Glen Feshie, Highland

[NN 846 914], [NN 853 974], [NH 850 023] AND [NH 845 051]

A. Werritty and L.J. McEwen

Highlights

Glen Feshie contains an assemblage of exceptional fluvial landforms and encompasses some of the most active reaches of channel presently found in Britain. The development of the valley floor from deglaciation to the present has been the subject of numerous investigations, making this the most important valley in Scotland and of international renown for the study of fluvial forms and processes.

Introduction

The River Feshie (the headwaters of which rise in the Cairngorm and Gaick plateaux) is a north-flowing tributary of the River Spey. Throughout its course, the river provides a series of outstanding examples of alluvial landforms (terraces and alluvial fans) and active, highly divided channels. As a result the river and its adjacent valley floor have been the object of intensive research since the mid-1970s, including parts of four doctoral dissertations (Imes, 1982; McEwen, 1986; Robertson-Rintoul, 1986a; Brazier, 1987). The following outline account traces the major investigations into the evolution of the valley floor from deglaciation *c.* 13 000 BP to the present.

The geomorphic impact of ice-sheet wastage in lower Glen Feshie is discussed in detail by Young (1975) and Sissons (1974a). The latter also mapped the limits of the small Loch Lomond Readvance outlet glaciers which descended from the Gaick ice cap into the upper valleys of the Feshie. Glaciofluvial landforms are abundant in the lower part of the catchment and local accumulations of outwash materials are 10 m thick. Young (1976) identified three stages of terrace development within these deposits. More recently, five terrace levels have been identified in the lower part of the valley by Robertson-Rintoul (1986b) on the basis of soil–stratigraphic relationships. During the Holocene, the river trimmed the distal margins of fans and cones in the upper part of the glen (Brazier and Ballantyne, 1989). Rates of channel change are remarkably high for the British uplands and have resulted in extensive reworking of the floodplain over the past 200 years (Werritty and Ferguson, 1980; McEwen, 1986; Werritty and Brazier, 1991a).

Description

The River Feshie is a right-bank tributary of the River Spey and drains a catchment area of 240 km^2 in the western Cairngorms (Figure 2.24). Most of the drainage basin is underlain by Moinian schist which lies at 700–1000 m, but to the north-east, on the Cairngorm granite batholith, the basin rises to 1265 m. The basin is bisected by a steep-sided glacial trough (Linton, 1949) through which the river flows westwards before turning north at about 400 m into the wider, lower valley cut into glacial tills and outwash. These glacigenic deposits are restricted to the valley floor and lower slopes, the bedrock on the plateaux (600–800 m) being mantled by blanket peat. Sparse remnants of the native Scots pine (*Pinus sylvestris*) forest are found in the lower part of the glen, but these give way to a *Calluna–Empetrum* heath, alpine grassland and almost bare frost-shattered regolith on the highest ground (Steven and Carlisle, 1959). The lower course of the river is confined locally by bedrock, and more extensively by Lateglacial and Holocene terraces, but in three reaches (upper Glen Feshie, lower Glen Feshie and the confluence) it is free to migrate laterally and is actively reworking its floodplain.

There are five main assemblages of fluvial land-forms to be found in Glen Feshie, each of which is described in turn.

Terraces and alluvial fans

The valley fill in Glen Feshie was created at the end of the Dimlington Stadial as the ice sheet in the glen downwasted *in situ* (Young, 1975). Three groups of landforms comprise the major geomorphological features within this valley fill (Figure 2.25) and are extremely well-exhibited in the reach from the Allt Fhearnagan to the Allt Garbhlach (Werritty and Brazier, 1991a):

1. kame and kettle landforms and an associated extensive palaeosandur;
2. an extensive suite of terraces;
3. tributary valley alluvial fans.

The dominant landform assemblage is the Allt Garbhlach fan and dissected palaeosandur. The latter is pitted with kettle holes between which fossil braided channel networks can be traced. Partially buried by fan deposits but projecting above the level of the fan are several kames. The fan was probably built during the later stages of Late Devensian ice-sheet deglaciation, *c.* 13 000 BP (Robertson-Rintoul, 1986b).

Within this reach, lying some metres below the level of the 13 000 BP pitted outwash, is a group of three low-level terraces. The highest of the terraces, dated by soil–stratigraphic methods at 10 000 BP, is about 5 m above present river level (Robertson-Rintoul, 1986b). The middle terrace is about 3 m above the present river and has been dated to 3600 BP, and the lowest terrace (*c.* 1.5 m above the present river) has been dated to *c.* 1000 BP. All of the more extensive terrace fragments possess well-developed braided palaeochannel networks on the terrace surfaces.

In the upper braided reach of the River Feshie (see section below) where the valley floor is almost 700 m wide, the terrace fragments become laterally very extensive (Figure 2.26). The high dissected palaeosandur is not represented in this reach: instead, the terraces comprise three low-level Late Holocene surfaces (dated by soil–stratigraphic methods at 3600, 1000 and 80 years BP; Robertson-Rintoul, 1986b). At the upstream end of this reach the tributary valley of the Allt Lorgaidh terminates in a complex alluvial fan composed of debris transported by meltwaters from the Gaick ice cap. This was an outlet tongue which descended into Glen Feshie during the Loch Lomond Stadial (Sissons, 1974a). The three age units on the eastern side of this fan correlate with the low-level Holocene terraces in the upper braided reach. Erosion by the present Allt Lorgaidh stream on the western side of the fan has exposed a buried podzol with an organic-rich layer (dated by ^{14}C at 3620 ± 50 BP, Robertson-Rintoul, 1986b). This gives an estimated age for the initiation of late Holocene sediment aggradation in the tributary valley which in turn buried the former, possibly Loch Lomond Stadial age surface on the upper terrace of the Allt Lorgaidh fan.

Glen Fesbie debris cones

Three coalescing debris cones have built out from the steep gullied walls of the glacial trough in upper Glen Feshie at a mean altitude of 390 m. These gullies are cut into the Moinian schist of Creag na Caillich, from which sediment has been readily supplied into a set of coalescing cones. Basal erosion of these cones by the River Feshie has resulted in the exposure of an extensive section over 60 m long and in places up to 10 m high (Figure 2.27). The exposure consists almost entirely of coarse debris flow deposits, with poorly sorted and dominantly angular clasts embedded in a coarse sandy matrix. These deposits extend down to the level of the river, with the exception, of the northernmost cone which has buried a low river terrace (Brazier and Ballantyne, 1989).

Radiocarbon dating of organic material (mainly woody roots) has been undertaken to establish the timing of debris cone initiation and the subsequent periodicity in debris flow activity at the site. The results indicate that aggradation of these debris cones in upper Glen Feshie was initiated by *c.* 2000 BP. The site may then have remained stable for *c.* 1700 years until, within the last 300 years, rapid and episodic debris flow aggradation formed the bulk of the deposits at present visible in a stream-cut exposure (Brazier and Ballantyne, 1989). (Figure 2.27) (a) The surveyed section across the base of the Glen Feshie debris cones, showing boundaries between individual debris flow units. (b) Detailed sections at sampling sites 1–4. (After Brazier and Ballantyne, 1989.)

River Feshie: the upper braided reach

Active low-sinuosity channel patterns in Britain are associated with high stream power, which the River Feshie possesses by virtue of its combination of a steep channel gradient (averaging 0.009 in this reach) and frequent large floods (Ferguson, 1981). This site, which drains a catchment area of 110 km^2, records a mean flow of 3–4 m^3s^{-1} and peak flows > 100 m^3s^{-1}. Channel capacity varies throughout the reach, but bankfull discharges are estimated to lie between 20 and 30 m^3s^{-1} and the mean annual flood is around 70–80 m^3s^{-1}. The river is very flashy by British standards, as evidenced by the fact that one summer flood rose to over 100 m^3s^{-1} in under 2 hours, and was over within 24 hours (Ferguson and Werritty, 1983).

Given this hydrological regime and a relatively steep slope, the river at this site is actively reworking the non-cohesive sediments that comprise the valley floor (Werritty and Ferguson, 1980). The result is a braided channel pattern that displays a scale of channel subdivision that is exceptional within upland Britain (Figure 2.28). Bedload transport is episodic but highly significant during floods, with substantial volumes of bed material (D_{50} *c.* 45 mm) being mobilized. This results in the episodic development of gravel bar complexes, which is accompanied by channel cut and fill of 0.5 m per year and bank erosion that can locally exceed 10 m per year, making this probably the most active river in Britain relative to its width (Ferguson and Werritty, 1983).

The basic geomorphic unit present throughout this reach is the 'bar-pool–riffle' sequence, the development of which controls the detailed configuration of the whole channel system. Bar growth can cause avulsion, but more commonly it is accompanied by bank erosion together with changes in the flow distribution within the channel. This often results in the abandonment of inner channels and the attachment of alternate bars to the bank. An idealized model was derived by Ferguson and Werritty (1983) based on detailed analysis of channel development at this site over a period of 6 years. Tracer experiments and direct measurement of bed shear stress and bedload transport have enabled this model to be refined and extended (Ferguson and Werritty, 1991).

In addition to diagonal bars, other types of bars are also found at this site. These include the 'longitudinal' and 'transverse' bars of Smith (1974) and the 'lateral' and 'medial' bars of Bluck (1976), the former often becoming attached to one bank, thereby being converted into the latter. Bar surfaces are typically decorated by falling-stage sediments of a finer grade than that of the main bar platform. A range of primary and secondary sedimentary structures can be inspected during low flows. Bars typically have cobble and gravel frameworks with infill and superficial lobes of finer material. Transport rates during major floods are so high locally that coarse cobble sheets are often deposited across the floodplain.

River Feshie: lower braided reach

The lower River Feshie near Lagganlia, draining a catchment area of 205 km^2, displays a channel planform with many similar elements to those of the upper braided reach (see section above). The designated reach is located between the confluences of the Feshie with the tributaries Allt a' Mharcaidh and Allt Ruadh, a distance of approximately 2 km. The planform is that of a wandering gravel-bed river, with an area of active reworking varying between 100 and 200 m and confined at the margins by the rate at which the glaciofluvial terraces can be undercut (Young, 1976; Werritty and Brazier, 1991a).

This site is noteworthy since the frequent shifting and abandonment of channels together with the regular reworking of both medial and lateral bars (Buck, 1978; Werritty and Brazier, 1991a) have resulted in some of the highest rates of channel change recorded in Scotland. It thus provides good examples both of intra-channel avulsion around unstable, unvegetated gravel bars, together with extra-channel avulsion re-occupying former channels located on the floodplain and low terraces (cf. Ferguson and Werritty, 1983). Analysis of bankfull stream power demonstrates that the river is competent to transport the bed material (D_{50} 90–110 mm) and thus adjusts its planform in response to floods which occur at least once a year (McEwen, 1986). Larger floods (e.g. that of February 1990) can access greater reserves of sediment either flushed down from coarse-grained sediment stores in the upper reaches or derived from undercutting local glaciofluvial terraces (Werritty and Brazier, 1991a). The release of such sediment typically results in extensive planform disruption. In the late 1980s, an unsuccessful attempt was made to channelize this reach in order to reduce the impact of flooding and bank erosion (Werritty and Brazier, 1991a). This site is also an important sediment store within the Feshie system and periodically releases sediment through the Feshie gorge to be redeposited within the Feshie confluence fan site (see below).

The Feshie confluence alluvial fan

The alluvial fan above the confluence of the River Feshie with the River Spey provides an exceptional example of a low-angle, highly active gravel fan, on a scale rarely seen in Scotland ((Figure 2.29): Werritty and Brazier, 1991b). The River Feshie, which at this site drains an area of 234 km^2, debouches from the confinement of a bedrock gorge at Feshiebridge and, as a result of the dramatic reduction of its slope downstream, has deposited a large volume of reworked glacigenic sediments over a wide area. This fan also acts as a local base level for the River Spey, damming the outflow from Loch Insh, since the coarse material comprising the fan is accumulating more rapidly than it can be evacuated by the Spey (Werritty and Brazier, 1991b). The present active fan is involved in reworking only a small portion of the palaeofan surface formed during the Lateglacial as the ice sheet downwasted (Young, 1976). The present channel is sinuous to wandering in planform with various degrees of channel subdivision present depending on the date of observation. Sediment size (D_{50}) varies between 70 and 120 mm directly below the Feshiebridge gorge and decreases towards the distal part of the fan.

Channel change at this site has been investigated by McEwen (1986) and Werritty and Brazier (1991b), using historical maps, Ordnance Survey maps and aerial photographs. Analysis reveals a major avulsion in the mid-1860s, following which the location of the distributary system was contained within a well-defined corridor at the distal end of the alluvial fan. This channel alignment persisted until the flood of 1990, which triggered a fresh avulsion. The processes leading up to this avulsion were similar to those reported for the upper braided reach (Ferguson and Werritty, 1983) and involved steady aggradation of the channel bed within the distributary channels. In 1990, the flood flows breached the margins of this central corridor and created a new main channel to the River Spey across agricultural land, re-occupying an alignment last utilized in the 1860s (Werritty and Brazier, 1991b). This in turn generated a demand by the local landowners that both the Spey and the Feshie be channelized to reduce the damage caused by flooding and to stabilize the course of the Feshie across its alluvial fan. As a result of this, some artificial realignment of the course of the Spey has been permitted immediately downstream of the confluence (Brazier and Werritty, 1994).

Interpretation

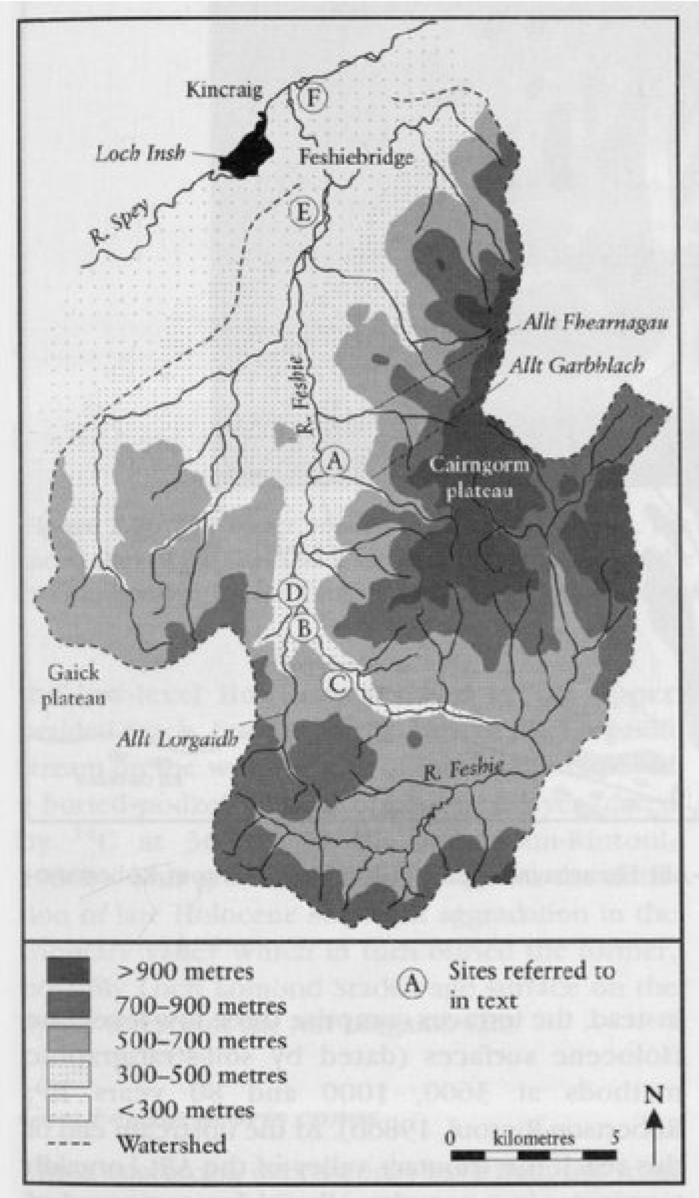
Glen Feshie represents the most important fluvial site in Scotland because it encompasses such a rich assemblage of fluvially-derived landforms. It is of international significance for the study of Lateglacial and Holocene valley floor development since it has provided the type site for the development of an alluvial chronology based on soil stratigraphy. It also demonstrates with remarkable clarity the complex nature of the coupling of slope and channel processes in the Scottish uplands and the highly episodic nature of fan and debris cone development. Finally, it provides a number of locations at which the processes controlling the development of gravel-bed rivers have been directly studied. From this work a general evolutionary model has been developed for coarse-grained alluvial channels. In sum, this is an exceptional site for the study of gravel-bed rivers on account of the rich diversity of past and present fluvial processes and landforms.

Conclusion

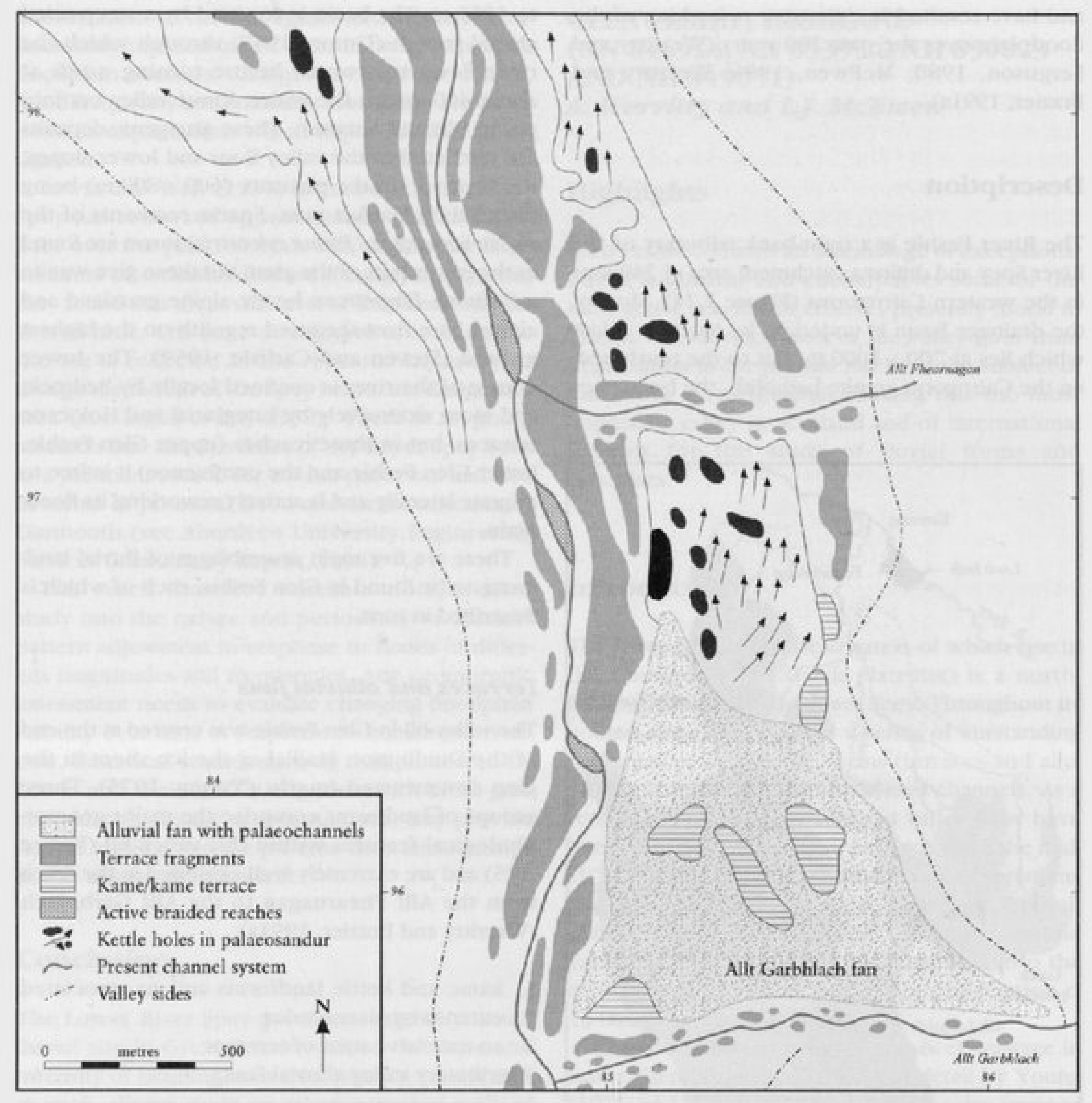
The Lateglacial, Holocene and present-day development of the valley floor of Glen Feshie is now extremely well-documented, making this the most important valley in Scotland in terms of the study of fluvially derived landforms. The sequence of events documenting the development of the valley floor is summarized below.

Following deglaciation during the Late Devensian, a pitted sandur surface was deposited, inset within which a series of alluvial terraces developed throughout the Holocene. Large alluvial fans developed on the main valley floor at confluence sites from tributary valleys, in response to episodic releases of large quantities of sediment from the steeper tributary streams. At other sites at which slope processes have constructed debris cones directly on to low terraces and the adjacent floodplain, substantial debris flow activity is reported over the past 300 years. Within the same timescale, in response to a flashy runoff regime and a steep slope, the River Feshie has extensively reworked its valley floor in three major reaches. This has resulted in the development of one of the most active and highly divided channel systems in upland Britain.

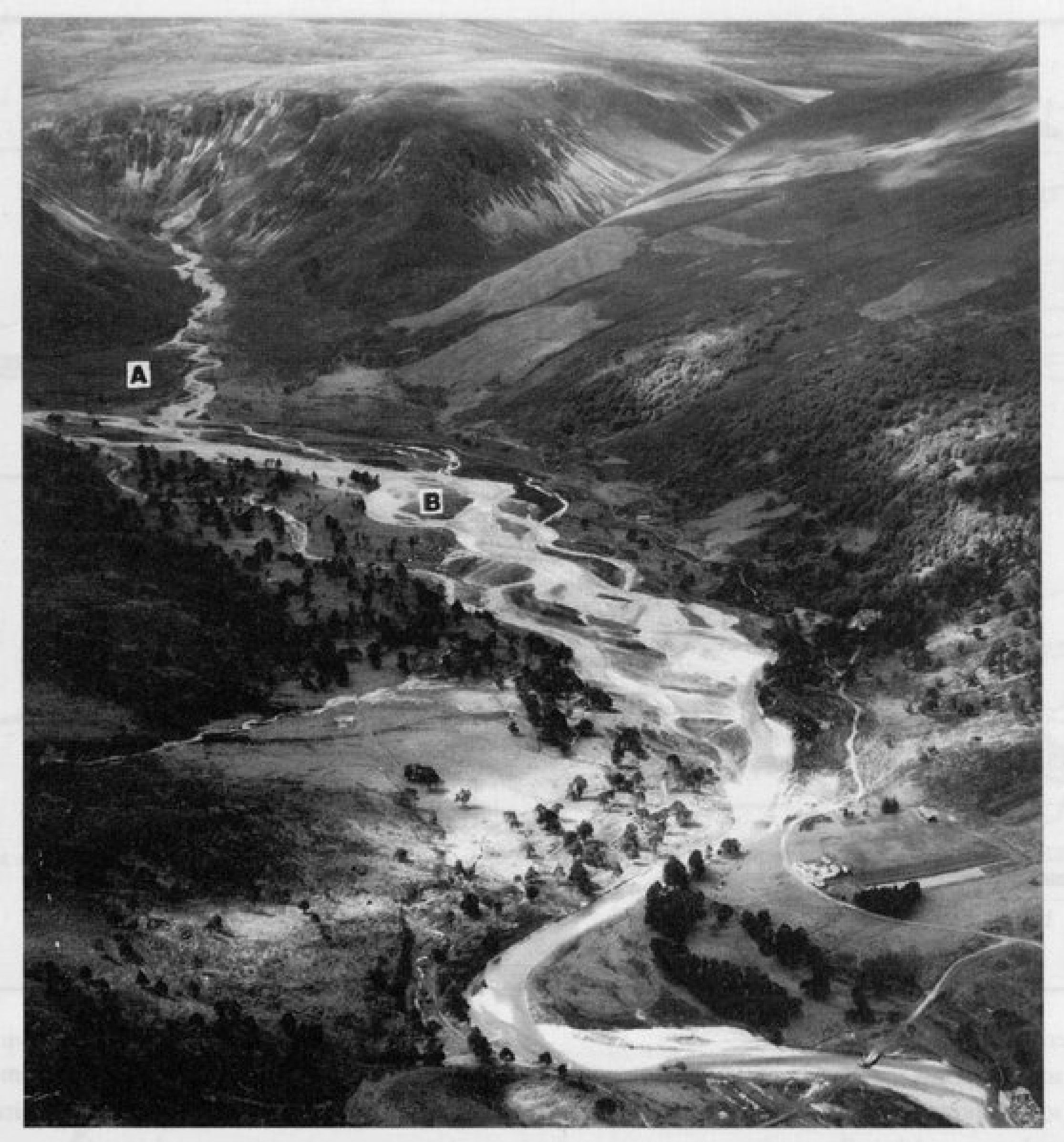
References



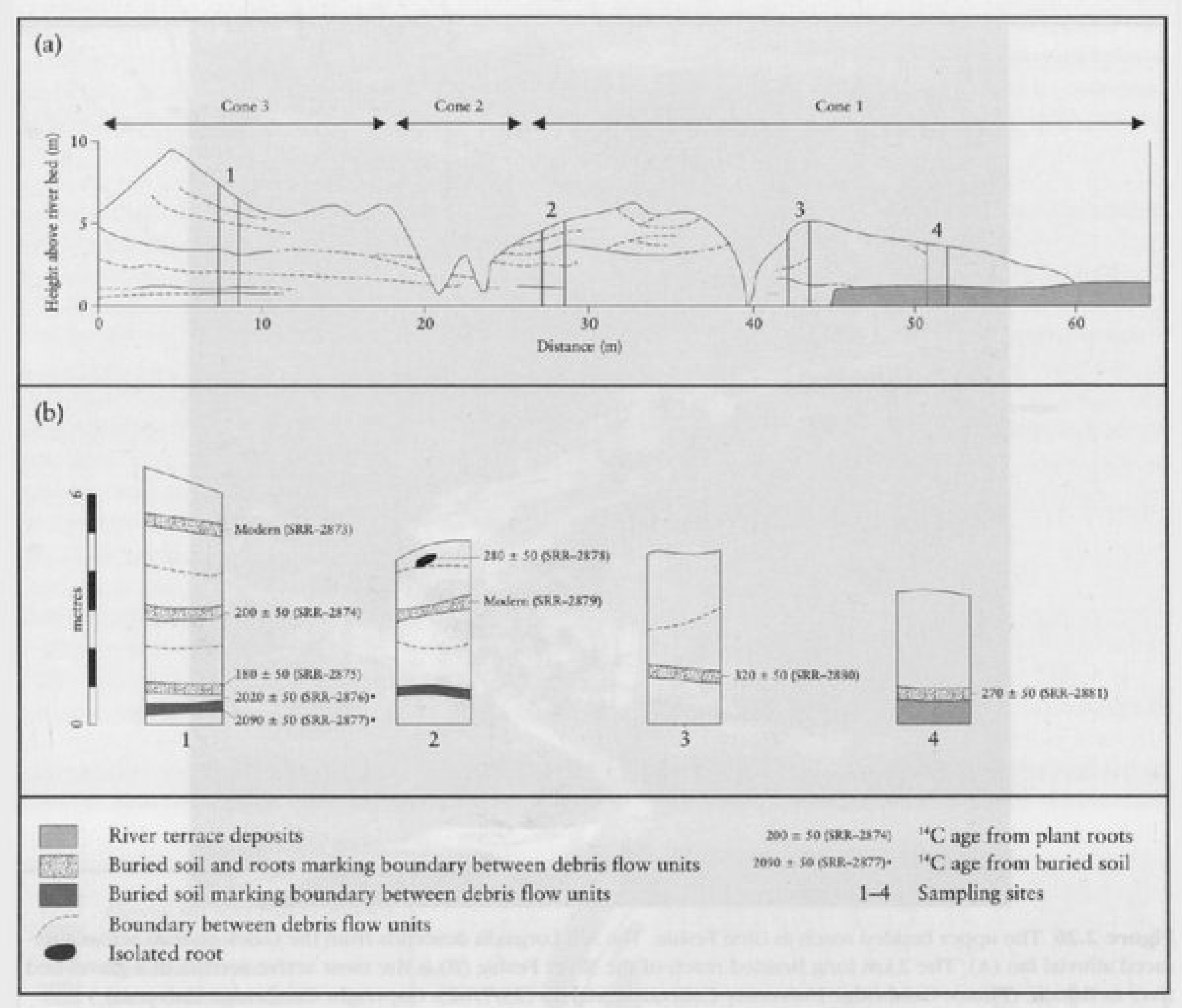
(Figure 2.24) The drainage basin of the River Feshie, with sites referred to in the text. A, Allt Garbhlach alluvial fan and river terraces; B, Allt Lorgaidh alluvial fan; C, Upper Glen Feshie debris cones; D, River Feshie upper braided reach; E, River Feshie lower braided reach; F, River Feshie confluence alluvial fan.



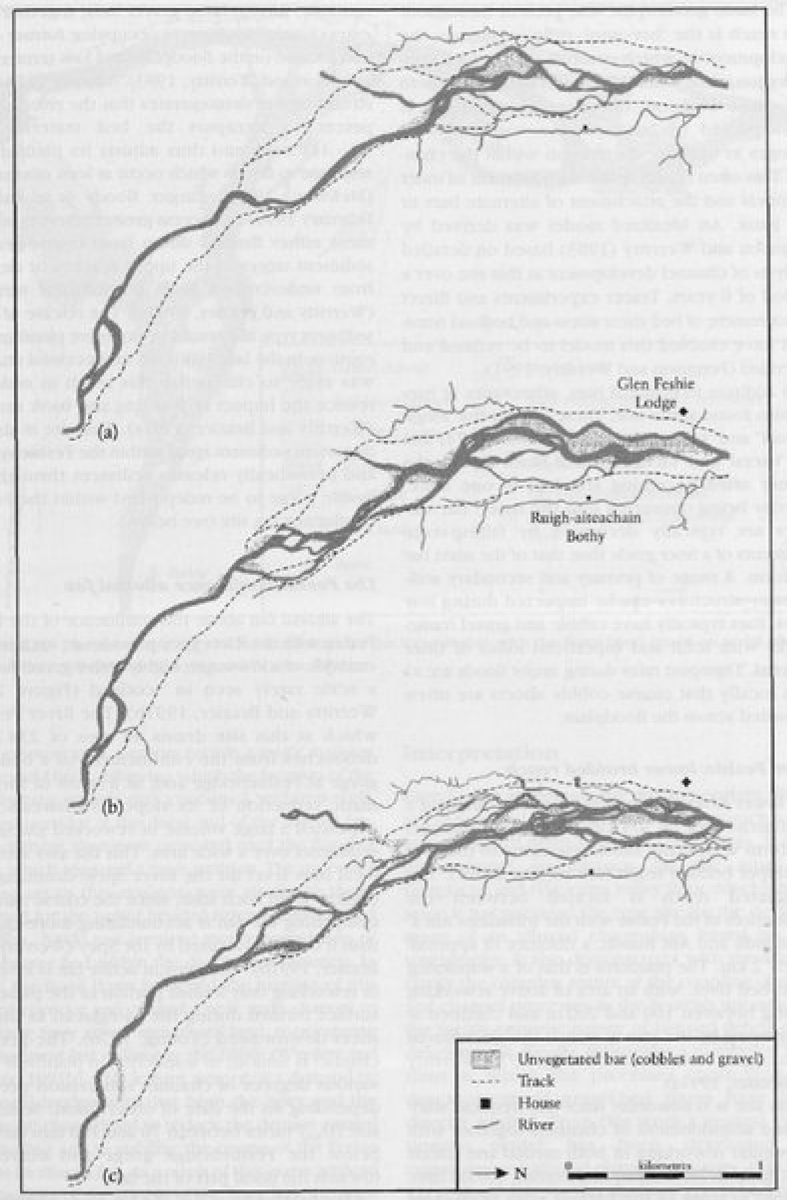
(Figure 2.25) The geomorphology of the Allt Garbhlach–Allt Fhearnagan area of Glen Feshie. (From Robertson-Rintoul, 1986a; Werritty and Brazier, 1991a.)



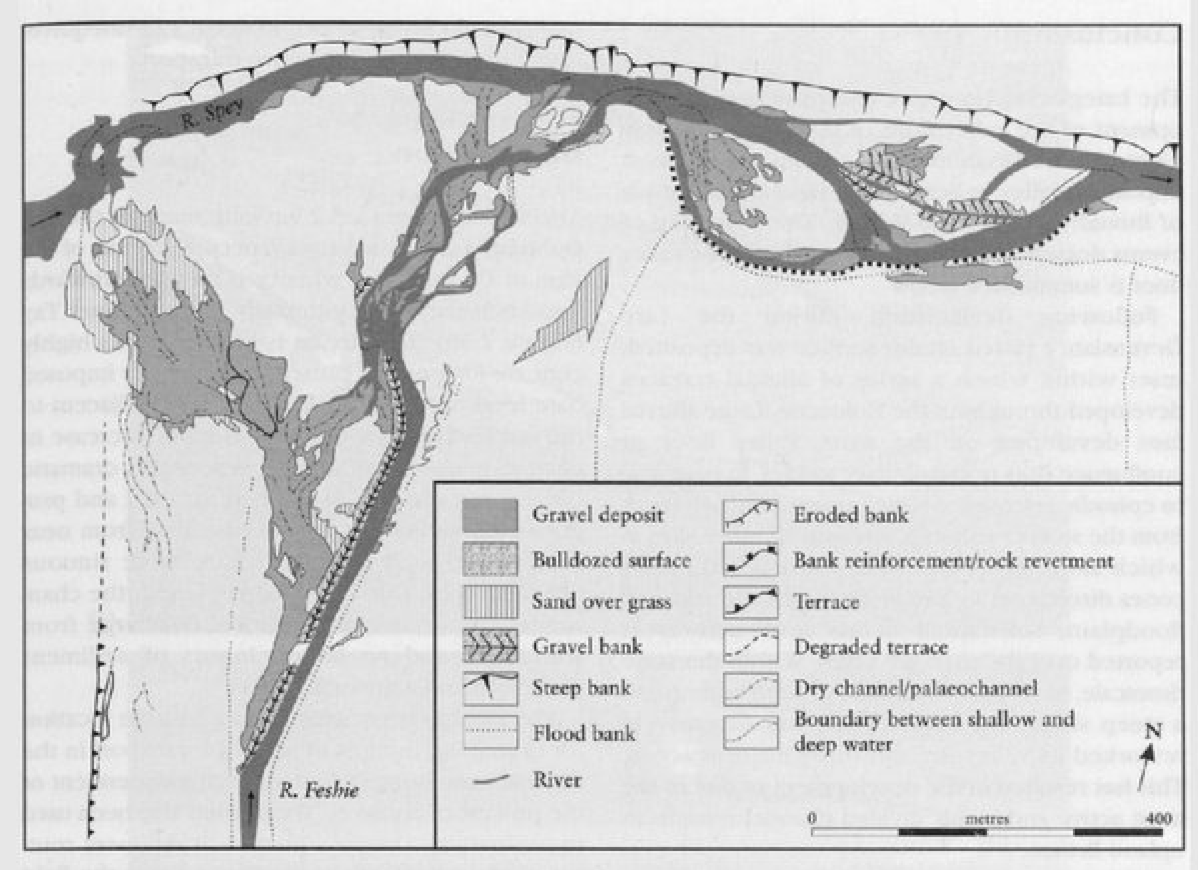
(Figure 2.26) The upper braided reach in Glen Feshie. The Allt Lorgaidh descends from the Gaick plateau across a terraced alluvial fan (A). The 2 km long braided reach of the River Feshie (B) is the most active section of a gravel-bed river in Britain. (Photo: Cambridge University Collection AGJ 36 (23/7/62): Copyright Cambridge University.)



(Figure 2.27) (a) The surveyed section across the base of the Glen Feshie debris cones, showing boundaries between individual debris flow units. (b) Detailed sections at sampling sites 1-4. (After Brazier and Ballantyne, 1989.)



(Figure 2.28) The upper braided reach, 1869–1971. Changing channel patterns mapped in successive editions of Ordnance Survey large-scale maps: (a) First edition survey, 1869; (b) Second edition resurvey, 1899; (c) Metric edition survey, 1971. (After Werritty and Ferguson, 1981.)



(Figure 2.29) The geomorphology of the confluence of the River Feshie with the River Spey: based on aerial photograph of July 1991. (After Werritty and Brazier, 1991b.)