Alturlie Point and the Alturlie Gravels Formation

Jon Merritt and Callum Firth

Alturlie Point is formed of a series of roughly east-west-orientated ridges that reach a maximum elevation of about 31 m OD (Firth, 1984, Merritt, 1990). The promontory offers a good viewpoint from which to consider the evidence of relative sea-level change around the Inverness Firth in general (Merritt et al., 2017), and it contains morphological evidence for shorelines at 29.3, 23.2, 16.6, 14.7 and 11.8 m OD (Firth, 1989a) (Fig. 20 & 21). It is the type area of the *Bothyhill Gravels Member* of the *Alturlie Gravels Formation* (Merritt et al., 1995), which stretches eastwards from Alturlie Point within the 'marine Limit' (Fig. 14). The kettled spread is generally lower-lying than the peninsula because it remained either beneath glacier ice, or sediment containing buried ice-masses, until relative sea level had fallen, possible to below 13 m OD (Firth, 1984) (Fig. 22). Although many of the sections in Bothyhill Pit [NH 715 491] (AP2) have degraded since being described by Merritt et al. (1995) and Fletcher et al. (1996), lower parts of the sequence were still exposed in 2017 and new exposures may become available.

The Bothyhill Gravels contain cobbles of the distinctive 'Inchbae' granitic augen gneiss (Fig. 23), which have almost certainly been carried by ice from central Ross-shire via the Beauly Firth (Fig. 8). The uppermost 10 m or so of the sequence at Bothyhill is mainly formed of dense, poorly-sorted, subrounded to well-rounded, clast-supported cobble-gravel that is locally openwork, but generally has a matrix of silty sand. The gravels, composed mainly of psammite and quartzite, were observed in 1989 to be capped by up to 1.5 m of gravelly diamict filling north-east orientated channels. The gravels are poorly stratified, but cross lamination in lenses of sand indicated a north-eastward palaeocurrent flow. The lowermost 10 m of the pit reveals loose shingle interstratified with thickly bedded medium to coarse-grained sand, disposed in very large scale, tangentially based, deltaic foresets dipping east-north-east (Fig. 24 & 25). There is evidence of both syn-depositional and post-depositional slumping and faulting, the latter being related to the formation of kettleholes. An excavation in one such feature revealed a drape of rhythmically laminated silt and fine-grained sand (Fig. 26).

The sequence resembles that of a Gilbert-type delta (cf. Clemmensen and Houmark-Neilsen, 1981), although the upper unit of gravel is not typical of the fluviatile topsets of such bodies. Indeed, the silty matrix of much of this unit together with the presence of a channel-constrained, unstratified deposit of pebbly sand at its base (Fig. 27) are more typical of subaqueous fans than deltas (Cheel and Rust, 1982; Nemec and Steel, 1984). It is possible that the deposit formed initially as a grounding-line fan that developed into a glaciomarine ice-contact delta (cf. Powell, 1990). Deposits similar to, but more sandy than those exposed in the lower part of the pit at Bothyhill, were found also at Morayhill Pit [NH 7546 4961] (Fig. 14 & 28). The palaeocurrent indicators there also point to east-north-east directed flow.

The promontory clearly has been modified by marine processes whilst relative sea level dropped from about 30 m OD (Synge and Smith, 1980; Firth, 1989a). Horizontally bedded gravel with good size and shape sorting has been observed at

the entrance to the pit at 29 m OD (Firth, 1990). The ongoing debate, however, concerns whether the combined morpholological and sedimentological evidence at Bothyhill indicates uninterrupted fall in relative sea level following ice-proximal deposition during a still-stand (Firth, 1989a), or whether relative sea level might have risen during, or following that event (Merritt et al., 1995). The latter is suggested by two lines of evidence. Firstly, the unconformable base of the topset unit at Bothyhill lies at about 24 m OD, which represents the minimum relative sea level, below the influence of tidal resorting; this is typically between 2-5 m depth (Greenwood and Davis, 2000). Secondly, the rhythmically laminated and graded sediments infilling the former kettlehole within the pit (Fig. 24 F) suggests that fine-grained sand and silt was still raining out from turbid meltwater plumes after the topset unit had been deposited. Buried ice was probably melting whilst sea level was above 25 m OD, the approximate height of this kettlehole infill. The lowest kettle-hole on the promontory has a lip at 17 m OD (Fig. 20 A). This kettle, together with flat-bottomed basins to the south-east (Fig 20 B & C) are filled with laminated silts and clays that contained no faunal evidence (Firth, 1986).

No erratics of 'Inchbae' granitic augen gneiss have been found in the Alturlie Gravels lying north-east of Morayhill, where they were laid down a little earlier, probably before ice from the Great Glen had retreated sufficiently to allow meltwaters derived from ice flowing out of the Beauly Firth to enter the area. These older gravels assigned to the *Braicklaich Sand Member* of the formation were exposed at Mid Coul Pit [NH 774 502] (Fig. 14), where palaeochannels filled with cross-bedded sandy gravel indicated palaeocurrent directions towards N000º and 112º. However, the type section of the member is located in a small pit beside the railway at Milton of Gollanfield (Braicklaich) [NH 7861 5227] where rhythmically bedded sands are exposed (Fig. 29). The basal 5.5 m thick unit consists of planar, 20 to 40 cm-thick beds of fine-to medium-grained sand, each grading upwards into silt, the relative thicknesses of sand and silt being about 4:1. The planar lamination in the sand beds merges north-westwards into stoss-side preserved climbing ripple cross-lamination (Merritt et al., 1995). The sands are cut by south-east directed channels containing tangentially cross-laminated medium-grained sand and the whole sequence is capped unconformably by cross-bedded gravel containing sparse rip-up clasts of sand. The rhythmic bedding seen in the lower unit is reminiscent of that commonly developed in the Ardersier Silts Formation (see **Ardersier Peninsula**), representing cyclosams typical of ice-proximal glaciomarine sedimentation (cf. Cowan and Powell, 1990; Mackiewicz et al., 1984). The truncation of the lower unit by channel-constrained, cross-stratified sands and gravels suggests that water level was dropping during the accretion of the sequence, which probably formed as a subaqueous fan.

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Figures

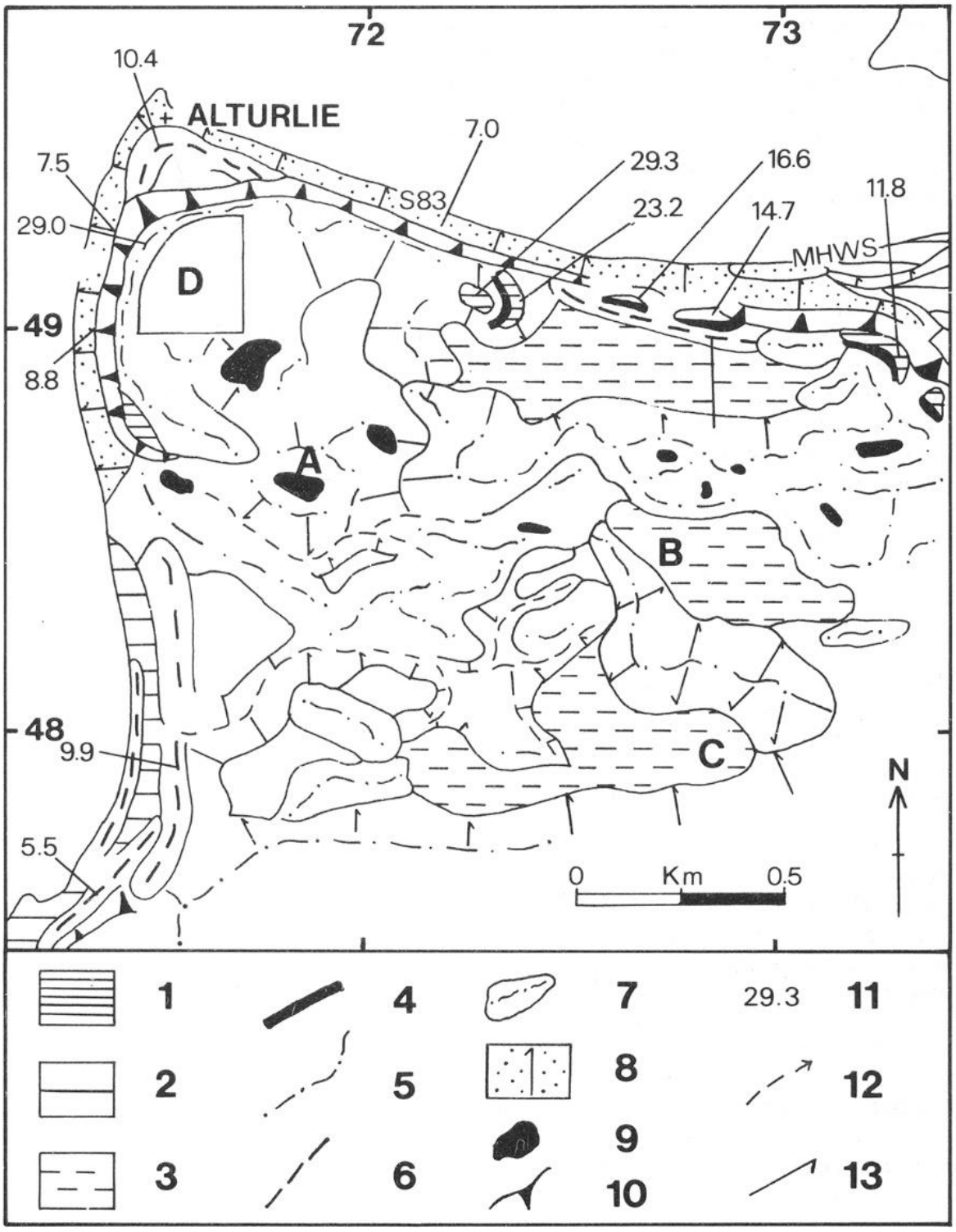

Figure 20. Geomorphological map of Alturlie Point (from Firth, 1990). (1) Late-Devensian raised beach, (2) Holocene raised beach, (3) silt and clay-filled ice decay hollow, (4) raised shoreline fragment, (5) ridge, (6) shingle ridge, (7) kame, (8) sloping marine terrace, (9) kettle hole, (10) degraded raised cliffline, (11) altitude of

raised beach or shoreline fragment (m OD), (12) former channel, (13) general slope. Localities A-D mentioned in the text.

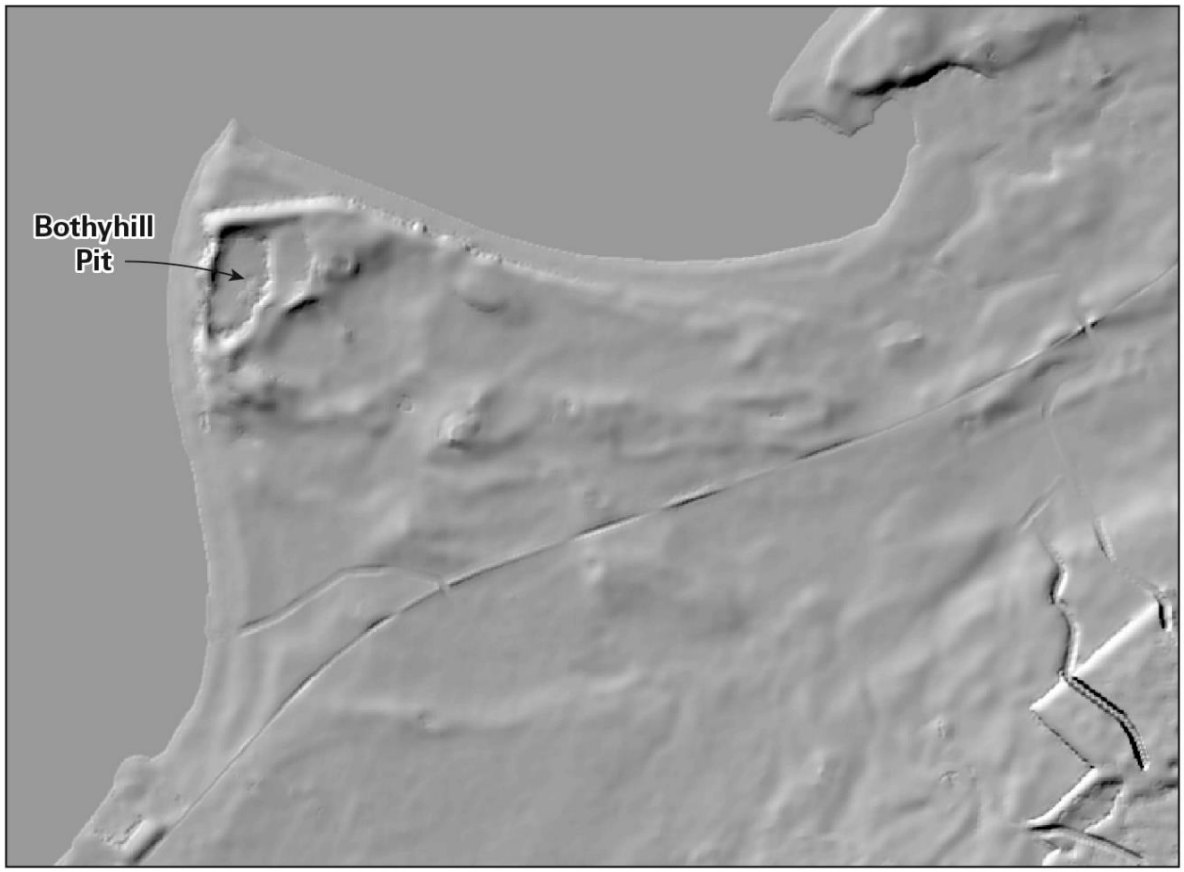

Figure 21. NEXTMap hill-shaded digital surface model of the Alturlie promontory built from Intermap Technologies NEXTMap Britain elevation data.

Figure 22. Kettlehole on Alturlie Point (Fig. 20 A), looking northwards.

Figure 23. Boulder of 'Inchbae' granitic gneiss from Bothyhill Pit.

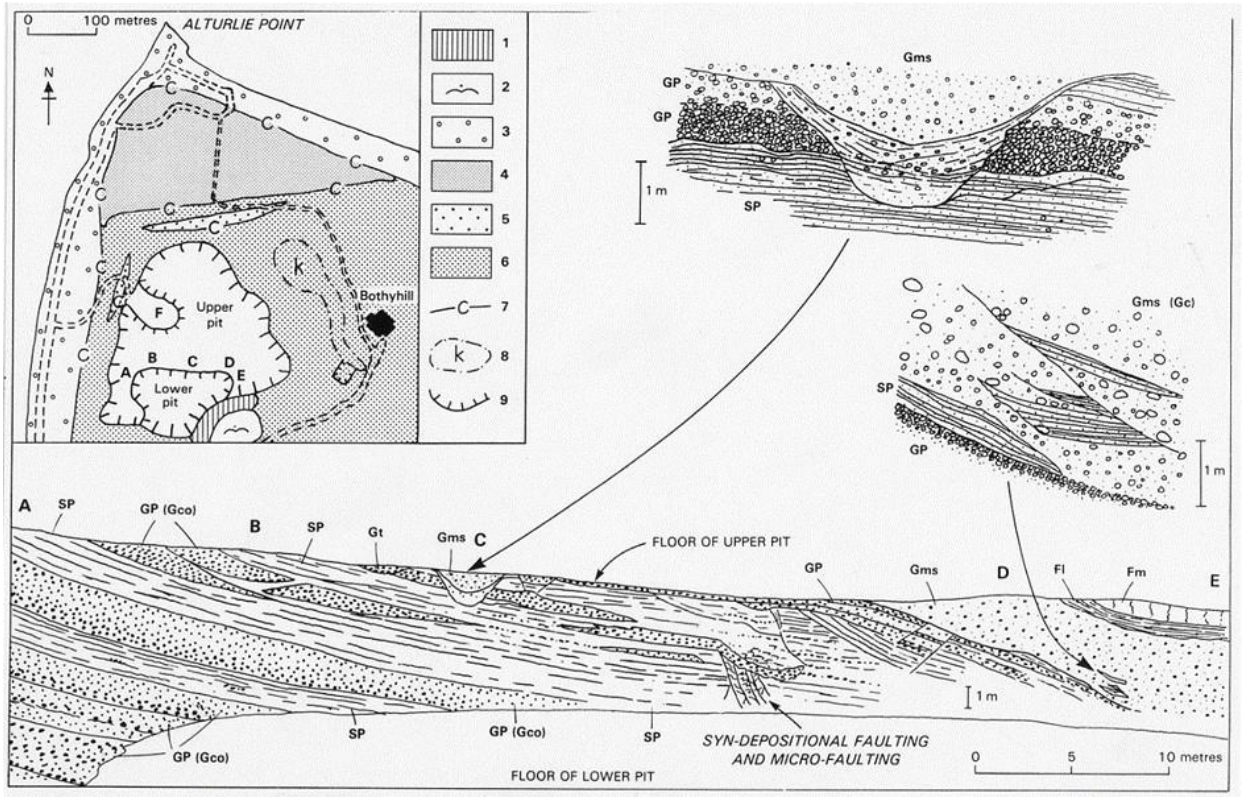

Figure 24. Cross-section through deltaic-style foresets exposed in the lower part of Bothyhill Pit (from Merritt et al., 1995). Inset: (1) Made ground, (2) Peat, (3) Holocene raised beach, (4) Late Devensian raised beach at 10.4 m OD, (5) Late Devensian raised beaches at 20 to 24 m OD, (6) Bothyhill Gravels forming undulating topography, (7) Back feature of raised cliffline, (8) Kettlehole, (9) Quarry face (1989).

Figure 25. Shingly foresets in the lower part of Bothyhill Pit (Fig. 24 A).

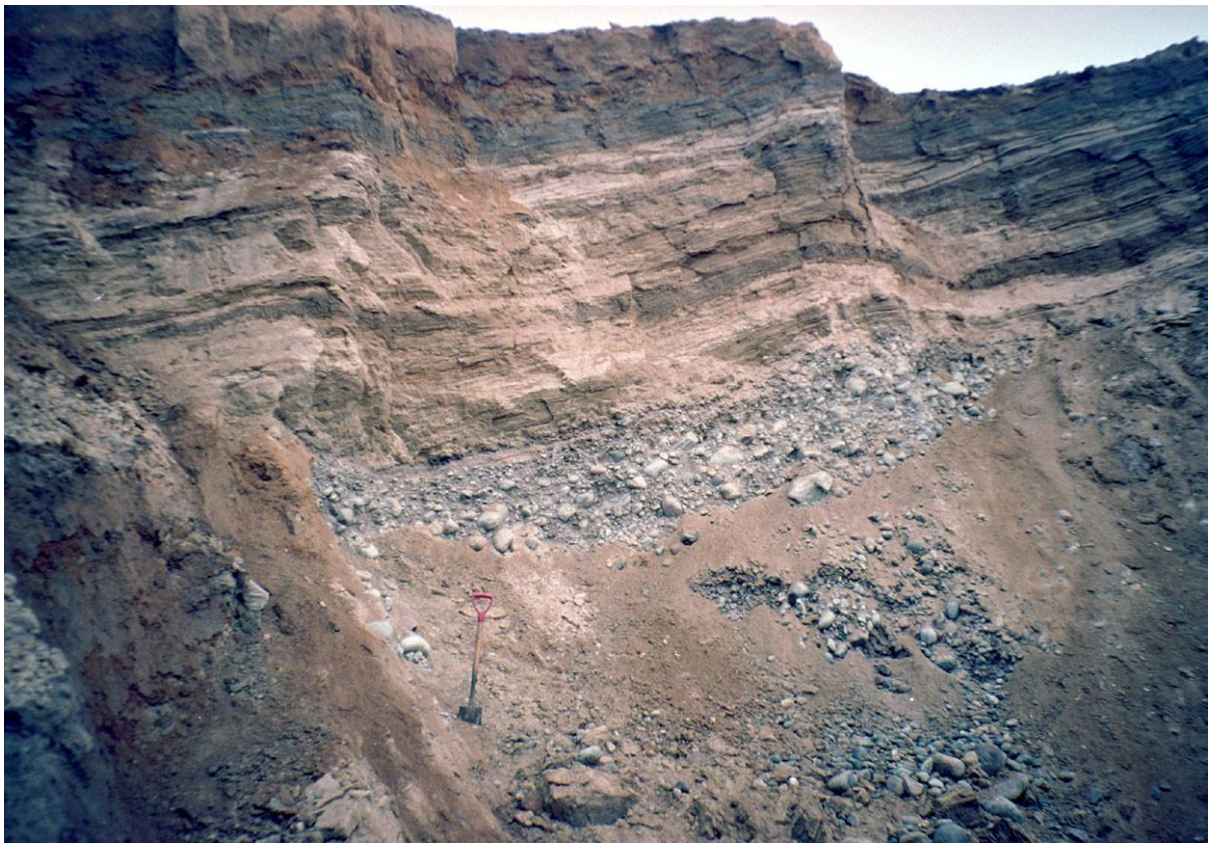

Figure 26. Kettlehole infill (Fig. 24 F) revealing rhythmically laminated silt and very fine-grained sand.

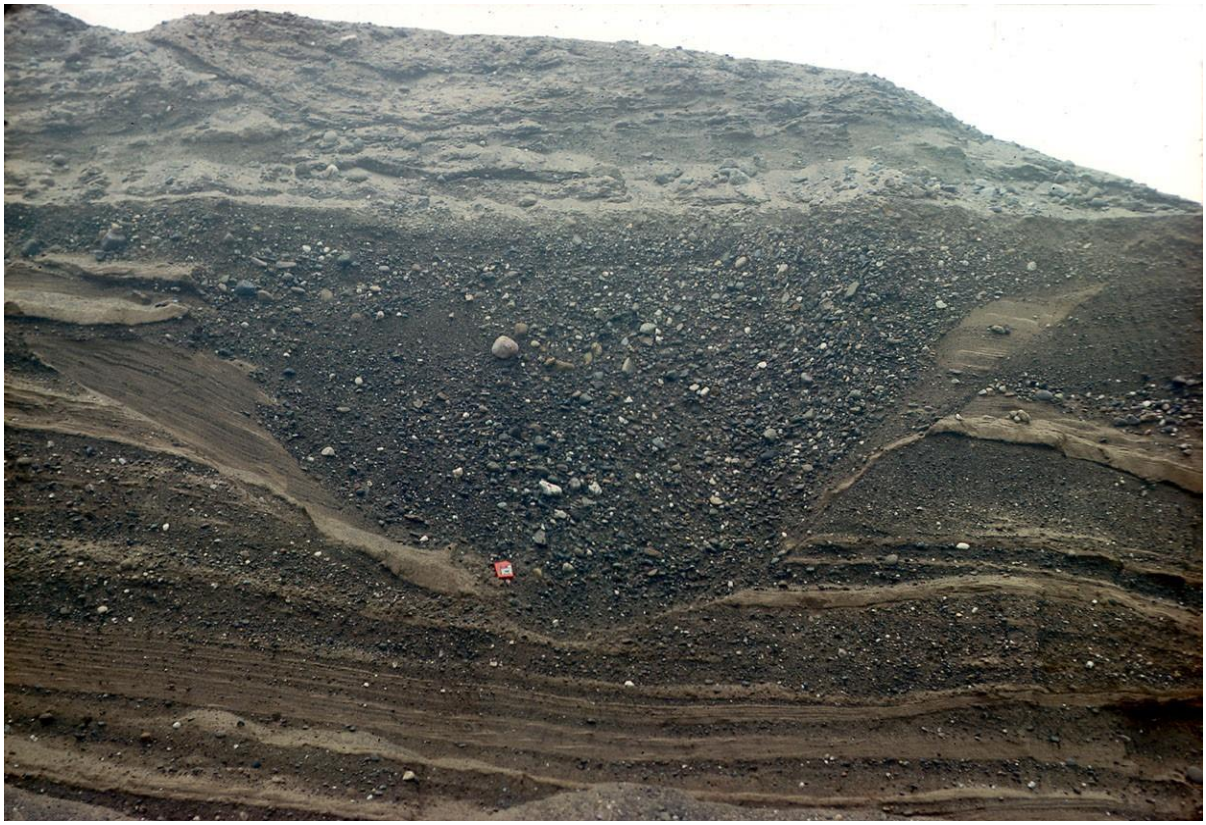

Figure 27. Channel filled with a cohesionless debris flow deposit (Fig. 24 C). Red tape measure is about 6 cm square.

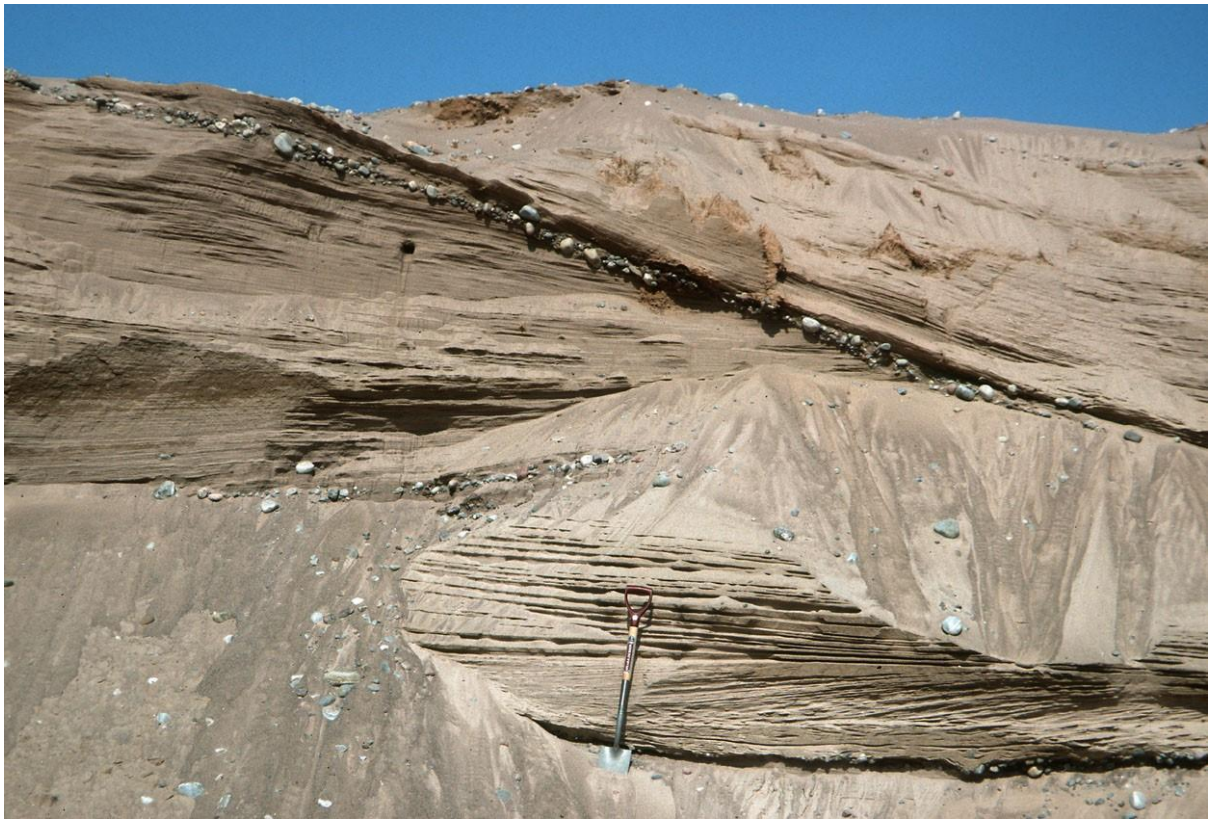

Figure 28. Large-scale trough cross bedding in the Alturlie Gravels at Morayhill Pit (1989).

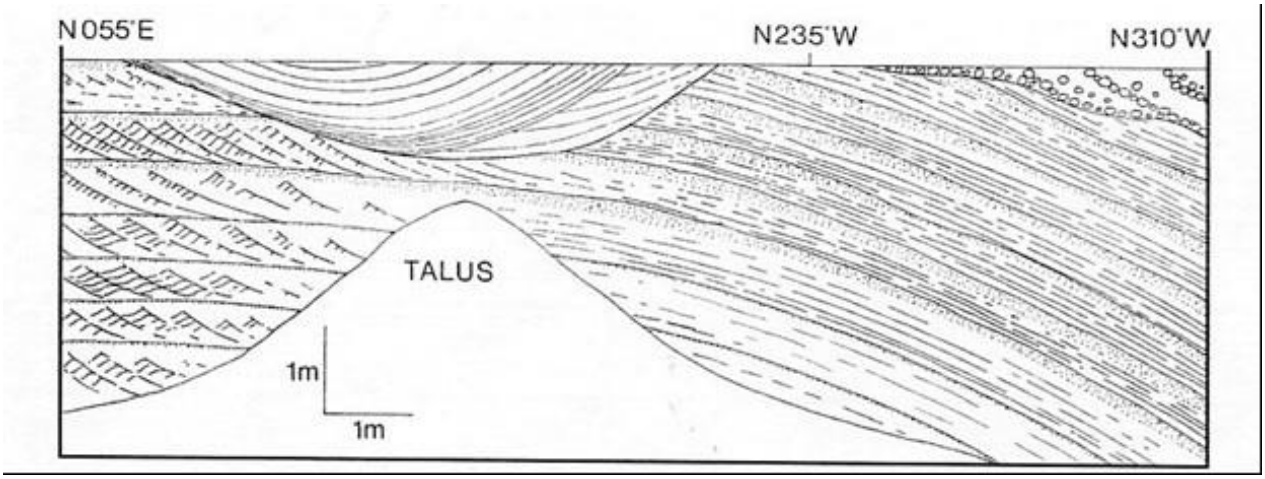

Figure 29. Section in the Braicklaich Sands Mb of the Alturlie Gravels Fm at Milton of Gollanfield [NH 7861 5227], facing south-eastwards (from Merritt et al., 1995). Top of section at c. 20 m OD.