THE CHARACTERISTICS AND SIGNIFICANCE OF DEEP WEATHERING IN THE GAICK AREA, GRAMPIAN HIGHLANDS, SCOTLAND

BY

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ABSTRACT. The Gaick area is a landscape of selective linear glacial erosion. Deep weathering of Moine psammites occurs on preglacial slopes but is absent from glacially-overdeepened valleys. The weathering is of gruss type and its thickness, together with the importance of halloysite in the clay fraction, indicates that the weathering predates the middle Quaternary ice sheet glaciations. The weathering demonstrates very limited erosion of the preglacial slopes and owes its preservation in part to the development of an ice dome over the Gaick area during successive glaciations.

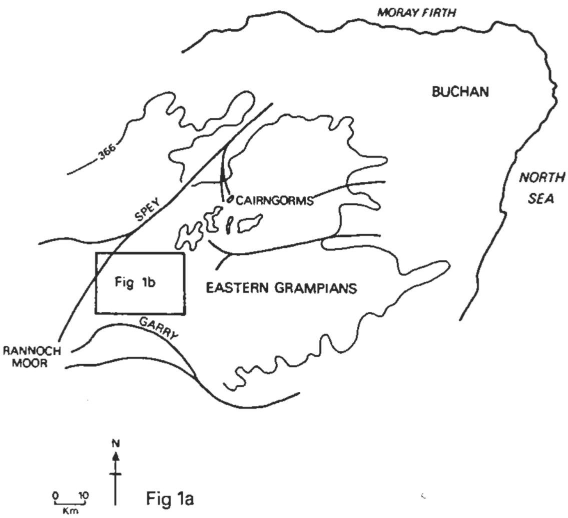


Figure 1a. Location map, with main ice flow lines.

Introduction

A landscape of selective linear glacial erosion is one in which glacial troughs dissect upland plateaus which otherwise show few signs of glacial erosion. Development of these landscapes is thought to reflect a fundamental threshold on the efficiency of glacial erosion: the presence or absence of basal ice at the pressure melting point (PMP). Within depressions, basal ice temperatures may rise above PMP and deep troughs may be excavated beneath streaming ice: on plateaus, basal ice temperatures remain below PMP, basal sliding is prevented and glacial erosion is limited or absent (Sugden 1974).

This model has been widely applied (Sugden and John 1976) and yet a key assumption remains to be tested. This assumption is that glacial erosion of plateau surfaces has been insignificant. To date, no feature has been identified which unequivocally demonstrates that the plateau surfaces mirror the pre-Quaternary morphology. There is little doubt that the gross morphology of the plateau surfaces is pre-Quaternary in age but macro-forms can provide no precise information on depths of glacial erosion. In the Cairngorm Mountains, Scotland, perhaps the type area for landscapes of selective linear glacial erosion, tors, shallow saprolites and sheet joints have been taken as pre-Quaternary meso-features (Sugden 1968) but the origin and significance of each of these features is controversial and there is as yet no firm evidence of a pre-Quaternary age. This paper reports findings from a key locality, the Gaick area, where the extraordinary development of deep weathering indicates detailed preservation of a pre-Quaternary surface as part of a landscape of selective linear glacial erosion.

Relief and Glacial History

The Gaick area is a landscape of selective linear

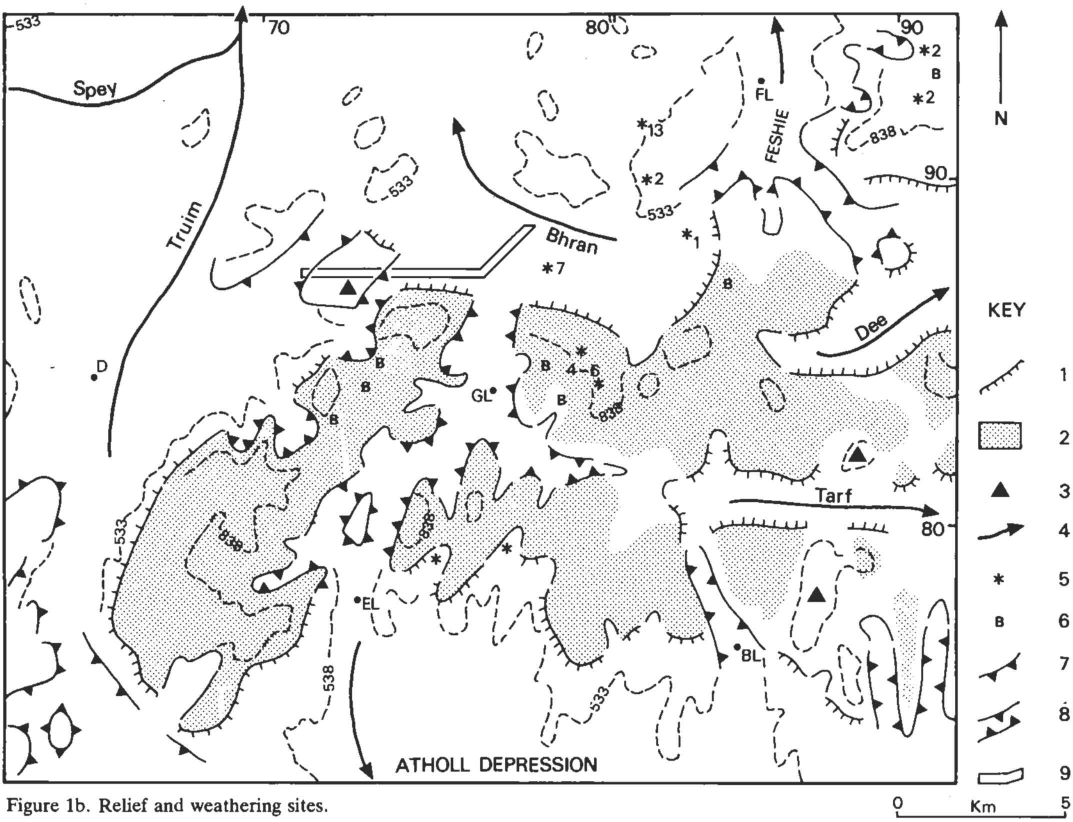


Figure 1b. Relief and weathering sites.

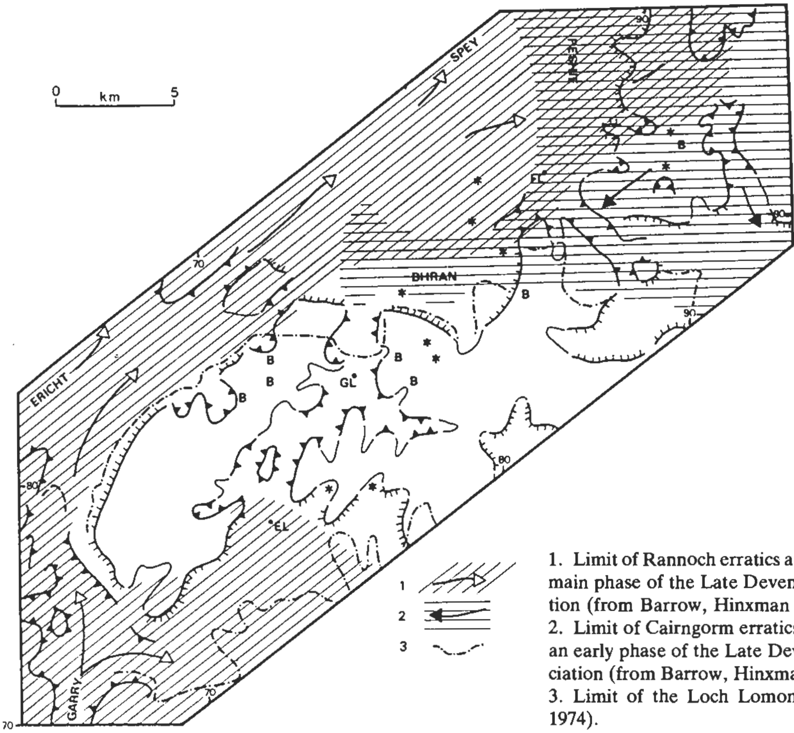
BL Bruar Lodge, D Dalwhinnie, EL Edendon Lodge, FL Feshie Lodge, GL Gaick Lodge

1. Preglacial break of slope at the edge of the Gaick Surface.
2. Gaick Surface.
3. Isolated hill rising above the level of the Gaick Surface.
4. Preglacial drainage line.
5. Weathering site, with depth of weathering in m.
6. Subsurface blocky disintegration site.
7. Glacially over-steepened slope.
8. Glacial trough or breach.
9. Hydro-electric tunnel.

erosion lying in the centre of the Grampian Highlands, 15 km SW of the Cairngorms (Fig. 1a). The main relief feature is a plateau at 720–940 m OD, the Gaick Surface, which is bounded by a steep break of slope to lower surfaces in the Atholl basin and the Spey valley (Fig. 1b). These preglacial relief forms carry little or no signs of glacial erosion but are dissected by glacial troughs which breach the preglacial watershed at Drumochter, Gaick Lodge and in upper Glen Feshie (Linton 1951).

The number, timing and extent of glacial phases in the Gaick area is poorly understood. At least 4 separate phases of glaciation can be recognised (Fig. 1c):

1. A phase or phases of ice sheet glaciation prior to the Late Devensian when the main glacial troughs.were cut (Sutherland 1984).
2. A phase or phases of mountain glaciation prior to the Late Devensian when the corries were formed which bite into the margins of the Gaick Surface.
3. The Late Devensian (Dimlington Stadial) ice sheet glaciation. During this phase, early expansion of Cairngorm ice carried granite erratics into the upper Feshie and Bhran valleys (Barrow, Hinxman and Cunningham-Craig 1913). Later, however, ice originating in the Rannoch basin and flowing NE via the Ericht trough crossed the plateau at over 900 m OD to the E of Glen Feshie



1. Limit of Rannoch erratics and direction of ice flow during the main phase of the Late Devensian (Dimlington Stadial) glaciation (from Barrow, Hinxman and Cunningham-Craig 1913).
2. Limit of Cairngorm erratics and direction of ice flow during an early phase of the Late Devensian (Dimlington Stadial) glaciation (from Barrow, Hinxman and Cunningham-Craïg 1913).
3. Limit of the Loch Lomond Stadial ice cap (from Sissons 1974).

Figure 1c. Glacial limits and ice flow lines in the Gaick area

and deposited metamorphic erratics (Fig. 1c). To the S. ice turning eastwards out of the Garry trough deposited Rannoch erratics across the Atholl basin. No erratics occur in the central Gaick area (Barrow, Hinxman and Cunningham-Craig 1913). This area lay beneath the ice-shed zone of the last ice sheet in the central Grampians and supported an ice dome where local ice seems to have been largely hemmed in by the surrounding ice masses (Sutherland 1984).

4. The Loch Lomond Stadial. During this final phase, a large but relatively thin ice cap developed on the Gaick plateau (Sissons 1974; Fig. 1c).

Deep Weathering

The existence of deep weathering in the Gaick area was reported by the Geological Survey (Barrow, Hinxman and Cunningham-Craig 1913). The weathering is developed in Moine psammites. These are quartz-feldspar schists, with variable quantities of biotite and often some muscovite, which show a well-developed, sub-horizontal flaggy fabric due to shearing. The schists are traversed by veins of pegmatite and, less commonly, aplite and microgranite. These veins often have haematite coatings on joint surfaces and may show partial kaolinisation of feldspar. Thin coatings of haematite and chlorite occur on fracture surfaces in the schists. It is likely that these clay minerals are mainly hydrothermal alteration products related to intrusion of the granite veins.

Minor late-stage alteration, together with high fracture densities, have rendered the psammites susceptible to subaerial weathering. Hydrothermal alteration is not responsible for rock breakdown, however, as clay coatings occur on fracture surfaces in both weathered and fresh rocks. Also excavations for hydro-electric tunnels NW and NE of Gaick Lodge (Fig. 1b) revealed no traces of sandy weathering at depth (Anderson 1951).

Deep weathering occurs E of Gaick Lodge in meltwater channels cut into the preglacial slopes (Fig. 1b). The glacial troughs and the lower parts of the valleys which drain into them are cut in fresh rock and drift. The weathering is found at eleva-

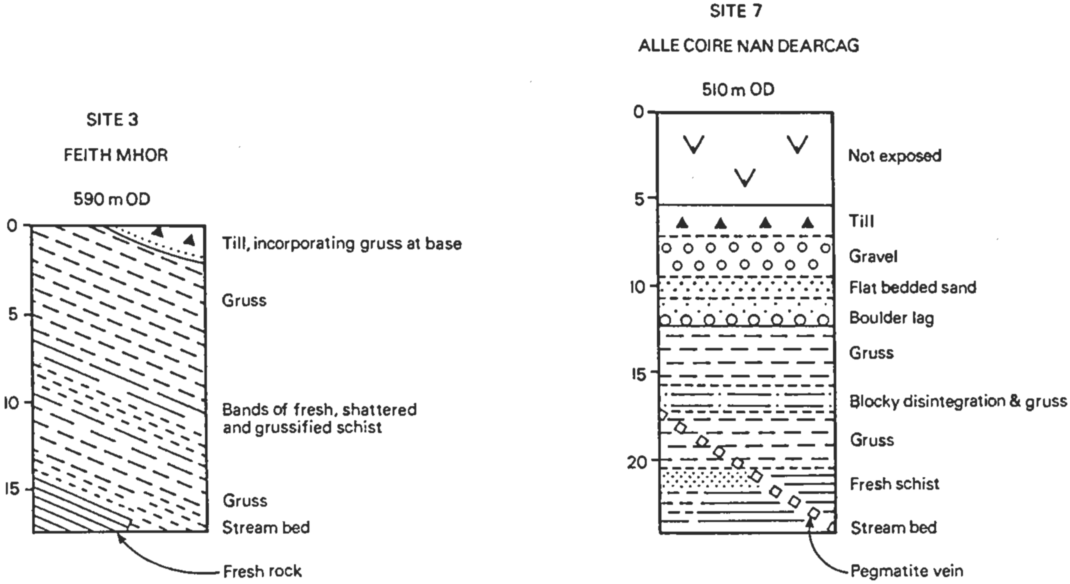


Figure 2. Schematic Weathering Profiles.

tions of between 530 and 800 m above sea level and is developed beneath the slopes of the Gaick Surface and beneath the floors of preglacial valleys and basins. Subsurface blocky disintegration of highly-fractured but little-altered psammites is also widespread on the plateau, with disintegration reaching depths of at least 10 m (Fig. 1b).

The weathering profiles are overlain by variable thicknesses of till, sand and gravel of probable Late Devensian age (Fig. 2). Reworking of previously weathered rock into the base of tills demonstrates that the profiles are truncated and predate the Late Devensian. The profiles are deep, with exposed thickness of saprolite at Site 3 of 17 m and at Site 7 of 11.5 m. There is no clear horizon development but a downward decrease in the degree of disaggregation can frequently be observed in the profiles. Staining by Fe and Mn oxides is widespread.

The weathering is arenaceous in texture, with clay contents of 0–5 % and abundant little-altered feldspar and biotite. The clay fraction was analysed by X-ray diffraction, using procedures described elsewhere (Hall, Mellor and Wilson, 1989), and by transmission electron microscopy (TEM). Micaceous clays are dominant and, together with quartz and feldspar, are probably inherited directly from the parent rock (Table 1). The main weathering product in the clay fraction shows a broad peak at 7.2 Å and the abundance of scroll- and lath-shaped crystals on TEM micrographs indicates that this mineral is halloysite, perhaps occurring in association with some kaolinite. Vermiculite is present in the shallow grusses at Sites 1 and 2. TEM also indicates the presence of an amorphous component rich in Fe and Al.

The weathered psammites in the Gaick area closely resemble, in granulometry and mineralogy, saprolites developed on similar lithologies in the lowlands of north-east Scotland of the gruss weathering type (Hall, Mellor and Wilson 1989), notably in the dominance of halloysite in the clayey alteration products. The gruss weathering type is a product of humid temperate weathering environments which existed in Scotland during the Pliocene, early Pleistocene and interglacial periods of the middle and late Pleistocene (Hall, Mellor and Wilson 1989).

The Gaick weathering profiles must predate the Late Devensian as glacial deposits of this age incorporate previously weathered rock. The deep profiles are unlikely to date from interglacial periods as there is no evidence, even from rocks susceptible to weathering, that saprolites 10–15 m deep can develop within interglacial periods in glaciated areas (Hall, Mellor and Wilson 1989).

Table 1. Clay Mineralogy

Site	Name	Grid Ref.	Depth (m)	Vermiculite	Mica	Halloysite (Kaolinite)	Quartz	Feldspar
1	Meur Meadhonach	NN 821885	3.0	X	XXX	X	XX	XX
2	Allt an Dubh-chadha	NN 807907	2.0	X	XXX	tr	XX	tr
3	Feith Mhor	NN 808923	15.0	—	XXX	XX	X	—
4	Allt Domhain	NN 782851	2.0	—	XXX	X	XX	X
5	Allt Domhain	NN 779850	5.5	—	XXX	X	XX	X
6	Allt Domhain	NN 777849	7.0	—	XXX	XX	X	X
7	Allt Coire nan Dearcag	NN 776882	13.0	—	XXX	XX	tr	tr
			23.0	—	XXX	XX	X	—

Estimates of relative abundance are semi-quantitative and based on peak intensities on X-ray diffraction traces

XXX = abundant (>2/3rd height of tallest peak)
XX = frequent (>1/3rd but <2/3rd height of tallest peak)
X = rare (<1/3rd but >1/10th height of tallest peak)
tr = trace (<1/10th height of tallest peak)
— = absent

The deep weathering probably predates regional glaciation and the profiles are regarded as largely relict, more or less truncated features. Additional support for this conclusion is provided by
1. the presence of halloysite, a mineral generally considered to be inherited from preglacial weathering covers in Scotland (Wilson and Tait, 1977),
2. the presence of Mn oxides in several profiles, implying restricted drainage during weathering. These profiles now have been rendered free-draining by drainage incision during the Pleistocene due to meltwater activity and excavation of the glacial troughs but the presence of hydromorphic minerals indicates that profile development predates drainage incision and
3. the weathering is absent from glacial troughs and is present only beneath preglacial slopes.

The deep weathering is therefore likely to have developed during the Pliocene and early Pleistocene.

Implications

In the Gaick area, outside the valleys, glacial erosion has apparently been largely confined to the truncation of preglacial deep weathering profiles. In this landscape of selective linear glacial erosion, the detail of the preglacial relief is preserved outside the troughs and Pleistocene glacial and periglacial denudation has amounted to the removal of, at most, a few tens of metres of saprolite.

The preservation of the deep weathering implies that successive ice covers were incapable of efficient erosion. An ice dome from which vigorous radial flow was prevented by surrounding ice streams is known to have developed in the Gaick area in the Late Devensian (Sutherland 1984). The absence of erratics and of landforms of glacial erosion from much of the Gaick plateau suggests that similar ice domes also formed in this area earlier in the Pleistocene. The restricted movement of ice within the Gaick ice dome has undoubtedly been a major factor in the preservation of the deep weathering. There are problems, however, with this simple reasoning. Firstly, the weathering sites N of the Bhran valley occur outside the limits of the Late Devensian ice dome and were crossed by the southern margin of the Rannoch ice stream (Fig. 1c). Secondly, the presence of till, for example on the plateau to the E of Gaick Lodge, indicates that ice within the ice dome area was at least temporarily able to entrain debris, perhaps during ice sheet build up and decay. Finally, formation of the main glacial breaches requires invasion of the Gaick area prior to the Late Devensian by ice capable of vigorous linear erosion (Sutherland 1984). The reasons for the preservation of the weathering are therefore complex and unclear.

The characteristics of the Gaick saprolites match those of grusses developed on similar lithologies in the lowlands of north-east Scotland (Hall, Mellor and Wilson 1989). Whilst the main concentrations of weathering sites in north-east Scotland are found below 300 m above sea level (FitzPatrick 1963; Hall 1986), saprolites are also known from numerous sites at higher elevations around Glen Dye (Reid, Macleod and Cresser 1981), Glen Gairn (Crofts 1974), the Cabrach (Basham 1974) and elsewhere (FitzPatrick 1963; Hall 1983). Shallow granite grusses also occur, with tors, at elevations of over 1000 m on the Cairngorm plateau (Sugden 1968; Hall, unpub.). There are grounds, therefore, for suggesting that a mantle of gruss covered the plateaus of the central and eastern Grampians before glaciation. This mantle may have been of considerable thickness, for in Buchan the preglacial saprolites are locally over 50 m thick (Hall 1986) and in the Gaick area the saprolites reach a maximum thickness of 17 m, despite truncation and limited exposure. Deep weathering under humid temperate environments in the late Cenozoic therefore has been of considerable morphogenic significance in the uplands of north-east Scotland, as well as in the lowlands (Hall 1986). Outside the Gaick area, it seems that only shallow pockets of this weathering mantle have survived Pleistocene glacial and periglacial denudation. The plateau fragments of the central and eastern Grampians therefore can be regarded as 'dominantly stripped etchsurfaces' (Thomas 1974) from which thick grusses were stripped during the Pleistocene to reveal a basal surface of weathering little modified by the passage of ice.

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