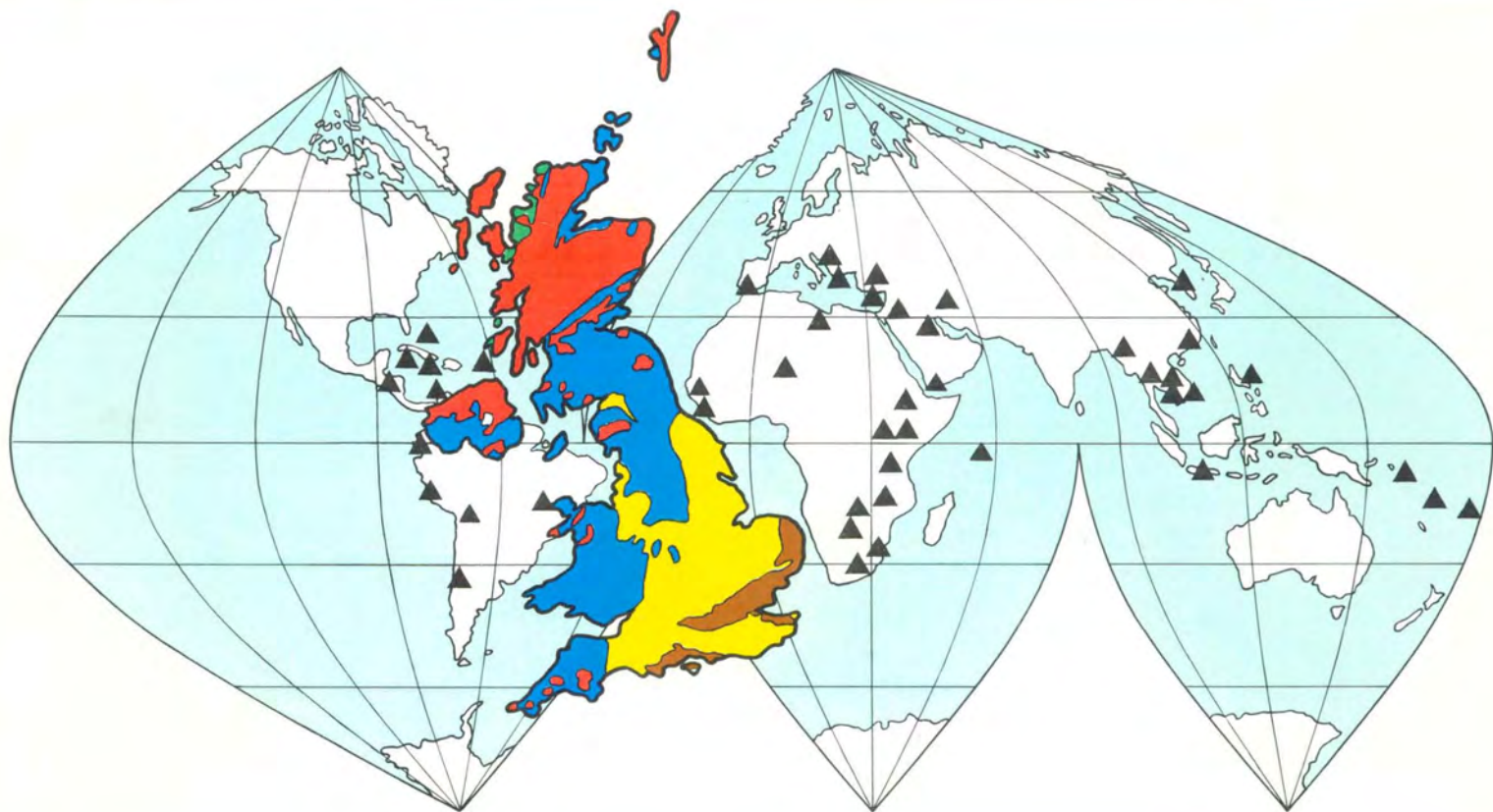


NATURAL ENVIRONMENT RESEARCH COUNCIL

INSTITUTE OF GEOLOGICAL SCIENCES

Sand and gravel resources of the Tayside Region

REPORT No. 77/6



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I. B. Paterson

London: Her Majesty's Stationery Office 1977

It is recommended that reference to this report be made in the following form:

**PATERSON, I. B. 1977. Sand and gravel resources of the Tayside Region.
Rep. Inst. Geol. Sci., No. 77/6, 30 pp.**

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ISBN 0 11 884008 8

PREFACE

The following account of the sand and gravel resources of the Tayside Region has been compiled by the Institute of Geological Sciences at the request of the Scottish Development Department. It is essentially a summary of the published and unpublished records of the Institute together with other published data mentioned in the list of references at the end of the report. The information has been augmented by visits to selected areas where time has permitted. The coverage is not comprehensive, but further detailed information is available for many localities and can be consulted at the Institute's Edinburgh office, Murchison House, West Mains Road, Edinburgh EH9 3LA.

For convenience of description, the Tayside Region has been divided into ten areas, of which six lie within the Perth District, three form the Angus District and the last corresponds to the Dundee District. The areas have been further subdivided as necessary. The sand and gravel deposits in each administrative district are described separately.

The following constraints have been adopted in compiling this report:

1. The ratio of sand and gravel to overburden is 1:1 or more.
2. The thickness of deposit is 2 m or more.
3. The deposits are classified as resources rather than reserves and may include silt, clay, till and other unsuitable materials. Tonnages, where given, are at best inferred, being based on experience rather than detailed records of boreholes and sections. The conversion factor of one cubic metre equals two tonnes has been used throughout.
4. Deposits above and below the water table have been considered separately.
5. Such considerations as possible markets and accessibility have been ignored.
6. Land use, conservation, and amenity considerations have been given only passing mention. There are many National Nature Reserves and sites of special scientific interest in the Region: information on these can be obtained from the Nature Conservancy Council, Hope Terrace, Edinburgh.
7. Resources underlying built-up areas are included in the tables.

A list of working sand and gravel quarries and their localities for each District is given in Appendix 1. This includes only sites visited in May and June 1975 and omits those worked intermittently or on a small scale.

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1 December 1976

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Sand and gravel resources of the Tayside Region

I. B. PATERSON

Introduction

OUTLINE OF THE SOLID GEOLOGY

The Tayside Region is crossed by a major north-easterly trending fracture system which is known as the Highland Boundary Fault (Fig. 1). In the Highland area to the north of the fault the rocks are mainly of metamorphic origin and consist largely of quartzites and psammitic granulites but also include slates, phyllites and mica-schists. These rocks are cut by many igneous intrusions, the most important of which are the granitic complexes at Moor of Rannoch, Glen Tilt and Carn Mor. The lower ground to the south of the Highland Boundary Fault is mainly underlain by rocks of Lower Old Red Sandstone age. These consist largely of sandstone but in the vicinity of the Highland Boundary Fault include thick conglomerate formations which contain material of volcanic or metamorphic origin. Farther south, in Strathmore, there is a narrow but widespread outcrop of reddish-brown silty mudstone, the Cromlix Mudstone, and in the Ochil and Sidlaw hills there is a major development of andesitic and basaltic lavas.

CLASSIFICATION OF THE SUPERFICIAL DEPOSITS

The most valuable resources of sand and gravel in the Tayside Region consist of fluvioglacial deposits which were laid down by meltwater in or around the margins of decaying glacier ice. Two main types of deposit have been distinguished, principally on the basis of their topographical form. The first of these is characterised by hummocky topography formed by the melting of masses of buried ice. Common features in such deposits are steep-sided mounds (kames), sinuous ridges (eskers) and terrace-like forms (kame terraces) laid down by meltwater at the margins of valley glaciers. The sand and gravel is commonly poorly bedded in deposits of this type and may show considerable variation in grain size. The second type of deposit was laid down by meltwater streams formerly issuing from the ice margin and generally forms extensive flat-topped spreads. These may be pitted by kettleholes, caused by the melting of remnants of buried ice, and are commonly terraced as a result of erosion and redistribution by glacial streams. The sand and gravel deposits in these outwash spreads are usually well stratified and show less grain-size variation than the hummocky deposits into which they may merge upstream.

Large areas in the Highland part of the Tayside Region are covered by morainic drift, heterogeneous material left in hummocks and valley bottom spreads as the glacier ice in which it had

accumulated wasted away during the closing stages of the last Ice Age. Such material ranges from till (a sandy or silty boulder clay) to well bedded and well sorted sand and gravel. Individual hummocks may be as much as 15 to 20 m high but are commonly less than 6 m. In many cases, they consist of a core of bedded sand and gravel, which is overlain by a variable thickness of till generally containing large erratic blocks; in other cases, the hummocks have rock cores or consist entirely of till. In the absence of drilling or excavation it is commonly impossible to infer the sand and gravel potential of spreads of morainic drift and they are omitted from this reconnaissance study.

The floodplains of rivers are underlain by alluvial deposits which may also occur in flanking terraces and in fan-shaped accumulations where rivers and streams emerge from steep valleys. The deposits, although commonly well sorted, may comprise all grades of material from coarse boulder-gravel to silt and clay. In places, unsuitable alluvial deposits rest on or are terraced into fluvioglacial sand and gravel. Unsuitable deposits may therefore conceal potentially workable material which in some cases may occupy glacially-deepened buried channels.

When deglaciation of the coastal areas of the region occurred, relative mean sea level was up to 30 m higher than at present, due to depression of the land area by the weight of superincumbent ice at the time of maximum glaciation. Subsequent isostatic rebound has caused the beaches which were formed at this time to be raised above present sea level. In the Tayside Region, the raised beach deposits consist mainly of silt and clay, particularly in the Tay estuary, but locally, on the more open coast between Monifieth and Montrose, they include sand and gravel. At Barry Links, Lunan Bay and Montrose, the raised beaches are in places overlain by dunes of blown sand. These deposits are mainly composed of fine grained, clean sand but may contain considerable amounts of broken shell debris which may be detrimental for some uses.

LITHOLOGY OF THE DEPOSITS

The majority of the sand and gravel deposits of the Tayside Region are derived ultimately from material incorporated within and transported by glacier ice during the last Ice Age. The composition of these deposits is accordingly strongly influenced by the nature of the bedrock traversed by the former glaciers. Thus the morainic drift and gravel deposits in the Highland valleys consist mainly of Moine and Dalradian psammitic granulite and quartzite pebbles with lesser quantities of vein quartz. Small amounts

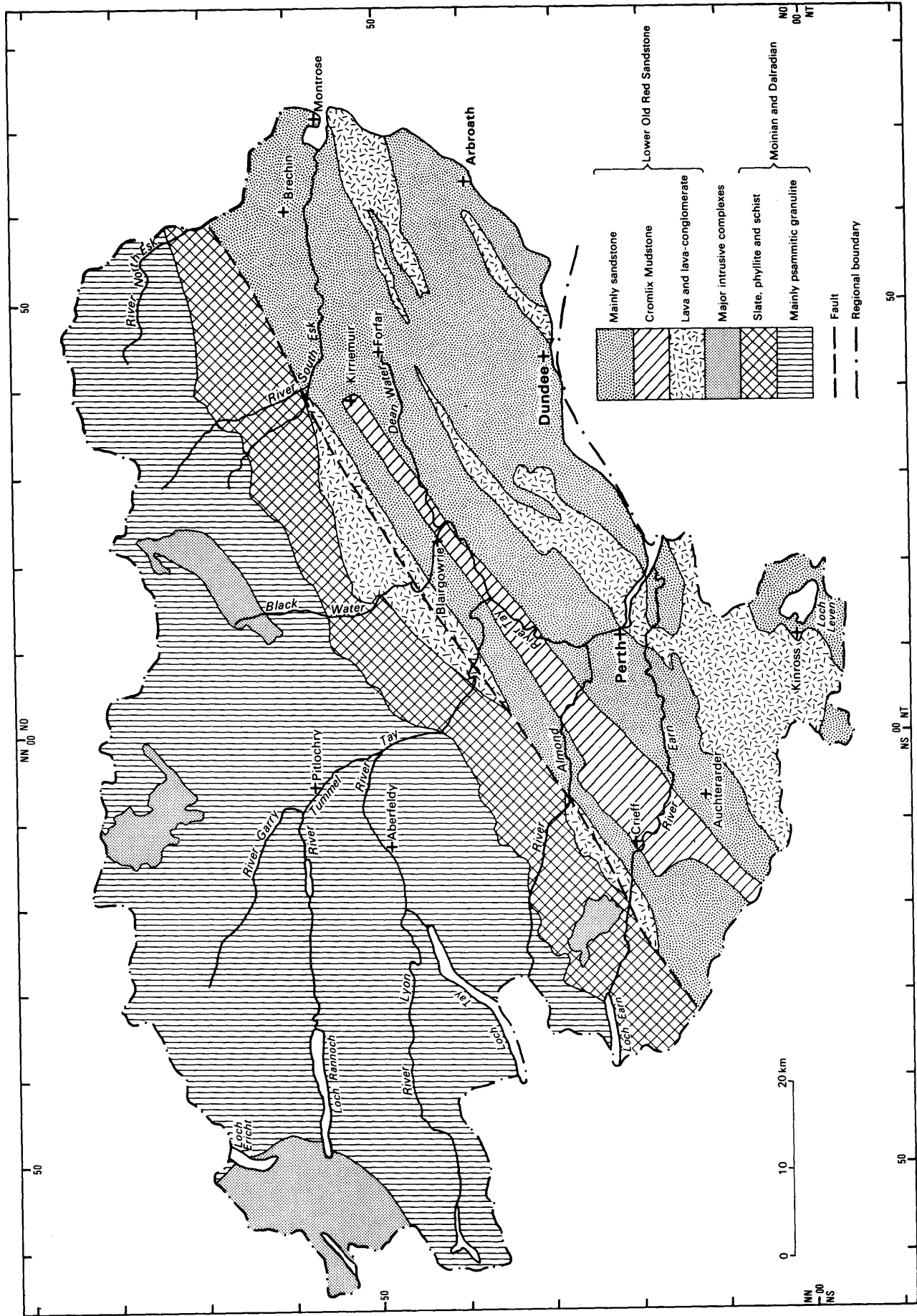


Fig. 1. Sketch map of the solid geology of the Tayside Region

of material have been contributed by igneous bodies of various kinds, the proportion rising to as much as 50 per cent in the vicinity of major intrusions such as the Moor of Rannoch granite. Slates, phyllites, mica-schists and other platy rocks, which crop out mainly in a narrow zone on the north side of the Highland Boundary Fault, locally form a significant proportion of the pebble content but do not survive abrasion for long.

The gravel deposits in the lowland portion of the Tayside Region generally contain between 50 and 80 per cent of quartz, quartzite and granulite, some of which may have been derived from Lower Old Red Sandstone conglomerates in the Highland Border area. The remainder consists for the most part of sandstone (5 to 20 per cent) and lava, the latter being mainly obtained by the erosion of volcanic conglomerates. Locally, in the Highland Border area and in the neighbourhood of the Ochil and Sidlaw hills, the proportion of lava debris rises to more than 60 per cent although more commonly it varies between 5 and 15 per cent. Close to the outcrop of the Cromlix Mudstone (Fig. 1), the gravel may contain as much as 20 per cent of crumbly reddish brown mudstone.

Quartz, quartzite, granulite and the acid intrusive igneous rocks of the Highlands are generally of high strength and tend to form equidimensional pebbles. Andesite and basalt lavas have similar properties but may have high shrinkage values especially when weathered or amygdaloidal. There is a tendency for slate, phyllite and other schistose rocks to form flaky particles which are liable to fracture when subject to stress. The proportion of such rock types, however, generally does not exceed 10 per cent in the gravel deposits in the lowland areas although locally in the Highlands it may rise to 60 per cent. The sedimentary rocks of Lower Old Red Sandstone age are of low strength, especially the Cromlix Mudstone; they commonly constitute from 10 to 20 per cent of the pebbles in the lowland gravels but rise exceptionally to 50 per cent in some cases.

DISTRIBUTION OF THE DEPOSITS

The general distribution of the gravel deposits is shown on Fig. 2 and is amplified in the district descriptions that follow. Morainic drift is confined to the Highland part of the Tayside Region, the most extensive deposits being in the neighbourhood of Loch Rannoch and Loch Lyon. Fluvioglacial sand and gravel, mainly in the form of kame terraces which in some cases pass downstream into outwash spreads, occurs in all the major Highland valleys. The most important resources are in the Tummel-Tay valley system, Strathardle, Glen Shee, Glen Clova and Glen Esk. Many of these valleys also contain sand and gravel in glacially deepened buried channels.

In the lowland area of the Region, the largest resource lies in Strathmore between Blairgowrie [NO 180 450] and Inverkeilor [NO 665 495] and consists largely of hummocky fluvioglacial sand and gravel. Smaller deposits of similar type occur in Strathallan and in the low ground adjacent to Loch Leven. Outwash spreads are

associated with the mounded deposits in the area south of Blairgowrie and in the valley of the River North Esk at Edzell.

The total quantity of sand and gravel contained in major deposits other than morainic drift is estimated to be about 3750 million tonnes (Table 1). A considerable proportion of this total lies within built-up areas or is subject to other constraints.

Table 1. Sand and gravel resources of the Tayside Region by districts
million tonnes

Perth District	
Above water table	1500
Below water table	750
Angus District	
Above water table	1200
Below water table	250
Dundee District	
Above water table	20
Total, Tayside Region	about 3750

Perth District

For convenience, the Perth District is discussed in six areas (Fig. 3), each of which is further subdivided (Fig. 2). The most important deposits are illustrated by larger scale sketch-maps.

AREA 1: FOREST OF ATHOLL—GLEN LYON

In this deeply dissected mountainous area (Fig. 2), some 1500 km² in extent, the principal sources of sand and gravel are in the morainic drift deposits which cover about one-third of its surface. The majority of the area is inaccessible and, in the time available for the present study, only a brief reconnaissance of the deposits in Glen Garry, Glen Errochty, the Tummel Valley and Glen Lyon was possible. From the available sections, it is apparent that the composition of the morainic mounds is highly variable and that few have a core of bedded sand or gravel. In much of the area examined, the mounds are scattered and have an average height of 5 m or less. At a few localities, however, groups of large mounds up to 15 m high may provide a useful local source of gravel, particularly as the pebbles consist largely of psammitic granulite.

Deposits above water table

Deposits of fluvioglacial sand and gravel in the area occur only in Glen Garry, Glen Errochty and Glen Lyon (1:1, 1:2 and 1:4 on Fig. 2 respectively). In Glen Garry, small terrace-form deposits occur 1.4 km north-west of Edenden Bridge [NN 703 716], at Edenden Bridge [NN 715 707] and at Dalnacardoch [NN 722 704] and appear to consist mainly of sand and coarse gravel probably no

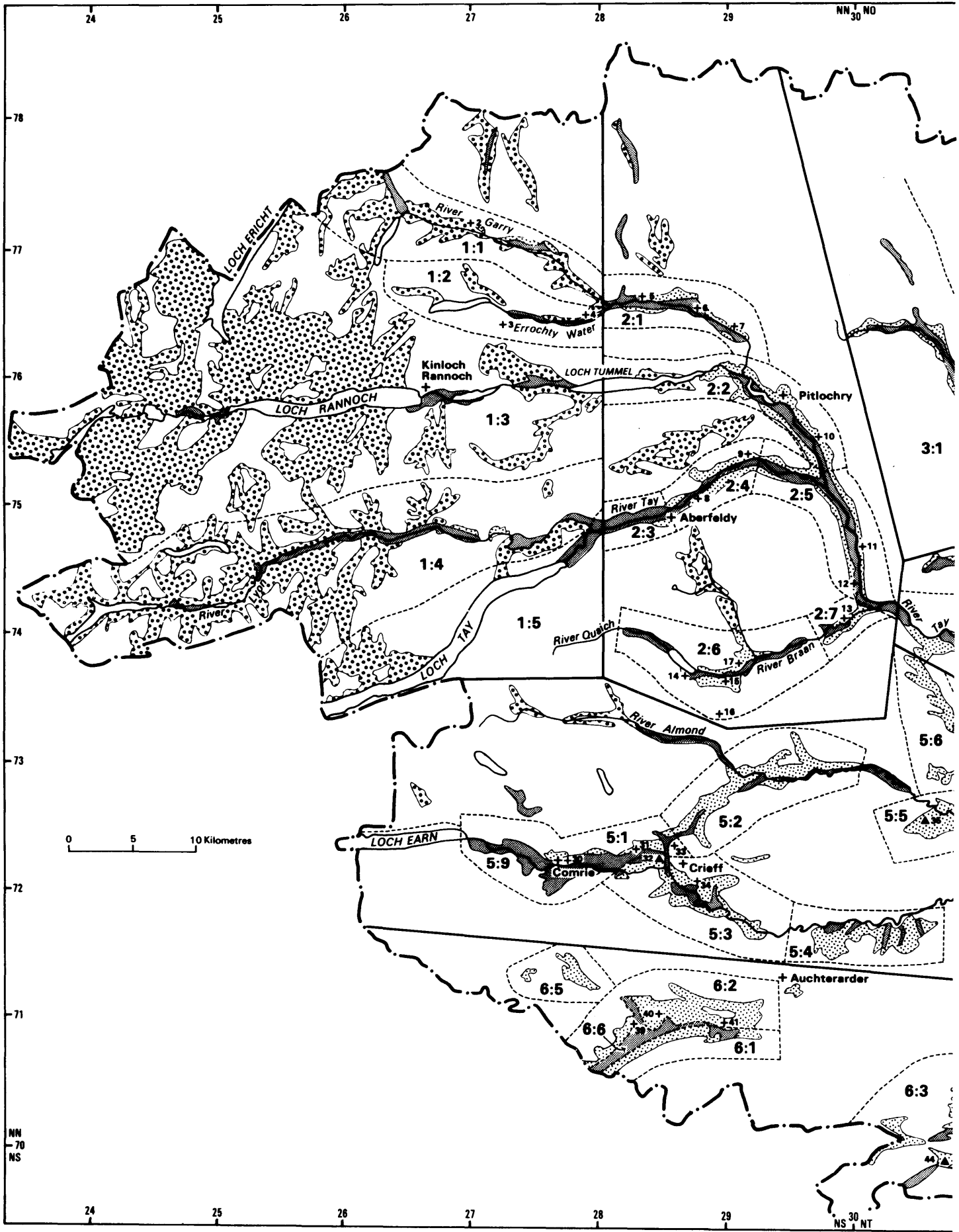
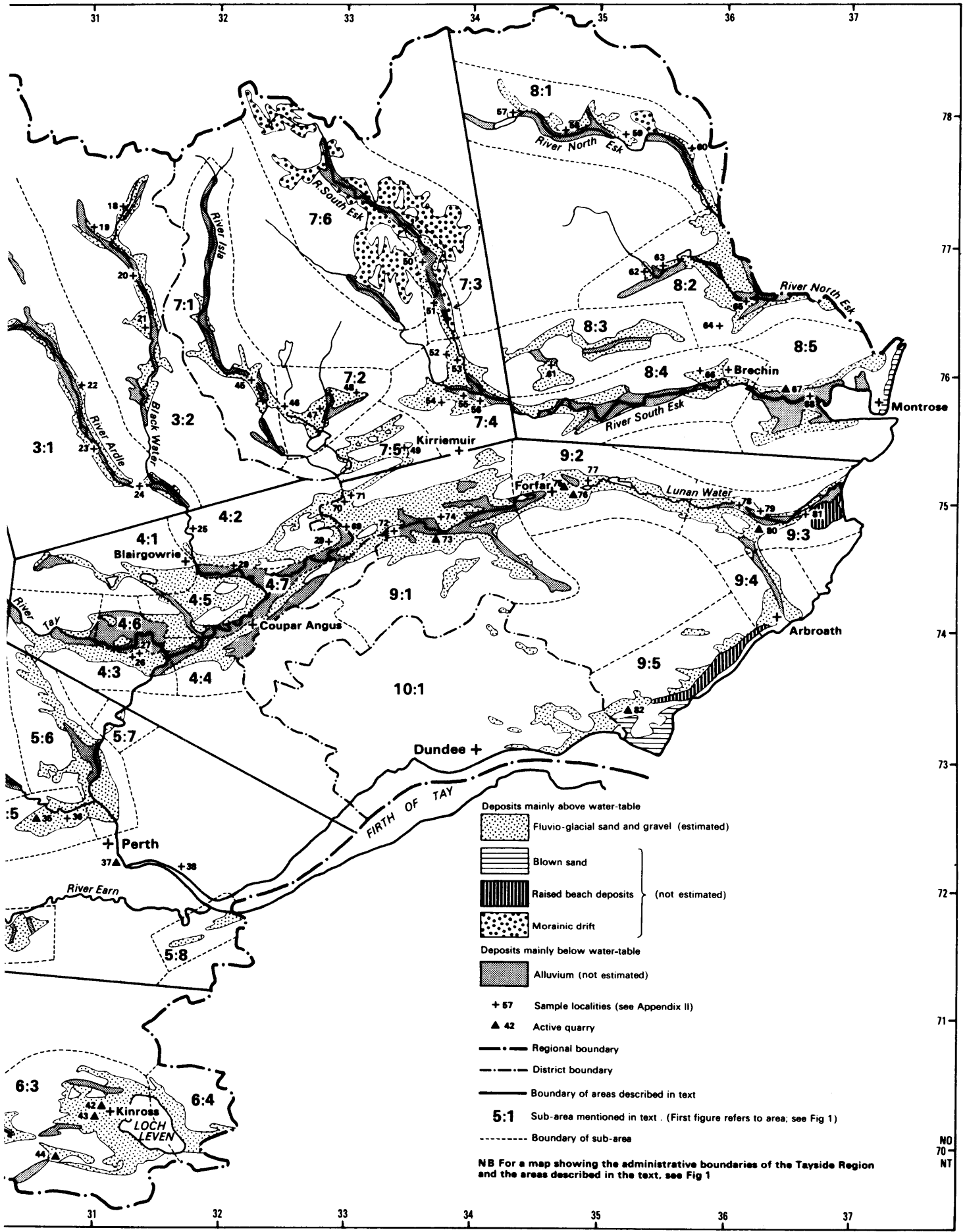


Fig. 2. Sand and gravel of the Tayside Region



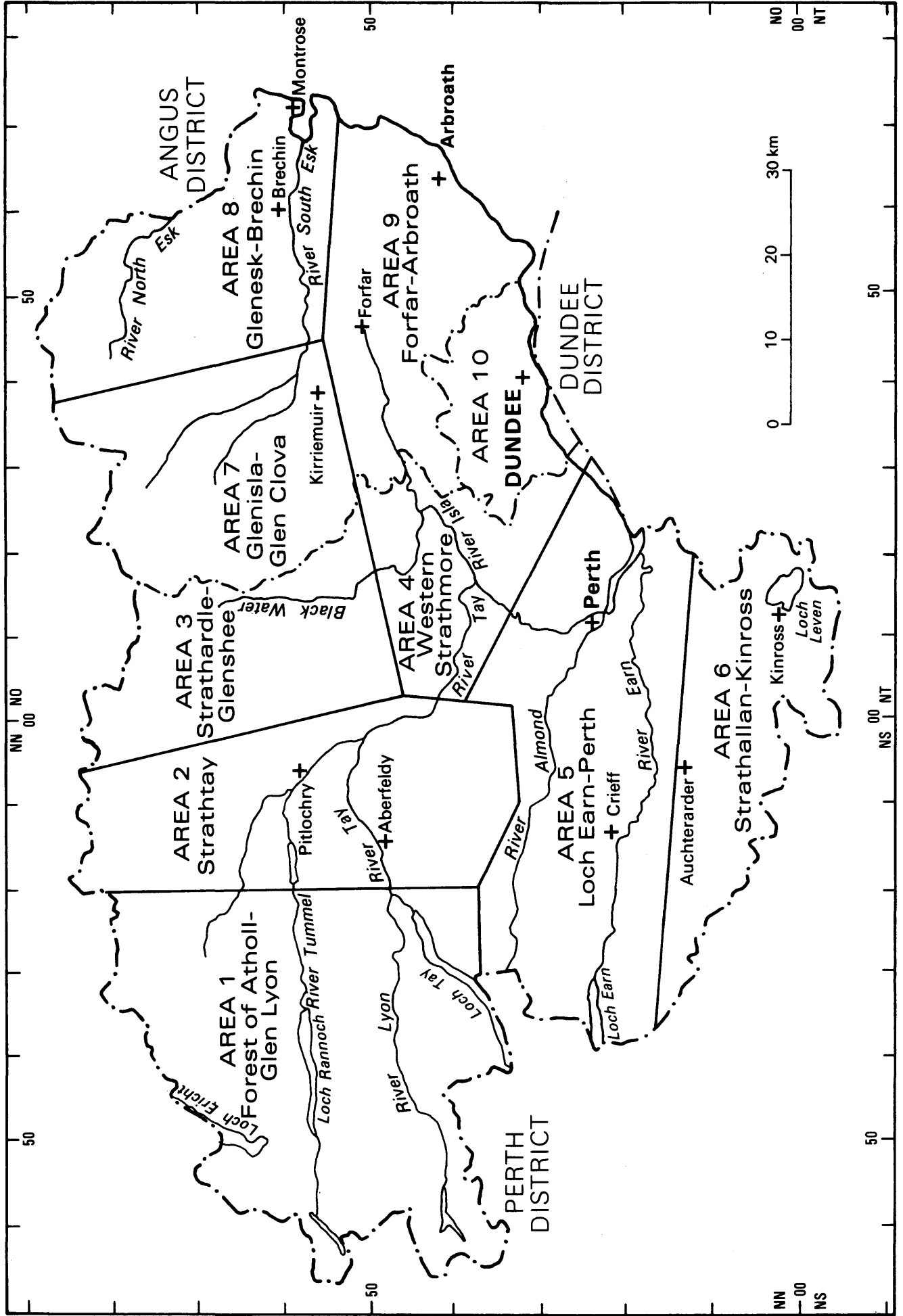


Fig. 3. Administrative boundaries of the Tayside Region and areas described in text

more than 6 m thick. A sample of the pebbles (Appendix 2, No. 2) contained 90 per cent of psammitic granulite. The deposits cover a total area of about 41 hectares and contain about 2.5 million tonnes of material (see Table 2).

In Glen Errochty, a kame terrace, from 3 to 5 m high and up to 150 m broad, extends north-eastwards for a distance of 800 m from Cuitaloskin [NN 790 642]. The possible resource may exceed 400 000 tonnes. A smaller terrace, which extends south-westwards from Cuitaloskin for some 500 m, may contain 300 000 tonnes of sand and gravel. In a sample (Appendix 2, No. 4) from a 3-m high section showing coarse gravel with cobbles up to 15 cm long, 75 per cent of the pebbles were of granulite.

Glen Lyon is floored by terraced deposits probably composed mainly of outwash sand and gravel. The alluvial tract, which includes the floodplain of the present river, is generally from 100 to 200 m wide but increases to 600 m between Innerwick [NN 589 475] and Balmenoch [NN 611 475] and to 800 m east of Balnahanaid [NN 624 475]. The alluvium is also 800 m wide between Bridge of Lyon [NN 728 466] and Duneaves [NN 748 469]. The thickness of deposit above the water table is commonly a few metres only and may consist mainly of sand and silt. At Fortingall, however, the terrace surfaces are up to 20 m above river level but there is no information regarding the nature and thickness of the deposit.

Deposits below water table

A tract of alluvial deposits extends north-westwards in Glen Garry (1:1 on Fig. 2) for a distance of 2 km from Dalnaspidal Lodge [NN 646 733]. It is probable that sand and gravel of fluvioglacial origin is concealed beneath peat and sandy alluvium. A similar deposit of terraced alluvium up to 500 m wide, which extends from Dalnacardoch Lodge [NN 721 703] to Dalinturuaine [NN 760 792], may also cover fluvioglacial sand and gravel in a glacially deepened channel. There is, however, no information concerning the thickness of sand and gravel in either area.

In Glen Errochty (1:2 on Fig. 2) the floodplain is generally less than 200 m wide and is unlikely to conceal a major buried channel. The valley of the River Tummel (1:3 on Fig. 2), however, is occupied for a distance of 4.5 km east of Kinloch Rannoch [NN 662 581] by a broad alluvial tract up to 1 km wide, much of it now drowned as a result of the river being dammed at Dunalastair [NN 709 586]. It is probable that much of the deposit consists of fluvioglacial outwash gravel and that its thickness at Kinloch Rannoch is considerable, possibly in excess of 60 m. An alluvial deposit, approximately 2 km² in area, lying to the west of Loch Tummel, may similarly consist of fluvioglacial sand and gravel but its thickness is unlikely to be so great.

It is probable that the broader stretches of alluvium in Glen Garry (1:4 on Fig. 2), at Innerwick, Balnahanaid and Fortingall conceal sand and gravel in glacially scoured channels. There is no information concerning the nature

and thickness of such a deposit, nor is there any in the valley of the River Tay (1:5 on Fig. 2) between Loch Tay and the confluence with the River Lyon. The alluvial spread in this area is up to 1 km wide and almost certainly overlies a buried channel deposit.

Miscellaneous deposits

Hummocky morainic drift, commonly strewn with large boulders of granulite, occurs extensively on the southern slope of Glen Garry (1:1 on Fig. 2) between Dalnaspidal and Calvine. As shown by boreholes, the thickness of the deposit may exceed 5 m but is generally less. Individual mounds are usually small and are less than 5 m high. They are composed for the most part of poorly sorted till ranging from silt to boulders up to 50 cm long and contain little bedded sand and gravel.

Hummocks of morainic drift up to 5 m high occur in a strip which reaches a maximum width of 300 m on the northern slope of Glen Errochty (1:2 on Fig. 2), between Blairfetty [NN 750 643] and the confluence with Glen Garry. No exposures were available. In the Moor of Rannoch—Tummel area (1:3 on Fig. 2), there are very widespread deposits of morainic drift, especially in the eastern part of the moor between Loch Laidon and Gleann Duibhe. Roadside exposures between the Bridge of Gaur [NN 504 564] and Loch Eigheach showed that many of the mounds, which are up to 10 m high, consist of typical morainic drift with large granite boulders set in a matrix of silt and sand. None of the exposures showed bedded sand and gravel.

Extensive deposits of morainic drift, with individual mounds up to 5 m high, have been mapped also on the valley side north of Loch Rannoch, especially between Bridge of Erich [NN 522 582] and Kilchonon [NN 544 583], at Anlich [NN 609 592] and in the valley of Allt na Moine Buidhe. Beach gravel derived from the morainic material at the lochside (Appendix 2, No. 1) contained equal quantities of granite and granulite. On the southern side of Loch Rannoch, there are mounded deposits of morainic drift in the tributary valleys of the Allt Camghouran, the Dall Burn, the Allt na Bagair, Inverhadden Burn and the Allt Kynachen.

Glen Lyon (1:4 on Fig. 2) and the tributary valleys which enter it between Loch Lyon and Invervar all contain deposits, probably mainly thin, of morainic drift. Farther east, the southern side of the valley between Achloa Cottages [NN 768 484] and Comrie Castle [NN 787 486] is covered with morainic drift formed into large isolated mounds, in some cases more than 10 m high.

AREA 2: STRATH TAY

In this area (Fig. 2), the sand and gravel resources consist principally of kame-terrace and outwash deposits formed in association with glacier ice in the valleys of the rivers Garry, Tummel, Tay and Braan. These valleys have been deeply scoured by glacial action and in many cases sand and gravel occurs to considerable depths below present river level.

Table 2. Sand and gravel resources in the Perth District

Area	Sub-area	Resources above water table			Resources below water table		
		Max. thick-ness	Av. thick-ness	Quantity	Max. thick-ness	Av. thick-ness	Quantity
		m	m	(million tonnes)	m	m	(million tonnes)
1 Forest of Atholl — Glen Lyon	1:1	6	3	2.5	?	?	nq
	1:2	5	2.5	0.7	-	-	-
	1:3	-	-	-	? 60	?	nq
	1:4	?	?	nq	?	?	nq
	1:5	-	-	-	?	?	nq
2 Strathtay	2:1	30	5	27	-	-	} 600
	2:2	30	5	60	15	?	
	2:3	-	-	-	?	?	
	2:4	25	8	100	?	?	
	2:5	30	10	75	40	?	
	2:6	10	3	35	-	-	
	2:7	?	?	nq	-	-	
3 Strathardle — Glenshee	3:1	25	6	72	?	?	nq
	3:2	15	2	25	?	?	nq
4 Western Strathmore	4:1						
	4:2						
	4:3	15	8	500	10	2	100
	4:4						
	4:5						
	4:6				20	?	nq
	4:7				?	?	nq
5 Loch Earn — Perth	5:1	30	5	25			
	5:2	? 20	5	25			
	5:3	6	3	53			
	5:4	3	1	nq			
	5:5	30	8	45			
	5:6	15	5	50			
	5:7	10	5	6			
	5:8	?	?	nq			
	5:9				?	?	nq
6 Strathallan — Kinross	6:1	15	5	180			
	6:2	20	5	58			
	6:3	10	4	150	6	1	50
	6:4	10	3	30			
	6:5	10	?	nq			
	6:6				2	?	nq

nq not quantified

Deposits above water table

In Glen Garry (2:1 on Fig. 2) between Calvine [NN 803 658] and the rock-cut gorge at Killiecrankie [NN 914 629], kame-terrace deposits, from 100 to 300 m wide, occur on the valley sides to a height of more than 30 m above river level. There is little evidence concerning the nature of the deposits, but gravels near Baluain [NN 834 658] and near Aldclune [NN 899 637] contain pebbles and cobbles up to 15 cm across, which are composed predominantly of granulite (Appendix 2, Nos. 5 and 7). Outwash gravels, exposed in a 4-m high section at Blair Atholl Golf Clubhouse [NN 876 651], also consist mainly of granulite (Appendix 2, No. 6) but include 30 per cent of rocks derived from the igneous complex in Glen Tilt. The deposits are known from borehole information to exceed 15 m in thickness in the area between Ballentoul [NN 880 654] and Killiecrankie but generally average less than 5 m. The resources above the water table may amount to about 27 million tonnes.

The valley of the River Tummel between Loch Tummel and the confluence with the River Tay (Fig. 4, 2:2) is occupied by a complex deposit of fluvioglacial sand and gravel up to 1.5 km wide. On the valley sides the deposit, which commonly reaches a height of 20 to 40 m above river level, is hummocky or formed into prominent kame terraces. The surface of the highest of these terraces generally lies 20 to 30 m above the river and descends from about 105 m OD at Pitlochry to about 95 m OD at Ballinluig. Information regarding the nature and thickness of the deposits is generally lacking but it seems that, whereas the hummocky spreads on the upper slopes of the valley consist mainly of gravel with subordinate sand, the kame terraces are composed largely of fine grained sand with little gravel. The quantity of material in the hummocky deposits is estimated to be about 30 million tonnes on the basis of an average thickness of 3 m. The kame terraces contain a similar quantity of sand and gravel but are considered to have a mean thickness of 8 m.

The Tay Valley (2:3, 2:4, 2:5 on Fig. 2) from Aberfeldy to Dunkeld is occupied by a complex fluvioglacial deposit some 1200 to 1400 m wide (Fig. 4), which includes hummocky gravel, kame terraces and outwash spreads. In the area to the west of Aberfeldy (2:3 on Fig. 2), the hillsides are mainly till-covered and there is little sand and gravel. In the area (2:4 on Fig. 2) between Aberfeldy and Pitnacree [NN 924 536], however, the River Tay flows in a narrow channel eroded into an extensive deposit of fluvioglacial sand and gravel. For a distance of 1.5 km east of Aberfeldy, the deposit is less than 1 km wide but farther east it expands to 1.5 km and reaches a height of about 120 m OD on the valley sides. The deposit is characterised by a hummocky topography ('kame and kettle') but adjacent to the river there are narrow kame terraces. Few exposures are available but the deposit appears to contain a high proportion of sand, possibly as much as 75 per cent. Samples of the gravel (Appendix 2, Nos. 8 and 9) consisted predominantly of quartz, quartzite and granulite with minor

amounts of intrusive igneous rocks and schists. The total resource of sand and gravel above the water table in this area may amount to 100 million tonnes.

Farther east in the Tay Valley, between Pitnacree and Inver (Fig. 4) fluvioglacial sand and gravel forms only narrow kame terraces, which commonly occur on both sides of the valley. They are generally from 100 to 150 m wide but are up to 400 m wide between Dalmarnock [NN 997 456] and Inver (Fig. 4). The uphill limit of the terraces on the valley sides is about 90 m OD, that is, they rise to some 50 m above the level of the floodplain. Numerous exposures and excavations, for example near Rotmell Farm [NO 005 470], indicate that the kame terraces are composed largely of fine grained sand with few beds of gravel. Samples of the gravel (Appendix 2, Nos. 10 and 11) consisted predominantly of quartz, quartzite and granulite with minor amounts of igneous rocks and schists. An average thickness of 10 m has been used in calculating the sand and gravel resources above the water table to be 70 to 80 million tonnes.

An extensive hummocky sand and gravel deposit with kame-terrace features in places occupies Strathbraan (2:6 on Fig. 2) between Loch Freuchie and Dullator [NN 936 383] and extends into the valley of the Garron Burn. The deposit contains mounds from 5 to 10 m high of ill-sorted material which ranges in grain size from silt to pebbles and cobbles, up to 15 cm in diameter and composed mainly of quartz and granulite (Appendix 2, Nos. 14, 16, 17). In a small disused quarry at Amulree [NN 900 366], however, the gravel consisted mainly of chlorite-schist pebbles (Appendix 2, No. 15). The deposit, on the basis of an estimated mean thickness of 3 m, contains about 35 million tonnes of material.

There is little gravel between Dullator and Trochrie [NN 978 402] but in the area to the east (2:7 on Fig. 2), there are thin hummocky deposits of poorly sorted sand and gravel, mainly on the northern side of the valley.

Deposits below water table

All the principal valleys in the Strath Tay area are floored with low-lying tracts of terrace and alluvium, formed mainly of sand and silt with beds of peat in places. These deposits are known to conceal deep glacially scoured channels which in some cases are filled with sand and gravel of fluvioglacial origin to depths exceeding 40 m. From borehole evidence, it is evident that in Glen Garry (2:1 on Fig. 2) between Calvine [NN 803 658] and Blair Atholl, the buried channel is at least 20 m deep beneath the alluvial plain which is up to 500 m wide in places. In the Tummel Valley (2:2 on Fig. 2) between Loch Tummel and the confluence with the River Tay, terraces, alluvium and other floodplain deposits are generally from 400 to 500 m wide. Boreholes at the site of the Faskally Dam at Pitlochry show that these are underlain by a buried channel at least 15 m deep containing coarse gravel with beds of sand.

West of Aberfeldy in the Tay Valley (2:3 on Fig. 2) a buried channel filled with sand and gravel may

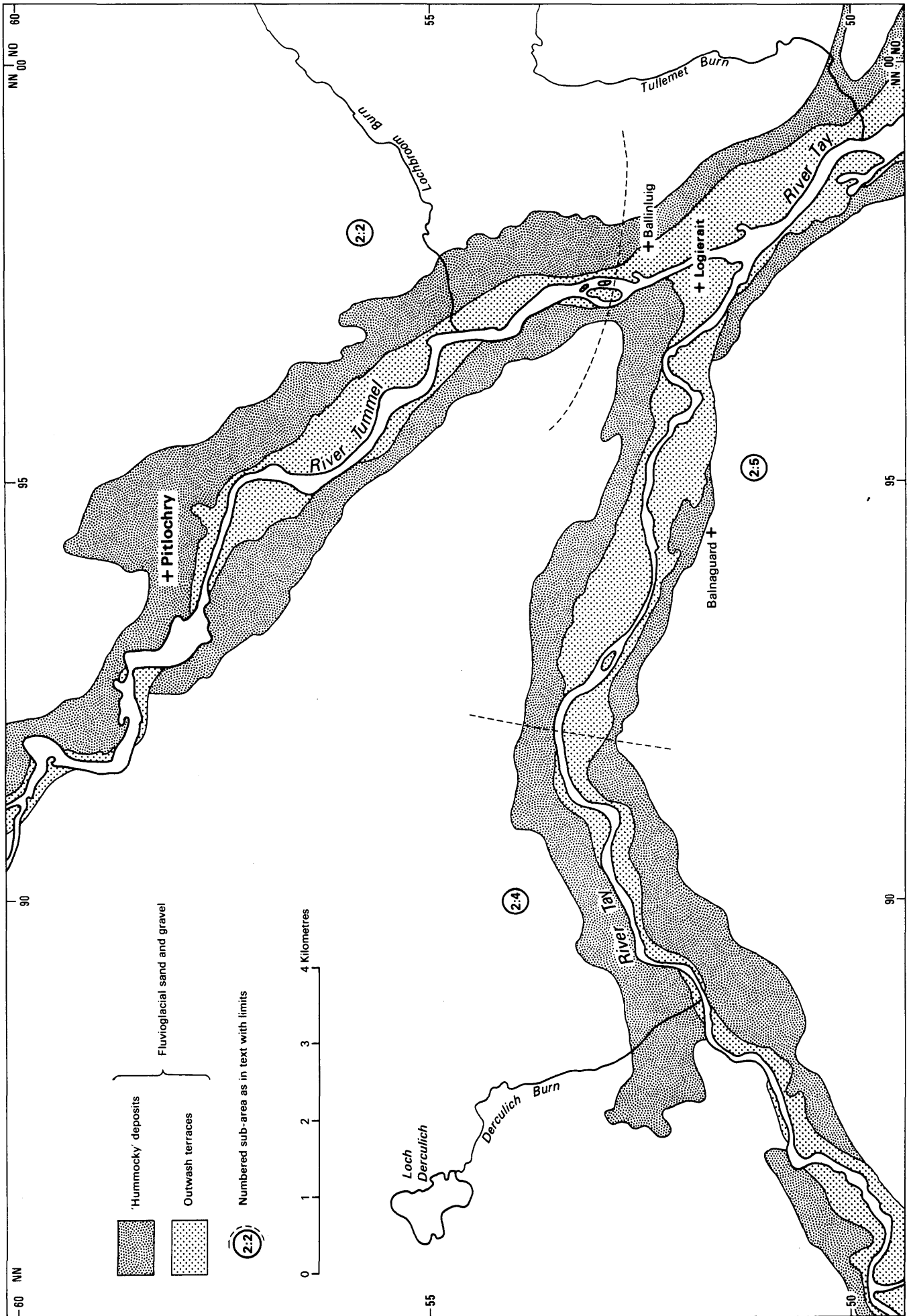


Fig. 4. Sand and gravel deposits in the Tay and lower Tummel valleys

lie beneath a low-lying alluvial spread some 8 to 900 m wide. Between Aberfeldy and Pitnacree (2:4 on Fig. 2), however, there are rock exposures in the river bed and it is unlikely that a buried channel exists. Eastwards in the Tay Valley (2:5 on Fig. 2) between Pitnacree [NN 924 536] and Inver, where the alluvial plain is generally from 400 to 600 m wide, coarse gravel has been proved to depths up to 40 m in places, for instance near Dalmarnock [NN 997 456]. Strathbraan (2:6, 2:7 on Fig. 2) is generally narrower than the other valleys in the Strath Tay area and it is unlikely that it contains an important buried channel.

There is insufficient evidence to assess the amount of sand and gravel contained in the buried channels of the rivers Garry, Tummel and Tay. It is, however, clear that very large resources are present which may well exceed the total amount of sand and gravel in deposits above the water table, and are tentatively estimated at 600 million tonnes.

AREA 3: STRATHARDLE-GLENSHEE

The sand and gravel resources of this area (Fig. 2) are contained in kame terraces and outwash spreads in Strathardle (3:1) and Glenshee (3:2). In both valleys the kame-terrace gravels are composed mainly of quartz, quartzite and granulite pebbles but include between 15 and 20 per cent of platy schistose rocks. They are generally poorly sorted and coarse grained, containing all grain sizes from fine sand to boulders more than 60 cm long.

Deposits above water table

Strathardle (3:1 on Fig. 2), and its continuation, Glen Brenechan, are flanked on both sides by fluvioglacial deposits laid down in association with glacier ice. The deposit is composed mainly of kame terraces which pass downstream into outwash spreads and descend to or below the level of the modern floodplain. The kame-terrace complex is generally from 100 to 200 m wide and reaches a height on the valley sides about 20 to 30 m above river level. The deposit was seen in exposures near Milton [NO 074 614] and Kirkmichael [NO 081 603] to consist of ill-sorted coarse gravel with boulders up to 60 cm across. Pebbles from the gravel (Appendix 2, Nos. 22 to 25) contained from 60 to 80 per cent of quartz, quartzite and granulite, the remainder being schist (14 to 27 per cent), and various igneous rocks (5 to 28 per cent). There is little information concerning the nature and thickness of the outwash deposits but it seems unlikely that there is a major gravel-filled channel beneath the floodplain in Strathardle. The resources of sand and gravel above the water table in the kame-terrace complex are estimated, on the basis of a mean thickness of 6 m, to be 72 million tonnes.

In Glenshee (3:2 on Fig. 2) and its principal tributary Glen Beag, the modern floodplain is flanked by fluvioglacial gravel deposits. North of Tigh-na-Coille [NO 142 652], these are mainly in the form of kame terraces which are from 50 to 200 m wide and stand some 10 to 15 m above the floodplain level. South of Tigh-na-Coille, the

fluvioglacial deposits are generally hummocky with individual mounds up to 10 m high. Where tributary streams enter Glenshee from the west, as at Lair [NO 142 633], Glen Kilrie [NO 137 606] and Soilzarie [NO 133 596], the deposit expands and in places exceeds 1 km in width. Kame-terrace features are locally developed adjacent to the river.

The deposit was seen at a number of localities to be poorly sorted, ranging in grain size from silt or fine sand to boulders up to 25 cm across. About 50 per cent of the gravel consisted of quartz, quartzite and granulite (Appendix 2, Nos. 18 to 21), the remainder being schist (14 to 34 per cent) and various igneous rocks (15 to 24 per cent).

North of Tigh-na-Coille [NO 142 652], where the maximum thickness of gravel above the water table may locally be as much as 20 m, the sand and gravel content has been calculated on an average thickness of 3 m to be 20 million tonnes. The thickness of the mounded fluvioglacial deposits south of Tigh-na-Coille is estimated to be 2 m on average, and the quantity of sand gravel is calculated to be about 25 million tonnes.

Deposits below water table

Considerable resources of sand and gravel may lie beneath the floodplain in Strathardle (3:1 on Fig. 2), especially in the broader stretches between Cotterton [NO 038 638] and Enochdu [NO 065 628] and between Kirkmichael [NO 083 598] and Woodhill House [NO 098 545]. The floodplain covers an area of approximately 300 hectares but there is no information concerning the nature of thickness of the deposit.

In Glenshee (3:2 on Fig. 2) north of Tigh-na-Coille, the floodplain is from 150 to 400 m wide and covers an area of about 130 hectares. Fluvioglacial sand and gravel may lie beneath a thin layer of alluvial silt and sand. Farther south, the floodplain is narrow, rarely exceeding 100 m, and there is little evidence of a deep gravel-filled channel.

AREA 4: WESTERN STRATHMORE

Approximately one-third of the surface of western Strathmore (Fig. 2) is covered by deposits of fluvioglacial origin which accumulated in association with stagnant glacier ice formerly occupying the low ground south of Blairgowrie [NO 175 455]. The greater part of the deposit consist of hummocky sand and gravel which was laid down by meltwater constrained to flow eastwards because the lower Tay Valley was blocked by ice. Later, when the Tay drainage had been unblocked, the hummocky deposits were covered in part by outwash spreads of sand and gravel issuing from ice fronts in the Tay Valley near Dunkeld and in the Ericht valley above Blairgowrie. Masses of ice, buried or enclosed by this deposit, subsequently melted leaving large kettleholes, some still occupied by lochs. In areas adjacent to the rivers Tay, Ericht and Isla, the fluvioglacial deposits lie beneath terrace and alluvial sediment.

Deposits above water table

Western Strathmore is flanked to north and south



Fig. 5. Sand and gravel deposits in the Murthly-Blaigowrie area of western Strathmore

by hummocky deposits of sand and gravel as shown on Figs. 5 and 6. Because the deposit was laid down by generally eastward-flowing meltwater its grain size diminished in that direction. Gravel predominates in the area (4:1) between Loch of Clunie [NO 115 445] and Blairgowrie and in the narrow strip (4:2) which extends eastwards from Blairgowrie to Dillavaid [NO 294 503]. On the southern side of Strathmore, in the area (4:3) between Birnam and Court Hill [NO 143 377], the deposit consists mainly of medium gravel with subordinate beds of sand. Farther east, however, in the area (4:4) between Bridge of Isla [NO 163 383] and Meigle [NO 286 446], gravel occurs only in thin beds or is confined to esker ridges.

In the area (4:5) between Blairgowrie and Meikleour [NO 157 395], the hummocky sand and gravel deposit is overlain by a large outwash spread, laid down by meltwater issuing from ice in the valleys of the Tay and Isla. In the Tay valley, only remnants of the spread survive, the largest fragments being near Spittalfield [NO 108 409] and Delvine [NO 124 403]. Near Blairgowrie and in the Spittalfield area, the deposit consists largely of gravel but, to the east and south, the proportion of sand increases and in the neighbourhood of Meikleour gravel occurs only in thin beds.

Pebble counts taken from the gravel complex at a number of sites (Appendix 2, Nos. 26 to 29), showed 70 to 80 per cent of quartz, quartzite and schistose grit, the remainder consisting of schists, Lower Old Red Sandstone lava, and various intrusive igneous rocks in approximately equal amounts. Little information is available concerning the thickness of the sand and gravel but in excavations for pipelines near Bishophall [NO 136 386] more than 2 m was generally present and up to 10 m was proved at the northern edge of the deposit. Similar excavations near Stobcross [NO 245 419] exposed up to 3 m of sand with a little gravel and a borehole at Larghan [NO 228 407], on the ridge which extends eastwards from Coupar Angus, penetrated more than 16 m of sand and gravel. Kettlehole lochs, which were formed by the melting of masses of ice buried or enclosed by gravel, include Marlee Loch [NO 140 445], Fingask Loch [NO 165 430] and Stormont Loch [NO 190 423]. These and similar lochs in the neighbourhood of Blairgowrie are more than 15 m deep and it is inferred that in this area the gravel thickness exceeds the depths of the lochs. The total quantity of fluvio-glacial deposit above the water table is thought to be about 500 million tonnes, with a further 100 million tonnes beneath the present water table. Extraction of the sand and gravel could, however, lower the water table. About one-third of the total resources is thought to consist of gravel, the remainder being sand.

Deposits below water table

A broad area (4:6 on Fig. 5) of terrace and silty alluvium in the Tay Valley near Spittalfield [NO 107 408] is known, from a borehole near Delvine [NO 124 403], to cover a deposit of sand and gravel at least 15 m thick in places. As the

average thickness of the deposit is unknown, no meaningful estimate of the total quantity of sand and gravel is possible. The overlying silty alluvium is known from excavations to exceed 2 m in thickness and presents a considerable overburden. It is probable that the floodplain alluvium of the rivers Isla and Erich (4:7 on Fig. 6), which is known generally to exceed 2 m in thickness, similarly rests on fluvio-glacial sand and gravel.

AREA 5: LOCH EARN-PERTH

The principal sand and gravel deposits in the area (Fig. 2) lie in the valleys of the rivers Tay, Almond and Earn and their tributaries. The bulk of these deposits consists of moundy fluvio-glacial material but there are extensive outwash terraces in the Almond valley near Almondbank [NO 065 263] and in Strathearn downstream of Crieff.

Deposits above water table

A strip of kame-terrace sand and gravel deposits extends along the north side of the Earn valley from Comrie to Crieff (5:1 on Fig. 2). The surface of the terraces stands from 15 to 20 m above the river floodplain level. The deposit is currently being extracted from quarries at Greenend [NN 830 233] where up to 6 m of gravel is worked and at Dalvreck [NN 856 229] where from 6 to 8 m of medium to coarse (more than 10 cm) gravel rests on about 12 m of sand. From pebble counts (Appendix 2, Nos. 31 to 32), the gravel contains 30 to 45 per cent of quartz, quartzite and granulite, 20 to 40 per cent of Lower Old Red Sandstone lava and 20 to 25 per cent of mixed intrusive igneous rocks. At a disused quarry near Culcrieff [NN 862 237], up to 30 m of deposit was formerly worked, consisting mainly of sand with some thick beds of gravel, in which the proportion of lava debris was less (Appendix 2, No. 33). In the area (5:2 on Fig. 2) between Monzie [NN 879 251] and Harrietfield [NN 983 298] in Glenalmond, a hummocky deposit of sand and gravel up to 1 km wide extends from a distance of about 11 km (Fig. 7). There is little information about the nature and thickness of the deposit but some of the mounds are up to 20 m high, particularly in the area close to the mouth of the Sma' Glen [NN 915 285]. The total quantity of sand and gravel in areas (5:1) and (5:2) is estimated at about 50 million tonnes.

South-eastwards from Crieff for a distance of approximately 10 km (5:3 on Fig. 7), the River Earn is flanked by a terraced fluvio-glacial outwash deposit composed of sand and gravel from 2 to 6 m thick which rests on fine grained sand or marine clays. The deposit was formerly worked at a quarry near North Forr [NN 840 202], where a working face up to 6 m high was established in well bedded and well sorted gravel with pebbles up to 10 cm across and a few thin lenticular beds of sand. A pebble count of the gravel (Appendix 2, No. 34) showed 35 per cent of quartz, quartzite and granulite, a similar amount of various intrusive igneous rocks and 20 per cent of Lower Old Red Sandstone lava. The total quantity of material in the outwash terraces, estimated on a

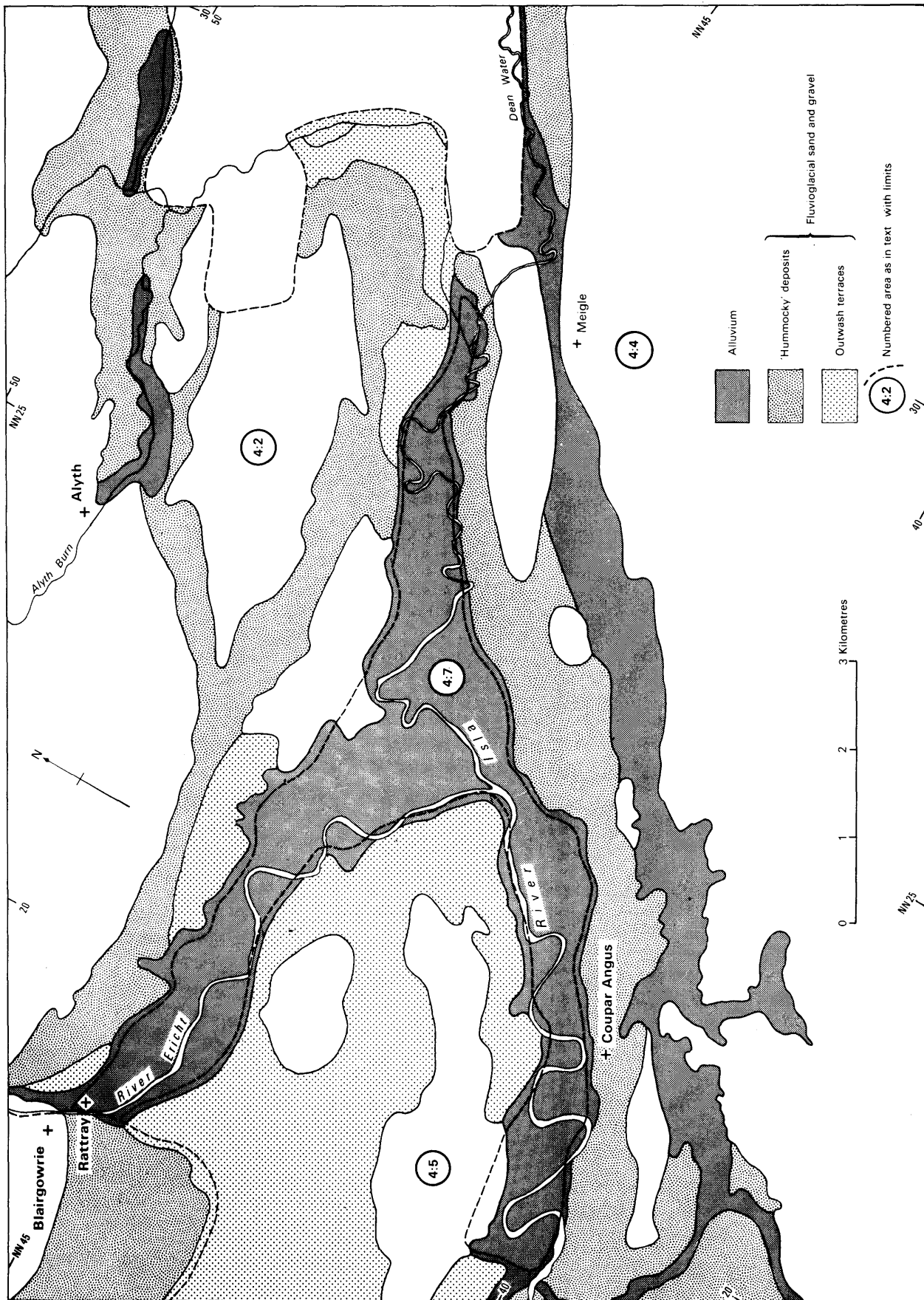


Fig. 6. Sand and gravel deposits in the Blairgowrie-Meikle area of western Strathmore

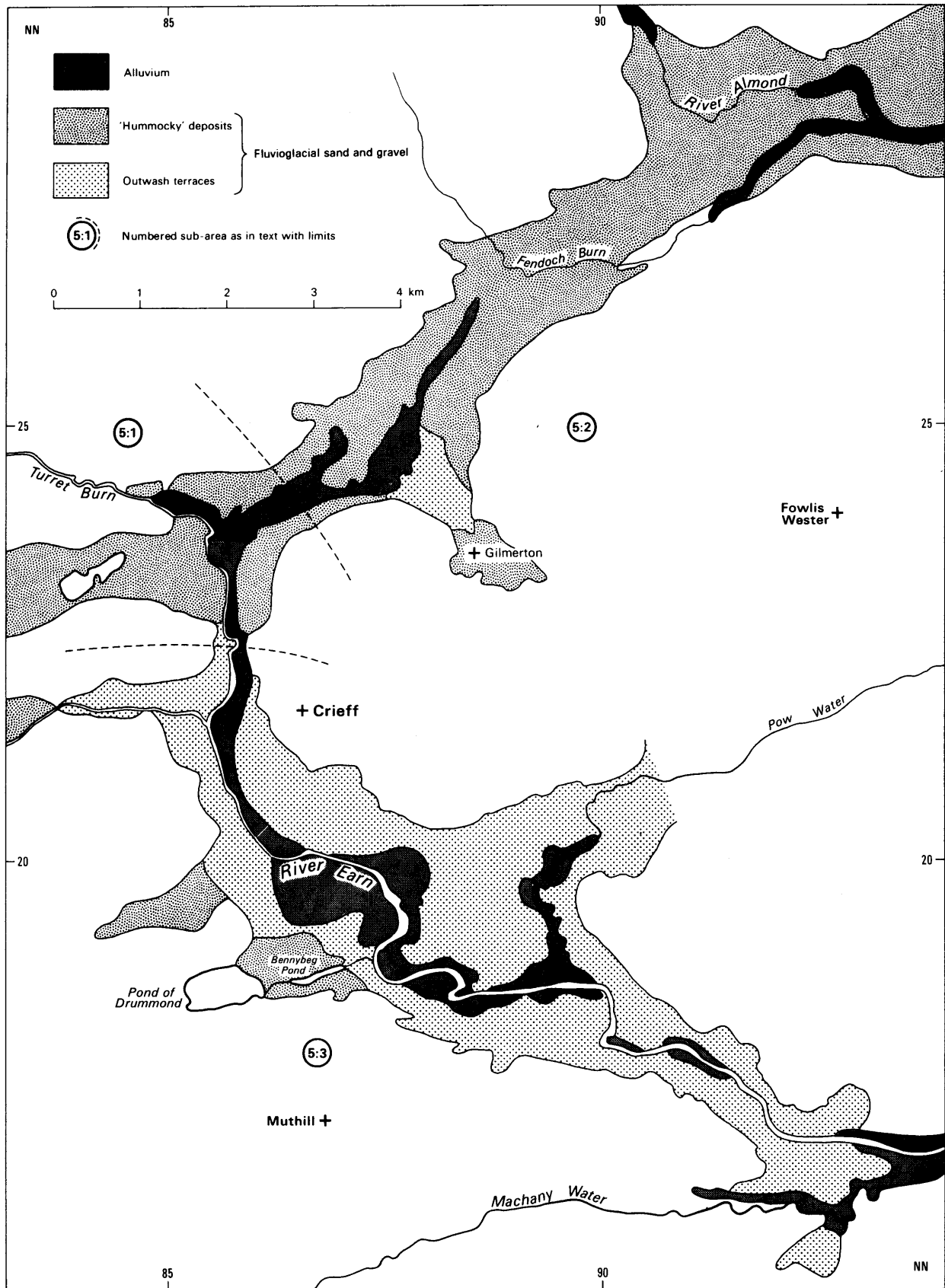


Fig. 7. Sand and gravel deposits in the Creiff area

mean thickness of 3 m, is about 53 million tonnes.

On the southern side of Strathearn, between Aberuthven [NN 977 154] and Forteviot [NO 053 176], there are widespread deposits of outwash sand and gravel (5:4 on Fig. 2). These rest on marine clays and are generally thin and do not represent a major resource.

In the lower Almond Valley (5:5 on Fig. 2), near its confluence with the Tay Valley, sand and gravel occurs in a major outwash spread which contains numerous large kettleholes. The deposit consists predominantly of gravel, generally coarse grained with pebbles and boulders up to 30 cm in diameter, mainly of quartz, quartzite and granulite (60 per cent) with 20 per cent of various schists and small amounts of Lower Old Red Sandstone lavas and sediments (Appendix 2, No. 35). The deposit is currently being worked at a quarry [NO 053 254] near Loanleven where there are faces up to 5 m high in gravel which is underlain by sand. The deposit thickens northwards from Loanleven and attains its maximum thickness of about 30 m near Almondbank [NO 065 265]. It thins eastwards and is only 4 m thick at an exposure [NO 084 263] 800 m south-west of Berthapark. The total quantity of sand and gravel in the outwash spread is estimated to be about 45 million tonnes.

The tract of low ground (5:6 on Fig. 2) followed by the A9 road between Stare Dam [NO 047 387] and Luncarty [NO 096 259] is occupied by a series of small deposits of fluvio-glacial sand and gravel. The largest of these, in part hummocky and in part composed of terraced outwash material, extends from Bankfoot [NO 067 354] to Luncarty and covers an area of about 400 hectares. Borehole evidence in the vicinity of Luncarty indicates that the average thickness of sand and gravel may be about 5 m and the deposit therefore amounts to about 40 million tonnes. The gravel is generally coarse grained, with pebbles of quartz, quartzite, various intrusive igneous rocks and Lower Old Red Sandstone sediments and lavas up to 15 cm long. Sand is generally subordinate but near Luncarty may constitute about one-third of the deposit.

Smaller and probably thinner deposits of a similar nature occur also between Stare Dam and Bankfoot on the southern side of the Shochie Burn near Moneydie [NO 065 296]. An exposure [NO 072 293], 800 m east-south-east of Moneydie, showed 4 m of coarse gravel with little sand.

In the valley of the River Tay (5:7 on Fig. 2) between Kinclaven Castle [NO 158 378] and Colen [NO 108 304], erosion has removed all but a few outwash terraces of sand and gravel. The most prominent of these are at Campsie [NO 125 336] and Cambusmichael [NO 117 323]. Each has an area of approximately 30 hectares and may contain an average thickness of 5 m of coarse gravel. Their combined resources may thus exceed 6 million tonnes. A small spread (5:8 on Fig. 2) of mounded fluvio-glacial sand and gravel extends east-north-eastwards from Abernethy [NO 190 165] to Newburgh. There is little information concerning the nature and thickness

of the deposit which covers an area of about 235 hectares.

Deposits below water table

Westwards from Loch Monzievaird [NN 840 233], Strathearn is occupied by an alluvial plain (5:9 on Fig. 2) up to 1.5 km wide, which extends as far as Comrie where gravel is known to underlie the alluvium. It is probable that the alluvium, which covers an area of about 925 hectares, conceals a glacially scoured, gravel-filled channel. There is no borehole information concerning the thickness of such a deposit which is, however, likely to represent a very large resource of sand and gravel.

An extensive spread of outwash sand and gravel, known from excavations and boreholes to be up to 4 m thick, lies in the valley of the River Almond (5:5 on Fig. 2) near its confluence with the River Tay. The deposit consists mainly of coarse gravel with pebbles up to 15 cm long composed predominantly of quartz and quartzite (73 per cent) with minor amounts of schist and Lower Old Red Sandstone lavas and sediments (Appendix 2, No. 36). The gravel covers an area of 340 hectares and on an estimated average thickness of 3 m amounts to about 20 million tonnes.

AREA 6: STRATHALLAN-KINROSS

In this area there are two main developments of sand and gravel, the first being in Strathallan (Fig. 2, 6:1, 6:2, 6:6) between Nether Cambushinnie [NN 809 067] and Blackford, the second lying mainly to the west of Loch Leven (Fig. 2, 6:3, 6:4). Both consist mainly of mounded fluvio-glacial sand and gravel. A third much smaller deposit (Fig. 2, 6:5), lies in the valley of the River Knaik near Langside [NN 785 140].

Deposits above water table

Fluvio-glacial sand and gravel is extensively developed on the northern side of Strathallan particularly in the area (Fig. 8, 6:1) between Braco [NN 837 095] and Gleneagles Hotel [NN 916 115]. The deposit has a highly irregular topography but locally contains large flat-topped mounds, standing up to 15 m above the floodplain of the Allan Water. It is probable that gravel predominates over sand but there are few exposures of the deposit and no borehole evidence is available. Pebble counts of the gravel near Braco and Blackford (Appendix 2, Nos. 39 and 41) showed from 35 to 45 per cent of quartz, quartzite, granulite and mixed intrusive igneous rocks of Highland origin, the remainder consisting mainly of sediments (30 to 50 per cent) and lavas (12 to 24 per cent) of Lower Old Red Sandstone age. The sand and gravel deposit covers an area of approximately 1800 hectares; calculated on an estimated average thickness of 5 m, its total resource amounts to 180 million tonnes.

The Allan Water is flanked on the southern side (Fig. 8, 6:2) by narrow deposits of mounded sand and gravel similar to those on the northern side. The surface of deposits is irregular and reaches a height on the valley sides of 120 to 145 m above OD. There is no information concerning the composition of the deposit but it is probable that

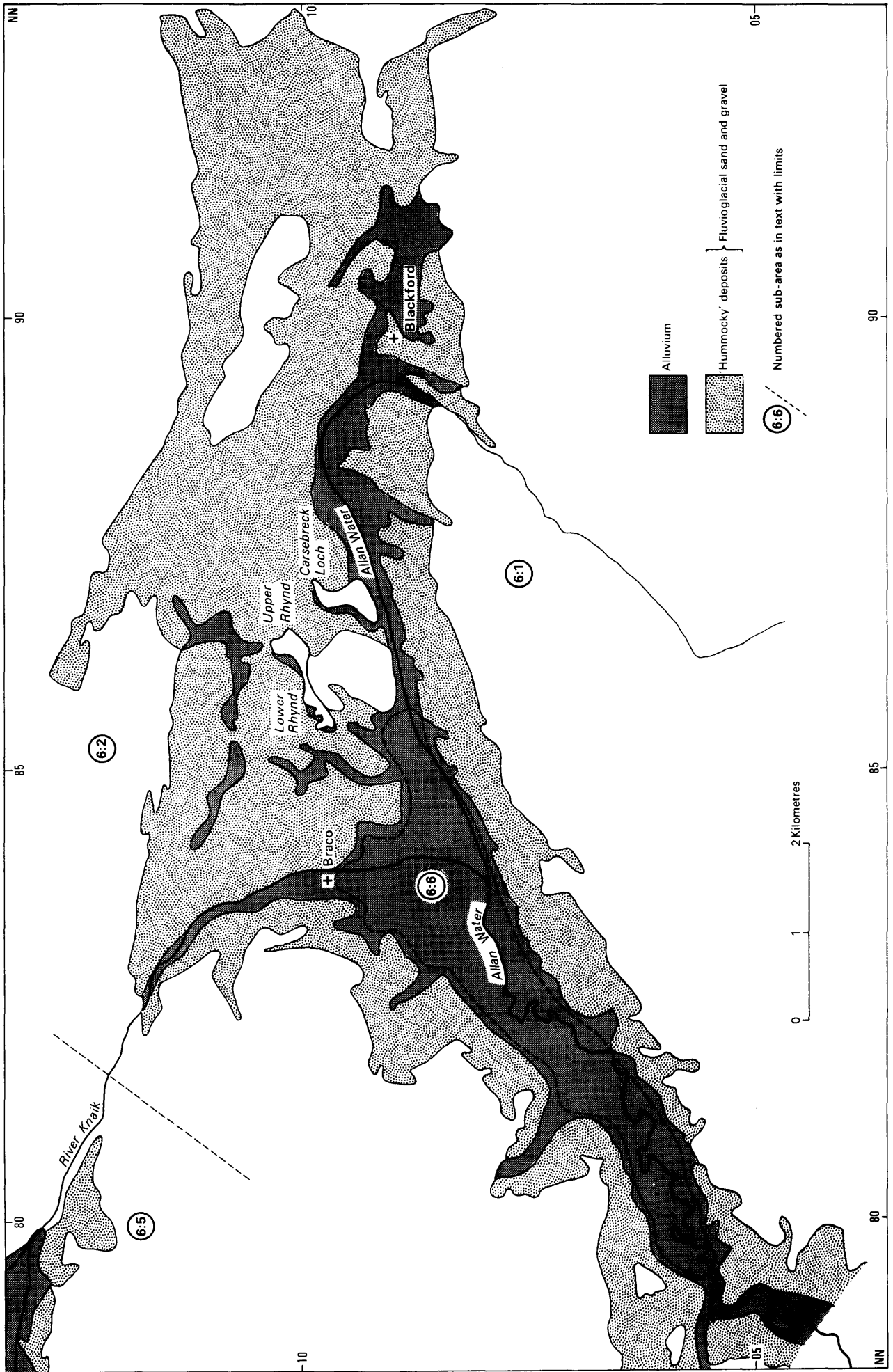


Fig. 8. Sand and gravel deposits in Strathallan

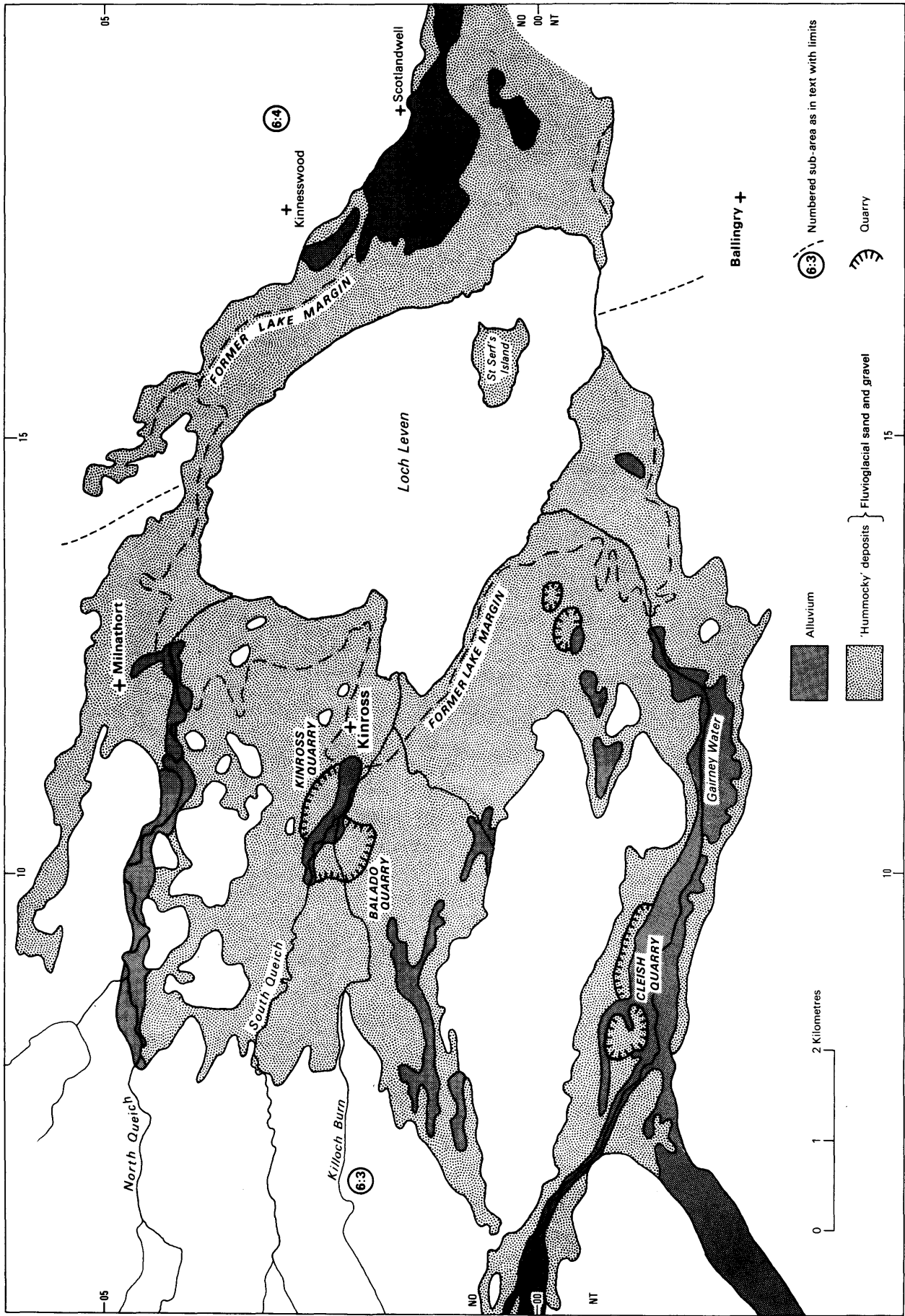


Fig. 9. Sand and gravel deposits in the Loch Leven area

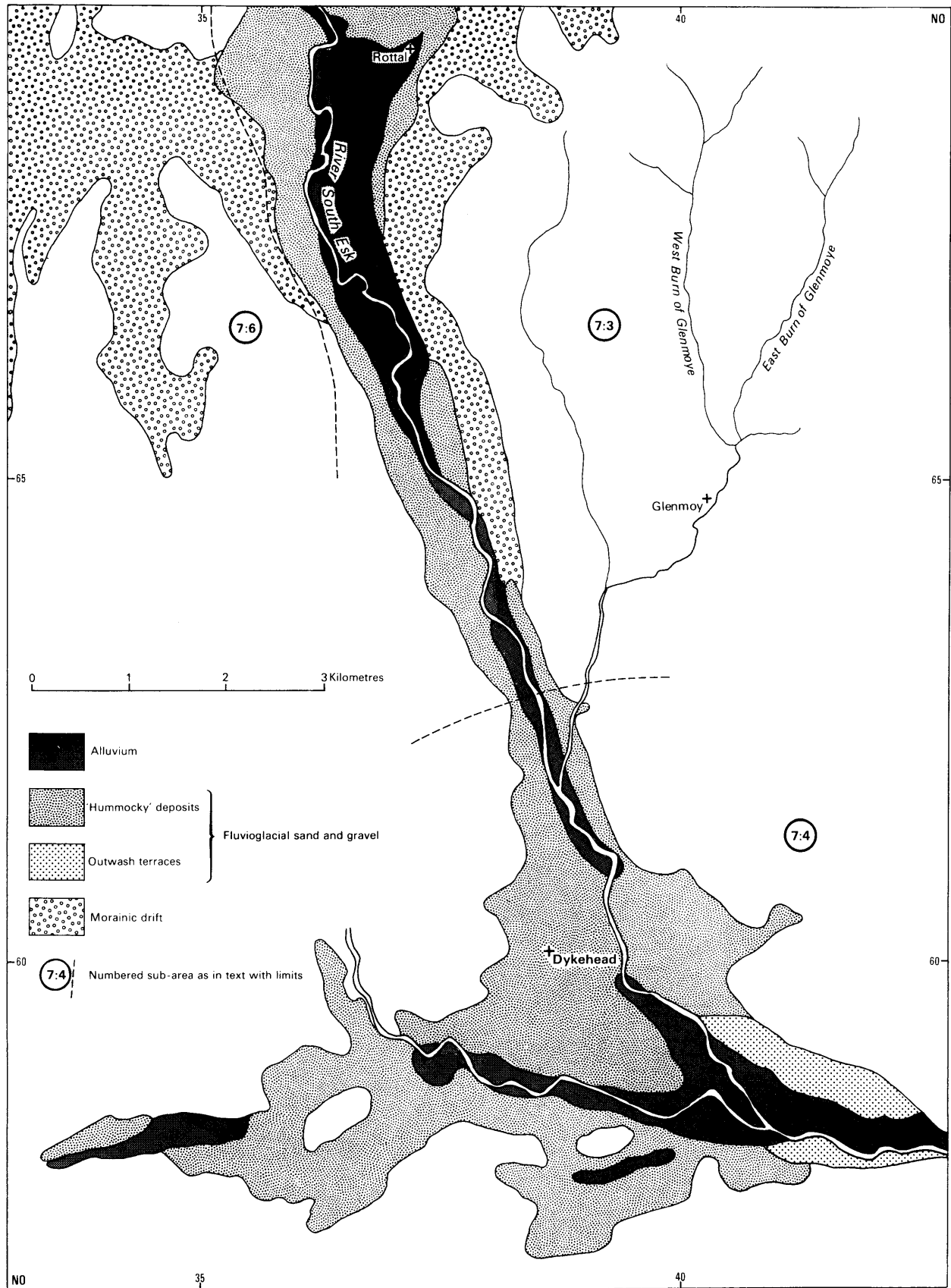


Fig. 10. Sand and gravel deposits in lower Glen Clova

gravel predominates. Sand and gravel covers an area of approximately 576 hectares and on the basis of an estimated average thickness of 5 m amounts to about 58 million tonnes.

In the Kinross area, a tract of undulating ground (Fig. 9, 6:3) to the west of Loch Leven is underlain by gravel with subordinate amounts of sand. The deposit is currently being worked at the Kinross [NO 102 026], Balado [NO 102 023] and Cleish [NT 080 990] quarries, where working faces up to 4 m high are established in coarse gravel (average particle size 5 to 7.5 cm) with thin beds of coarse sand. At these sites, considerable amounts of material may exist below the water table and at one time were exploited at Cleish to a depth of some 6 m.

Pebble counts on samples taken from the working pits (Appendix 2, Nos. 42 to 44) showed a preponderance of Lower Old Red Sandstone lava (more than 60 per cent) and sediment (12 to 20 per cent), the remainder consisting mainly of quartz, quartzite, granulite and schistose grits. Outside the worked areas, information concerning the thickness of the deposit is limited but more than 8 m of sand and gravel is present in a borehole [NO 111 020] situated 480 m E 20° N of Turfhill. The mean thickness of sand and gravel is estimated at 5 m and its quantity accordingly is calculated at 200 million tonnes, most of which probably lies above the water table. Adjacent to Loch Leven, there may be beds of peat within the sand and gravel.

A smaller deposit of sand and gravel (Fig. 9, 6:4) lies to the east of Loch Leven. There is little information regarding the nature and thickness of material in this area but the proportion of sand to gravel may well be greater than to the west of the loch. The amount of material, on an assumed average thickness of 3 m, is about 30 million tonnes but may contain beds of peat.

Terraced fluvio-glacial spreads (6:5 on Fig. 2), associated with hummocky deposits of sand and gravel in the upper reaches of the River Knaik near Langside [NN 792 138], are covered in part by peat. There is little information concerning the nature of the material but in places the deposit is from 6 to 10 m thick.

Deposits below water table

South-westwards from Braco, the Allan Water flows through a broad terraced alluvial plain (Fig. 8, 6:6) which occupies an area of about 600 hectares. Recently, excavations have shown that a variable but generally thin layer of sand and silt rests on gravel which may be of fluvio-glacial origin. The gravel is known to exceed 2 m in thickness and it has been estimated on this basis to amount to more than 24 million tonnes.

Angus District

Large quantities of sand and gravel in the form of kame terraces and outwash spreads occur in the valleys of the rivers Isla, South Esk and North Esk (Fig. 2). The greatest single resource, however, lies in Strathmore between Ruthven and Forfar and continues eastwards to the sea at

Arbroath and Lunan Bay. Smaller deposits of fluvio-glacial and raised beach gravels occur in the coastal strip from Dundee to Arbroath, where there are also considerable areas covered by dunes of wind-blown sand. The District has been subdivided into three areas (Fig. 3, areas 7 to 9) for convenience of description.

AREA 7: GLEN ISLA—GLEN CLOVA

In this area (Fig. 2) the principal sand and gravel deposits were laid down in association with glacier ice in Glen Isla and Glen Clova. Considerable deposits also occur in the area to the north and east of Loch of Lintrathen and in the neighbourhood of Cortachy where the Prosen Water joins the River South Esk.

Deposits above water table

Kame terraces from 100 to 300 m wide, flank the River Isla (7:1) between Little Forter [NO 186 649] and Needs [NO 237 583]. They generally stand from 6 to 10 m above stream level and consist of poorly sorted, very coarse gravel containing large boulders in a silty matrix. The terrace deposits cover an area of about 340 hectares and on an estimated average thickness of 3 m contain over 30 million tonnes of sand and gravel. The composition of the gravel is not known but probably consists mainly of quartz, quartzite and granulite. South of Needs, there are no kame terraces and it is clear that in late glacial times, the meltwater drainage was diverted eastwards and entered the valley of the Melgam Water at Dykends [NO 251 577]. In this area (7:2), north of Loch of Lintrathen, widespread deposits of fluvio-glacial sand and gravel were laid down. This deposit has an irregular surface, marked by mounds and esker ridges, and consists of ill-sorted material, similar to morainic drift and ranging in grain size from silt to boulders more than 20 cm long. It is probable that gravel occurs only in the kames and esker ridges and is therefore of limited quantity and has not been estimated. Pebbles from the gravel (Appendix 2, Nos. 45 to 48) generally contained more than 70 per cent of quartz, quartzite and granulite, the remainder consisting of schist and various intrusive igneous rocks in about equal amounts.

Kame terraces occur on one or both sides of Glen Clova (7:3) between Clova [NO 326 732] and Elly [NO 388 672] and are commonly from 100 to 300 m wide but between When [NO 361 710] and Rottal [NO 375 646] they exceed 500 m in width (Fig. 10). The surface of the terraces in places stands as much as 20 to 25 m above the level of the floodplain of the River South Esk. The deposit is poorly exposed but in a small quarry [NO 359 687] near Kilburn, 5 m of very coarse ill-sorted gravel with boulders up to 30 cm were seen and this section is probably representative of the whole. Pebble counts of samples taken at several localities (Appendix 2, Nos. 50 and 51) show that the gravel consists mainly of quartzite, granulite and quartz (60 to 70 per cent) with small amounts of various igneous rocks and schists. The quantity of sand and gravel, calculated on the basis of an estimated average

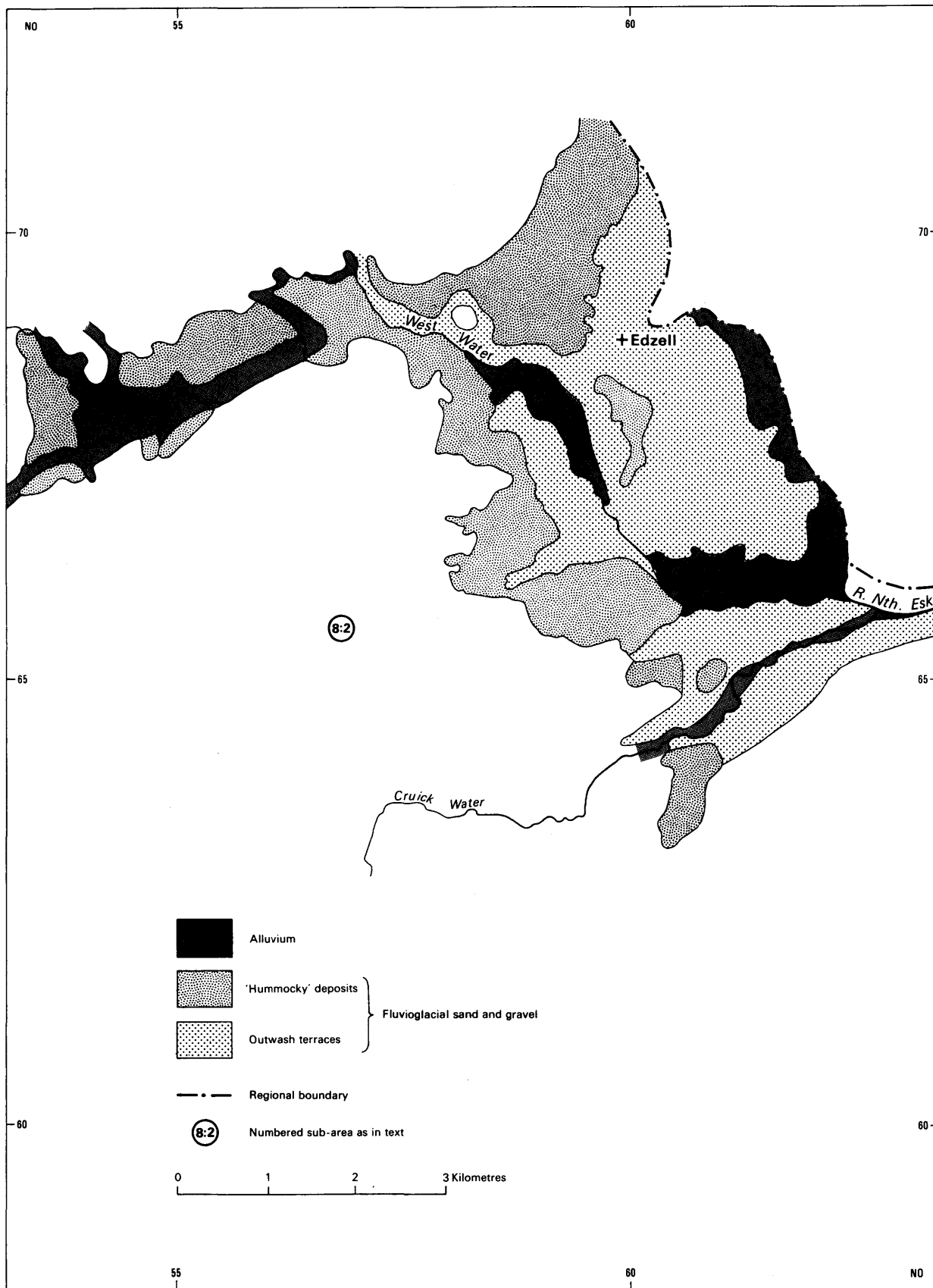


Fig. 11. Sand and gravel deposits in the Edzell area

thickness of 10 m, is 100 million tonnes (see Table 3).

South of Elly, narrow kame terraces composed of coarse gravel pass into a large spread (Fig. 10, 7:4) of hummocky sand and gravel laid down by meltwater from glaciers occupying Glen Clova, Glen Prosen and the valley of the Carity Burn. The deposit was seen in a small quarry [NO 383 584] near Prosen Bridge, and also near Newmill [NO 375 580], to consist of gravel with pebbles up to 10 cm long and sand in about equal amounts.

The kame terrace deposits in lower Glen Clova were sampled north of Cullow [NO 387 409] (Appendix 2, Nos. 52 and 53) where they consist mainly of locally derived pebbles of slate and chloritic schist (52 to 55 per cent) with lesser amounts of quartz and quartzite (40 per cent). Samples of the gravels flanking the Carity Burn (Appendix 2, Nos. 54 to 56) are quite different, however, and contain from 40 to 65 per cent of quartz and quartzite pebbles, 10 to 12 per cent of schist and up to 45 per cent of Lower Old Red Sandstone lava derived from conglomerate in the Highland Border region. The thickness of the deposit is not known but gravel mounds are commonly more than 10 m high. The quantity of sand and gravel, estimated on an average thickness of 3 m, is about 55 million tonnes. Small deposits of hummocky fluvioglacial sand and gravel (Fig. 2, 7:5) between Greenmyre [NO 312 550] and Nether Ascreavie [NO 339 563] and in the valley of the Cromie Burn, west of Kirkton of Kingoldrum [NO 335 550], are probably thin and are unlikely to constitute a resource.

Deposits below water table

In Glenisla (Fig. 2, 7:1) between Tulchan [NO 186 723] and Needs [NO 237 583], the River Isla flows through a spread of terrace and alluvium which in places is up to 500 m wide and may cover deposits of fluvioglacial sand and gravel. The alluvial plain in Glen Clova varies considerably in breadth but between Acharn [NO 282 763] and Clova [NO 326 732] (Fig. 2, 7:6), between Ruttal [NO 370 696] and Clachnabrain (Fig. 2, 7:3), and at the confluence of the Prosen Water and the River South Esk (7:4) it is generally about 500 m wide. The alluvium which has a total area of about 8 km², probably consists in part of sand and gravel and may overlie deposits in glacially scoured channels.

Miscellaneous deposits

Morainic drift occurs extensively in the upper part of Glen Clova (Fig. 2, 7:6) and its tributary valleys. Its potential as a source of sand and gravel has not been assessed.

AREA 8: GLENESK-BRECHIN

The sand and gravel resources of this area (Fig. 2, area 8) are contained mainly in kame terraces and outwash spreads in the valleys of the rivers North and South Esk. In addition, sand and gravel occurs in hummocky deposits to the south and west of Kirkton of Menmuir.

Deposits above water table

Narrow kame terraces, standing from 6 to 12 m above floodplain level, flank Glenesk (Fig. 2, 8:1) between Woodhaugh [NO 489 789] and Dalbog [NO 587 718]. They consist of ill-sorted coarse grained material resembling morainic drift and ranging in grain size from silt to boulders up to 50 cm across. Quartz, quartzite and granulite form up to 90 per cent of the rock fragments, the remainder being schist (up to 10 per cent) and igneous intrusive rocks. (Appendix 2, Nos. 57 to 60). The maximum thickness of the deposit may locally exceed 10 m but the average thickness is probably no more than 3 m. The quantity of sand and gravel in the deposit is estimated at 30 million tonnes.

In the area about Edzell where the River South Esk converges with the West Water, there are important resources of sand and gravel in hummocky deposits and fluvioglacial outwash terraces (Fig. 11). The terraced spreads which lie mainly between the two rivers consist of well sorted, generally fine grained gravel with pebbles less than 5 cm in diameter. The proportion of sand is generally small, amounting to less than 30 per cent. In samples from the gravel (Appendix 2, Nos. 65 and 66) quartz and quartzite fragments predominate (40 to 75 per cent) but there were also considerable amounts of Lower Old Red Sandstone lavas and sediments (10 to 20 per cent in each case). From excavations near Struan [NO 614 670] and to the east of the River North Esk, the gravel is known to be about 2 m thick over wide areas although locally it may be thicker. Its quantity, calculated on a mean thickness of 2.5 m, is 30 million tonnes.

The mounded deposits of sand and gravel, which lie mainly to the north-west of Edzell and in the valley of the West Water, are generally less well sorted and coarser grained than the terrace gravels. Samples of the material (Appendix 2, Nos. 62 and 63) consisted mainly of quartz, quartzite and schist pebbles. Except where concentrated in mounds, the deposit is probably thin and as the gravel is of poor quality its quantity has not been assessed.

A widespread deposit of sand and gravel (Fig. 2, 8:3) between Easter Ogil [NO 452 618] and Kirkton of Menmuir [NO 534 644] has been shown by recent excavations to be generally less than 1 m thick and thus cannot be regarded as a resource.

In the area (Fig. 2, 8:4) between Tannadice [NO 474 582] and Brechin, the River South Esk flows through a broad tract of alluvium flanked by terraces which stand up to 6 m above river level. The terraces are individually small but have a total area of approximately 250 hectares. Estimated on an assumed average thickness of 3 m, the quantity of sand and gravel is 15 million tonnes. There is no information concerning the nature of the deposits.

The Montrose Basin (Fig. 2, 8:5) is flanked on the north by narrow fluvioglacial sand and gravel terraces. This deposit is currently being worked near Arrat's Mill [NO 647 587] where up to 6 m of well sorted, fine grained gravel with pebbles

less than 5 cm rests on a further 3 m of sand with a few beds of silt and gravel. A sample of the gravel (Appendix 2, No. 67) contained 45 per cent of quartz and quartzite pebbles, 20 per cent of Lower Old Red Sandstone lavas and 14 per cent of Lower Old Red Sandstone sedimentary rocks. The total remaining reserve in the Kinncraig—Arrat's Mill area amounts to about 7 million tonnes.

A second deposit, which is not currently being worked, lies about 2 km north of Montrose, in the vicinity of Hillside [NO 705 615]. No information is available on the nature of material but it is likely to be similar to that at Arrat's Mill, possibly containing a higher proportion of sand. Estimated on an average thickness of 3 m the quantity of sand and gravel is 7.5 million tonnes.

Deposits below water table

The alluvium of the River South Esk between Tannadice and Brechin (Fig. 2, 8:4) is known from excavations to consist mainly of coarse gravel beneath a thin layer of sand. The thickness of the deposit, which covers an area of about 720 hectares, probably exceeds 2 m and the amount of sand and gravel present therefore amounts to at least 29 million tonnes.

Miscellaneous deposits

The coastal strip (Fig. 2, 8:6) at Montrose between the mouths of the rivers North and South Esk contains a thin deposit of raised beach sand and shingle, more than 3 m thick in places. On its seaward side, this deposit is overlain by dunes of blown sand up to 8 m high. Shingle banks in the River South Esk at Bridge of Dun [NO 664 585] are currently being exploited for gravel on a small scale.

AREA 9: FORFAR—ARBROATH

The principal resource of sand and gravel in this area (Fig. 2) lies in Strathmore between Ruthven [NO 396 489] and Forfar. Smaller deposits occur also in the valley of the Lunan Water and at Arbroath. Some sand and gravel is present also in raised beach and associated deposits in the coastal area.

Deposits above water table

The area (9:1) around Ruthven and Glamis Castle [NO 386 481] is occupied by an extensive deposit of sand and gravel which is contained in mounds and flat-topped kames (Fig. 12). The surface of the deposit is irregular and is pitted by large kettleholes formed by the melting of buried ice masses. The mounds in many cases reach a height of from 15 to 20 m above stream level and consist of generally fine grained gravel (less than 5 cm) with variable amounts of sand. The proportion of sand to gravel is generally about 1 to 4 but increases towards the south-east. Thus, at the only quarry operating, Bridgend Quarry [NO 374 485] near Glamis, gravel is present only as impersistent beds in the upper part of a working face 10 to 12 m high.

In samples taken of the pebbles at several sites (Appendix 2, Nos. 69 to 74), quartz and quartzite

generally amounted to 50 to 65 per cent, schist from 6 to 10 per cent, various intrusive igneous rocks from 10 to 20 per cent and Lower Old Red Sandstone lavas also from 10 to 20 per cent. Lower Old Red Sandstone sediments were present, generally in small amounts but in the Bridgend Quarry they formed 60 per cent of the sample. The deposit has a total area of about 5100 hectares and on the basis of an estimated mean thickness of 5 m contains about 510 million tonnes of sand and gravel.

Hummocky sand and gravel deposits cover a large area at Forfar (Fig. 13, 9:2) and extend eastwards in the valley of the Lunan Water to Guthrie [NO 567 505]. The surface of the deposit is pitted with large kettleholes, some of which still contain lochs such as Rescobie and Balgavies lochs. Individual mounds and flat-topped kames are up to 15 m high and consist mainly of coarse gravel with pebbles up to 15 cm long.

Sand and gravel is currently being worked at two sites near Forfar, Lochhead Quarry [NO 477 507] and Gowanbank [NO 472 512]. At the first of these, coarse gravel is overlain by fine grained sand which passes up into fine grained well sorted gravel with beds of sand. The maximum depth of the deposit is from 12 to 15 m, about one-third of which consists of sand but there is considerable lateral variation within the quarry. At Gowanbank and at a disused quarry at Fledmyre [NO 489 517] up to 4 m of gravel is exposed, resting on sand.

Pebble counts of the gravel in the Forfar area (Appendix 2, Nos. 75 to 77) showed 60 to 72 per cent of quartz and quartzite, 9 to 17 per cent of Lower Old Red Sandstone lavas and small amounts of schist and various intrusive igneous rocks. The area of the deposit, excluding major kettleholes, is approximately 1600 hectares and the resource, calculated on the basis of an average thickness of 5 m, amounts to 160 million tonnes.

The Forfar sand and gravel deposit continues eastwards in the valley of the Lunan Water (Fig. 14, 9:3) to the sea at Lunan Bay. Extensive spreads, mainly flat-topped, are developed in the neighbourhood of Friockheim [NO 595 497], where they are worked at Kinnell Quarry [NO 604 500]. Until recently, gravel was also extracted at quarries near Boysack Mill [NO 623 496] and Waulkmill [NO 624 482]. At each of these localities, working faces up to 5 m high were established in gravel with thin beds and lenses of sand. Pebbles in the gravel are commonly about 5 cm long but range up to 30 cm. The composition of the gravel (Appendix 2, Nos. 78 to 80) is similar to the deposits at Forfar but the proportion of Lower Old Red Sandstone sedimentary rocks is significantly increased (20 to 25 per cent) at the expense of quartz. Further east in the Lunan valley towards Inverkeilor [NO 666 495], sand and gravel occurs only in narrow terraces (Fig. 23) and has already been extensively exploited, for instance at Bandoch [NO 645 491] and near Grange [NO 656 496]. The proportion of gravel to sand diminishes rapidly towards the east and at a recently opened quarry at Myreside [NO 662 494] near

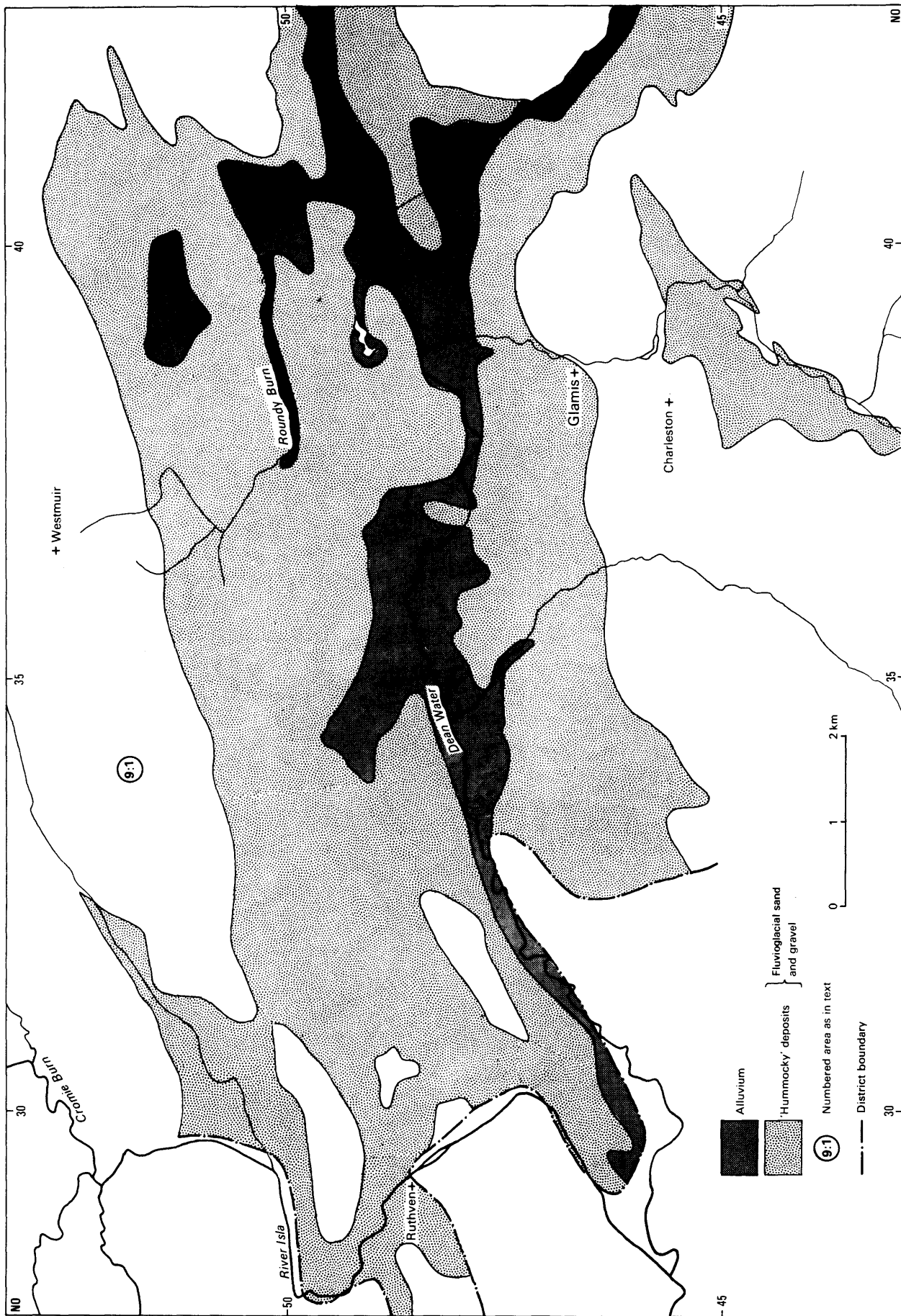


Fig. 12. Sand and gravel deposits in the Ruthven-Guthrie area

Table 3. Sand and gravel resources in the Angus District

Area	Sub-area	Resources above water table			Resources below water table		
		Max. thickness	Av. thickness	Quantity	Max. thickness	Av. thickness	Quantity
		m	m	10 ⁶ tonnes	m	m	10 ⁶ tonnes
1 Glenisla– Glen Clova	7:1	10	3	30	?	?	nq
	7:2	?	?	nq			
	7:3	20	10	100	?	?	nq
	7:4	10	3	55	?	?	nq
	7:5	?	?	nq			
	7:6	?	?	nq	?	?	nq
2 Glensik– Brechin	8:1	12	3	40			
	8:2	8	2	60			
	8:3	1	-	nq			
	8:4	6	3	15			
	8:5	8	4	14.5			
3 Forfar– Arbroath	9:1	15	5	510	} 1.5		240
	9:2	15	5	160			
	9:3	10	5	150			
	9:4	10	4	36			
	9:5	12	5	23			

nq not quantified

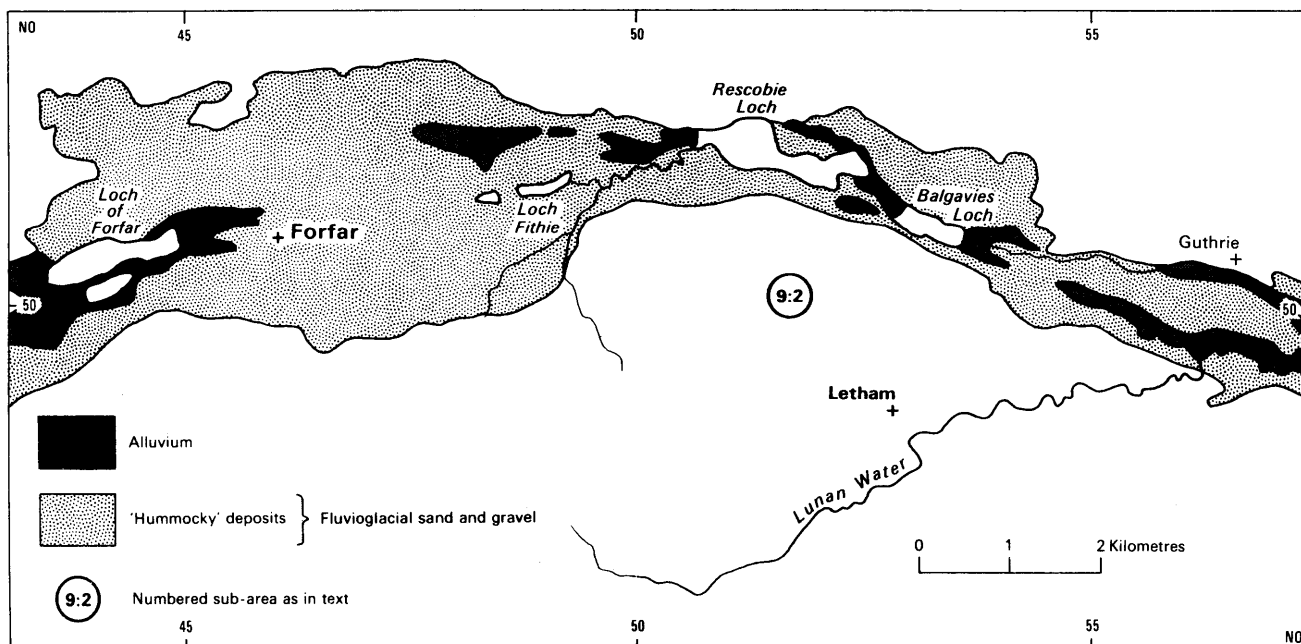


Fig. 13. Sand and gravel deposits in the Forfar–Guthrie area

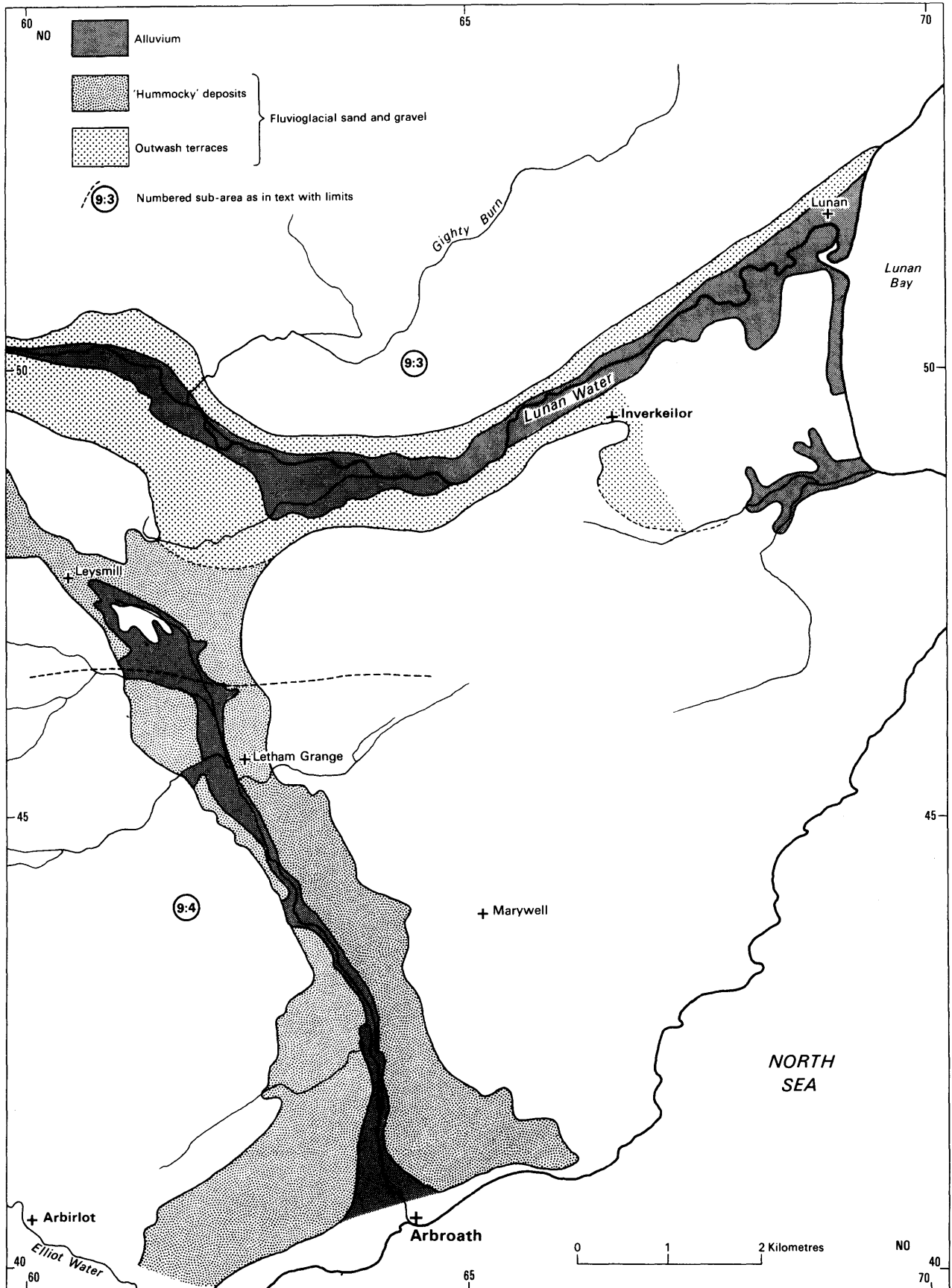


Fig. 14. Sand and gravel deposits in the Arbroath-Lunan Bay area

Inverkeilor, the ratio of sand to gravel in a working-face up to 4.5 m high is about 3 to 1. The total area of sand and gravel in the Friockheim—Inverkeilor area is about 1485 hectares and on the basis of an estimated average thickness of 5 m the quantity of material available amounts to about 150 million tonnes.

The Friockheim sand and gravel deposit continues south-eastwards in the valley of the Brothock Water (Fig. 14, 9:4) as kame terraces pitted with large kettleholes. Much of the deposit lies beneath the town of Arbroath, where a thickness of up to 6 m of sand and gravel was proved in boreholes and wells, and is inaccessible. There is little information concerning the nature of the deposit, which covers an area of 450 hectares, but it may consist mainly of gravel. The total resource, on an estimated thickness of 4 m, is 36 million tonnes.

In the coastal strip between Dundee and Arbroath (Fig. 2, 9:5) there are a number of deposits of fluvioglacial sand and gravel with a characteristically irregular surface. The largest spread extends from Mains of Ardestie [NO 505 342] to Barry where it is currently worked at Cotside Quarry [NO 528 342]. There is little information covering the general nature and thickness of the deposit but at Cotside, a working-face up to 12 m high consisted mainly of fine sand with silty clay bands, which was overlain by coarse gravel. The deposit was laterally variable but the ratio of sand to gravel appeared to be about 3 to 1. A sample of the pebbles, which ranged in size up to 15 cm, consisted mainly of Lower Old Red Sandstone lava (44 per cent) and sediment (21 per cent) with subordinate amounts of quartzite and various intrusive igneous rocks (Appendix 2, No. 82). The deposit covers an area of about 230 hectares and on the basis of an estimated thickness of 5 m contains 23 million tonnes of sand and gravel. About one-quarter of the deposit, however, lies in built-up areas.

Smaller deposits to the east at West Scryme [NO 574 371] and Balcathie [NO 608 396] have a combined area of 214 hectares but there is no information about their thickness and composition. They may contain a further 12 million tonnes of material.

Deposits below water table

The sand and gravel spread which extends from Ruthven to Inverkeilor (Fig. 2, 9:1, 9:2, 9:3) is known to lie in part below the present water table. The deposit covers a total area of over 8000 hectares and may reach depths below water table of more than 5 m. Assuming an average thickness of sand and gravel below water table of 1.5 m, the total resource amounts to 240 million tonnes.

Miscellaneous deposits

Raised beach deposits which extend in a narrow strip along the coast between Carnoustie and Arbroath (Fig. 2, 9:5) may consist in part of sand and gravel. Their thickness is unknown and may not exceed 2 m. The deposit covers an area of more than 700 hectares, however, and may be a useful local source of supply.

Dunes of wind-blown sand up to 10 m high cover an area of more than 800 hectares in the neighbourhood of Buddon Ness.

Dundee District

This area (Fig. 2, area 10:1) is largely built-up but in any case contains only a small resource of sand and gravel.

Deposits above water table

A small deposit of mounded fluvioglacial sand and gravel extends from Pitkerro House [NO 453 337] to Mains of Ardestie [NO 505 342]. There is no information concerning the nature and thickness of the deposit which covers an area of about 550 hectares. The mean thickness of sand and gravel is unlikely to exceed 2 m, however, so that the deposit probably does not amount to more than 20 million tonnes.

Smaller deposits in the neighbourhood of Newbigging [NO 426 380] also consist of mounded fluvioglacial sand and gravel. They appear to be generally thin, with an average thickness of less than 2 m, and have not been assessed.

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1:50 000 Geological Survey Maps
39W Stirling
39E Alloa

One-Inch to One Mile (1:63 360) Geological Survey Maps
40 Kinross (D) 1958 4th ed. 1973
54 Rannoch (S & D)*
55 Blair Atholl (S & D)*
64 Kingussie (S & D)*
65 Balmoral (S & D)*

Appendix I: Active sand and gravel quarries in the Tayside region

Quarry	National Grid Reference	Name and address of operator	Nature of deposit
PERTH DISTRICT			
Dalvreck	NN 855 236	Mr and Mrs T.A.K. Torrance, Dalvreck, Crieff. Tel. No. Crieff 2401/3	Fluvioglacial sand and gravel (kame terrace)
Greenend	NN 830 233	W. P. Keith Murray, Esq., Per factor, Estates Office, Ochertyre, Crieff. Tel. No. Crieff 2017	Fluvioglacial sand and gravel (kame terrace)
Loanleven	NO 055 257	Scottish Aggregates Ltd., Bonnyfield Farm, Bonnybridge, Stirlingshire	Fluvioglacial sand and gravel (outwash terrace)
Tay	NO 120 226	Earnbank Sand and Gravel Co., Upper Harbour, Perth PH2 8BH	River gravel
Kinross	NO 105 026	Springbank Sand and Gravel Co., 6 Union Street, Bridge of Allan, Stirlingshire. Tel. No. Bridge of Allan 2555	Fluvioglacial sand and gravel ('hummocky')
Balado	NO 102 023	P. S. Nelson and Sons, Balado Quarry, Kinross. Tel. No. Kinross 2334	Fluvioglacial sand and gravel ('hummocky')
Cleish	NT 080 990	Cleish Sand and Gravel Co. Ltd., 110 Main Street, Larbert, Stirlingshire FK5 3LA	Fluvioglacial sand and gravel ('hummocky')
ANGUS DISTRICT			
Kinnell	NO 604 500	David Geddes (Contractors), Swirlburn, Colliston, by Arbroath, Angus. Tel. No. Gowanbank 266	Fluvioglacial sand and gravel (outwash terrace)
Gowanbank	NO 472 512	Kings and Co. Ltd., 134 Northside Drive, Glasgow G41 2PP	Fluvioglacial sand and gravel ('hummocky')
Lochhead	NO 477 508	J. G. Laird, Gowan Bank, Montrose Road, Forfar DD8 2SY. Tel. No. Forfar 2525	Fluvioglacial sand and gravel ('hummocky')
Arrat	NO 643 585	Rt. Hon. the Earl of Southesk, KCVO, Haughs of Kinnaird, Brechin DD9 6UB	Fluvioglacial sand and gravel (outwash terrace)
Bridgend	NO 371 483	Bridgend Sand Quarry, Estates Office, Glamis. Tel. No. Glamis 243	Fluvioglacial sand and gravel ('hummocky')
Myreside	NO 662 494	Wm Clark and Co. Ltd., Inverkeilor Sand Quarry, Inverkeilor. Tel. No. Inverkeilor 239	Fluvioglacial sand and gravel (outwash terrace)
Cotside	NO 528 343	Wm Clark, Cotside Farm, Barry, Angus DD7 7RR	Fluvioglacial sand and gravel ('hummocky')

Appendix 2: Pebble counts of gravels from the Tayside Region

The percentages of different rock types in each sample are given in columns 1 to 6. The rock types are as follows:

- 1 Vein quartz and pure quartzite
- 2 Impure quartzite, psammitic granulite and schistose grit
- 3 Chlorite-and mica-schists, slate

- 4 Intrusive igneous rocks including epidiorite
- 5 Lower Old Red Sandstone sedimentary rocks
- 6 Lower Old Red Sandstone lavas

Sample No.	Locality	National Grid reference	1	2	3	4	5	6
1	720 m W 26° S of Bridge of Ericht	NN 516 578		49.4		50.6		
2	1320 m W 25° N of Edenden Bridge	NN 703 713	3.5	89.8	1.3	5.4		
3	1140 m S 21° W of Trinafour	NN 722 635	3.0	73.0	9.0	15.0		
4	200 m S 35° W of Cuitaloskin	NN 790 640	3.0	74.3	5.0	19.3		
5	240 m S 27° E of Baluain	NN 834 659	1.4	88.6	3.2	6.8		
6	At Blair Atholl Golf Clubhouse	NN 878 652	16.0	51.5	2.6	29.8		
7	300 m SE of Aldclune	NN 902 636		93.0	2.7	4.3		
8	600 m N 18° W of Duireasain	NN 874 505	17.6	66.4	10.1	5.9		
9	660 m W of Pitnacree	NN 918 536	31.2	55.1	6.8	5.9		
10	420 m S 29° E of Tomnabreck	NN 968 552	16.7	66.7	4.1	12.7		
11	300 m SW of Rotmell Farm	NO 003 468	23.9	61.5	3.1	10.7		
12	450 m SE of Littleton	NO 000 443	16.3	56.9	7.5	12.0		
13	100 m E 30° W of Lagganallachy	NN 991 411	9.2	61.1	29.2	0.5		
14	300 m E 37° S of Croftmill	NN 866 368	16.4	50.2	31.0	2.3		
15	360 m S 16° W of Amulree Hotel	NN 899 364	17.2	15.8	62.4	3.6		
16	750 m S 27° W of Corrymuckloch	NN 892 338	25.2	59.1	10.1	5.7		
17	960 m E 21° N of Amulree Hotel	NN 909 370	12.6		87.4			
18	2950 m N 22° E of Spittal of Glenshee Hotel	NO 122 727	21.4	46.3	14.3	18.2		
19	1150 m NW of Spittal of Glenshee Hotel	NO 103 707		48.2	32.1	19.7		
20	At Tom an t-Suidhe	NO 132 675	33.3	22.7	19.8	24.1		
21	180 m N 20° E of Lair	NO 143 635	8.4	43.0	33.5	15.1		
22	300 m W 23° N of Mains of Dunie	NO 087 591	24.4	53.3	16.0	6.2		
23	120 m of Ballintuim House	NO 103 547	18.5	39.5	14.1	27.8		
24	360 m W 8° S of Bridge of Cally Hotel	NO 136 514	22.8	36.8	26.8	13.5		
25	720 m E 26° S of Morganston	NO 174 488	27.2	53.1	14.2	5.5		
26	120 m SE of Kercock	NO 130 386	24.0	56.0		9.5		12.5
27	120 m NW of Bishophall	NO 134 387	22.9	46.9	10.4	6.3	2.1	11.5
28	660 m N 34° W of Eastmill	NO 209 454	29.5	38.7	8.3	4.1	10.1	8.3
29	360 m W 5° N of Balendoch	NO 283 478	21.7		68.3	3.3		6.7
30	180 m W 18° S of Tomperran	NN 776 223	9.4	42.5	5.2	40.6		
31	200 m S 21° E of Westerton House	NN 830 233	9.3	38.1	11.9	18.0	0.5	22.2
32	At Dalvreck	NN 856 228	6.5	21.7		26.7	4.9	40.2
33	360 m W 10° E of Culcrieff	NN 862 237	10.3	44.0	7.0	26.6		12.0
34	At North Forr	NN 870 202	4.2	31.5	6.1	35.1	3.6	19.4
35	540 m W 8° S of Loanleven	NO 055 257	23.1	40.1	19.8	2.9	4.7	9.4
36	360 m E 35° N of Ruthven House	NO 084 258	24.1	48.8	5.6	3.1	5.6	13.0
37	South Inch, Perth	NO 120 226	8.8	39.2	5.2	10.8	7.2	28.9
38	360 m E 17° N of Seggieden	NO 170 217	23.2	32.3	3.5	9.6	13.1	18.2
39	400 m E 5° S of Silverton, Braco	NN 835 095	11.0	35.8	0.6	9.2	30.7	12.7
40	1080 m W 17° S of Millhill	NN 853 103	11.2	20.6		10.0	34.7	23.5
41	1080 m N 14° W of Drumhead, Blackford	NN 903 096	8.2	19.4		9.4	50.5	12.4
42	750 m E 20° N of Easter Balado	NO 105 026	3.6	13.8		2.1	19.5	61.0
43	420 m E 5° S of Easter Balado	NO 102 023	6.5	12.9		3.5	14.7	62.4
44	360 m W 40° N of Gairney House	NT 080 990	7.6	10.5		5.1	12.2	64.5
45	360 m NW of Whitehill	NO 228 598	7.7	34.5	28.9	28.7		
46	120 m W of Dykends	NO 250 577	12.4	53.3	17.2	17.3		
47	600 m E 5° N of Wester Coul	NO 278 575	18.8	58.0	14.4	8.9		
48	720 m E 18° S of Knowhead	NO 306 584	29.4	42.7	10.5	11.2		6.3
49	540 m E 5° S of Balfour Castle	NO 344 546	10.6	38.0	3.4	11.7	1.7	34.6
50	200 m E of Kilburn	NO 360 686	0.6	76.4	11.5	11.4		
51	600 m W 7° S of Gella	NO 369 655	11.7	49.6	6.6	32.1		
52	At Park Cottages	NO 378 617	7.6	35.2	52.4	4.9		
53	300 m N 41° W of Cullow	NO 385 613	9.0	28.2	55.0	3.3	2.6	1.3
54	720 m 14° N of Newmill	NO 375 579	15.0	26.1	8.9	2.8	2.2	45.0
55	400 W 7° S of Prosen Bridge	NO 394 585	12.6	37.7	11.3	2.5	3.3	32.5

Appendix 2: continued

Sample No.	Locality	National Grid reference	National Grid					
			1	2	3	4	5	6
56	550 m SE of Prosen Bridge	NO 402 582	19.0	47.5	12.4	3.9	3.8	13.3
57	200 m W 30° S of Kirkton	NO 430 802	5.6	83.8	9.5	1.2		
58	400 m W 8° S of West Migvie	NO 471 786	4.9	85.7	6.0	3.2		
59	540 m W 9° S of Auchintoul	NO 518 784	8.4	74.7	10.6	6.3		
60	500 m S 20° E of Colmeallie	NO 567 777	7.0	56.2	13.9	22.5		
61	660 m W 5° N of Noranpark	NO 462 608	22.5	48.8	11.7	3.6	1.8	13.5
62	250 m N of Blairno	NO 533 682	10.5	39.8	27.8	8.8	6.6	7.2
63	840 m E 21° N of Blairno	NO 541 683	11.8	72.7	11.2	3.1	1.2	
64	360 m S 15° E of Bonhard	NO 593 639	9.9	29.0	2.3	1.5	39.7	17.6
65	250 m W 35° N of Smiddyhill	NO 612 659	17.1	24.8	4.8	10.5	20.0	22.9
66	600 m W 13° S of Dubton	NO 579 604	10.6	43.6	5.3	7.0	17.0	16.5
67	660 m E 9° W of Arrat	NO 647 589	12.9	35.4	5.1	11.8	14.0	20.8
68	150 m E of Bridge of Dun	NO 664 584	22.1	52.5	3.3	3.3	8.8	9.9
69	540 m E 26° N of Balbirnie	NO 299 488	21.2	29.3	7.1	27.2	2.0	13.1
70	360 m E of Dillavaird	NO 299 503	19.4	37.9	6.6	7.6	5.2	23.2
71	840 m E 36° N of Dillavaird	NO 302 508	15.8	49.8	8.8	17.7	0.9	7.0
72	250 m S 34° W Cookston	NO 338 482	19.0	41.3	9.5	9.5	7.9	12.7
73	At Broom Hill	NO 371 483	13.5	17.1		1.7	59.1	8.5
74	360 m E 18° S of Mossend	NO 375 497	21.0	39.0		16.4	7.4	15.7
75	At Gowanbank	NO 472 572	15.3	55.8	2.1	6.9	12.1	7.9
76	600 m W 10° S of Lochhead	NO 477 508	18.6	53.4	0.6	13.6	9.3	10.6
77	300 m NE of Fledmyre	NO 489 517	20.7	38.0	6.2	5.0	17.9	12.3
78	200 m SW of Kinnell	NO 604 500	7.9	32.5	6.6	9.9	25.8	17.2
79	300 m NW of Boysack Mills	NO 623 494	12.0	44.3	5.5	4.9	24.0	9.3
80	480 m W 11° S of Westfield	NO 624 482	9.2	52.6	5.6	5.2	18.3	9.2
81	540 m N 33° W of Myreside	NO 662 494	8.2	55.2	3.0	1.5	21.1	10.8
82	200 m W of Cotside	NO 528 342	1.8	15.1		17.4	21.4	44.4

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ISBN 0 11 884008 8