Glen Roy and The Parallel Roads of Lochaber

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Highlights

The area of Glen Roy and adjacent parts of Glen Spean and Glen Gloy is one of outstanding international importance for geomorphology. It is best known for the Parallel Roads, a series of ice-dammed lake shorelines which developed during the Loch Lomond Stadial. These form part of a much wider assemblage of glacial, glaciofluvial and glaciolacustrine features which provide unique evidence for the dramatic impact of geomorphological processes on the landscape during the stadial.

Introduction

The interest of this site extends across an area c. 146 km^2 east of Fort William, in Lochaber, covering parts of Glen Roy, Glen Gloy and Glen Spean. Glen Roy is a long-recognized site of international importance for its former ice-dammed lake shorelines, the 'Parallel Roads', which are the most extensive and best developed examples in Britain. The Parallel Roads, first documented by Thomas Pennant in 1771, have been the subject of some 70 scientific papers, and the site is widely regarded as being a classic example of former lake shorelines in standard texts on geomorphology and physical geology. Much of the original research on the Parallel Roads, which also occur in Glen Gloy and Glen Spean, was carried out during the 19th century when the landforms of this area were found to provide significant evidence for the former existence of glaciers in Scotland (Agassiz, 1842). The Parallel Roads were first recognized as the shorelines of ice-dammed lakes by Agassiz (1841b, 1842), an interpretation later confirmed in the definitive work of Jamieson (1863, 1892). More recently, in a series of papers Sissons (1977e, 1978, 1979a, 1979b, 1979c, 1981c, 1981d) has elucidated the formation of the Parallel Roads through detailed field observations and mapping and by setting them into the wider geomorphological context of contemporaneous events in Glen Spean and the Great Glen; additional evidence and details have been considered by Sissons and Cornish (1982a, 1982b, 1983), Peacock (1986, 1989a) and Peacock and Cornish (1989).

Of outstanding interest in their own right, the Parallel Roads also form part of a remarkable system of glacial, glaciofluvial and glaciolacustrine landforms extending from Loch Laggan west to near Fort William and north to the Great Glen (Figure 10.8). The total system and many of its individual elements are of considerable geomorphological interest both intrinsically and in their relationships to the Parallel Roads and the sequence of later events in Glen Roy. The scientific interest of the area therefore extends well beyond Glen Roy, and the site boundary is drawn to include not only the Parallel Roads of Glen Roy but also the wider landform system of which they are part.

Description

The landform assemblage and key localities

The geomorphology of the Glen Roy–Glen Spean area, including the form and location of the Parallel Roads, have been described extensively in the literature; the principal references are by MacCulloch (1817), Dick (1823), Darwin (1839), Maclaren (1839), Agassiz (1841b, 1842), Milne Home (1847b, 1849, 1876, 1879), Chambers (1848), Mackenzie (1848), Thomson (1848), Bryce (1855), Jamieson (1862, 1863, 1892), Rogers (1862), Mackie (1863), Watson (1866), Babbage (1868), Lubbock (1868), Nicol (1869, 1872), James (1874), Jolly (1873, 1880a, 1880b, 1886a, 1886b), Brown (1875), Campbell (1877), Dakyns (1879), Tyndall (1879), Livingston (1880, 1906), Prestwich (1880), Macfadzean (1883), Melvin (1887), Kinahan (1887), Wilson (1900), MacDonald (1903), Peacock (1970b) and Sissons (1978). The Parallel Roads are almost entirely former lake shorelines, although locally they occur as glaciofluvial terraces. Three main roads occur in Glen Roy at average altitudes of 350 m, 325 m and 260 m OD; one in Glen Gloy at 355 m and one in Glen Spean at 260 m OD (Figure 10.8). Typically they are cut in bedrock (Figure 10.9) and comprise an erosional floor and backslope and a

depositional foreslope. Horizontal widths range from 1.6 to 63.6 m, and the backing cliff reaches a maximum height of 6 m (Sissons, 1978). To explain the formation of the features, Sissons (1978) invoked a combination of wave action and powerful frost disruption of the bedrock along each shoreline (see Matthews *et al,* 1986; Dawson *et al.,* 1987b and Shakesby and Matthews, 1987 for discussion of possible modern analogues). Detailed levelling by Sissons and Cornish (1982a, 1982b) has shown that the shorelines are not uniformly tilted or warped, and that differential movements have occurred between blocks of the Earth's crust.

As noted above, the Quaternary landforms and deposits of the Glen Roy area are not only many and varied, but are also represented at a large number of key localities. Only the main features are summarized below, while additional details and sites are reported in Peacock (1989a).

Glen Roy

1. The important features in the uppermost part of Glen Roy are the Roy–Spey col [NN 410 943] at 350 m, which controlled the level of the highest lake in the glen, and a suite of glaciofluvial landforms extending from the Allt Chonnal across the lower valley slopes on the north side of the River Roy to the col. These deposits are crossed by the highest Parallel Road and although their origin and relations have not been determined, they probably relate to the decay of the main Late Devensian ice-sheet. Palynological evidence from a bog on the col overflow channel shows that sediment began to accumulate there during the early Holocene (MacPherson, 1978; Lowe and Cairns, 1989, 1991), which supports a Loch Lomond Stadial age for the ice-dammed lakes.

2. Several sites demonstrate key aspects of the lake shorelines. The section of Parallel Road on the south side of Glen Roy north of the Burn of Agie [NN 369 920] is one of the clearest examples of a shoreline cut in bedrock. It is associated with a prominent delta formed by the penecontemporaneous Burn of Agie. For a distance of about 300 m north of the burn the middle road is a rock-cut platform up to 12 m wide with a backing cliff up to 5 m high. Shorelines cut in bedrock are also well demonstrated at Braigh Bac [NN 306 882] and Creagan na Gaoithe [NN 370 925]. In a gully on the east side of Glen Roy at [NN 307 877] there is a good exposure showing the middle road cut in bedrock, and in a similar situation at [NN 304 868] the top road is clearly cut across the structural grain of highly fractured bedrock. The susceptibility of the bedrock to weathering, demonstrated at the latter locality and elsewhere, is an important consideration in explaining the processes of formation of the Parallel Roads (Peacock and Cornish, 1989). Well-developed aggradational shorelines are represented in grid squares [NN 35 92] and [NN 36 92]. Locally, additional Parallel Roads are present, for example at 334 m and possibly 344 m at Braigh Bac.

3. At the junction of Glen Roy and Glen Turret there is an important and controversial set of deposits comprising a fan with, at its northern end, an irregular, hummocky surface aligned with a series of subparallel mounds and terraces climbing obliquely up-valley on the east side of Glen Turret (Figure 10.10). Details of several important sections are described by Peacock (1986) and Peacock and Cornish (1989). Sections exposed in the south-east bluff of the fan (for example at [NN 346 924]) show it to comprise coarse, poorly bedded gravels, and fine-grained lake sediments can be seen in scrapings on its surface. In a section in the fan (at [NN 338 919]) Peacock and Cornish (1989) reported the following sequence (see also Peacock, 1986):

(3) Well-bedded gravel, clast-supported, bouldery and cobbly (particularly towards the top), with a poorly-sorted, sandy matrix. Bedding subhorizontal, parallel to the fan surface, with beds less than 0.3 m thick. Local sand beds a few centimetres thick. Local imbrication.	21 m
(2) Interbedded, hard, pebbly, laminated silt, and gravel.	5.0 m
(1) Gravelly till.	1.5 m

Sections in the mounds at the back of the terrace (for example, at [NN 339 928]) reveal a variety of materials ranging from silts and clays to coarse, angular debris. The sedimentology of these fan deposits and their interpretation is critical in understanding the sequence of events (Sissons and Cornish, 1983; Peacock, 1986; Peacock and Cornish, 1989). Sissons (1977e) interpreted the fan as a delta, and later as a subaerial fan (quoted in Gray, 1978b). However, the

association of the deposits, the terrace, the mounds on its surface and the lateral ridges up-valley closely resembles that of a former ice margin, and the north-west flank of the terrace closely resembles an ice-contact slope. Thus Rose (quoted in Gray, 1978b) interpreted the terrace feature as an outwash fan formed at an ice limit at some time during ice-sheet decay. Peacock (1986) concurred with this interpretation. Sissons and Cornish (1983), however, favoured outwash deposition into the 260 m lake of the rising sequence, at a time when the Gloy glacier extended across the col between Glen Gloy and Glen Roy. They suggested that the rise in lake level in Glen Roy resulted in ablation of the Gloy glacier and its retreat into Glen Gloy, which thus allowed the higher shorelines to form in Glen Turret. The absence of Lateglacial pollen from a sequence of organic deposits in a section and borehole at Turret Bank [NN 337 925] suggested to Lowe and Cairns (1989, 1991) that Glen Turret was occupied by a Loch Lomond Readvance glacier. Although the pollen evidence on its own is inconclusive, Lowe and Cairns (1991) considered that this interpretation best fitted the wider pattern of landforms. However, Peacock (in Peacock and Cornish, 1989) considered that the commencement of organic sedimentation simply related to the drainage of the 260 m lake and not to the end of any glacial event. Further work on the Turret fan to resolve these outstanding issues is awaited (cf. Lowe and Cairns, 1991).

4. In the lower part of the valley of the Allt a'Chotnlain near its junction with Glen Turret [NN 330 929] is a series of gravel mounds and deposits, with kettle holes, which have been terraced and dissected by the river. These were formed during the deglaciation of the area, although the precise details are unclear (Peacock and Cornish, 1989). Also in this area is a terrace which appears to be a delta of the 325 m lake (Peacock and Cornish, 1989).

5. Several superb examples of alluvial fans occur in Glen Roy (Sissons and Cornish, 1983; Peacock, 1986; Evans and Hansom, 1991, figures 1 and 2). On the east side (at [NN 330 907] and [NN 318 896]) two large dissected fans extend across the valley floor from Coire na Reinich and Coire Dubh (the Reinich and Brunachan fans, respectively). Others are associated with the Burn of Agie, Canal Burn, the East Allt Dearg and the West Allt Dearg. Peacock (1986) described several sections in the fans, which principally comprise coarse gravels and sands, in places both overlain and underlain by laminated sediments. According to Sissons and Cornish (1983) these fans were deposited into the lowest lake of the rising sequence, but Peacock (1986) interpreted them as being older, subaerial features.

6. Thick drift deposits are present at the head of Glen Turret. In a gully section [NN 329 944] there are up to 27 m of laminated silts, sands and gravels containing many angular clasts, which are overlain by up to *3 m* of till. Sissons (1978) believed the source of the angular material to have been frost-riven debris transported from the lake shores by ice floes. Peacock (1986), however, considered the material to be waterlain till. East of the section a prominent fan appears to be graded to the level of the 325 m Parallel Road and may therefore be, in part, a delta (Peacock and Cornish, 1989).

7. In upper Glen Roy a particularly fine suite of river terraces, formed by the River Roy after drainage of the lowest lake, occurs on the south side of the River Roy between about [NN 368 920] and [NN 345 920] (Figure 10.10). Terraces also continue along the floor of the glen south-west from Braeroy Lodge.

8. Landslides are well represented (Sissons and Cornish, 1982a, 1982b; Holmes, 1984; Peacock and Cornish, 1989): a fine example occurs on the east side of Glen Roy (at [NN 342 915]) and crosses the upper two roads (Figure 10.10). Another, which cuts across both the middle and lower roads, occurs 0.5 km down the valley from the viewpoint (at [NN 295 849]). On the west side of Glen Roy, opposite Brunachan, Sissons and Cornish (1982a, 1982b) described a large landslide which they related to earthquake activity along a fault line activated by glacio-isostatic uplift. Ringrose (1987) (see also Davenport *et al.,* 1989; Peacock and Cornish, 1989), however, has suggested that the fault could have been activated by lateral movement along an adjacent fault line; it may therefore be only indirectly associated with glacio-isostatic uplift, if at all.

9. A series of interesting landforms and deposits are represented in the Allt Bhreac Achaidh area [NN 298 875] (Peacock and Cornish, 1989). These include ridges of laminated silt and gravel with liquefaction and other deformation structures (Ringrose, 1987, 1989c), river terraces underlain by laminated silt, and glacial and paraglacial landforms and deposits.

10. The viewpoint [NN 297 853] affords the classic view of the Parallel Roads, which are strikingly displayed on both the west and east hillsides of Glen Roy. On the hillside north of the viewpoint, the limit of the Loch Lomond Readvance ice in the glen occurs at, or a little beyond, the northern end of a massive, dissected drift plug up to 80 m thick (approximately

[NN 298 864]–[NN 300 850]) (Sissons, 1979b). The former ice margin is probably marked by a clear drift limit, while on the east side of the glen there is a landslide and drift ridge at the ice limit. Older moraine ridges occur beyond the readvance limit. Roadside sections near the top of the infill reveal glaciofluvial sands and gravels, and lacustrine silts and sands with drop stones and slump structures [NN 296 858]. Various gully exposures (see Peacock and Cornish, 1989) reveal further sands and gravels, and till near the base. These deposits form a glaciolacustrine delta with foreset and bottomset beds. A sequence of river terraces extends from the southern end of the drift plug to Roy Bridge and merges with the Glen Spean terraces. The former relate to the dissection of the drift plug by the waters of a remnant lake impounded by the plug following the drainage of the 260 m lake (Sissons, 1979a).

11. The Caol Lairig is an important site where a variety of glacial, glaciofluvial and glaciolacus-trine landforms are easily accessible. The Loch Lomond Readvance ice limit is marked by an arcuate moraine ridge 5 m high across the col [NN 288 864] and its lateral extension can be traced along the hillslope to the west [NN 276 861] as the upper limit of small meltwater channels (Sissons, 1979b). Four shorelines, in part lacustrine deltas, are present on the valley sides; the additional one at 297 m is related to the altitude of the Caol Lairig–Glen Roy col, and the lake overflow can be seen as a channel cut through the end moraine. Inside the latter, deltas and fans occur on the valley floor. Several sections occur in glaciolacustrine sediments (Peacock and Cornish, 1989), which include sedimentary structures that may relate to earthquake deformation (Ringrose, 1987, 1989c).

12. North of Bohuntine and Bohenie end moraine ridges on both sides of Glen Roy (at [NN 291 839] and [NN 297 836]) mark the ice limit when the 325 m lake was formed.

13. Good sections in lake sediments are frequently exposed in cuttings along the public road in Glen Roy, and they provide a valuable source of sedimentary information. For example, Miller (1987) has identified two types of rhythmic deposit on the basis of their sediment characteristics and stratigraphic position. 'Group I laminates' (fine sands and silts) tend to cap major sediment bodies. They are typical of proximal glaciolacustrine deposits and they were probably deposited in the 350 m lake during the Loch Lomond Stadial. 'Group II laminates' (silts and clays) typically underlie major sediment bodies. They have characteristics of distal glaciolacustrine sediments, probably deposited during an early stage of the rising lake sequence.

Glen Gloy

1. Several mounds (at [NN 280 910]) near Alltnaray are believed to mark the limit of the Loch Lomond Readvance ice in Glen Gloy (Peacock, 1970b; Sissons, 1979b), although this was not accepted by Sissons and Cornish (1983) (see also discussion of the Turret fan above). Inside this limit thick drift deposits are exposed along the forest road on the west side of the glen. They are attributed to debris flows and delta formation (Peacock and Cornish, 1989).

2. A second important site in Glen Gloy is the col at the head of the glen through which the waters of the 355 m lake spilled over into Glen Turret and Glen Roy. A small glaciofluvial terrace is present. Lowe and Cairns (1989, 1991) recorded 7.0 m of peat and lake sediments and showed that organic sedimentation began during the early Holocene.

3. At the Allt Neurlain [NN 303 926] several features are of interest, including fault-controlled streams, possible recent movement along a fault (Ringrose, 1987), a delta at the 355 m road and sandy hummocks that possibly comprise a subglacial fan.

4. Glenfintaig [NN 265 885] is important for an assemblage of landforms, comprising a sequence of up to eight shorelines (the clearest at 295 m, 355 m, 416 m and 426 m), a landslide, a drift limit possibly marking the maximum extent of the Loch Lomond Readvance glacier, and lake sediments and river terraces (Peacock and Cornish, 1989).

5. In addition to Glenfintaig, the main Parallel Road in Glen Gloy at 355 m is also well-developed at Allt Grianach (also 295 m road and delta) [NN 270 905], Auchivarie [NN 287 928] (partly cut in bedrock) and Allt Fearna (partly cut in bedrock) [NN 305 935].

Glen Spean

1. The Roughburn area (Figure 10.11) is important for an assemblage of glacial and glaciolacustrine deposits. To the north of the A86 in the valley of the Feith Shiol a double end moraine marks the limit of the confluent Spean–Treig glacier, which impounded the 260 m lake in Glen Spean at the Loch Lomond Readvance maximum (Sissons, 1979b). The overflow from the 325 m lake in Glen Roy through the col at the head of Glen Glas Dhoire followed the valley of the Feith Shiol and breached the moraine ridges before entering the 260 m lake. At Roughburn a delta [NN 377 813], comprising up to 10 m of coarse gravel in steeply dipping foreset beds on top of silty sands, records the torrential overspill into the lake (Jamieson, 1863; Peacock and Cornish, 1989). Eastwards along the north shore of Loch Laggan, fine-grained sediments of the distal part of the delta (bottomset or low-angle foreset beds) are well exposed (Peacock and Cornish, 1989).

2. The Inverlair–Fersit area north of Loch Treig (Figure 10.11) is important in several respects. It demonstrates an excellent example of a partly kettled delta formed in the 260 m lake as the Treig glacier receded back into the valley now occupied by Loch Treig (Peacock and Cornish, 1989). The delta extends from around Inverlair to south of the Treig dam and comprises an extensive area of sand and gravel, with remnants of the original delta surface preserved, particularly around Fersit. A series of kame terraces lead from the delta southwards between Fersit and Loch Treig, notably on the east side of the valley. Foreset beds in the delta are exposed in the former gravel quarry at Fersit and in sections on the west side of Loch Treig. Following drainage of the lake, a series of outwash and river terraces formed in front of the receding glacier. These are represented on the east bank of the Treig (Peacock and Cornish, 1989), and younger terraces are particularly well seen to the south of Tulloch Station, where they continue down Glen Spean (Sissons, 1979a). Areas of water-worn bedrock and p-forms occur on the west shores of Loch Treig. The Fersit area also demonstrates relationships between the lowest Parallel Road and glaciofluvial landforms: south of about [NN 345 789], the 260 m shoreline merges with, and becomes a kame terrace. Spectacular kettle holes, up to 25 m deep, are present in deltaic deposits at Inverlair. Palynological investigations of several of these in the Inverlair–Fersit area have revealed that organic sedimentation began during the early Holocene (McPherson, 1978; Lowe and Cairns, 1989, 1991). Finally, the Inverlair–Fersit area is also of significant historical interest. The glacial features there greatly impressed Agassiz during his tour in 1840 (Agassiz, 1842), when he first recognized the former existence of glaciers in Scotland.

3. The valley of the Allt Leachdach provides important evidence for lake levels above 113 m (Peacock and Cornish, 1989). Near Loch a'Bhuic [NN 264 788], which is dammed by an esker, a kame terrace grades into the 260 m shoreline and a 'collapsed' fan/delta is also associated with it. Lower down the valley, deltas and fans are associated with successively lower lake levels at about 143 m, 130 m, 122 m and 114 m. The last level corresponds to the 113 m lake discussed by Sissons (1979a). These levels provide significant evidence for interpreting the sequence of lakes that followed drainage of the 260 m lake. However, it is unclear whether they relate to the period of variable lake level following drainage of the 260 m lake (see Sissons, 1979a) or indicate an intermittent drop in lake level (Peacock and Cornish, 1989). Later terraces and HjulstrOm-type deltas in the Spean valley are also well demonstrated in this area, for example near Coirechoille [NN 250 807].

4. Deltas, fans and high-level terraces elsewhere in Glen Spean provide important evidence for interpreting the sequence of events at the time of, and following, the 260 m lake:

i. Kame terrace/delta at Achnacochine [NN 310 807] associated with the 260 m Parallel Road and with retreat of the Spean glacier.

ii. The 175 m delta of the River Spean at Tulloch [NN 330 807].

iii. Glaciolacustrine delta at Innis nan Seangan [NN 317 794] above the level of the 260 m Parallel Road and with a good section showing internal composition.

iv. Large outwash trains in the valley of the Allt nam Bruach [NN 314 807], associated with the 260 m lake. Following the drainage of the lake, the outwash was dissected by the Allt nam Bruach and the material redeposited at the mouth of the valley as steeply sloping terraces which merge with those of Glen Spean (Sissons, 1979a). Near [NN 309 802] the lowest Parallel Road merges with a glaciofluvial terrace.

v. High Spean terrace at Insch [NN 264 802], with good sections in deltaic bottomset beds.

Many of these Spean valley deposits consist of delta topset beds overlying bottomset beds, without foreset beds, in contrast to the Rough-burn and Treig deltas. They are thus probably of Hjulstrom type rather than Gilbert type (J. D. Peacock, unpublished data).

5. An important suite of river terraces recording the stages of valley infill and dissection after the drainage of the 260 m lake occurs between Roy Bridge and Spean Bridge (Sissons, 1979a). The upper terraces largely comprise sands (seen in section at [NN 217 819] and [NN 274 811]), which overlie lacustrine silts and clays (Peacock, 1970b). The lower terraces are believed to be cut in lake sediments (Sissons, 1979a). East of Roy Bridge a higher-level terrace remnant is prominent (Peacock and Cornish, 1989). At Spean Bridge a sandpit [NN 217 819] shows that the terrace in which it is excavated comprises laminated sands with ripple bedding and a small channel near the surface (Peacock and Cornish, 1989). On the south side of the Spean valley, Peacock and Cornish (1989) recorded a series of exposures in the terrace sequence between Insch and Spean Bridge.

6. In addition to Roughburn (see above) several sites are notable for landforms associated with the Loch Lomond Readvance limit:

i. On the west side of the Allt nam Bruach the upper limit of hummocky moraine on the valley side (grid square [NN 31 78]) marks the former ice limit, which is continued northwards by a series of lateral moraines (Sissons, 1979a, 1979b).

ii. Lateral moraines (grid square [NN 29 79]) below the ice limit suggest that the ice remained active during the early part of its retreat.

7. In the area of Murlaggan [NN 317 812], in Glen Spean, a gap in the river terraces and the presence of kame and kettle topography records the position of a residual mass of stagnant ice, left after the active glacier had receded westwards to the vicinity of Spean Bridge and the 260 m lake had drained (Sissons, 1979a).

8. The Inverlair [NN 341 806] and Monessie [NN 298 811] gorges on the River Spean are of interest as features of fluvial erosion and, although utilized during Lateglacial times, are possibly older in origin. At the eastern end of the Monessie gorge several large and numerous small potholes are of note.

9. The 260 m Parallel Road is extensively developed in Glen Spean. Particular areas of note are: (i) at Creag Bhuidhe [NN 304 803], where there is a well preserved stretch 10–13 m wide; and (ii) in grid square [NN 29 79] where it is cut in drift and demonstrates the original lakeward slope of the shore.

10. The cross-valley moraines that occur in the Spean and Allt Achadh na Dalach valleys west of Spean Bridge are an important assemblage of landforms ((Figure 10.12), A–E). They comprise five sets of aligned ridge fragments made largely of till, although locally of sand and gravel. Peacock (1970b) described them in some detail and concluded that they were unlikely to be ice-marginal landforms. Sissons (1979c), however, interpreted them as end-moraine ridges of the Spean glacier and related their occurrence to the transfer of drainage from the Spean to the Lundy Gorge, when the calving ice front may have become lower and more stable after drainage of the 260 m lake. The ridges are similar in their form and lacustrine association to those of Coire Dho (see above) and to cross-valley moraines described from the arctic (Andrews, 1963a, 1963b; Andrews and Smithson, 1966; Holdsworth, 1973; Barnett and Holdsworth, 1974), but their processes of formation have not been fully investigated. The westernmost three ridges ((Figure 10.12), F–H) in the valley of the Allt Achadh na Dalach comprise sand and gravel (for example in a section at Tom na Brataich [NN 179 795] and may have formed in crevasses parallel with the ice edge (Sissons, 1979c).

11. West of Spean Bridge the River Spean turns abruptly northwards to flow through a gorge, 3 km long and up to 30 m deep, into the Great Glen at Gairlochy, while the obvious continuation of the valley to the south-west is occupied by the misfit Allt Achadh na Dalach. The gorge functioned as a subglacial routeway for the catastrophic drainage of ice-dammed lakes in Glen Spean, but may have originated earlier (Sissons, 1979a). The relationships of river terraces to the gorge are discussed by Sissons (1979a, 1979c). In this area, around Brackletter and across the valley to the east, there is a

varied and important assemblage of landforms (Figure 10.12):

i. A sequence of cross-valley moraines associated with the Spean Glacier.

ii. A Gilbert-type glaciolacustrine delta related to the 113 m lake ((Figure 10.12), I). Good sections in topset, foreset and bottomset beds have been exposed in Brackletter sandpit.

iii. Giant potholes in the gorge of the Allt a'Mhill Dhuibh [NN 197 827], possibly formed subglacially by *jökulhlaup* discharge (Peacock and Cornish, 1989).

iv. Glaciofluvial landforms including eskers, kames and kettles.

12. At the northern exit of the Spean Gorge and in the area around Gairlochy two suites of terraces relate to former higher levels of Loch Lochy (Peacock, 1970b; Sissons, 1979a, 1979c).

13. The meltwater channel between [NN 203 831] and [NN 205 837] ((Figure 10.12), J) is an important landform in the sequence of events associated with the draining of the ice-dammed lakes in Glen Spean: it functioned as the overspill channel for the 113 m lake (Sissons, 1979a, 1979c).

14. The Lundy Gorge (Figure 10.12) is a large meltwater channel which functioned as an outlet for ice-dammed lakes in Glen Spean for a period after the drainage of the 260 m lake. As such it is an important element in the history of events in the area. Its role and relationships have been discussed in detail by Sissons (1979c). Recent sand and gravel extraction has exposed the rock-cut north wall of the gorge from beneath the kamiform sand and gravel deposits that extend to the north and north-east. There is a good section in these deposits at Tom na h-Iolaire.

15. An unusual, 'cirque-like' feature which leads into a meltwater channel on a hilltop south of Glenfintaig House [NN 201 857] ((Figure 10.12), K), has been interpreted by Sissons (1979c) as an abandoned waterfall site recording the final *jökulhlaup* of the ice-dammed lake in Glen Spean that had been periodically discharging through the Lundy Gorge.

Interpretation

The first published description of the Parallel Roads was by Thomas Pennant in 1771 in his work *A Tour in Scotland* 1769*.* Although bad weather prevented him from visiting what he called the 'celebrated parallel roads', he noted the local belief that they had been constructed to facilitate hunting, a view later echoed by Rev. Thomas Ross in the *Old Statistical Account.* According to Ross (1796) the roads, or the 'Casan' as they were known locally, were 'one of the most stupendous monuments of human industry' (p. 549). Local tradition held that they were built either by the Kings of Scotland when they resided in the Castle at Inverlochy, or by the Gaelic mythical hero, Fingal, and his followers. In support of the latter explanation Ross noted that the features were locally called 'Fingalian roads'.

Historically Glen Roy played an important role in the development of geomorphological theories of landscape evolution. In addition, the search for a theory of formation of the Parallel Roads provides an instructive case study in the history and philosophy of science and the development of scientific ideas (Rudwick, 1974). In the 19th century various theories were proposed in the scientific literature to account for the origin of the Parallel Roads (Rudwick, 1974). These included aqueducts for irrigation (Playfair, cited by Jolly, 1880b), diluvial shorelines (Mackenzie, 1848; Rogers, 1862), lake shorelines (Greenough, 1805, cited by Rudwick, 1962; MacCulloch, 1817), marine shorelines (Darwin, 1839; Maclaren, 1839; Lyell, 1841b; Chambers, 1848; Watson, 1866; Nicol, 1869, 1872; Campbell, 1877; Macfadzean, 1883) and shorelines of debris-dammed (Dick, 1823; Milne Home, 1847b, 1849, 1876, 1879) or ice-dammed lakes (Agassiz, 1841b, 1842; Buckland, 1841b; Thomson, 1848; Jamieson, 1863, 1892; Lyell, 1863; Mackie, 1863; Geikie, 1865; Jolly, 1873, 1880a, 1880b, 1886a, 1886b; James, 1874; Brown, 1875; J. Geikie, 1877; Tyndall, 1879; Livingston, 1880; Prestwich, 1880). Several authors considered the shorelines to have formed by mass movements of slope debris (Jamieson, 1863; Lyell, 1863; MacCulloch, 1817; Babbage, 1868; Prestwich, 1880). Lubbock (1868) advocated redistribution of sediments by wave processes, while Melvin (1887) and Livingston (1906) believed that the roads were glacier-margin deposits. Dakyns (1879) made an important observation that the roads were locally cut in bedrock.

The marine school initially found strong proponents in both Charles Darwin and Charles Lyell. The former, in particular, was deeply impressed by Glen Roy. On 9 August 1838 he wrote to Lyell, 'I wandered over the mountains in all directions and examined that most extraordinary district. I think without any exception, not even the first volcanic island, the first elevated beach, or the passage of the Cordillera, was so interesting to me as this week. It is far the most remarkable area I ever examined.... I can assure you Glen Roy has astonished me' (Darwin, 1887, p. 293). At that time Darwin favoured a marine origin for the Parallel Roads. It was only 23 years later, in 1861, that he recanted in print this belief and accepted the fact that the roads represented the shores of a glacial lake (Barrett, 1973; Rudwick, 1974). However, it was Agassiz (1841b, 1842), a pre-eminent figure in the application of the glacial theory in Britain, who first identified the imprint of glacier ice and propounded the existence of former ice-dammed lakes in Glen Roy, following a visit there in 1840 with William Buckland. This idea was subsequently elaborated by Jamieson (1863, 1892). More recently, as outlined below, Sissons (1977e, 1978, 1979a, 1979b, 1979c, 1981c, 1981d) has refined the explanation of the Parallel Roads and established in some detail the sequence of events in their formation. His work also reveals the Parallel Roads to be part of a remarkable complex of glacial, glaciofluvial and glaciolacustrine landforms and sediments extending from Loch Laggan in the east through Glen Spean, Glen Roy and Glen Gloy, to near Fort William in the west, and north-east to the Great Glen, Loch Ness and Inverness.

Current understanding of the sequence of events in the formation of the ice-dammed lakes and their subsequent drainage was summarized by Sissons (1981d), drawing on the details of his earlier papers (Sissons, 1977e, 1979a, 1979b, 1979c). Lakes in Glen Roy, Glen Gloy and Glen Spean were impounded by ice of the Loch Lomond Readvance from west of the Great Glen, coalescing with glaciers from the Ben Nevis range and from the ground to the south via the Laire and Treig breached valleys (Figure 10.13). Wilson (1900) and Peacock (1970b) established ice-movement patterns from striations and the distribution of erratics, and Sissons (1979b) has mapped and discussed the ice limits and related landforms, which include spectacular lateral moraines, end moraines and hummocky moraine. At its maximum extent the ice reached the western end of the present Loch Laggan and penetrated up-valley into Glen Roy and Glen Gloy (Figure 10.13). As it advanced, the ice ponded back a series of ice-dammed lakes, successively at 260 m, 325 m and 350 m OD (the rising sequence). The levels of these were controlled by the altitudes of the lowest ice-free cols on their perimeters (Jamieson, 1863; Sissons, 1977e). At the maximum extent of the ice the Glen Gloy lake overflowed through the col at 355 m on the Gloy–Turret watershed into the Glen Roy lake which attained maximum dimensions of 16 km in length and 200 m in depth. The level of the Glen Roy lake was controlled by the 350 m col leading into Strathspey at the head of the glen. The waters of a contemporary lake in Glen Glas Dhoire escaped to the east through a col at 325 m into an extensive lake at 260 m controlled by the Feagour col at the eastern end of the present Loch Laggan. As the ice retreated, lakes were formed at successively lower levels (the falling sequence). First in Glen Roy, the 325 m col became available as an outlet for the Roy lake, and the latter fell to its second major level. Subsequent decay and westward retreat of the ice margin to the vicinity of Spean Bridge allowed the Roy lake to fall to the level of the 260 m lake in Glen Spean, which at its maximum extent was 35 km long. In Glen Gloy the level of the lake remained constant, as the col at the head of the glen is the lowest in the watershed.

Drainage of the 260 m lake may be inferred by analogy with modern ice-dammed lakes in many parts of the world, which drain periodically by catastrophic subglacial flow of the ponded water (for example, Liestol, 1956; Stone, 1963; Mathews, 1973; Dawson, 1983c; Clement, 1984; Shakesby, 1985; Russell, 1989); the resulting floods are commonly described by the Icelandic term '*jökulhlaup*' (glacier burst). From his detailed investigation of the field evidence, Sissons (1979c) proposed that the 260 m lake was drained by catastrophic subglacial flow through the Spean Gorge and northwards along the Great Glen to the Moray Firth. At Fort Augustus (see above) an extensive spread of sand and gravel is thought to have been deposited by the '*jökulhlaup*', as is a large gravel deposit in the Beauly Firth at Inverness (Sissons, 1981c). Very perceptively, Jamieson (1865) first raised the possibility that gravel deposits in the Inverness area might be related to the final catastrophic drainage of the Glen Roy and Glen Gloy lakes, although those he possibly had in mind are eskers and kames (see Torvean). Subsequently, there was a period of oscillating lake levels and smaller *jökulhlaup* events through the Spean Gorge and later through the Lundy Gorge. Upon the abandonment of the latter route, drainage shifted back to the north-east, first in the form of a *jökulhlaup* along a now-abandoned waterfall and channel near Glenfintaig House then via an overspill channel from a later lake in Glen Spean at 113 m. Considerable fluvial infill took place in Glen Roy and Glen Spean after the drainage of the 260 m lake, and a complex series of over twenty terraces has been identified (Sissons, 1979a), some of which relate to a variety of lower lake levels in Glen Spean and other,

later, ones to higher levels of Loch Lochy. Failure of the ice dam in Glen Spean led to final drainage through the Spean Gorge, dissection of the valley infill and terrace deposition in the Gairlochy area.

In upper Glen Roy, Sissons and Cornish (1983) mapped extensive fans of coarse gravel deposited in the lowest lake in the sequence of rising lake levels. The largest feature is associated with outwash from a glacier in Glen Turret. Sissons and Cornish (1983) suggested this glacier had flowed over the col from Glen Gloy. As the lake level rose, the glacier retreated and the gravels were mantled with lake sediments (clays and silts). However, following a re-examination of the sediments, Peacock (1986) considered that the fans were largely subaerial in origin and that they pre-dated the lakes. He suggested that the Turret outwash dated from the time of Late Devensian ice-sheet decay. Lowe and Cairns (1991) favoured Sisson's hypothesis, but the evidence is inconclusive and further investigation is required.

Detailed levelling of the Glen Roy shorelines has demonstrated differential glacio-isostatic uplift and dislocation of crustal blocks at the start of the Holocene (Sissons and Cornish, 1982a, 1982b). The dislocations, together with several associated landslips may have been triggered by stresses induced by the loading and unloading of the crust by the Loch Lomond Readvance glaciers and by the formation and catastrophic drainage of the lakes. This evidence raises the possibility that crustal dislocation at sites of ice limits and glacial lakes may be of wider significance than formerly recognized. Holmes (1984) observed a correlation in Glen Gloy, Glen Roy and Glenfintaig between the occurrence of landslips and possible Loch Lomond Readvance ice limits. Further evidence for palaeoseismicity has been recorded by Ringrose (1987, 1989a, 1989c) (see also Davenport and Ringrose, 1985, 1987; Davenport *et* al., 1989) who inferred two deformation events from the pattern of liquefaction structures preserved in the lake sediments. The first was attributed to an earthquake which occurred before drainage of the 260 m lake in Glen Roy and the 355 m lake in Glen Gloy. The second was interpreted as a response to either a second earthquake or lake drainage.

Aspects of the vegetational history of the area and the chronology of lake drainage were studied by McPherson (1978) from pollen sites in Glen Roy and Glen Spean. She concluded that the highest lake existed until the time of the juniper pollen zone (transition from the Lateglacial to the Holocene), and that the lowest had drained by the start of the birch pollen zone (early Holocene). More detailed investigations by Lowe and Cairns (1989, 1991), however, suggest that some revision of MacPherson's chronology is necessary and that organic sedimentation began earlier, at the start of the Holocene. In addition, the absence of Lateglacial pollen from deposits in Glen Turret and on the Gloy–Turret col lends some support to the interpretation that these areas were glaciated during the Loch Lomond Stadial (Sissons and Cornish, 1983).

Glen Roy is a site of outstanding importance for geomorphology. It is unique in Britain not only for the extent, clarity and degree of development of its shorelines, but also for the remarkable assemblage of related landforms and deposits. These record geomorphological processes both during and following successive episodes of ice-dammed lake development and catastrophic drainage, and include glacier moraines, stagnant-ice deposits, kame terraces, meltwater gorges, lake-floor sediments, fans, Gilbert-type and Hjulström-type deltas, river terraces and landslides. Glen Roy and adjacent areas provide the clearest and most complete assemblage of morphological and sedimentological evidence in Britain for the formation and drainage of ice-dammed lakes. Moreover, variations in the altitudes of the shorelines have provided new and significant evidence concerning deformation and dislocation of the Earth's crust in glaciated areas. The pre-eminence of Glen Roy is also recognized historically when, particularly during the 19th century, Glen Roy played a significant role in the development of geomorphological ideas and models of landscape formation.

Scientific interest in Glen Roy, Glen Gloy and Glen Spean is therefore focused not only on individual or unique landforms, but also on the total assemblage of features, how they interrelate and together provide the evidence for interpreting the complex sequence of events recorded in the geomorphology and sediments of the area. The prime features of this interest are as follows:

1. The lake shorelines (the Parallel Roads, which are the best examples in Britain); their extent, altitudes, clarity of preservation, variations in form and nature (both erosional and depositional) and relationships to former ice fronts are all of major importance.

2. Landforms associated with former ice limits, including end moraines, drift limits, hummocky moraine, outwash fans and cross-valley moraines. Individual features, such as the Turret fan and the cross-valley moraines, are exceptional examples of their kind in Britain.

3. The alluvial fans in Glen Roy, which are among the best of their type in Britain, both as landform examples and for their potential for sedimentological studies.

4. The lake deltas, particularly at Inverlair–Fersit, Roughburn and Brackletter, which are of key interest both for landforms and sedimentology, and are among the best examples of their kind in Britain; compared with Achnasheen (see above) they generally demonstrate much more extensive sediment collapse related to burial and melting of masses of glacier ice. The contrasting Gilbert-type and Hjulström-type deltas are essential elements in understanding the sedimentary processes during and following the time of the Parallel Roads lakes.

5. The river terraces in the lower Roy and middle and lower Spean valleys, which in their landforms and sediments preserve a detailed record of Holocene geomorphological change.

6. The numerous landslides, which are significant in relation to former ice-front positions, earthquake history and controls on release mechanisms.

7. The meltwater gorges, possibly related to catastrophic lake drainage.

8. The lake sediments with their potential for process studies and interpreting patterns of palaeoseismicity.

9. The periglacial slope deposits, which as yet have received little attention.

10. The organic sediments preserved in kettle holes and bogs, which have potential for elaboration of the chronology of lake drainage.

11. The total assemblage of features, which provides uniquely detailed evidence in Britain for catastrophic glacial lake drainage.

12. The archive of landforms and deposits clearly related to a particular geological datum, which provides unsurpassed potential for comparative studies of a whole range of geomorphological process magnitudes and rates during a period of extremely rapid environmental change.

Although ice-dammed lakes have been identified elsewhere in Britain (see Shotton, 1953; Straw, 1979; Gaunt, 1981), extensive shorelines are rarely preserved. They have been recognized in association with, for example, Lake Harrison (Duly, 1951 — but see Ambrose and Brewster, 1982) and Lake Humber (Edwards, 1937). However, it is in the Highlands of Scotland, in areas glaciated during the Loch Lomond Stadial, that examples of shorelines are best preserved, as in Coire Dho (Sissons, 1977b), at Loch Tulla (Ballantyne, 1979), at Achnasheen (see above) and, most remarkably of all, in Glen Roy. Beyond the limits of the last glaciers any shorelines will be considerably older and will therefore have undergone significantly greater modification, particularly through the activity of periglacial processes known to have been widespread in Britain during the Loch Lomond Stadial (Sissons, 1979e).

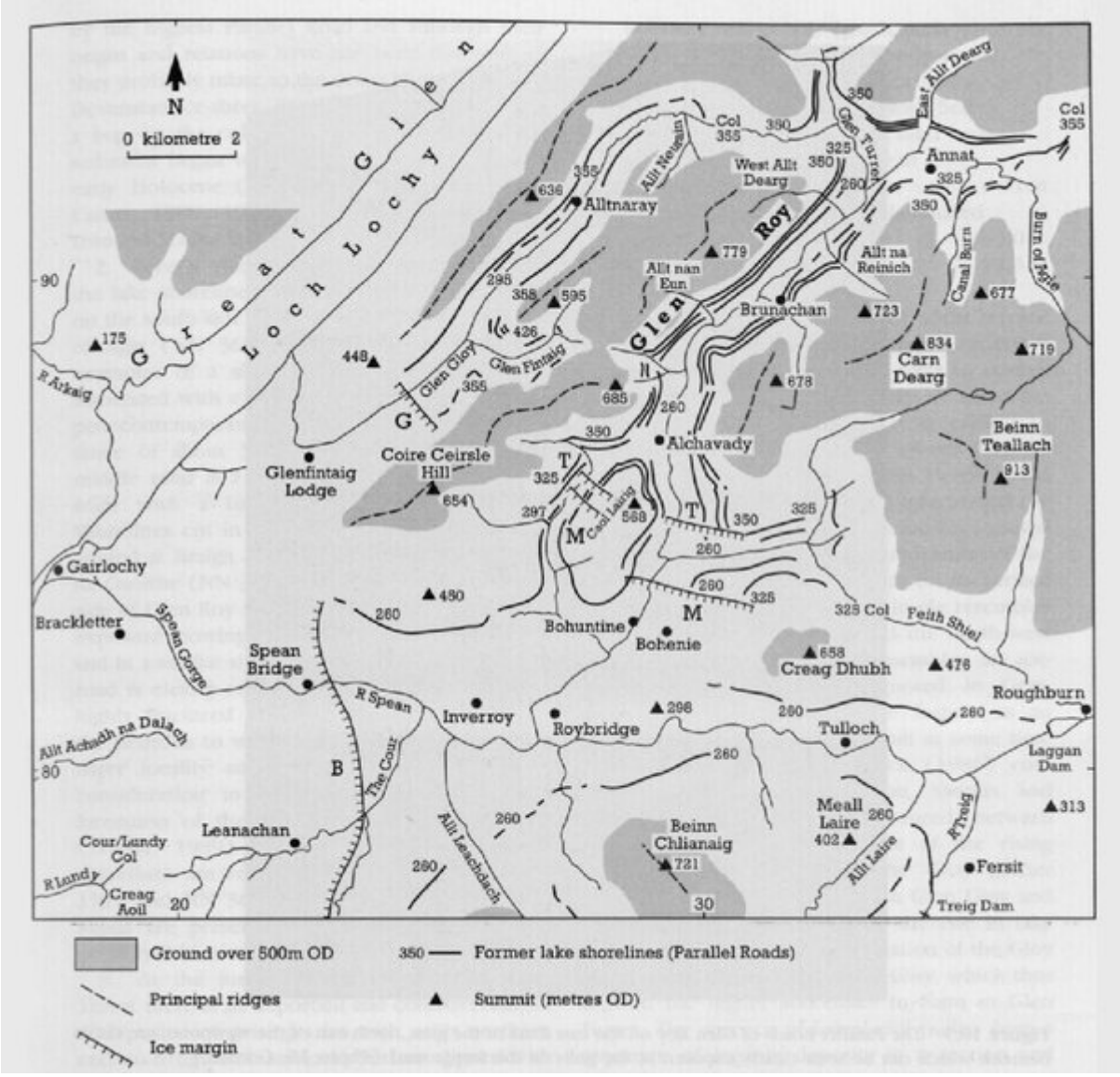
The Parallel Roads are comparable, for example, to Pleistocene lake shorelines in Scandinavia (Mannerfelt, 1945) and the Holocene shorelines in south-west Greenland recently described by Dawson (1983c); or even to some of the features associated with the Great Lakes of North America during the Wisconsin (last glaciation) (Spencer, 1890), although the latter occur on a vastly greater scale (Leverett and Taylor, 1915; Fulton, 1989). However, what distinguishes Glen Roy and the Parallel Roads as a locality of international importance for geomorphology is the total range of landforms, their clearly demonstrated relationships and the relatively compact extent of the whole assemblage.

Although the area has been studied for over two hundred years, it still has significant potential for further research, particularly on the sedimentology of the various deposits, the relationships between sediments, landforms and geomorphological processes, process rates and outstanding problems of landform genesis and chronology.

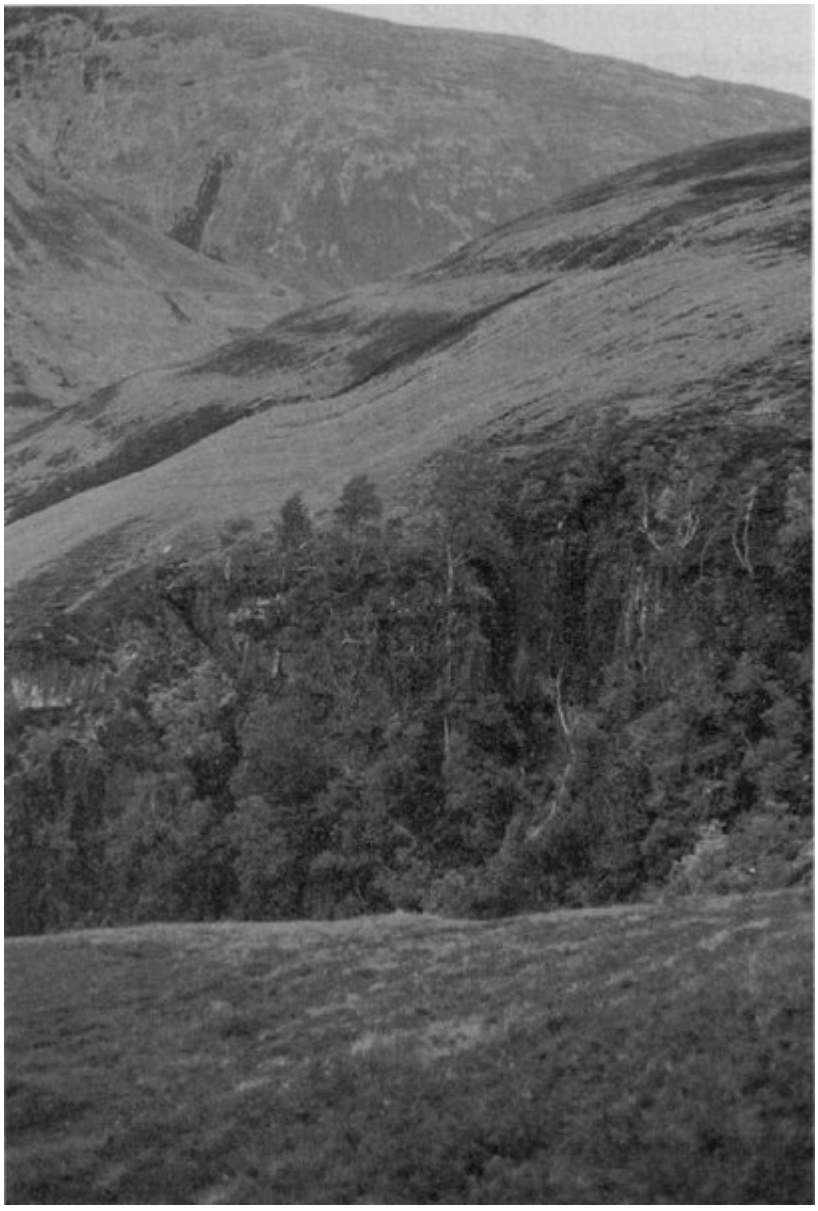
Conclusion

Glen Roy is one of the most famous landform landmarks in Britain and is internationally recognized as a classic locality for the shorelines of an ice-dammed lake, represented by the Parallel Roads, that formed during the period of glacier readvance known as the Loch Lomond Stadial (approximately 11,000–10,000 years ago). In their extent, continuity and degree of preservation, the Parallel Roads of Glen Roy and adjacent glens are unique in Britain. They are of outstanding geomorphological interest both in their own right, and as part of a remarkable system of glacial, glaciofluvial and glaciolacustrine landforms and deposits recording a complex sequence of landscape changes in Lateglacial and early Holocene times.

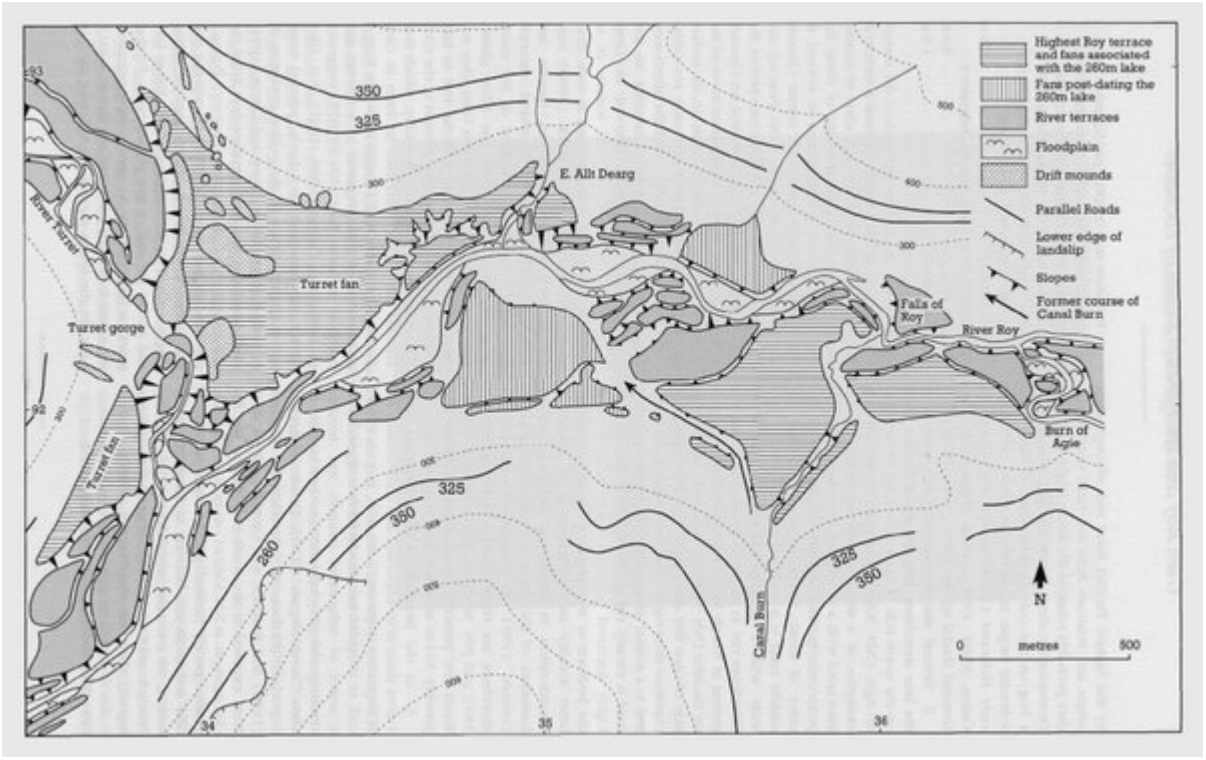
References



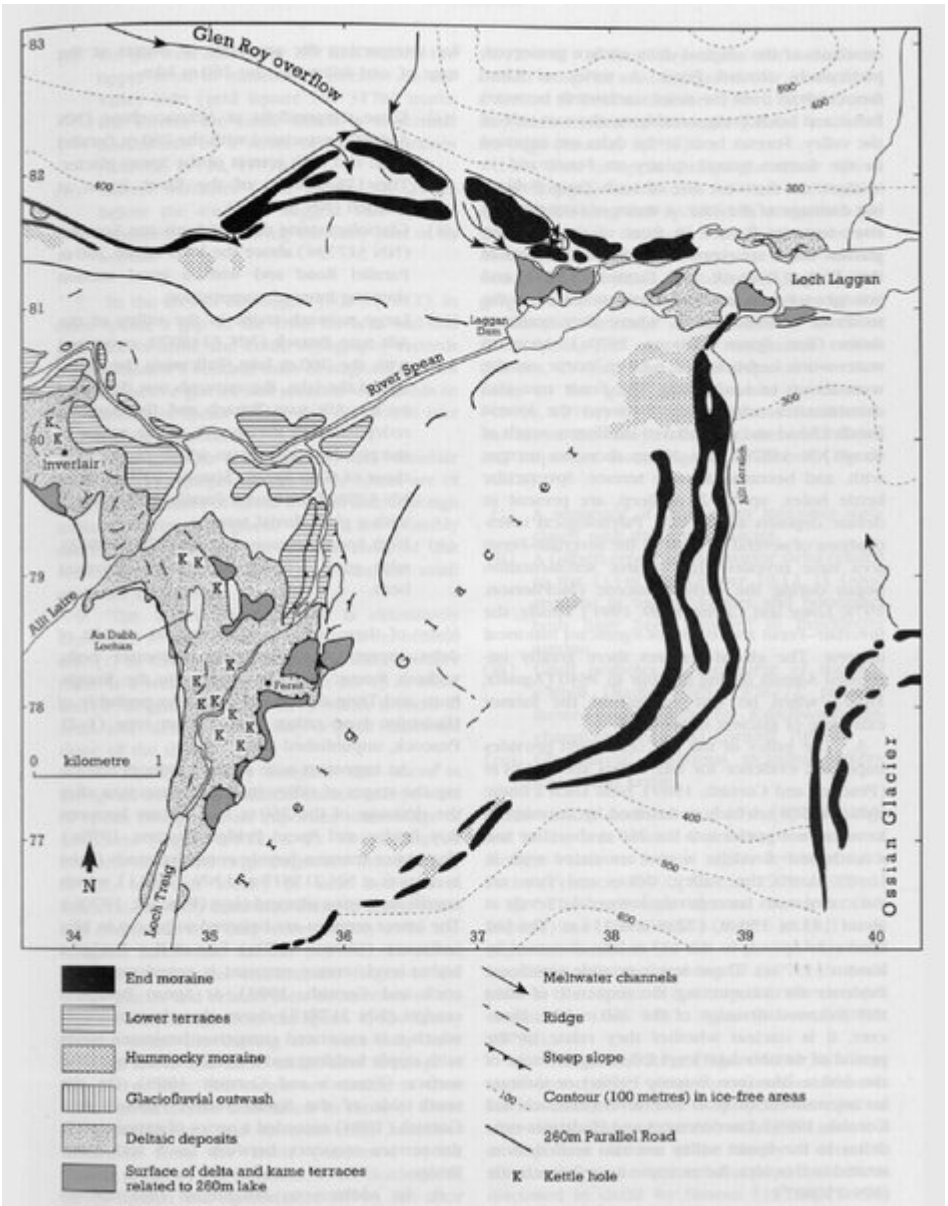
(Figure 10.8) The Parallel Roads of Lochaber. The letters T, M, B and G identify the final positions of the ice-fronts damming the 355 m, 325 m, 260 m and Glen Gloy lakes respectively (from Peacock and Cornish, 1989).



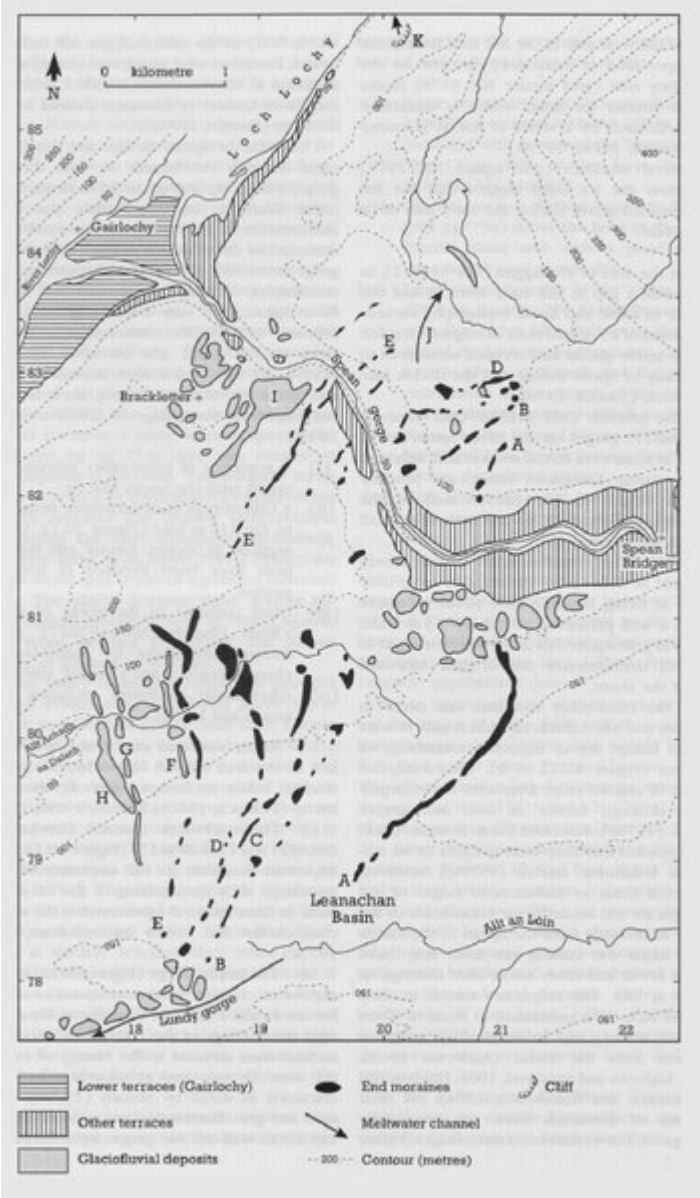
(Figure 10.9) The Parallel Roads of Glen Roy on the east flank of the glen, north-east of the viewpoint, are cut in bedrock which can be seen clearly exposed in the gully in the foreground. (Photo: J.E. Gordon.)



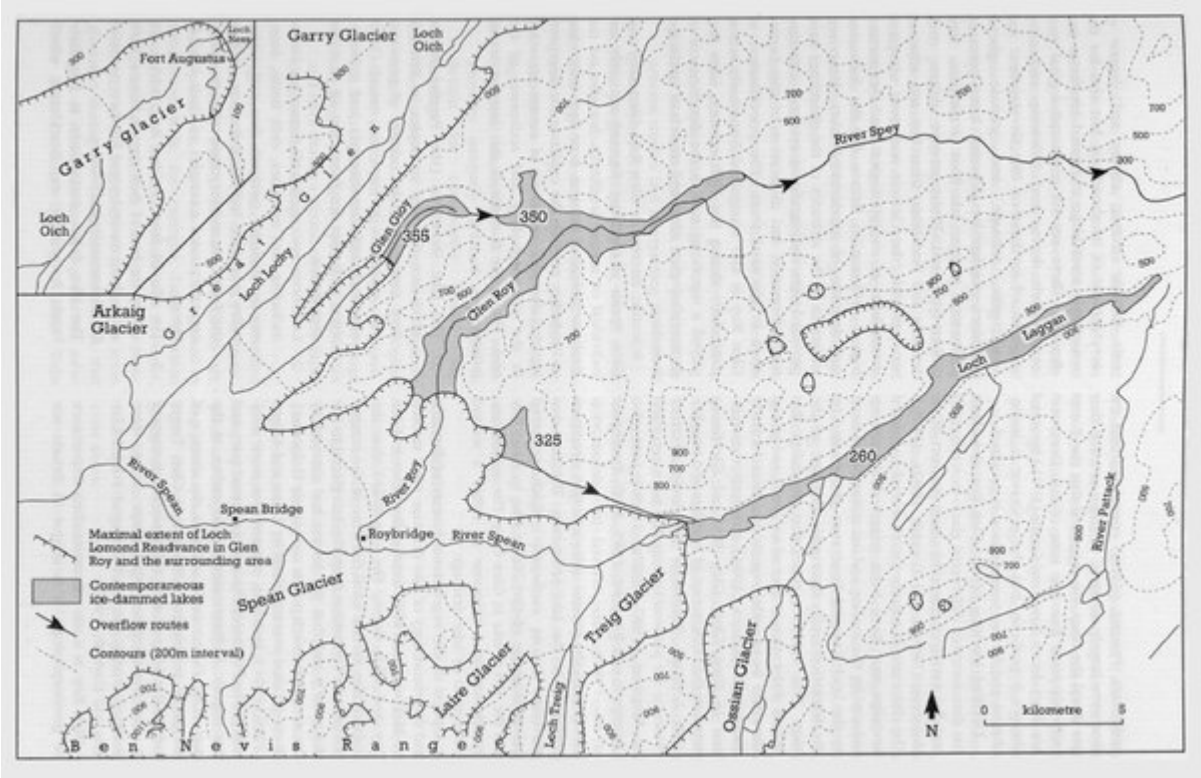
(Figure 10.10) Geomorphology of the northern part of upper Glen Roy (from Sissons and Cornish, 1983).



(Figure 10.11) Landforms and deposits of the Treig–Laggan area (from Sissons, 1977e; Peacock and Cornish, 1989).



(Figure 10.12) Geomorphology of the Spean Bridge–Gairlochy area (from Sissons, 1979c). See text for explanation of letters.



(Figure 10.13) Loch Lomond Readvance ice limits and associated ice-dammed lakes in the Glen Roy–Glen Spean area (from Sissons, 1981d).