SCARISDALE

J.M. Gray

OS Grid Reference: NM523378

Highlights

The bedrock surfaces exposed on the coast at Scarisdale demonstrate the best examples in Britain of p-forms, smalläscale features produced by a combination of meltwater and glacial erosion.

Introduction

The Scarisdale site covers approximately a 3 km long stretch of coast on the southern shore of Loch na Keal on the Isle of Mull, between the head of the loch (NM 535389) and Rubha na Moine, about half way along the loch (NM 510372). The site does not have a long history of investigation. It was first noted by J.E. Richey in the Geological Survey Memoir for Mull (Bailey *et al*., 1924, p. 396) for a "remarkable series of little striated hollows and winding grooves' eroded in the bedrock. Over 50 years later the site was reinvestigated by Gray (1981) who recognized the features as p-forms (*cf.* Dahl, 1965). He described them, mapped their distribution, and discussed their origin. He argued that no single genesis could explain all the characteristics of the features and instead suggested that they were formed by meltwater erosion, but later striated by active ice moving through them (see also Gray, 1984).

Description

The landforms are best seen between low water mark and a few metres above high water mark, probably mainly due to the absence of masking sediment, soil and vegetation. They comprise an assemblage of small-scale, smooth depressions eroded in the Palaeogene basalt and have the appearance of plastically sculptured forms (p-forms) (Dahl, 1965). The p-forms occur on flattish rock surfaces, but they have been cut irrespective of geological structure. Although p-forms occur along the entire length of the site there are areas where they are particularly common (Figure 11.5). The most impressive suites of features are at localities 1 and 2.

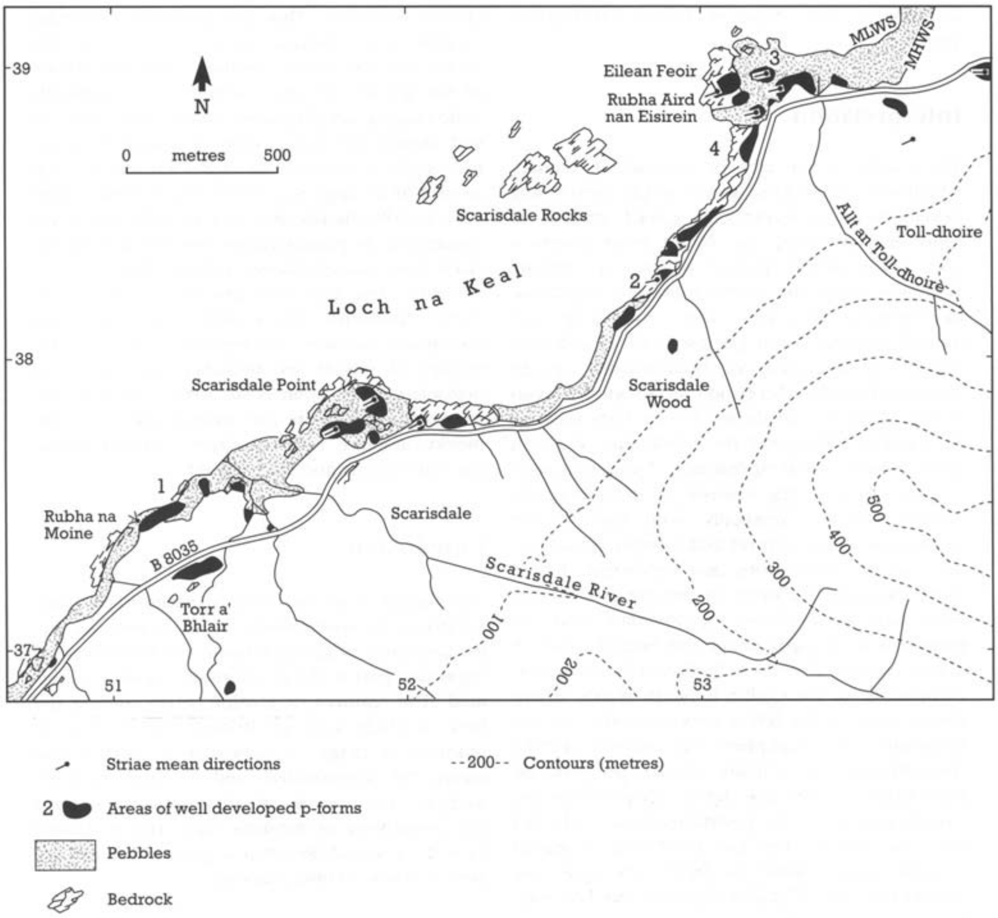

Figure 11.5: Scarisdale: localities with well-preserved p-forms (from Gray, 1981).

Although channels are by far the most abundant p-form type at Scarisdale, they are very variable in both size and morphology (Figure 11.6).. The largest channel (at site 3) is about 3 m wide with steep side walls over 1 m high. It consists of a single curve about 12 m long with an undercut outer wall and smooth inner wall, both of which are covered with glacial striae that follow the curvature of the channel. At the other extreme, some channels are only 0.01 m or so deep and under 0.1 m wide. Occasionally, individual channels can be traced for over 20 m.

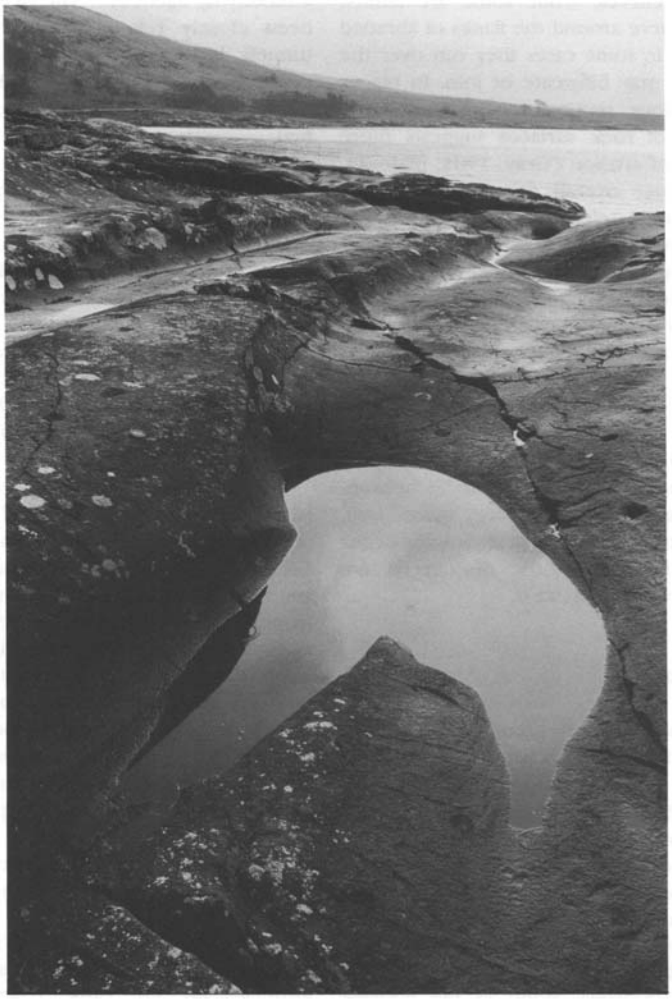

Figure 11.6: P-form channels at Scarisdale, Mull. (Photo: S. Campbell.)

Channel sides vary from very gently sloping to vertical or even undercut. A particularly good example of undercutting (site 2) has a depth of 0.05 m, but the deepest undercut (site 3) is 0.1 m high. Asymmetrical cross-profiles are common, with the south (inland) slopes usually being the steeper. Most channels have rounded upper edges, although in several places sharp edges occur.

In plan, some channels are winding, others describe single curves, while some are almost straight. Some curve around the flanks of abraded hillocks, though in some cases they run over the crests. Channels may bifurcate or join. In places overdeepened floor sections occur and sometimes facetting of rock surfaces suggests more than one phase of erosion (Gray, 1981, plate 2).

The approximate overall orientations of 142 channels reveals a clear pattern, with 96% orientated between 50° and 90°E of N. This is consistent with the trend of Loch na Keal and the main striae direction. Where a number of channels with similar orientations occur together, the rock may take on a furrowed appearance (Gray, 1981, plate 7).

Other p-form types also occur at Scarisdale. Bowls are fairly common, most being under 2 m in diameter and only a few centimetres deep. A few larger examples are also present. "Sichelwannen' (sickle-shaped troughs) are quite rare, although two exceptionally large examples occur (at sites 1 and 4). All those discovered are concave to the west-south-west.

Interpretation

The three most favoured theories for p-form formation are (1) glacial abrasion (for example, Boulton, 1974), (2) movement of water-soaked till (Gjessing, 1965) and (3) meltwater moving under high velocities (for example, Dahl, 1965). The main characteristics of the Scarisdale channels are most successfully explained by meltwater flow, which accounts particularly well for the sinuousity, overdeepened floors, undercut lips, sharp edges, facets, and asymmetrical cross-profiles of the channels. None of the p-forms explained in the literature by glacial abrasion or till squeezing has all these characteristics. On the other hand, turbulent meltwater flow cannot account for the regular striae on the walls and floors of the channels. Thus it has been suggested that a two-stage origin is likely. First, the channels were cut by turbulent, high-velocity meltwater flow probably involving corrasion and/or cavitation associated with current vortices. Subsequently, active ice moved through the channels striating their floors and sides (Gray, 1981, 1984). This explanation had previously been proposed by J.E. Richey (in Bailey *et al.*, 1924) when first describing the Scarisdale site – "the hollows are almost certainly potholes; the winding channels stream courses. Ice has been merely a modifying agent...'. The two phases may have been closely related in time since subglacial tunnels kept open by meltwater flow would probably close if the flow diminished or shifted, allowing active ice to come into contact with the bed.

Although not accepted by all workers such ideas have gained wide acceptance in Canada, where research is leading to a realization of the importance of meltwater as a subglacial erosional agent (see Sharpe, 1987). Shaw (1988) and Sharpe and Shaw (1989) have described comparable features from Ontario and Quebec and emphasized the important role of turbulent subglacial meltwaters in their formation. They suggested that the glacier was decoupled from its bed during periodic subglacial floods, then subsequently reattached.

Other British p-form sites occur on the Isle of Islay (Gray, 1984), the Isle of Seil (J.M. Gray, unpublished data), the shore of Loch Treig (see Glen Roy and the Parallel Roads of Lochaber), and in Snowdonia (Gray and Lowe, 1982). However, the Scarisdale site represents the best assemblage of p-forms in Britain. The site is important since the characteristics of the features may be used to test the various hypotheses proposed to explain the formation of such smooth depressions. In particular, the wider importance of glacial meltwater as a subglacial erosional agent is suggested, especially in association with subglacial floods.

The significance of subglacial meltwater in understanding both subglacial erosion and glacier dynamics at both large and small scales has become increasingly apparent (for example Bindschadler, 1983; Kamb *et al.*, 1985; Drewry, 1986; Röthlisberger and Lang, 1987). Sites such as Scarisdale potentially provide important field evidence for reconstructing former subglacial drainage systems on bedrock and their hydrological characteristics (for example, see Hallet and Anderson, 1980; Sharpe and Shaw, 1989; Sharp *et al.*, 1989b). Such reconstructions would not only allow field testing of theoretical models of glacier hydrology, but would also provide valuable insights into the local dynamics of Pleistocene glaciers.

Conclusions

Scarisdale is the best example in Britain of an assemblage of small-scale features of erosion known as p-forms. These are smoothed grooves, channels and scalloping in the bedrock. The range of features present and their clarity of detail provides an unrivalled opportunity to test the different explanations proposed for their origin. The most likely of these is that they were formed by a combination of glacial meltwaters and moulding by overlying glacier ice, and therefore they may allow a reconstruction of aspects of glacier hydrology.

Reference list

Bailey, E.B., Clough, C.T., Wright, W.B., Richey, J.E. and Wilson, G.V. (1924) *Tertiary and Post-Tertiary Geology of Mull*, *Loch Aline and Oban*. (A description of parts of Sheets 43, 44, 51, and 52 of Geological Map). Memoirs of the Geological Survey of Scotland. Edinburgh, HMSO, 445pp.

Bindschadler, R. (1983) The importance of pressurised subglacial water in separation and sliding at the glacier bed. *Journal of Glaciology*, **29**, 3–19.

Boulton, G.S. (1974) Processes and patterns of glacial erosion. In *Glacial Geomorphology* (ed. D.R. Coates). Binghampton, State University of New York, 41–87.

Dahl, R. (1965) Plastically sculptured detail forms on rock surfaces in northern Nordland,

Norway. *Geografiska Annaler*, **47A**, 83–140.
Drewry, D.J. (1986) *Glacial Geologic Processes*. London, Edward Arnold, 276pp.
Gjessing, J. (1965) On plastic scouring and subglacial erosion.*Norsk Geografisk Tidsskrift*, **20**, 1–37.
Gray, J.M. (1981) P-forms from the Isle of Mull.*Scottish Journal of Geology*, **17**, 39-47.
Gray, J.M. (1984) A p-form site on the Isle of Islay, Scottish Inner Hebrides.*Quaternary Newsletter*, **42**, 17–20.
Gray, J.M. and Lowe, J.J. (1982) Problems in the interpretation of small-scale erosional forms on glaciated bedrock surfaces: examples from Snowdonia, North Wales.*Proceedings of the Geologists' Association*, **93**, 403–14.
Hallet, B. and Anderson, R.S. (1980) Detailed glacial geomorphology of a proglacial bedrock area at Castleguard Glacier, Alberta, Canada. *Zeitschrift für Gletscherkunde und Glazialgeologie*, **16**, 171–84.
Kamb, B., Raymond, C.F., Harrison, W.D., Englehardt, H., Echelmeyer, K.A., Humphrey, N., Brugman, M.M. and Pfeffer, T. (1985) Glacier surge mechanism: 1982-1983 surge of Variegated Glacier, Alaska. *Science*, **227**, 469–79.
Sharp, M., Gemmell, J.C. and Tison, J.-L. (1989b) Structure and stability of the former subglacial drainage system of the Glacier de Tsanfleuron, Switzerland.*Earth Surface Processes and Landforms*, **14**, 119–34.
Sharpe, D.R. (1987) Glaciomarine fans built within and marginal to the Champlain Sea. In *Quaternary of the Ottawa Region and Guides for Day Excursions* (ed. R.J. Fulton). (XII INQUA Congress). National Research Council of Canada, 63–74.
Sharpe, D.R. and Shaw, J. (1989) Erosion of bedrock by subglacial meltwater, Cantley, Quebec. *Geological Society of America Bulletin*, **101**, 1011–20.
Shaw, J. (1988) Subglacial erosional marks, Wilton Creek, Ontario.*Canadian Journal of Earth Sciences*, **25**, 1256–67.