOR DEPOSITS (alluvium)											
83 NE 5	3.8	0.8	–	5	7	21	14	17	19	17	G

* Sections are marked with an asterisk; pits include the prefix P before their number.

Statistical assessment of the valley-side deposits

Area of exposed mineral	4.21 km^2
Area of continuous or almost continuous spreads of mineral beneath overburden	0 km^2
Total area of mineral	4.21 km^2
Area of worked-out sand and gravel	0.32 km^2
Mean thickness of overburden	0.1 m
Mean thickness of mineral	5.5 m
Estimated volume of mineral	**23.0 million m^3** ±31% *or* 7.1 *million m^3*

Inferred assessment of the valley-floor deposits

Area of exposed mineral	1.76 km^2
Area of continuous or almost continuous spreads of mineral beneath overburden	0 km^2
Total area of mineral	1.76 km^2
Mean thickness of overburden	0.8 m
Mean thickness of mineral	4.6 m
Estimated volume of mineral	**8.1 million m^3**

'valley-floor' and 'valley-side' deposits have been distinguished. The former include deposits buried beneath the floodplain terrace and lying below the water-table: the latter include the fluvioglacial terraces, most of which could be worked dry. Although a statistical assessment of resources is offered for the valley-side deposits, only an inferred assessment is possible for the valley-floor deposits, there being only one sample point (Table 5).

Valley-side deposits Fragmentary fluvioglacial terraces border both banks of the River Ythan. Commonly the terrace surface lies 5 to 6 metres above the floodplain, but in places, as for example beneath Bellmuir [875 365], it may be 22 m or more above that level. The higher terraces are often hummocky and have a surface strewn with numerous boulders up to 3 m in diameter, suggesting that deposition was in close proximity to the melting ice-sheet. The lower terraces are generally flat and have been cultivated. They are underlain by material that is finer grained, better sorted and more rounded. They are the product of braided meltwater streams which reworked older terrace deposits.

The terraces in the immediate vicinity of Methlick are probably largely erosional, as demonstrated by borehole 83 NE 2 which proved 0.9 m of sand and gravel overlying bedrock. At Bellmuir the base of the terrace gravels was proved only at borehole 83 NE 3, which was sited upon a bluff separating terraces of differing elevations. The bedrock surface elevation here suggests that terrace deposits in the vicinity may be up to 20 m thick. Sections at two small gravel workings on Bellmuir were used together with shallow trenches to estimate the resource: 83 NE 6 proved 5.0 m of shingly gravel and 83 NE 7 6.2 m of a similar deposit, questionably on bedrock.

Downstream, the Bellmuir terraces abut rock at Oldtown Leys [891 362] and between this spur and Tangland Bridge [888 361] there is a ridge that may be overlain by up to 7 m of sand and gravel.

Terrace gravel underlies Tangland Moor, to the south of Tangland Bridge. Borehole 83 NE 4 proved 7.0 m of sand and gravel possibly overlying bedrock and at nearby Tangland Pit [8851 3576], section 83 NE 8 revealed 5.9 m of mineral. A flat, linear alluvial tract to the south of Tangland Moor probably marks a former course of the River Ythan. It passes laterally southwards into the valley occupied by the Burn of Kelly, and although the surface deposits are generally fine-grained there is possibly a concealed deposit of sand and gravel here, the uncertainty reflecting the absence of sample points in the vicinity.

To the south-east of Tangland Moor there is a higher, rather hummocky terrace centred on Warldsend [898 345]. Although boulders up to 1 m diameter were noted, hand-augering, records of a

former pit [897 341], and inspection of a gas pipeline trench, suggest that the deposit contains more sand than is usual in the terrace gravels. The only borehole (83 SE 1) on this terrace fragment proved 9.2 m of sand and gravel, fining downwards, resting on 6.0 m gravelly till, 3.7 m of which was judged to be potentially workable.

A terrace deposit to the north of the River Ythan near Mill of Schivas [896 357] has been extensively worked but as the full thickness is not known section 83 NE 9, which records 3 m of sand and gravel, has not been used in the assessment.

An extensive terrace at Michael Muir [907 341] mainly lies 5 to 6 m above floodplain level and forms an interfluve between the River Ythan and an unnamed tributary burn, to the east, that joins the main river at [909 330]. Borehole 93 SW 2 proved 6.2 m of sand and gravel overlying 4.5 m of waste (mostly till) on bedrock. Trench 93 SW P1 in the bottom of the disused 'Muir' gravel pit [907 339] showed 1.3 m of sand and gravel overlying 1.5 m interlaminated silt and clay on 0.2 m gravelly till. As the quarry face adjacent to this trench revealed 3 m sand and gravel, the thickness of the terrace deposit hereabout has been taken as 4.3 m in the thickness calculations.

The southern part of the terrace at Michael Muir has been extensively worked around Waulkmill Hill Farm [908 334] where in 1979 the old working was being used for stockpiling aggregate and housed a tarmacadam plant. Trench 93 SW P2, dug a little to the north of the site, proved 3.0 m sand and gravel.

The terrace continues laterally to the south-east of the tributary burn referred to above, where it was being worked at the time of survey. Temporary section 93 SW 3 demonstrated 5.9 m of sand and gravel, chiefly coarse gravel but with sandy developments towards the base. Borehole 93 SW 4, 240 m to the south, proved 7.5 m sand and gravel overlying 3.2 m waste (chiefly till) on bedrock.

On the valley side opposite Michael Muir and Waulkmill Hill, exposed rock borders the floodplain almost without a break for a distance downstream of over 2 km. However, to the south of Quarrybrae of Auchedly [904 334] a denuded terrace fragment is underlain in part by sand and gravel, but there are no thickness or grading data.

The most extensive sand and gravel pit [922 321] within the survey area was worked from Upper Ardlethen Farm [915 316], where low fluvioglacial terraces including deposits below the water table were formerly exploited and a lake now occupies the site. Where higher terraces had been dug pinnacles of bedrock surrounded by coarse shingly gravel could be observed at the time of survey. In a separate, intermittently operational, pit [918 318] in a higher terrace, a section revealed 4 m of bedded sand and gravel containing numerous boulders. Much of the gravel was badly weathered, in particular the schist, quartz-dolerite and coarse-grained igneous rocks. In contrast, gravel exposed in the old workings nearer to the River Ythan appeared to comprise more durable constituents. Borehole 93 SW 5 sited on a mound about 250 m to the east of the section proved 5.8 m sand and gravel.

Excepting for a terrace fragment [922 314] immediately to the south of Craighorn Wood, rock at or near the surface mainly forms the valley side opposite Ardlethen. A pipeline trench across the terrace showed approximately 2 m of coarse, angular gravel on shattered bedrock.

Data used in the statistical assessment of resources on the valley side together with the results, are summarised in Table 5.

Valley-floor deposits In block A these deposits are solely represented by the alluvium of the River Ythan which is considered to be predominantly composed of sand and gravel. Borehole 83 NE 5 sited on the floodplain near Mill of Schivas is the only sample point. It proved 0.8 m of clayey silt on 3.8 m sand and gravel which in turn overlay thin till capping bedrock. Four hundred metres to the south of the block, however, borehole 93 SW 6 proved 5.4 m sand and gravel beneath 0.8 m silt. In view of the proximity of this sample point it has been considered with borehole 83 NE 5 in an inferred assessment.

Block B

The block boundary circumscribes the mapped extent of alluvial and fluvioglacial deposits within the valley of the River Ythan from Ardlethen Bridge to the estuary. Upstream of Ellon fluvioglacial terraces flank the valley of the present river but downstream the present and former river courses diverge. A buried valley or gorge that predates the deposition of the lower fluvioglacial terraces underlies much of the block.

For a stretch of 1.5 km downstream of Boat of Fechil [973 303] the River Ythan passes through a relatively narrow craggy gorge whereafter the valley broadens and the river is bordered by muddy estuarine tidal flats. In late-Glacial times the River Ythan followed an alternative course to the south of the gorge, departing from the present valley at Cromleybank [964 302] and passing to the south of the Hill of Logie [978 297] to link up with the course of the present valley to the south of Kirkton of Logie Buchan [988 295].

Boreholes drilled for the present survey together with site-investigation boreholes for the Ellon bridge and bypass indicate that downstream of Ardlethen Bridge the fluvioglacial deposits and alluvium rest on various sediments filling a buried valley or gorge which to the east of Ellon follows the former course of the river and presumably continues out to sea beneath the estuary. A possible interpretation of this buried feature is given in the geology section: four schematic geological sections across the valley, border the resource sheet. The generalised drift sequence is terrace gravel on glaciolacustrine silt and clay, on till. Sand and gravel considered to be of glacial origin was encountered both within and below the till, but within the axial region of the channel there is uncertainty that the full drift sequence to bedrock has been proved.

As in block A, the valley-side deposits have been statistically assessed and an inferred assessment is offered for the valley-floor deposits (Table 6). Although the sporadic deeply buried deposits of glacial sand and gravel are considered potentially workable, there is insufficient data to define their areal extent: consequently this resource has not been assessed.

Valley-side deposits The fluvioglacial terrace gravels of block B are generally better sorted, more rounded and finer than upstream. Nonetheless, they proved difficult to drill, especially in the vicinity of Ellon and

Table 6 Block B: data from sample points and the assessment of resources

Sample point	Recorded thickness			Mean grading percentage							Descriptive category (see Figure 11)
Borehole, section*, or pit	Assessed mineral	Over-burden	Waste partings	Fines	Fine sand	Medium sand	Coarse sand	Fine gravel	Coarse gravel	Cobbles and boulders	
	m	m	m	$-\frac{1}{16}$ mm	$+\frac{1}{16}$ $-\frac{1}{4}$ mm	$+\frac{1}{4}$ -1 mm	$+1$ -4 mm	$+4$ -16 mm	$+16$ -64 mm	$+64$ mm	
VALLEY-SIDE DEPOSITS (fluvioglacial sand and gravel)											
92 NE 2	4.0	0.2	–	8	27	13	13	13	17	9	SG
92 NE 3	10.1	0.3	–	7	11	14	17	23	25	3	G
92 NE 4	5.1	0.2	–	4	10	22	14	27	23	0	G
92 NE 5*	4.7+	0.0	–	4	11	53	5	16	11	0	SG
92 NE 6*	3.8+	0.2	–	4	3	17	9	25	38	4	G
92 NE P1	2.8+	0.2	–	5	1	3	12	26	30	23	G
93 SW 7	5.2	0.2	–	9	9	15	15	29	21	2	G
93 SW 8	6.5	0.3	–	6	7	17	17	20	30	3	G
93 SE 10*	6.5	0.2	–	2	15	24	4	14	32	9	G
93 SE X2	3.6+	0.4	–	(2)†	(0)	(1)	(9)	(27)	(61)	(0)	G
93 SE X6	1.6	0.8	–	(6)	(9)	(27)	(22)	(36)	(0)	(0)	SG
Mean	5.0	0.3	–	5	10	20	12	22	25	6	G
VALLEY-FLOOR DEPOSITS (alluvium)											
93 SW 6	5.4+	0.8	–	4	4	8	14	27	30	13	G
93 SE 6R	4.3	1.8	–	No grading information available							
93 SE X4	1.6	0.8	–								
93 SE X5	1.1	1.3	–	(3)	(3)	(3)	(3)	(17)	(71)	(0)	G
Mean	3.7	1.2	–	4	4	8	14	27	30	13	G

* Sections are marked with an asterisk; pits include the prefix P before their number.
† Site investigation grading data in brackets; not used in mean grading calculation.

Statistical assessment of the valley-side deposits

Area of exposed mineral	2.92 km²
Area of continuous or almost continuous spreads of mineral beneath overburden	0 km²
Total area of mineral	2.92 km²
Area of worked out sand and gravel	0.14 km²
Mean thickness of overburden	0.3 m
Mean thickness of mineral	5.0 m
Estimated volume of mineral	**14.5 million m³** ±37% *or* 5.4 *million m³*

Inferred assessment of the valley-floor deposits

Area of exposed mineral	0.77 km²
Area of continuous or almost continuous spreads of mineral beneath overburden	0 km²
Total area of mineral	0.77 km²
Mean thickness of overburden	1.2 m
Mean thickness of mineral	3.7 m
Estimated volume of mineral	**2.8 million m³**
Area of post-Glacial beach deposits (not assessed)	0.04 km²
Built-up area of Ellon	2.46 km²

the grading results may underestimate the proportion of cobble and boulder gravel. Few badly weathered clasts were observed.

To the south of Kinharrachie Cottage [927 310] the River Ythan takes an arcuate course and terrace deposits occur on the northern side of the valley at heights up to about 15 m above floodplain level. Hearsay suggests that a partly infilled pit [9259 3095] exposed about 4 m of sand and gravel and a temporary exposure [9281 3088] revealed 2 m of coarse gravels. Borehole 93 SW 7 proved 5.2 m sand and gravel resting on 2.4 m till on bedrock. To the east of this terrace fragment the river floodplain is bordered by rock which crops out for a distance of about 2 km. Solid rock also is exposed along the bank opposite Kinharrachie where no terraces have been recorded.

Along the southern side of the valley in the vicinity of Meiklemill [943 303] a low flat terrace 2 to 3 metres above the floodplain is cut into a higher moundy terrace extending to the south and east. A small pit [9446 3052] dug on the back-feature of the lower terrace exposed about 4 m of bedded sand and gravel containing boulders and thin seams of clay. Borehole 93 SW 8, 140 m to the south of the section, penetrated 6.5 m of very compact sand and gravel with numerous cobbles and boulders, overlying 8.9 m of glaciolacustrine silt and clay on 3.0 m of gravelly till. The eastern continuation of the terrace is largely sterilised by a new housing development which is known in places to overlie at least 2 m of sand and gravel.

The older part of Ellon is largely built across a fluvioglacial terrace some 5 to 6 m above the level of the floodplain. In a small pit [9686 3060] near Waterton a trench was excavated at the base of a face 4 m high; amalgamated record 93 SE 10 indicates that 6.5 m of moderately well-sorted sand and gravel overlies 1.2 m of till on bedrock. Eighty metres to the west, temporary section 93 SE P2 on a new factory estate revealed 3.0 m of gravel.

The fluvioglacial deposits underlying the former valley of the River Ythan south-east of Ellon constitute a major sand and gravel resource. The terraces have been dissected by post-glacial drainage and become

increasingly moundy eastwards. Kettle-holes south of Kirkton of Logie Buchan indicate that the gravels hereabout were deposited on ice which subsequently melted causing local collapse of material.

Records of a line of site investigation boreholes and trenches (not all are shown on the resource map) between the farm offices at Cromleybank [965 299] and Waterton [972 306] have been used in the preparation of geological cross-section B–B′ and clearly show that the terrace deposits are separated from the gravelly alluvial terrace by a bluff composed of glaciolacustrine silt and clay. However, these glaciolacustrine deposits have not been identified at the surface and an inferred boundary on the resource map delineates a possible area of barren ground occupied by this material.

Site investigation trench 93 SE X2, 150 m east of Cromleybank proved 3.6 m sand and gravel and pit 92 NE P1, 250 m north-east of the office buildings proved 2.3 m extremely coarse gravel: the base of the deposit was not proved at either site. A borehole at Cromelybank sited in connection with this survey had to be abandoned, the gravels proving too coarse to drill.

Borehole 92 NE 2, 1 km south-east of Cromleybank proved 4.0 m of terrace sand and gravel resting on 13.3 m of interbedded glaciolacustrine silt, fine sand and clay, overlying 1.5 m gravelly till. The borehole was abandoned at 23.5 m having penetrated 4.5 m sand and gravel beneath the till.

The terrace gravels have been worked extensively in a pit situated to the north of Deepheather [976 290] where section 92 NE 5 revealed 4.7 m of sandy gravel. The base of the deposit was not encountered but it is known to overlie glaciolacustrine clays.

Two boreholes were drilled between Deepheather Pit and the estuary of the River Ythan. Borehole 92 NE 3, sited on a relatively high moundy terrace, proved 10.1 m sand and gravel overlying 1.8 m clayey till on 1.6 m of glaciolacustrine silt. After penetrating 0.7 m of well-sorted sand beneath the silt the borehole was abandoned owing to sand rising up the casing. On a lower terrace nearer the estuary borehole 92 NE 4 penetrated a complex sequence comprising 5.1 m fluvioglacial sand and gravel on 7.8 m glaciolacustrine silt and clay which in turn overlay 1.5 m of sand and gravel on 3.9 m till; a further 2.1 m of sand and gravel was penetrated before the borehole was abandoned owing to very slow progress. The sand and gravel proved at depth in both boreholes is potentially workable but as the extent of the resource has not been defined no volume estimate is offered. Midway between the two borehole sites section 92 NE 6 demonstrated 3.8 m of moderately well sorted sand and gravel.

Schematic cross-section D–D′ for the lower reaches of the valley of the River Ythan illustrates that on the west, fluvioglacial terraces bottom at two distinct levels. If this interpretation is correct then in spite of differing surface elevations the fluvioglacial gravels proved at borehole 92 NE 3 correlate with those proved at borehole 92 NE 4 and relate to the lower of the two terraces. The only data available for the high terrace is provided by pit 92 NE P2 which revealed 2.9 m of very coarse gravel. However, the deposit here is probably 10 m or more thick.

A terrace rising to a little over 10 m above floodplain level flanks the northern bank of the River Ythan in the vicinity of Macharmuir [997 295]. Borehole 02 NW 1 was sited in a small gravel working [001 295] adjacent to a working face which revealed about 2 m of well-sorted sand and gravel. The amalgamated borehole and section record indicates that 2.6 m of fluvioglacial terrace gravel rests upon 19 m of interbedded glaciolacustrine deposits and very clayey, red till.

Valley-floor deposits Valley-floor deposits comprise the gravelly alluvium underlying the floodplain of the River Ythan and the fragmentary alluvial terraces which border the tidal stretch of the river. Unlike block A, where deeply buried deposits were not found beneath the floodplain, a substantial thickness of drift underlies parts of the valley floor of block B.

The only IMAU borehole, namely 93 SW 6, sited on the floodplain proved 5.4 m of sand and gravel, including many cobbles and boulders, capped by 0.8 m sandy silt. The borehole was abandoned owing to slow progress but it is likely that bedrock was almost reached.

Borehole 93 SE 6R is representative of a number of site investigation bores sunk to prove foundation conditions for Ellon Bridge. The record shows 4.3 m of sand and gravel overlying 7.2 m of waste (probably glaciolacustrine silt and clay on till) overlying bedrock. Other logs indicate that the deepest part of the buried channel underlies the terrace deposits to the north of the floodplain.

The records of several site investigation boreholes and trenches in connection with a proposed bridge, 1 km downstream of Ellon Bridge, have been utilised in the preparation of cross-section B–B′. Two of the records are used in the assessment, namely 93 SE X4 and 93 SE X5: they proved 1.6 m and 1.1 m respectively of alluvial gravel overlying a thick sequence of glaciolacustrine silt and clay overlying till on bedrock. Several other boreholes at this locality proved a similar succession but in addition, those sited on the river bank, for example 93 SE X5, penetrated sand and gravel either within the till unit, or below it. Clearly a buried gorge underlies part of the floodplain and the fluvioglacial terrace to the north of the river. No borehole in this vicinity reached bedrock, largely because drilling was severely hampered by artesian water conditions. Boreholes 93 SE 5 and 93 SE 6 were both abandoned having respectively proved 1.1 m and 8 m of glacial sand and gravel beneath the till.

An inferred assessment is offered for the floodplain alluvium, based upon borehole 93 SW 6 and the site-investigation records. The latter include some grading information which is graphically displayed on the resource map but which is insufficiently detailed for use in the calculation of mean grading. Although deeply buried deposits of glacial sand and gravel have been proved at several boreholes within the former valley of the River Ythan, there are insufficient sample points on which to base a volumetric assessment.

Block C

Block C is the most extensive of the four resource blocks. On the western sheet it includes the area outwith the valley of the River Ythan which is considered to be predominantly barren of sand and gravel deposits. On the eastern sheet it takes in many isolated patches of sand and gravel that collectively

Table 7 Block C: data from sample points and the assessment of resources

Sample point	Recorded thickness			Mean grading percentage							Descriptive category (see Figure 11)
Borehole, section*, or pit	Assessed mineral	Overburden	Waste partings	Fines	Fine sand	Medium sand	Coarse sand	Fine gravel	Coarse gravel	Cobbles and boulders	
	m	m	m	$-\frac{1}{16}$ mm	$+\frac{1}{16}$ $-\frac{1}{4}$ mm	$+\frac{1}{4}$ -1 mm	$+1$ -4 mm	$+4$ -16 mm	$+16$ -64 mm	$+64$ mm	
GLACIAL SAND AND GRAVEL											
92 NE 1	2.2	2.6	–	7	9	28	18	18	14	6	SG
02 NW 10*	10.3+	0.1	–	3	10	11	22	20	26	8	G
03 NW 1	8.4	6.0	–	6	53	28	3	6	4	0	PS
03 NW 2	6.8	0.2	–	14	56	24	2	1	3	0	CPS
03 NW 4	13.1	1.6	0.5	10	52	37	1	0	0	0	CS
03 NW 5	10.9	0.5	–	10	85	5	0	0	0	0	CS
03 NW 7*	3.7	0.0	–	9	21	25	18	19	8	0	SG
03 NE 2	7.6	0.9	–	6	24	55	11	3	1	0	S
03 NE 15*	17.3+	0.5	–	14	38	33	6	5	4	0	CPS
03 SW 1	11.6	0.5	–	8	17	16	7	17	33	2	G
03 SW 5	1.5	1.5	–	20	16	23	11	14	16	0	VCSG
03 SW 9	22.3	0.3	–	6	10	27	16	18	21	2	SG
03 SW 10	21.0+	4.0	–	6	11	31	18	15	16	3	SG
03 SW 12*	12.2+	0.3	–	1	2	24	17	18	32	6	G
Mean	10.5	1.4	–	8	28	26	11	11	14	2	SG
BUCHAN RIDGE GRAVELS†											
03 NW 3	9.4	1.6	–	10	8	11	6	7	45	13	CG

* Sections are marked with an asterisk; pits include the prefix P before their number.
† Additional assessment data are given in Table 10.

Statistical assessment of the glacial sand and gravel

Area of exposed mineral	3.32 km^2
Area of continuous or almost continuous spreads of mineral beneath overburden	2.43 km^2
Total area of mineral	5.75 km^2
Area of worked out sand and gravel	0.05 km^2
Mean thickness of overburden	1.4 m
Mean thickness of mineral	10.5 m
Estimated volume of mineral	**60.4 million m^3** ±40% *or* 24.2 *million* m^3

constitute a major resource but which cannot be assessed individually at the level of detail of the present survey.

In general the sand and gravel forms isolated hillocks and broad ridges with a smoothed topography. The deposits are usually associated with the dark grey and brown tills, commonly being sandwiched between the two units and partly or wholly concealed. Towards the coast south of Cruden Bay several deposits associated, but probably not interstratified, with the red drift are included in the block. They have distinctive fresh-looking land-forms, are generally capped by thin drapes of red clayey till, and contain much Mesozoic calcareous siltstone and limestone (41 per cent in the 10- to 14-mm fraction at Whitefields Pit).

Fragmentary deposits of ?Pliocene gravel (Buchan Ridge gravels) cap hills towards the north of the block and are discussed in the additional notes following the block descriptions.

With the limited number of sample points available it is possible to offer a statistical assessment of resources only if data relating to the geographically isolated bodies of sand and gravel are considered together in one calculation. In this way an overall estimate of volume may be computed and confidence limits quoted. An alternative procedure would be to estimate volume using the borehole data in combination with studies of the shape of deposits. However, particularly where landform is subdued, there is insufficient information on the three-dimensional form and such an approach has not usually been attempted. Exceptionally, however, the Buchan Ridge gravels have been assessed by considering the deposit to have the form of a triangular prism.

In view of the fragmentary nature of the resource, volume may be slightly overestimated in the assessment because boreholes are more likely to have been drilled in the central parts of inextensive deposits where thickest sequences might be expected, than in peripheral thinner parts.

To the north and north-east of Ellon numerous commercial borehole and trial pit records suggest that the till is generally less than 5 m thick and, although locally gravelly, it is generally not potentially workable. Bedrock is locally decomposed to depths of up to 30 m but only the disaggregated granites have any foreseeable use as aggregate.

The Ellon, Cross-Stone, Esslemont area Moundy sand and gravel occurs between Ellon and Cross-Stone

Farm [954 279]. The most extensive patch is centred on Cross-Stone Wood [953 283] where a hillock of sand and gravel rising to some 20 m above the level of the surrounding land is deeply dissected. Borehole 92 NE 1 sited in a gully beside the road proved 2.6 m of till overlying 2.2 m of sandy gravel on 1.1 m of till before it was abandoned owing to a rock obstruction, possibly bedrock. An old pit [9529 2817] to the south-west of the borehole site showed about 8 m of moderately sorted sand and gravel with lenses of medium to coarse sand, but no suitable section could be found for systematic sampling. Anderson (1943) reported that a sand and gravel pit, formerly about 7 m deep, was once worked approximately 275 m north-north-east of Cross-Stone Farm.

South of Cross-Stone Wood the deposit forms isolated mounds, generally 4 to 5 m high. West of the wood there is a narrow esker which throughout much of its length stands between 5 and 6 m high. Although it is laterally discontinuous the esker can be followed across Target Wood [948 284] towards Ulaw Farm [942 292]. A second, arcuate ridge lies immediately to the north of Target Wood and can be followed northwards towards the Croft of Ulaw [9454 2972]. Both ridges are considered to be largely constructed of sand and gravel and by analogy with eskerine deposits elsewhere they probably extend at least as deeply below the level of the surrounding land as they stand above.

Three patches of sand and gravel located between Cross-Stone Wood and Hillhead of Fechil [957 297] are poorly exposed though Anderson (1943) recorded 5 m of poorly sorted sand and gravel in an overgrown pit [9566 2946].

A flat-topped mound, presumably of sand and gravel, is located immediately to the north of Littlemill of Esslemont [926 290] where a small pit was once worked.

The Auchleuchries area Seven isolated patches of sand and gravel occur between Tillybrex [002 348] and Oldtown Croft [017 388]. The largest patch occurs at Tillybrex where a gravel pit, intermittently worked at the time of survey, displayed about 5 m of well-rounded gravel containing many badly weathered clasts, most notably gneiss and pelitic schist, and largely bound by ferruginous hardpan. Red stony till, a metre or less in the central part but thickening towards the periphery of the pit, capped the deposit. Combining the results of borehole 03 SW 1 sited at the base of a working face with the section record indicates that 11.6 m sand and gravel overlies 0.8 m gravelly till on bedrock.

The Tillybrex deposit has little surface expression and almost certainly extends laterally beyond the mapped outcrop. An area of concealed mineral is portrayed on the resource map but the deposit may extend beyond the limits shown, especially in the west (see geological cross-sections E–E′ and H–H′).

Three patches of sand and gravel border the western side of the Moss of Auchleuchries and form a more or less continuous ridge: the most extensive includes the Hill of Auchleuchries where about 5 m of sand and gravel was formerly exposed in a small pit [0065 3652]. Borehole 03 NW 1 sited in a hollow near the top of the hill proved 8.4 m of sand and gravel, fining downwards, beneath 5.8 m of till: 2.9 m waste, chiefly till, separated the mineral deposit from bedrock. A borehole sited on exposed sand and gravel, 40 m west and about 4 m higher proved only 1.6 m of gravel before an impenetrable boulder was encountered. There is no information available for the other two patches in this vicinity. However, between the Hill of Auchleuchries and the sand and gravel deposit behind the old school at Muirtack [9988 3696] pit 03 NW P4 revealed over 1.2 m of sand and gravel beneath 1.0 m of till suggesting that at least two of the patches may be laterally continuous but are locally concealed by till.

Three hillocks of sand and gravel occur in the neighbourhood of Oldtown [018 382]. There is no information to hand regarding the southerly patch at Nether Hawkhillock but borehole 03 NW 2 sited on the middle of the three revealed 6.8 m of silty sand and gravel, fining in grade with depth, overlying 11.0 m of till on bedrock. The till, which is potentially workable between 11.7 and 14.0 m depth, contained much well-rounded gravel probably derived from the ?Pliocene gravels. The third hillock, which is crossed by the road linking Oldtown and Oldtown Croft, is now probably largely worked out. Excavation at the base of a pit face [0187 3847] showed a total thickness of 3.7 m of sandy gravel overlying 1.5 m of till on bedrock (section 03 NW 7). The section revealed considerably disturbed bedding with well-sorted sands in contact with very poorly sorted sand and gravel containing much pink granite.

Slains–Pitlurg area A long gravel ridge, the Kippet Hills Esker, which borders the eastern shore of Meikle Loch [030 307] and links in the north with a possible kame plateau at Knapsleask [031 324], probably represents the most attractive resource of sand and gravel in the assessment area outwith the valley of the River Ythan. The esker lies between Cotehill Loch [027 293] and a point about 350 m north of the road at Ladies Brig [0294 3182]. It consists of four sections, the longest of which is located to the north of the A975 road at Slains [036 305] where it stands between 8 and 10 m high along most of its length but rises to over 15 m at Round Top and Broom Hill. To the south of the road the ridge is generally lower, 4 to 5 m high at Gallows Hill, falling to about 3 m towards Cotehill Loch.

The ridges have been worked on a small scale at a number of localities notably [0289 3175] near Thiefseye Moss, Gallows Hill [0323 3033] and [0302 2960] near Cotehill. At the first two localities the ridge has been removed, whereas at the last site sand and gravel was excavated to a depth of several metres below the level of the surrounding land and the ground has been partially reinstated.

Assessment borehole 03 SW 10, sited on almost the highest point along the ridge, proved 21 m of well-sorted sand and gravel underlying 3.6 m red till. The base of the esker deposit here lies at least 10 m below the level of Meikle Loch, as is illustrated by geological cross-section I–I′.

A fan-shaped plateau of sand and gravel at about 10 to 12 m above the surrounding ground extends from Ladies Brig in a north-easterly direction. It probably represents a former delta deposited by meltwater which flowed northwards along the line of the Kippet Hills esker and issued into either a lake or the high-level late-Glacial sea. A schematic cross-section H–H′ is shown on the resource sheet.

Table 8 Block D: data from sample points and the assessment of resources

Sample point	Recorded thickness			Mean grading percentage							Descriptive category (see Figure 11)
Borehole section*, or pit	Assessed mineral	Over-burden	Waste partings	Fines	Fine sand	Medium sand	Coarse sand	Fine gravel	Coarse gravel	Cobbles and boulders	
	m	m	m	$-\frac{1}{16}$ mm	$+\frac{1}{16}$ $-\frac{1}{4}$ mm	$+\frac{1}{4}$ -1 mm	$+1$ -4 mm	$+4$ -16 mm	$+16$ -64 mm	$+64$ mm	
FLUVIOGLACIAL TERRACE DEPOSITS (Water of Cruden)											
03 NW 8*	4.2	0.2	–	2	2	11	17	26	36	5	G
03 NE 11	4.9	0.3	–	2	5	28	20	15	21	9	SG
Mean	4.6	0.3		2	3	20	18	20	30	7	G
GLACIAL SAND AND GRAVEL (isolated spreads)											
03 SW 13*	5.2+	0.1	–	3	1	7	15	27	37	10	G
03 NE 5	2.1	1.4	–	1	2	13	30	39	15	0	G
03 SE 1	7.8	2.2	–	4	5	12	16	36	25	2	G
03 SE 4	1.6	0.0	–	6	4	10	17	29	34	0	G
Mean	4.2	0.9		4	3	10	18	33	28	4	G
INTERSTRATIFIED SAND AND GRAVEL (red drift)											
a Glaciolacustrine deposits											
03 SW 3	3.8	3.2	–	19	50	31	0	0	0	0	CS
03 SW 6	3.5	10.5	–	29	54	17	0	0	0	0	VCS
03 SW 7	9.2	2.1	–	20	49	28	2	1	0	0	VCS
03 SE 2	6.2	2.0	3.8	18	56	20	3	1	2	0	CS
03 SE 3	6.6	1.4	1.0	14	77	8	0	1	0	0	CS
Mean (**a**)	5.7	3.8		19	58	21	21	1	0	0	CS
b Glacial sand and gravel (buried)											
03 SW 7	13.7	–	–	7	19	34	19	15	6	0	PS
03 SE 2	3.0	–	–	14	25	17	11	15	18	0	CSG
03 SE 3	5.5	–	10.5	6	46	47	1	0	0	0	S
Mean (**b**)	7.4			8	27	35	13	11	6	0	PS
Mean (**a**+**b**)	3.4	3.8		14	44	27	7	5	3	0	CPS
BLOWN SAND AND BEACH DEPOSITS (excluding modern beach)											
c Blown sand											
02 NW 3	1.1	0.1	–	9	27	63	1	0	0	0	S
02 NW 4	5.9	0.1	–	2	25	73	0	0	0	0	S
02 NW 6	5.7	0.0	–	3	36	61	0	0	0	0	S
02 NW 7	4.3	0.0	–	2	21	77	0	0	0	0	S
03 NE 14	4.4	0.0	–	2	67	31	0	0	0	0	S
Dune	4.5	0.0		7	36	57	0	0	0	0	S
Mean (**c**)	4.3	0.0		3	36	61	0	0	0	0	S
d Beach deposits (buried)											
02 NW 4	2.0	–	–	4	15	35	6	16	24	0	SG
03 NE 14	8.1	–	–	2	54	29	5	4	6	0	PS
Mean (**d**)	5.1	–		3	46	30	5	6	10	0	PS
Mean (**c**+**d**)	6.4	0.0		4	38	52	1	2	3	0	S

* Sections are marked with an asterisk; pits include the prefix P before their number.

Inferred assessment of the fluvioglacial terrace deposits of the Water of Cruden

Area of exposed mineral	0.49 km^2
Area of continuous or almost continuous spreads of mineral beneath overburden	0 km^2
Total area of mineral	0.49 km^2
Mean thickness of overburden	0.3 m
Mean thickness of mineral	4.6 m
Estimated volume of mineral	**2.2 million m^3**

Inferred assessment of the isolated spreads of glacial sand and gravel

Area of exposed mineral	0.92 km^2
Area of continuous or almost continuous spreads of mineral beneath overburden	0.13 km^2
Total area of mineral	1.05 km^2
Mean thickness of overburden	0.9 m
Mean thickness of mineral	4.2 m
Estimated volume of mineral	**4.4 million m^3**

Table 8 *continued*

Inferred assessment of the interstratified sand and gravel (red drift)

Area of discontinuous spreads of mineral exposed or beneath overburden	25.96 km²
Mean thickness of overburden	3.8 m
Mean thickness of mineral	3.4 m
Estimated volume of mineral	**89.0 million m³**

Inferred assessment of blown sand and beach deposits

Area of exposed mineral	7.02 km²
Area of continuous or almost continuous spreads of mineral beneath overburden	0 km²
Total area of mineral	7.02 km²
Mean thickness of overburden	0.0 m
Mean thickness of mineral	6.4 m
Estimated volume of mineral	**44.5 million m³**

Section 03 SW 12, in an intermittently worked pit [0327 3205] cut into the southern edge of the plateau near Whitefields, revealed 12.2 m of moderately well-sorted sand and gravel capped by a laterally discontinuous red clayey till, generally less than 1 m in thickness. Three hundred metres to the north, borehole 03 SW 9 penetrated 22.3 m of sandy gravel on bedrock.

Between the western edge of the plateau, Nether Leask [0215 3260] and Pitlurg [0265 3310] mounds and ridges up to 10 m in height may be underlain by sand and gravel, but little confirmatory information is available. The features become lower to the north and may be genetically related to the possible deltaic deposit at Whitefields, in which case the sand and gravel might be expected to fine northwards. Indeed, a disused pit in the south-eastern side of the mound [027 326] north-west of Knapsleask once revealed about 5 m of 'sharp' sand (Anderson, 1943).

Borehole 03 SW 5 at Pitlurg, just to the north of the moundy area described above, proved 1.5 m of very poorly sorted sand and gravel beneath 1.5 m of till and overlying 5.6 m of till on bedrock. Many of the low mounds hereabout are probably composed of till or very poorly sorted sand and gravel.

There is little information about the patch of sand and gravel underlying Pole Hill [024 336] and Bellscamphie [019 338] except that at Home Farm of Pitlurg trench 03 SW P3 demonstrated 3.0 m of poorly sorted silty sand and gravel. In a railway cutting 4 m high near the former station [022 343] at Pitlurg, Jamieson (1906) recorded 'rough' gravel containing limestone overlying indigo-coloured till on bedrock.

Many of the sand and gravel deposits described above are partly buried by till and glaciolacustrine deposits, as illustrated in the cross-sections. Consequently, inferred boundaries have been drawn on the resource map to delineate the major areas thought to contain concealed mineral: the areas may be more or less extensive than shown.

Waterside There is a ridge of sand and gravel up to 20 m in height near the eastern bank of the River Ythan, some 400 m south-east of Waterside Bridge [002 269]. Section 02 NW 10 in a small pit at the southern end of the feature revealed 10.3 m of sand and coarse gravel. Although this deposit is surrounded by block D, compositionally it is more comparable with the eskerine deposits described above than with the red drift: it is therefore included within block C for assessment.

The Hatton area Around Hatton the red drift overlaps sands and gravels probably associated with the brown and grey till units. As far as is practically possible the relatively thick deposits of yellow-brown coloured sand and gravel are included within block C for assessment whereas the reddish-coloured, often very silty, sand and gravel interbedded with red till and glaciolacustrine silts and clays are included along with comparable deposits in block D. The alluvium and terrace gravels associated with the Water of Cruden are also included in block D.

A broad ridge, some 2.5 km long, stretches from the north of Hatton towards the Mains of Auquharney [028 366]. At the western end of the ridge borehole 03 NW 4 proved 1.3 m of till overlying 13.6 m of silty sand on 2.8 m of till on bedrock: at the eastern end, borehole 03 NW 5 proved 10.9 m of silty sand overlying 8.1 m of till on bedrock. At both sites mineral comprised pale brown fine- to medium-grained sand with some gravel and many thin seams of laminated silt and clay. Along the northern flank of the ridge mineral is concealed beneath till.

Section 03 NE 15, in an intermittently worked pit [0536 3706] at the western end of a ridge lying between Hatton and the A952 road, displayed 4.0 m of sand and gravel on 13.3 m of silty sand including many seams of micaceous silt and clay. The eastern end of the ridge is probably underlain by bedrock against which the sand and gravel is banked.

A further deposit of sand and gravel forms Tippet Hill [0560 3845], 1.5 km north of Hatton where borehole 03 NE 2 proved 7.6 m of medium-grained sand on 2.3 m waste (chiefly laminated silt and clay) overlying bedrock. Mineral may continue westwards beneath till as indicated on the resource map.

Block D

The block encompasses the coastal region and is predominantly underlain by the red drift. Although red deposits occur farther inland, the thickest and most widespread developments are thought to be included within this resource block.

Sand and gravel occurs within the red drift, it underlies the alluvial and fluvioglacial terraces associated with the valley of the Water of Cruden, forms isolated mounds over higher ground and occurs as sand dunes and raised beach deposits along stretches of the coastline. Separate assessments are offered for each of these mineral deposits.

The valley of the Water of Cruden Fluvioglacial deposits associated with the Water of Cruden probably represent the most easily worked resource of the block but only cover 0.49 km² of ground. Terrace fragments at Waterside [073 367] and Nook [033 361] are shown on the resource map but there may be smaller patches which have not been determined.

Between Nethermill [081 368] and Waterside an undulating terrace at up to 16 m above floodplain level is probably largely constructed of moderately well-sorted sand and gravel. The deposit was formerly worked on a small scale at a pit [0785 3660] near Nethermill. Assessment borehole 03 NE 11 sited on a high part of the terrace proved 4.9 m of sandy gravel

overlying 7.0 m waste (glaciolacustrine deposits and till) on bedrock.

West of Hatton terrace features recorded during the most recent field survey are most probably erosional as there is apparently no associated sand and gravel. However, a small depositional terrace occurs at the interfluve of the Water of Cruden and a southerly tributary at the Nook, 2 km south-west of Hatton. The combined log (03 NW 8) of two trenches in old workings 130 m north-west of the farm indicates that 4.2 m of shingly angular gravel rests on 0.7 m of red till.

An inferred assessment for the fluvioglacial terrace deposits is presented in Table 8.

The alluvium of the Water of Cruden downstream of the Nook probably comprises sand and gravel covered by silt and clay but there is little supporting evidence. Two boreholes about 180 m apart and on opposite river banks were sunk to prove foundations for a new road bridge at Midmill, 1.5 km east of Hatton. Borehole 03 NE X1 proved 7.2 m of sand and gravel resting on 1.9 m of stiff, grey till and borehole 03 NE X2, 1.7 m of sand and gravel overlying bedrock. Clearly, there is a buried channel of unknown lateral extent hereabout.

Lack of data precludes an assessment of the alluvial deposits. However, the mean grading results for some site investigations are portrayed on the resource map but the accuracy of the sampling is not known.

Isolated patches of glacial sand and gravel Around Lochlundie Moss [045 335] and towards the coast the drift is probably relatively thin, comprising a widespread mantle of till, red at surface but often becoming grey with depth, and isolated pockets or spreads of glacial sand and gravel. Potentially workable glaciolacustrine deposits are thought to be restricted to depressions in the bedrock surface situated to the north and south of this area.

The most extensive glacial sand and gravel deposit includes the Hill of Ardiffery and Diery Hill, north-west of South Mains of Ardiffery [058 353]. Borehole 03 NE 5 adjacent to a small gravel working 200 m north of the farm proved 2.1 m of sand and gravel overlying 5.5 m of till on bedrock. As soils in the vicinity are very gravelly but locally clayey it is probable that over much of the mapped extent of this deposit a 'float' of sand and gravel rests on till or glaciolacustrine deposits.

Lochlundie Moss may overlie an ice-scoured rock basin in which peat has accumulated about irregularly shaped low mounds of gravelly till. In two areas the moundy deposits are sufficiently gravelly to be mapped as glacial sand and gravel: the southernmost [040 328] comprises several mounds that stand at up to 4 to 5 m above the level of the moss and are probably formed of poorly sorted sand and gravel. In the other area, section 03 SW 13 showed 5.2 m of very poorly sorted gravel.

Between the A975 road and the coast there are two isolated patches of sand and gravel. The largest forms a hillock [059 333] some 6 m in height and has been almost dug away. Borehole 03 SE 1 was sited 30 m to the south of the pit, now disused, and proved 7.8 m of sand and gravel overlying 0.5 m of till on bedrock. An area of mineral which may be more or less extensive than is shown on the map, surrounds the hillock (see cross-section F–F′). The second patch occurs at the Hill of Mulonachie [0634 3462] where a small pit was being worked intermittently during 1978. The combined record (03 SE 4) of a trench dug adjacent to a small section shows that 1.6 m of sand and gravel overlies 1.7 m of waste on bedrock: the deposit appears to have been almost worked out.

Interstratified sand and gravel within the red drift Borehole evidence indicates that the red drift has an extremely variable lithology consisting predominantly of a firm to stiff pebbly silty clay which is a vivid red-brown, and which often passes down into micaceous clayey silt and silty fine-grained sand. Although seams and pods up to 30 cm thick of well-sorted brown sand are commonly interbedded with the clay, thicker deposits of sand and gravel are rare. The sequence usually includes stiff red-brown gravelly till and often overlies a very stiff dark grey stony clay which rests on bedrock.

The paucity of sample points severely limits the assessment of a deposit as variable as the red drift. However, an attempt has been made to identify the two most likely mineral-bearing areas, the largest being in the neighbourhood of Slains and Collieston, the other athwart the valley of the Water of Cruden. It appears that both areas largely coincide with depressions of the buried bedrock surface and include the thickest drift sequences proved during the present survey. As only one third of the boreholes sited within the two areas proved potentially workable sand and gravel the resource is considered to be 'discontinuous spreads of mineral, exposed or beneath overburden' and is portrayed accordingly on the resource map. An inferred assessment is presented in Table 8.

Slains–Collieston area Two localities can be identified as more likely to contain buried sand and gravel deposits than elsewhere. The first lies immediately to the south of Meikle Loch, between East Brogan [028 304] and Upper Brogan [021 306] where a moundy area is underlain by red silt and clay. Borehole 03 SW 7 sited towards the top of a broad ridge proved 13.7 m of moderately well-sorted buff-coloured sand and gravel underlying 11.3 m of red drift, of which 9.2 m comprised potentially workable glaciolacustrine deposits (predominantly a silty fine-grained sand). As there are strong compositional similarities, the basal sand and gravel at this site may be laterally continuous at depth with the eskerine deposit forming the Kippet Hills, as suggested on cross-section I–I′. North-west of Meikle Loch boreholes 03 SW 3 and 03 SW 6 both proved potentially workable glaciolacustrine deposits but here a lower unit of sand and gravel was not penetrated. South-west of Meikle Loch borehole 02 NW 2 proved only 4.0 m of red drift overlying bedrock. It is concluded that this borehole and 03 SW 4 prove a north–south buried ridge of relatively resistant metaquartzite against which the red drift deposits are banked to either side.

The second locality where buried deposits of sand and gravel are most likely lies between Meikle Loch and the sea where a hummocky tract of country is cut by winding steep-sided valleys (probably meltwater channels). The area is underlain by red drift which towards the coast is sufficiently sandy at the surface to be mapped as glaciolacustrine. Along a 3-km stretch of coastline north of Collieston at least 10 m of chiefly red-coloured silty fine- to medium-grained sand is

commonly exposed underlying a thin mantle of red pebbly clay. Locally, for example in a cove [047 294] near Hummel Craig, an orange-coloured shelly sand containing varying amounts of gravel is exposed at the foot of the drift (Ross, personal communication). Jamieson (1882a) described a coastal section approximately 1 km to the north of Hummel Craig in which 7.3 m of red till overlay 17.1 m of chiefly brown-grey sand interbedded with red clayey silt and sand, and resting on 3.4 m of grey till on bedrock. Thicknesses are difficult to assess from the coastal sections because of slumping, but several boreholes inland identified a similar sequence to that exposed. Boreholes 03 SE 2 and 03 SE 3 respectively proved 12.0 m and 19.5 m of potentially workable glaciolacustrine deposits interbedded with subordinate seams of silt, clay or till. At both sites a lower deposit of shelly sand and gravel, chiefly yellowish brown, was penetrated: 3.0 m at borehole 03 SE 2 and over 5.5 m at borehole 03 SE 3. The variable lithology of the red drift in this area is emphasised by boreholes 03 SE 3 and 02 NW 9 which were only 1 km apart: 03 SE 3 encountered 12.2 m of mineral whereas 02 NW 9 proved none, the sequence comprising clay, silt and till.

Potentially workable deposits of sand and gravel occurring in or below the red drift may extend southwards beneath the Sands of Forvie, as indicated on the resource map. Although the assessment boreholes in this vicinity did not prove such mineral deposits at Perthudden Bay, 0.5 km south of Collieston, Jamieson (1882a) described 4.9 m of red clay overlying 16.8 m of predominantly brown-grey fine sand and silt with subordinate seams of sand and gravel (particularly near the base) and resting on 2.4 m of grey till on bedrock.

Hatton–Cruden Bay area Perhaps the thickest sequences of red drift occur beneath a broad ridge which lies to the south-east of Hatton between Merrytop [055 366] and Gallows Hill (of Ardiffery) [065 366]. At Aad Braes [065 367] the Water of Cruden has cut a high river cliff exposing till, glaciolacustrine deposits and sand and gravel. Borehole 03 NE 7, sited 300 m to the west of the cliff discovered 18 m of interbedded red-coloured silt, clay, fine sand and till with subordinate pale brown sand and gravel, none of which is potentially workable. As the borehole was sited at about 50 m above the level of the base of the river cliff, the log clearly represents only a small part of the total thickness of red drift which may be present, that is assuming the rockhead altitude is relatively constant in the vicinity and that the whole of the cliff is cut in drift. As borehole 03 NE 8 near Gallows Hill proved bedrock 9.4 m below ground level it is perhaps more likely that the lower part of the cliff is cut into bedrock but obscured by slumped material, as suggested on cross-section F–F′. In his description of the river cliff section, Jamieson (1858) noted a basal deposit of fine grained shelly sand, chiefly pale grey, closely resembling sands underlying red till along the coast at, and to the north of, Collieston.

Apart from borehole 03 NE 7 only borehole 03 NE 3 proved beds of sand and gravel of any thickness within the red drift: however, here, as at the former site, the deposits are judged not potentially workable because the overburden-to-mineral ratio exceeds 3:1. Doubtless there are patches of sand and gravel within the red drift hereabout which could be dug, but there are probably no extensive deposits that could be worked commercially in the foreseeable future.

South of the valley of the Water of Cruden and towards Meikle Loch the red drift thins against a broad dome of bedrock centred on Lochlundie Moss and over this area glaciolacustrine deposits and buried sand and gravel generally appear to be absent. North of the valley of the Water of Cruden the bedrock surface rises both towards the coast and towards the north-west, enclosing a depression, roughly centred at Ardmachron [091 377], which is apparently largely filled with red drift deposits. However, unlike deposits farther south, borehole evidence indicates that the sequence here is dominated by till, silty clay and sandy silt with little interbedded sand and gravel. Eyles and Anderson (1946) reported that a deposit of sand and gravel underlay red till at the Cruden Bay brickworks [090 369] but borehole 03 NE 13 nearby proved 20.0 m of red till and glaciolacustrine deposits with only a few beds of sand and gravel, generally less than 10 cm in thickness.

It is probable that the 'Peterhead' granite which crops out from Cruden Bay northwards is the principal resource of aggregate in this area. The rock is locally completely disaggregated yet not severely weathered, as demonstrated at borehole 03 NE 10, and has been worked as a medium for bedding pipelines.

Blown sand and raised-beach deposits Blown sand fringes the coast at Cruden Bay extending inland towards a former cliff-line. Active dunes occur within a belt 50 to 100 m wide along the shore whereas farther inland the sands are stabilised and form Cruden Bay Golf Links. Borehole 03 NE 14, sited between active sand dunes, proved 4.4 m of blown sand overlying 8.1 m of post-Glacial beach deposits largely composed of dark grey shelly sand resting on a basal gravelly deposit. Buried beach deposits are probably widespread beneath the blown sand and may become more gravelly towards the base of the cliffs.

South of Collieston sand dunes form an extensive area that is largely designated as the Sands of Forvie Nature Reserve. In contrast to Cruden Bay, where the dunes occupy low ground underlain by beach deposits, at the Sands of Forvie the dunes have spread as far as 2 km inland, occur up to 57 m above OD, are commonly 12 m or more in height, and are generally active towards the coastline and across the peninsula at the southern end of the reserve.

The records of five assessment boreholes sited on the Reserve demonstrate that the thickness of blown sand is largely controlled by the topography of the buried land surface. Boreholes 02 NW 3 and 02 NW 5 are probably located on the southerly continuation of the north–south bedrock ridge proved to the west of Meikle Loch: at the former site 1.1 m of blown sand overlay 3.5 m of waste on bedrock whereas at the latter rock was proved at less than one metre below the surface. Boreholes 02 NW 6 and 02 NW 7 proved 5.7 m and 4.3 m respectively of blown sand overlying thin till or glaciolacustrine deposits whereas borehole 02 NW 4 revealed 5.9 m of blown sand resting on 2.0 m of dark grey sandy gravel, probably a post-Glacial raised-beach deposit. Fragmentary raised beaches, partly composed of sand and gravel, flank the estuary of the River Ythan and may underlie much of the peninsula where difficulties in access prevented drilling. A

Table 9 Windyhills gravels: data from sample points and the assessment of resources

Borehole	Recorded thickness			Mean grading percentage							Descriptive category (see Figure 11)
	Mineral	Overburden	Waste partings	Fines	Fine sand	Medium sand	Coarse sand	Fine gravel	Coarse gravel	Cobbles and boulders	
	m	m	m	$-\frac{1}{16}$ mm	$-\frac{1}{4}$ $+\frac{1}{16}$ mm	-1 $+\frac{1}{4}$ mm	-4 $+1$ mm	-16 $+4$ mm	-64 $+16$ mm	$+64$ mm	
73 NE 1	14.3	0.0	–	5	8	20	12	28	25	2	G
73 NE 2	11.1	0.2	–	7	17	19	7	19	29	2	G
Mean	12.7	0.1		6	12	19	10	24	27	2	G

Inferred assessment of the Windyhills gravels

Area of exposed mineral	1.16 km^2
Area of continuous or almost continuous spreads of mineral beneath overburden	0.42 km^2
Total area of mineral	1.58 km^2
Mean thickness of overburden	0.1 m
Mean thickness of mineral	12.7 m
Estimated volume of mineral	**20.0 million m^3**

detailed study of the area has been made by Ritchie and others (1978).

As all boreholes sited on blown sand were positioned between dunes it is clear that the total volume cannot be estimated using this data alone, as no account would be taken of the sand forming the dunes. For the purpose of assessment it is considered that the dunes rest upon a 'mantle' of blown sand. Consequently, the volume calculation is the sum of an estimate of the mantle, the product of mean thickness and area and an estimate for the dunes which assumes that one half of the total area mapped as blown sand is covered by dunes, that the average height of the dunes is 10 m, that the average slope of the dune face is 30° from the horizontal, and that usually the form of a dune approximates to a square-based pyramid.

Borehole data and the results of the assessment are summarised in Table 8 where a figure of 4.5 m, the nominal mean thickness of the sand dunes as computed above, is given. The grading data quoted is for a sand dune which was sampled by hand.

Additional notes

The origin of the ?Pliocene gravel deposits of Buchan has attracted a great deal of attention in the literature but with the exception of Anderson (1943) little has been written about them as a potential resource of aggregate. In a recent paper (McMillan and Merritt, 1980) differences in lithology and sedimentology were used to distinguish two units, namely, the Windyhills gravels for which the type locality is the Windyhills ridge, 4 km north-east of Fyvie (Figure I on the western resource sheet), and the Buchan Ridge gravels which occur principally beneath the Mosses of Cruden and Auquharney, the Corse of Balloch and the Hill of Aldie and which collectively constitute the major part of the 'Buchan Ridge' (Flett and Read, 1921) situated some 13 km north-east of Ellon (Figure II on the eastern resource sheet). Much of the Buchan Ridge lies to the north of the Ellon resource sheet and has been assessed elsewhere (McMillan and Aitken, 1981). However, additional data now allows an assessment to be offered for the whole of the Buchan Ridge as outlined in Figure II. Although Windyhills lies 5 km west of the main survey area the deposit has been assessed for completeness.

The Windyhills gravels The deposit at Windyhills [801 399] forms a flat topped ridge trending north-east of heathland lying at about 122 m (400 ft) above OD. A locality and outline map is shown in Figure I. Boreholes 73 NE 1 and 73 NE 2 sited on the ridge proved 14.3 m and 11.1 m respectively of gravel overlying pelitic schist thoroughly decomposed to silty clay.

The Windyhills gravels principally comprise well-rounded vein-quartz and white quartzite with up to about 12 per cent of friable white quartzite and a trace of flint. The results of a pebble count on the 10- to 14-mm fraction of gravel collected from Davidson's Quarry, Mosslip [7932 3934] are presented in Table 2. Although parts of the deposit are bound by a matrix of white kaolinitic sandy clay the gravel can be relatively easily washed free, especially if the material has been heaped up and allowed to weather. With beneficiation the deposit yields a visually attractive aggregate with potential uses as a decorative dressing and for preparing concrete with high light-reflective properties.

The gravel, which has a high sphericity, was once tried in ball-mills but found to be too brittle (Anderson, 1943), explaining the poor AIV result given in Table 3. The high quartz content of the deposit may suggest specific end-uses, but the abundance of white mica in the sand fraction would have to be considered.

Grading and assessment data are given in Table 9. For the purposes of volume estimation the deposit has been considered to have planar upper and lower surfaces and relatively steep margins which are partially concealed by till. The assessment presented therefore is the product of the area of mineral-bearing ground and mean thickness as calculated from the borehole data.

Smaller isolated patches of Windyhills gravels have been described near Turriff, for example at Delgaty [744 508] (Read, 1923) and at Dalgatty Wood

Table 10 Buchan Ridge gravels: data from sample points and the assessment of resources

Sample point	Recorded thickness			Mean grading percentage							Descriptive category (see Figure 11)
Borehole, section, or pit	Mineral	Over-burden	Waste partings	Fines	Fine sand	Medium sand	Coarse sand	Fine gravel	Coarse gravel	Cobbles and boulders	
	m	m	m	$-\frac{1}{16}$ mm	$+\frac{1}{16}$ $-\frac{1}{4}$ mm	$+\frac{1}{4}$ -1 mm	$+1$ -4 mm	$+4$ -16 mm	$+16$ -64 mm	$+64$ mm	
03 NW 3	9.4	1.6	–	10	8	11	6	7	45	13	CG
04 SW 3	25.0+	0.0	–	15	16	18	4	7	32	8	CG
04 SW 4	3.0*	10.5	–	No grading information available							
04 SE 6	17.8+	1.6	–	11	7	16	6	12	41	7	CG
Mean	17.4	1.1		13	11	16	5	9	37	9	CG

* This deposit is non-mineral owing to excessive overburden thickness: data are not used in assessment calculations.

Inferred assessment of the Buchan Ridge gravels (occurring in the Ellon survey area)

Area of exposed mineral	0.08 km^2
Area of continuous or almost continuous spreads of mineral beneath overburden	0.41 km^2
Total area of mineral	0.49 km^2
Estimated volume of mineral (based on a calculation explained in the text)	**5.17 million m^3**

Inferred assessment of the Buchan Ridge gravels (the whole ridge as shown in Figure II)

Area of exposed mineral	0.84 km^2
Area of continuous or almost continuous spreads of mineral beneath overburden	1.79 km^2
Total area of mineral	2.63 km^2
Mean thickness of overburden	1.1 m
Mean thickness of mineral	10.1 m
Estimated volume of mineral (based on a calculation explained in the text)	**26.6 million m^3**

[735 460] (Mendum *in* Peacock and others, 1977).

The Buchan Ridge gravels The Buchan Ridge forms a gently rounded, east-north-east trending ridge which rises to about 140 m (460 ft) above OD (Figure II) and is extensively blanketed by upland peat. The Buchan Ridge gravels were proved at four borehole sites and principally comprised a coarse well-sorted well-rounded gravel composed of flint with subsidiary amounts of vein-quartz and pale grey quartzite with a smaller and variable proportion of friable, white quartzite and decomposed quartzofeldspathic rocks. Although some unconsolidated beds of pebbly silty sand were penetrated, the bulk of the deposit was bound by a matrix of stiff micaceous kaolinitic sandy clay. Unless the unusual composition of the material attracts a specific market the amount of beneficiation required to prepare the aggregate will adversely affect the economic working of the deposit.

The gravels are covered in part by pale grey, brown or white kaolinitic till which invariably contains clasts of well-rounded flint and quartzite, and has a maximum recorded thickness of 10.5 m at borehole 04 SW 4. This flint-quartzite till is widespread and gives a false impression of the extent of the Buchan Ridge gravels. Possible areas of concealed mineral are shown in Figure II; their delineation is made difficult because of the non-planar base and fragmentation of the deposit, and by the effects of cryoturbation.

The volume of the Buchan Ridge gravels as a whole has been calculated: that is, data from the assessment sheet to the north (McMillan and Aitken, 1981) has been included with the results obtained during the present investigation. It is assumed that the deposit has the form of a triangular prism whose length and breadth approximate to the distance between the inferred boundaries shown in Figure II and whose height corresponds to the mean of thickness of material proved in the boreholes. Grading and assessment data are given in Table 10. The volume of mineral occurring within the Ellon survey area has been determined by assuming that the area occupied by the Buchan Ridge gravels on this resource sheet is directly related to volume.

A small concealed patch of Buchan Ridge gravels occurs on Whitestone Hill [978 391], 9 km north-east of Ellon. No assessment data are available but Koppie (1977) described a trench sited at the top of the hill in which over 2.5 m of clay-bound, kaolinitic flint and quartzite gravel was overlain by 2.0 m of till.

APPENDIX A: FIELD AND LABORATORY PROCEDURES

Trial and error during initial studies of the complex and variable glacial deposits of East Anglia and Essex showed that an absolute minimum of five sample points evenly distributed across the sand and gravel are needed to provide a worthwhile statistical assessment, but that, where possible, there should be not less than ten. 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 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 may be used in the calculations, it is held confidentially by the Institute and cannot be disclosed.

The mineral shown on each 1:25 000 sheet is divided into resource blocks. The arbitrary size selected, 10 km^2, 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 river terrace gravels are separated. Otherwise division is by arbitrary lines, which may bear no relationship to the geology. The blocks are drawn provisionally before drilling begins.

A reconnaissance of the ground is carried out to record any exposures and inquiries are made to ascertain what borehole information is available. Borehole sites are then selected to provide an even pattern of sample points at a density of approximately one per square kilometre. However, because broad trends are independently overlain by smaller scale characteristically random variations, it is unnecessary to adhere to a square grid pattern. Thus such factors as ease of access and the need to minimise disturbance to land and the public are 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 drilling results.

The drilling machine employed should be capable of providing a continuous sample representative of all unconsolidated deposits, so that the in-situ grading can be determined, if necessary, to a depth of 30 m (100 ft) at a diameter of about 250 mm (10 in), beneath different types of overburden. It should be reliable, quiet, mobile and relatively small (so that it can be moved to sites of difficult access). Shell and auger rigs have proved to be almost ideal.

The rigs are modified to enable deposits above the water table to be drilled 'dry', instead of with water added to facilitate the drilling, 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 may result in the loss of some of the fines fraction and the pumping action of the bailer tends to draw unwanted material into the hole from the sides or the bottom.

A continuous series of bulk samples is taken throughout the sand and gravel. Ideally samples are composed exclusively of the whole of the material encountered in the borehole between stated depths. However, care is taken to discard, as far as possible, material which has caved or has been pumped from the bottom of the hole. A new sample is commenced whenever there is an appreciable lithological change within the deposit or, ideally, at every 1 m (3.3 ft) depth. The samples, each weighing between 25 and 45 kg (55 and 100 lb), are despatched in heavy duty polythene bags to a laboratory for grading. The grading procedure is based on British Standard 1377 (1975). Random checks on the accuracy of the grading are made in the IMAU soils laboratory.

All data, including mean grading analysis figures calculated for the total thickness of the mineral, are entered on standard record sheets, abbreviated copies of which are reproduced in Appendix F.

Detailed records may be consulted at the Institute's Edinburgh Office, upon application to the Officer-in-Charge, Industrial Minerals Assessment Unit.

APPENDIX B

STATISTICAL PROCEDURE

Statistical assessment

1 A statistical assessment is made of an area of mineral greater than 2 km^2, if there is a minimum of five evenly spaced boreholes 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. 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 areas (A) and the mean thickness ($\bar{l}_m$) calculated from the individual thicknesses at the sample points. The standard deviations for these variables are related such that

$$S_V = \sqrt{(S_A^2 + S_{\bar{l}_m}^2)} \qquad [1]$$

4 The above relationship may be transposed such that

$$S_V = S_{\bar{l}_m}\sqrt{(1 + S_A^2/S_{\bar{l}_m}^2)} \quad .$$

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

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 $l_{m_1}, l_{m_2}, \ldots l_{m_n}$, then the best estimate of mean thickness, $\bar{l}_m$, is given by

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

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

$$S_{\bar{l}_m} = (1/\bar{l}_m)\sqrt{[\Sigma\,(l_m - \bar{l}_m)^2/(n-1)]}$$

where l_m is any value in the series l_{m_1} to l_{m_n}.

6 The sampled area in each resource block is 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 small relative to those in thickness. The relationship $S_A/S\bar{l}_m \leqslant \frac{1}{3}$ is assumed in all cases. It follows from equation [2] that

$$S_{\bar{l}_m} \leqslant S_V \leqslant 1.05\, S_{\bar{l}_m} \qquad [3]$$

7 The limits on the estimate of mean thickness of mineral, $L_{\bar{l}_m}$, may be expressed in absolute units $\pm(t/\sqrt{n}) \times S_{\bar{l}_m}$ or as a percentage $\pm(t/\sqrt{n}) \times S_{\bar{l}_m} \times (100/\bar{l}_m)$ 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.)

Block calculation 1:25 000 Block } Fictitious

Area
Block: 11.08 km²
Mineral: 8.32 km²

Mean thickness
Overburden: 2.5 m
Mineral: 6.5 m

Volume
Overburden: 21 million m³
Mineral: 54 million m³

Confidence limits of the estimate of mineral volume at the 95 per cent probability level: ±20 per cent
That is, the volume of mineral (with 95 per cent probability): 54±11 million m³

Thickness estimate measurements in metres, l_o = overburden thickness l_m = mineral 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	IMAU 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	Hydrogeology Unit record
123/45	½	2.0		4.6		
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

$$1.05(t/\overline{wl_m})\sqrt{[\Sigma(wl_m - \overline{wl_m})^2/n(n-1)]} \times 100$$
$$= 1.05 \times (2.365/6.5)\sqrt{[15.82/(8 \times 7)]} \times 100$$
$$= 20.3$$
$$\simeq 20 \text{ per cent}$$

Figure 9 Example of resource block assessment: calculation and results.

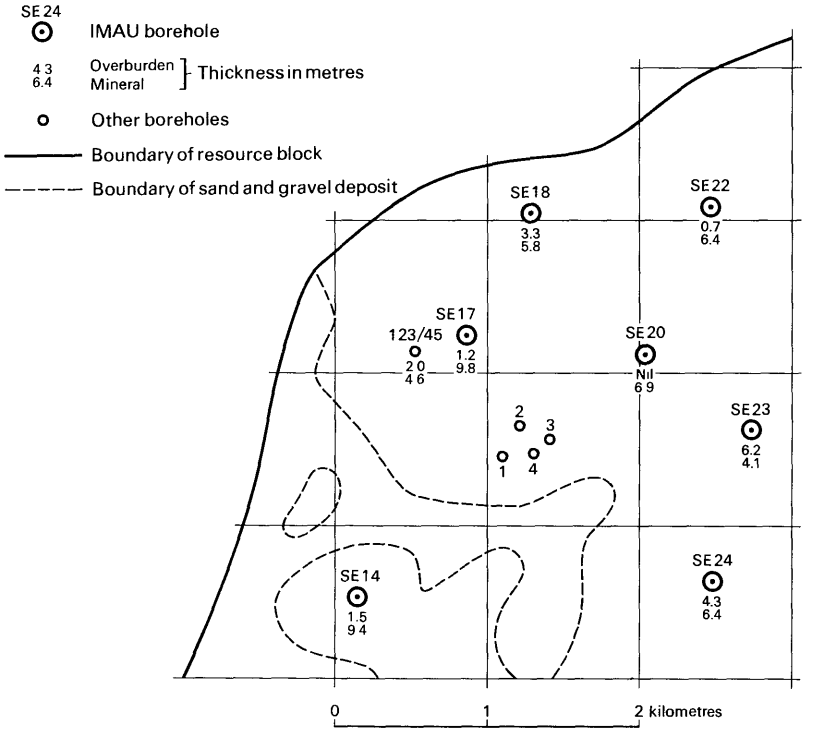


Figure 10 Example of resource block assessment: map of fictitious block.

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

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

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

9 In calculating confidence limits for volume, L_V, the following inequality corresponding to equation [3] is applied: $L_{\bar{l}_m} \leqslant L_V \leqslant 1.05\, L_{\bar{l}_m}$

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

$$[(1.05 \times t)/\bar{l}_m] \times [\sqrt{\Sigma (l_m - \bar{l}_m)^2/n(n-1)}] \times 100$$

per cent, and when n is greater than 20, as

$$[(1.05 \times 1.96)/\bar{l}_m] \times [\sqrt{\Sigma (l_m - \bar{l}_m)^2/n(n-1)}] \times 100$$

per cent.

11 The application of this procedure to a fictitious area is illustrated in Figures 9 and 10.

Inferred assessment

12 If the sampled area of mineral in a resource block is between 0.25 km^2 and 2 km^2 an assessment is inferred, based on geological and topographical information usually supported by the data from one or two boreholes. 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.

13 In some cases a resource block may include an area left uncoloured on the map, within which mineral (as defined) is interpreted to be generally absent. If there is reason to believe that some mineral may be present, an inferred assessment may be made.

14 No assessment is attempted for an isolated area of mineral less than 0.25 km^2.

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

APPENDIX 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 deposit, 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 $\frac{1}{16}$ 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.

When the fines content exceeds 40 per cent the material is not considered to be potentially workable and falls outside the definition of mineral. Deposits which contain 40 per cent fines or less are classified primarily on the ratio of sand to gravel but qualified in the light of the fines content, as follows: less than 10 per cent fines—no qualification; 10 per cent or more but less than 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 $\frac{1}{16}$ mm. Thus it has no mineralogical significance and includes particles falling within the size range of silt. The normal meaning applies to the term clay where it does not appear in single quotation marks.

The ratio of sand to gravel defines the boundaries between sand, pebbly sand, sandy gravel and gravel (at 19:1, 3:1 and 1:1).

Thus it is possible to classify the mineral into one of twelve descriptive categories (see Figure 11). The procedure is as follows:

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

For example, a deposit grading 11 per cent gravel, 70 per cent sand and 19 per cent fines is classified as 'clayey' pebbly sand.

Many differing proposals exist for the classification of the grain size of sediments (Atterburg, 1905; Udden, 1914; Wentworth, 1922; Wentworth, 1935; Allen, 1936; Twenhofel, 1937; Lane and others, 1947). 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 $\frac{1}{16}$ 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 (Table 11), which is used in this Report.

The fairly wide intervals in the scale are consistent with the general level of accuracy of the qualitative assessments of the resource blocks. Three sizes of sand are recognised, fine ($+\frac{1}{16} - \frac{1}{4}$ mm), medium ($+\frac{1}{4} - 1$ mm) and coarse ($+1 - 4$ mm). The boundary at 16 mm distinguishes a range of finer gravel ($+4 - 16$ mm), often characterised by abundance of worn tough pebbles of vein quartz, from larger pebbles often of notably different materials. The boundary at 64 mm distinguishes pebbles from cobbles. 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, which is presented by the laboratory as logarithmic cumulative curves (see, for example, British Standard 1377: 1975). In this report the grading is tabulated

on the borehole record sheets (Appendix F), the intercepts corresponding with the simple geometric scale $\frac{1}{16}$ mm, $\frac{1}{4}$ mm, 1 mm, 4 mm, 16 mm and so on as required. Original sample grading curves are available for reference at the appropriate office of the Institute.

Each bulk sample is described, subjectively, by a geologist at the borehole site. Being based on visual examination, the 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, 'flint and quartz' indicates very approximate equal proportions with neither constituent accounting for less than about 25 per cent of the whole; 'flint with quartz' indicates that flint is dominant and quartz, 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. Rare constituents are referred to as 'trace'.

The terms used in the field to describe the degree of rounding of particles, which is concerned with the sharpness of the edges and corners of a clastic fragment and not the shape (after Pettijohn, 1957), 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 almost 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 orignal 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.

Table 11 Classification of gravel, sand and fines

Size limits	Grain size description	Qualification	Primary classification
	Cobble		
64 mm –			
		Coarse	Gravel
16 mm –	Pebble		
		Fine	
4 mm –			
		Coarse	
1 mm –			
	Sand	Medium	Sand
$\frac{1}{4}$ mm –			
		Fine	
$\frac{1}{16}$ mm –			
	Fines (silt and clay)		Fines

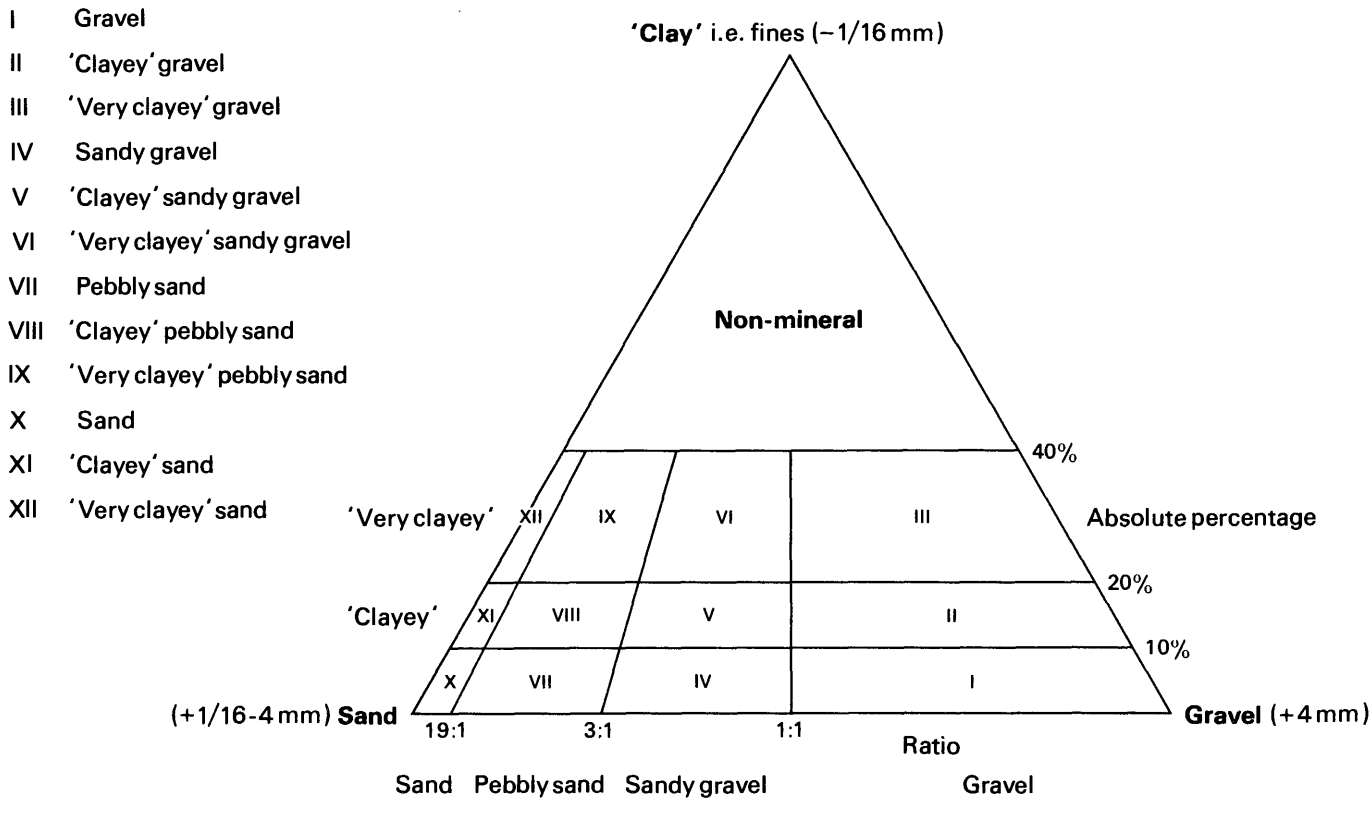


Figure 11 Diagram to show the descriptive categories used in the classification of sand and gravel.

APPENDIX D

EXPLANATION OF THE BOREHOLE, SECTION AND PIT RECORDS

Annotated Example

NK 03 NW 2[1] 0145 3820[2] Oldtown, Cruden[3] BLOCK C

Surface level + 78 m (+ 256 ft)[4]
Groundwater level + 72 m[5]
250 mm and 200 mm percussion and shell[6]
October 1978

Overburden[7] 0.2 m
Mineral 6.8 m
Waste 4.7 m
Mineral 2.3 m
Waste 4.0 m
Bedrock 0.2 m +[9]

LOG

Geological classification		Lithology	Thickness[8] m	Depth m
		Soil	0.2	0.2
Glacial sand and gravel[10]	a	'Clayey' sand (fining downwards)[11] Gravel: coarse and fine, well rounded, quartzite and vein-quartz, stained black Sand: fine with medium and a trace of coarse, quartzose, 'soft', yellow-brown Fines: silt, disseminated, increasing downwards. Discrete seams of silt below 5.2 m, also rare laminae of medium grey silty clay	6.8	7.0
		Clay, silty, yellow-brown	0.4	7.4
Till		Clay, silty with coarse sand and fine gravel, stiff to very stiff, brown-grey becoming medium grey downwards	4.3	11.7
	b	'Clayey' sandy gravel Gravel: fine and coarse, cobbles rare, chiefly subangular psammite, semipelitic schist, granite and quartzite also well rounded, quartzite and vein-quartz (from Buchan Ridge gravels?) Sand: fine, medium and coarse, quartz and rock. Pale yellow-brown Fines: clay and silt, deposit clay-bound	2.3	14.0
		Clay, silty, much coarse sand and fine gravel, stiff, pale yellow-brown	4.0	18.0
Dalradian		Gneiss, semipelitic ochreous brown, recovered as sand, becoming hard with depth	0.2 +	18.2

GRADING

	Mean for deposit[15] *percentages*			Depth below surface (m)[12]	*percentages*[13]							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
a	14	82	4	0.2–1.2	8	45	35	5	2	5	0	
				1.2–2.2	4	42	38	3	1	12	0	†[14]
				2.2–3.2	8	53	36	2	0	1	0	†
				3.2–4.2	6	72	20	1	1	0	0	†
				4.2–5.2	12	69	18	1	0	0	0	†
				5.2–7.0	33	57	9	1	0	0	0	†
				Mean	14	56	24	2	1	3	0	
b	15	44	41	11.7–14.0	15	13	16	15	21	20	0	†
a&b	14	73	13	Mean	14	46	22	5	6	7	0	

The numbered paragraphs below correspond with the annotations given on the specimen record above.

1 Borehole registration number
Each Industrial Minerals Assessment Unit (IMAU) borehole is identified by a registration number. This consists of two statements.

1 The number of the 1:25 000 sheet on which the borehole lies, for example NK 03
2 The quarter of the 1:25 000 sheet on which the borehole lies and its number in a series for that quarter, for example NW 2

Thus the full registration number is NK 03 NW 2. Usually this is abbreviated to 03 NW 2 in the text.

Natural sections used in the assessment have been registered under the same series. They are distinguished by an asterisk following the registration number. Shallow pits are identified by the letter P which precedes the access number. They are registered in a separate series to the boreholes and sections, for example, 03 NW P9.

2 The National Grid reference
National Grid references in this publication lie within the 100-km squares NJ and NK. Grid references are given to eight figures, accurate to within 10 m for borehole locations. (In the text, six-figure grid references are used for more approximate locations, for example, for farms.)

3 Location
The position of the borehole is generally referred to the nearest named locality on the 1:25 000 base map and the resource block in which it lies is stated.

4 Surface level
The surface level at the borehole site is given in metres and feet above Ordnance Datum. Measurements were made in metres; approximate conversions to feet are given in brackets.

5 Groundwater conditions
If groundwater was present the level at which it was either encountered or statically measured is normally given (in metres above Ordnance Datum).

6 Type of drill and date of drilling
Shell and auger rigs both conventional and modified were used in this survey. The drilling method, the external diameter of the casing used, and the month and year of completion of the borehole are stated.

7 Overburden, mineral, waste and bedrock
Mineral is sand and gravel which falls within the arbitrary definition of potentially workable material (see p. 1). In the Ellon area, granitic bedrock is locally deeply weathered and in this state may be potentially workable aggregate. However, no assessment is offered. 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 potentially workable material 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.

12 Sampling
A continuous series of bulk samples is taken through the thickness of potentially workable aggregate. A new sample is commenced whenever there is an appreciable lithological change within the deposit or ideally at every 1 m of depth.

13 Grading results
The results are expressed as per cent by weight retained on British Standard sieves whose aperture sizes are given in millimetres or fractions thereof. If, exceptionally, grading results are not available, an attempt may be made to estimate the descriptive category of the mineral by comparing the grading and field descriptions of similar material with the samples in question.

14 Bailed samples
Fully representative sampling of natural aggregate 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 proportions of fines and coarse gravel (+16 mm) may be lower. Samples obtained by the bailing technique (that is, from deposits below the water table) are indicated by a dagger †.

15 Mean grading
The grading of the full thickness of mineral identified in the log is the mean of the individual sample gradings weighted by the thicknesses represented. The classification used is shown in Table 11. Where two or more distinct mineral deposits form continuous sequences, the mean grading of each is also given. Where two or more mineral deposits form a continuous sequence separated from another sequence by waste, combined mean gradings are given in addition to the mean grading for the full thickness of mineral identified.

APPENDIX E:

LIST OF BOREHOLES, SECTIONS AND SHALLOW PITS USED IN THE ASSESSMENT OF RESOURCES

Sample point*	Grid reference
Industrial Minerals Assessment Unit boreholes and sections	
WESTERN SHEET [Grid square NJ]	
NJ 73 NE	
1	7923 3940
2	7999 3997
NJ 83 NE	
2	8607 3684
3	8703 3639
4	8871 3553
5	8924 3573
6†	8726 3671
7†	8772 3662
8†	8851 3576
9†	8942 3575
NJ 83 SE	
1	3972 3461
NJ 92 NE	
1	9542 2843
2	9721 2951
3	9850 2910
4	9942 2891
5†	9787 2902
6†	9902 2911
NJ 93 SW	
2	9044 3437
3†	9115 3311
4	9127 3291
5	9204 3185
6	9238 3091
7	9330 3090
8	9446 3032
NJ 93 SE	
10†	9686 3060
EASTERN SHEET [Grid square NK]	
NK 02 NW	
1	0010 2949
2	0151 2956
3	0113 2700
4	0193 2665
5	0108 2611
6	0291 2775
7	0203 2742
8	0324 2924
9	0468 2993
10†	0054 2662
NK 03 NW	
1	0057 3649
2	0145 3820
3	0250 3981
4	0323 3668
5	0439 3695
6	0483 3510
7†	0187 3847
8†	0322 3624

Sample point*	Grid reference
NK 03 SW	
1	0005 3489
2	0076 3206
3	0185 3160
4	0134 3074
5	0263 3312
6	0258 3157
7	0253 3062
8	0383 3454
9	0336 3235
10	0337 3054
11	0418 3156
12†	0327 3206
13†	0458 3420
NK 03 NE	
2	0560 3845
3	0592 3766
4	0524 3629
5	0583 3546
6	0689 3826
7	0607 3675
8	0681 3641
9	0767 3966
10	0795 3781
11	0768 3662
12	0711 3557
13	0895 3719
14	0858 3555
15†	0536 3706
NK 03 SE	
1	0588 3327
2	0527 3246
3	0515 3088
4†	0634 3462
5	0620 3166
6	0748 3300
Ancillary boreholes (or pits)	
WESTERN SHEET	
NJ 92 NE	
X1‡	9630 2987
NJ 93 SE	
X1‡	9646 3000
X2‡	9655 3009
X3‡	9662 3017
X4	9678 3034
X5	9686 3043
X6	9690 3046
X7	9700 3054
6R	9569 3035
EASTERN SHEET	
NK 03 NE	
1	0915 3845
X1	0635 3737
X2	0653 3738
X3	0678 3735
X4	0689 3750
X5	0727 3762
X6	0813 3800

Sample point*	Grid reference
Industrial Minerals Assessment Unit pits (shallow pits dug by excavator)	
WESTERN SHEET [Grid square NJ]	
NJ 92 NE	
P1	9672 2998
P2	9930 2867
NJ 93 SW	
P1	9072 3389
P2	9057 3361
NJ 93 NE	
P1	9865 3939
P2	9899 3909
P3	9866 3825
P4	9855 3537
P5	9945 3732
P6	9961 3621
NJ 93 SE	
P1	9663 3088
P2	9678 3061
P3	9981 3195
EASTERN SHEET [Grid square NK]	
NK 03 NW	
P1	0089 3978
P2	0027 3903
P3	0077 3830
P4	0012 3677
P5	0189 3961
P6	0176 3890
P7	0219 3971
P8	0231 3973
P9	0266 3878
P10	0322 3965
P11	0368 3785
P12	0333 3556
P13	0476 3968
P14	0421 3887
P15	0477 3827
P16	0493 3686
P17	0430 3597
NK 03 SW	
P1	0029 3493
P2	0164 3203
P3	0228 3338
P4	0214 3265
P5	0377 3372
P6	0360 3106
NK 03 NE	
P1	0557 3948
P2	0807 3655
NK 03 SE	
P1	0630 3365

* By sheet quadrant.
† Section.
‡ Ancillary pit.

APPENDIX F

INDUSTRIAL MINERALS ASSESSMENT UNIT BOREHOLE, SECTION AND SHALLOW PIT RECORDS

NJ 73 NE 1 7923 3940 Mosslip, Fyvie FIGURE I

Surface level + 127 m (+ 416.5 ft)
Water not struck
250 mm and 200 mm percussion and shell
December 1978

Mineral 14.3 m
Bedrock 2.8 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
Windyhills gravels	Gravel Gravel: fine and coarse, cobbles rare. 4 to 10 mm clasts subangular to subrounded, larger clasts predominantly well rounded. White vein-quartz and quartzite with some friable, weathered quartzite and rare flint. Deeply weathered quartzo-feldspathic clasts, largely comminuted by drilling, becoming more abundant downwards Sand: medium with coarse and fine, coarse grains subangular to subrounded, otherwise subangular to well rounded, quartz and vein-quartz, much white mica. Less fine sand recovered below 7.0 m probably as a result of shelling Fines: chiefly silt, disseminated, pale yellow to white. Deposit is slightly cohesive in uppermost 3 m. Clay matrix and pods of white silty clay, also clasts of quartzo-feldspathic rock deeply weathered to sandy silty clay. Silt and clay predominantly kaolinite.	14.3	14.3
Dalradian	Pelitic schist, knotted, deeply weathered to greenish grey silty clay becoming harder with depth. Relict quartzo-feldspathic veining	2.8 +	17.1

Note: approximately 0.5 m soil removed from borehole site

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
5	40	55	0.0–1.0	8	10	24	15	23	20	0	
			1.0–2.0	11	13	54	9	5	8	0	
			2.0–3.0	10	11	32	20	15	12	0	
			3.0–4.0	9	10	16	9	21	35	0	
			4.0–5.0	7	10	16	11	25	31	0	
			5.0–6.0	3	7	11	15	39	25	0	†
			6.0–7.0	6	13	15	13	37	16	0	†
			7.0–8.3	2	7	14	14	26	25	12	†
			8.3–9.3	2	5	9	12	33	36	3	†
			9.3–10.3	2	5	16	16	26	29	6	†
			10.3–11.3	2	6	23	11	35	23	0	†
			11.3–12.3	2	3	15	13	36	31	0	†
			12.3–13.3	3	3	20	9	34	31	0	†
			13.3–14.3	2	4	22	9	36	27	0	†
			Mean	5	8	20	12	28	25	2	

NJ 73 NE 2 7999 3997 Windyhills, Fyvie FIGURE I

Surface level + 122 m (+ 400 ft)
Groundwater level + 112.1 m
250 mm and 200 percussion and shell ≠
December 1978

Overburden 0.2 m
Mineral 11.1 m
Bedrock 0.8 m +

LOG

Geological classification		Lithology	Thickness m	Depth m
		Soil, peaty, gravelly	0.2	0.2
Windyhills gravels	a	Gravel Gravel: coarse with fine, scattered cobbles, predominantly well rounded pale grey to white vein-quartz and quartzite with some friable, weathered quartzite and rare flint Sand: medium with coarse and fine, subangular to well rounded, quartz and vein-quartz, much white mica Fines: chiefly silt, disseminated, white. Upper 0.7 m of deposit bound by pale grey sandy clay. White clay matrix between 3.2 and 3.4 m. Silt and clay predominantly kaolinite.	4.2	4.4
	b	'Clayey' pebbly sand Gravel: fine and coarse, cobbles rare, composition similar to deposit above Sand: fine with medium and a trace of coarse, quartzose, micaceous (flakes up to 4 mm) Fines: chiefly silt, disseminated, kaolinitic, pale yellow or white with some black manganese speckling. Deposit is clayey and cohesive in part	3.0	7.4
	c	Gravel Gravel: coarse with fine, cobbles rare, well rounded, composition as for deposit above Sand: medium with fine and coarse, quartzose, much white mica Fines: chiefly silt, disseminated, white and kaolinitic. Clayey in parts, especially towards base.	3.9	11.3
Dalradian		Pelitic schist, knotted, deeply weathered to silty clay, soft becoming harder with depth. Yellowish orange becoming medium to pale grey with depth.	0.8 +	12.1

≠ Uppermost 3.9 m sampled by hand from adjacent section

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
a	6	28	66	0.2–1.2	8	6	13	6	17	44	6	
				1.2–2.2	3	6	13	10	23	45	0	
				2.2–3.2	5	6	14	10	24	29	12	
				3.2–3.9	6	8	16	8	24	38	0	
				3.9–4.4	Section obscured by talus							
				Mean	6	6	14	8	22	39	5	
b	16	72	12	4.4–5.4	22	51	24	1	2	0	0	
				5.4–6.4	17	56	22	0	3	2	0	
				6.4–7.4	9	23	34	6	15	13	0	
				Mean	16	43	27	2	7	5	0	
c	2	37	61	7.4–8.2	2	11	16	9	28	34	0	
				8.2–9.2	2	14	22	9	20	33	0	†
				9.2–10.2	2	10	19	8	29	32	0	†
				10.2–11.3	3	5	17	6	25	44	0	†
				Mean	2	10	19	8	25	36	0	
a to c	7	43	50	Mean	7	17	19	7	19	29	2	

NJ 83 NE 2 8607 3684 Methlick BLOCK A

Surface level c + 23 m (c + 75 ft)
Groundwater level c + 22 m
250 mm percussion and shell
December 1978

Waste 0.9 m
Bedrock 0.5 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly	0.3	0.3
Fluvioglacial sand and gravel	Sand and gravel. Gravel: fine and coarse, angular to subangular schistose grit (metagreywacke) with some well rounded vein-quartz and quartzite Sand: fine, medium and coarse, angular to subangular quartz and feldspar, much mica Fines: micaceous, grey-brown silt	0.6	0.9
Dalradian	Schistose grit (metagreywacke), thin veins of quartz, micaceous cleavage surfaces, green-grey weathering ochreous brown	0.5 +	1.4

NJ 83 NE 3 8703 3639 Bellmuir, Methlick BLOCK A

Surface level + 26 m (+ 85.5 ft)
Groundwater level + 22.8 m
250 mm percussion and shell
November 1978

Overburden 0.3 m
Mineral 2.4 m
Waste 1.6 m
Bedrock 0.3 m +

LOG

Geological classification		Lithology	Thickness m	Depth m
		Soil, peaty, black	0.3	0.3
Fluvioglacial sand and gravel	a	'Clayey' sand Sand: fine with some medium and a trace of coarse, a little mica, pale yellow-brown to pale yellow-grey Fines: silt, disseminated	1.1	1.4
	b	Gravel Gravel: coarse with fine, numerous cobbles and boulders up to 700 m, chiefly well rounded (fine gravel more angular than coarse) metagreywacke, psammite, pelitic schist, slate and vein-quartz with gneiss and red granite. Pelites generally platy, otherwise chiefly spherical Sand: coarse, medium and fine. Coarse subrounded to well rounded rock and vein-quartz, otherwise chiefly quartz and feldspar Fines: silt and clay, disseminated, pale yellow-brown	1.3	2.7
Till		Clay, very gravelly, sandy, stiff, slightly micaceous, pale yellow-brown	1.6	4.3
Caledonian		Diorite, medium grained, equigranular, predominantly mafics with white feldspar and some quartz, hard	0.3 +	4.6

GRADING $\oint$

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
					$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64
a	13	87	0	0.3–1.4	13	74	12	1	0	0	0
b	8	33	59	1.4–2.7	8	8	12	13	19	28	12
a&b	10	58	32	Mean	10	38	12	8	10	15	7

$\oint$ As noted in the text, there may be a significant underestimate of material greater than 64 mm in diameter

NJ 83 NE 4 8871 3553 Mill of Kelly Croft, Methlick BLOCK A

Surface level + 29 m (+ 95 ft)
Water not struck
250 mm and 200 mm percussion and shell
December 1978

Overburden 0.3 m
Mineral 7.0 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Fluvioglacial sand and gravel	Gravel Gravel: coarse and fine, cobbles common, subrounded to well rounded quartzite, psammite, metagreywacke and gneiss, with (platy) pelitic schist and slate, vein-quartz and rare pink felsite, granite and microgranite Sand: coarse with medium and some fine, subangular to subrounded, chiefly (platy) pelitic schist and slate, with quartz and some vein-quartz, feldspar and felsite. Coarse sand and fine gravel becoming more angular below 4.3 m. Brown-grey Fines: chiefly silt, disseminated, but sufficient clay to make deposit slightly cohesive. Claybound between 1.3 and 2.3 m and between 4.3 and 5.3 m.	7.0 +	7.3
	Borehole terminated owing to rock obstruction, possibly bedrock		

GRADING ϕ

Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
6	37	57	0.3–1.3	4	2	17	11	17	32	17	
			1.3–2.3	13	8	17	15	28	19	0	
			2.3–3.3	7	5	10	17	32	29	0	
			3.3–4.3	5	4	14	24	20	25	8	
			4.3–5.3	5	5	12	13	17	27	21	†
			5.3–6.3	3	6	15	26	30	20	0	†
			6.3–7.3	2	4	14	22	24	27	7	†
			Mean	6	5	14	18	24	25	8	

ϕ As noted in the text, there may be a significant underestimate of material greater than 64 mm in diameter.

NJ 83 NE 5 8924 3573 Mill of Schivas, Tarves BLOCK A

Surface level + 16 m (+ 52.5 ft)
Groundwater level + 15.6 m
250 mm shell
November 1978

Overburden 0.8 m
Mineral 3.8 m
Waste 1.2 m
Bedrock 0.2 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
Alluvium	Silt, clayey, peaty, soft, mottled medium brown-grey	0.8	0.8
	Gravel Gravel: coarse with fine, cobbles and small boulders common, subangular to subrounded with some well rounded, quartzite, psammite, metagreywacke, and vein-quartz with grey granite, diorite, knotted pelitic schist and slate, ultrabasic igneous and feldspar-rock Sand: medium with coarse and fine, poorly sorted. Coarse sand comprising angular quartz and feldspar and subrounded to well rounded vein-quartz, slate and psammite, otherwise chiefly quartz. Silty fine sand present below 3.0 m Fines: much silt, disseminated. Partially claybound below 3.0 m. Pale yellow-grey	3.8	4.6

(continued)

Geological classification	Lithology	Thickness m	Depth m
Till	Clay, very sandy ('Gritty'), greenish pale brown, chiefly composed of weathered granodiorite	1.2	5.8
Caledonian	Contaminated rock, probably gneissose psammite veined by granodiorite, pyrite common in the former rock-type which is hard, the latter being badly weathered	0.2 +	6.0

GRADING ϕ

Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
5	42	53	0.8–1.8	3	6	16	14	15	19	27	†
			1.8–3.0	6	7	26	15	18	19	9	†
			3.0–4.6	No grading data available							
			Mean	5	6	22	14	17	19	17	

ϕ As noted in the text, there may be a significant underestimate of material greater than 64 mm in diameter.

NJ 83 NE 6* 8726 3671 Bellmuir, Methlick BLOCK A

Surface level + 40 m (+ 131 ft) Mineral 5.0 m +
Water not struck
Section, sampled by hand and excavator
November 1978

LOG

Geological classification	Lithology	Thickness m	Depth m
Fluvioglacial sand and gravel	Gravel Gravel: coarse with some fine, a cobble-gravel with boulders commonly up to 300 mm and rarely up to 1 m, generally well rounded metagreywacke (some gneissose), psammite, knotted semipelitic and pelitic schist, vein-quartz and some gneiss and pink granite. Spherical or cuboid except for pelites which are platy Sand: coarse, medium and fine, subrounded to well rounded rock and subangular to subrounded quartz and feldspar Fines: some silt, disseminated	5.0 +	5.0

GRADING ϕ

Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
1	17	82	0.0–5.0	1	3	6	8	20	50	12	

ϕ As noted in the text, there may be a significant underestimate of material greater than 64 mm in diameter

NJ 83 NE 7* 8772 3662 Bellmuir, Methlick BLOCK A

Surface level + 38 m (+ 124.5 ft)
Water not struck
Section, sampled by hand and excavator
November 1979

Mineral 6.2 m
Bedrock 0.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
Fluvioglacial sand and gravel	Gravel Gravel: coarse with some fine, a cobble-gravel with boulders commonly up to 300 mm and rarely up to 1 m, generally well rounded, metagreywacke (some gneissose), psammite, knotted semipelitic and pelitic schist, slate, and vein-quartz, pink granite and gneiss. Spherical or cuboid except for pelites which are platy Sand: coarse with medium and fine, subrounded to well rounded rock and sub-angular to subrounded quartz and feldspar Fines: chiefly silt coating clasts. Sandy silty clay matrix between 5.2 m and 5.5 m. Pale grey to pale yellow-grey	6.2	6.2
Caledonian	Granite, coarse grained, pink. Possibly an enormous boulder	0.1 +	6.3

GRADING ϕ

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64
1	13	86	0.0–5.2	1	4	3	1	9	62	20
			5.2–5.5	Clay-bound gravel, not sampled						
			5.5–6.2	2	3	5	15	21	42	12
			Mean	1	4	4	6	13	56	17

ϕ As noted in the text, there may be a significant underestimate of material greater than 64 mm in diameter

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NJ 83 NE 8* 8851 3576 Gravel Pit, Tangland, Methlick BLOCK A

Surface level + 27 m (+ 88.5 ft)
Water not struck
Section, sampled by hand
March 1979

Mineral 5.9 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
Fluvioglacial sand and gravel	Gravel Gravel: coarse with some fine, a cobble-gravel with numerous boulders commonly up to 600 mm and often up to 1 m. Boulders disposed in beds, sometimes forming a continuous network. Subangular to subrounded psammite and metagreywacke. Subrounded to well rounded pink granite, pegmatite, grey granite and bluish grey diorite, with some gneiss, gneissose psammite, quartzites, vein-quartz, pelitic schist and slate. Diorite is very difficult to crush when fresh and rapidly weathers spheroidally. Most of gravel is spherical or cuboid except for pelitic schist and slate which are tabular to platy and which are most abundant in the finer grade Sand: coarse with some medium and a trace of fine, chiefly well rounded (spherical) quartzites, psammite, and vein-quartz and (platy) slate, with subangular to subrounded quartz and feldspar. Iron-stained in upper few metres of deposit Fines: a little clay and silt coating clasts but not making deposit cohesive	5.9 +	5.9

(continued)

GRADING ϕ

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
1	30	69	0.0–3.0	0	1	5	19	38	37	0
			3.0–5.9	1	2	11	23	41	22	0
			Mean	1	1	8	21	39	30	0

ϕ As noted in the text, there may be a significant underestimate of material greater than 64 mm in diameter

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NJ 83 NE 9* 8942 3575 Gravel Pit, Mill of Schivas, Tarves BLOCK A

Surface level c + 24 m (c + 79 ft) Mineral 3.0 m +
Water not struck
Section, sampled by hand
March 1979

LOG

Geological classification	Lithology	Thickness m	Depth m
Fluvioglacial sand and gravel	Gravel Gravel: coarse with some fine, boulders commonly up to 400 mm diameter, subangular to subrounded gneiss, gneissose metagreywacke, psammite, quartzite, diorite and some coarse grained basic igneous rock, often badly weathered. Some pink granite and well rounded white quartzite, vein-quartz and pink feldspar rock. Abundant well rounded, (platy) slate, often knotted Sand: coarse with medium and some fine, much subangular diorite and granite rock debris, dark orange-brown Fines: chiefly silt, disseminated (Base of quarry very uneven, generally slopping parallel to the valley-side. No section greater than 3.0 m in height was available for sampling but deposit is probably over 6 m thick)	3.0 +	3.0

GRADING ϕ

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
1	33	66	0.0–1.5	1	1	8	16	23	46	5
			1.5–3.0	2	2	14	24	30	26	2
			Mean	1	2	11	20	27	35	4

ϕ As noted in the text, there may be a significant underestimate of material greater than 64 mm in diameter

NJ 83 SE 1 3972 3461 School, Warldsend, Tarves BLOCK A

Surface level + 25 m (+ 82 ft)
Groundwater level + 19 m
250 mm and 200 mm percussion and shell
December 1978

Overburden 0.2 m
Mineral 9.2 m
Waste 1.9 m
Mineral 3.7 m
Waste 0.4 m +

LOG

Geological classification		Lithology	Thickness m	Depth m
		Soil, brown, gravelly	0.2	0.2
Fluvioglacial sand and gravel	a	Gravel Gravel: fine and coarse, some cobbles,subrounded to well rounded with some subangular, quartzites, metagreywacke and pink granite with psammite, and (platy) knotted slate, and some vein-quartz, mica schist, pink felsite and diorite Sand: chiefly coarse with some medium and fine, angular to subangular quartz and feldspar, subangular to well rounded psammite, quartzite and (platy) slate. Brownish grey Fines: silty, slightly clayey and cohesive	4.1	4.3
	b	Pebbly sand Gravel: (chiefly in basal 1.4 m) coarse and fine, subrounded to well rounded, quartzite, psammite, gneiss, knotted slate and granite with some diorite, pink felsite and vein-quartz Sand: medium with fine and some coarse, coarsening downwards, 'soft', micaceous, quartz and feldspar, yellow-brown speckled by mafics Fines: silt, disseminated and as seams	5.1	9.4
Till		Clay, stony, silty, stiff, yellow-brown, micaceous	1.9	11.3
Glacial sand and gravel	c	Gravel Gravel: coarse with fine, cobbles common, chiefly subrounded, psammite, quartzites, diorite, metagreywacke, pegmatite, slate and vein-quartz Sand: coarse with medium and some fine, subangular rock and quartz Fines: silt with clay, the latter increasing downwards	1.0	12.3
Till	d	Sandy gravel Gravel: fine and coarse, predominantly crystalline rocks with vein-quartz and quartzite Sand: medium to coarse with fine, poorly sorted Fines: deposit is bound by brown sandy silty clay or grey-brown clay, becoming very compact below 14.0 m	2.7	15.0
		Clay, gravelly, stiff, grey-brown	0.4 +	15.4
		Borehole abandoned owing to rock obstruction, possibly on hard, dark grey, crystalline bedrock		

(continued)

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
					$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
a	3	34	63	0.2–1.2	2	4	8	15	39	27	5	
				1.2–2.2	4	3	7	23	41	22	0	
				2.2–3.2	4	3	6	22	30	28	7	
				3.2–4.3	3	4	7	33	28	21	4	
				Mean	3	4	7	23	34	25	4	
b	9	82	9	4.3–5.3	17	27	47	8	1	0	0	
				5.3–6.3	3	30	57	9	1	0	0	†
				6.3–8.0	11	23	57	7	2	0	0	†
				8.0–9.4	4	8	32	25	19	12	0	†
				Mean	9	21	48	13	6	3	0	
c	3	49	55	11.3–12.3	3	6	16	20	19	36	0	†
d	6	56	38	12.3–14.0	6	11	25	23	22	13	0	†≠
				14.0–15.0	6	11	23	16	18	17	9	†≠
				Mean	6	11	24	21	21	14	3	
a&b	6	61	33	Mean	6	13	30	18	18	13	2	
(a to c)	6	59	35	Mean	6	13	28	18	18	15	2	
(a to d)	6	58	36	Mean	6	12	28	18	19	15	2	

≠ Non-mineral: not considered in calculation of mean grading

NJ 92 NE 1 9542 2843 Cross-stone Wood, Ellon BLOCK C

Surface level + 66 m (+ 216.5 ft)
Water struck at + 62 m
250 mm and 200 mm percussion and shell
December 1978

Overburden 2.6 m
Mineral 2.2 m
Waste 1.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, peaty, pebbly, black	0.6	0.6
Till	Clay, pebbly, red-brown	2.0	2.6
Glacial sand and gravel	Sandy gravel Gravel: coarse and fine, some cobbles, subrounded to well rounded pink granite, schist, psammite, slate and quartzites, and some vein-quartz Sand: medium with coarse and some fine, coarsening downwards, chiefly subangular quartz with feldspar and rock, micaceous, yellow-brown Fines: clay, brown, slightly clay-bound below 3.6 m	2.2	4.8
Till	Clay, gravelly, stiff, red-brown	0.3	5.1
	Clay, gravelly, stiff, grey-brown	0.8 +	5.9
	Borehole abandoned owing to rock obstruction		

(continued)

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64
7	55	38	2.6–3.6	7	12	34	14	16	12	5
			3.6–4.8	6	7	24	21	20	15	7 †
			Mean	7	9	28	18	18	14	6

NJ 92 NE 2 9721 2951 Fechil, Ellon BLOCK B

Surface level + 17 m (+ 56 ft)
Groundwater level + 11.2 m
250 mm and 200 mm percussion and shell
November 1978

Overburden 0.2m
Mineral 4.0 m
Waste 14.8 m
Mineral 4.5 m +

LOG

Geological classification		Lithology	Thickness m	Depth m
		Soil	0.2	0.2
Fluvioglacial sand and gravel	a	Gravel Gravel: coarse with fine, numerous cobbles and some small boulders, chiefly subrounded to well rounded psammite, gneiss, metagreywacke, quartzite and some vein-quartz, slate and pink felsite Sand: fine to coarse, fining downwards, uppermost 2 m 'sharp' consisting of angular to subangular quartz and feldspar with subrounded to well rounded quartz and slate. Below 2.0 m sand is 'soft', micaceous, with well rounded vein-quartz and quartz. Yellow-brown Fines: silt, disseminated (Deposit is very compact and iron-stained above 1.5 m)	2.9	3.1
	b	'Very clayey' pebbly sand Gravel: fine and coarse, well rounded vein-quartz and slate Sand: predominantly fine, micaceous, 'soft', pale yellow-grey Fines: much silt, disseminated	1.1	4.2
Glaciolacustrine deposits		Interbedded silty fine sand and fine sandy silt, pale yellow-grey, with subordinate laminae of pale red-brown, tenacious silty clay	1.6	5.8
		Clay, silty, firm becoming stiffer downwards, banded and sometimes finely laminated red-brown and greenish medium grey. Parts of deposit contain sand, chiefly fine grained. Some thin seams (10 mm) micaceous silt and fine sand	11.7	17.5
Till		Clay, sandy, gravelly, very stiff, medium green-grey to dark grey	1.5	19.0
Glacial sand and gravel	c	'Clayey' sandy gravel Gravel: fine and coarse, some cobbles, subangular to well rounded, psammite quartzites, metagreywacke, pink and grey granite, vein-quartz, gneiss, granulite and (platy) knotted slates. Pale grey quartzite more abundant below 22.9 m Sand: medium with coarse and fine, coarsening downwards below 20.0 m, subangular to well rounded quartz, vein-quartz and slate, brownish grey Fines: generally little associated with gravelly part of deposit. Clay-bound (?till) between 22.8 m and 22.9 m (Silty, pebbly fine sand between 19.0 m and 20.0 m, micaceous, bluish dark grey) Borehole abandoned at 23.5 m for technical reasons	4.5 +	23.5

(continued)

GRADING ϕ

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
					$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
a	2	47	51	0.2–1.2	1	1	5	25	26	31	11	
				1.2–2.0	3	2	7	16	17	24	31	
				2.0–3.1	2	35	32	10	9	12	0	
				Mean	2	14	16	17	17	22	12	
b	25	70	5	3.1–4.2	25	62	6	2	3	2	0	
c	11	54	36	19.0–20.0	28	41	27	3	1	0	0	†
				20.0–21.0	3	10	26	15	24	22	0	†
				21.0–22.0	3	3	17	18	31	28	0	†
				22.0–22.8	13	4	18	24	25	16	0	†
				22.8–22.9		till not sampled						
				22.9–23.5	6	8	24	33	17	7	5	†
				Mean	11	14	23	17	20	15	1	
(a&b)	8	53	39	Mean	8	27	13	13	13	17	9	
(a to c)	10	53	37	Mean	10	20	18	15	16	16	5	

ϕ As noted in the text, there may be a significant underestimate of material greater than 64 mm in diameter

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NJ 92 NE 3 9850 2910 Backhill, Logie Buchan BLOCK B

Surface level + 12 m (+ 39.5 ft)
Groundwater level + 3 m
250 mm and 200 mm percussion and shell
November 1978

Overburden 0.3 m
Mineral 10.1 m
Waste 4.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, gravelly loam	0.3	0.3
Fluvioglacial sand and gravel	Gravel	10.1	10.4
	Gravel: coarse and fine, some cobbles. Coarse gravel subrounded to well rounded, fine gravel a little more angular. Psammite, metagreywacke and quartzite with red granite, vein-quartz, (platy) pelitic schist and slate, pink felsite, diorite, gneiss, pegmatite and rare sandstone		
	Sand: coarse, medium and fine, chiefly medium above 5.5 m and coarse below. Subangular to subrounded becoming more angular below 5.5 m. Quartz with feldspar, much rock debris in coarse fraction, chiefly (platy) pelitic schist and slate		
	Fines: silt, disseminated		
	(Bed of silty fine sand between 3.0 and 4.5 m; reddish pale brown, interbedded with thin seams of silty clay)		
Till	Clay, silty, some fine pebbles, red-brown. Becoming sandy below 11.7 m and grey, including seam of fine sand and silt between 12.0 and 12.1 m	1.8	12.2
Glaciolacustrine deposits	Silt with fine sand, very soft, micaceous, greenish pale grey	1.6	13.8
	Sand	0.7 +	14.5
	Sand: medium with fine and some coarse, well sorted, subangular to subrounded quartz with subrounded to well rounded vein-quartz and rock, the latter mainly (platy) pelitic schist and slate. Buff coloured		
	Fines: silt, disseminated		
	Borehole abandoned owing to 'piping' sand		

(continued)

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
7	42	51	0.3–1.3	7	9	21	6	14	26	17	
			1.3–2.3	3	2	17	14	23	32	9	
			2.3–3.4	4	16	25	10	21	24	0	
			3.4–4.5	28	61	5	4	2	0	0	
			4.5–5.5	6	4	16	14	18	42	0	
			5.5–7.5	5	5	11	27	23	25	4	†
			7.5–8.5	3	1	12	31	32	21	0	†
			8.5–9.5	0	2	14	20	33	31	0	†
			9.5–10.4	1	1	11	15	46	26	0	†
			Mean	7	11	14	17	23	25	3	
3	94	3	13.8–14.5	3	25	59	10	3	0	0	†≠

≠ Non-mineral: not considered in calculation of mean grading

NJ 92 NE 4 9942 2891 Kirkton of Logie Buchan BLOCK B

Surface level + 6 m (+ 19.5 ft)
Groundwater level + 3.3 m
250 mm and 200 percussion and shell
October 1978

Overburden 0.2 m
Mineral 5.1 m
Waste 7.8 m
Mineral 1.5 m
Waste 3.9 m
Mineral 2.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, black gravelly loam	0.2	0.2
Fluvioglacial sand and gravel	Gravel Gravel: fine and coarse, cobbles and small boulders rare, subangular to subrounded psammite and quartzite with knotted pelitic schist and slate, gneiss and granite. Well rounded pale grey quartzite and vein-quartz common Sand: medium with coarse and fine, coarsening downwards,chiefly subangular to subrounded rock and quartz, some mica Fines: silt, disseminated. Red, tenacious silty clay matrix between 3.1 m and 3.3 m	5.1	5.3
Glaciolacustrine deposits	Silt, micaceous, predominantly red-brown with thin seams of red clay	3.0	8.3
	Silt, micaceous, predominantly grey with seams of grey-brown silty clay and, more rarely, red-brown clay	4.8	13.1
Glacial sand and gravel	Sandy gravel Gravel: fine and coarse, some cobbles, chiefly subangular with angular and well rounded, psammite, schist and gneiss with quartzite, granite, (?) diorite and vein-quartz Sand: coarse with medium and some fine, rock with quartz, feldspar and mica Fines: a little disseminated silt	1.5	14.6
Till	Clay, sandy, pebbly, red-brown. Many clasts of gneiss	3.9	18.5
Glacial sand and gravel	Gravel Gravel: coarse and fine, some cobbles, subangular with some well rounded, quartzite and vein-quartz with granite, (?) diorite, gneiss and schists Sand: coarse with medium and some fine, chiefly angular rock, quartz and feldspar with some mica Fines: some silt, disseminated	2.1 +	20.6

(continued)

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
					$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
a	4	46	50	0.2–1.2	3	19	30	6	26	16	0	
				1.2–2.2	6	15	24	8	22	25	0	
				2.2–3.1	5	10	27	13	26	19	0	
				3.1–4.1	3	4	18	19	29	27	0	†
				4.1–5.3	1	3	13	23	31	29	0	†
				Mean	4	10	22	14	27	23	0	
b	2	52	46	13.1–14.1	3	3	18	30	29	17	0	†
				14.1–14.6	1	2	21	30	19	16	11	†
				Mean	2	3	19	30	25	17	4	
c	2	48	50	18.5–19.5	1	5	17	21	25	31	0	†
				19.5–20.6	2	5	19	29	23	22	0	†
				Mean	2	5	18	25	24	26	0	
a to c	3	47	50	Mean	3	7	20	20	26	23	1	

NJ 92 NE 5* 9787 2902 Gravel pit, Deep Heather, Logie Buchan BLOCK B

Surface level + 12 m (+ 39.5 ft) Mineral 4.7 m +
Water struck at + 7.3 m
Section, sampled by hand and excavator
November 1978

LOG

Geological classification		Lithology	Thickness m	Depth m
Fluvioglacial sand and gravel	a	Sandy gravel Gravel: fine and coarse, cobbles rare, chiefly subrounded to well rounded quartzites, psammite, metagreywacke with pink granite, vein-quartz and pelitic schist and slate, the last two more common in fine Sand: chiefly medium with coarse and fine, subangular to well rounded, 'soft', rock, quartz and feldspar. Speckled yellow-brown Fines: silt, disseminated	1.9	1.9
	b	Pebbly sand Gravel: fine and coarse, subrounded to well rounded. Composition as above Sand: medium with fine and a trace of coarse becoming chiefly medium downwards, well sorted, 'soft', micaceous, buff coloured Fines: thin seams silty fine sand, laminated silt and pebbly silty clay between 1.9 m and 3.7 m, otherwise very little	2.8 +	4.7

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
					$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
a	3	49	48	0.0–1.0	2	2	26	9	35	26	0	
				1.0–1.9	3	6	49	7	21	14	0	
				Mean	3	4	37	8	28	20	0	
b	4	84	12	1.9–3.7	5	20	64	3	5	3	0	
				3.7–4.7	3	9	63	6	10	9	0	
				Mean	4	16	64	4	7	5	0	
a&b	4	69	27	Mean	4	11	53	5	16	11	0	

NJ 92 NE 6* 9902 2911 Gravel Pit, Kirkton of Logie Buchan BLOCK B

Surface level + 6 m (+ 19.5 ft)
Groundwater level + 3.1 m
Section, sampled by hand and excavator
November 1978

Overburden 0.2 m
Mineral 3.8 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Fluvioglacial sand and gravel	Gravel Gravel: coarse and fine, cobbles and small boulders rare, subrounded to well rounded with some subangular quartzites, psammite, and metagreywacke with red granite, vein-quartz and slate Sand: medium with coarse and some fine, subangular to subrounded quartz and feldspar with well rounded quartz and slate. Orange, becoming pale yellow-grey by 1.2 m Fines: deposit is bound by ironstained silt above 1.2 m. A little disseminated silt below 1.2 m	3.8 +	4.0

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
4	29	67	0.2–1.2	7	2	11	9	24	39	8	
			1.2–2.5	3	4	18	8	26	36	5	
			2.5–4.0	4	2	20	9	26	39	0	†
			Mean	4	3	17	9	25	38	4	

NJ 93 SW 2 9044 3437 Smithfield, Ythanbank, Ellon BLOCK A

Surface level + 23 m (+ 75.5 ft)
Groundwater level + 16 m
250 mm and 200 mm percussion and shell
November 1978

Overburden 0.1 m
Mineral 6.2 m
Waste 4.5 m
Bedrock 0.4 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.1	0.1
Fluvioglacial sand and gravel	Gravel Gravel: coarse with fine, numerous cobbles and boulders up to 300 mm, coarse is subrounded to well rounded whereas fine is subangular to well rounded. Psammite, quartzites, gneiss, metagreywacke, red granite, vein-quartz and slate, the last component usually platy and relatively more common in fine gravel Sand: coarse with medium and some fine, subangular to subrounded quartz with vein-quartz, psammite and platy slate. Becoming very 'sharp' below 5.1 m Fines: a little silt, disseminated	6.2	6.3
	Clay, pebbly, silty, soft, pale brown	0.5	6.8
Till	Clay, gravelly, sandy, stiff, pale yellow-brown	3.6	10.4
	Sand and gravel with subangular to well rounded quartzites, psammite and vein-quartz	0.4	10.8
Caledonian	Diorite, badly weathered, medium grained, pink feldspar and mafics	0.4 +	11.2

(continued)

GRADING ϕ

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64
3	26	27	0.1–1.1	1	2	5	10	15	19	48
			1.1–2.1	2	3	10	19	23	43	0
			2.1–3.1	2	4	12	14	22	35	11
			3.1–4.1	3	3	7	13	17	28	29
			4.1–5.1	3	3	9	11	27	44	3
			5.1–6.3	8	5	9	15	25	38	0
			Mean	3	3	9	14	21	35	15

ϕ As noted in the text, there may be a significant underestimate of material greater than 64 mm in diameter

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NJ 93 SW 3* 9115 3311 Waulkmill Hill Pit, Ythanbank, Ellon BLOCK A

Surface level + 18 m (+ 59 ft) Mineral 5.9 m +
Dry
Section, sampled by hand
March 1979

LOG

Geological classification	Lithology	Thickness m	Depth m
Fluvioglacial sand and gravel	Gravel Gravel: coarse with fine, numerous cobbles and boulders up to 400 mm, some larger, predominantly spherical or cuboid, well rounded metagreywacke, psammite and quartzites with gneiss, diorite, pink granite, vein-quartz, felsite and schist. Much platy slate in fine gravel Sand: coarse with medium and some fine, angular to subrounded rock, quartz and feldspar. Much well rounded, platy slate in coarse. Pale brown to neutral Fines: deposit loosely bound in upper 2 m. Disseminated silt. A few thin seams of red-brown, silty clay (Coarser parts of deposit are horizontally bedded, finer parts display cross-bedding. Several metres of buff coloured, fine grained sand underlies the gravels in the south-east of the face sampled)	5.9 +	5.9

GRADING ϕ

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64
1	21	78	0.0–3.0	1	2	6	16	29	40	6
			3.0–5.9	1	2	6	9	26	46	10
			Mean	1	2	6	13	27	43	8

ϕ As noted in the text, there may be a significant underestimate of material greater than 64 mm in diameter

NJ 93 SW 4 9127 3291 Inverebrie Croft (Waterside) Ellon BLOCK A

Surface level + 16 m (+ 52.5 ft)
Groundwater level + 11.6 m
250 mm and 200 mm percussion and shell
November 1978

Overburden 0.2 m
Mineral 7.5 m
Waste 3.2 m
Bedrock 0.5 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Fluvioglacial sand and gravel	Gravel Gravel: coarse and fine, numerous cobbles and rare small boulders, coarse gravel subrounded to well rounded, fine gravel more angular, quartzites and metagreywacke with vein-quartz, psammite, knotted pelitic schist and slate, and some igneous Sand: medium with coarse and fine, becoming coarse below 4.5 m, subrounded to well rounded becoming more angular below 4.5 m. Vein-quartz, (platy) pelitic schist and slate, quartz and some feldspar. Buff coloured Fines: silt, disseminated. Upper 1.2 m partially bound by iron-pan	7.5	7.7
	Clay, silty, soft to firm, laminated, pale green-grey and red-brown	0.9	8.6
Till	Clay, sandy, gravelly, stiff, olive grey, clasts up to 300 mm diameter	2.3	10.9
Dalradian	Psammite, very hard, dark grey, fine grained bands displaying micaceous crenulated cleavage. Associated with andalusite schist	0.5 +	11.4

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
2	39	59	0.2–1.2	4	6	17	9	20	29	15	
			1.2–2.5	4	4	12	7	18	24	31	
			2.5–3.5	2	6	29	14	20	25	4	†
			3.5–4.5	2	3	24	20	28	23	0	†
			4.5–6.0	1	0	5	37	36	21	0	†
			6.0–7.7	1	1	7	34	35	22	0	†
			Mean	2	3	14	22	27	24	8	

NJ 93 SW 5 9204 3185 Upper Ardlethen, Ellon BLOCK A

Surface level + 21 m (+ 69 ft)
Water not struck
250 mm and 200 mm percussion
November 1978

Overburden 0.2 m
Mineral 5.8 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Fluvioglacial sand and gravel	Gravel Gravel: coarse and fine, cobbles and small boulders common. Subrounded to well rounded quartzite, metagreywacke, psammite and knotted pelitic and semi-pelitic schist, some vein-quartz, pink felsite, pegmatite and diorite Sand: coarse with medium and some fine, subangular to well rounded quartz with vein-quartz, psammite, (platy) pelitic schist and slate and feldspar. Dull orange-brown Fines: silt, disseminated. Deposit bound by pale grey, tenacious silty clay below 5.2 m	5.8 +	6.0
	Borehole abandoned owing to rock obstruction		

(continued)

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
7	33	60	0.2–1.2	5	4	9	17	25	40	0
			1.2–2.2	5	8	12	14	30	31	0
			2.2–3.2	5	5	9	18	27	24	12
			3.2–4.2	5	6	13	20	32	24	0
			4.2–5.2	8	5	8	17	34	28	0
			5.2–6.0	13	5	9	20	20	33	0
			Mean	7	5	10	18	28	30	2

NJ 93 SW 6 9238 3091 Boat (Bridge) of Ardlethen, Ellon BLOCK B

Surface level + 10 m (+ 30.5 ft)
Groundwater level + 8 m
250 mm percussion and shell
November 1978

Overburden 0.8 m
Mineral 5.4 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Alluvium	Silt with fine grained sand, yellow-brown	0.6	0.8
	Gravel	5.4 +	6.2
	Gravel: coarse with fine, some cobbles, coarse gravel subrounded to well rounded metagreywacke, psammite and quartzites with knotted slate, schist and gneiss, and some pink felsite and granite. Fine gravel more angular, similar composition but more vein-quartz and slate		
	Sand: coarse, medium and some fine, angular to subrounded rock, quartz, vein-quartz and some feldspar. Grey-brown to yellow-brown		
	Fines: some silt, disseminated. Silty clay matrix between 2.0 m and 2.4 m		
	Borehole abandoned owing to rock obstruction, possibly bedrock		

GRADING ϕ

Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
4	26	70	0.8–1.8	3	5	9	9	18	26	30	
			1.8–2.8	8	4	11	13	26	32	6	
			2.8–3.8	3	3	7	16	28	38	5	†
			3.8–4.8	3	4	7	17	36	24	9	†
			4.8–6.2		No grading data available						
			Mean	4	4	8	14	27	30	13	

ϕ As noted in the text, there may be a significant underestimate of material greater than 64 mm in diameter

NJ 93 SW 7 9330 3090 East Kinharrachie, Ellon BLOCK B

Surface level + 20 m (+ 65.5 ft)
Water not struck
250 mm and 200 mm percussion and shell
November 1978

Overburden 0.2 m
Mineral 5.2 m
Waste 2.4 m
Bedrock 0.3 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Fluvioglacial sand and gravel	Gravel Gravel: fine and coarse, some cobbles below 3.2 m, subrounded to well rounded, quartzite, psammite, and metagreywacke with vein-quartz and some red granite, gneiss and (platy) pelitic schist Sand: coarse, medium and fine, subrounded to well rounded, rock, quartz and some feldspar, rock chiefly quartzite, vein-quartz and psammite. Grey to yellow-brown Fines: chiefly silt, disseminated. Seams of silt and fine sand, greyish yellow-brown, between 2.2 and 3.2 m. Clay present below 3.2 m, deposit barely cohesive. Laminae of red-brown clay	5.2	5.4
Till	Clay, pebbly, slightly sandy, stiff, yellow-brown clasts up to cobble-size	2.4	7.8
Dalradian	Gneissose psammite with quartz segregations	0.3 +	8.1

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
9	39	52	0.2–1.2	3	4	7	14	39	27	6
			1.2–2.2	5	8	22	10	23	27	5
			2.2–3.2	19	24	25	6	10	16	0
			3.2–4.2	9	3	6	23	45	14	0
			4.2–5.4	10	6	14	21	27	22	0
			Mean	9	9	15	15	29	21	2

NJ 93 SW 8 9446 3032 Meiklemill, Ellon BLOCK B

Surface level + 16 m (+ 52.5 ft)
Groundwater level + 7 m
200 mm percussion and shell
November 1978

Overburden 0.3 m
Mineral 6.5 m
Waste 11.9 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Fluvioglacial sand and gravel	Gravel Gravel: coarse with fine, numerous cobbles and boulders greater than 300 mm, (considerable comminution caused by chiselling) chiefly well rounded psammite, gneiss, quartz-garnet-schist, andalusite-schist, slate, quartzite and granite Sand: coarse and medium with fine, chiefly angular rock with quartz and feldspar. Yellow-grey-brown Fines: silt (largely washed away)	6.5	6.8
Glaciolacustrine deposits	Interbedded silt, pale brown, and silty clay, red-brown, soft becoming stiff by 11.0 m, some sand and fine gravel	7.2	14.0
	Clay, pebbly, some sand, red-brown and pale green-grey mottled, firm to stiff, some seams of silty clay	1.7	15.7

(continued)

Geological classification	Lithology	Thickness m	Depth m
Till	Clay, sandy, becoming increasingly gravelly, greenish medium grey, firm to stiff. Angular clasts of schistose psammite	3.0 +	18.7
	Borehole terminated for technical reasons		

GRADING ϕ

Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
6	41	53	0.3–3.0	No grading data available							
			3.0–4.0	8	11	20	11	11	28	11	†
			4.0–5.5	6	7	19	22	23	23	0	†
			5.5–6.8	5	5	11	15	23	41	0	†
			Mean	6	7	17	17	20	30	3	†

ϕ As noted in the text, there may be a significant underestimate of material greater than 64 mm diameter

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NJ 93 SE 10* 9686 3060 Gravel pit, Waterton, Ellon BLOCK B

Surface level + 14 m (+ 47 feet)
Groundwater level c + 7.3 m
Section sampled by hand and excavator
August 1978

Overburden 0.2 m
Mineral 6.5 m
Waste 1.2 m
Bedrock 0.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Flavioglacial sand and gravel	Gravel (sand between 2.2 m and 3.2 m) Gravel: coarse with fine, cobbles and small boulders common, coarse-gravel subrounded to well rounded, fine-gravel more angular. Metagreywacke, psammite and quartzite with (platy) pelitic schist and slate and vein-quartz gneiss and granite Sand: medium with fine and some coarse, subangular to rounded, quartz, feldspar and rock, some mica. 'Soft' becoming 'sharp' below 5.7 m Fines: some silt, disseminated. Deposit becoming a little cohesive below 5.7 m. Pale yellow-brown becoming grey-brown	6.5	6.7
Till	Clay, silty with sporadic pebbles, ochreous brown, stiff, micaceous in parts. Laminae of fine sand	1.2	7.9
Dalradian	Gneissose grit, medium to coarse-grained with varying degree of schistocity, veinlets of quartz and micaceous partings, pale grey	0.1 +	8.0

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
2	43	55	0.2–1.2	2	6	22	6	20	44	0
			1.2–2.2	1	1	20	4	15	44	15
			2.2–3.2	3	51	43	1	1	1	0
			3.2–5.7	No grading data available						
			5.7–6.7	2	3	9	6	19	38	23
			Mean	2	15	24	4	14	32	9

NK 02 NW 1 0010 2949 Auchmacoy gravel pit, Logie Buchan BLOCK B

Surface level + 9 m (+ 29.5 ft)
Groundwater level + 4.6 m
200 m shell ≠
October 1978

Overburden 0.2 m
Mineral 2.6 m
Waste 0.6 m
Mineral 1.1 m
Waste 17.3 m +

LOG

Geological classification		Lithology	Thickness m	Depth m
		Soil, gravelly	0.2	0.2
Fluvioglacial sand and gravel	a	Gravel Gravel: fine and coarse, cobbles common, subangular to well rounded, quartzite, psammite, vein-quartz, metagreywacke, red granite, red felsite, gneiss and knotted slate, the three last-named being platy and mainly in fine gravel **Sand**: medium with some coarse and fine, well sorted, chiefly subrounded to well rounded, slate common in coarse, otherwise quartz with some feldspar and mica, pale orange-brown Fines: a little silt, disseminated	2.6	2.8
Glaciolacustrine deposits		Clay, silty, laminae of fine sand, red-brown	0.6	3.4
	b	'Very clayey' pebbly sand Gravel: fine and coarse, well rounded, metagreywacke, pelitic schist and slate Sand: fine with medium and a trace of coarse, well rounded slate in coarse, micaceous red-brown Fines: silt, and clay, deposit cohesive	1.1	4.5
Till		Clay, silty, some sand and fine gravel, firm, predominantly red-brown. Thin seams of micaceous silt	16.7	21.2
Glaciolacustrine		Silt with fine sand, micaceous, medium grey	0.6 +	21.8
		Borehole abandoned owing to rock obstruction		
		≠ Uppermost 2.6 m sampled by hand from adjacent section		

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
					$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
a	1	48	51	0.2–1.2	0	5	33	14	29	19	0	
				1.2–2.8	1	7	31	8	24	21	8	
				Mean	1	6	32	10	26	20	5	
b	27	68	5	3.4–4.5	27	37	29	2	2	3	0	†
a&b	9	54	37	Mean	9	15	31	8	19	15	3	

NK 02 NW 2 0151 2956 Milton of Collieston, Slains BLOCK D

Surface level + 38 m (+ 124.5 ft)
Water not struck
250 mm percussion
October 1978

Waste 4.0 m
Bedrock 0.6 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Till	Clay, gravelly, sandy, red-brown	1.3	1.5
	Clay, silty, red-brown	2.1	3.6
	Clay, sandy, pebbly, yellow-brown	0.4	4.0
Dalradian	Psammite, flaggy, very hard, micaceous cleavage surfaces, greenish pale grey	0.6 +	4.6

NK 02 NW 3 0113 2700 Sands of Forvie, Slains BLOCK D

Surface level + 21 m (+ 69 ft)
Groundwater level + 19.6 m
250 mm percussion and shell
November 1978

Overburden 0.1 m
Mineral 1.1 m
Waste 3.5 m
Bedrock 0.2 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.1	0.1
Blown sand	Sand Sand: medium with fine, 'soft' peaty, pale yellow becoming grey downwards Fines: silt, disseminated	1.1	1.2
	Sand, fine grained, with silt and black ooze	0.7	1.9
Peat	Peat, sandy, silty, very soft, dark brown to black	1.1	3.0
Till	Clay, gravelly, some sand, firm to stiff, red-brown	1.0	4.0
	Clay, gravelly, some sand, stiff, bluish medium grey	0.7	4.7
Dalradian	Schistose psammite with quartz segregations, micaceous sheen to cleavage surfaces, very hard, dark grey to greenish medium grey	0.2 +	4.9

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64
9	91	0	0.1–1.2	9	27	63	1	0	0	0

NK 02 NW 4 0193 2665 Forvie Church, Slains BLOCK D

Surface level + 12 m (+ 39.5 ft)
Groundwater level + 11.2 m
250 mm and 200 mm percussion and shell
November 1978

Overburden 0.1 m
Mineral 7.9 m
Waste 3.7 m
Bedrock 0.4 m +

LOG

Geological classification		Lithology	Thickness m	Depth m
		Soil	0.1	0.1
Blown sand	a	Sand Sand: medium with fine, well sorted, quartzose, buff coloured becoming medium grey by 4.3 m Fines: a little silt, disseminated	5.9	6.0
Post-Glacial beach deposits	b	Sandy gravel Gravel: coarse and fine, cobbles rare, chiefly subangular psammite, gneiss, metagreywacke and slate, well rounded quartzite and vein-quartz, and some red granite Sand: medium with fine and some coarse, coarse grains subangular, otherwise more rounded, quartz, pink feldspar and rock. No shell observed, dark grey Fines: silt, disseminated	2.0	8.0
Till		Clay, gravelly, some sand, stiff, bluish medium grey becoming dark grey	3.7	11.7
Dalradian		Schist, semipelitic, micaceous, knotted, some quartzo-feldspathic segregations, medium green-grey weathering red-brown	0.4 +	12.1

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
a	2	98	0	0.1–1.0	2	31	67	0	0	0	0	
				1.0–2.0	2	29	69	0	0	0	0	†
				2.0–3.0	2	20	78	0	0	0	0	†
				3.0–4.0	1	21	78	0	0	0	0	†
				4.0–5.0	2	16	82	0	0	0	0	†
				5.0–6.0	5	32	63	0	0	0	0	†
				Mean	2	25	73	0	0	0	0	
b	4	56	40	6.0–7.0	5	18	47	3	10	17	0	†
				7.0–8.0	2	13	22	10	22	31	0	†
				Mean	4	15	35	6	16	24	0	
a&b	3	87	10	Mean	3	22	63	2	4	6	0	

NK 02 NW 5 0108 2611 Sands of Forvie, Slains BLOCK D

Surface level + 17 m (+ 56 ft)
Water not struck
250 mm percussion and shell
November 1978

Waste 0.9 m
Bedrock 0.6 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
Blown sand	Sand, medium with fine, well sorted, 'soft', pale yellow	0.5	0.5
	Loam, black, peaty, pebbly	0.4	0.9
Dalradian	Schistose psammite/semipelite, quartz segregations, flaggy, hard, pale green-grey weathering ochreous brown	0.6 +	1.5

NK 02 NW 6 0291 2775 Sands of Forvie, Slains BLOCK D

Surface level + 33 m (+ 108 ft)
Groundwater level + 32.6 m
250 mm percussion and shell
December 1978

Mineral 5.7 m
Waste 1.5 m
Bedrock 0.2 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
Blown sand	Sand Sand: medium with fine, 'soft', little mica, pale yellow Fines: a little silt, disseminated (Becoming silty below 4.0 m with thin seams of red-brown pebbly silty clay)	5.7	5.7
Glaciolacustrine deposits	Clay, silty, faintly laminated, red-brown becoming red	1.4	7.1
Till	Clay, very sandy and gravelly, angular psammite and some subrounded granite, quartzite and vein-quartz	0.1	7.2
Dalradian	Schistose metagreywacke, hard, dark grey	0.2 +	7.4

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
3	97	0	0.0–1.0	2	43	55	0	0	0	0	
			1.0–2.0	2	38	59	1	0	0	0	
			2.0–3.0	2	39	59	0	0	0	0	†
			3.0–4.0	7	36	57	0	0	0	0	†
			4.0–5.0	1	30	69	0	0	0	0	†
			5.0–5.7	5	26	68	1	0	0	0	†
			Mean	3	36	61	0	0	0	0	

NK 02 NW 7 0203 2742 Sands of Forvie, Slains BLOCK D

Surface level + 37 m (+ 121.5 ft)
Groundwater level + 36 m
250 mm and 200 mm percussion and shell
December 1978

Mineral 4.3 m
Waste 3.4 m
Bedrock 0.4 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
Blown sand	Sand Sand: medium with fine, well sorted, 'soft', a little mica, pale yellow becoming grey and peaty at 2.4 m Fines: silt, disseminated, and peat	4.3	4.3
Till	Clay, silty, firm to stiff, red-brown. Thin seams of micaceous fine sand and pebbly clay	2.9	7.2
	Clay, gravelly with coarse, 'gritty' sand, bluish medium to dark grey	0.5	7.7
Dalradian	Schistose grit (metagreywacke) with pelitic bands and quartz segregations, micaceous cleavage surfaces, very hard, dark grey	0.4 +	8.1

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
2	98	0	0.0–1.0	1	26	73	0	0	0	0	
			1.0–2.0	2	21	77	0	0	0	0	†
			2.0–2.9	1	16	83	0	0	0	0	†
			2.9–4.3	2	20	78	0	0	0	0	†
			Mean	2	21	77	0	0	0	0	†

NK 02 NW 8 0324 2924 Mains of Collieston, Slains BLOCK D

Surface level + 44 m (+ 144.5 ft)
Water struck at + 35.9 m
200 mm percussion and shell
October 1978

Waste 9.0 m
Bedrock 0.3 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Made ground	1.2	1.2
Glaciolacustrine deposits	Clay, stiff, red-brown interbedded with subordinate clayey silt, silt and silty fine sand. Laminae of silty fine sand, micaceous, pale blue-grey. Becoming silty clay below 5.0 m, finely laminated in part	6.9	8.1
Glacial sand and gravel	Sand and gravel composed of angular clasts of psammite with vein-quartz, some subrounded to well rounded vein-quartz and slate and rare diorite and peletic gneiss	0.9	9.0
Dalradian	Gneiss, pelitic, quartz segregations and veining, very hard, micaceous cleavage surfaces, some knotting, dark grey with bands of red-brown	0.3 +	9.3

(continued)

NK 02 NW 9 0468 2993 Mains of Slains, Slains BLOCK D

Surface level + 53 m (+ 174 ft) Waste 12.3 m +
Water not struck
250 mm and 200 mm percussion and shell
October 1978

LOG

Geological classification		Lithology	Thickness m	Depth m
		Soil, black, gravelly	0.2	0.2
Till		Clay, silty, some sand and fine gravel, firm becoming stiff, red-brown. Psammite cobble at 3.7 m	5.6	5.8
Glaciolacustrine deposits	a	'Clayey' sand Gravel: fine with rare coarse, subrounded to well rounded, platy slate Sand: fine with some medium, micaceous, red-brown Fines: thin seams of red-brown silty clay and much silt	0.7	6.5
		Silt and fine sand with thin seams of clayey silt and silty clay, red-brown	2.1	8.6
	b	'Very clayey' pebbly sand Gravel (only present below 10.0 m): coarse and fine, subrounded to well rounded pink granite, psammite, pale grey calcareous siltstone, vein-quartz and platy slate. Cobbles at base Sand: fine with medium above 10.0 m, becoming medium and fine, red-brown, some comminuted white shell Fines: much silt, thin seams of clayey silt and silty clay	2.7	11.3
Till		Clay, gravelly, very stiff, red-brown	1.0 +	12.3
		Borehole abandoned owing to rock obstruction, probably a boulder within till		

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
	Finesq	Sand	Gravel		Fines	Sand			Gravel			
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
a	16	82	2	5.8–6.5	16	68	12	2	2	0	0	† ≠
b	21	66	13	8.6–10.0	31	49	14	3	2	1	0	† ≠
				10.00–11.3	11	28	34	3	7	17	0	† ≠
				Mean	21	39	24	3	4	9	0	≠
a&b	20	69	11	Mean	20	45	21	3	4	7	0	≠

≠ Non-mineral: data not considered in calculation of mean grading

NK 02 NW 10* 0054 2662 Waterside Bridge, Slains BLOCK C

Surface level + 14 m (+ 46 ft)
Water not struck
Section, sampled by hand
March 1979

Overburden 0.1 m
Mineral 10.3 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.1	0.1
Glacial sand and gravel	Gravel	10.3 +	10.4
	Gravel: coarse with fine, many cobbles and boulders, rarely over 500 mm but up to 1 m, very poorly sorted in uppermost 0.5 m, chiefly subrounded to well rounded with some subangular in fine. Gneissose psammite, psammite, quartz-biotite-schist, pink granite, gneiss, pegmatite and quartzite with some vein-quartz, pink felsite, ultrabasic igneous and slate. Platy schist and slate common in fine gravel, gneissose rock common as boulders		
	Sand: chiefly coarse with medium and a trace of fine, subangular to subrounded rock, quartz and some feldspar, a little mica. Pale brown		
	Fines: silt, disseminated. Some seams (50 to 100 mm) silt and fine sand, laminated, micaceous, red-brown		
	(Silty fine sand, between 0.6 and 2.1 m, including whisps of medium and coarse sand, pale brown)		

GRADING ϕ

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
3	43	54	0.1–0.6	3	4	8	17	22	29	17
			0.6–2.1	14	59	8	6	10	3	0
			2.1–3.4	2	1	6	17	29	41	4
			3.4–4.8	1	1	6	21	20	41	10
			4.8–6.2	1	1	8	20	15	40	15
			6.2–7.6	1	0	11	22	22	27	17
			7.6–9.0	3	2	21	34	23	17	0
			9.0–10.4	2	1	18	39	21	13	6
			Mean	3	10	11	22	20	26	8

ϕ As noted in the text, there may be a significant underestimate of material greater than 64 mm in diameter

NK 03 NW 1 0057 3649 Hill of Auchleuchries, Cruden BLOCK C

Surface level + 103 m (+ 338 ft)
Water not struck
250 mm and 200 mm percussion and shell
October 1978

Overburden 6.0 m
Mineral 8.4 m
Waste 3.0 m
Bedrock 0.4 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Till	Clay, silty, sandy, pebbly, firm to stiff, yellow brown	5.8	6.0
Glacial sand and gravel	Pebbly sand (fining downwards) Gravel: fine and coarse, some cobbles above 9.0 m, angular to well rounded, fine gravel more angular than coarse, pink granite, gneiss, psammite and quartzite with metagreywacke and vein-quartz and rare fine-grained basalt Sand: medium with fine becoming chiefly fine downwards, well sorted, 'soft', micaceous, yellow-brown Fines: silt, disseminated, increasing downwards. Fissile, stiff, olive-grey clay between 12.5 m and 12.7 m	8.4	14.4
	Silt/fine sand, micaceous, yellow-grey	0.1	14.5
Till	Clay, sandy, silty, pebbly, firm to stiff, dark grey becoming mottled orange-brown below 16.0 m, some white comminuted shell	2.9	17.4
Dalradian	Schistose grit with quartz segregations, very hard, pale yellow weathering orange	0.4 +	17.8

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
6	84	10	6.0–7.4	5	15	20	10	29	21	0	†
			7.4–9.0	5	45	42	4	2	2	0	†
			9.0–10.9	3	46	50	0	1	0	0	†
			10.9–12.5	6	76	18	0	0	0	0	†
			12.5–12.7		Seam of clay						
			12.7–13.6	2	83	14	1	0	0	0	†
			13.6–14.4	22	76	2	0	0	0	0	†
			Mean	6	53	28	3	6	4	0	

NK 03 NW 2 0145 3820 Oldtown, Cruden BLOCK C

Surface level + 78 m (+ 256 ft)
Groundwater level + 72 m
250 mm and 200 mm percussion and shell
October 1978

Overburden 0.2 m
Mineral 6.8 m
Waste 4.7 m
Mineral 2.3 m
Waste 4.0 m
Bedrock 0.2 m +

LOG

Geological classification		Lithology	Thickness m	Depth m
		Soil	0.2	0.2
Glacial sand and gravel	a	'Clayey' sand (fining downwards) Gravel: coarse and fine, well rounded, quartzite and vein-quartz, stained black Sand: fine with medium and a trace of coarse, quartzose, 'soft', yellow-brown Fines: silt, disseminated, increasing downwards. Discrete seams of silt below 5.2 m, also rare laminae of medium grey silty clay	6.8	7.0
		Clay, silty, yellow-brown	0.4	7.4
Till		Clay, silty with coarse sand and fine gravel, stiff to very stiff, brown-grey becoming medium grey downwards	4.3	11.7
	b	'Clayey' sandy gravel Gravel: fine and coarse, cobbles rare, chiefly subangular psammite, semipelitic schist, granite and quartzite also well rounded, quartzite and vein-quartz (from Buchan Ridge gravels?) Sand: fine, medium and coarse, quartz and rock. Pale yellow-brown Fines: clay and silt, deposit clay-bound	2.3	14.0
		Clay, silty, much coarse sand and fine gravel, stiff, pale yellow-brown	4.0	18.0
Dalradian		Gneiss, semipelitic, ochreous brown, recovered as sand, becoming hard with depth	0.2 +	18.2

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
					$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
a	14	82	4	0.2–1.2	8	45	35	5	2	5	0	
				1.2–2.2	4	42	38	3	1	12	0	†
				2.2–3.2	8	53	36	2	0	1	0	†
				3.2–4.2	6	72	20	1	1	0	0	†
				4.2–5.2	12	69	18	1	0	0	0	†
				5.2–7.0	33	57	9	1	0	0	0	†
				Mean	14	56	24	2	1	3	0	
b	15	44	41	11.7–14.0	15	13	16	15	21	20	0	†
a&b	14	73	13	Mean	14	46	22	5	6	7	0	

NK 03 NW 3 0250 3981 Moss of Auquharney, Cruden BLOCK C

Surface level + 128 m (+ 420 ft)
Groundwater level + 121.5 m
250 mm and 200 mm percussion and shell
October 1978

Overburden 1.6 m
Mineral 9.4 m
Bedrock 1.6 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, peaty	0.2	0.2
Till	Gravel with a matrix of silty, sandy clay, mottled pale grey and orange. Gravel consisting of well rounded small boulders, cobbles and coarse and fine pebbles of quartzite, vein-quartz and flint. (Deposit probably represents cryoturbated Buchan Ridge gravels	1.4	1.6
Buchan Ridge gravels	'Clayey' gravel (probably a continuous network gravel) Gravel: coarse with some fine, numerous cobbles, predominantly well rounded flint and pale grey quartzite with vein-quartz (largely in fine gravel) and friable, decomposed psammite Sand: medium with fine and coarse, quartzose. Coarse sand is 'sharp' and probably derived from comminuted, decomposed psammite and granite. Much white mica Fines: kaolinitic clay and silt matrix	9.4	11.0
Dalradian	Clay, sandy, silty, white, kaolinitic, probably representing deeply decomposed gneiss	0.9	11.9
	Gneiss (?), medium grained, breaking down to constituent grains of kaolinised feldspar, biotite and quartz, becoming hard with depth	0.7 +	12.6

GRADING ϕ

Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-1/16$	$+1/16-1/4$	$+1/4-1$	+1–4	+4–16	+16–64	+64	
10	25	65	1.6–2.6	12	7	19	8	8	41	5	
			2.6–3.2	23	15	17	7	3	21	14	
			3.2–6.0	No grading data available							
			6.0–8.0	5	6	6	4	8	54	17	†
			8.0–11.0	No grading data available							
			Mean	10	8	11	6	7	45	13	

ϕ As noted in the text, there may be a significant underestimate of material greater than 64 mm in diameter

NK 03 NW 4 0323 3668 Mains of Auquharney, Cruden BLOCK C

Surface level + 72 m (+ 236 ft)
Groundwater level + 65.4 m
250 mm and 200 mm percussion and shell
August 1978

Overburden 1.6 m
Mineral 5.4 m
Waste 0.5 m
Mineral 7.7 m
Waste 2.8 m
Bedrock 1.0 m +

LOG

Geological classification		Lithology	Thickness m	Depth m
		Soil, dark brown	0.3	0.3
Till		Clay, sandy and gravelly, pale red-brown, with thin seams of sand. Clasts up to cobble-size	1.3	1.6
Glacial sand and gravel	a	'Clayey' sand (clay between 4.4 m and 5.0 m) Gravel: fine to coarse, restricted to upper metre, rounded to well rounded, composition varied. Sand: fine with medium and some coarse, becoming chiefly fine downwards, quartz with feldspar and mica, pale brown to pale orange-brown Fines: silt, disseminated. Chocolate-brown clay with thin seams of fine sand and silt between 4.4 m and 5.0 m	5.4	7.0
		Clay, laminated, chocolate-brown (0.2 m), resting on silty sand with thin seams of clay, pale orange-brown	0.5	7.5
	b	Sand Gravel: rare, restricted to base of deposit Sand: fine to medium with a trace of coarse, chiefly subrounded to well rounded, quartz with feldspar and rare granite, pale brown Fines: silt, disseminated, rare seams of clay at about 15.0 m	7.7	15.2
Till		Clay, silty, gravelly, very stiff, dark grey-brown, becoming increasingly sandy below 17 m	2.8	18.0
Dalradian		Schistose grit, quartzo-feldspathic, veined with quartz, largely weathered to clay	1.0 +	19.0

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
a	19	80	1	1.6–2.6	12	46	30	7	3	2	0	
				2.6–3.6	16	58	25	1	0	0	0	
				3.6–4.4	24	67	7	2	0	0	0	
				4.4–5.0		Clay						
				5.0–6.0	28	66	6	0	0	0	0	
				6.0–7.0	17	79	4	0	0	0	0	
				Mean	19	63	15	2	1	0	0	
b	4	96	0	7.5–9.0	7	47	45	1	0	0	0	†
				9.0–10.0	3	44	52	1	0	0	0	†
				10.0–11.0	3	54	43	0	0	0	0	†
				11.0–12.0	2	53	45	0	0	0	0	†
				12.0–13.0	1	35	64	0	0	0	0	†
				13.0–14.0	2	27	69	2	0	0	0	†
				14.0–15.2	6	56	37	0	1	0	0	†
				Mean	4	45	50	1	0	0	0	
a&b	10	90	0	Mean	10	52	37	1	0	0	0	

NK 03 NW 5 0439 3695 Hobshill, Near Hatton, Cruden BLOCK C

Surface level + 68 m (+ 223 ft)
Groundwater level c + 56 m
250 mm and 200 mm percussion and shell
August 1978

Overburden 0.5 m
Mineral 10.9 m
Waste 1.4 m
Mineral 1.0 m
Waste 5.7 m
Bedrock 1.0 m +

LOG

Geological classification		Lithology	Thickness m	Depth m
		Soil, dark brown, sandy	0.5	0.5
Glacial sand and gravel	a	'Clayey' sand Sand: predominantly fine with some medium, subangular to subrounded quartz with feldspar and mica, orange-brown Fines: silt, disseminated, with thin seams of clay at 1.8 m and 2.2 m	10.9	11.4
Till		Clay, silty, sandy and gravelly, firm, mid-brown	1.4	12.8
	b	'Clayey' pebbly sand (clay-bound) Gravel: fine, angular to rounded, chiefly granite with quartz and other rocks Sand: medium with coarse and fine, 'sharp', rock and quartz Fines: silt and clay	1.0	13.8
		Silt and clay, interlaminated, mid-brown	0.9	14.7
		Clay, gravelly, stiff, dark grey-brown becoming mid-grey by 17.0 m. Clasts generally rounded to well rounded, up to cobble size	3.8	18.5
		Gravel with clay matrix, chiefly composed of bedrock, orange-brown	1.0	19.5
Dalradian		Schist, semipelitic, biotite-rich, weathered	1.0 +	20.5

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
a	10	90	0	0.5–1.5	16	76	5	2	1	0	0	
				1.5–2.5	7	84	7	1	0	1	0	†
				2.5–3.5	5	93	2	0	0	0	0	†
				3.5–4.5	11	88	1	0	0	0	0	†
				4.5–5.5	5	89	6	0	0	0	0	†
				5.5–6.5	9	88	3	0	0	0	0	†
				6.5–7.5	13	78	9	0	0	0	0	†
				7.5–8.5	12	82	6	0	0	0	0	†
				8.5–9.5	4	88	8	0	0	0	0	†
				9.5–10.5	7	87	6	0	0	0	0	†
				10.5–11.4	23	75	2	0	0	0	0	†
				Mean	10	85	5	0	0	0	0	
b	16	79	5	12.8–13.8	16	20	36	23	5	0	0	†
a&b	11	89	0	Mean	11	79	8	2	0	0	0	

NK 03 NW 6 0483 3510 Hill of Ardiffery, Cruden BLOCK D

Surface level + 73 m (+ 239.5 ft)
Water not struck
250 mm percussion and shell
August 1978

Waste 2.3 m
Bedrock 0.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Glacial sand and gravel	'Clayey' sandy gravel Gravel: coarse and fine, some cobbles, schist and psammite, rare granite Sand: coarse with medium and some fine, quartz and feldspar, mid- to dark brown Fines: silt and clay	0.5	0.7
Till	Clay, stony, sandy between 1.4 m and 1.8 m, red-brown becoming brown with depth	1.6	2.3
	Andalusite schist, knotted, fissured, greenish pale grey	0.1 +	2.4

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
10	47	43	0.2–0.7	10	4	15	28	17	15	11	‡

‡ Non-mineral: not considered in calculation of mean grading

NK 03 NW 7* 0187 3847 Gravel pit, Oldtown, Cruden BLOCK C

Surface level + 97 m (+ 318 ft)
Water struck at + 93.3 m
Section, sampled by hand and excavator
December 1978

Mineral 3.7 m
Waste 1.5 m
Bedrock 0.4 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
Glacial sand and gravel	Sandy gravel ≠ Gravel: fine with coarse, scattered cobbles, subangular with some well rounded, pink granite and felsite, some gneiss, pelitic schist, quartzite, vein-quartz, grey granite and psammite Sand: coarse with medium and some fine above 2.0 m, very poorly sorted, angular to subangular, pink feldspar and quartz. Fine to medium with some coarse below 2.0 m, some mica, buff coloured Fines: silt, disseminated, prominent between 2.0 and 3.0 m. Some thin seams of clay, red-brown	3.7	3.7
Till	Clay, silty, much fine sand, pebbly, yellow-brown. Becoming red by 5.2 m with bedrock clasts	1.5	5.2
Dalradian	Schistose psammite/semipelite with quartz segregations, weathered maroon to pale green-grey	0.4 +	5.6

≠ Section displayed considerable lateral variation in grading, generally poorly sorted

(continued)

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64
9	64	27	0.0–1.0	5	7	18	23	33	14	0
			1.0–2.0	4	6	16	31	32	11	0
			2.0–3.0	18	51	29	2	0	0	0
			3.0–3.7	8	21	42	17	8	4	0
			Mean	9	21	25	18	19	8	0

NK 03 NW 8* 0322 3624 Nook, Cruden BLOCK D

Surface level + 47 m (+ 154 ft)
Groundwater level c + 44.1 m
Trench dug by excavator
August 1978

Overburden 0.2 m
Mineral 4.2 m
Waste 0.7 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Fluvioglacial sand and gravel	Gravel Gravel: coarse and fine, some cobbles and small boulders, angular to well rounded with particularly angular coarse gravel, (tabular) mica-schist with psammite and (spherical) gneiss and vein quartz. Some quartzite and flint Sand: coarse with medium and some fine, 'sharp' rock in coarse sand, otherwise chiefly quartz Fines: silt, disseminated, orange-brown	4.2	4.4
Till	Clay, silty, stiff, red-brown	0.7 +	5.1

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64
2	30	68	0.2–1.2	3	2	10	18	27	37	3
			1.2–2.7	1	2	5	13	33	34	12
			2.7–4.4	3	2	17	20	20	38	0
			Mean	2	2	11	17	26	36	5

NK 03 SW 1 0005 3489 Tillybrex, Logie Buchan BLOCK C

Surface level + 70 m (+ 229.5 ft)
Groundwater level + 61.3 m
200 mm shell/face-sampling by hand from section
September 1978

Overburden 0.5 m
Mineral 11.6 m
Waste 0.8 m
Bedrock 0.6 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Till	Clay, gravelly, red-brown becoming yellow-brown downwards	0.3	0.5
Glacial sand and gravel	Gravel Gravel: coarse with fine, some cobbles and small boulders, subrounded to well rounded becoming increasingly angular downwards, fine gravel more angular than coarse. Psammite, metagreywacke and quartzite with some vein-quartz, gneiss and (platy) slate, the latter two constituents often badly weathered. Rare flint Sand: grain-size varying considerably with depth, especially below 7.0 m. Coarse sand generally angular to subrounded, 'sharp' quartz, feldspar and rock. 'Soft' sand between 7.2 m and 8.6 m and between 9.5 m and 10.5 m Fines: chiefly silt, disseminated. Clay cuticles to clasts between 2.5 m and 6.0 m making deposit slightly clay-bound. Yellow-brown	11.6	12.1
Till	Clay, sandy and gravelly, stiff, yellow-brown, psammite, vein-quartz, quartzite and some flint	0.8	12.9
Dalradian	Psammite with quartz and pink feldspar segregations, coarse grained, containing white mica, blocky fracture, weathered golden or red-brown	0.6 +	13.5
	(The borehole was sited at the foot of a section in a gravel working: depths are from ground level. At the time of survey only the uppermost 6.0 m of sand and gravel was being worked)		

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
8	40	52	0.5–1.5	4	4	13	9	30	40	0	
			1.5–2.5	4	4	4	7	37	37	7	
			2.5–3.5	8	4	5	5	22	56	0	
			3.5–4.5	9	5	5	6	16	54	5	
			4.5–6.0	11	6	6	7	23	47	0	
			6.0–7.0	4	6	14	2	5	63	6	
			7.0–7.2	8	21	17	4	8	21	21	
			7.2–8.6	10	43	37	2	4	4	0	
			8.6–9.5	3	9	22	18	22	26	0	†
			9.5–10.5	14	54	27	3	2	0	0	†
			10.5–11.5	9	19	10	9	22	31	0	†
			11.5–12.1	16	33	34	15	2	0	0	†
			Mean	8	17	16	7	17	33	2	

NK 03 SW 2 0076 3206 North Artrochie, Logie Buchan BLOCK C

Surface level + 35 m (+ 115 ft)
Water not struck
250 mm and 200 mm percussion and shell
October 1978

Waste 2.6 m
Bedrock 1.9 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Till	Clay, gravelly, stiff, red-brown	1.2	1.4
	Clay, sandy, pebbly, micaceous, pale brown	1.2	2.6
Dalradian	Gneiss, semipelitic, quartz veining, coarse grained, deeply weathered but becoming harder with depth	1.9 +	4.5

NK 03 SW 3 0185 3160 Smiddyhill, Slains BLOCK D

Surface level + 50 m (+ 164 ft)
Water not struck
250 mm and 200 mm percussion and shell
September 1978

Overburden 3.2 m
Mineral 3.8 m
Waste 7.9 m
Bedrock 0.2 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Glaciolacustrine deposits	Clay, silty with some fine sand, stiff, red-brown	2.0	2.2
	Interbedded clayey fine sand, silt and sandy clay, red-brown. Thin seams of brown, well sorted, fine to medium grained sand	1.0	3.2
	'Clayey' sand Sand: fine with medium, some mica, red-brown Fines: silt, disseminated	3.8	7.0
	Silty fine sand, red-brown	1.0	8.0
	Interbedded red-brown silty clay, clayey silt and silty fine sand, and brown fine sand. Stiff becoming firm or soft	3.0	11.0
	Silt with fine sand, micaceous, red-brown	3.7	14.7
Till	Clay, sandy and gravelly, micaceous, yellow-brown	0.2	14.9
Dalradian	Schist, semipelitic, deeply weathered, fine grained, veined with quartz, thinly banded, micaceous, yellow-brown, breacking down into a sand	0.2 +	15.1

(continued)

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
19	81	0	3.2–4.4	30	50	20	0	0	0	0	†
			4.4–6.0	15	49	36	0	0	0	0	†
			6.0–7.0	14	52	34	0	0	0	0	†
			Mean	19	50	31	0	0	0	0	
			7.0–8.0	50	45	3	0	0	0	0	† ‡

‡ Non-mineral: not considered in calculation of mean grading

NK 03 SW 4 0134 3074 Milton of Brogan, Slains BLOCK C

Surface level c + 36 m (c + 118 ft)
Water not struck
250 mm percussion
September 1978

Waste 2.1 m
Bedrock 0.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Till	Clay, silty, gravelly, red-brown	0.3	0.5
	Clay, sandy, gravelly, stiff, yellow-brown	1.6	2.1
Dalradian	Psammite with pelitic bands, dark grey	0.1 +	2.2

NK 03 SW 5 0263 3312 Pitlurg, Slains BLOCK C

Surface level + 59 m (+ 193.5 ft)
Groundwater levels at + 55.8 m and + 53.3 m
250 mm and 200 mm percussion and shell
September 1978

Overburden 1.5 m
Mineral 1.5 m
Waste 5.6 m
Bedrock 1.4 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil and made-ground	1.0	1.0
Till	Clay, sandy ('gritty'), mottled greenish pale brown and red-brown	0.5	1.5
Glacial sand and gravel	'Very clayey' sandy gravel Gravel: coarse and fine, cobbles rare, subrounded to well rounded psammite and pale grey calcareous siltstone, with vein-quartz, 'rotten' mica schist and slate Sand: medium with fine and coarse, 'soft', subrounded to well rounded quartz and rock Fines: much silt. Thick clay cuticles causing deposit to be cohesive	1.5	3.0
Till	Clay, gravelly, sandy, red-brown	0.2	3.2
	Clay, silty, little sand or gravel, stiff, red-brown, becoming dark grey below 5.0 m	5.1	8.3
	Clay, sandy ('gritty'), gravelly, orange to yellow-brown	0.3	8.6
Dalradian	Schistose psammite/semipelite with quartzo-feldspathic veins, deeply weathered almost to clay, becoming harder with depth	1.4 +	10.0

(continued)

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64
20	50	30	1.5–3.0	20	16	23	11	14	16	0

NK 03 SW 6 0258 3157 Thiefseye Moss, Slains BLOCK D

Surface level + 51 m (+ 167.5 ft)
Water struck at + 38 m
250 mm and 200 mm percussion and shell
September 1978

Overburden 10.5 m
Mineral 3.5 m
Waste 0.3 m
Bedrock 0.5 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.1	0.1
Till (interbedded with glaciolacustrine deposits)	Clay, silty with some coarse sand and fine gravel, stiff, red-brown. Becoming increasingly sandy (fine only) below 2.5 m	4.9	5.0
	Clay, silty, pebbly, stiff, interbedded with clayey fine sand, fine sandy silt and brown sand. Becoming very stiff, gravelly clay by 7.0 m	3.5	8.5
Glaciolacustrine deposits	Fine sand/silt with sporadic pebbles, thin seams of clayey silt and brown sand, micaceous, firm, red-brown	2.0	10.5
	'Very clayey' sand Sand: chiefly fine, medium increasing in abundance downwards, micaceous Fines: chiefly disseminated silt, some clayey bands, red-brown	3.5	14.0
Till	Clay, sandy, gravelly, micaceous, angular clasts, orange-brown	0.3	14.3
Dalradian	Schistose metagreywacke, quartz and ? pink feldspar veining, finely banded, very hard, dark grey with a bluish 'sheen' on cleavage surfaces	0.5 +	14.8

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
			8.5–9.5	43	43	4	4	3	3	0	‡
			9.5–10.5	42	44	5	3	4	2	0	‡
29	71	0	10.5–12.0	40	59	1	0	0	0	0	
			12.0–13.0	26	56	18	0	0	0	0	†
			13.0–14.0	16	43	40	1	0	0	0	†
			Mean	29	54	17	0	0	0	0	

‡ Non-mineral: data not considered in calculation of mean grading

NK 03 SW 7 0253 3062 Upper Brogan, Slains BLOCK D

Surface level + 53 m (+ 174 ft)
Groundwater level + 32.2 m
250 mm and 200 mm shell
September 1978

Overburden 2.1 m
Mineral 22.9 m +

LOG

Geological classification		Lithology	Thickness m	Depth m
		Soil	0.1	0.1
Till		Clay, sandy, gravelly with pockets of sand and gravel, red-brown	1.5	1.6
		Clay, becoming sandy downwards, stiff, red-brown	0.5	2.1
Glaciolacustrine deposits	a	'Very clayey' sand Gravel: fine, subangular to subrounded psammite, metagreywacke and (platy) schist and slate Sand: fine with medium and a trace of coarse, coarse sand chiefly rock, otherwise quartzose, 'soft', slightly micaceous Fines: silt, disseminated, or as rare seams of clayey silt, red-brown	9.2	11.3
Glacial sand and gravel	b	Sandy gravel Gravel: fine with coarse, subangular to subrounded psammite and quartzite with vein-quartz, red granite, metagreywacke, knotted pelitic schist and slate and cream coloured, calcareous siltstone Sand: medium with coarse and fine, coarse sand chiefly subangular to subrounded psammite and slate, otherwise quartz with some feldspar, some shell debris Fines: silt, disseminated, buff coloured	8.8	20.1
	c	Sand Gravel: rare fine Sand: medium with fine and coarse, chiefly quartz, red-brown becoming buff by 22.3 m Fines: silt, disseminated	4.9 +	25.0

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
					$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
a	20	79	1	2.1–3.3	12	46	38	2	1	1	0	†
				3.3–4.3	18	50	27	4	1	0	0	†
				4.3–5.3	29	46	23	2	0	0	0	†
				5.3–6.3	18	37	41	4	0	0	0	†
				6.3–7.3	17	51	32	0	0	0	0	†
				7.3–8.3	19	43	37	1	0	0	0	†
				8.3–9.3	28	46	25	1	0	0	0	†
				9.3–10.3	23	65	12	0	0	0	0	†
				10.3–11.3	20	53	19	4	4	0	0	†
				Mean	20	49	28	2	1	0	0	
b	6	64	30	11.3–12.3	2	11	19	36	27	5	0	†
				12.3–13.3	2	13	26	33	23	3	0	†
				13.3–14.3	3	15	20	22	27	13	0	†
				14.3–15.7	7	18	47	15	10	3	0	†
				15.7–17.0	2	11	41	17	13	16	0	†
				17.0–18.0	3	12	35	35	14	1	0	†
				18.0–20.1	13	12	15	13	30	17	0	†
				Mean	6	13	29	22	21	9	0	
c	9	87	4	20.1–22.3	16	44	38	2	0	0	0	†
				22.3–23.6	6	20	53	17	4	0	0	†
				23.6–25.0	3	19	46	22	8	2	0	†
				Mean	9	31	44	12	3	1	0	
a to c	12	75	13	Mean	12	31	32	12	9	4	0	

NK 03 SW 8 0383 3454 Moss Croft, Cruden BLOCK D

Surface level + 74 m (+ 242.5 ft)
Groundwater level + 68.5 m
250 mm and 200 mm percussion and shell
October 1978

Waste 8.4 m
Bedrock 0.9 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Till	Clay, sandy, silty, with some fine gravel, firm to stiff, olive grey and orange mottled. Dark grey and very stiff between 1.4 m and 1.9 m and below 2.2 m	2.0	2.3
	Clay, very sandy, silty, with rare pebbles, soft, medium grey (charged with water)	0.7	3.0
	Clay, silty, some coarse sand and gravel, very stiff, dark grey	5.4	8.4
Dalradian	Schistose psammite/semipelite, moderately fresh, greyish white to dark grey	0.9 +	9.3

NK 03 SW 9 0336 3235 Knapsleask, Slains BLOCK C

Surface level + 66 m (+ 216.5 ft)
Groundwater level + 48.1 m
250 mm and 200 mm percussion and shell

Overburden 0.3 m
Mineral 22.3 m
Bedrock 0.5 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Glacial sand and gravel	Sandy gravel Gravel: coarse and fine, some cobbles above 4.3 m and below 18.3 m, subrounded to well rounded becoming a little more angular below 18.3 m. Psammite, meta-greywacke, quartzite and (platy) calcareous siltstone with (platy) knotted pelitic schist and slate, and some vein-quartz, gneiss, yellow shelly sandstone, red gritstone and granite. Noticeable decrease in proportion of the siltstone below 18.3 m Sand: medium with coarse and some fine, medium to coarse in gravelly horizons, consisting of 'gritty' quartz, feldspar and rock (chiefly platy pelitic schist and slate). Medium to fine-grained in sandier horizons, well sorted and 'soft'. Greyish medium brown becoming pale orange or pale brown below 4.3 m, and neutral below 18.3 m. Black manganese staining at 17.8 m. Some shell debris Fines: chiefly disseminated silt. Clay present above 4.3 m causing deposit to be slightly cohesive. Thin seams (± 10 cm thick) clayey silt, laminated, slightly micaceous, red-brown, between 14.3 m and 18.3 m	22.3	22.6
Dalradian	Flaggy psammite with quartz segregations, fine grained, very hard, breaking into tabular blocks, micaceous sheen on cleavage surfaces, greenish medium to pale grey	0.5 +	23.1

(continued)

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
6	53	41	0.3–1.3	9	9	18	16	18	30	0	
			1.3–2.3	10	6	19	20	12	25	8	
			2.3–3.3	5	4	28	37	10	16	0	
			3.3–4.3	5	3	24	17	14	25	12	
			4.3–5.3	12	21	33	7	12	15	0	
			5.3–6.3	9	8	16	16	24	27	0	
			6.3–7.3	6	6	50	16	12	10	0	
			7.3–8.3	6	7	28	14	23	22	0	
			8.3–9.3	6	23	28	10	14	19	0	
			9.3–10.3	7	18	55	10	8	2	0	
			10.3–11.3	7	12	15	10	18	38	0	
			11.3–12.3	5	5	14	17	21	38	0	
			12.3–13.3	6	12	22	19	26	15	0	
			13.3–14.3	12	17	10	13	24	24	0	
			14.3–15.3	4	16	29	16	21	14	0	
			15.3–16.3	6	9	19	16	23	13	14	
			16.3–17.3	5	6	25	28	24	12	0	
			17.3–18.3	3	8	41	17	15	16	0	†
			18.3–19.3	5	2	18	18	23	34	0	†
			19.3–20.5	3	8	41	16	9	23	0	†
			20.5–21.5	1	9	26	12	22	30	0	†
			21.5–22.6	3	7	31	16	21	22	0	†
			Mean	6	10	27	16	18	21	2	

NK 03 SW 10 0337 3054 Broom Hill. Slains BLOCK C

Surface level + 55 m (+ 180.5 ft)
Groundwater level + 36.2 m
250 mm and 200 mm percussion and shell
September 1978

Overburden 4.0 m
Mineral 21.0 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Till	Clay, silty, sandy, sporadic pebbles chiefly of psammite, red-brown	3.6	4.0
Glacial sand and gravel	Sandy gravel Gravel: coarse and fine, cobbles rare, subrounded to well rounded becoming a little more angular below 18.6 m. Psammite, metagreywacke, quartzite and (platy) calcareous siltstone with knotted pelitic schist and slate (generally platy and becoming more abundant downwards), and some gneiss, granite, yellow shelly sandstone and vein-quartz Sand: medium with coarse and some fine, coarser in gravelly horizons, 'soft' to 6.0 m and between 7.6 m and 8.6 m, otherwise 'sharp'. Angular coarse grains of quartz, feldspar and rock (chiefly platy pelitic schist and slate). Some shell debris. Micaceous between 7.6 m and 8.6 m. Pale yellow-brown becoming neutral at 14.6 m Fines: chiefly disseminated silt. Clay binding deposit between 7.0 m and 7.6 m. Infrequently encountered seams ($\pm$ 10 cm thick) and laminae of silty clay, laminated, micaceous, red-brown, common only between 7.6 m and 8.6 m	21.0 +	25.0

(continued)

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
6	60	34	4.0–5.0	9	15	25	16	20	15	0	
			5.0–6.0	9	14	21	11	12	16	17	
			6.0–7.0	9	21	28	13	16	13	0	
			7.0–7.6	4	8	15	7	21	45	0	
			7.6–8.6	23	42	23	4	4	4	0	
			8.6–9.6	9	12	20	15	20	24	0	
			9.6–10.6	16	20	13	14	14	23	0	
			10.6–11.6	1	3	17	24	21	20	14	
			11.6–12.6	2	3	37	28	11	10	9	†
			12.6–13.6	3	3	49	18	11	16	0	†
			13.6–14.6	6	4	55	17	9	9	0	†
			14.6–15.6	1	9	40	14	21	15	0	†
			15.6–16.6	2	5	38	18	12	25	0	†
			16.6–17.6	1	2	23	27	20	27	0	†
			17.6–18.6	1	1	18	24	16	17	23	†
			18.6–19.6	2	13	42	21	14	8	0	†
			19.6–20.6	4	18	56	19	3	0	0	†
			20.6–21.9	7	15	50	12	5	11	0	†
			21.9–22.9	1	3	18	19	21	38	0	†
			22.9–23.9	5	6	26	18	28	17	0	†
			23.9–25.0	9	7	20	35	21	8	0	†
			Mean	6	11	31	18	15	16	3	

NK 03 SW 11 0418 3156 Blackhill, Slains BLOCK D

Surface level + 61 m (+ 200 ft)
Groundwater level + 54.9 m
200 mm percussion and shell
October 1978

Waste 13.0 m
Bedrock 0.3 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil and made-ground	0.3	0.3
Till	Clay, very gravelly, some sand, stiff, red-brown and medium grey mottled	3.7	4.0
	Clay, silty, some coarse sand and fine gravel, stiff, red-brown	6.9	10.9
Glacial sand and gravel	Sandy gravel Gravel: fine and coarse, some cobbles, subrounded to well rounded, fine gravel more angular than coarse. Siltstone, cherty-rock, limestone, granite, psammite, knotted pelitic schist and vein-quartz Sand: medium with coarse and fine, subangular to subrounded, quartz and rock, the latter chiefly in coarse sand and composed of siltstone, psammite, pelitic schist and slate Fines: some silt, disseminated	2.1	13.0
Dalradian	Schistose metagreywacke, very hard, crenulate micaceous cleavage partings, dark grey. (Overlain by thin pale yellow-brown till)	0.3 +	13.3

(continued)

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
4	67	29	10.9–11.9	4	8	22	26	20	20	9	† ‡
			11.9–13.0	4	23	39	13	10	8	0	† ‡
			Mean	4	16	31	20	15	14	0	

‡ Non-mineral: not considered in calculation of mean grading

NK 03 SW 12* 0327 3206 Gravel pit, Whitefields, Slains BLOCK C

Surface level + 65 m (+ 213 ft)
Groundwater level + 53.7 m
Section, sampled by hand and excavator
August 1978

Overburden 0.3 m
Mineral 12.2 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Glacial sand and gravel	Gravel Gravel: coarse with fine, cobbles and small boulders common, especially in uppermost 3 m, subrounded to well rounded (tabular) psammite and meta-greywacke, (spherical) quartzite and (platy) calcareous siltstone with (spherical) gneiss, granite and diorite, some vein-quartz, red sandstone, pink felsite and yellow shelly sandstone Sand: medium with coarse and trace of fine, quartz with feldspar and rock (chiefly platy slate). Some shell debris. Neutral coloured and generally 'sharp' Fines: silt, disseminated and rarely as thin seams	12.2 +	12.5

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64
1	43	56	0.3–1.3	2	2	23	11	22	29	11
			1.3–2.3	1	2	33	13	8	31	12
			2.3–3.3	2	3	18	14	15	42	6
			3.3–4.3	2	4	29	21	18	26	0
			4.3–5.3	1	2	37	20	17	23	0
			5.3–6.3	1	1	29	20	19	30	0
			6.3–7.3	1	1	24	24	16	34	0
			7.3–9.3	Section obscured by talus						
			9.3–10.3	2	1	18	20	25	34	0
			10.3–11.3	1	1	14	14	19	33	18
			11.3–12.5	1	1	19	14	19	35	11
			Mean	1	2	24	17	18	32	6

NK 03 SW 13* 0458 3420 Gravel pit, Lochlundie, Slains BLOCK D

Surface level + 74 m (+ 242.5 ft)
Water struck at + 69.9 m
Section, sampled by hand and excavator
October 1978

Overburden 0.1 m
Mineral 5.2 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, peaty	0.1	0.1
Glacial sand and gravel	Gravel Gravel: coarse with fine, coarsening downwards with numerous cobbles and small boulders, angular to subrounded (tabular) psammite, schist and slate, with (spherical) subrounded to well rounded gneissose psammite, diorite, vein-quartz, pink granite and gneiss. Knotted slates and schist (platy) common in fine. Schist generally 'rotten' Sand: coarse with medium and some fine, coarsening downwards, angular to subrounded, 'sharp', quartz, feldspar and (platy) slate, rusty orange-brown Fines: disseminated peaty silt and some clay	5.2 +	5.3

GRADING ϕ

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
3	23	74	0.1–1.1	4	3	11	19	25	38	0
			1.1–2.1	2	2	6	10	22	48	10
			2.1–3.1	3	2	6	15	28	37	9
			3.1–5.3	2	0	5	16	29	32	16
			Mean	3	1	7	15	27	37	10

ϕ As noted in the text, there may be a significant underestimate of material greater than 64 mm in diameter

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NK 03 NE 2 0560 3845 Tippet Hill, near Hatton, Cruden BLOCK C

Surface level + 60 m (197 ft)
Groundwater level c + 55 m
250 mm and 200 mm percussion and shell
August 1978

Overburden 0.9 m
Mineral 7.6 m
Waste 2.3 m
Bedrock 1.0 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Till	Clay, slightly sandy, rust-coloured, containing cobbles of pelitic schist	0.7	0.9
Glacial sand and gravel	Sand Gravel: fine with coarse, subrounded to rounded, varied composition including granite, vein-quartz, igneous rocks and flint Sand: medium with fine and some coarse, generally subangular to rounded, 'soft', quartz with feldspar, mica and mafic minerals Fines: silt, disseminated, red-brown	7.6	8.5
	Silt and clay, interlaminated with thin seams of sandy silt, pale orange-brown becoming grey-brown below 9.0 m	1.5	10.0
Till	Clay, sandy and silty with stones less than 64 mm diameter, grey-brown	0.8	10.8
Dalradian	Andalusite/cordierite schist, quartzo-feldspathic, considerably jointed	1.0 +	11.8

(continued)

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
6	90	4	0.9–1.9	15	62	16	3	1	3	0	
			1.9–2.9	7	29	60	3	1	0	0	
			2.9–3.9	9	45	42	4	0	0	0	
			3.9–4.9	5	21	64	9	1	0	0	
			4.9–5.9	3	9	46	31	11	0	0	
			5.9–6.9	2	11	79	5	3	0	0	
			6.9–7.9	2	4	71	18	4	1	0	†
			7.9–8.5	2	6	60	18	9	5	0	†
			Mean	6	24	55	11	3	1	0	

NK 03 NE 3 0592 3766 Midmill, near Hatton, Cruden BLOCK D

Surface level +53 m (+ 174 ft)
Water not encountered
250 mm and 200 mm percussion and shell
August 1978

Waste 16.2 m
Bedrock 0.5 m +

LOG

Geological classification		Lithology	Thickness m	Depth m
		Soil, clayey loam	0.3	0.3
Till		Clay, silty, sandy and pebbly, firm, red-brown, becoming clayey pebbly silt below 1.7 m, stones generally less than 50 mm. Fine to medium grained sand between 1.5 m and 1.7 m	2.0	2.3
		Clay, becoming increasingly sandy and gravelly downwards, firm, rare cobbles, pale brown	2.4	4.7
Glacial sand and gravel	a	Sand, fine and medium with some coarse, chiefly angular to subangular, quartz with feldspar, mica and rock. Fines chiefly of silt	1.2	5.9
Till		Clay, stony (0.1 m) passing downwards into an alternating sequence of clayey pebbly silt and well sorted fine sand, micaceous. Mid-brown	1.6	7.5
Glacial sand and gravel	b	Sand and gravel, buff coloured. Gravel: coarse and fine with cobbles, subrounded to well rounded, granite, schist, gneiss and flint. Sand: coarse and medium with fine, 'sharp', quartz, feldspar and rock. A little disseminated silt	1.2	8.7
Till		Clay, gravelly, silty, firm, mid-brown becoming grey (and stiff) by 9.0 m	3.7	12.4
Glacial sand and gravel	c	Sand and gravel, pale yellow-brown Gravel: coarse and fine, rare cobbles, subangular to well rounded flint and quartzites with psammite, metagreywacke and some granite, schist and pelite Sand: fine, medium and coarse, 'sharpish', quartz and rock with feldspar. Some clayey bands and disseminated silt throughout	3.8	16.2
Dalradian		Pelitic (andalusite) schist, fine to coarse grained, crenulate cleavage displaying micaceous sheen, some pyrite, dark grey	0.5 +	16.7

(continued)

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
					$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
a	9	90	1	4.7–5.9	9	49	36	5	1	0	0	‡
b	3	50	47	7.5–8.7	3	6	16	28	19	9	19	‡
c	5	56	39	12.4–14.0	3	17	20	20	20	20	0	† ‡
				14.0–15.0	9	20	21	16	12	22	0	† ‡
				15.0–16.2	5	16	23	16	14	18	8	† ‡
				Mean	5	17	21	18	16	20	3	
a to c	5	61	34	Mean	5	21	23	17	14	14	6	

‡ Non-mineral: not considered in calculation of mean grading

NK 03 NE 4 0524 3629 Stones Farm, near Hatton, Cruden BLOCK D

Surface level + 67 m (+ 219.5 ft)
Water not struck
250 mm percussion
August 1978

Waste 3.1 m
Bedrock 0.9 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Till	Clay, silty, pebbly, with sandy bands, red-brown becoming pale brown by 2.3 m	2.4	2.7
	Clay containing clasts of weathered bedrock, red-mauve	0.4	3.1
Dalradian	Schistose psammite with quartz segregations and micaceous cleavage surfaces	0.9 +	4.0

NK 03 NE 5 0583 3546 South Mains of Ardiffery, Cruden BLOCK D

Surface level + 64 m (+ 210 ft)
Groundwater level c + 61 m
250 mm percussion and shell
August 1978

Overburden 1.4 m
Mineral 2.1 m
Waste 5.5 m
Bedrock 0.5 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, very gravelly	1.0	1.0
Till	Clay, silty, sandy containing subangular clasts	0.4	1.4
Glacial sand and gravel	Gravel Gravel: fine with coarse, chiefly subangular psammite and metagreywacke with rare quartzite, porphyry and granite Sand: coarse with medium and some fine, angular to subrounded rock, quartz and feldspar Fines: silt and clay, reddish brown, present particularly between 1.8 m and 1.9 m. Fines lost due to shelling	2.1	3.5
Till	Clay, silty and sandy with stones mainly less than 40 mm, firm to stiff, dark red-brown at top becoming mid to dark grey, metagreywacke, schist, granite and miscellaneous igneous	5.5	9.0
Dalradian	Andalusite schist, psephitic bands, quartz veining, rodded, locally micaceous, blue-grey, hard without obvious jointing	0.5 +	9.5

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
1	45	54	1.4–2.4	1	2	11	29	39	18	0	†
			2.4–3.5	1	2	14	31	39	13	0	†
			Mean	1	2	13	30	39	15	0	

NK 03 NE 6 0689 3826 Hardhill, Cruden BLOCK D

Surface level + 43 m (+ 141 ft)
Groundwater level + 40.8 m
250 mm and 200 mm percussion and shell
September 1978

Waste 14.4 m
Bedrock 0.6 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Till (including glaciolacustrine deposits)	Clay, silty, becoming increasing sandy downwards, pebbly, soft to firm, red-brown. Thin seams of brown, micaceous, well sorted sand	1.9	2.2
	Silt, clayey, with fine sand, soft, red-brown	0.9	3.1
	Clay, silty, sandy, pebbly, soft to firm, yellow-brown becoming medium to dark blue-grey by 3.3 m	1.9	5.0
	Clay, silty, some fine gravel and coarse sand, stiff to very stiff, medium to dark blue-grey	8.3	13.3
	Clay, very sandy, greenish yellow-brown	1.1	14.4
Dalradian	Gneiss (?), recovered as a sand comprising feldspar, quartz and biotite	0.6 +	15.0

NK 03 NE 7 0607 3675 Mains of Ardiffery, near Hatton BLOCK D

Surface level + 72 m (+ 236 ft) Waste 18.0 m +
Groundwater levels at 65.2 m and 63.2 m
250 mm and 200 mm percussion and shell
September 1978

LOG

Geological classification		Lithology	Thickness m	Depth m
		Soil	0.2	0.2
Till		Clay, silty and pebbly, becoming sandy by 1.8 m, stiff red-brown (yellow-brown between 1.8 m and 2.4 m)	3.6	3.8
		Sand, silty, pebbly, slightly cohesive, 'soft', yellow-brown	0.3	4.1
		Clay, silty, sandy and pebbly, stiff, red-brown, micaceous	1.7	5.8
Glaciolacustrine deposits		Silt with fine sand becoming more sandy downwards, red-brown, seams of clay	1.5	7.3
		Clay (till) as between 4.1 m and 5.8 m including 0.2 m bed of sand with fine gravel between 8.1 m and 8.3 m	1.5	8.8
	a	Sand with some fine gravel. Gravel composed of psammite, metagreywacke, quartzite and vein-quartz with pink granite and calcareous siltstone. Medium with fine and coarse sand	0.9	9.7
		Clay (till), as between 4.1 m and 5.8 m, very stiff	0.5	10.2
		Sand, as between 8.8 m and 9.7 m	0.2	10.4
		Clay, silty, thinly laminated, red-brown	0.1	10.5
	b	Sand with trace of fine gravel. Medium and fine grained, 'soft', pale brown	1.5	12.0
		Clay (till), silty and sandy, stiff, red-brown	1.4	13.4
		Interbedded clayey silt, silty clay, clayey fine/medium grained sand and fine with medium, well sorted sand, reddish browns and pale brown	2.8	16.2
Till		Clay, silty and pebbly, containing some mica, red-brown	1.8 +	18.0

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
					$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
a	5	86	9	8.8–9.7	5	23	40	23	9	0	0	†‡
b	9	90	1	10.5–12.0	9	31	54	5	1	0	0	†‡
a&b	7	89	4	Mean	7	28	49	12	4	0	0	

‡ Non-mineral: not considered in calculation of mean grading

NK 03 NE 8 0681 3641 Howe of Doubledirks, Cruden BLOCK D

Surface level + 35 m (+ 115 ft)
Groundwater level + 26.4 m
250 mm and 200 mm percussion and shell
August 1978

Waste 9.4 m
Bedrock 0.6 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, silty loam, red-brown	0.3	0.3
Glaciolacustrine deposits	Silty with fine sand, micaceous, red-brown, thin seams of red-brown clay	4.2	4.5
	Silt, interbedded with seams of clay up to 150 mm thick. Silt a reddish brown, clay chocolate brown or red-brown	4.7	9.2
Till	Clay, stony, containing fragments of metagreywacke	0.2	9.4
Dalradian	Andalusite-quartz-mica schist, very hard, strongly jointed, grey-brown	0.6 +	10.0

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
64	36	0	0.3–1.3	61	38	1	0	0	0	0	‡
			1.3–2.3	No grading data available							
			2.3–3.3	69	31	0	0	0	0	0	‡
			3.3–4.5	63	37	0	0	0	0	0	‡
			Mean	64	36	0	0	0	0	0	

‡ Non-mineral: not considered in calculation of mean grading

NK 03 NE 9 0767 3966 East Teuchan, Cruden BLOCK D

Surface level + 57 m (+ 187 ft)
Groundwater level + 46.1 m
250 mm and 200 mm percussion and shell
September 1978

Waste 14.1 m
Bedrock 0.3 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.5	0.5
Till	Clay, silty, pebbly bands, firm to stiff, mottled grey becoming red-brown by 0.8 m. Thin seams of brown, micaceous, silty fine sand	2.5	3.0
Glaciolacustrine deposits	Clay, silty, some fine sand, firm to stiff, red-brown. Thin seams olive-grey, micaceous, silty fine sand and brown, well sorted, micaceous, fine sand	4.4	7.4
Till	Clay, some sand and fine gravel, stiff, red-brown	1.3	8.7
	Clay, silty, sandy, pebbly becoming more gravelly downwards, stiff to very stiff, dark grey. Silt with fine sand between 10.9 and 11.1 m, medium dark grey. Clay-bound sand and gravel between 12.7 and 13.1 m	4.9	13.6
Glacial sand and gravel	Sand and gravel Gravel: fine and coarse, some cobbles, well rounded quartzite, vein-quartz and flint, subangular to subrounded pink granite, quartzite, schist, psammite and grit. Much angular psammite and quartz in fine gravel. Sand: coarse with medium and fine, 'sharp', quartz, feldspar, pelitic schist and psammite Fines: silt and clay, brownish grey	0.5	14.1

(continued)

Geological classification	Lithology	Thickness m	Depth m
Caledonian	Granite, pink, medium to coarse grained, decomposed to sand although individual grains are fresh	0.3 +	14.4

NK 03 NE 10 0795 3781 Auchiries, Cruden BLOCK D

Surface level + 41 m (+ 134.5 ft)
Water struck at + 37.9 m
250 mm percussion and shell
September 1978

Waste 3.1 m
Bedrock 2.2 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Till	Clay, silty with scattered fine gravel, firm, red-brown. Thin seams of micaceous silt	2.8	3.1
Caledonian	Granite, pink, medium to coarse grained, decomposed to sand although individual grains are fresh	2.2 +	5.3

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
3	80	17	3.1–5.3	3	8	24	48	17	0	0	† ‡

‡ Non-mineral: not considered in calculation of mean grading

NK 03 NE 11 0768 3662 Nethermill, Cruden BLOCK D

Surface level + 30 m (+ 98.5 ft)
Groundwater level + 21.3 m
250 mm and 200 mm shell
September 1978

Overburden 0.3 m
Mineral 4.9 m
Waste 7.0 m
Bedrock 0.2 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Fluvioglacial sand and gravel	Sandy gravel Gravel: coarse and fine, with cobbles, subangular to subrounded psammite, meta-greywacke and quartzite with red granite, gneiss, red sandstone and well rounded white quartzite and vein-quartz Sand: medium with coarse and some fine; angular to subrounded with coarse more angular than fine, chiefly quartz with rock fragments contributing to the coarse fraction. Buff coloured Fines: a little silt, disseminated	4.9	5.2
Glaciolacustrine deposits	Silt with fine sand passing downwards into silty sandy clay, faintly laminated, micaceous, red-brown	0.9	6.1
	Clay, silty, firm becoming stiff downwards, micaceous, red-brown. Thin seams of fine grained, pale brown sand and clayey silt	5.9	12.0
Till	Clay, sandy, stiff, yellow-brown	0.2	12.2
Caledonian	Granite, coarse grained, pink	0.2 +	12.4

(continued)

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
Fines	Sand	Gravel		Fines	Sand			Gravel			
				$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
2	53	45	0.3–1.3	2	5	21	21	23	20	8	†
			1.3–2.3	1	2	26	27	16	16	12	†
			2.3–3.3	1	5	37	25	14	18	0	†
			3.3–5.2	2	6	29	12	11	26	14	†
			Mean	2	5	28	20	15	21	9	

NK 03 NE 12 0711 3557 Parsonage Farm, Cruden BLOCK D

Surface level + 58 m (+ 190 ft)
Groundwater level + 53.2 m
200 mm percussion and shell
October 1978

Waste 7.6 m
Bedrock 0.4 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Till (including glacio-lacustrine deposits	Clay, silty, becoming increasingly sandy downwards, scattered fine gravel, stiff becoming firm downwards, red-brown. Whisps of pale brown, micaceous, silty and fine grained sand	6.4	6.7
	Clay, silty, sandy, gravelly, stiff, dark blue-grey	0.9	7.6
Dalradian	Semipelitic gneiss, fine to medium grained, quartz segregations, micaceous cleavage surfaces, dark grey weathering ochreous brown, crumbly becoming harder downwards	0.4 +	8.0

NK 03 NE 13 0895 3719 Errollston, Cruden BLOCK D

Surface level + 25 m (+ 82 ft)
Groundwater level + 21.8 m
250 mm and 200 mm percussion and shell
September 1978

Waste 20.0 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Till (including glacio-lacustrine deposits)	Clay, silty, a little coarse sand and fine gravel, firm to stiff, red-brown. Whisps of brown, micaceous, silty fine-grained sand. Rare seams of red-brown, clay-bound sand and gravel	9.3	9.6
	Clay, silty, sandy, pebbly, micaceous, soft to firm, red-brown, rough lamination	2.8	12.4
	Clay, silty, pebbly, some sand, firm to stiff, red-brown. Whisps of brown, micaceous, silty, fine-grained sand. Mixed with dark grey gravelly till between 13.6 and 14.6 m	7.6 +	20.0

NK 03 NE 14 0858 3555 Golf Links, Cruden Bay BLOCK D

Surface level + 3 m (+ 10 ft)
Water struck at + 0.6 m
200 mm percussion and shell
September 1978

Mineral 12.5 m
Waste 3.5 m +

LOG

Geological classification		Lithology	Thickness m	Depth m
Blown sand	a	Sand Sand: fine with medium, well sorted, 'soft', quartzose, pale yellow-brown Fines: a little silt, disseminated	4.4	4.4
Post-Glacial beach deposits	b	Sand Sand: fine with some medium, 'soft', medium grey, including shell debris Fines: a little silt, disseminated	5.0	9.4
	c	Sandy gravel Gravel: fine with coarse becoming coarser towards base where cobbles are present, subrounded to well rounded psammite, metagreywacke, slate red granite and quartzite Sand: medium with fine and coarse, chiefly subangular quartz and pink feldspar Fines: very little but responsible for medium grey coloration	3.1	12.5
Till		Clay, silty, sandy and pebbly, firm to stiff, micaceous, roughly laminated in parts, red-brown, becoming more sandy downwards with discrete seams (10 cm) of pale brown sand	3.5 +	16.0
		Borehole abandoned owing to slow progress and technical difficulties		

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
a	2	98	0	0.0–2.4	1	51	48	0	0	0	0	
				2.4–4.4	3	86	11	0	0	0	0	†
				Mean	2	67	31	0	0	0	0	
b	2	98	0	4.4–5.4	2	81	17	0	0	0	0	†
				5.4–6.4	1	77	22	0	0	0	0	†
				6.4–7.4	2	58	40	0	0	0	0	†
				7.4–8.4	1	88	11	0	0	0	0	†
				8.4–9.4	2	80	18	0	0	0	0	†
				Mean	2	77	21	0	0	0	0	
c	2	72	26	9.4–10.4	4	25	53	13	5	0	0	†
				10.4–11.5	2	17	60	14	6	1	0	†
				11.5–12.5	trace	7	13	13	22	45	0	†
				Mean	2	16	43	13	11	15	0	
a to c	2	91	7	Mean	2	58	30	3	3	4	0	

NK 03 NE 15* 0536 3706 Sand Pit, Hatton, Cruden BLOCK C

Surface level + 54 m (+ 177 ft)
Water not struck
Section, sampled by hand and excavator
August 1978

Overburden 0.5 m
Mineral 17.3 m +

LOG

Geological classification		Lithology	Thickness m	Depth m
		Soil, gravelly loam	0.5	0.5
Glacial sand and gravel	a	Sandy gravel (upper 2.0 m slightly clay-bound) Gravel: fine to coarse, scattered cobbles, angular to subrounded metagreywacke and slate (tabular or flaky), and subrounded to well rounded spherical quartzite and psammite with some gneiss and vein-quartz. Sand: medium with coarse and fine, coarse chiefly composed of angular quartz and feldspar, otherwise chiefly subangular to subrounded quartz Fines: clay and disseminated silt. Thin seams of red-brown, micaceous silt below 2.5 m. Rusty orange-brown becoming yellow-brown	4.0	4.5
	b	'Clayey' sand Gravel: fine, restricted to between 14.2 and 15.2 m, subangular flint and vein-quartz and subrounded to well rounded psammite, metagreywacke and quartzite with some calcareous siltstone Sand: chiefly fine and medium with a little coarse but relative proportions vary down section, generally buff or yellow-brown, 'soft' and micaceous with shell debris present below 16.4 m Fines: chiefly silt, disseminated or as discrete seams, often laminated, micaceous and either red-brown or pale yellow. Thin seams of clay towards base. Deposit slightly clay-bound between 14.2 and 15.2 m (Till, pebbly, sandy, stiff, green-grey between 12.5 and 13.0 m and between 15.2 and 15.4 m)	13.3 +	17.8

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
a	9	59	32	0.1–1.5	6	5	12	14	28	35	0
				1.5–2.5	8	9	34	21	16	12	0
				2.5–3.5	15	20	49	9	3	4	0
				3.5–4.5	7	16	34	12	13	18	0
				Mean	9	13	32	14	15	17	0
b	15	83	2	4.5–5.5	16	67	16	1	0	0	0
				5.5–6.5	8	30	54	5	1	2	0
				6.5–7.5	2	17	69	9	3	0	0
				7.5–8.5	17	30	44	6	3	0	0
				8.5–9.5	10	55	34	1	0	0	0
				9.5–10.5	20	40	35	3	2	0	0
				10.5–11.5	22	40	30	5	3	0	0
				11.5–12.5	23	35	31	6	4	1	0
				12.5–13.0	Till: non-mineral						
				13.0–14.2	23	70	7	0	0	0	0
				14.2–15.2	15	51	26	4	2	2	0
				15.2–15.4	Till: non-mineral						
				15.4–16.4	26	66	8	0	0	0	0
				16.4–17.8	6	50	43	1	0	0	0
				Mean	15	47	33	3	1	1	0
a&b	14	77	9	Mean	14	38	33	6	5	4	0

NK 03 SE 1 0588 3327 Broadmuir Cruden BLOCK D

Surface level + 73 m (+ 239.5 ft)
Water not struck
250 mm and 200 mm percussion and shell
August 1978

Overburden 2.2 m
Mineral 7.8 m
Waste 0.5 m
Bedrock 0.5 m +

LOG

Geological classification		Lithology	Thickness m	Depth m
		Soil	0.4	0.4
Till		Clay, silty, sandy with sporadic fine pebbles, firm to stiff, red-brown	1.8	2.2
Glacial sand and gravel	a	'Clayey' gravel (clay-bound) Gravel: coarse and fine, rare cobbles, angular to subrounded psammite, meta-greywacke and schist, subrounded to well rounded quartzite with some vein-quartz Fines: clay, red to yellow-brown	1.8	4.0
	b	Gravel Gravel: fine with coarse, rare boulders, chiefly angular to subrounded, dark grey psammite or metagreywacke Sand: coarse with medium and some fine, chiefly rock fragments with vein-quartz, quartz and some feldspar Fines: silt, disseminated	6.0	10.0
Till		Clay, gravelly, sandy, silty, stiff, brown-grey	0.5	10.5
Dalradian		Schistose metagreywacke, poorly developed crenulate cleavage displaying micaceous sheen, very hard, medium grey weathering to ochreous brown	0.5 +	11.0

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
					$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64	
a	12	29	59	2.2–3.1	9	7	6	8	12	35	23	
				3.1–4.0	15	7	12	18	27	21	0	
				Mean	12	7	9	13	20	28	11	
b	2	33	65	4.0–5.0	1	3	11	23	48	14	0	†
				5.0–6.0	2	2	10	16	43	27	0	†
				6.0–7.0	1	2	4	15	52	26	0	†
				7.0–8.0	4	8	24	22	36	6	0	†
				8.0–9.0	1	6	17	15	29	32	0	†
				9.0–10.0	0	2	8	14	39	37	0	†
				Mean	2	4	12	17	41	24	0	
a&b	4	33	63	Mean	4	5	12	16	36	25	2	

NK 03 SE 2 0527 3246 West Broadleyhill, Slains BLOCK D

Surface level + 59 m (+ 193.5 ft)
Water struck at + 57 m and + 47 m
250 mm and 200 mm percussion and shell
August 1978

Overburden 2.0 m
Mineral 1.2 m
Waste 3.8 m
Mineral 8.0 m
Bedrock 0.5 m +

LOG

Geological classification		Lithology	Thickness m	Depth m
		Soil and made-ground	0.3	0.3
Till		Clay, silty with rare sand and fine gravel, firm, tenaceous, micaceous, red-brown	1.7	2.0
Glaciolacustrine deposits	a	'Clayey' sand (unconsolidated) Sand: fine with trace of medium, micaceous, red-brown Fines: silt and some clay, the latter increasing downwards	1.2	3.2
		Silty sand, as above but non-mineral	0.9	4.1
Till		Clay, silty, some sand and fine gravel, stiff becoming very stiff, red-brown	2.9	7.0
Glaciolacustrine deposits	b	'Clayey' sand (non-mineral between 8.0 m and 9.0 m) Gravel: some fine and coarse gravel below 9.0 m, pelitic schist and metagreywacke Sand: chiefly fine above 9.0 m, becoming fine with medium and trace of coarse, coarse sand is angular to subangular, quartz with slate and shell fragments, micaceous, red-brown Fines: silt, disseminated, and infrequent thin seams of clay	5.0	12.0
Glacial sand and gravel	c	'Clayey' sandy gravel Gravel: coarse and fine, cobbles towards base, subangular to well rounded (fine gravel more angular), chiefly psammite, metagreywacke, quartzite and (platy) knotted slate, some vein-quartz, schist, ?diorite and cream-coloured calcareous siltstone Sand: medium with fine and coarse (chiefly fine between 13.0 m and 14.0 m), coarse grains angular to subrounded, chiefly slate with quartz and feldspar Fines: silt, disseminated, red-brown becoming yellowish-brown. Seams of silt between 13.0 m and 14.0 m.	3.0	15.0
Dalradian		Schistose grit (metagreywacke), quartz veining, very hard, medium to dark grey, grains of quartz and pink ?feldspar	0.5 +	15.5

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
a	17	81	2	2.0–3.2	17	75	5	1	1	1	0	†
				3.2–4.1	44	55	1	0	0	0	0	† ‡
b	19	78	3	7.0–8.0	16	77	6	1	0	0	0	†
				8.0–9.0	57	40	3	0	0	0	0	† ‡
				9.0–10.0	13	46	32	3	1	5	0	†
				10.0–11.0	33	37	25	2	1	2	0	†
				11.0–12.0	12	46	33	6	2	1	0	†
				Mean	19	51	24	3	1	2	0	
c	14	53	33	12.0–13.0	4	13	21	18	19	25	0	†
				13.0–14.0	32	44	11	4	3	6	0	†
				14.0–15.0	5	18	18	13	22	24	0	†
				Mean	14	25	17	11	15	18	0	
a to c	16	70	14	Mean	16	45	19	6	6	8	0	

‡ Non-mineral: not considered in calculation of mean grading

NK 03 SE 3 0515 3088 Clochtow, Slains BLOCK D

Surface level + 55 m (+ 180.5 ft)
Water struck at c + 35.5 m
250 mm and 200 mm percussion and shell
August 1978

Overburden 1.4 m
Mineral 1.0 m
Waste 1.0 m
Mineral 5.6 m
Waste 10.5 m
Mineral 5.5 m +

LOG

Geological classification		Lithology	Thickness m	Depth m
		Soil and made-ground	1.4	1.4
Glaciolacustrine deposits	a	'Very clayey' pebbly sand Gravel: fine and coarse, some cobbles, subangular to subrounded psammite and metagreywacke Sand: fine, with medium and some coarse, 'soft', micaceous. Bands of buff coloured, well sorted, medium grained sand Fines: much silt, disseminated, some clay	1.0	2.4
		Silty pebbly sand, as above but non-mineral	1.0	3.4
	b	Sand Sand: fine with trace of medium, well sorted, 'soft,' some mica Fines: silt, disseminated, and as discrete seams below 8.0 m, red-brown to buff	5.6	9.0
		Interbedded silt, clayey silt and silty fine sand, micaceous, red-brown with thin seams of tenaceous silty clay	4.5	13.5
		Clay, silty, stiff, red-brown, interbedded with clayey silt	6.0	19.5
Glacial sand and gravel	c	Sand Sand: fine and medium with a trace of coarse, well sorted, some mica, buff coloured. Chiefly quartz with some shell debris. (Rare pebbles, less than 20 mm) Fines: silt, disseminated	5.5 +	25.0

GRADING

	Mean for deposit *percentages*			Depth below surface (m)	*percentages*							
	Fines	Sand	Gravel		Fines	Sand			Gravel			
					$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64	
a	40	50	10	1.4–2.4	40	31	16	3	6	4	0	
				2.4–3.4	48	44	4	1	1	2	0	‡
b	9	91	0	3.4–4.7	6	80	14	0	0	0	0	†
				4.7–6.0	5	86	9	0	0	0	0	†
				6.0–7.0	6	92	2	0	0	0	0	†
				7.0–8.0	7	92	1	0	0	0	0	†
				8.0–9.0	23	76	1	0	0	0	0	†
				Mean	9	85	6	0	0	0	0	
				10.0–11.0	48	52	0	0	0	0	0	†‡
c	6	94	0	19.5–20.5	7	40	52	1	0	0	0	†
				20.5–21.5	5	41	53	1	0	0	0	†
				21.5–22.5	7	62	31	0	0	0	0	†
				22.5–23.5	5	43	50	2	0	0	0	†
				23.5–25.0	6	45	47	2	0	0	0	†
				Mean	6	46	47	1	0	0	0	
a to c	10	89	1	Mean	10	63	25	1	1	0	0	

† ‡ Non-mineral: not considered in calculation of mean grading

NK 03 SE 4* 0634 3462 Hill of Mulonachie, Cruden BLOCK D

Surface level + 80 m (+ 262.5 ft)
Water struck at 76.5 m
Section sampled by excavator
October 1978

Mineral 1.6 m
Waste 1.7 m
Bedrock 0.2 +

LOG

Geological classification	Lithology	Thickness m	Depth m
Glacial sand and gravel	Gravel Gravel: coarse and fine, some cobbles and small boulders, chiefly angular to subrounded,(tabular) psammite, metagreywacke and (platy) andalusite schist, some vein-quartz and rare microgranite Sand: coarse with medium and some fine, predominantly angular psammite Fines: deposit is slightly cohesive owing to cuticles of clay. Quite clayey below 1.2 m and red-brown	1.6	1.6
	Silt, clayey, some fine grained sand, soft, micaceous, faintly laminated, yellow to red-brown	0.8	2.4
Till	Clay, gravelly, very stiff, olive-grey	0.9	3.3
Dalradian	Schistose psammite, fine grained, very hard, medium grey weathering to ochreous brown	0.2 +	3.5

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
6	31	63	0.0–1.6	6	4	10	17	29	34	0

NK 03 SE 5 0620 3166 Mid Newclochtow, Slains BLOCK D

Surface level + 44 m (+ 144.5 ft)
Water not struck
200 mm percussion
October 1978

Waste 4.4 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
Till	Clay, gravelly, becoming increasingly sandy downwards, stiff becoming firm, red-brown. Some laminae of micaceous, pale brown silt	4.0 +	4.4
	Borehole abandoned owing to rock obstruction		

NK 03 SE 6 0748 3300 West Sandend, Cruden BLOCK D

Surface level + 55 m (+ 180.5 ft)
Water not struck
250 mm percussion
October 1978

Waste 5.5 m
Bedrock 0.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Till	Clay, pebbly, stiff to very stiff, red-brown	5.0	5.2
	Clay, very sandy, stony, pale brown	0.3	5.5
Dalradian	Metagreywacke, containing clasts of white quartz up to 5 mm, knotting in pelitic bands, very hard, dark grey	0.1 +	5.6

NJ 92 NE P1 9672 2998 Cromleybank, Ellon BLOCK B

Surface level c + 15 m (c + 49 ft)
Water not struck
Pit
November 1978

Overburden 0.2 m
Mineral 2.8 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Fluvioglacial sand and gravel	Gravel (very compact) Gravel: numerous cobbles and boulders up to 1 m diameter, also coarse and fine gravel, subrounded to well rounded psammite, gneiss, red granite, quartzite and metagreywacke with schist, slate and vein-quartz. Slate relatively more common in fine gravel Sand: predominantly coarse, angular to subrounded quartz and feldspar with well rounded slate, quartz, psammite and felsite. Grey-brown Fines: deposit is bound by iron-stained silt in uppermost metre, otherwise a little disseminated silt	2.8 +	3.0

GRADING ϕ

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64
5	16	79	0.2–1.2	12	1	4	13	24	18	28
			1.2–2.2	2	1	2	13	26	37	19
			2.2–3.0	1	1	2	11	27	36	22
			Mean	5	1	3	12	26	30	23

ϕ As noted in the text, there may be a significant underestimate of material greater than 64 mm in diameter

NJ 92 NE P2 9930 2867 Tarty Plantation, Logie Buchan BLOCK B

Surface level c + 13 m (c + 43 ft)
Water not struck
Pit
November 1978

Overburden 0.1
Mineral 2.9 +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.1	0.1
Fluvioglacial sand and gravel	Gravel (consolidated) Gravel: coarse and fine, cobbles and small boulders common, chiefly subrounded to well rounded with some subangular quartzites, psammite, metagreywacke, gneiss and some pink granite, vein-quartz, pelitic schist and slate Sand: coarse with medium and some fine, angular to well rounded, rock with quartz and feldspar, grey-brown Fines: silt, disseminated. Slightly clayey above 0.6 m	2.9 +	3.0

GRADING ϕ

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64
2	27	72	0.1–1.1	1	2	12	21	27	37	0
			1.1–2.1	1	1	6	16	24	46	6
			2.1–3.0	3	2	5	15	29	34	12
			Mean	2	2	8	17	27	39	6

ϕ As noted in the text, there may be a significant underestimate of material greater than 64 mm in diameter

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NJ 93 SW P1 9072 3389 Gravel Pit, Michael Muir, Ellon BLOCK A

Surface level + 21 m (+ 69 ft)
Groundwater level + 19.7 m
Pit
November 1978

Mineral 1.3 m
Waste 1.7 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
Fluvioglacial sand and gravel	Gravel (No grading data available) Gravel: coarse and fine, cobbles and small boulders, subrounded to well rounded with fine gravel more angular than coarse, psammite, quartzites, metagreywacke, gneiss, pink granite, vein-quartz and (platy) pelitic schist and slate, the last two most common in fine Sand: medium with coarse and some fine, subangular to subrounded psammite, (platy) pelitic schist and slate, quartz and some feldspar. Brown-grey Fines: a little silt, disseminated	1.3	1.3
Glaciolacustrine deposits	Interlaminated silty clay and clay with silt and fine sand, micaceous partings. Yellow-brown with red-brown laminae, becoming generally bluish grey. Firm	1.5	2.8
Till	Clay, very gravelly but with little sand, stiff, bluish medium grey	0.2 +	3.0
	(Pit sited within old gravel working, approx. 3 m sand and gravel removed)		

NJ 93 SW P2 9057 3361 Gravel pit, Waulkmill Hill, Ellon BLOCK A

Surface level c + 16 m (c + 52 ft)
Groundwater level c + 13 m
Pit
November 1978

Overburden 0.2 m
Mineral 3.0 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Fluvioglacial sand and gravel	Gravel Gravel: coarse with fine, numerous cobbles and boulders up to 400 mm, coarse gravel well rounded, fine gravel subangular to well rounded, metagreywacke, psammite, quartzite, red granite, gneiss, vein-quartz, diorite and (tabular) knotted pelitic schist and slate Sand: medium with coarse, little fine, chiefly subrounded to well rounded, (platy) slate, psammite and vein-quartz, otherwise mainly quartz with some feldspar, yellow-grey to brown Fines: silt, disseminated. Iron-pan binding deposit down to 2.5 m	3.0 +	3.2

GRADING ϕ

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
1	26	73	0.1–1.2	1	2	15	14	15	28	25
			1.2–2.2	2	1	11	11	23	35	17
			2.2–3.2	1	2	13	8	17	46	13
			Mean	1	2	13	11	18	36	19

ϕ As noted in the text, there may be a significant underestimate of material greater than 64 mm in diameter

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NJ 93 NE P1 9865 3939 Mosstown of Dudwick, Ellon BLOCK C

Surface level c + 116 m (c + 381 ft)
Water not struck
Pit
December 1978

Waste 1.0 m
Bedrock 1.0 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, black, gravelly with well rounded flint, white quartzite and vein-quartz	0.2	0.2
Till	Clay, sandy, silty, some pebbles, micaceous, crumbly, pale yellow-brown. Angular, weathered schist and rare, well rounded quartzite	0.8	1.0
Dalradian	Quartz-mica schist, medium grained, deeply weathered to a pale grey and yellow speckled micaceous clay	1.0 +	2.0

NJ 93 NE P2 9899 3909 Den of Auldmaling, Ellon BLOCK C

Surface level c + 101 m (c + 331 ft)
Water not struck
Pit
December 1978

Waste 2.7 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, black, peaty, gravelly	0.2	0.2
'Float'	Clay, loamy with well rounded pebbles and cobbles of pale grey quartzite, vein-quartz and flint	0.7	0.9
Till	Clay, very sandy, silty, pebbly, crumbly to firm, orange. Chiefly angular clasts of schistose metagreywacke	1.8 +	2.7

NJ 93 NE P3 9866 3825 Backhill of Dudwick, Ellon BLOCK C

Surface level c + 146 m (c + 479 ft)
Water entering at base of pit
Pit
December 1978

Waste 0.8 m
Bedrock 1.2 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.1	0.1
Till	Clay, silty, sandy, pebbly, mottled pale grey and white, firm. Chiefly fine, well rounded pebbles of vein-quartz and angular white quartzite with some pelitic schist and slate	0.7	0.8
Dalradian	Brecciated psammite (?) with segregations of quartz and muscovite, pale green-grey weathering to shades of orange brown and yellow, badly weathered	1.2 +	2.0

NJ 93 NE P4 9855 3537 Mains of Kinmuck, Ellon BLOCK C

Surface level c + 93 m (c + 305 ft)
Water not struck
Pit
August 1978

Waste 2.1 m
Bedrock 0.3 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil and made-ground	0.3	0.3
Till	Clay, silty, very gravelly, yellowish orange-brown, clasts chiefly mica schist (gneiss)	1.8	2.1
Dalradian	Semipelitic gneiss, deeply weathered, breaking up into a micaceous sand	0.3 +	2.4

NJ 93 NE P5 9945 3732 Muirtack, Cruden BLOCK C

Surface level c + 102 m (c + 335 ft)
Water not struck
Pit
August 1978

Waste 2.4 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Till	Clay, silty, gravelly, mottled pale grey and orange. Subangular to well rounded gneiss with well rounded quartzite	1.1	1.3
	Clay, silty with lenses of fine sand, pale green-grey	0.7	2.0
Glacial sand and gravel	Sand, medium to fine grained, 'soft', greenish pale grey. Some lumps of till as above	0.4 +	2.4

NJ 93 NE P6 9961 3621 Mill of Kinmuck, Ellon BLOCK C

Surface level c + 82 m (c + 269 ft)
Water not struck
Pit
August 1978

Waste 2.1 m
Bedrock 0.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil and made-ground	0.3	0.3
Till	Clay, silty, gravelly, yellowish orange-brown. Angular to subrounded clasts of gneiss and psammite with mica schist and well rounded pale grey quartzite	1.8	2.1
Dalradian	Semipelitic gneiss, coarse grained, biotitic, badly weathered and fractured	0.1 +	2.2

NJ 93 SE P1 9663 3088 East Industrial Estate, Ellon BLOCK C

Surface level c + 20 m (c + 66 ft)
Water not struck
Pit
August 1978

Waste 3.0 +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Till	Clay, sandy ('gritty'), gravelly, stiff, deep red-brown becoming yellowish medium grey by 1.5 m. Deeply weathered mica schist with quartzite, gneissose psammite and gneiss	2.8 +	3.0

NJ 93 SE P2 9678 3061 East Industrial Estate, Ellon BLOCK B

Surface level c + 15 m (c + 49 ft)
Dry
Trench dug for sewer
October 1978

Overburden 0.2 m
Mineral 3.0 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Fluvioglacial sand and gravel	Gravel Gravel: coarse with fine, many cobbles up to 250 mm, subrounded to well rounded, quartzites, psammite, granite, dolerite (?) gneiss, felsite and vein-quartz. Some slate in finer gravel Sand: medium with some coarse and fine, quartz with some feldspar. Slate common, especially in coarse sand, generally platy. Cemented by orange-brown iron-pan above 1.2 m, otherwise neutral colour Fines: silt and some clay above 1.2 m, some disseminated silt below (Parts of the trench revealed up to 1 m red-brown and pale grey mottled, stiff clay overlying the gravels)	3.0 +	3.2

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
2	40	58	0.2–1.2	2	1	20	7	20	42	8
			1.2–2.2	3	2	30	3	12	32	18
			2.2–3.2	1	1	50	6	9	24	9
			Mean	2	1	34	5	14	32	12

NJ 93 SE P3 9981 3195 Artrochie School House, Logie Buchan BLOCK C

Surface level c + 31 m (c + 102 ft)
Water not struck
Pit
August 1978

Waste 2.8 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Made ground	1.0	1.0
Till	Clay, silty, stony, firm to stiff, deep red-brown. Clasts up to 1.2 m diameter of schist, quartzite and vein-quartz with rare flint	1.8 +	2.8

NK 03 NW P1 0089 3978 East Backhill, Old Deer BLOCK C

Surface level + 113 m (+ 371 ft)
Water not struck
Pit and hand-auger
September 1979

Waste 6.7 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, very peaty	0.2	0.2
? Buchan Ridge gravels	Clayey silt, pale cream-coloured to white, chiefly kaolinite, crumbly becoming firmer with depth. Possibly deeply weathered granitic bedrock	6.5 +	6.7

NK 03 NW P2 0027 3903 Easter Hawkhillock, Old Deer BLOCK C

Surface level c + 102 m (c + 335 ft)
Water not struck
Pit
August 1978

Waste 0.8 m
Bedrock 0.7 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.1	0.1
Till	Clay, silty, sandy with scattered pebbles of gneiss, quartz and 'rotten' mica schist	0.7	0.8
Dalradian	Quartz-mica schist with quartz segregations, very weathered, breaking-up into a sand	1.7 +	2.5

NK 03 NW P3 0077 3830 South Hawkhillock, Old Deer BLOCK C

Surface level c + 82 m (c + 269 ft)
Water not struck
Pit
August 1978

Waste 1.4 m
Bedrock 0.4 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Till	Angular blocks of schist set in a matrix of orangey medium brown sand derived from decomposed schist. Scattered well rounded cobbles of quartzite	1.2	1.4
Dalradian	Quartz biotite schist with quartz segregations, deeply weathered	0.4 +	1.8

NK 03 NW P4 0012 3677 Hill of Auchleuchries BLOCK C

Surface level c + 94 m (c + 308 ft)
Water not struck
Pit
August 1978

Waste 1.2 m
Mineral 1.2 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, peaty	0.2	0.2
Till	Clay, silty, sandy, gravelly, crumbly, pale yellow-brown	1.0	1.2
Glacial sand and gravel	Sandy gravel Gravel: fine and coarse, cobbles and large boulders, chiefly subrounded to well rounded quartzite, gneiss and psammite with some flint and weathered mica-schist Sand: fine, medium and coarse, 'soft', pale orange-brown Fines: silt, disseminated	1.2 +	2.4

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64
9	61	30	1.2–2.4	9	23	20	18	15	15	0

NK 03 NW P5 0189 3961 Hillhead of Auquharney, Cruden BLOCK C

Surface level c + 113 m (c + 371 ft)
Water not struck
Pit
May 1978

Waste 1.6 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Peat	0.4	0.4
Till	Clay, silty, sandy, becoming increasingly gravelly downwards, firm, mottled, pale yellow-orange and pale grey. Well rounded white quartzite, vein-quartz and flint with granite and some pelitic gneiss	1.2 +	1.6

NK 03 NW P6 0176 3890 Oldtown Croft, Cruden BLOCK C

Surface level c + 86 m (c + 282 ft)
Water not struck
Pit
August 1978

Waste 2.6 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Till	Clay, sandy ('gritty'), very gravelly, firm to stiff, yellow-brown. Well rounded white quartzite, vein-quartz and flint with gneiss and psammite. Increasing content downwards of mica schist	2.4 +	2.6

NK 03 NW P7 0219 3971 Moss of Auquharney, Cruden BLOCK C

Surface level + 122 m (+ 400 ft)
Water not struck
Pit
December 1978

Waste 4.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
Peat	Peat	1.0	1.0
'Float'	Clay, gravelly, orange to yellow-orange with mottling of pale grey. Predominantly well rounded white quartzite, vein-quartz and flint	1.5	2.5
Till	Clay, sandy ('gritty'), gravelly, orange-grey, micaceous. Besides clasts described above an increasing content downwards of metagreywacke, psammite and pelitic schist	1.6 +	4.1

NK 03 NW P8 0231 3973 Moss of Auquharney, Cruden BLOCK C

Surface level + 125 m (+ 410 ft)
Water not struck
Pit
December 1978

Waste 0.8 m
Bedrock 1.2 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Peat	0.3	0.3
Till ('Float')	Clay, silty, pebbly, pale grey becoming mottled pale grey and orange below 0.5 m. Well rounded white quartzite, flint and vein-quartz	0.5	0.8
Dalradian	Semipelitic schist decomposed to clay, soft and crumbly, speckled pale yellow and pale grey	1.2 +	2.0

NK 03 NW P9 0266 3878 Earlseat, Cruden BLOCK C

Surface level c + 102 m (c + 335 ft)
Water not struck
Pit
May 1978

Waste 0.6 m
Bedrock 0.4 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.1	0.1
Till ('Float')	Clay, gravelly, tenacious, mottled pale grey and yellow-brown. Well rounded white quartzite, flint and vein-quartz	0.5	0.6
Dalradian	Pelitic gneiss, micaceous, dark green-grey deeply weathered	0.4 +	1.0

NK 03 NW P10 0322 3965 Stoneygate, Cruden BLOCK C

Surface level c + 105 m (c + 344 ft)
Water not struck
Pit
May 1978

Waste 2.0 m
Bedrock 0.2 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.1	0.1
Till ('Float')	Clay, pebbly, firm to stiff, mottled pale brown, pale grey and yellow-orange. Well rounded white quartzite, flint and vein-quartz with granite and gneiss	1.9	2.0
Dalradian	Quartz-mica schist, muscovitic with pods of quartz and feldspar, weathered	0.2 +	2.2

NK 03 NW P11 0368 3785 Yonderton, Cruden BLOCK C

Surface level c + 63 m (c + 207 ft)
Water not struck
Pit
August 1978

Overburden 0.1 m
Mineral 1.5 m
Waste 1.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.1	0.1
Glacial sand and gravel	Gravel Gravel: coarse and fine, some cobbles, subangular to subrounded with well rounded, mica-schist, gneiss, quartzite and psammite Sand: medium and coarse, some fine, chiefly angular rock, orange-brown Fines: silt, disseminated	1.5	1.6
Till	Clay, gravelly, yellowish orange-brown. Clasts chiefly of gneiss	1.1 +	2.7

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
6	31	63	0.1–1.6	6	3	15	13	22	41	0

NK 03 NW P12 0333 3556 Bogbrae, Cruden BLOCK C

Surface level c + 61 m (c + 200 ft)
Water not struck
Pit
August 1978

Overburden 1.3 m
Mineral 1.2 m
Waste 0.8 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
	Sand and gravel, well rounded pebbles, orange	0.2	0.4
Till	Clay, silty, gravelly, mottled pale grey-brown and orange	0.9	1.3
Glacial sand and gravel	'Clayey' sandy gravel Gravel: fine with coarse, chiefly subrounded to well rounded psammite, quartzite and vein-quartz Sand: medium with coarse and fine, rock and quartz, orange-brown Fines: silt, disseminated and as seams. Inclusions of till, either pale grey or red-brown	1.2	2.5
Till	Clay, gravelly, with thin seams of pale grey or yellow silty fine sand, generally grey. Clasts of gneiss, psammite, quartzites, vein-quartz and schist, rare flint	0.8 +	3.3

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
17	57	26	1.3–2.5	17	10	33	14	17	9	0

NK 03 NW P13 0476 3968 Wester Hardslacks, Cruden BLOCK C

Surface level c + 80 m (c + 262 ft)
Water at 1.7 m beneath surface
Pit
August 1978

Waste 1.3 m
Bedrock 0.6 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Till	Clay, sandy ('gritty'), gravelly, mottled medium grey and orange brown. Chiefly mica schist up to boulder size with well rounded white quartzite, vein-quartz and rare flint	1.1	1.3
Dalradian	Quartz-biotite schist with quartz segregations, weathered ochreous brown	0.6 +	1.9

NK 03 NW P14 0421 3887 Mossend, Cruden BLOCK C

Surface level c + 71 m (c + 233 ft)
Water entering at base of pit
Pit
August 1978

Waste 2.6 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Till ('Float')	Clay, gravelly, greyish orange-brown. Well rounded white quartzite and flint	2.0	2.2
Till	Clay, sandy, becoming increasingly gravelly downwards, soft, medium bluish grey. Chiefly tabular psammite	0.4 +	2.6

NK 03 NW P15 0477 3827 Midtown of Hatton, Cruden BLOCK C

Surface level c + 66 m (c + 217 ft)
Water not struck
Pit
August 1978

Waste 1.1 m
Bedrock 1.0 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil and made-ground	0.3	0.3
Till	Clay, sandy ('gritty'), gravelly, orange-brown to orange-grey. Psammite with quartzite and rare flint	0.8	1.1
Dalradian	Schistose metagreywacke, deeply weathered, crumbling to a sand, becoming harder by 2.1 m	1.0 +	2.1

NK 03 NW P16 0493 3686 Auchlethen, Hatton, Cruden BLOCK D

Surface level c + 57 m (c + 187 ft)
Water entering at base of pit
Pit
August 1978

Waste 3.2 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Till	Clay, silty, very sandy, pebbly, pale yellow-brown, containing irregularly shaped inclusions of stiff, medium grey pebbly clay. Becoming increasingly sandy downwards, soft	3.0 +	3.2

NK 03 NW P17 0430 3597 Auchenten, Cruden BLOCK D

Surface level c + 46 m (c + 151 ft)
Water not struck
Pit
October 1978

Overburden 1.5 m
Mineral 1.3 m
Waste 0.2 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
	Sand and gravel, clayey, orange-brown, chiefly subangular to subrounded quartzite, medium to coarse sand	0.4	0.7
Till	Clay, gravelly, stiff, deep red-brown	0.3	1.0
	Silty clay, clayey silt with laminae of brown, micaceous sand. Predominantly pale orange to pale brown	0.5	1.5
Glacial sand and gravel	Sandy gravel Gravel: coarse and fine, a few cobbles, subrounded to well rounded (tabular) quartzite and psammite, (spherical) granite and gneiss, and (platy) pelitic schist and slate Sand: medium with fine and coarse, subrounded to well rounded rock and quartz, pale orange-brown Fines: some silt, disseminated	1.3	2.8
Till	Clay, pebbly, firm, yellow-brown	0.2 +	3.0

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-^1/16$	$+^1/16-^1/4$	$+^1/4-1$	+1–4	+4–16	+16–64	+64
5	52	43	1.5–2.8	5	14	26	12	16	21	6

NK 03 SW P1 0029 3493 Tillybrex, Logie Buchan BLOCK C

Surface level c + 72 m (c + 236 ft)
Water not struck
Pit
December 1978

Overburden 0.2 m
Mineral 2.9 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Glacial sand and gravel	Gravel Gravel: coarse and fine, some cobbles and rare small boulders, subrounded to well rounded, psammite, metagreywacke and quartzite with some vein-quartz, gneiss, and platy quartz- mica-schist and pelitic schist (usually badly weathered). Very compact and ferruginous above 2.1 m Sand: medium to coarse becoming fine to medium downwards, chiefly quartz with well rounded coarse grains of rock. Dull orange-brown becoming yellowish medium grey Fines: silt and clay. Deposit is clay-bound above 2.1 m, becoming 'cleaner' downwards	2.9 +	3.1

(continued)

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
7	30	63	0.2–1.2	8	6	11	10	38	21	6
			1.2–2.1	6	6	14	12	27	25	10
			2.1–3.1	6	13	13	6	20	37	5
			Mean	7	8	13	9	28	28	7

NK 03 SW P2 0164 3203 Milltown of Leask, Slains BLOCK C

Surface level c + 42 m (c + 138 ft) Waste 3.0 m +
Water not struck
Pit
August 1978

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.1	0.1
Till	Clay, silty, stony, soft becoming stiff by 2.1 m, red-brown. Whisps of well sorted silty sand below 2.1 m	2.5	2.6
	Clay, sandy ('gritty'), stiff, yellowish brown	0.4 +	3.0

NK 03 SW P3 0228 3338 Home Farm of Pitlurg, Slains BLOCK C

Surface level + 56 m (+ 183.5 ft) Mineral 3.0 +
Water not struck
Pit
August 1978

LOG

Geological classification	Lithology	Thickness m	Depth m
Glacial sand and gravel	'Clayey' pebbly sand Gravel: fine with coarse, chiefly psammite and platy slate Sand: medium with fine and some coarse, fining downwards, quartz and rock, orange-brown Fines: silt, disseminated, some seams of dark grey silt, and below 2.0 m thin seams of soft clayey till	3.0 +	3.0

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
14	73	13	0.0–1.0	11	18	39	14	12	6	0
			1.0–2.0	10	24	47	11	6	2	0
			2.0–3.0	20	26	32	10	6	6	0
			Mean	14	23	39	11	8	5	0

NK 03 SW P4 0214 3265 Nether Leask, Slains BLOCK C

Surface level c + 45 m (c + 148 ft)
Water not struck
Pit
October 1978

Waste 3.2 m
Bedrock 0.3 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Till	Clay, pebbly to gravelly with fine sand, red-brown	1.5	1.8
	Clay, very sandy, variable gravel content, stiff, orange to yellow-brown	1.4	3.2
Dalradian	Schistose psammite/semipelite, fine grained, hard, fracturing into tabular blocks, pale grey weathering ochreous brown, micaceous along cleavage surfaces	0.3 +	3.5

NK 03 SW P5 0377 3372 Lochlundie Moss, Slains BLOCK D

Surface level c + 70 m (c + 230 ft)
Water not struck
Pit
August 1978

Waste 0.8 m
Bedrock 0.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Peat	0.2	0.2
Till	Clay, gravelly, very sticky, gleyed	0.6	0.8
Caledonian	Granodiorite, fresh, very hard, grey	0.1 +	0.9

NK 03 SW P6 0360 3106 South Meiklemoss, Slains BLOCK D

Surface level c + 53 m (c + 174 ft)
Water not struck
Pit
August 1978

Waste 3.4 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Till	Clay, silty, pebbly, firm, red-brown. Becoming stiff and with partings of micaceous fine-grained sand by 1.8 m. Becoming soft and very silty by 2.6 m	3.1 +	3.4

NK 03 NE P1 0557 3948 South Stonehousehill, Cruden BLOCK C

Surface level c + 70 m (c + 230 ft)
Water not struck
Pit
August 1978

Waste 2.1 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.1	0.1
'Float'	Clay, gravelly, stiff, mottled orangey pale grey and brown. Well rounded pebbles and cobbles of flint and white quartzite	0.7	0.8
Till	Clay containing fine sand and a little gravel, crumbly to stiff, large well rounded boulders of very hard quartz dolerite	1.3 +	2.1

NK 03 NE P2 0807 3655 Nethermill, Cruden BLOCK D

Surface level c + 25 m (c + 82 ft)
Water not struck
Pit
October 1978

Overburden 2.3 m
Mineral 1.0 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.1	0.1
Till	Clay, pebbly, stiff, deep red-brown	0.9	1.0
	Clay, gravelly with coarse sand, red-brown, including seams of yellow-brown sand and and gravel, very clayey, comprising deeply weathered schist and gneiss	1.3	2.3
Glacial sand and gravel	Sandy gravel Gravel: fine and coarse, subangular to well rounded quartzite and psammite with vein-quartz, gneiss and (particularly in fine) platy, pelitic schist and slate Sand: medium with coarse and some fine, well sorted, rock and quartz, the former most common in coarse sand, yellow-brown Fines: some silt, disseminated	1.0 +	3.3

GRADING

Mean for deposit *percentages*			Depth below surface (m)	*percentages*						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				$-\frac{1}{16}$	$+\frac{1}{16}-\frac{1}{4}$	$+\frac{1}{4}-1$	+1–4	+4–16	+16–64	+64
5	59	36	2.3–3.3	5	10	30	19	19	17	0

NK 03 SE P1 0630 3365 Broadmuir, Cruden BLOCK D

Surface level c + 72 m (c + 236 ft)
Water not struck
Pit
August 1978

Waste 3.0 m +

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Till	Clay, silty, pebbly, stiff, deep red-brown with whisps of fine-grained, micaceous sand. Clasts chiefly of weathered mica schist and gneiss, and psammite	2.8 +	3.0

APPENDIX G

LIST OF WORKINGS

In March 1979 two sand and gravel pits were operational on a large scale and one pit was temporarily closed; pits at other localities were known to be worked intermittently. A list of the active* and the more extensive intermittently worked† and disused‡ pits is given below.

Location	*Logged section*	*Grid reference*	*Deposits worked*
WESTERN SHEET			
Tangland (Haddo)*	83 NE 8	NJ 8851 3576	Fluvioglacial terrace
Mill of Schivas†	83 NE 9	NJ 8942 3575	Fluvioglacial terrace
Waulkmill Hill*	93 SW 3	NJ 9115 3311	Fluvioglacial terrace
Upper Ardlethen†	—	NJ 9180 3185	Fluvioglacial terrace
Upper Ardlethen‡	—	NJ 9205 3200	Fluvioglacial terrace
Waterton†	93 SE 10	NJ 9686 3060	Fluvioglacial terrace
Deepheather‡	93 NE 5	NJ 9787 2902	Fluvioglacial terrace
Mosslip (Windyhills)†	—	NJ 7932 3934	Windyhills gravels
EASTERN SHEET			
Tillybrex†	03 SW 1	NK 0005 3489	Glacial sand and gravel
Oldtown†	03 NW 7	NK 0187 3847	Glacial sand and gravel
Hatton†	03 NE 15	NK 0536 3706	Glacial sand and gravel
Whitefields†	03 SW 12	NK 0327 3206	Glacial sand and gravel
Waterside Bridge†	02 NW 10	NK 0054 2662	Glacial sand and gravel
Auchmacoy†	02 NW 1	NK 0010 2949	Fluvioglacial terrace

APPENDIX H

CONVERSION TABLE, METRES TO FEET (to nearest 0.5 ft)

m	ft	m	ft	m	ft	m	ft	m	ft
0.1	0.5	6.1	20	12.1	39.5	18.1	59.5	24.1	79
0.2	0.5	6.2	20.5	12.2	40	18.2	59.5	24.2	79.5
0.3	1	6.3	20.5	12.3	40.5	18.3	60	24.3	79.5
0.4	1.5	6.4	21	12.4	40.5	18.4	60.5	24.4	80
0.5	1.5	6.5	21.5	12.5	41	18.5	60.5	24.5	80.5
0.6	2	6.6	21.5	12.6	41.5	18.6	61	24.6	80.5
0.7	2.5	6.7	22	12.7	41.5	18.7	61.5	24.7	81
0.8	2.5	6.8	22.5	12.8	42	18.8	61.5	24.8	81.5
0.9	3	6.9	22.5	12.9	42.5	18.9	62	24.9	81.5
1.0	3.5	7.0	23	13.0	42.5	19.0	62.5	25.0	82
1.1	3.5	7.1	23.5	13.1	43	19.1	62.5	25.1	82.5
1.2	4	7.2	23.5	13.2	43.5	19.2	63	25.2	82.5
1.3	4.5	7.3	24	13.3	43.5	19.3	63.5	25.3	83
1.4	4.5	7.4	24.5	13.4	44	19.4	63.5	25.4	83.5
1.5	5	7.5	24.5	13.5	44.5	19.5	64	25.5	83.5
1.6	5	7.6	25	13.6	44.5	19.6	64.5	25.6	84
1.7	5.5	7.7	25.5	13.7	45	19.7	64.5	25.7	84.5
1.8	6	7.8	25.5	13.8	45.5	19.8	65	25.8	84.5
1.9	6	7.9	26	13.9	45.5	19.9	65.5	25.9	85
2.0	6.5	8.0	26	14.0	46	20.0	65.5	26.0	85.5
2.1	7	8.1	26.5	14.1	46.5	20.1	66	26.1	85.5
2.2	7	8.2	27	14.2	46.5	20.2	66.5	26.2	86
2.3	7.5	8.3	27	14.3	47	20.3	66.5	26.3	86.5
2.4	8	8.4	27.5	14.4	47	20.4	67	26.4	86.5
2.5	8	8.5	28	14.5	47.5	20.5	67.5	26.5	87
2.6	8.5	8.6	28	14.6	48	20.6	67.5	26.6	87.5
2.7	9	8.7	28.5	14.7	48	20.7	68	26.7	87.5
2.8	9	8.8	29	14.8	48.5	20.8	68	26.8	88
2.9	9.5	8.9	29	14.9	49	20.9	68.5	26.9	88.5
3.0	10	9.0	29.5	15.0	49	21.0	69	27.0	88.5
3.1	10	9.1	30	15.1	49.5	21.1	69	27.1	89
3.2	10.5	9.2	30	15.2	50	21.2	69.5	27.2	89
3.3	11	9.3	30.5	15.3	50	21.3	70	27.3	89.5
3.4	11	9.4	31	15.4	50.5	21.4	70	27.4	90
3.5	11.5	9.5	31	15.5	51	21.5	70.5	27.5	90
3.6	12	9.6	31.5	15.6	51	21.6	71	27.6	90.5
3.7	12	9.7	32	15.7	51.5	21.7	71	27.7	91
3.8	12.5	9.8	32	15.8	52	21.8	71.5	27.8	91
3.9	13	9.9	32.5	15.9	52	21.9	72	27.9	91.5
4.0	13	10.0	33	16.0	52.5	22.0	72	28.0	92
4.1	13.5	10.1	33	16.1	53	22.1	72.5	28.1	92
4.2	14	10.2	33.5	16.2	53	22.2	73	28.2	92.5
4.3	14	10.3	34	16.3	53.5	22.3	73	28.3	93
4.4	14.5	10.4	34	16.4	54	22.4	73.5	28.4	93
4.5	15	10.5	34.5	16.5	54	22.5	74	28.5	93.5
4.6	15	10.6	35	16.6	54.5	22.6	74	28.6	94
4.7	15.5	10.7	35	16.7	55	22.7	74.5	28.7	94
4.8	15.5	10.8	35.5	16.8	55	22.8	75	28.8	94.5
4.9	16	10.9	36	16.9	55.5	22.9	75	28.9	95
5.0	16.5	11.0	36	17.0	56	23.0	75.5	29.0	95
5.1	17	11.1	36.5	17.1	56	23.1	76	29.1	95.5
5.2	17	11.2	36.5	17.2	56.5	23.2	76	29.2	96
5.3	17.5	11.3	37	17.3	57	23.3	76.5	29.3	96
5.4	17.5	11.4	37.5	17.4	57	23.4	77	29.4	96.5
5.5	18	11.5	37.5	17.5	57.5	23.5	77	29.5	97
5.6	18.5	11.6	38	17.6	57.5	23.6	77.5	29.6	97
5.7	18.5	11.7	38.5	17.7	58	23.7	78	29.7	97.5
5.8	19	11.8	38.5	17.8	58.5	23.8	78	29.8	98
5.9	19.5	11.9	39	17.9	58.5	23.9	78.5	29.9	98
6.0	19.5	12.0	39.5	18.0	59	24.0	78.5	30.0	98.5

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INSTITUTE OF GEOLOGICAL SCIENCES

INDUSTRIAL MINERALS ASSESSMENT UNIT

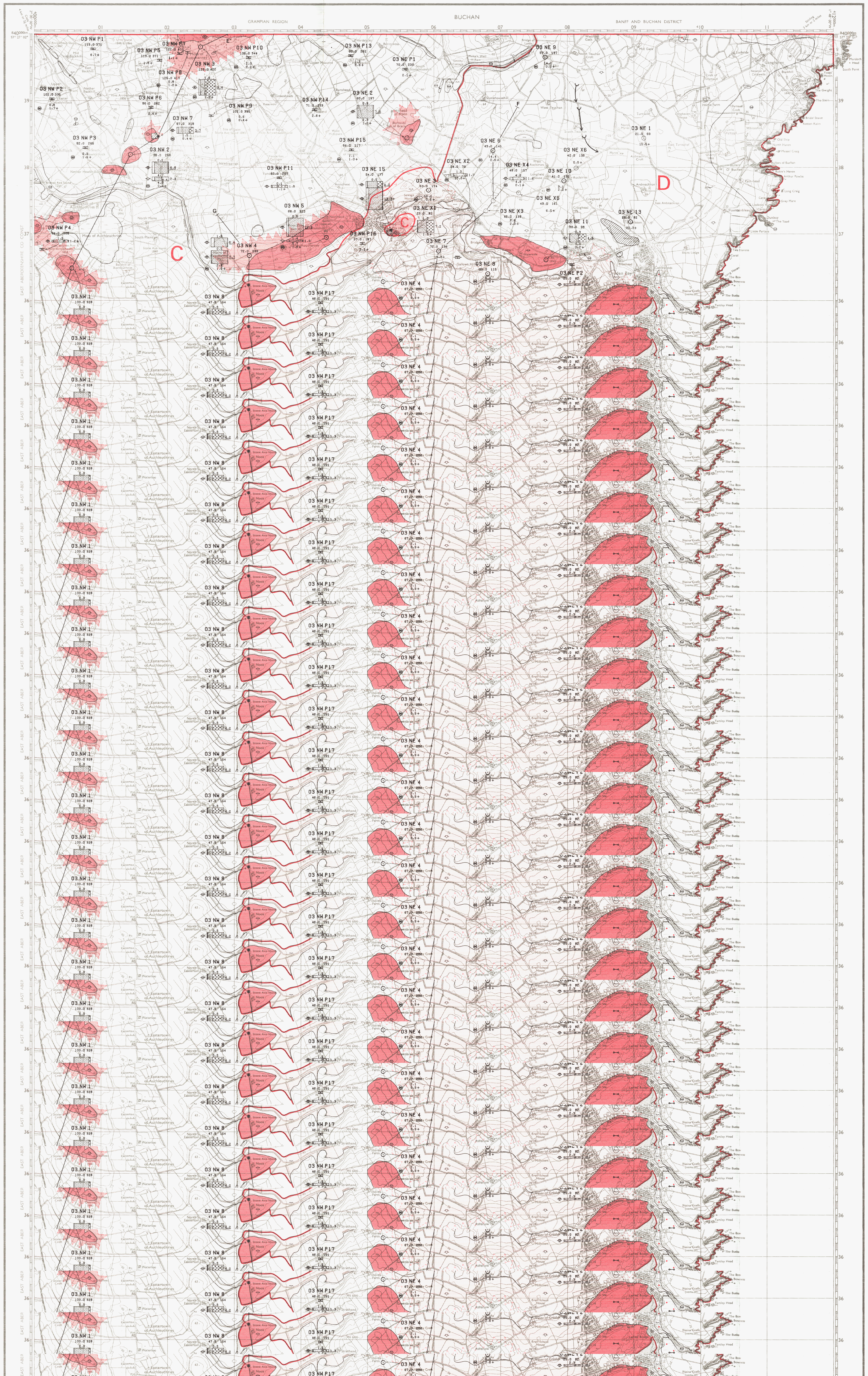
THE SAND AND GRAVEL RESOURCES OF THE ELLON AREA (EAST), GRAMPIAN REGION

Scale 1:25 000

ORDNANCE SURVEY

SHEET NK 03 & PARTS OF SHEETS NK 02, 13

SECOND SERIES

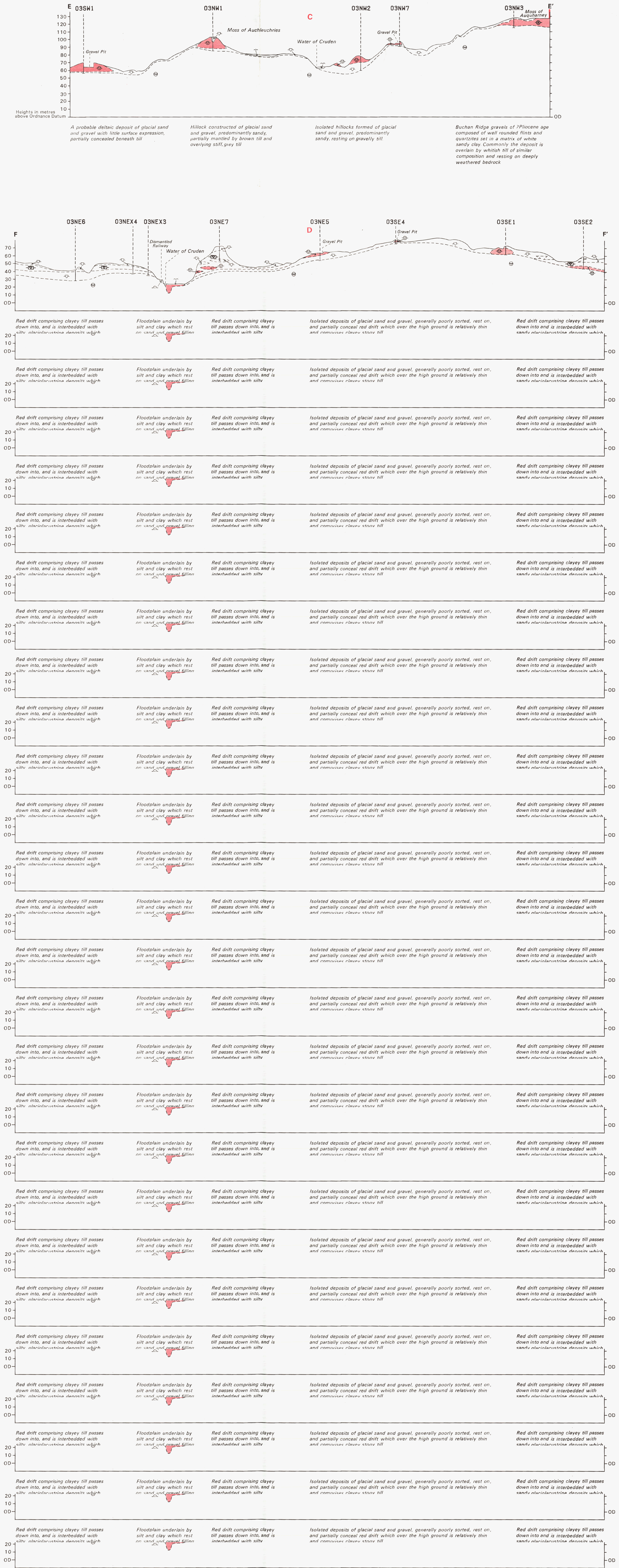


This map should be read in conjunction with the accompanying Report which contains details of the assessment of resources

THE SAND AND GRAVEL RESOURCES OF THE ELLON AREA (EAST), GRAMPIAN REGION

76 (EAST)

GENERALISED HORIZONTAL SECTIONS SHOWING RELATIONSHIPS OF DRIFT DEPOSITS



INSTITUTE OF GEOLOGICAL SCIENCES

INDUSTRIAL MINERALS ASSESSMENT UNIT

THE SAND AND GRAVEL RESOURCES OF THE ELLON AREA (WEST), GRAMPIAN REGION

Scale 1:25 000 or about 2½ Inches to 1 Mile

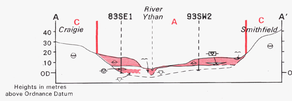
ORDNANCE SURVEY
SHEET NJ 93 & PARTS OF SHEETS NJ 82, 83, 92
PROVISIONAL EDITION

THE SAND AND GRAVEL RESOURCES OF THE ELLON AREA (WEST), GRAMPIAN REGION.

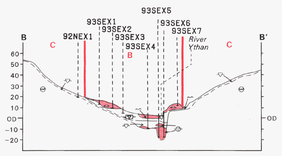
This map should be read in conjunction with the accompanying Rep contains details of the assessment of resources.

GENERALISED HORIZONTAL SECTIONS SHOWING RELATIONSHIPS OF DRIFT DEPOSITS

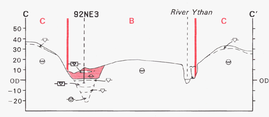
HORIZONTAL SCALE 1:25 000
VERTICAL EXAGGERATION 10x



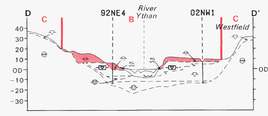
The fluvioglacial terraces are mainly underlain by poorly sorted gravel containing numerous cobbles and boulders in a matrix of coarse sand; sandier developments locally occur towards the base. Near Smithfield the terrace gravels overlie laminated silt and clay, possibly a lake deposit. The alluvium underlying the floodplain of the River Ythan is broadly of similar composition to the terrace gravel excepting that the clasts are generally more rounded and less weathered. The mineral deposits overlie brown or grey till (in places potentially workable), or bedrock



Gravelly fluvioglacial terrace deposits, similar to those upstream but a little finer, rest on two or more erosion surfaces which are usually cut into glaciolacustrine silt and clay. The latter deposits probably formerly infilled the valley to a height of about 30m O.D in late-Glacial times. The terrace and glaciolacustrine deposits conceal a deep, buried valley filled with brown and grey till and poorly sorted sand and gravel



The River Ythan flows through a gorge (right) cut into bedrock but once occupied the apparently much deeper valley to the south (left) now almost completely filled with drift. The gravelly fluvioglacial terrace deposits follow the former course of the River Ythan downstream of Ellon where they conceal glaciolacustrine deposits and till. A thick sequence of till and sand and gravel may infill the more deeply buried parts of the older valley



The present and former courses of the River Ythan merge at the estuary. The gravelly terrace deposits have two or more distinct base levels and usually overlie glaciolacustrine silt and clay. The gravels of the lower terrace, bottoming at below O.D., are probably late-Glacial: gravels at a still lower level may be concealed beneath the estuarine alluvium. The post-Glacial beach deposits, often gravelly, relate to the Flandrian transgression when sea level rose above O.D for a time before falling to its present level

KEY TO SECTIONS

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

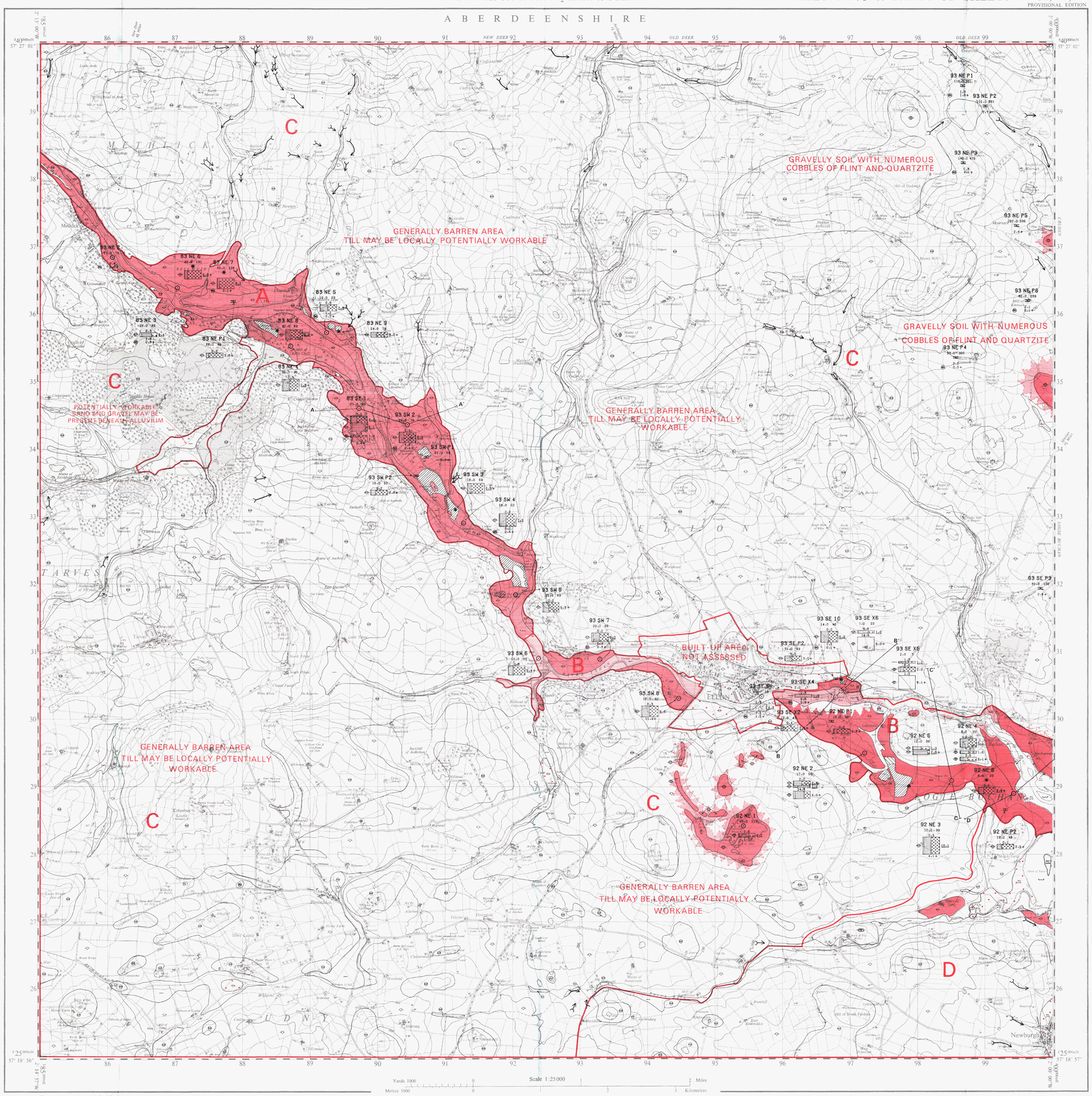
Bedrock and waste, including overburden, are uncoloured

Geological boundary (broken line denotes uncertainty)

Inferred boundary limiting the extent of potentially workable material

Otherwise symbols and abbreviations as map legend

0 1 2 3 Kilometres
0 1 2 Miles



The representation on this map of a Road, Track, or Footpath, is no evidence of the existence of a right of way

The GRID lines on this sheet are at 1 Kilometre interval
Heights are in feet above Mean Sea Level at Newlyn.
Contour intervals are 50 ft.
1 square inch on this map represents 0.672 square km on the ground

Compiled from 6" sheets last fully revised 1899-1924.
Other partial systematic revision 1935-56 has been incorporated.

Produced for the Institute of Geological Sciences
Clyde Surveys Scotland Ltd., Livingston, West Lothian
Printed by John Bartholomew & Son Ltd., Edinburgh 1981

Original geological survey on the Six-inch scale by J. S. Grant Wilson and D. R. Irvine, 1885.

Partial re-survey by D. L. Ross in 1977-78, G. S. Johnstone, District Geologist

Sand and Gravel survey by J. W. Merritt and A. M. Aitken in 1978-79 under the supervision of E. F. P. Nickless, R. G. Thurrell, Head, Industrial Minerals Assessment Unit

The 1:25 000 Sand and Gravel Resource Sheet published 1981.
G. M. Brown D. Sc., F. R. S., *Director, Institute of Geological Sciences, incorporating the Geological Survey of Great Britain, the Museum of Practical Geology and Overseas Geological Surveys*

Borehole Graphics drawn by computer using programs written by J. L. McInnes, Computer Unit, I. G. S., Edinburgh

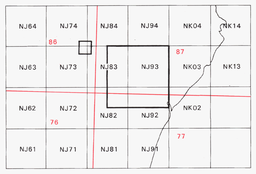
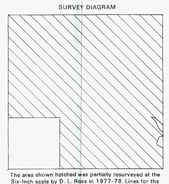


Diagram showing the relation of the National Grid squares to the One-Inch Geological Sheets

SURVEY DIAGRAM



The area shown hatched was partially resurveyed at the Six-Inch scale by D. L. Ross in 1977-78. Lines for the remainder of the sheet are based on a desk compilation of the original geological survey and of sheets 77 and 87 of the Soil Survey of Scotland.

EXPLANATION OF SYMBOLS AND ABBREVIATIONS

76 (WEST)

DRIFT

Recent and Pleistocene

Peat P-1

Alluvium (undifferentiated) -silt, clay, sand and gravel A-51

Present day beach and estuarine deposits -mainly well sorted, medium sand or silt and mud PB-2

Post-Glacial beach and estuarine deposits -silt and clay, medium to coarse sand with some gravel PO-3

Fluvioglacial sand and gravel -mainly coarse gravel with medium and coarse sand, moderately to poorly sorted FL-5

Glacial sand and gravel -deposits vary from poorly sorted coarse gravel with coarse and medium sand to well sorted, silty fine sand GS-55

Glaciolacustrine deposits -fine sand, micaceous silt and clay, often interbedded with clayey till, sometimes laminated, typically vivid red-brown GL-4

Till -typically a vivid red-brown pebbly silty clay towards the coast whereas inland, mainly grey-brown, sandy and with sand and gravel lenses. Widespread basal, stiff, grey stony till TL-7

SOLID

Buchan Ridge gravels, ?Pliocene -mainly well rounded flints and quartzites set in a matrix of white sandy clay

Windyhills gravels, ?Pliocene. -mainly a well sorted, well rounded, quartzite gravel with a matrix of white silty sand or sandy clay

Bedrock, at or near surface -Bedrock mainly comprises metamorphic rocks of the Grampian Caledonides, typically gneiss, migmatite and mica schist in the central and southern parts of the sheet, quartzite and psammite in the north-east and spotted slate and metagreywacke towards the north-west. Several Caledonian plutonic masses which include granite, gabbro and norite underlie the central part of the sheet; the basic igneous rocks commonly contain partially assimilated metasediments. There are a number of felsite and quartz-dolerite dykes. (See Figure 2 in the Report).

Made ground -waste and/or natural earth materials deposited either on the original ground surface or in man-made workings Ma-3

Worked ground -boundaries as at December 1978. Colour beneath ornament indicates that the mineral has not been exhausted. In the survey area, usually the sand and gravel is worked only above water table Wa-2

BOUNDARY LINES

Geological boundary

Inferred boundary between categories of deposit

Resource block boundary

Glacial drainage channel, arrow shows direction of water flow

BOREHOLE AND OTHER DATA

SITE LOCATIONS

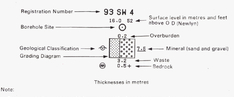
Industrial Minerals Assessment Unit (I.A.M.U.) borehole

Other borehole

Recorded exposure

Shallow pit

I.M.A.U. 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

Registration Number

Each I.M.A.U. borehole is identified by a registration number, e.g. **93SW4.** The first numbers and letters refer to the quarter sheet and the final figures to the I.G.S. serial numbers for that quarter. The unique designation for borehole **93SW4** is **NJ93SW4**

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 either registered in the same series as I.M.A.U. boreholes, e.g., **93SE6R**, or 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. **93SEX5**

EXPOSURE RECORDS

Information from the inspection of exposures is shown in the same way as for I.M.A.U. boreholes but they are located by an asterisk, thus ✱. The exposures are registered in the same series as the boreholes, for example, **93SE10**

SHALLOW PITS

Where space permits the locations of shallow pits providing ancillary assessment data are shown by a distinctive symbol, thus ⧈. Each pit is identified by serial registration numbers prefixed by the letter **'P'** and indexed by the numbers and letters of the relevant standard quarter sheet, for example, **93SEP2**

CATEGORIES OF DEPOSITS

Exposed, potentially workable sand and gravel CAT-E7

Continuous or almost continuous spreads of potentially workable sand and gravel beneath overburden CAT-C1

Discontinuous spreads of potentially workable sand and gravel exposed or beneath overburden. CAT-D2

Sand and gravel not assessed CAT-N1

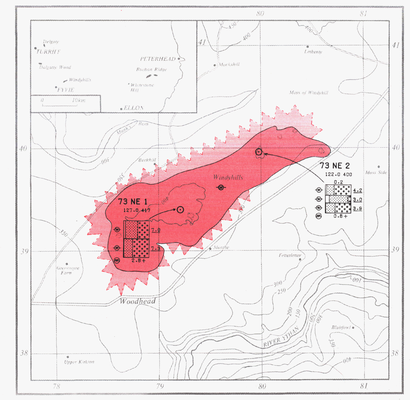
Sand and gravel absent or not potentially workable CAT-A4

RESOURCE BLOCKS

For the purpose of assessment, the mineral-bearing land is divided into Resource Blocks (see Report). Each is designated by a letter

Detailed records may be consulted on application to the Officer-in-Charge, Industrial Minerals Assessment Unit, Institute of Geological Sciences, Murchison House, West Mains Road, Edinburgh, EH9 3LA

Fig. 1 Geological sketch-map of the ?Pliocene gravels at Windyhills, 7km WNW of Methlick. Other localities in Scotland at which material of supposedly the same age have been reported are shown on an inset map.



Geological line after J. Horne (1880 to 1884) revised by H. H. Read (1917 to 1919)

Geological boundary limiting Windy hills gravels

Inferred boundary limiting concealed, potentially workable Windyhills gravels. (The Windyhill gravels are partially concealed by till)

Otherwise symbols, abbreviations and colour notation as map legend