GLEN ROY AREA

Field Guide

Edited by

J D Peacock & R Cornish

Quaternary Research Association

Transactions of the Geological Society Vol 4. PLATE 16

Drawn by J. MacCulloch M.D. *Engraved by G. Cooke*

VIEW in GLEN ROY taken near GLEN FINTEC.

1989

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PREFACE

This field guide describes the Late Quaternary history of three valleys lying adjacent to the Great Glen in what was formerly part of Inverness-shire. The area is notable not only for the occurrence of the ancient lake shorelines known as the Parallel Roads of Lochaber, but for evidence of the effects of palaeoseismicity and a complex sequence of Late-glacial and early Holocene events. The Introduction (Chapter 1) gives an overview of Quaternary work and a general description. Chapters 2 to 5 give details of localities respectively in Glen Gloy, lower and middle Glen Roy, upper Glen Roy and Glen Spean and refer also to aspects of the Quaternary history not covered in Chapter 1. The localities are arranged roughly in a convenient order for visiting: the two referred to in Chapter 1 will together require about half a day and the excursions in the remaining chapters about a day each. The district is covered by Ordnance Survey topographical 1:50 000 Sheets 34 (Fort Augustus) and 41 (Ben Nevis). Though many footpaths are open to the walker, permission should be sought before crossing enclosed land and before entering sporting estates, particularly during the autumn.

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1. INTRODUCTION

The area of some 200 sq. km. covered by this account lies immediately to the east of the Great Glen, a NE trending fault guided valley between Inverness and Fort William which bisects northern Scotland. It is occupied by several lochs, including Loch Lochy (Fig. 1). Much of the district is rolling upland between 600 and 800 m OD which is dissected by the glaciated troughs of Glen Gloy, Glen Roy and Glen Spean, the last two valleys being separated by low cols from the eastward flowing drainage of the River Spey. To the south lies Ben Nevis (1334 m), which is flanked by several peaks over 1000 m and, to the east, the Creag Meagaidh massif (1130 m).

The Parallel Roads of Lochaber and the accompanying landforms have excited the interest of observers from the earliest times, giving rise to some 80 publications between their mention by Pennant in 1776 and by Charlesworth in 1957. Their recognition as lake shorelines rested ultimately on the acceptance of the glacial theory, first put forward for the area by Agassiz in 1840 (though not without opposition, see Chambers 1848). This was subsequently expanded and corrected by Jamieson (1863, 1892) whose work has stood the test of time and has only been recently augmented.

It is salutory to note how much was known about the Roads in the mid-Nineteenth Century. Thus the distribution of the shorelines and their relationship to cols at 260 m, 325 m and 350 m was well known to Chambers (1848): this writer was also aware of landslips which antedated and postdated the Roads. Likewise, evidence that the shorelines were cut in bedrock was put forward by Dakyns in 1879, but had to wait until recently for a reasonable explanation (Sissons 1978). Finally, Jamieson (1892) surmised that the ice-dammed lakes may have drained catastrophically, but evidence supporting this view was only obtained in the last decade (Sissons 1979a).

Since 1950 the western part of the area has been mapped and described by the Geological Survey (Institute of Geological Sciences 1975; Peacock 1970; Wilson 1899; 1900). Between 1978 and 1983, J.B. Sissons singly and together with R. Cornish carried out detailed geomorphological investigations, particularly in Glen Roy and Glen Spean, on several aspects of the Late-glacial and early Post-glacial history. Their work on rapid differential glacio-isostatic uplift and fluvial landforms in Glen Roy (1982a; 1982b) has stimulated further research on palaeoseismicity (Ringrose 1987; 1989) and on alluvial fans (Peacock 1986). The biostratigraphy of the area has been investigated by J. Macpherson (1978) and by J.J. Lowe and P. Cairns (1989).

The following account is chiefly a compilation of previous work, but includes contributions by Dr. J.J. Lowe and Mr. P. Cairns, Mr. M. Miller and Dr. P.S. Ringrose on pollen stratigraphy, lake sediments and palaeoseismicity respectively. These are individually acknowledged in the text. The remainder incorporates the results of additional unpublished research undertaken by J.D. Peacock both privately and on behalf of the Nature Conservancy Council.

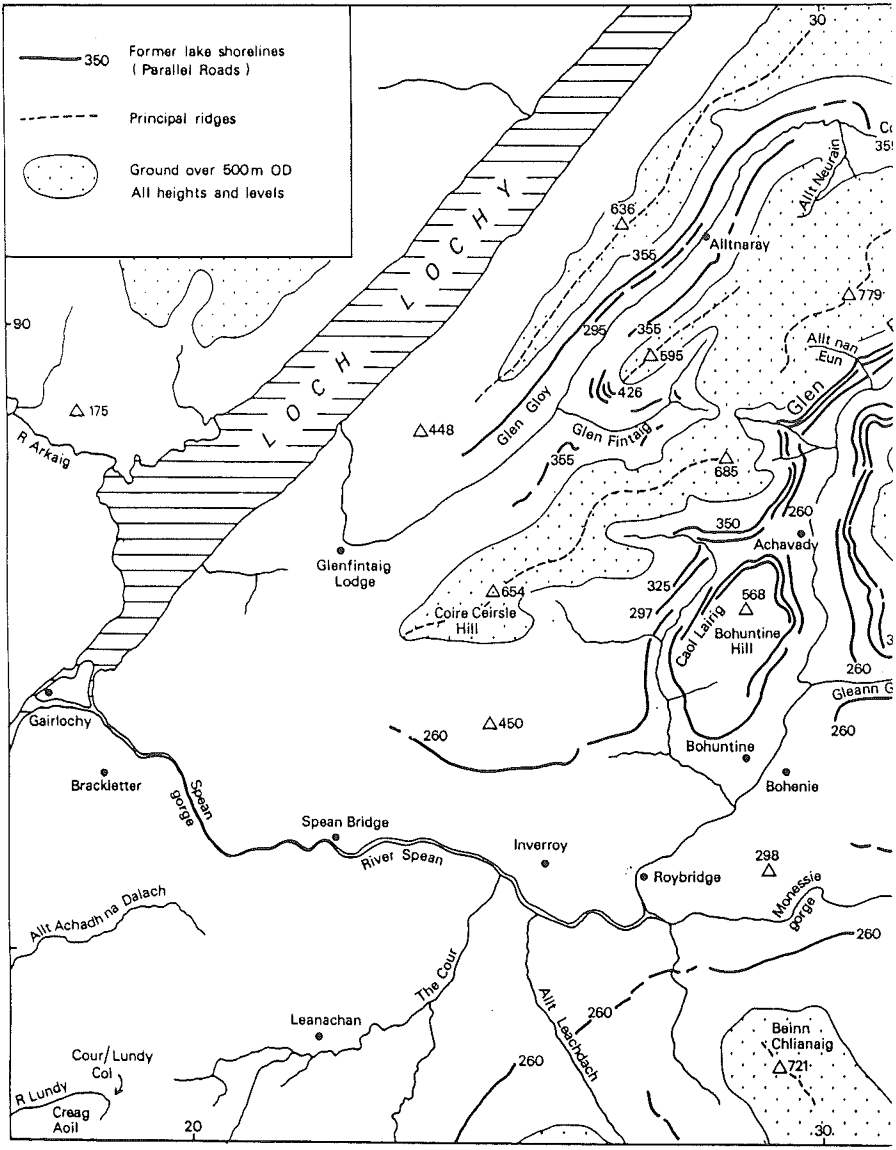
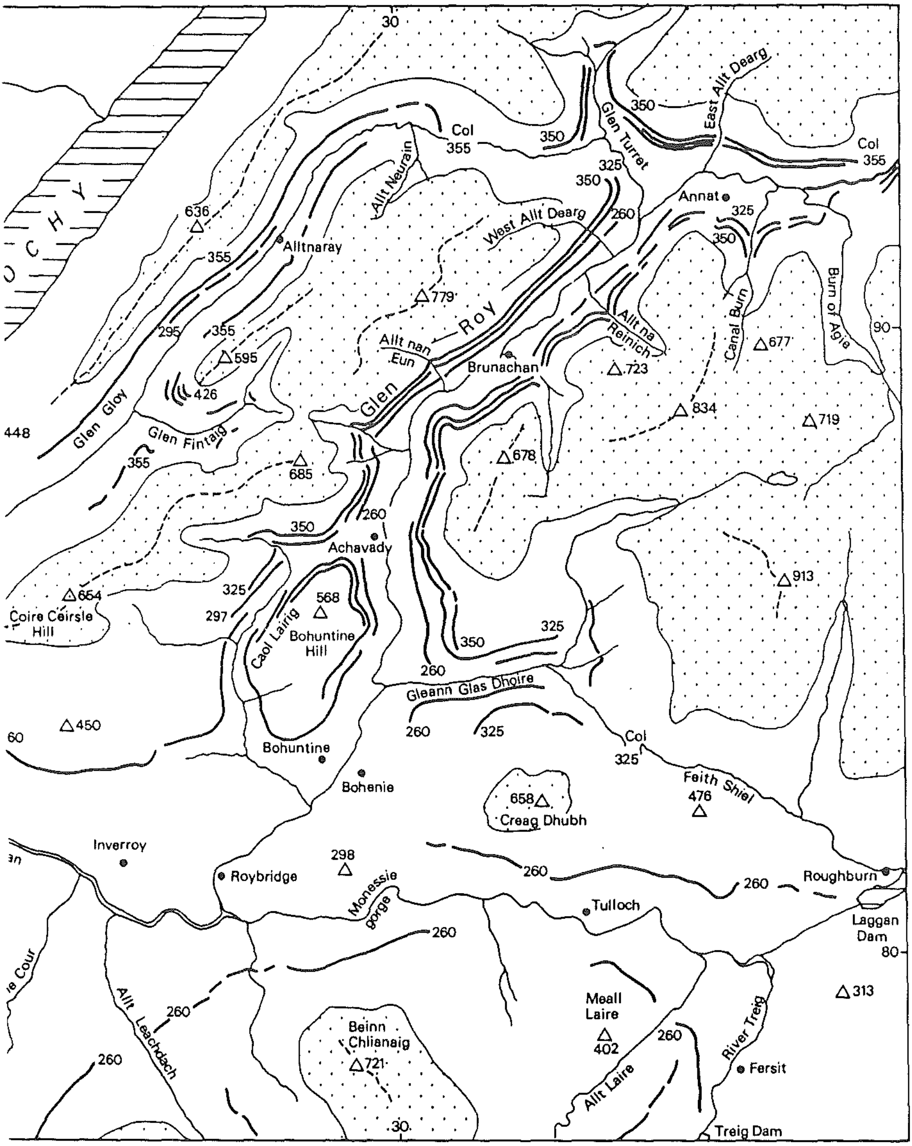


Figure 1 Topography and place-names.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Tulloch
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Laggan Dam
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Allt Leachdach
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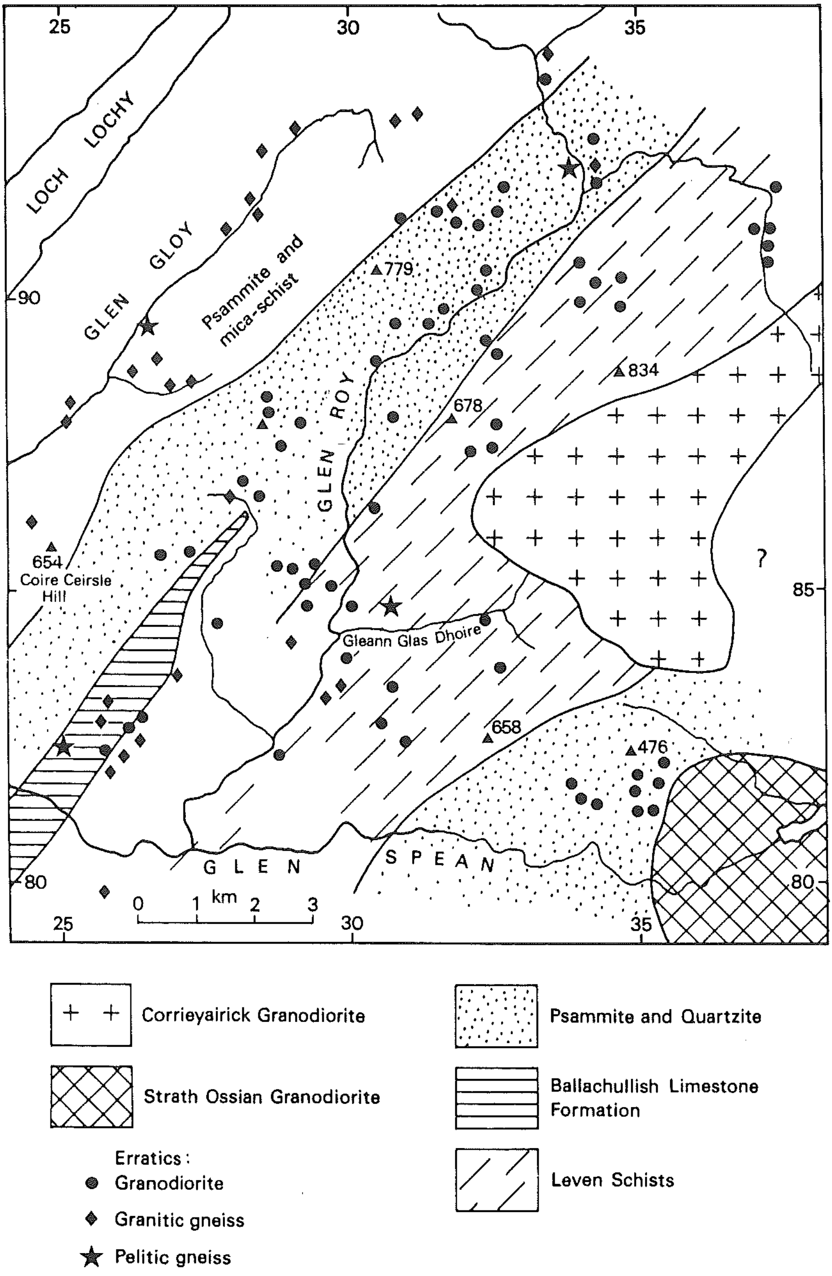

Figure 2 Bedrock geology and erratics.

Bedrock Geology

Excepting for the west of the area, which is covered by 1:50 000 Sheet 62E of the British Geological Survey, the bedrock geology is known only in outline. For the most part the country rock consists of steeply dipping, NE-trending beds of psammite (metamorphosed sandstone) and mica-schist (metamorphosed shale), chiefly of the Grampian and Appin groups (Precambrian) of the Dalradian Supergroup (Fig. 2). Adjacent to the Great Glen Fault zone these are locally unconformably overlain by Devonian conglomerate and sandstone (not shown on Fig. 2). The belt of interbanded mica-schist and psammite between Spean Bridge and Roybridge is succeeded eastwards by a thick band of psammite, quartzite and quartz-schist, which can be traced NE-wards on the floor of middle Glen Roy and particularly in the hills between Glen Roy and Glen Gloy. In middle Glen Roy this psammite (Grampian Group) is overlain by Leven Schists (Appin Group), the boundary between them being sharp. Farther south however, the psammite and Leven Schist are separated by calc-schist and limestone of the Ballachullish Limestone Formation along the line of the Fort William Slide. The upper part of Glean Spean is underlain by another broad band of psammite.

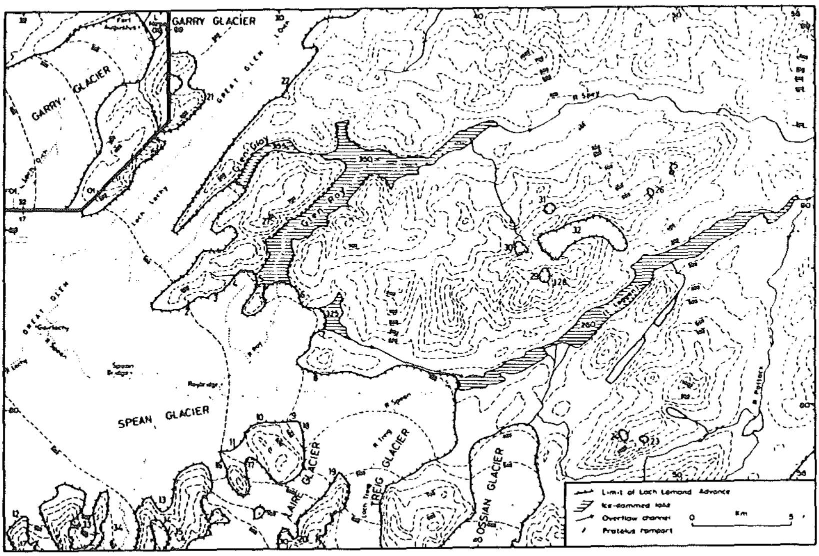

Figure 3 Limit of the Loch Lomond Readvance (from Sissons 1979c, fig. 1).

The country rocks are cut by two major intrusions of Late Caledonian age, the Strath Ossian and Corrieyairick granodiorites (Fig. 2), by minor intrusions of appinite (dioritic rocks of basic to ultrabasic composition) and by porphyrite and lamprophyre dykes of the Nevis and Etive swarms. Away from the Great Glen Fault zone, which includes bands of mylonite, there are many minor faults and crush zones, but the presence of a possible major NE-trending fault in Glen Roy (Anderson 1956) has not been confirmed.

The lithology has a considerable influence on the mode of weathering of the bedrock. Thus in middle Glen Roy the slabby psammite or quartzite forming the west side of the valley has given rise to stony and boulder strewn slopes whereas the thinly flaggy and cleaved psammites, quartz-schist and mica-schist, which crop out on the eastern slope have disaggregated and decomposed readily to a grass covered mineral soil. Moreover, in upper Glen Roy the intensely glaciated Leven Schists in the valley bottom are resistant to weathering and tend to break into large blocks. Some of the thinly flaggy and schistose rocks are weathered to considerable depths and are susceptible to the washouts, which are a feature of parts of Glen Roy. The appinites, which form irregular bodies up to several hundred metres long, are locally deeply weathered even where they crop out on the floor of glaciated troughs.

Distribution of Superficial Deposits

Much of the lower ground is mantled by till, gravelly diamicton and moundy gravelly drift (all included in the 'morainic drift' of the Geological Survey - see Fig. 23, p. 48), by meltwater deposits and, in the Spean and lower Roy valleys, by glaciolacustrine deposits associated with the ice-dammed lakes. Outwith the limit of the Loch Lomond Readvance (LLR - see Fig. 3) there are thick dissected sheets of diamicton and meltwater deposits in some of the valleys (Fig. 16, p. 00). Large areas of wasting blanket peat occur on high ground, particularly in the NW of the area. Peat also occupies many of the hollows in the till sheet on low ground and was formerly common on the fluvial terraces in the Spean valley before it was removed during land improvement. Bedrock on high ground outwith the limit of the LLR is locally glacially rounded, though no striations have been observed. Scattered erratics are visible in the thin layer of locally derived debris between exposures and on the occasional till surfaces at these levels

Parallel Roads

The Parallel Roads are shorelines of ice-dammed lakes found at elevations of 355 m in Glen Gloy, at 350, 325 and 260 m in Glen Roy and at 260 m in Glen Spean. Minor shorelines occur between these altitudes in places. The major Roads have commonly been formed by erosion at the back and gravel deposition at the front, the volume of deposit and width being greater where the fetch is longer or where fluvial deposition has occurred (Sissons 1978). At some localities the Roads are cut in rock, chiefly in upper Glen Gloy, Glen Roy and the north side of Glen Spean east of Roybridge. Short stretches of apparently rock-cut 260 m shoreline were also noted by the geological surveyors NW of Roybridge and west of the Allt Leachdach (Fig. 1) (British Geological Survey Records), but in most of Glen Spean the Road is either cut in drift or is aggradational. Rock-cut shorelines have been explained by Sissons (1978) as being due to a combination of frost and wave action: additional factors that merit discussion are the weathered nature of some of the bedrock and the possibility that the ground was 'prepared' by frost action during the LLR prior to the damming of the lakes. Small perched fans, probably deltas, are associated with the Roads at many localities where side streams enter the main glens and there are large glaciolacustrine deltas at the level of the 260 m Road at Roughburn and the north end of Loch Treig.

Landslip

Landslips in both bedrock and superficial deposits are common in the steeper parts of Glen Gloy and Glen Roy. In the former glen and its tributary Glen Fintaig there are three major landslips spatially associated with the possible terminations of former LLR glaciers (*cf.* Holmes 1984). All of these, however, post-date the 355 m Parallel Road and thus the maximum of the LLR. In Glen Roy there are six prominent landslips and many of the slopes overlooking the middle part of the glen exhibit slip features where there has been little obvious movement. Some of the slips, or parts thereof, predate the Parallel Roads of the falling sequence; others are cut by the 260 m Road and others post-date the former shorelines altogether.

Lake Sediments

Laminated silt, clay and fine-grained sand occur at many localities below the Parallel Roads in the Gloy, Spean and Roy valleys, chiefly on gentle slopes. In Glen Roy and Glen Gloy these sediments can be referred to the Parallel Road Lakes, but in Glen Spean many of the sequences were laid down in the deltas associated with lakes at lower levels.

Rhythmic sediment accumulation in Glen Roy (M.M.). Field logging and detailed laboratory analyses (microscopic measurements, grain-size analyses) of laminated sequences at numerous sites within middle and upper Glen Roy and adjacent side-valleys (Miller 1987) has demonstrated that the rhythmic accumulations can be resolved into two distinct types:

Group I laminates: laminated fine sands and silts, predominantly brown to fawn, usually forming a thin (0.3m) capping sequence to the major sedimentary bodies.

Group II laminates: laminated silts and clays, grey/blue, forming a more extensive (1+ m) sequence, generally in a basal position with respect to the major sedimentary bodies.

None of the deposits can be classified as true varved sediments since microscopic examination of sequences in the laboratory shows the contacts between silt and clay laminae to be gradational: sharp contacts are generally absent throughout. Parts of the Group II sequences, however, approximate varves where the clay laminae are considerably thicker than adjacent silt laminae (e.g. 3.8 mm compared with 0.89 mm in one sequence).

It is tentatively concluded that the Group II laminates represent distal glaciolacustrine deposits laid down at an early stage of the rising lake sequence, while Group I laminates have the characteristics of more proximal deposits (following the definitions of Ashley 1975) and were probably laid down in the higher (350 m) lake during the Loch Lomond Stadial.

Evidence for Palaeoseismicity

From detailed levelling of the former shorelines in Glen Roy and parts of Glen Gloy and Glen Spean, Sissons and Cornish (1982a; 1982b) suggested that differential uplift of blocks of the earth's crust had taken place. The surfaces of some blocks have gradients up to at least 4.6 m/km and are tilted in different directions (Fig. 11, p. 25). In three areas 0.7 to 2.0 km long, shorelines are distorted by crustal movements; in all these areas there are landslides whose generation is attributed to earthquakes that accompanied the release of stress. In the area of greatest local distortion, in middle Glen Roy, three shorelines rise about 3 m above their average altitudes for the immediately surrounding area, and a fault scarp has been produced. These local distortions possibly accompanied catastrophic lake drainage by jökulhlaup, analogous to crustal movements associated with man-made lakes. The authors also found that the Roads attained high altitudes within a short distance of the LLR limit (Fig. 11).

Evidence from lake sediments (P.S.). A recent examination of lake sediments and associated deposits (Ringrose 1987; 1989) suggests a more complex picture than the above and the following sequence of events from oldest to youngest (Fig. 10, p. 24):

1. Deposition of lake sediments.
2. <u>First deformation event</u> (fault grading; ball-and-pillow structures).

   \- unconformity -
3. Further deposition of lake sediments.

   \- unconformity -
4. Deposition of red sand and silt; local gravel and clay clasts.
5. <u>Second deformation event</u> (slumping).
6. Deposition of silt, sand and gravel, production of freeze-thaw structures.

Of these, items 1 to 3 are thought to be associated with lake sedimentation in the 260 m lake; items 4 and 5 with the end of lake sedimentation (possibly post-dating it) and item 6 with subaerial conditions following lake drainage. The first deformation event involved pervasive liquifaction and is associated with an elliptical pattern of deformation which decreases outwards. The zone of greatest deformation extends from upper Glen Gloy through Glen Roy into middle Glen Spean. It was followed by deposition, still in the 260 m lake, of about 20 varves. The second deformation event , with a similar pattern of distribution to the first, was characterised by slumping which sometimes destroyed the evidence of the first deformation. The structures attributed to freeze-thaw (item 6) include involutions and minor faulting.

The structures associated with the first deformation (fault grading and ball-and-pillow) have been associated with palaeoseismicity elsewhere and are thought to have been caused by an earthquake which took place before drainage of the 260 m lake in Glen Roy and the 355 m lake in Glen Gloy. This earthquake is attributed to movement on a reactivated NNE-trending fault which extends from upper Glen Gloy to a locality adjacent to the earthquake scar of Sissons and Cornish (Davenport *et al.* 1989). The second deformation is attributed either to a second earthquake or to lake drainage.

Palynological Investigations

Pioneer work by Macpherson (1978) suggested that the highest stage of the Parallel road lakes persisted until the time of the juniper pollen zone and that the lowest stage had disappeared by the time of the beginning of the birch pollen zone. Lowe and Cairns (1989 and below), however, disagree with these conclusions.

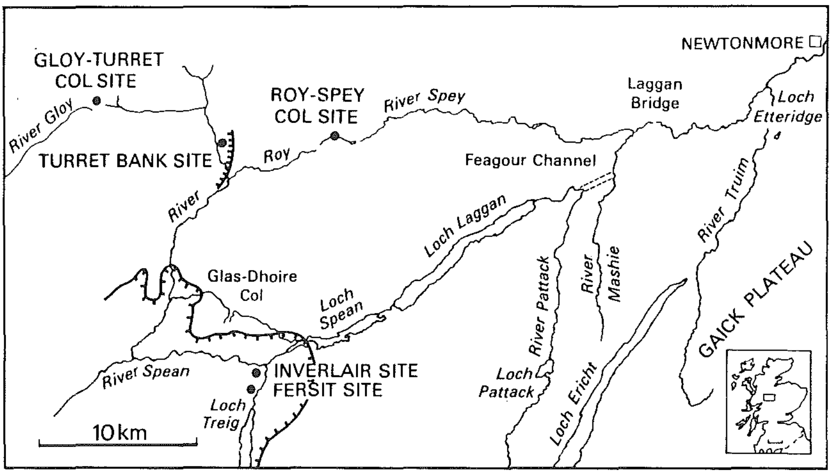

Figure 4 Location of pollen sites and principal glacier limits in Glen Roy and Glen Spean identified by Sissons and Cornish (1983).

Biostratigraphy (J. J. L. & P. C.). A number of infilled lake basins have been investigated in Glen Roy and adjacent areas (Fig. 4). Some contain mid- to late-Flandrian peats only, but 5 basins contain lake clays, gyttjas and organic muds with typical early Flandrian pollen-stratigraphic successions at the base. Comparison of these successions shows the earliest sediment accumulation to have occurred at the site immediately behind the Turret fan (Fig. 19, p. 40). The information available is summarised as follows:

Gloy-Turret Col [NN 316 928]: situated on the col separating the drainage of the Gloy and Allt a' Chomhlain; 7.0 m of lake sediments and peats; *Empetrum-Juniperus* pollen zone at base.

Roy-Spey Col [NN 411 942]: situated on the col separating the Roy and Spey drainage; site previously investigated by Macpherson 1978; 6.0 m of sediment infill; *Empetrum* dominated pollen zone at base.

Turret Bank [NN 337 925]: a section revealing organic silts can be seen on the left bank of the River Turret c. 200 m NNW of the point where the river breaches the Turret fan; coring at this point has proved in excess of 8 m of sediment, the corer eventually seizing in coarse sands; the basal pollen zone (Fig. 19) shows a rising *Empetrum* curve.

Fersit [NN 348 782]: due west of the bridge that crosses the River Treig at Fersit; coring proved 9.40 m of sediment infill at the deepest point; high *Juniperus* with *Empetrum* pollen zone at the base.

Inverlair [NN 341 803]: deep, circular kettle close to the east side of the road immediately north of the farm buildings; 11.4 m of sediment infill at deepest point; high *Empetrum* and rising *Juniperus* values in basal pollen.

Macpherson (1978) attempted to provide a chronology of lake drainage during the deglacial sequence at the end of the Loch Lomond Stadial employing pollen-stratigraphic correlations. The principle involved here is that enclosed lake basins situated within former lake spillways would have started to accumulate sediments immediately following the abandonment of each spillway, and that age differences between the basal sediments retained in each basin can be determined on the basis of pollen stratigraphy. Our new results lead us to question the conclusions of Macpherson (1978) since:-

a. one of her sites, An Dubh Lochan [NN 349 785] in the Spean valley, is a lake and the cores upon which the results are based were obtained from the edge of the lake. It is likely that older deposits occur under the lake water, and we have in any case obtained earlier pollen zones from the adjacent sites of Inverlair and Fersit.

b. she employed a Hiller corer, which does not retain the lowermost 7 to 10 cm of sediment. This could be critical given the fine resolution of the early Flandrian pollen sequence; for the recovery of basal cores piston corers have been employed which retain the lowermost lake sediments.

c. Macpherson does not report in detail the field methods adopted, but does not appear to have used the exacting site sampling strategy required of this methodology (see Walker and Lower 1977; 1980; Tipping 1988). In this work basal contours of each site were estimated using numerous boreholes arranged in a grid. Consequently we have found that sedimentation probably commenced earlier at the Roy - Spey Col site than envisaged by Macpherson. The precise pollen-stratigraphic differences between the basal sediment successions of the sites reported by Macpherson (1978) thus need to be re-examined.

The results given above have been compared with a well established and detailed early Flandrian pollen zonation for the western Scottish Highlands (e.g. Walker *et al* 1988). Collectively the evidence available shows remarkable consistency, with detailed and well preserved stadial-Flandrian transition sequences, which lead to the conclusion that all of the sites lie within areas last occupied by ice or lake overflows active during the Loch Lomond Stadial. The absence of Late-glacial deposits at the Turret Bank and Gloy-Turret Col sites lends support to the view of Sissons and Cornish (1983) that glacier ice occupied Glen Turret during the Loch Lomond Stadial. Sedimentation commenced earliest at the Turret Bank site (perhaps earlier than 10 000 BP) and last at the Fersit locality and the Gloy-Turret col (between 9 600 and 9 000 BP). Commencement of sedimentation at Inverlair and at the Roy-Spey col is probably intermediate in age between the Turret Bank site on the one hand and the Fersit and Gloy-Turret sites on the other.

Directions of Ice-Movement

The directions of ice movement indicated by striae and erratics are complex. Erratics from west of the Great Glen include granitic gneiss and Moine lit-par-lit pelitic gneiss ('injected' Moine pelite) carried some 30 km from outcrops at the heads of Loch Eil and Loch Arkaig (Fig. 2), as well as basic igneous rocks and sillimanite-schist from the Loy Complex (Fig. 23, p. 00 and Peacock 1970a; 1979b). Most of these 'western' erratics occur within the LLR limit (Fig. 3), but the occurrence of boulders of granitic gneiss in upper Glen Gloy, lower Glen Turret and adjacent to the 'West' Allt Dearg up to a level of at least 650 m OD (Figs 1 and 2) suggest an earlier, easterly movement of ice, probably from the Loch Arkaig valley.

Boulders of coarse-grained leucocratic non-porphyritic hornblende-biotite-granodiorite are common in Glen Roy and on the adjacent high ground (Fig. 2) both inside and outside the LLR limit. Some of these, particularly in the north or the area, are characterised by both pink and white feldspar and can be matched with parts of the Corrieyairick Granodiorite. Others, for instance on the east side of Bohuntine Hill in lower Glen Roy (Fig. 1) contain only one, (pinkish weathering) grey feldspar and scattered skeletal crystals of sphene. As such they have almost certainly been derived from the Strath Ossian Granodiorite (Hinxman *et al* 1923) rather than the Ben Nevis 'granite' to the south, much of which is porphyritic (Bailey and Maufe 1916). The occurrence of the granodiorite erratics is therefore taken to be an indication of ice movement from the east or SE, either from a northerly extension of the former Treig glacier (*cf.* Jamieson 1892) or from an ice mass centred on the high ground of Creag Meagaidh to the east. The age of this westerly or northwesterly ice movement is certainly pre-LLR, but its place in the glacial history of the area must await further work.

Sporadic striated surfaces within the LLR limit support the eastward movement of ice across the Great Glen (see below), but outside the limit striated surfaces are uncommon. Exceptions are, first, upper Glen Roy, where striae and roches moutonées suggest that there was an eastward movement of ice which was partly coeval with a northward movement of ice out of the Burn of Agie valley (Fig. 22, p. 47), second, the Allt na Reinich above middle Glen Roy (Fig, 1) where striations below till indicate a late stage WNW movement out of the corrie and, third, the west end of Loch Laggan where striae suggest a west-east or east-west ice movement.

Glacial History

In this highly glaciated district of Scotland there is no certain evidence for Quaternary events prior to the Devensian. The area seems to have been entirely submerged by ice during the Late Devensian (Dimlington Stade) (about 18 000 BP). Following complete or almost complete deglaciation during the Windermere Interstadial (13 000 - 11 000 BP) it was partly reoccupied by the glaciers of the LLR, probably towards the end of the Loch Lomond Stadial (11 000 - 10 000 BP). Excepting the palynological work referred to above, the evidence on which these statements is made is indirect and scant in the area under consideration, but supported by a large corpus of data from other parts of Scotland (Rose *et al* 1988 and summary in Sutherland 1984).

Dimlington Stade, The early advance of ice into the area may have followed an easterly or northeasterly course similar to that of the LLR (Sissons 1979a, p. 41), but ice movement during the glacial maximum may have included a westerly component (see above). Later, as ice became increasingly confined to the valleys an easterly movement was resumed in upper Glen Roy with local ice movement controlled by topography. In the valley of the 'West' Allt Dearg, which debouches into middle Glen Roy (Fig. 1), the moraines shown on Fig. 16 (p. 32) may indicate the presence of a small corrie glacier possibly dating from the period of ice retreat. Differing opinions concerning the age of alluvial fans and the Turret outwash fan and moraines in Glen Roy are referred to below and in Chapter 4).

Loch Lomond Readvance. During the LLR, which followed what was probably almost complete deglaciation during the Windermere Interstadial, ice from the Loch Eil basin as well as from the smaller valleys of Glen Loy and Gleann Laragain (Fig. 23, p. 48) crossed the Great Glen and extended eastwards up Glen Spean to a point south of Creag Dhubh (Fig. 1), blocking first Glen Spean and then Glen Roy (Fig. 3). Here it met a glacier that had extended into upper Glen Spean chiefly from the Loch Treig basin, the junction being marked by thick and extensive deposits of meltwater sand and gravel disposed as kames. At the same time ice from the Loch Arkaig basin extended into Glen Gloy. The blocking of Glen Spean led to the formation of a lake with a surface level of about 260 m OD which overflowed eastwards through the Loch Laggan valley into the drainage of the River Spey. Subsequently lake margins at 325 m and 350 m were formed in Glen Roy as successive cols were blocked by the advancing ice. A lake with a level of about 355 m OD dammed by ice in Glen Gloy overflowed eastwards into upper Glen Roy (Fig. 3). Retreat of the ice led to drainage of the lakes in reverse order.

The maximum position of the LLR ice is clearly marked at many localities by end moraines, drift limits and other evidence for ice margins, but the situation in Glen Gloy is controversial. Peacock (1970b) followed by Sissons (1979a) placed the limit at Alltnaray (Fig. 1), but Sissons and Cornish (1983) later suggested that the LLR ice extended across the col into Glen Turret where it formed an outwash fan related to the 260 m lake of the rising sequence. Rose (*in* Gray 1978) and Peacock (1986), however, supported the view that the outwash fan predates the LLR. More recent work in Glen Gloy tends to suggest restricted glaciation of this valley during the LLR (Chapter 2), but Lowe and Cairns using palynological evidence prefer the chronology of Sissons and Cornish (see above and p. 39).

Early Holocene. The complex events that followed the LLR maximum are examined in detail in Chapter 5. The westward retreat of the Spean glacier was followed by the catastrophic drainage of the 260 m lake subglacially along the lower Spean valley and then northeastwards along the Great Glen (Sissons 1979a). Catastrophic drainage of the 260 m lake is thought by Sissons and Cornish (1982a; 1982b) to have triggered an earthquake, but, as noted above, there may have been two palaeoseismic events the earlier of which was related to reactivation of a fault in Glen Roy. Some of the extensive landslipping in Glen Roy has been related to such events. Following a period of fluctuating lake level a series of lakes was formed at successively lower elevations in Glen Spean as ice downwasted and finally disappeared from the Great Glen (Sissons 1979b). These lakes are also thought to have drained catastrophically both NE towards Inverness and across the Leanachan - Lundy col towards Fort Willam (Sissons 1979a).

2. GLEN GLOY

The chief purpose of the excursion to this valley is to examine a major landslip and proposed LLR limit in Glen Fintaig and a proposed LLR limit in Glen Gloy itself. A locality at the head of the glen is described in Chapter 4.

Glen Gloy is a narrow NE trending valley some 10 km long that debouches into the Great Glen. A glacier that extended into the lower part of the glen during the LLR dammed up a lake which discharged across a col at 355 m OD at the head of the valley (Fig. 1). At Glenfintaig Lodge the river changes course abruptly to flow NW through a gorge to Loch Lochy, a diversion said to be have been the result of catastrophic discharge of the ice dammed lake as the ice retreated into the Great Glen following the LLR maximum (Sissons 1979a). About 2 km upstream of the Lodge the 355 m Road appears suddenly on the west side of the valley above a small cross-valley moraine that marks the final position of the ice dam. Of the other shorelines which occur in Glen Gloy that at 295 m is the most widespread (Fig. 1); it is commonly a metre or two wide and is locally associated with small side-stream deltas. The 355 m shoreline, which is up to 12 m across where best preserved, is rock-cut in places, particularly at the head of the valley where it was exposed to a long fetch. Laminated silts that were deposited in the lake are common on the valley floor within the area bounded by the 355 m Road. The straight NNW trending stream course in uppermost Glen Gloy (Fig. 1) follows a fault which Ringrose (1987) believes was reactivated at the close of the LLR.

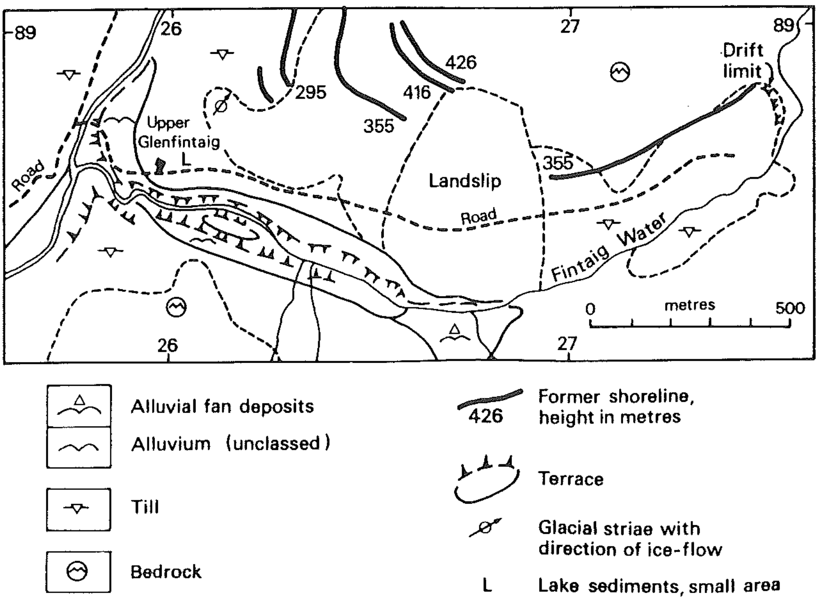

Figure 5 Glenfintaig: landforms and superficial deposits.

Glen Fintaig

At the entrance to Glen Fintaig the western slope of Glen Gloy is partly scree covered and exhibits small landslip scars. The valley fill of thin laminated silt overlying gravelly diamicton (chiefly till) has been dissected by the River Gloy and the Fintaig Water (Fig. 5). Just east of Upper Glenfintaig, roadside exposures show contorted laminated silt overlying up to 2 m of hard pale yellow silty till. The erratics include boulders of granitic gneiss derived from west of the Great Glen (Fig. 2). Above here there are at least 5 and possibly as many 8 lake shorelines of which the most prominent are shown on Fig. 5. Of these, only the 295 m and 355 m Roads are widespread, the others possibly being associated with local ice-dammed lakes. The upper two Roads are apparently cut in shattery quartzite. The top of the scar at the head of the landslip is level with the highest Road, i.e. 426 m OD. The slip itself, which is in mica-schist, has taken place on vertical joints trending 300° and on steeply westward dipping joints trending about 340° and is more or less at right angles to the bedding and schistosity. Some of the slipped blocks are intact; others show brittle folding or have been reduced to rubble. About 0.5 km east of the landslip the till sheet ends abruptly at a drift limit (Fig. 5) beyond which the main NE trending valley becomes V-shaped and is virtually free of glacial drift.

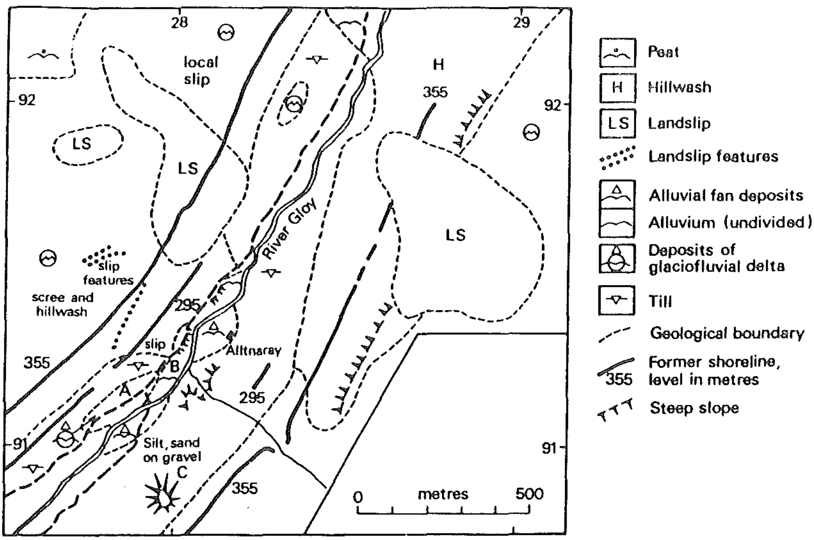

Figure 6 Alltnaray: landforms and superficial deposits.

There is no evidence for glaciation associated with the LLR Gloy glacier above the 426 m shoreline and no evidence that a lake or ice discharged across the nearby col, at about 510 m, eastwards into Glen Roy (Fig. 1). The drift limit is therefore taken to be the maximum position of the LLR in Glen Fintaig and the 426 m shoreline a near-maximum upper level for the glacier. The contortions in the silts mentioned above are similar to those which have been associated with seismic activity in Glen Roy by Ringrose (p. 8).

Alltnaray

The mounds of till and gravel (Locality C, Fig. 6) which occur south of the ruined cottage at Alltnaray were taken to be the approximate limit of the LLR in Glen Gloy by Peacock (1970b; 1986) and by Sissons (1979c), but Sissons and Cornish (1983) suggested a more advanced position in Glen Turret (Chapter 3). At Locality A (Fig. 6) there are roadside sections exposing silts and fine-grained sands overlain by horizontally bedded sand and gravel. These are locally interbedded with pebbly sand and silt interpreted as debris flow deposits. The silts and fine-grained sands are laminated with horizons of convolute bedding. Imbrication suggests that the gravel was laid down by a NE flowing current. These strata are interpreted as the bottomset or lower foreset beds of a small glaciofluvial delta (*cf.* the deltaic deposits at the Viewpoint in Glen Roy (Chapter 3)). That Allnaray remains a candidate for the maximum position of the LLR glacier is supported first, by the occurrence of many boulders of granitic gneiss in the river (Locality B) compared to few farther up the valley and second (very doubtfully) by the occurrence of major landslips (Holmes (1984) has noted the coincidence of landslip with the limits of former glaciers). Moreover, the postulated LLR ice limit in Glen Fintaig (see above) is difficult to reconcile with a glacier filling upper Glen Gloy. Whether or not the LLR limit was in Glen Gloy or over the col in Glen Turret is discussed further in Chapter 4.

3. LOWER AND MIDDLE GLEN ROY

The objectives of this part of the excursion are to examine the Parallel Roads, the landforms and deposits at and near the LLR limit in lower Glen Roy and the Caol Lairig, and, in middle Glen Roy, alluvial fans, lake deposits and evidence for the effects of palaeoseismicity.

Roybridge to the Viewpoint

On leaving Roybridge the road into Glen Roy follows the alluvial terraces on the west side of the Roy valley (Fig. 24, p. 50). These terraces are underlain at many localities by laminated lake silts, the gravel capping being merely a veneer. At a locality [NN 2778 8201] the terrace gravel overlies about 2.5+ m of weakly bedded medium- to coarse-grained sand. Before descending into the steep valley of the Allt Ionndrainn the road follows a stretch of the highest river terrace (2). At Bohuntinville, just south of Bohuntine, a moraine ridge, probably a cross-valley moraine is visible above the road. On the opposite side of the Roy valley a line of trees marks a sub-horizontal sandy terrace at approximately 145 m OD. This lies above and antedates the river terraces. As such it may be the remains of a prodeltaic deposit associated with a delta at about this level on the course of the Allt Leachdach (Chapter 5) in the Spean valley. Just to the north of Bohuntine a major cross-valley moraine coincides with the southward limit of the 325 m shoreline. This was probably formed as the lake level fell from 325 m to 260 m (Sissons 1979c). A little upstream, the River Roy at its junction with the Allt Glas Dhoire [298 843] has cut through laminated silts, gravel and till to flow in a rock gorge which is a little to the east of what appears to be the former drift-filled valley. From here to the Viewpoint the road follows the approximate boundary between the till-covered hillside and the dissected drift plug of gravel, sand, laminated silt and diamicton formed during the initial retreat of the LLR Roy glacier (see next).

The Viewpoint Area

The Viewpoint is the classic locality for a panorama of the Parallel Roads (350 m, 325 m and 260 m OD) as well as for the mass of sediment, distributed chiefly in foreset and bottomsets, which was laid down at or near the maximum position of the LLR ice. On the east side of the valley opposite the Viewpoint the LLR maximum can be traced by way of low lateral moraines (not visible from the road) and a drift limit to a ridge which is partly landslip debris and partly till (Fig. 7). The landslips here and on the west side of the valley NW of Achavady have taken place in appinite bodies which are partly deeply weathered. The biotite in such decomposed appinites has been locally converted into the expanding lattice clay mineral vermiculite (F. May, personal communication) , which may have assisted slipping. The Achavady slip, which involves both bedrock and superficial deposits, was recently reactivated by roadworks and has been stabalised by drainage ditches. On the west side of the valley the LLR ice may have reached the northward limit of the deltaic deposits or a limit of till which can be examined on the hillside above (Fig. 8). A drift limit probably marking the upper margin of the ice can also be seen above the 350 m Parallel

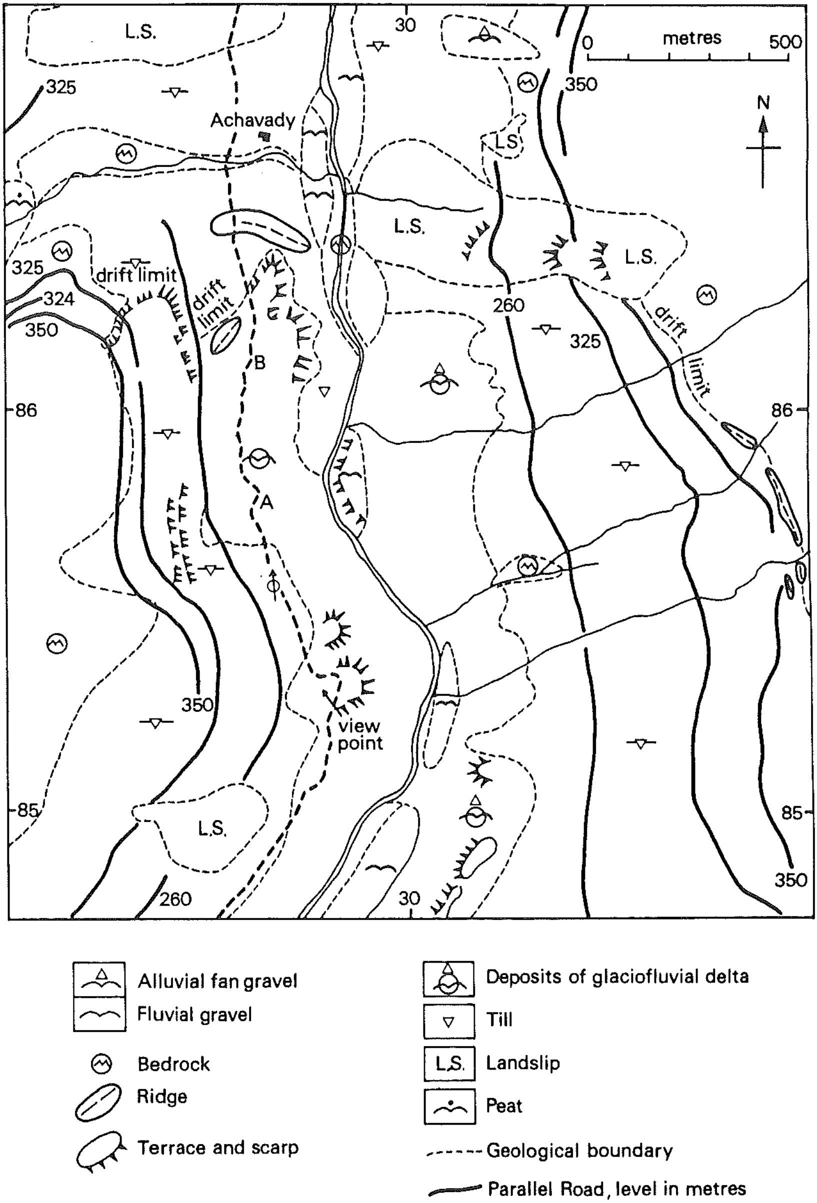

Figure 7 Glen Roy Viewpoint: landforms and sediments.

Road west and SW of the Viewpoint (not shown on Fig. 7). In this area there are many boulders of Strath Ossian granodiorite below the LLR limit which seem to have been transported from the Spean valley to the SW (though originally derived from the east). On the east side of the valley the first of the Roy terraces at about 190 m OD (Sissons 1979b) can be seen opposite the Viewpoint.

The drift fill consists in general of sand and gravel overlying diamicton which is probably partly basal till and partly debris flow. Roadside sections at the Viewpoint show interbedded sand and gravel in which the presence of very well rounded gravel uggests possible reworking from pre-existing fluvial deposits. At Locality A (Fig. 7) the following section was visible in 1986, the beds dipping at 20-30° to the north and NE:

		m
4.	Gravel, well sorted, interbedded with sand	3
3.	Gravel, coarse, interbedded with diamicton (matrix supported gravel)	3
2.	Diamicton, crudely bedded, matrix of fine-grained sand and silt	9
1.	Gravel and interbedded diamicton, clast- to matrix- supported. Local interbeds of silt.	3+

These beds are interpreted as deltaic foresets.

At Locality B the cross-section of a channel some 3 to 4 m across and 3 m deep was formerly exposed. This was cut in sub-horizontally bedded sand and floored by about 0.5 to 1.0 cm of laminated clay overlain by a few cm of clast supported gravel followed by a drape of laminated clay and silt. Such deposits can be compared with those formed in channels eroded by cold, dense, sediment-laden currents issuing from the conduits of sub-aqueous glaciomarine outwash fans (types B and C of Cheel and Rust 1982).

N. Miller recorded Group II laminates (blue-grey clay - see p. 8) overlain by a thin layer of Group I laminates (brown silt) at a basal stream-side exposure [NN 297 861] about 100 m ESE of Locality B.

An interesting feature for which the writer has no adequate explanation is the fact that the 260 m Road above Localities A and B is the local upper limit of sand and gravel deposition. There is no evidence to suggest that the Road here coincides with the topset beds of an ice marginal delta and it seems highly unlikely that the LLR ice extended into this part of Glen Roy when the lake was at 260 m.

Caol Lairig

The LLR maximum is marked by a well marked terminal moraine in the col between Glen Roy and the Caol Lairig and by a drift limit that can be traced on the hillside to the north, about 15 m above the 350 m Parallel Road (Fig. 8). Within the LLR limit the floor of the upper Caol Lairig is partly covered by lake deposits and there are small deltas associated with the 350 m, 325 m and 297 m Roads, the last being the shoreline of a small lake dammed in the Lairig between the retreating LLR ice and the Caol Lairig - Roy col.

A minor shoreline at about 334 m, which occurs widely but sporadically in Glen Roy, is well seen at Locality A (Fig. 9) where it ends abruptly against the terminal moraine, a relationship which suggests that it was formed on the rising sequence of lakes before the LLR ice reached its maximum extent. At Locality B a number of small deltas were deposited by an ice-marginal stream at the level of the 350 m Road during the initial retreat of the LLR ice. The sediments of the former glacial lake are exposed at Localities C and D (Fig. 8). At Locality C these comprise several metres of pebbly sand and cobbly gravel which rest on faintly laminated grey silty clay which passes downwards into silty sandy diamicton or matrix supported gravel with boulders. A scar in the 12 m high bank at Locality D shows:

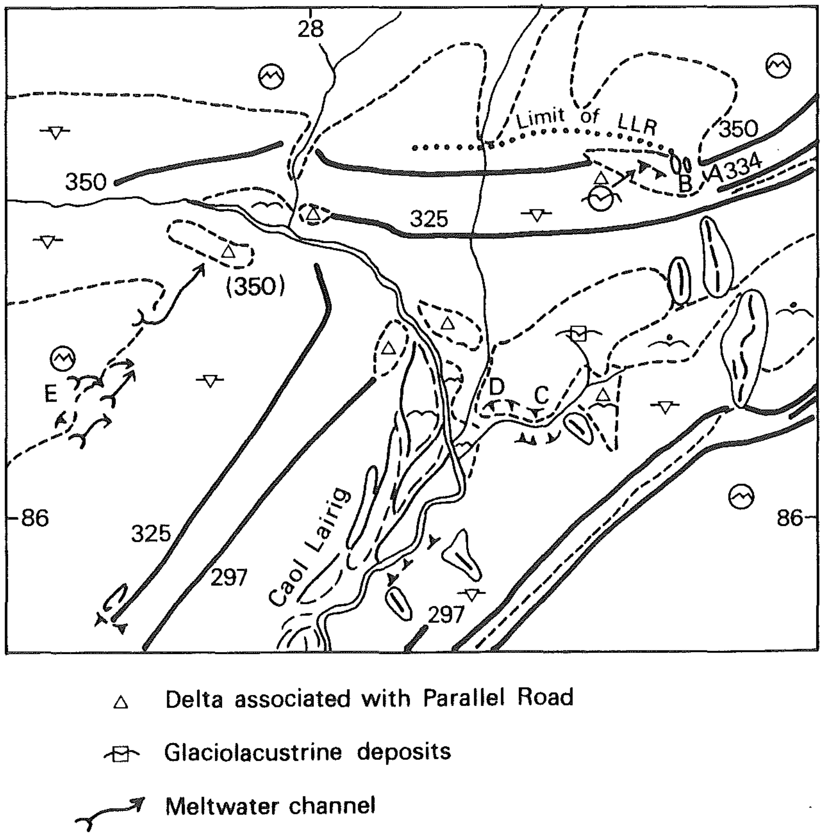

Figure 8 Caol Lairig: landforms and sediments.

		m
Soil		
Sand, fine-grained, in beds <5 cm thick with traces of ripples with clay drapes.		1
Silt and clay, finely laminated, with scattered pebbles of fine-grained gravel. Local convolute bedding.		0.6
Interbedded fine-grained sand and silt.		3.4

A little to the north, laminated to thinly bedded sand which is exposed at the top of the bank includes graded units up to 3 cm thick of coarse-grained sand passing upwards into fine-grained sand with a few clay laminae. The succession, which generally fines upwards, includes a few thin (3 cm) beds of diamicton, possibly debris flow. The bedding is locally vertical with folds and intrabedding shears. Possible dish structures suggest dewatering. These beds overlie chaotic, unbedded gravel, probably a debris flow deposit, which is exposed lower in the bank and which includes clasts up to 20 cm across of laminated silt. The upward succession at Locality D as a whole suggests a change from a proximal to a more distal glaciolacustrine environments resulting from the retreat of the LLR ice. The contorted bedding may equate with the second deformation of event of Ringrose (see Chapter 1 and next).

On the west side of the Caol Lairig the LLR limit is marked by a number of small submarginal channels (Sissons 1979c) and at Locality E by a 12 m high half pothole eroded in fractured quartzite.

The Allt Bhreac Achaidh Area

In this part of middle Glen Roy the floor of the steep-sided, U-shaped valley is occupied by a fill of till and glaciolacustrine sediments which have been strongly dissected, particularly on the west side of the river. The Parallel Roads adjacent to and north of the Allt Bohaskey (Fig. 9) are partly rock-cut and there are two minor roads at 334 m and 344 m, the latter merely a washing limit.

Between Localities A and B (Fig. 9) the public road cuts through dissected lake sediments for which Miller (p.7) has suggested a twofold stratigraphy, with grey-blue silts and clays overlain by brown silt and fine-grained sand (Chapter 1). These sediments have also been examined by Ringrose (p.8): two of his sections (RR8(E) and RR9(E) in Fig. 10) demonstrate in part or in whole the two deformation events in the lake sediments and the later structures attributed to frost (Chapter 1).

The public road cuts through a number of ridges about 3 m high, which are formed dominantly of laminated silt, clay and fine-grained sand unconformably overlain in places by up to a metre of matrix supported bouldery gravel. The latter may have been carried down on to the surface of the silts as subaerial debris flows immediately following drainage of the 260 m lake at a time when the exposed lake floor was unvegetated and the deposits liable to rapid erosion and redeposition at lower altitudes. At Locality A the laminated silt is highly contorted and includes an ovoid, anticlinal structure which is about 4 m long in a NW-SE direction with steep, outward dipping limbs and a vertical axial plane. At the NW end of the structure the axis plunges gently NW while

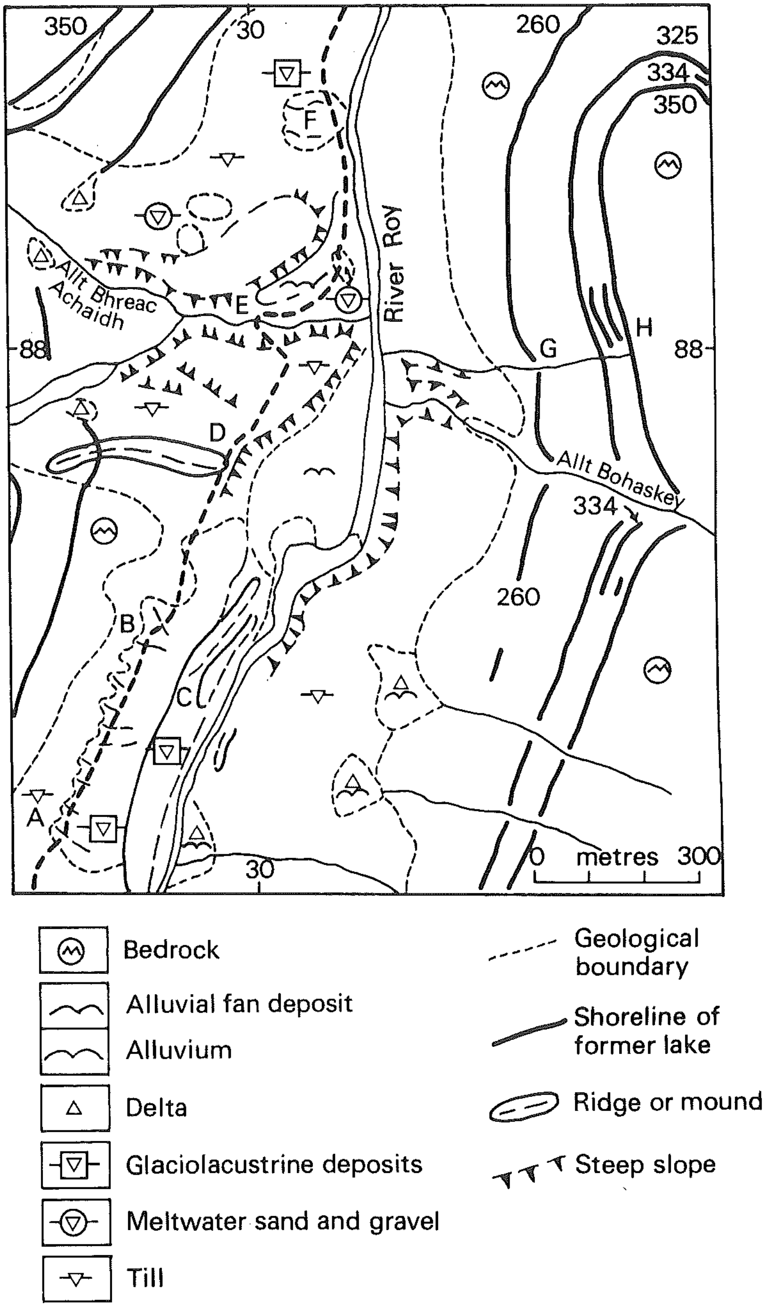

Figure 9 Allt Bhreac Achaidh area: landforms and sediments.

at the SE end the axis is vertical. The structure is probably a sheath fold which has been formed during the deformation of inhomogenous sediment. This folding and the large contortions seen here and at neighbouring localities may have originated during the second deformation event.

Below the road, at Locality C (Fig. 9), two river terraces are cut into the lacustrine deposits. These have yet to be surveyed in detail, but preliminary work suggests that they slope downstream towards the level of the bedrock exposed in the River Roy a little upstream of the Viewpoint.

At Locality D the core of a ridge extending down the hillside is seen to be formed of poorly sorted, unbedded matrix rich gravel which is overlain and flanked by pockets of laminated silt and sand. The morphology, composition and setting suggest that the ridge is a pre-LLR moraine.

The area by the lower course of the Allt Bhreac Achaidh is a complex of undulating till, sand and gravel mounds, lake sediments and erosional terraces. At Locality E (Fig. 9) poor exposures show a terrace to be underlain by about 0.3 m to 1.5 m of laminated clayey silt on about 4 m of silty till; laminated silt and clay also appear at the surface of this terrace a little to the NE. Though this and higher terraces are immediately underlain by silt it would be unwise in view of their 'fresh' appearance to conclude that they antedate the Parallel Road lakes (cf. the river terraces of Locality C above). A section in the mound (summit about 198 m OD) at Locality F shows the following:

	m
Silty, sandy diamicton	0.2
Silt, laminated, brown, with local pockets of coarse-grained gravel	1.5
Clay, laminated, grey	0.5+

Unlike the sections of lake deposits between Localities A and B the silt and clay are here unaffected by contortions. The brown silt belongs to Miller's Group I (upper) laminates and the grey clay to the Group II laminates and according to Miller the latter is over a metre thick at this locality. This mound, like the ridges between Localities A and B, seems to be an erosional remnant of a former much more extensive fill of lake sediments. It is of interest that there is no obvious evidence for a delta which might have been expected at this locality had the River Roy entered a lake dammed by the drift plug at the Viewpoint (*cf.* Peacock 1970b; Sissons 1979b).

The lake shorelines immediately north of the Allt Bohaskey, which can be viewed with binoculars from the public road, show great variability where benched into bedrock (Fig. 9). At Locality G the 260 m Road, here about 4 m wide, is backed by a well marked cliff cut in sound flaggy to slabby psammite at right angles to the bedding/foliation. Breakage of the psammite seems to have been on irregular joints giving rise to the angular blocks strewn on the bench. A little further north the rock cliff disappears to be replaced by an

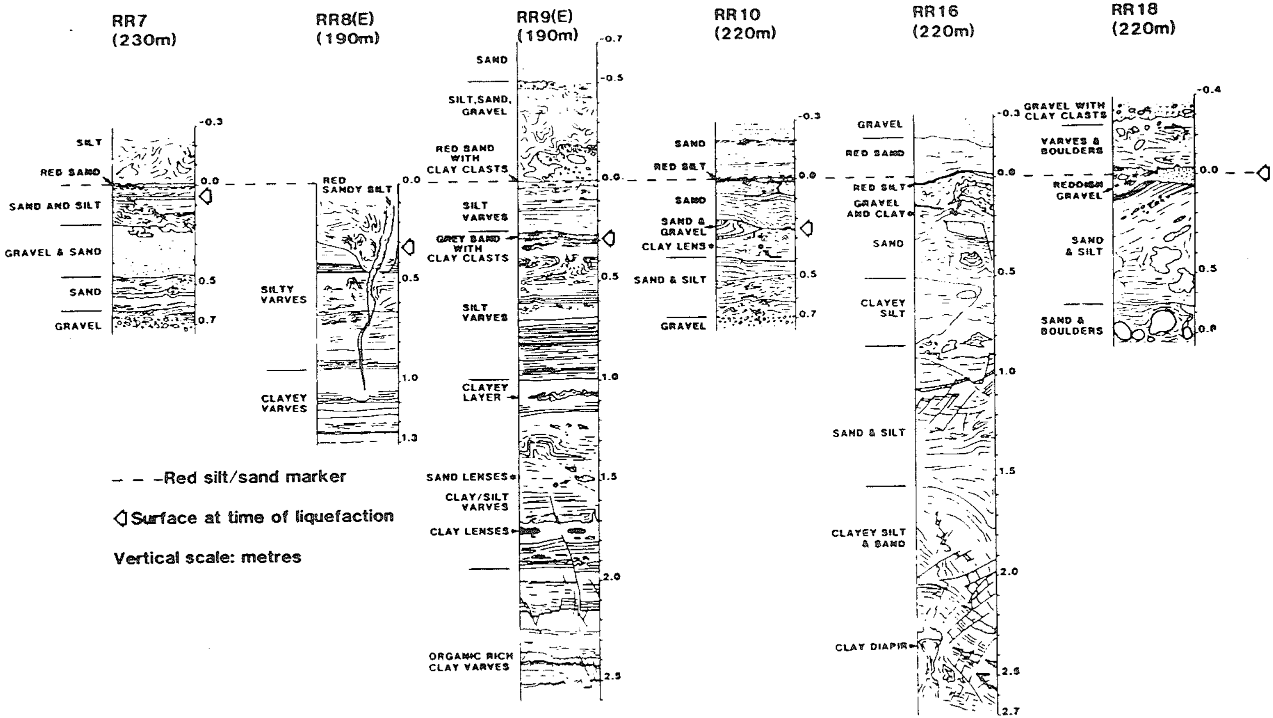

Figure 10 Glen Roy: sections in deformed sediments. RR8(E) located at [NN 296 872] and RR9(E) at [NN 298 875].

irregular sloping surface. That this and the 350 m shorelines are rock cut is confirmed by an examination both of the neighbouring stream section and that provided by the Allt Bohaskey itself (see Dakyns 1879). Neither of the two minor roads here appear to be benched in rock.

Brunachan Landslip and 'Earthquake' Features

North of the Allt Bhreac Achaidh the drift sheet thins and the steep hillsides are mantled in scree or landslip debris. Opposite the mouth of the Allt nan Eun (Fig. 1) two landslips on the SE side of Glen Roy are cut by all three Roads and thus either antedate or are contemporary with the highest, assuming history of the area outlined in Chapter 1. The mouth of the Allt nan Eun itself is marked by mounds and ridges in which roadside sections show up to 5 m of poorly stratified clast to matrix supported gravel. Between the ridges laminated sand and silt is locally exposed by the roadside. The position of the ridges is clearly related to the Allt nan Eun valley and it is suggested that they are the remains of a paraglacial fan formed when glacier ice was present.

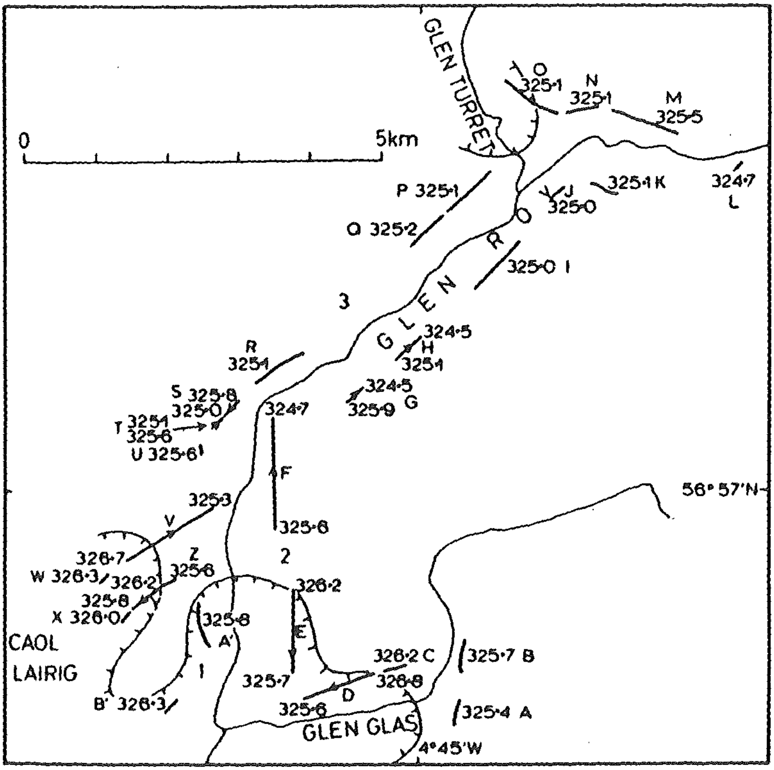

Figure 11 Altitudes (m) of parts of the 325 m shoreline (from Sissons and Cornish 1982b, fig. 4).

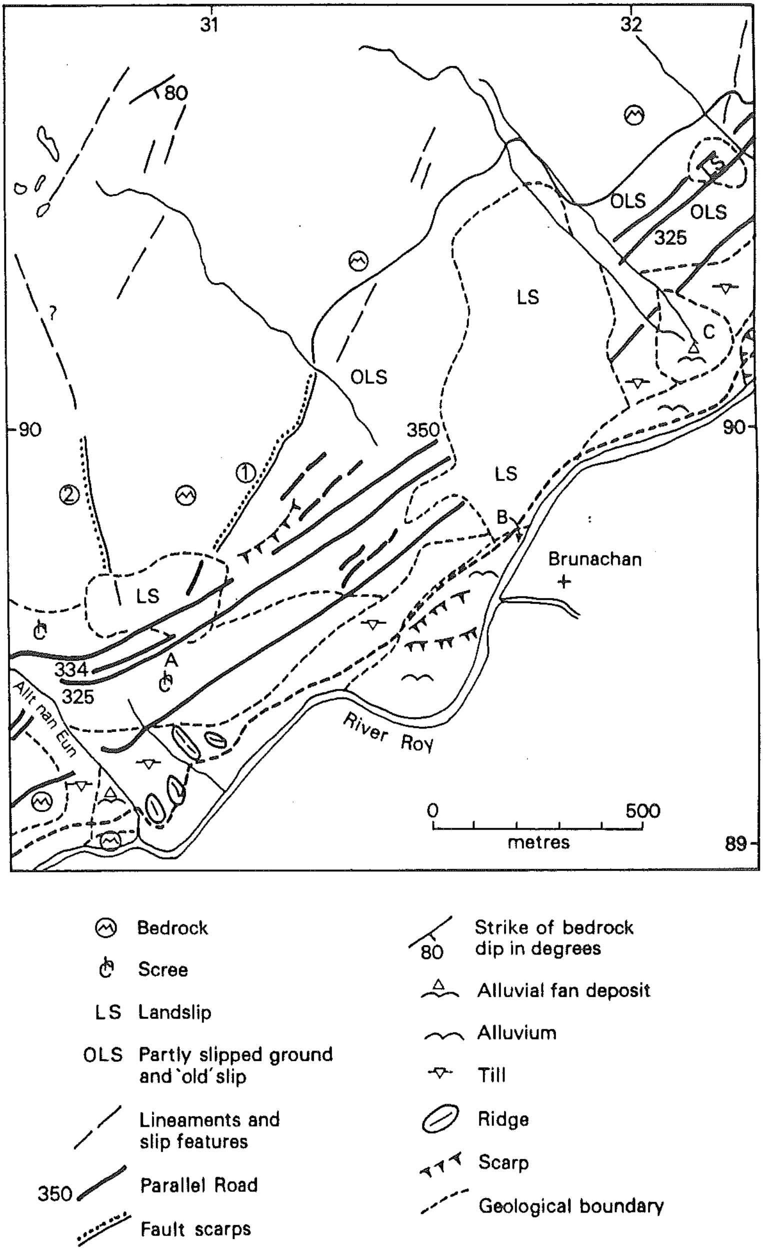

Figure 12 Brunachan landslip area and 'earthquake' features.

In their levelling of the Parallel Roads in this part of Glen Roy, Sissons and Cornish (1982a; 1982b) found evidence for both slight block movement (Fig. 11) and an abrupt rise in the Parallel Roads of about 3 m (Fig. 13). The latter they attributed to a fault which extends diagonally up the hillside (1 on Fig. 12). It comprises a low ridge a metre or so wide flanked upslope by a narrow depression up to 2 m deep. Though the feature itself cannot be traced downslope to the Parallel Roads, its southward projection coincides with a rise in level of the lower two shorelines by about 3 m (Fig. 12) (Sissons and Cornish 1979a). It thus post-dates the Parallel Roads, but antedates the river terraces which were formed immediately after the drainage of the 260 m lake. Ringrose (*in* Davenport *et al* 1989) however suggested that an adjacent feature (2 on Fig. 12), is a westward facing fault scarp (or scarps) with a throw of about 2 m. As such he believed it to be part of one or more NNW trending lineaments that can be traced to a fault of this orientation at the head of the River Gloy (see Chapter 1) for which he suggested a recent lateral movement of about 0.5 m. He further suggested (1987) that the feature mapped by Sissons and Cornish delineates the upslope edge of a block raised by movement on the NNW fault. The NNW-trending fault may have been associated with the earlier (or both) deformation events found in the lake sediments.

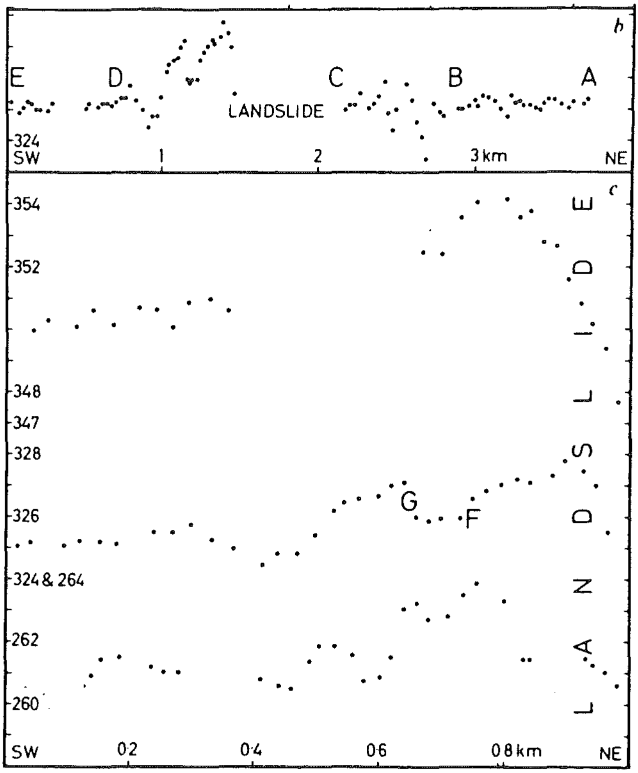

Figure 13 Height-distance diagram of shorelines in Figure 12.
b. middle shoreline on both sides of landslip.
c. all three shorelines SW of landslip.
Reproduced by permission from *Nature 297*, 213-4, fig. 1.

There are thus two explanations for the linear feature of Sissons and Cornish described above. Firstly that it is a reversed fault which is a direct expression of rapid glacio-isostatic recovery, perhaps brought about by catastrophic drainage of the 260 m lake (Sissons and Cornish 1982b): the resulting earthquake is thought to have been an effective trigger for the numerous landslides in the glen. Secondly that it a reversed fault that was formed secondarily as a consequence of lateral movement along a NNW trending fault and lineament.

Comment. (J. D. P.) If the correlation of movement with catastrophic drainage is correct the resulting earthquake cannot be recorded in the lake sediments by the first deformation as sedimentation continued after this: correlation with the second deformation would therefore be considered more likely.

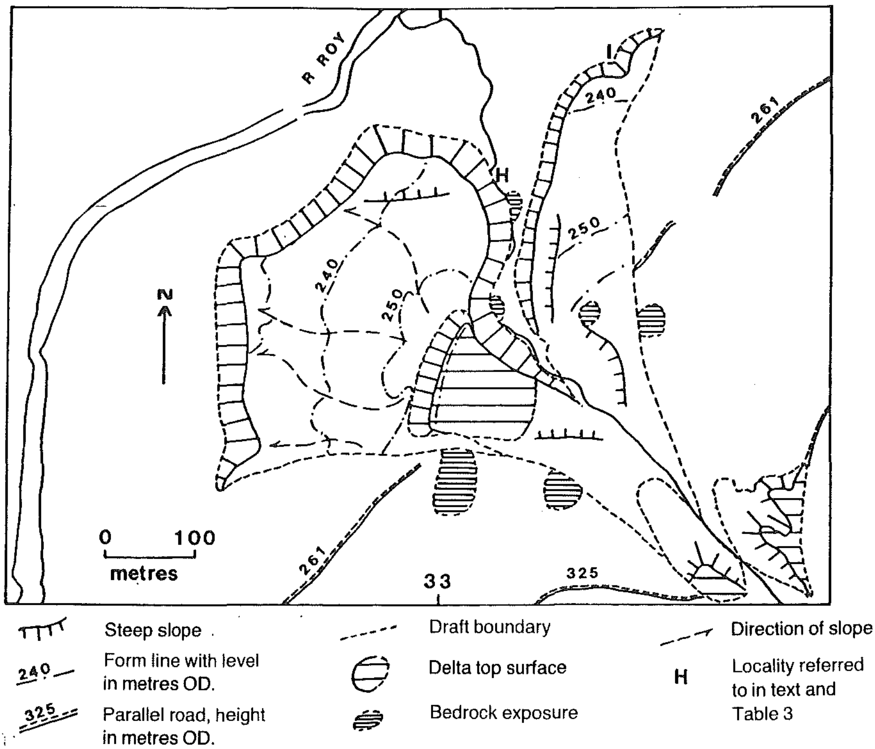

Figure 14 Reinich fan (from Peacock 1986, fig. 6a).

The major Roads are well developed on this part of the hillside, being cut partly in bedrock and partly in older landslip deposits on both sides of the main, post-Roads landslip (Fig. 12). The minor road at 334 m is also prominent to the SW of the main slip.

At Locality B (Fig. 12) an exposure in the bank below the highest river terrace shows about 1.5 m of imbricate bouldery gravel lying unconformably on highly contorted interbedded fine-grained sand and poorly sorted fine- to coarse-grained gravel. The significance of the latter deposit is in doubt: it could be deltaic or perhaps paraglacial. The surface expression and sedimentology of debris flows may be examined in the recent alluvial cone (C on Fig. 12).

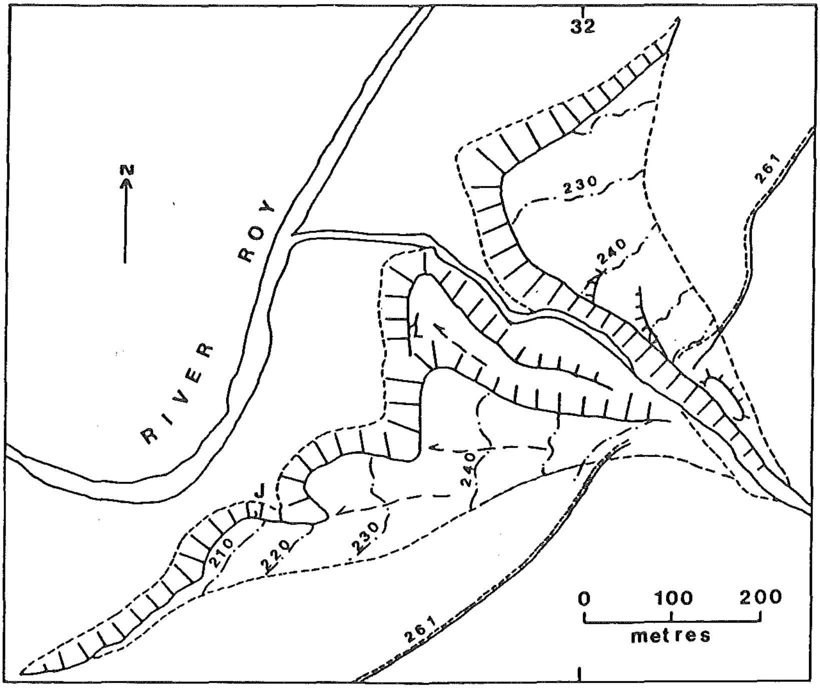

Figure 15 Brunachan fan (bedrock omitted) (from Peacock 1986, fig. 6b).

The Brunachan Fan

The Brunachan fan (Fig. 15), which is truncated by the fluvial terraces of the River Roy, is one of two fans in this part of the glen (the other being the Reinich fan described next) for which there are greatly differing interpretations. Much of the controversy is related to conditions higher up Glen Roy, these being discussed in Chapter 4. Sissons and Cornish (1983) suggested that the Brunachan and Reinich fans were formed subaqueously in the 260 m Parallel Road lake of the rising sequence, the gravels having been shot out into the lake into depths as great as 45 m during torrential spring floods associated with rapid snowmelt. Peacock (1986) on the other hand has interpreted both fans as having been laid down subaerially prior to the formation of the Parallel road lakes.

The Brunachan fan rises from below 210 m OD to 270 m at the apex and is cut by the 216 m Road (Fig. 15). The slope is about 1 in 8 to 1 in 10 in the lower part, steepening upwards. South of the Allt Bhrunachain the fan surface is diversified by shallow 2 - 3 m deep channels. North of the stream there are two discontinuous terrace bluffs at about 240 m and 245 m below the 260 m Parallel Road. Part of the fan surface away from the bluffs has been modified by recent stream action resulting in local dissection and deposition of gravel.

On the south side of the fan the base of the deposit can be seen in the left bank of a small stream [NN 3166 8929], where, below slumped gravel, there is a 10 mm to 20 mm thick bed of sheared looking yellow-brown laminated clay resting on and penetrating cracks in the bedrock. Nearby, hard packed matrix rich cobbly, crudely bedded gravel is exposed. At Locality J about 8.5 m of clast supported matrix rich cobbly gravel interbedded with openwork gravel and sand is exposed dipping about 5° to the west. At the top of the bluffs near here up to 1 m of laminated silt lies on matrix rich bouldery gravel. Upslope, matrix rich, hard, poorly sorted gravel is exposed in a scar [NN 3197 8940] and, nearby, there is an exposure of laminated silt at the fan surface immediately below the 260 Parallel Road. Peacock (1986) suggested that the basal laminated silt may indicate a lacustrine phase prior to fan deposition and that the overlying gravels were reworked from glacial drift deposited higher up the main stream to the south. Another possibility is that the gravels and thin silt in this part of the fan are entirely paraglacial and were deposited during the wasting of glacier ice in Glen Roy (see the Allt nan Eun above).

On the north side of the fan, near and at the top of the bluffs, there are exposures of very poorly sorted boulder gravel, the boulders being well imbricated in places. The boulders in the mound immediately above the 260 m Road (Fig. 15) are also imbricated: this mound is taken to be a remnant of stream bed remaining after dissection. Laminated silt overlies the imbricate gravels in the bluffs to a height of 245 m. The gravels here have been campared with the deposits of migrating channels on a subaerial fan (Peacock 1986).

The Reinich Fan

The fan lies between that of the Allt Bhrunachain and the Turret outwash, described in Chapter 4. The apex (Fig. 14) is situated immediately below a delta associated with the 325 m Road and the fan is truncated distally by river terraces to form a marked bluff the top of which is below 240 m OD. The main part of the fan comprises a lower sector crossed by shallow longitudinal valleys and ridges with a relief of 3 m to 4 m and an upper, gently inclined sector separated from the lower by another bluff some 5 m high, the top of which is at about 260 m OD, the height of the lowest Road. Sections at the top of the lower bluff show laminated silts up to 2 m thick, but exposures of the underlying deposits are few. Beds near the base of the fan are exposed at Locality H (Fig. 14) where the gravel of a subsidiary fluviatile terrace overlies about 0.5 m of laminated sand and silt with convolute bedding which are interpreted as lacustrine (Sissons and Cornish 1983). This in turn rests on thin gravel and probably till and bedrock. Compact, clast supported, bouldery gravel is exposed in the lower bluff at Locality I. The upper, gently inclined part of the fan was interpreted by Peacock (1986) as a delta associated with the 260 m Parallel Road and the lower part as an alluvial fan which could have been formed either subaerially or subaqueously. Sissons and Cornish preferred the latter interpretation (see above).

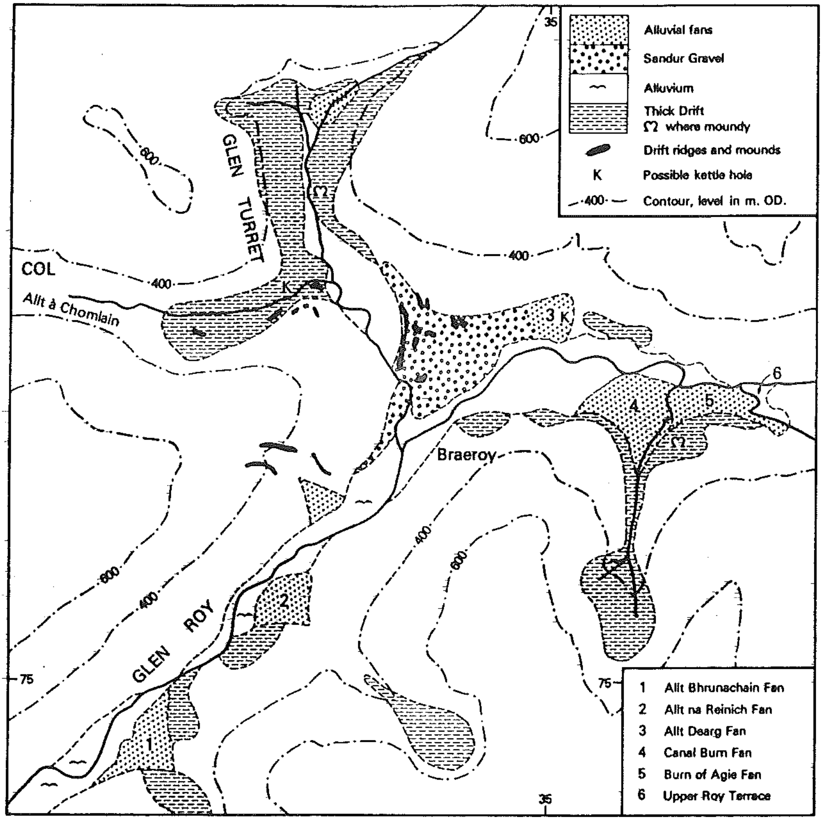

Figure 16 Sketch-map of superficial deposits in upper Glen Roy (from Peacock 1986, fig. 2).

4. UPPER GLEN ROY

This part of the excursion guide covers Glen Turret, the Roy-Gloy col and Glen Roy as far east as the confluence of the River Roy with the Burn of Agie. There is much more of interest than can be adequately examined in a day's excursion and if time permits it is suggested that most attention is given to the Turret outwash fan and to the fans and terraces on the south side of Glen Roy. The track from Turret Bridge just north of Braeroy provides ready access to the head of Glen Turret and the Allt a' Chomhlain and the south side of the upper Roy valley can be approached by the rough road to Annat by way of a bridge over the River Roy. A large part of the area lies within a sporting estate and permission should be sought at Braeroy before taking parties over the ground, particularly during the autumn stalking season.

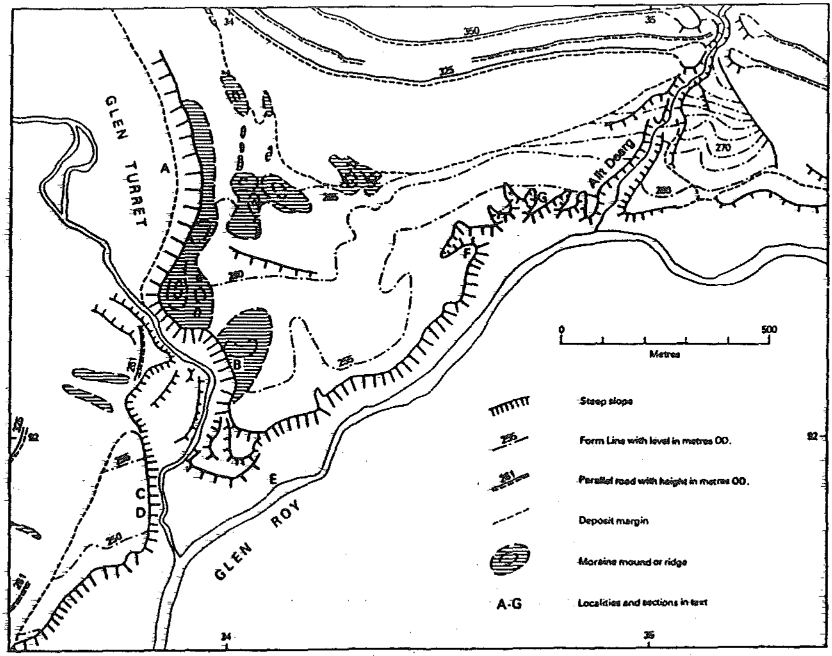

Figure 17 Turret outwash fan and moraines (from Peacock 1986, fig. 3).

The 325 m and 350 m Parallel Roads are well developed in upper Glen Roy, being either aggradational or cut in rock. Small deltas are present at stream re-entrants at several localities, that which was deposited in the 325 m lake by the Burn of Agie being particularly impressive (see below). The influence of waves and a SW wind in transporting debris (Sissons 1978) is well seen on the north side of upper Glen Roy where the accretionary shorelines reach their greatest width. Here also, for over a km opposite the confluence of the River Roy and the Burn of Agie, they are formed of quartzite gravel derived from the major psammite band which crosses the glen to the west. The underlying bedrock here is mica-schist.

Landslip cracks and small slips occur on the north side of Glen Roy north of the Roy/Agie confluence and a major landslip on the hillside east of Braeroy post-dates the Parallel Roads.

The origin and age of the fans which are present at the mouths of the tributary valleys in middle and upper Glen Roy (Fig. 16) have been the subject of discussion and disagreement which in the case of that at the entrance to Glen Turret goes back for over a century (Jamieson 1892). This worker suggested that the Turret fan is a delta, disputing Prestwich's (1879) view that it is a morainic accumulation re-modelled on the surface by water-action. There is now general agreement that it is an outwash fan backed by terminal moraines (Peacock 1986; Rose *in* Gray 1978; Sissons and Cornish 1983). The last two authors believed that the fan and moraines mark the maximum position of the Gloy glacier of LLR age. Their view is based on the occurrence of lake sediments above and below the gravels of the Turret and other alluvial fans and on their interpretation of detailed levelling. Fan gravels overlain by lacustrine silts are regarded as having been deposited subaqueously, chiefly in the 260 m Parallel Road lake of the rising sequence. Peacock and Rose, on the other hand, have suggested that the fan gravels are chiefly of subaerial origin and partly predate the Parallel Road lakes.

The Turret Fan and Moraines

The Turret fan (Figs. 17) is backed by moraines which on the north side of the valley are cut by both the 325 m and 350 m Roads. The moraines are only a few metres higher than the outwash deposits, but to the NW rise about 20 m above the floor of Glen Turret in a bluff interpreted as an ice-contact slope. There are the remains of 3 and possibly up to 5 moraine ridges, parts of which have been destroyed during the deposition of the outwash fan. Till overlain by lacustrine silts is exposed on the proximal slope of the main arcuate ridge (A in Fig. 17) and sand and gravel are seen in the bluff at the southern end of this ridge. The upper part of a low mound cut by the River Turret (B in Fig. 17) is formed of poorly sorted matrix-rich bouldery gravel with indistinct sub-horizontal bedding. The gravel is in part matrix supported and vertically oriented tabular boulders occur near the top of the deposit. These features suggest the presence of debris flow deposits as well as possible sheet flood sediments (see sedimentological references in Peacock 1986). The mound is therefore interpreted as an eroded proximal outwash deposit rather than a moraine.

The surface of the fan slopes from a little under 270 m to below 246 m OD in a little less than a km (Sissons and Cornish 1983). The fan surface is diversified by shallow channels, but details of the morphology are partly obscured by the cover of peat and lacustrine silts, the latter up to 2 m thick and proved by augering to a level of 270 m OD. The occurrence of the silts on the proximal (upstream) side of the arcuate moraines as well as on the fan surface and in the channels suggests that these landforms have been little modified since the time of formation of the upper two Parallel Roads. Traces of the 260 m Parallel Road can be seen on the west side of the River Turret (Fig. 17), but there is no evidence for an associated delta. A possible explanation for this is that the gap in the fan now followed by the River Turret was already present prior to the formation of the 260 m Road.

Features of interest on the fan surface include boulders of granitic gneiss from west of the Great Glen and boulders of granodiorite resembling the Corrieyairick Granodiorite (Fig. 2). Both can be seen adjacent to the path from Braeroy across the Turret fan into Glen Turret. P.S. Ringrose has noted deformation horizons in the laminated silts overlying the fan gravels.

Exposures in the fan have deteriorated considerably in recent years. N.B. Sections in the fan are dangerous and should be approached with care. A hard hat should be worn. At Localities C and D and northwards to Locality F (Figs. 17 and 18), exposures in the upper part of the bluff show laminated silt at the top overlying a generally coarsening upward sequence of well stratified clast supported gravel with minor sand and silt and local matrix rich, possibly matrix supported sandy gravel (Peacock 1986). At Locality C the following section was visible in 1967:

	m
3. Gravel, clast supported, bouldery and cobbly (particularly towards the top), poorly sorted sandy matrix, well bedded, beds less than 0.3 m thick. Bedding sub-horizontal, parallel to the fan surface. Local sand beds a few cm thick. Local imbrication.	21.0
2. Interbedded hard pebbly silt, laminated and gravel.	5.0
1. Till, stiff, gravelly.	1.5

Close by, at Locality D, the lower laminated silt is only 0.1 m thick and the underlying till, some 3 m thick, rests on bedrock.

Farther east, till is exposed from time to time beside the bridge at Locality E and laminated silt has been seen at the base of the bluff between Localities E and F. At Locality F there is the following composite section, only part of which is now exposed:

		m
4.	Gravel, bouldery and cobbly, locally imbricated, well bedded, bedding sub-horizontal.	4.0
3.	Gravel, coarse-grained, interbedded (0.2-0.5 m) with sand, bedding subhorizontal. Subsidiary massive silt (0.07 m beds). Units of cross-bedding (?planar) 0.3 m thick in lower part.	16.0
2.	Gravel.	1.5
1.	Silt, buff, laminated , with thin gravel beds, contorted in places.	0.5+

Highly thixotropic laminated silt and clay was seen by Macpherson (1978) in the bed of the river 150 m east of Locality F, where it was proved to a depth of 2.7 m. Here it yielded unidentifiable organic fragments, but no pollen. The laminated silts at the base of the bluffs have been interpreted as lake sediments (Sissons and Cornish 1983), perhaps deposited in the vicinity of glacier ice (Peacock 1986). Macpherson's deposit was correlated by Peacock (1986) with the silts at the base of the bluffs, but given the different lithology (gravel interbeds in the bluffs, none reported in the river) it could conceivably correlate with the lake silts overlying the outwash. In this case the River Roy might now be following a course similar to that which it took prior to the LLR.

Whether or not the Turret fan gravels are subaqueous or subaerial is of critical importance in understanding the Late-glacial history of Glen Roy. Peacock (1986) noted that the deposits are characterised by (a) dominance of poorly sorted, clast-supported sandy gravel with local clast imbrication, (b) parallel, sub-horizontal bedding defining lenticular sediment bodies which are thin (less than 1.5 m thick) compared to their lateral extent (which may exceed 20 m), (c) subsidiary matrix supported gravel, (d) very minor beds of sand and silt and (e) a depositional slope of about 1 in 40. These features suggest rapid deposition from bedload within the shallow migrating channels typically associated with proximal braided glacial rivers and contrast markedly with deposits interpreted as subaqueous fans in which the dominant facies is sand and in which gravel is mainly confined to channels, particularly near the source conduit, or to debris flow deposits and where the sediments might be expected to include turbidites and interbedded laminated silt and clay (for sedimentological references see Peacock 1986).

From the above Peacock concluded that most of the Turret fan was formed subaerially. At the start of fan formation, the level of any standing water in Glen Roy was below 230 m at Locality D (the local base of the (subaerial) gravel) and 235 m at Locality F. At the close, the level of any lake, if present, was below 246 m OD, which is the lowest surveyed point on the fan. If this is accepted, formation of the (subaerial) fan at a time when a lake was present at 260 m OD is excluded and the underlying lacustrine (or paraglacial) deposits must be referred to an episode predating the Parallel Road lakes. Further, deposition of such a fan during the LLR would require free drainage southwards into and through the Great Glen at a time when this was

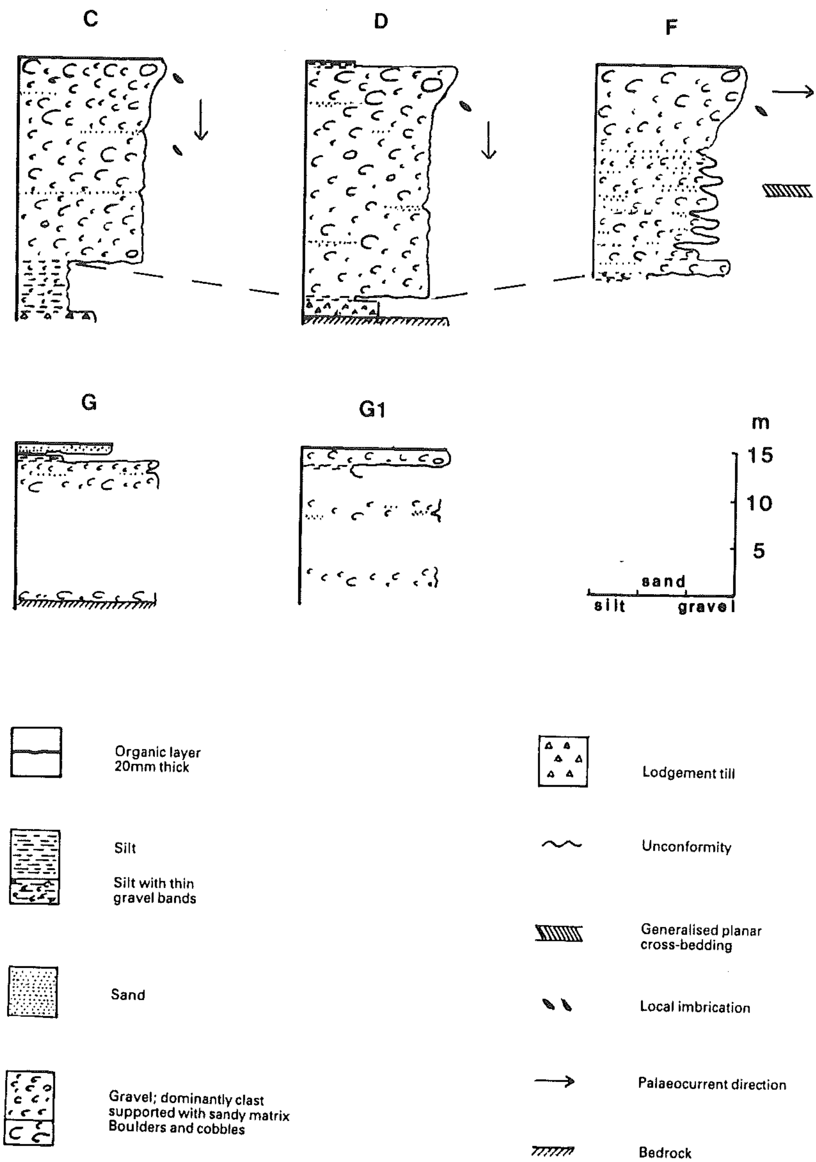

Figure 18 Lithological logs of sections of the Turret fan (C, D, F) and Allt Dearg fan (G, G1). For C, D etc, see Figure 17 and text. Locality G1 is about 10 m east of G. Tops of sections are fan surfaces. (From Peacock 1986, fig. 5).

occupied by a great thickness of ice, a scenario which is impossible to envisage. As a result, Peacock favoured the view that the fan belongs to the late retreat phase of the main Late Devensian glaciation rather than to the maximum of the LLR (see extended discussion in Peacock 1986). To this can be added , first, the absence in Glen Turret and the Gloy/Roy col of morphological features such as a sharp trimline which might be associated with an LLR ice-front (see below) and, second, the limited extent of any LLR glacier in Glen Gloy suggested by the drift limit in Glen Fintaig discussed in Chapter 2.

The 'East' Allt Dearg Fan

The apex of the fan is situated immediately below a small dissected delta of the 325 m Road (Figs. 17 and 18). The upper part is erosional, truncating underlying glacial deposits, but sparse exposures in the lower part of the fan suggest that much of this is depositional and formed of clast supported sandy bouldery gravel. At the base of the bluff south of Locality G a few metres of clast supported and subsidiary matrix rich gravel directly overlie bedrock and any silt and till if formerly present has been removed by erosion. At Locality G itself there is the following section:

	m
Gravel, fine- to medium-grained and sand	0.3
- unconformity -	
Sand, medium to coarse-grained and sandy gravel	0.4
Organic layers, black	up to 0.03
Silt and clay, grey, laminated	0.8
Gravel, medium- to coarse-grained, clast supported, interbedded with sand on a scale of 0.2 m	1.2+

The beds below the unconformity dip 12° NE and may be slightly slumped.

Lowe and Cairns believe that the bands of organic mud originated in small ephemeral pools on the fan surface. The pollen assemblages contain high Gramineae, Cyperaceae, *Salix* and *Empetrum* percentages with *Rumex*, Compositae and Ranunculaceae also well represented. They also believed that the muds accumulated during the transition from the Loch Lomond Stadial to the early Flandrian. Miller has correlated the laminated silts with the lower Group II laminates and records a sequence of 182 clear sediment couplets at this locality.

Excavation in the bluffs overlooking both the Allt Dearg and the River Roy show that there is a bed of laminated silt (thickness not determined) about 3.5 m below the surface, possibly associated with matrix-rich gravel. This is overlain and underlain by clast-supported sandy bouldery gravel, which in some sections is sub-horizontally bedded.

The presence of laminated silt on the fan surface indicates that the underlying deposits were laid down prior to the formation of the 260 m lake of the falling sequence. Sissons and Cornish (1983) followed by Peacock (1986) suggest that as the 'East' Allt Dearg fan merges with the

Turret outwash it is contemporaneous with it. The silt at a depth of a few metres below the fan surface could correlate on present evidence either with the lacustrine deposits at the surface at Locality G or with the laminated deposits at the base of the Turret outwash. However, according to Peacock (1986) the dominance of subhorizontally bedded clast supported gravel is consistent with the body of the fan being formed subaerially rather than subaequeously *(cf.* the Turret outwash discussed above). No sedimentological evidence for a delta at 260 m associated with the 'East' Allt Dearg fan has been found so far, any such delta having perhaps been removed by the River Roy.

The Parallel Roads facing down Glen Roy west of the apex of the fan are partly rock-cut (*cf.* the neighbourhood of the Allt Bohenie (Chapter 3)) and partly aggradational. Here, where fully exposed to the fetch from the SW the 350 m Road is 18 m to 35 m wide for over a km and the 325 m Road 14 to 22 m over a similar distance (Sissons 1978). The minor 334 m Road at this locality is, exceptionally, up to 7 m wide.

Turret Bank

The Turret Bank pollen diagram (Fig. 19), which is briefly discussed in Chapter 1, was obtained from an 8 m long bore [NN 337 925] sited a short distance west of Locality A (Fig. 17). Lowe and Cairns suggest that organic deposition began here during the earliest Flandrian (p. 11) and that the absence of Late-glacial deposits here and on the Gloy Turret col supports the view of Sissons and Cornish that glacier ice occupied Glen Turret during the LLR.

Comment (J.D.P.). The site is bounded to the east by the former ice-contact face of the Turret outwash fan and moraines and by a rock bar in the River Turret at about 252 m OD which may at one time have controlled the level of a small lake in this area. The 260 m lake seems also to have extended upstream of the Turret moraines as its shoreline can be traced towards and above the bar (Fig. 17). At both levels (252 and 260 m) the River Turret would have laid down a delta of sand and gravel starting at the head of the lake, the deposits so formed overlying any pre-existing lacustrine or glaciolacustrine silts. The fact that the borehole of Lowe and Cairns terminated in coarse sand rather than laminated silt supports this interpretation. Interpolation from the O.S. contours suggest that most if not all of the Turret Bank organic sediment must have been deposited in a body of standing water above 252 m, but below 260 m OD. The base of the organic deposit thus provides a minimum age for the drainage of the 260 m lake but is not necessarily related to any glacial event.

Glen Turret

The head of Glen Turret (Fig. 16) is partly floored by glacial deposits, chiefly silty sandy diamicton, overlain in places by laminated silt. On the west side of the valley the diamicton, which is over 7 m thick, passes gradually upwards into hillwash. Farther north, to the west of the alluvial fan (Fig. 16), the highly dissected drift sheet is up to 30 m thick and terminates abruptly upwards against bedrock. A

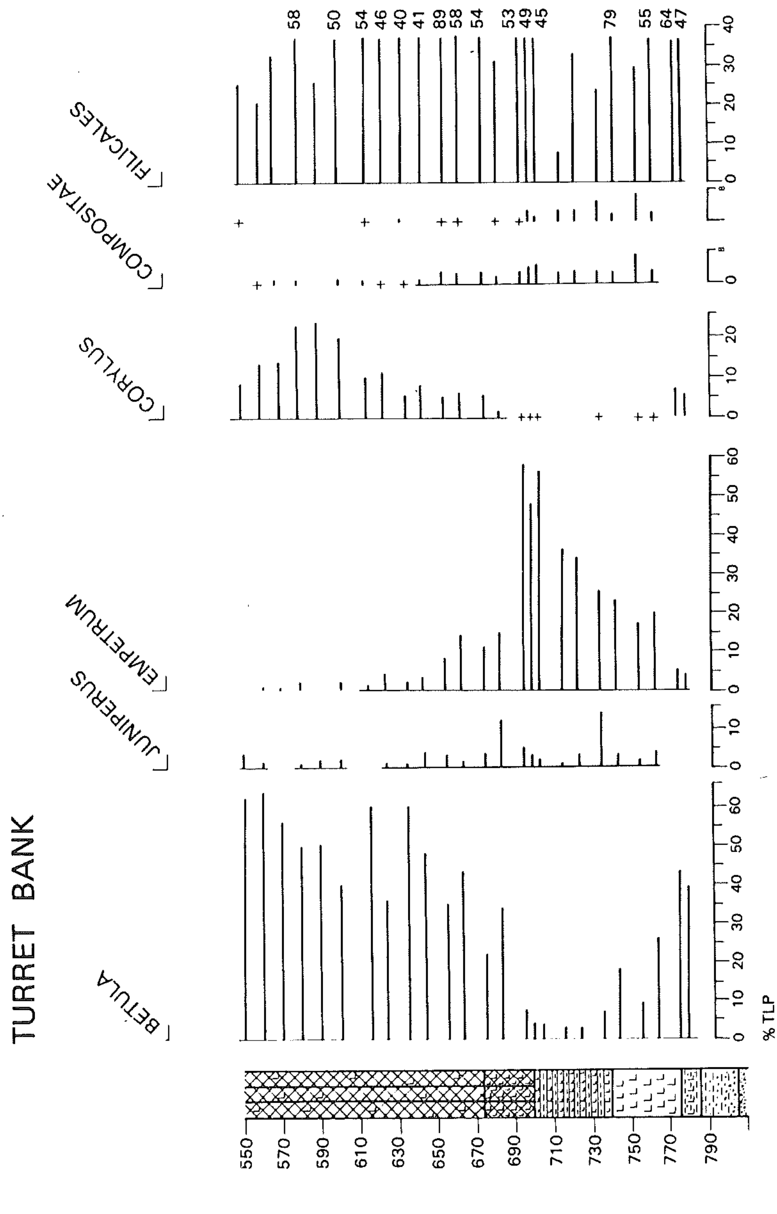

Figure 19 Summary pollen diagram from the Turret Bank site [NN 337 925] showing selected taxa; pollen counts based upon a minimum 'total land pollen' sum of 300.

section from the top downwards at this locality [NN 3297 9425] shows diamicton with striated boulders (till) over a metre thick underlain by many metres of very poorly sorted cobbly sand (diamicton) with angular to subangular gravel and hard, bedded silty sand with impersistent, deformed lamination. These strata, which are about 26 m thick, rest on fractured bedrock. Though they were thought by Peacock (1986) on cursory inspection to be waterlain till they clearly merit detailed examination in view of their similarity to the pebbly silt underlying the Turret outwash fan.

The fan at the head of Glen Turret seems to be at least in part graded to the 325 m Parallel Road and it may thus end in a delta, assuming that the toe has not been eroded by fluvial action. There is a small exposure of laminated silt at this level at its distal extremity. Much of the fan seems to be gravel, but exposures are insufficient to determine whether deltaic foresets or bottomsets are present. The 350 m Road here lies above the fan itself.

Allt a' Chomhlain

The thick drift sheet on the west side of Glen Turret can be traced southwards and westwards into the valley of the Allt a' Chomhlain (Fig. 16). The entrance to this valley is blocked by gravel mounds and ridges which have been terraced and dissected by the stream. The highest mound, Tom Bran, is kettleholed. A section in the left bank of the Allt a' Chomhlain [NN 3326 9305] near its mouth shows about 5 m of bedded gravel, possibly deltaic foresets, which are in part bouldery and in part sandy and medium grained. The deposit, which dips about 20 degrees north, includes clasts of till 0.3 m across. The mounds and ridges are interpreted as either having been deposited from water entering Glen Turret from the valley of the Allt a' Chomhlain while the former was still occupied by glacier ice or on the retreat of ice westwards into Glen Gloy.

A short distance upstream [NN 327 927] there are two alluvial terraces on the south bank of the Allt a' Chomhlain, the upper of which appears to be deltaic and graded to the 325 m Parallel Road. Sections in the banks of a side stream show the terrace to be underlain by interbedded gravel, including matrix rich and openwork gravel, and silt/fine-grained sand which is partly laminated and partly cross-bedded

The Gloy/Roy Col

The col here is a peaty flat from which Lowe and Cairns obtained a 7 m core of organic sediments with an *Empetrum-Juniperus* pollen zone at the base (p. 10). A small gravel terrace immediately west of the forestry fence is the only direct evidence for drainage of the 355 m Glen Gloy lake eastwards into Glen Turret.

The bedrock at the bottom of the valley (mica-schist and quartzite) is locally glacially smoothed, but on the slope north of the col the exposures, though still bearing evidence of glacially rounding, are weathered and fractured as far as the summit of Meall a' Chomhlain.

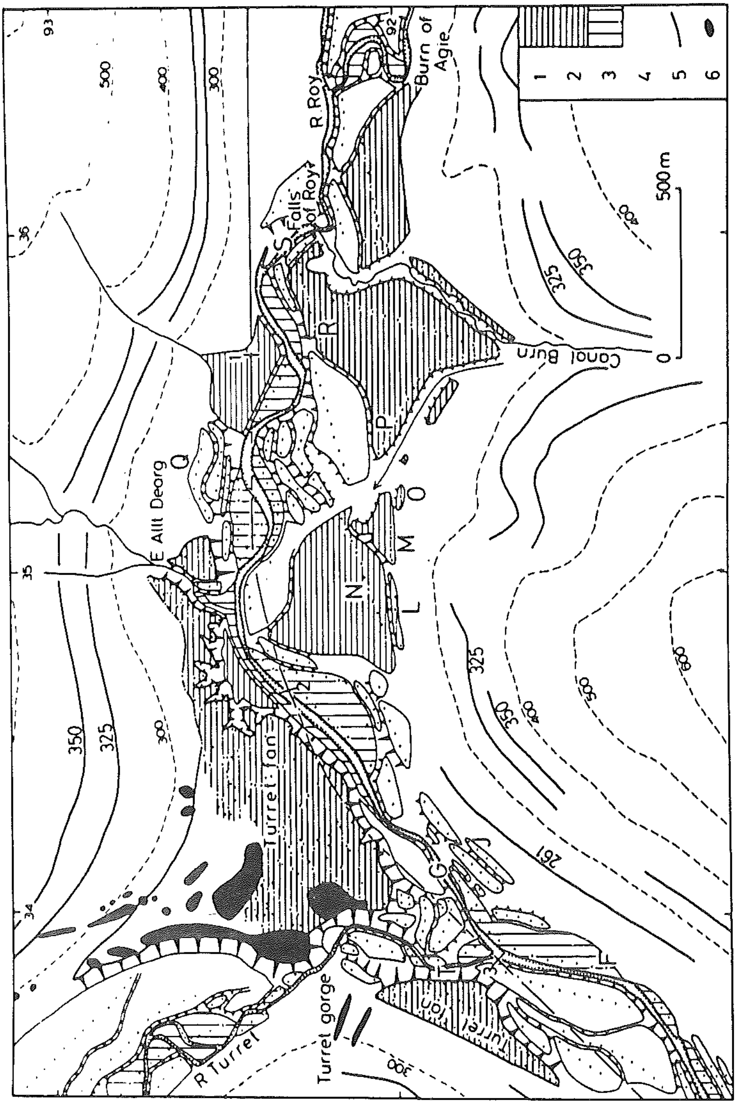

Figure 20 Fans and river terraces of upper Glen Roy (from Sissons and Cornish 1983, fig. 3).
1. Highest Roy terrace and fans associated with the 260 m lake,
2. Fans post-dating the 260 m lake, 3. Floodplain,
4. levelled points, 5. Parallel Roads, 6. Drift mounds.

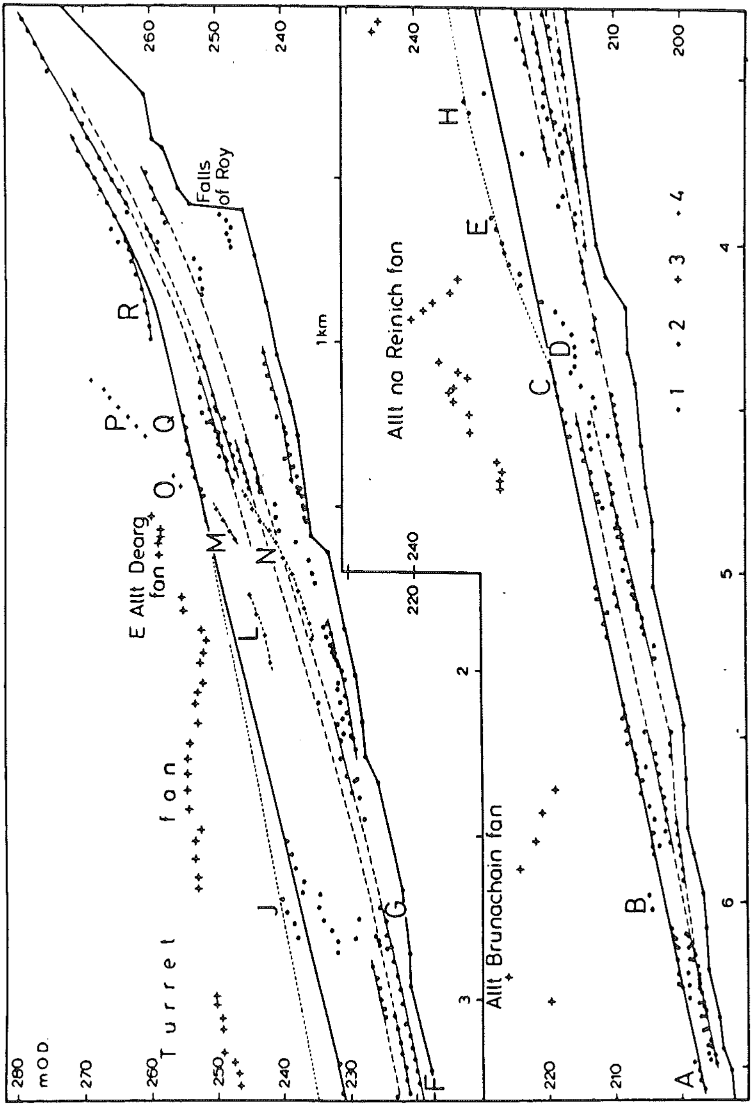

Figure 21 Height-distance diagram of the Roy terraces and associated features (from Sissons and Cornish 1983, fig. 4).
1, 2. Levelled points of terraces on the right and left sides respectively of the Roy, 3. Altitudes of the bluff tops cut by the Roy, 4. Levelled points on the surfaces of later fans formed by the Canal Burn.

This together with the absence of trimlines and sharp drift limits is difficult to reconcile with the passage of LLR ice over the col (*cf.* Ballantyne 1982).

The head of Glen Gloy may be approached (with permission) from the col through afforested ground or, alternatively by the private road from Glen Fintaig (Chapter 2). Here, at the mouth of the Allt Neurlain [NN 305 928], there is a mass of moundy gravel and diamicton similar to that seen at the confluence of the Allt a' Chomhlain and the River Turret. A paraglacial origin can also be suggested here, with supra- or subglacial deposition being related to water entering the head of Glen Gloy along the course of the Allt Neurlain while the main valley was still occupied by ice. The deposits have been partly reworked to form a delta associated with the 355 m Parallel Road. Also to be seen is the NNW trending fault at the confluence of the River Gloy and Allt Neurlain (Fig. 1) on which there may have been recent lateral movement (Davenport *et al* 1989). Ringrose (1987) has suggested very recent movement on a fracture in the fault at a locality [NN 3038 9272] within the stream gorge.

The Canal Burn Fan

The rough road from Braeroy to Annat skirts round the lower Canal Burn fan (Locality N on Fig. 20) to cross a magnificent series of terraces associated with the Post-glacial incision of the River Roy. From here the stalkers path is taken to the head of the Annat fan (Fig. 17).

Near the Annat cottage [NN 353 921] at Locality P (Fig. 20), a section at the beginning of the stalkers path near the top of the bluff which terminates the upper Canal Burn fan shows about 0.3 m of soil underlain by 1.5 m of gravel on 0.8 m+ m of laminated silt. The silt can be traced for over 200 m eastwards (R. Cornish, personal communication), its contact with the overlying gravel being about 4 m below the top of the bluff, which is here at a level of about 261 m OD (Fig. 21). The base of the bluff here has at one time been eroded by the River Roy and the height of 261 m cannot therefore be taken as relating to the 260 m lake without supporting evidence from sedimentology. A detailed study is clearly required here and at similar localities elsewhere in upper Glen Roy.

Exposures in the eastern part of the Canal Burn fan, about 200 NE of the apex are chiefly of imbricate cobble gravel of which up to 2.5 m is seen resting either on matrix-rich gravel or on laminated silt (at the apex itself). The imbricate gravel is taken to be Post-glacial in age, a suggestion reinforced by the occurrence of buried soils, e.g. at a section [NN 3588 0100]. The underlying matrix-rich gravel was clearly deposited under quite different conditions and is taken to be a paraglacial or ice-contact deposit.

The Falls of Roy

The Falls of Roy (Fig. 20) mark both a rock lip and the upper limit of the spectacular river terraces in this part of Glen Roy. An isolated mound separates the distal end of the Canal Burn fan from the continuation of the upper Roy terrace east of the mouth of the Canal Burn. Sections in the mound are chiefly of gravel and bouldery gravel, but there is a bed of laminated silt at about the same level as the upper Roy terrace. The significance of these exposures is in doubt, but if the mound is a terrace remnant they record events which have yet to be fitted into the history of the area.

Immediately below the Falls of Roy Sissons and Cornish (1983, p. 49) recorded the presence of lake sediments below the gravel fill. In 1987 a section about 3 m above river level showed:

	m
Sandy, cobbly gravel, probably to top of bank	-
Sand, fine-grained, interbedded with medium-grained gravel	1.5
Sand, fine-grained, laminated	1.0
- gap - (probably fine-grained sand)	1.5
Interbedded silt and fine-grained sand	0.5

The subhorizontally laminated basal deposits here could well be the bottomset beds of a former delta, now largely destroyed, associated with the 260 m lake. They may give an idea of the lithology of the infill which formerly occupied this part of the valley prior to the formation of the Roy terraces.

The Burn of Agie Fan and Uppermost Roy Terrace

Exposures at the distal (western) end of the Burn of Agie fan show laminated lacustrine silt overlain by up to 1.5 m of fluviatile gravel, probably Post-glacial. Upstream at Locality D in Fig. 22 the following section is exposed in the stream bank:

	m
Gravelly sand, pebbles to 6 cm	0.5
Grey, laminated clay and silt	1.0
Sand, fine- to coarse-grained	0.3
Gravel, well rounded, bouldery	0.1+

As the gravel at the base of the section appears to be fluviatile there is evidence here for subaerial conditions antedating and post-dating the 325 m and 350 m lakes.

The uppermost Roy terrace slopes partly with the River Roy (Fig. 21) and partly with the Burn of Agie. It is underlain by up to 2 m of laminated lacustrine silt and sand. These in turn lie on bouldery and cobbly sand which are probably of glacial origin. Peacock (1986) confused this terrace with the upper Roy Terrace of Sissons and Cornish (1983) which begins at Locality S in Fig. 20 and which is regarded by these authors as a continuation of the (left bank) Burn of Agie fan (R. Cornish, personal communication). As the uppermost Roy terrace is underlain by lake deposits it probably antedates rather than post-dates the 325 m and 350 m lakes.

Neighbourhood of the Burn of Agie Delta

At Locality A (Fig. 22), striae by the stalkers path which can be followed from the apex of the Canal Burn fan show ice movement from the west along Glen Roy, but immediately east of this locality glaciated slabs show striae directed NW indicating that ice also emanated from the Burn of Agie valley. That this ice movement, which carried large numbers of granodiorite erratics from the Corrieyairick Granodiorite to the south, was in part later than the eastward movement is confirmed by crossing striae, but the absence of terminal moraines suggests it was in part coeval. There is no evidence that the Burn of Agie ice penetrated far into Glen Roy

The 325 m delta of the Burn of Agie is best seen on the north side of the stream where it can be approached by the natural bridge (a bedrock chockstone in the gorge). Most of the deposit is gravel without cobbles and includes much granitic debris, but laminated clay can be seen in the bank below the delta top above the natural bridge. That the delta and its upstream subaerial fan originally extended as far as Locality C (Fig. 19) is suggested by the fact that the arcuate meander scar here is backed by a low ridge formed of the same non-cobbly gravel. The laminated clay may have been deposited when the lake level was 350 m and covered by the advancing deltaic gravels of the 325 m lake of the falling sequence. This delta can be taken as an analogue of deltas which may have been associated with the 260 m lake in upper Glen Roy.

At Locality B the 325 m Road is cut in bedrock (Sissons 1978) backed in places by a low cliff and is patchily developed. The trend of the shoreline is roughly parallel to the schistosity, but partly spalled blocks tend to be joint-bounded. The slope above and below the Road is formed both of glaciated bedrock and of locally derived boulders, some of which may have been spalled from it during the LLR stade before the formation of the Parallel Road lakes (*cf.* Ballantyne 1982). It may be speculated that this assisted the rapid cutting of the shoreline in bedrock by periglacial action.

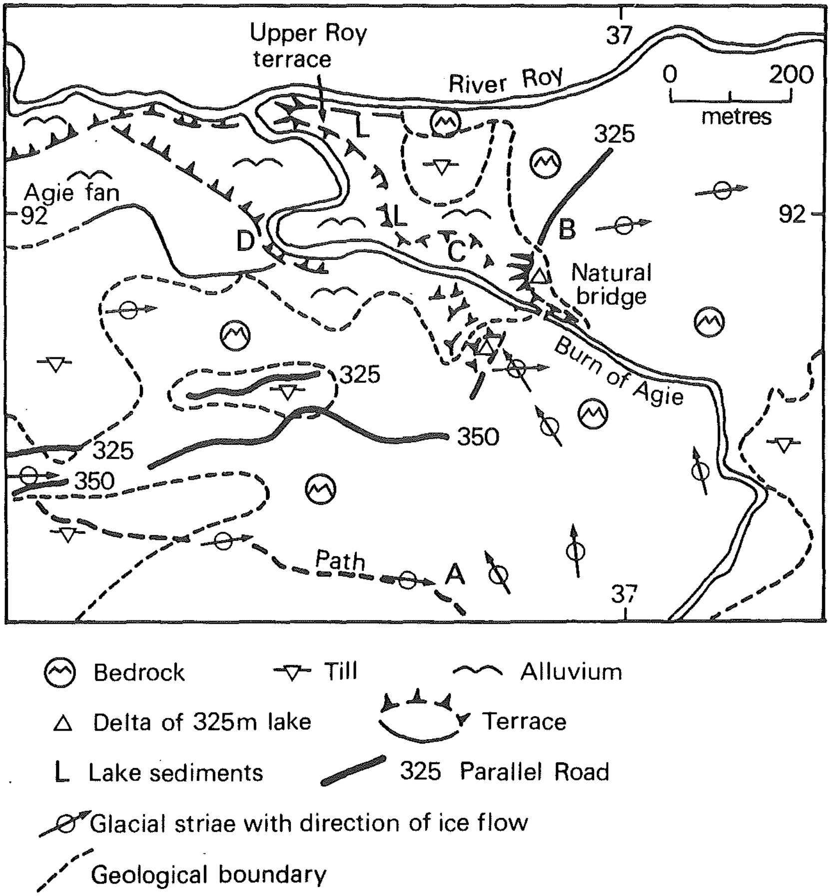

Figure 22 Lower Burn of Agie: landforms and deposits.

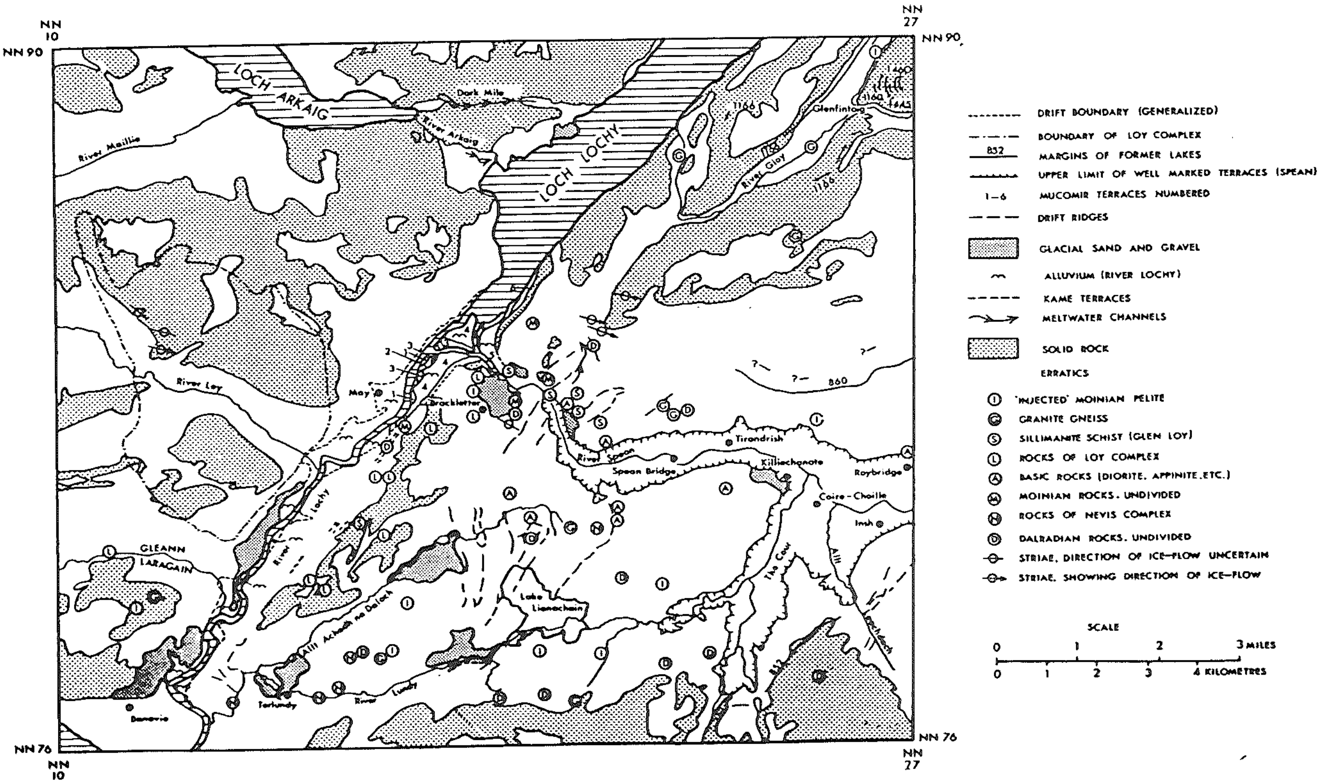

Figure 23 Glacial features of the Lochy-Spean area (heights in feet). Slightly modified from Peacock 1970b, Plate 21, Reproduced by permission of the Director, British Geological Survey. Crown Copyright Reserved.

5. GLEN SPEAN

This chapter covers the history of Glen Spean from the maximum of the LLR to the final dissolution of the ice in the Great Glen, probably in early Holocene times. Some key sites, such as the outlet channel of the 113 m lake NW of Spean Bridge (Fig. 32, p. 67) and much of the area near the Lundy-Leanachan col (Fig. 1) are at present concealed by forest and are only briefly referred to below. The excursion starts at Roughburn and after a diversion to Fersit continues along the main road to Spean Bridge. From here localities are visited on the south side of the river upstream to Insh and downstream to Brackletter.

At the beginning of the period much of Glen Spean was filled by ice emanating chiefly from west of the Great Glen (the Spean glacier) and from the Loch Treig basin (the Treig glacier). The enlarged Loch Laggan then dammed by this glacier ice discharged eastwards across the col at 260 m OD through the Feagour channel into the Spey drainage system (Figs. 3 and 4). It is clear from the mapping of striae that The Treig glacier formerly extended NW into Glen Spean across Meall Laire [NN 332 788] and it was this rather than the Lair glacier that came into contact with the Glen Spean glacier (Fig. 1). The junction of the Spean and Treig glaciers, which was probably due south of Creag Dhubh, is marked by a considerable area of sand and gravel disposed as kames (Fig. 27, p. 55).

The retreat of the Spean and Treig glaciers respectively westwards to Spean Bridge and southwards to the Loch Treig valley can be reconstructed from the moraines and from the kame terraces and deltas associated chiefly with the 260 m lake. In the valley of the Allt nam Bruach (Fig. 1), near the former confluence of the Spean and combined Lair/Treig ice, initial lowering of the glacier surface resulted in the formation of a small lake at about 310 m OD. Deltaic bottomset beds are overlain by terrace gravel that extends from the south (Fig. 27). West of the Allt nam Bruach the retreat of the Spean glacier is marked by the occurrence, first of a low angle kame terrace/delta about the level of the 260 m Parallel Road (Fig. 27) and then by several kame terraces and a kettled delta on the east side of the Allt Leachdach (Fig. 24). On the hillside north of Beinn Chlianaig [297 783] the occurrence of a series of lateral moraines on the hillside below the LLR limit at 475 m suggests that the Spean glacier remained active as its surface was lowered by at least 65 m. When dammed by ice near Spean Bridge, the 260 m lake reached its maximum length of about 35 km and, including the portion in Glen Roy, a maximum volume of about 5 km^3 (Sissons 1979a).

The later stages of ice retreat and lake drainage have been described by Sissons (1979a; 1979b) who envisaged that the 260 m lake drained catastrophically by way of the Spean gorge and thence NE along the Great Glen. The subglacial discharge probably excavated the Spean gorge itself, a landform that certainly antedates the latest glacial deposits. As noted in Chapter 3, the draining of the 260 m lake may have triggered an earthquake which caused widespread deformation of lake sediments in both Glen Roy and Glen Spean. Subsequently, according to Sissons, the level of the lake varied constantly as it was intermittently emptied by other sudden floods of lesser volume, some of

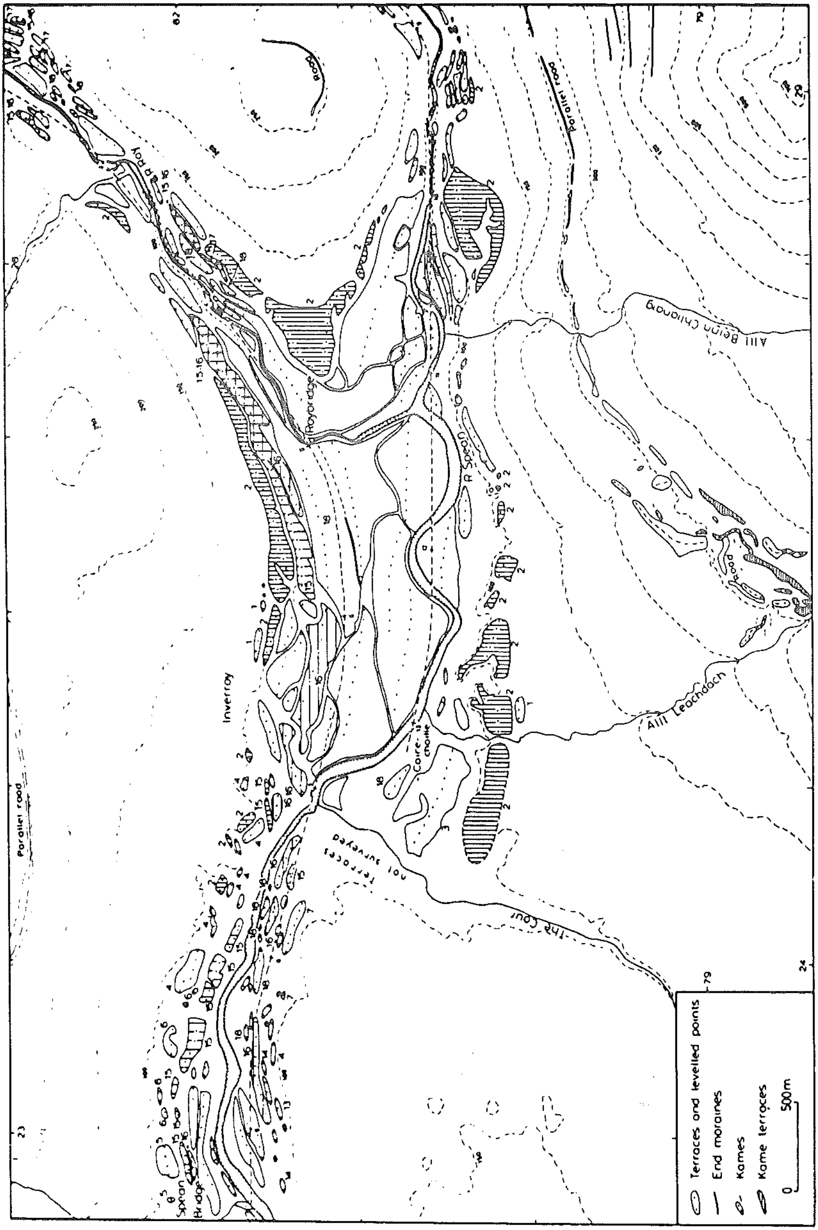

Figure 24 Terraces and some later landforms around Roybridge (from Sissons 1979b, fig. 6). Terraces are numbered as in Figure 25.

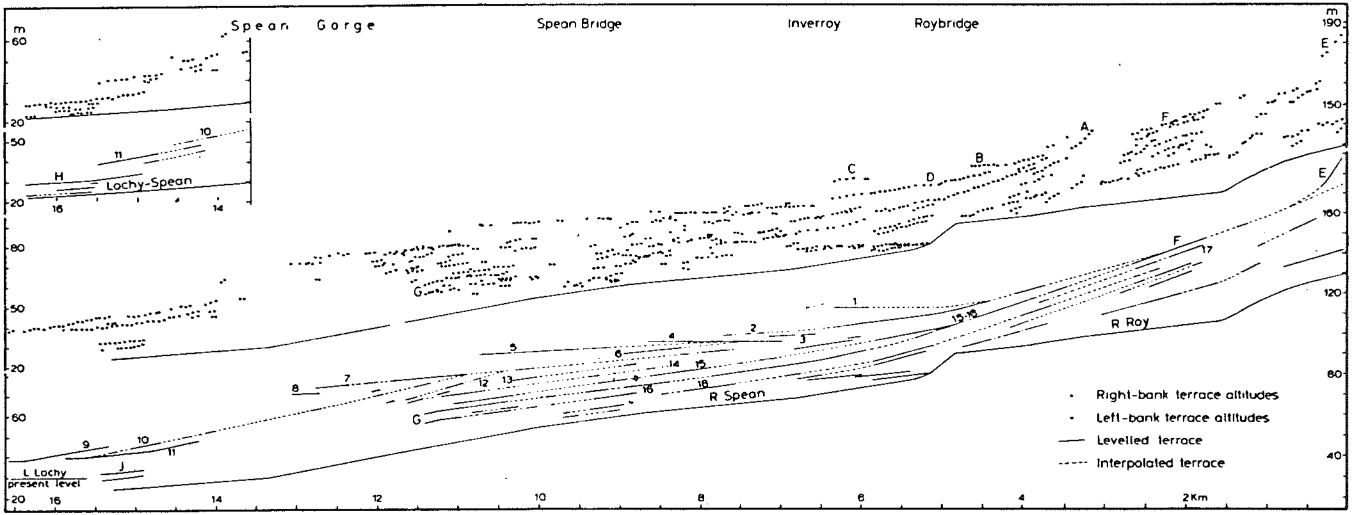

Figure 25 Height-distance diagram of the Roy-Spean-Lochy terraces (from Sissons 1979b, fig. 3).

which followed a gorge at the head of the River Lundy and one that produced a now abandoned waterfall site near Loch Lochy (Fig. 1). Some of these events were associated with numerous drift ridges which are interpreted as end moraines (Figs. 23 and 32). These ridges clearly post-date the drainage of the 260 m lake as they lie west of the ice-front at that time. Sissons suggested that they were formed during the period of constantly fluctuating lake level.

From detailed surveying and levelling Sissons (1979b) deduced that a complex system of more than 20 fluvial terraces occurs in Glen Spean, lower Glen Roy and associated valleys (Figs. 24 and 25). Mapping shows that, after the 260 m shoreline was abandoned, lake levels existed in Glen Spean at 113, 99, 96.5 and 90.5 m. Other terraces relate to higher levels of Loch Lochy at 39 to 40 and just below 34 m, the loch then draining northeastwards along the Great Glen instead of southwestwards as at present. In Glen Roy the drift barrier adjacent to the Viewpoint (Chapter 3) is said to have dammed a lake at a level of about 180 m, the outlet being little modified while a flight of at least 15 terraces was produced further down the valley (Sisson 1979b). In Glen Spean a gap of 2 km in the terrace sequence between the gorges at Monessie and Inverlair (Fig. 27) was caused by the presence of dead glacier ice. Many of the terraces do not decline regularly in altitude down valley and some terraces merge into each other.

The early Holocene history can therefore be summarised as follows (Sissons 1979a):

1. Retreat of the Spean glacier to an ice front position near Spean Bridge.
2. Catastrophic draining of the 260 m lake (jökulhlaup).
3. Period of fluctuating lake level with base level controlled by the Lundy-Leanachan col (c. 130 m). Catastrophic draining across the col with possible cutting of the Lundy gorge; formation of end moraines. Retreat of ice by 2.5 to 5 km and lowering of its surface by 150 to 300 m.
4. Jökulhlaup along the abandoned waterfall route (Fig. 1).
4. Formation of ice-dammed lake at 113 m OD in Glen Spean with outlet across col to NW of Spean Bridge. Commencement of sand infilling of the Spean valley.
5. Formation of terraces graded to deltas at 99, 96.5 and 90.5 m OD in the Spean valley. Continuation of sand infilling.
6. Formation of lower terraces graded to an enlarged Loch Lochy which was dammed by ice at its western end.
7. Dissolution of the ice and initiation of the present drainage system.

The Roughburn Area

At the west end of Loch Laggan the limit of the LLR Treig glacier is marked by massive gravel and boulder terminal moraines (Fig. 26). On the north side of the loch the moraines end abruptly eastwards at a possible ice-contact slope: they can best be viewed from the forestry road which is entered by a stile just east of the bridge carrying the

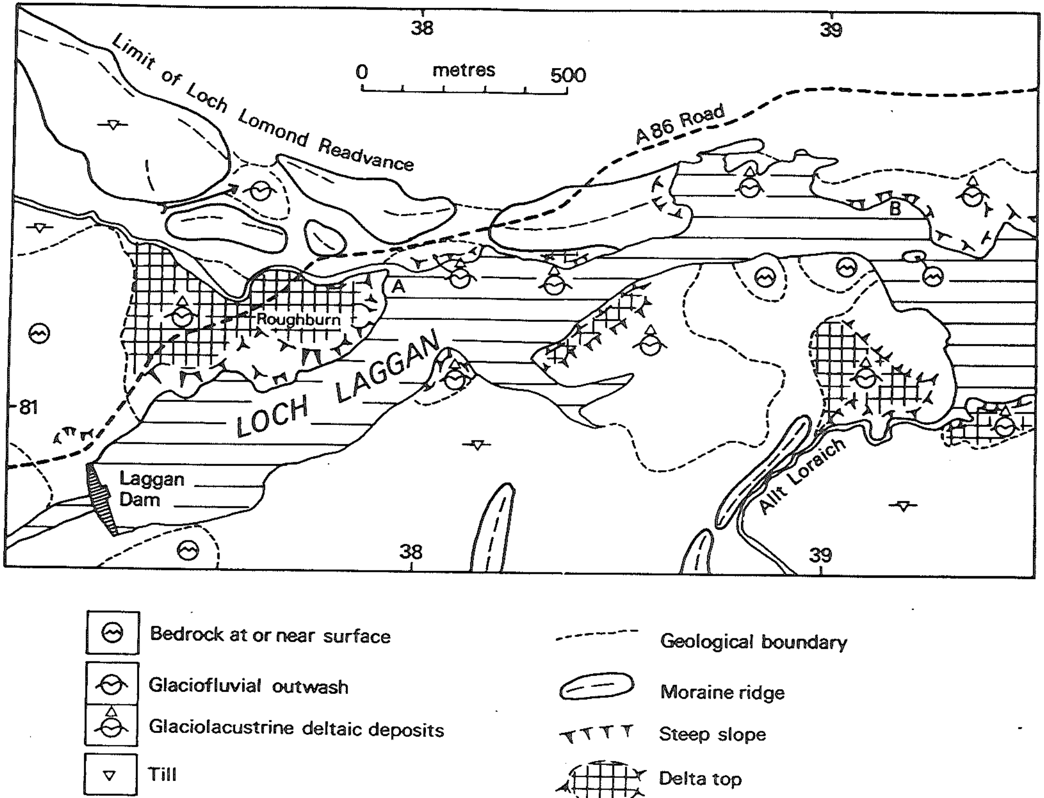

Figure 26 Landforms and deposits at the west end of Loch Laggan.

A 86 road over the Feith Shiol. The continuation of the multiple end moraines on the south side of the loch (Sissons 1979c) is obscured by forest.

On the north side of the loch at Roughburn the public road crosses an alluvial fan that terminates in steep, high bluffs. Exposures in the feature are few. Large, steeply dipping gravel foreset beds extending most of the height of the bluff were at one time visible at Locality A (Fig. 26) and can be seen at present in the bluffs opposite. In this vicinity Jamieson (1892, p. 14) noted about 30 m of fine silty sand below coarse, bouldery, waterworn gravel. At Locality B sections 5 to 6 m high expose fine- to coarse-grained sand overlying laminated silt. The sand is sub-horizontally bedded and much of it shows climbing ripples formed by a current from the WNW. At the top of the section at about 259 m OD the sand is pebbly and disposed in small channels.

The occurrence of the steeply dipping gravel foresets suggests that the fan is a Gilbert-type delta deposited in the 260 m lake. The ripple-drift sands may be bottomset beds, but the fact that they extend almost up to the level of the former lake suggests that they could be low angle foreset beds. The delta was probably largely deposited by the river which discharged across the col at the head of the Glen Glas Dhoire into the Feith Shiol when the lake level in Glen Roy had fallen to 325 m. There is no certain evidence, such as large water transported boulders and abnormal fluvial landforms, for the catastrophic drainage which might have been expected as the lake level in Glen Roy fell from 350 to 325 m: the large boulders on the right bank of the Feith Shiol near Locality A are likely to be part of the terminal moraines. Though the delta itself was almost certainly deposited by a flow of water considerably larger than that of the present stream, the width of the former shallow river bed in the upper reaches of the Feith Shiol is no more than 150 m. The distal topset part of the delta is preserved on the south side of Loch Laggan and by analogy with the Treig delta mentioned next it is likely that part of the area occupied by the west end of Loch Laggan was occupied by stagnant glacier ice at the time of delta formation. If this had not been so the River Spean would probably have found a more southerly course. As deposition of the delta does not appear to have been constrained by a nearby ice-front any coherent glacier ice may have been well to the west and south at this time.

The Roughburn delta can be compared with the well preserved Gilbert-type glaciolacustrine delta deposited in the 260 m lake that bisects Loch Laggan some 6 km farther east near Moy Lodge, beyond the area covered by the excursion. The gently to steeply dipping sandy foresets of this delta are exposed from time to time between Moy [NN 421 827] and the bridge [NN 433 830]] and are visible from the public road.

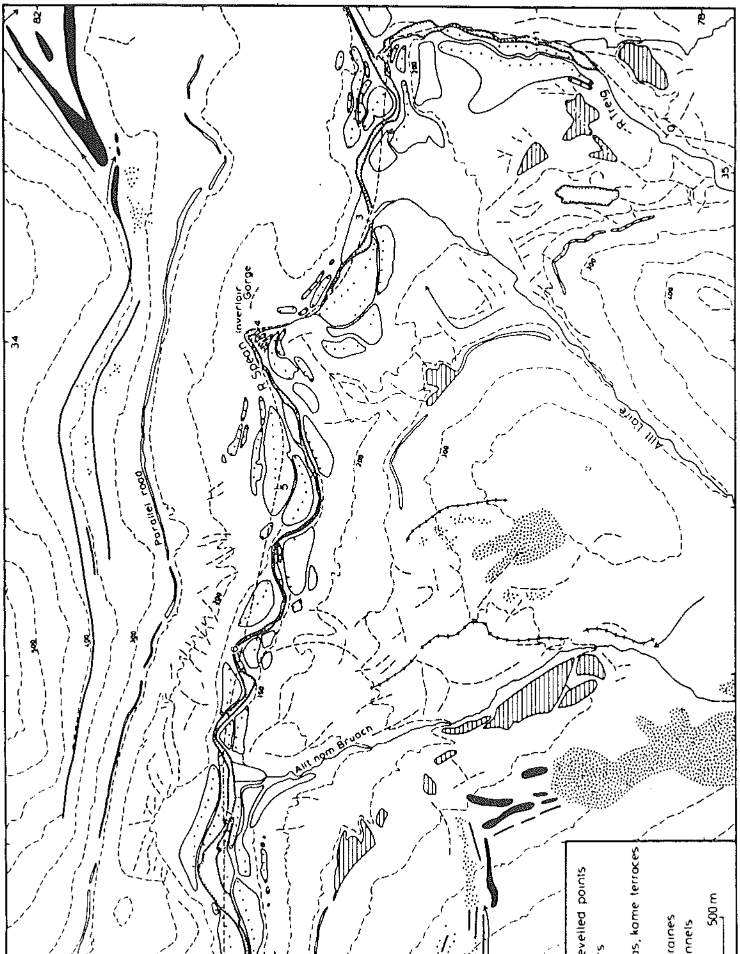

Figure 27 Terraces and other landforms in upper Glen Spean (from Sissons 1979b, fig. 2).

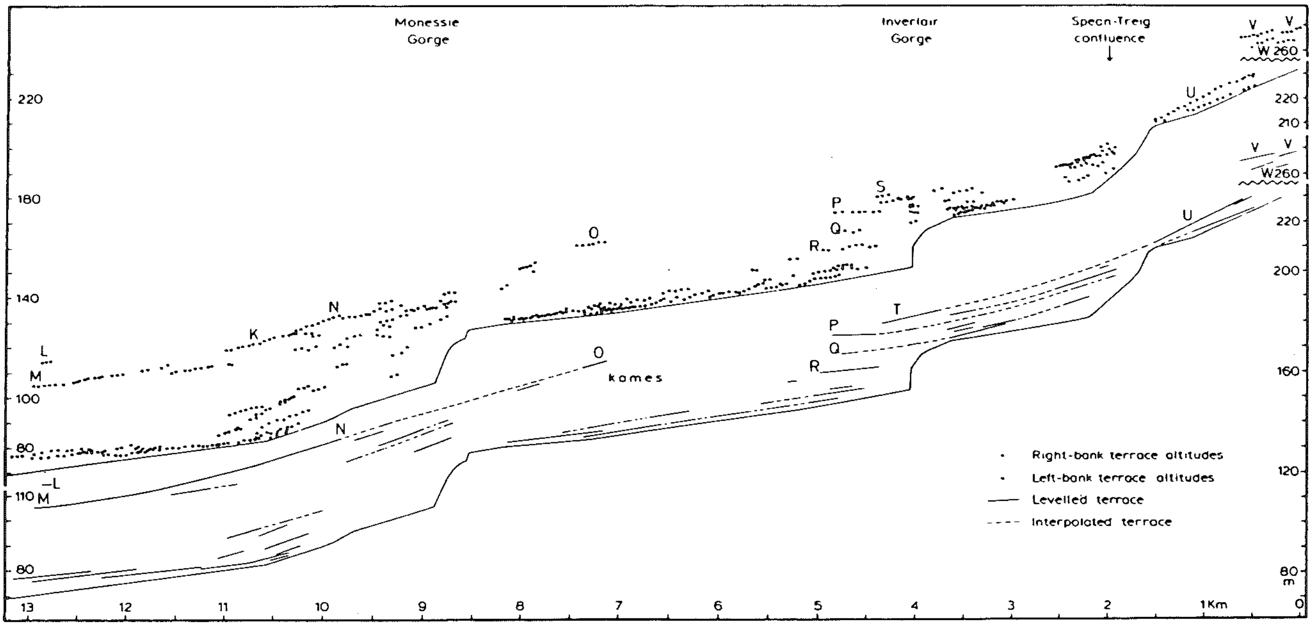

Figure 28 Height-distance diagram of the Treig-Spean terraces (from Sissons 1979b, fig. 8).

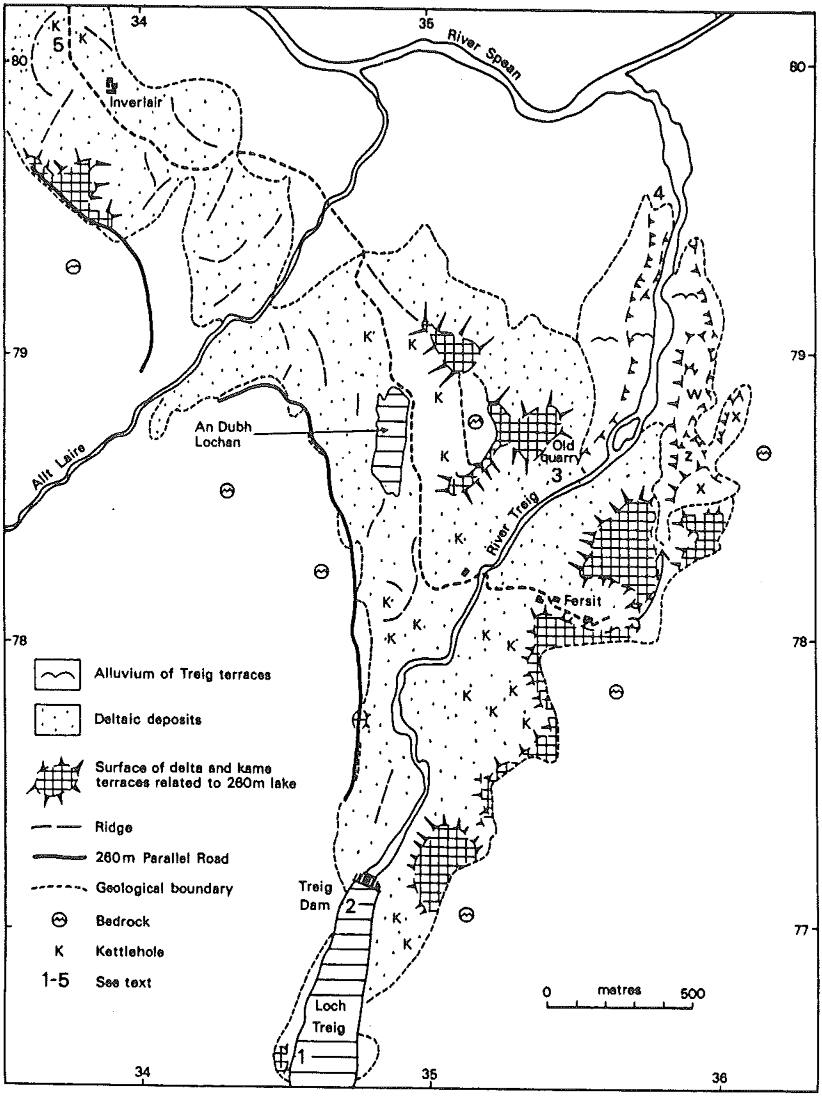

Figure 29 River Treig, landforms and deposits.

The Treig Delta

The Treig glaciolacustrine delta is one of the finest known to the writer (Fig. 29). It extends from Inverlair southwards to *c* 0.5 km south of the Treig dam and consists chiefly of kettled sand and gravel. Sections of the original delta surface are preserved in places, particularly on the flanks of the valley and where knobs of bedrock rise to near the 260 m level. These deltaic landforms comprise a series of gently sloping kame terraces that were deposited sequentially as the stagnant Treig glacier wasted southwards. Deposition of the delta commenced at Inverlair, at which time glacier ice still extended some 2 km north of the Treig dam. Part of the delta accumulated against glacier ice on its east side and it was only when the Treig glacier had retreated south of Fersit that deltaic gravels were freely deposited in the 260 m lake. By the time the 260 m lake was drained, the inactive Treig glacier had retreated into the Treig breach and the ice-front (if any) was well south of the Treig dam. Lake drainage was followed immediately by deposition of steeply sloping river terraces on the right bank of the Treig (these terraces were concealed by forestry when the area was mapped by Sissons (1979b)). The course of the river following lake drainage requires that the western part of the delta was still underlain by dead ice in places since, given the present topography this would otherwise have been the preferred exit. This accords with the fact that no glaciolacustrine sediments have yet been found in An Dubh Lochan, NW of Fersit (Macpherson 1978).

Following the Fersit road south from its junction with the A 86 a fine kettlehole some 25 m deep is seen at Locality 5 (Fig. 29). On the opposite side of the road a kettle hole immediately north of the farm buildings yielded 11.4 m of sediment at its deepest point according to Lowe and Cairns, with high *Empetrum* and rising *Juniperus* values in the basal pollen (p. 10). Lowe and Cairns also obtained organic lake sediments from another kettlehole [348 782] due west of Fersit with high *Juniperus and Empetrum* pollen at the base.

<u>Comment</u> (J.D.P.). One core was obtained from the low-lying kettled area west of Fersit which was almost certainly underlain by dead ice at the time of drainage of the 260 m lake (see above). Organic sediments presumably only began to accumulate when this ice had melted. A similar argument can be applied to the Inverlair core. The Turret Bank site (p. 39) may thus give a better minimum age than either of these sites for catastrophic draining of the 260 m lake.

Below the remnant of delta surface east of Dubh Lochan, foreset beds and bottomset beds are seen in the old quarry at Locality 3. The private road that leaves the public road west of Fersit can be taken (with permission) to Loch Treig. At Locality 2 water-worn rock with large half potholes, which occurs up to the 260 m level by the roadside south of the dam, suggests the position of a river which flowed between bedrock and ice immediately before the deposition of the ice marginal deltaic gravels at this locality. Exposures in the gravels by the lochside at Locality 1 show deltaic foresets. Possible sichelwannen occur on glacially grooved bedrock a short distance to the south.

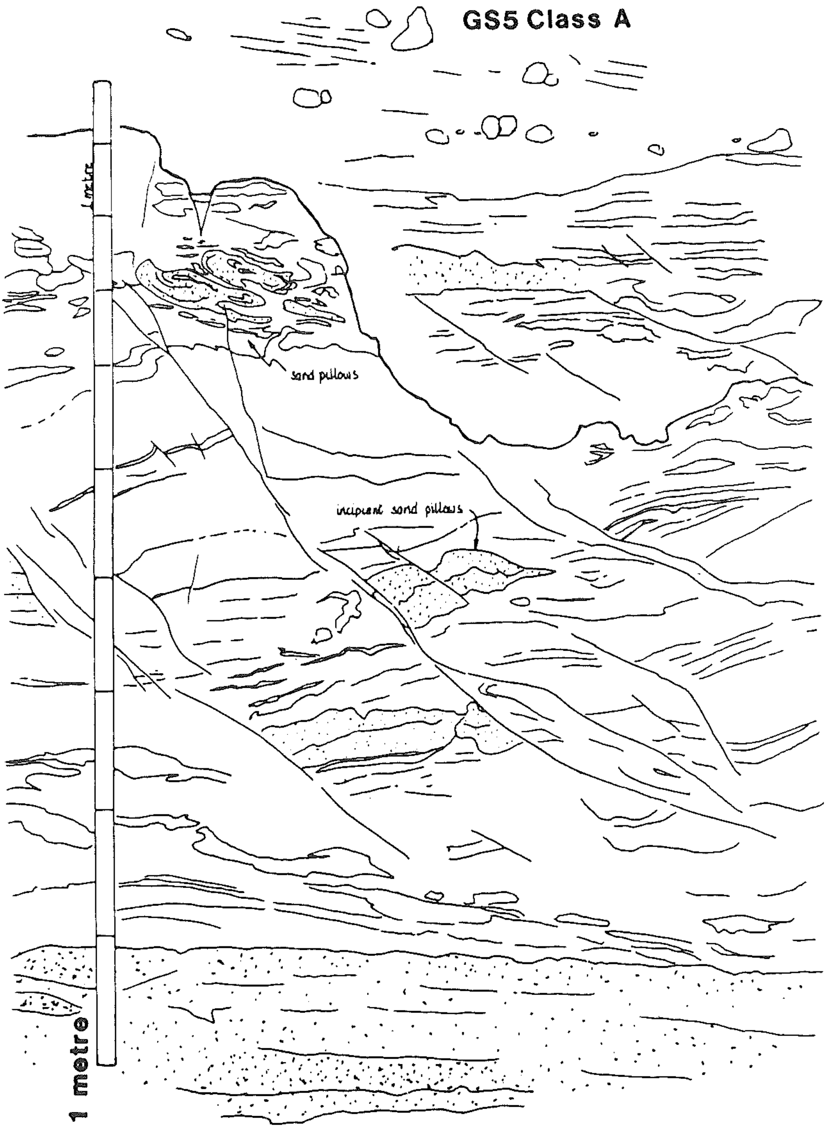

Figure 30 Field sketch of lake sediments at Tulloch [NN 332 809].

The high terraces on the right bank of the River Treig may be viewed by following the private road eastwards through Fersit and then northwards for a short distance. The slope of the terraces suggests that they were deposited by the river when it flowed partly near its present course, but partly also through the channel shown on Fig. 29. Like the left bank terraces they appear to be graded towards the bedrock exposed at Locality 4 and indicate that, following the initial catastrophic draining of the 260 m lake, the water level never again rose above 205 m. OD.

The Tulloch Area

West of the Inverlair Gorge (Fig. 27) there are a number river terraces the highest of which, on the north side of the river, terminates in a small delta that can be visited by crossing the fields below the A 86 road (permission to be sought from the farm at Tulloch [NN 329 807]). This delta (P on Fig. 28), which terminates at an altitude of 175 m, may have been deposited at the margin of a lake dammed downstream by the dead ice associated with the kames in the part of the valley (Sissons 1979b). Whether or not this is the case, it is the highest level for which there is evidence for a lake surface following the draining of the 260 m lake. A section (unfortunately now in poor condition) at the distal end of the highest terrace, in the stream bank [NN 3326 8078], shows *c* 4 m of gravel overlying about 5 m of fine-grained sand and laminated silt. Sections in the lower terraces show fluviatile gravel that also overlies laminated silt. The latter could belong at least in part to the 260 m lake: the presence or absence of liquifaction structures could be used as a time-marker (see next).

Roadside section (P.S.). At a nearby section [NN 332 809] 10 m from the roadside a face about a metre high (Fig. 30) shows a sequence of lacustrine silts and clays with faulting and ball-and-pillow structures associated with liquifaction thought to be caused by seismic activity (Ringrose 1987). A post-liquifaction channel is infilled by sand-rich sediment.

Comment (J.D.P.) These sediments lie above the 175 m delta and if the timing of the seismic activity is correct, must have been deposited when the lake level was 260 m.

Tulloch to Roybridge

Westwards from Tulloch to Achluachrach [NN 301 810] the A 86 road passes sand and gravel deposited at the junction of the Spean and Treig glaciers. These are disposed as kames, which occur at and below 260 m generally, but to higher levels on both sides of the Allt nam Bruach (Fig. 27). The lateral moraines of the LLR Spean glacier, which were mentioned earlier in this chapter, can be clearly seen above Monessie [298 805] on the the south side of the valley. Striated bedrock surfaces occur a few metres upslope of the highest moraine, but above this level the hillslope is covered in soliflucted till and other periglacial deposits with large angular blocks of country rock. This being so it is possible that the LLR ice extended above the apparent drift limit at this locality.

The broad terrace within the angle of the rivers Roy and Spean just east of Roybridge (Terrace 2, Fig. 24) was interpreted by Sissons (1979b) to be part of a widespread feature which ends in a delta at 99 m OD west of Inverroy. He recorded the interesting fact that this triangular remnant slopes from about 128 m at its eastern end above the Spean to a horizontal edge at 120 m overlooking the River Roy. This Sissons explained as indicating the greater influence of the Spean, but the horizontal edge could alternatively be regarded as a delta front which has been little modified by later fluvial erosion. The following section occurs at a locality [NN 2795 9095] in an upstream part of the terrace:

– Surface level approximately 128 m –

	m
Gravel, sand and cobbles (terrace gravel)	2
Unexposed	4
Sand, micaceous medium-grained, a few pebbles	7
Sand, fine-grained, laminated, scattered small pebbles	1.5
Till	

The lower part of the succession above the till and below the terrace gravel is interpreted as formed of deltaic bottomset beds. These reach a level of at least 122 m OD, which is well above the level of the highest post-260 m lake recorded by Sissons in lower Glen Spean.

Inverroy

The deposits underlying the thin and discontinuous terrace gravels flanking the lower Spean are the eroded remains of a fill formerly many metres thick. They comprise in general terms a few metres of laminated silt which are overlain by interbedded laminated silt and fine-grained, commonly ripple bedded or laminated sand. These sediments are interpreted as the bottomset beds (or possibly low angle foreset beds) of deltas deposited by the rivers Spean and Roy in the series of ice-dammed lakes referred to below. At some localities the deposit coarsens upwards to coarse-grained sand with interbeds of fine-grained gravel. These, together with the occurrence of channels immediatedly below the terrace top suggest shallowing of the lake with consequent localisation and increase in the velocity of the bottom currents.

It is noteworthy that the upper limit of laminated silt and sand at any one locality in this part of Glen Spean is commonly at or only a short distance above the highest terrace and that this limit declines downstream. This serves to distinguish these later lacustrine deposits from the patchily distributed laminated silts associated with the 260 m lake, which are found at higher levels. The limit may be partly due to erosion of any silt and fine-grained sand not preserved by a gravel capping, but it can also taken as evidence that the Spean valley was progessively infilled from the east as lake level declined and the deltas at its head prograded downstream, the sediment being supplied partly from erosion of the earlier formed deltas and partly from erosion of glacial deposits.

The apparent absence of steeply dipping foreset beds, as in Gilbert-type deltas, is problematical: it may be due to the predominance of fine-grained material in the transported sediment, lack of exposure, or erosion of the valley fill. Another possibility is that lake level fell continually and that the advancing terraces were eroded into the prodeltaic sediments which filled the valley ahead of them. On this basis the deltas are merely incipient, as the downstream end of each terrace corresponds to a temporary increase in the rate of lake drainage.

No sections have been seen that show topset gravels interbedded with bottomset beds and there is thus no evidence for the lake emptying and refilling during the period of formation of the deltas.

Sisson's (1979b) view that deltas were formed at levels at and below 113 m OD is supported by the occurrence of laminated silts and fine-grained ripple drift sands below the terraces. However, as similar bottomset beds can be traced up to at least 122 m below the highest terrace on the north side of the Spean east of Roybridge (Terrace 2 of Sissons 1979c - see above), it is evident that this is only part of the story and that lakes and accompanying deltas occurred in the Spean valley up to at least this level.

River terraces underlain by thin, patchy gravel resting on laminated silt and sand are well seen between Roybridge and Inverroy (Figs 1 and 24). Sections of the underlying deposits which occur in the ditches beside the road joining the upper and lower parts of Inverroy village comprise till overlain by laminated silt and discontinuous gravel. The road crosses a dissected remnant of the highest, horizontal Spean terrace (1 in Figs. 24 and 25, but not mapped by Sissons) above which laminated clays can the traced northwards to the T junction.

Spean Bridge Sandpit

The sections in this sandpit [NN 217 819], which is excavated into Sisson's Terrace 2, deteriorated considerably in the last few months of 1988. A recent exposure showed about 7 m of generally fine- to coarse-grained sand, subhorizontally laminated, dipping about 2° south. Horizons with climbing ripples alternate with slightly coarser beds with scattered pebbles on a scale of 0.1 to 0.3 m. There is a general coarsening upwards and small channel forms occur at the top.

Spean Bridge to Insh

The minor road on the south side of the river east of Spean Bridge follows the river terraces. Just east of the railway bridge, an old pit on the south side of the road [NN 228 815] exposes thin terrace gravel overlying about a metre of interbedded laminated silt, fine- to coarse-grained sand and medium-grained gravel in which the finer-grained beds show load casts. The pit formerly showed *c* 4 m of interbedded sand, gravel and pebbly silt, with cross-bedding suggesting derivation from the NE (Peacock 1970b). These and the terraced sand and gravel in a pit about 400 m to the east are interpreted as meltwater deposits. Upstream, one of the river terraces emerging from the Cour valley merges with the highest Spean terrace in this vicinity (7 on Fig. 24, p. 50).

The valley of the Allt Leachdach provides perhaps the clearest morphological evidence for lake levels above 113 m OD. Access is by the private road from Coire-choille, which stands on the prominent bluff marking the 99 m delta of Terrace 3 (Fig. 31). A little to the south another bluff at 99 m marks the combined delta of The Cour and the Allt Leachdach at this level. Pending detailed levelling it is not clear whether this correlates with Terrace 2 or Terrace 3 of Sissons (1979b). Farther south there are a number of partly dissected gravel fans with gently sloping treads and distal risers of 15° to 30°. As the distal bluffs are not dissected the fans are interpreted as raised deltas, which by interpolation from the Ordnance Survey contours, relate to former lake levels of, very roughly, 143m, 130 m, 122 m and 114 m. The last clearly corresponds to the lake level of 113 m inferred from the Spean terraces mapped by Sissons (1979b). Farther up the valley the road crosses another bluff which may be a remnant of a still higher delta (175 m?).

These deltas add a new dimension to the early Holocene history and suggest that Sisson's account may need revision. They could either relate to the 'period of constantly varying lake level' following drainage of the 260 m lake or merely indicate that lake level fell intermittently from this level to 113 m.

At a road junction about 150 m west of the farm of Insh [NN 264 802] there are a number of exposures in the bluff of Terrace 2, immediately south of the northward convex bend in the River Spean (Fig. 24). At a silage pit [NN 2623 8021] in the terrace top the following section was recorded:

		m
3.	Gravel, fg-cg and cobbly, chiefly poorly sorted, subangular to rounded.	0.5 - 1.3.
	- unconformity-	
2.	Channel, with cg sand and fg gravel	0 - 0.25
1.	Sand, fg-cg. ripples climbing NE-SW, dip subhorizontal to 10°SW	1.2+

A section [NN 2633 8012] at the base of the bank by a small stream is as follows:

		m
3.	Sand, fg, horizontally bedded	2+
2.	Silt, laminated	3
1.	Unexposed	1.

From the top of this last section to the base of the gravel in the silage pit is 5 m, which exposures in the roadside bank show to be chiefly ripple drift sand. These two sections thus show about 10 m of prodeltaic sediments underlying Terrace 2.

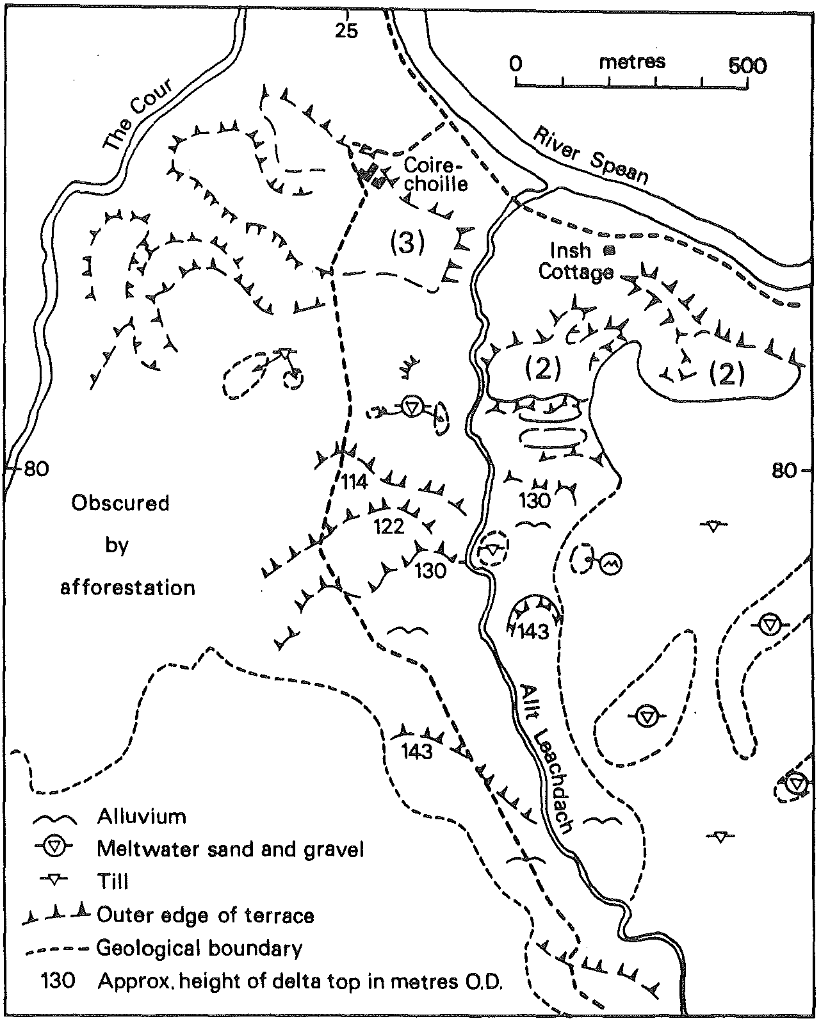

Figure 31 Allt Leachdach, landforms and deposits.

From the top of the terrace there is a fine view of the terraces on the opposite side of Glen Spean, the horizontal bench of the 113 m terrace (No. 1) being clearly visible.

Spean Bridge to Brackletter

West of Spean bridge at the Unachan Crossroads [NN 208 812] an area of kames marks the site of dead glacier ice that blocked the through valley to the west at the time of the 113 m lake (Sissons 1979b). The valley was a former course of the River Spean at some time prior to the diversion of the river northwards to cut the Spean gorge, an event that has been associated with the catastrophic draining of the 260 m lake (Sissons 1979a). Just north of the crossroads, on the Spean Bridge to Brackletter road, recent excavations for a caravan site showed the following section in a terrace bluff:

	m
5. Gravel	0.6
4. Silt and fine-grained sand, yellow brown, weakly laminated	7.0
3. Gravel and diamicton, silt and sand matrix, soft	2.0
2. Sand, fine-grained, yellow, scattered gravel and cobbles	1.0
1. Diamicton, dark grey, soft, matrix of fine-grained sand	1.0+

A short distance NW, Torr Beithe [NN 205 814] the remnant of a kame is preserved within the terrace sequence. A roadside exposure shows sandy diamicton overlain by a drape up to 2 m thick of laminated fine- to coarse-grained sand. The drape dips at angles up to 15°, probably induced by the melting of buried ice.

Brackletter

Drift ridges/end moraines extend from the north slope of the Spean valley west of Spean Bridge southwards towards the Cour/Lundy col (Figs. 23 and 32). Most of these have been referred to as terminal moraines by Sissons (1979a), who considered that they were formed during the period of constantly fluctuating lake level when the lake drained by jökulhlaup via a gorge across this col. [The north wall of this gorge, which was formerly entirely concealed by moundy sand and gravel has now been revealed by quarrying operations - serendipity!]. However, complex, ring like forms occur locally, which suggest that some of the features may have originated in other than an ice frontal position.

The drift ridges are well seen on both sides of the Spean valley east of Brackletter (Fig. 32). Here some are in part asymmetrical suggesting formation at the ice front, possibly as cross-valley moraines. Just west of the road [NN 193 821] a few morainic landforms a metre or two high and a few metres long may be the remains of annual moraines.

Most, if not all the evidence adduced by Sissons (1979a) for catastrophic draining is circumstantial, but positive evidence for rapid downcutting and therefore possible jökulhlaup can be seen in the lower course of the Allt Mhill Dhuibh. This small stream flows on bedrock in a shallow valley for some 400 m NE of the road and then plunges over a

20 m high waterfall into a rock-cut gorge (Locality B on Fig. 32). The waterfall is about 30 m north of the gorge head and the gorge downstream of the fall is incised between 33 and 48 m through the deposits of an alluvial terrace into the underlying rock (Peacock 1970b). Some 40 m below the waterfall laminated silt is exposed at the bottom of the gully adjacent to the stream and the remains of 3 giant potholes, the largest some 16 m high, are preserved on the vertical right bank of the gorge. The laminated silt is clearly the remains of the infill deposited in the lake during the downstream progression of the Spean terraces and shows that cutting of the gorge predated this event. As suggested by Sissons the incised course of the Spean, into which the gorge opens, is a feature contemporaneous with the formation of the potholes, and therefore in part excavated subglacially.

The glaciofluvial delta at Brackletter (Fig. 32) is currently being worked for sand and gravel with the inactive, older workings being used for waste disposal. The topset beds are not well exposed, but several faces show classic Gilbert-type foreset and bottomset beds indicating deposition by eastward flowing currents. This delta is important as it was deposited in the lake at 113 m for which evidence exists higher up the Spean valley (Terrace 1 of Sissons 1979b). The lake at this level drained at least partly subglacially be way of the spillway on the north side of the Spean valley shown on Fig. 32 (Peacock 1970b).

SW of the road where there is a small, unworked part of the delta the outwash cuts through one of the drift ridges or end moraines referred to above. The ridge, only small sections of which are preserved, is formed chiefly of gravel and sand and as such was classed by Sissons (1979a) as a crevasse filling rather than an end moraine. This conclusion is insecurely based as first, the landform is similar to those thought to be end moraines and second, end moraines are not necessarily formed of till.

Postscript

From the foregoing it seems likely that Sisson's view of the early Holocene history of the Spean valley needs to be modified, but it has so far not proved possible to put a coherent story in its place. There is little positive evidence for the 'period of fluctuating lake level' that followed the catastrophic drainage of the 260 m lake and the presence of deltas at levels between 260 m and 113 m OD needs to be taken into account in future research. The relationship between the horizontal 113 m terrace and the gently sloping 'lower' deltas needs to be reassessed as fine-grained sediments associated with the latter apparently extend above 113 m OD. Further topics for investigation are why silt and fine-grained sand rather than coarse sand and gravel predominate in the fill of the Spean valley and why Gilbert-type deltas occur at some localities but not at others.

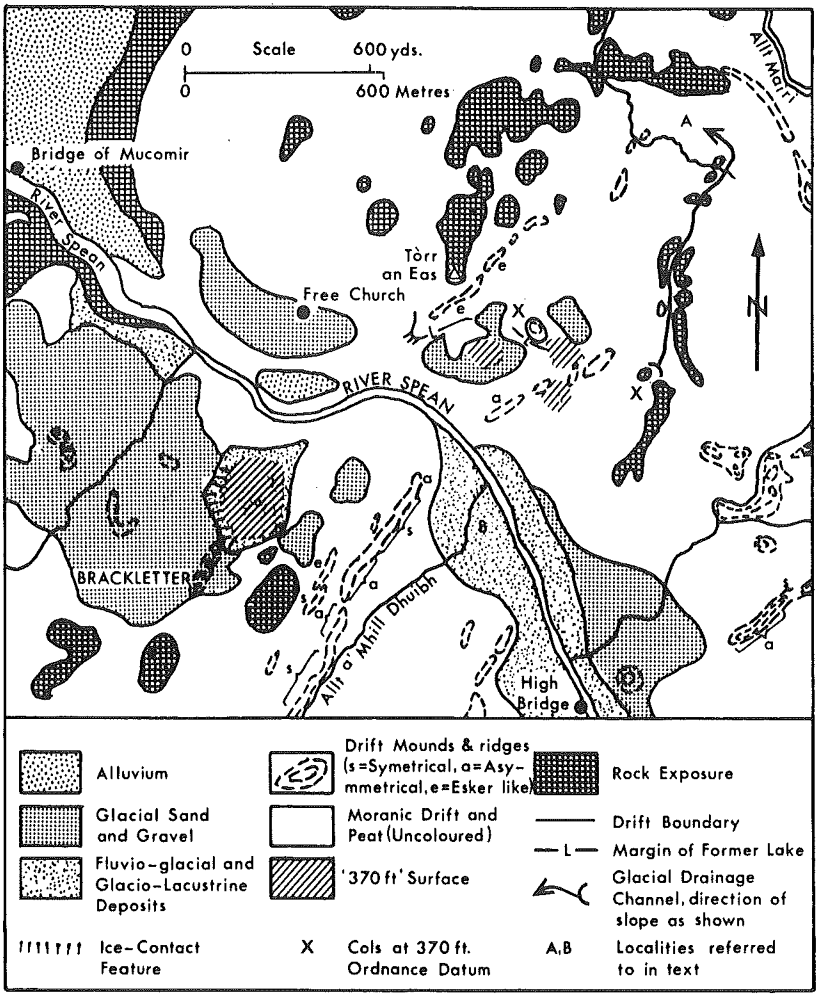

Figure 32 Landforms and deposits in the Brackletter area (from Peacock 1970b).

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