Transverse ridges around Mosstowie, near Elgin, and elsewhere around the Inner Moray Firth.

Jon Merritt, Clive Auton and Andrew Finlayson

Sets of broadly NNW to SSE trending, transverse ridges occur on Culloden Moor (**Upper Strathnairn**), around **Easterton** and along the Roseisle-Covesea Ridge, east of **Grange Hill**. Vestiges of ridges that have been ploughed-out occur in intermediate areas. The features are well-developed to the south-east of Grange Hill, around Mosstowie [NJ 156 609], 5 km west of Elgin (Finlayson et al., 2007) (Fig. 55).

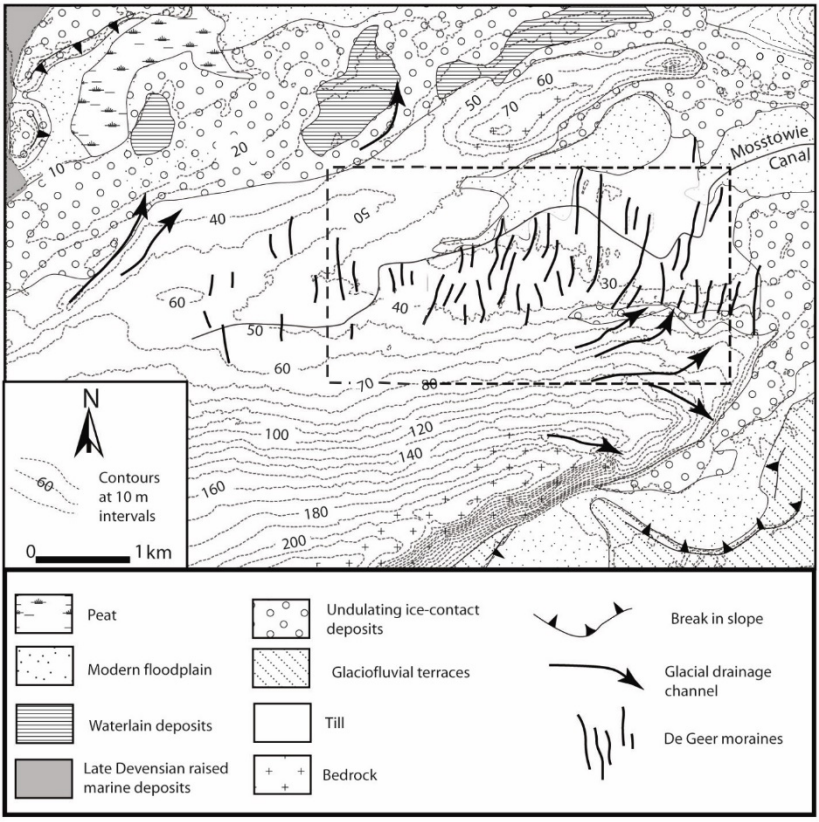

Figure 55. Geomorphological map of the Mosstowie Canal area, west of Elgin, with superficial geology simplified from Institute of Geological Sciences (1969).

The area around Mosstowie and Elgin is similar in many respects to the coastal lowland between Inverness and Nairn. Fragmentary Late Devensian raised shorelines occur at elevations of up to 26 m OD and many of the higher ones apparently pass laterally into glaciofluvial spreads (Peacock et al., 1968). Much of the ground within the marine limit has a 'washed-over' appearance and many kettleholes occur below the elevations of the higher shorelines. Some of the lower, kettled raised marine flats (< 20 m OD) are known to overlie fine-grained sediments of the *Spynie Clay Member* of the *Errol Clay Formation* (Merritt et al., 2003; 2017). These muds include a low-diversity, high-Arctic fauna including the mollusc *Portlandia arctica*, similar to the Errol Clays of eastern Scotland, which have yielded radiocarbon ages between 12.8 and 14.3k ^{14}C a BP (c. 14-16k cal. BP) (Peacock, 1999). The Spynie Clay includes large dropstones and lenses of diamict indicating the presence of an ice front nearby (Peacock, 1999). These deposits lie within the limits of the Elgin Oscillation established by Peacock et al. (1968).

The transverse ridges occurring around Mosstowie are generally 3 to 7 m high, 50 to 90 m wide, and 200 to 1220 m long, and traverse topographic undulations of up to 20 m. The major ridges have an average spacing of 190 m. Described as 'esker-like ridges' by Peacock et al. (1968) these NNW to SSE-aligned features (Fig. 55) lie within a complex of glaciofluvial and glaciolacustrine deposits (IGS, 1969; Merritt et al., 2003, map 1). Ice marginal glacial drainage channels are associated with the edge of the zone of where the ridges are developed; they are particularly well developed abutting the higher ground to the south (Fig. 56). Small-scale flutings are sporadically developed between the major ridges. These are aligned at an acute angle to the major ridges and are typically tens of metres in length and less than 1m in height.

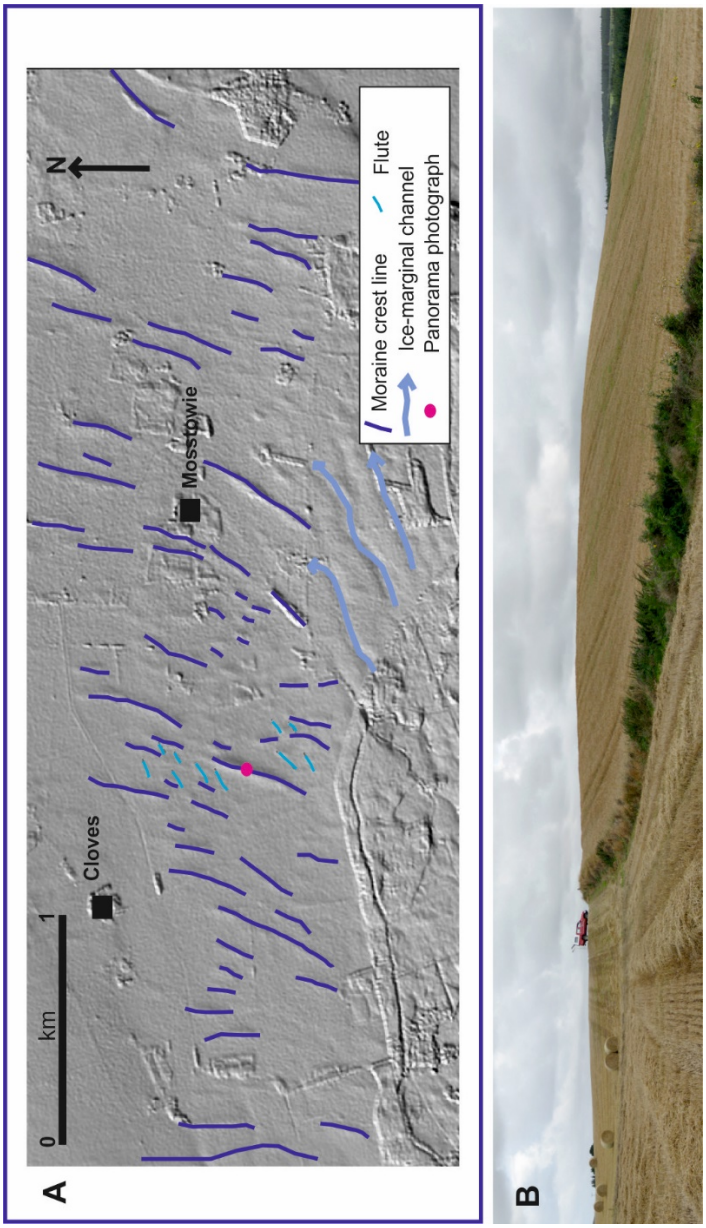

Figure 56. A) Hill-shaded digital surface model showing transverse ridges around Mosstowie. Surface model built from NEXTMap Britain 5 m topographic data with illumination from the north-west. B) Panorama photograph, looking eastwards, of a major transverse ridge c. 1 km west of Mosstowie.

Exposures in the Mosstowie ridges are sparse, but augering suggests that most of the ground between the ridges, and the crests of the ridges themselves, are underlain by red-brown till similar to that seen at **Easterton**. A thinly interbedded sequence of gravels and weakly laminated maroon and red brown silts was however, exposed at the base of one of the ridges near Mosstowie (Fig. 57). This suggests that at least parts of the sequence were formed in association with ponded water, but there is little evidence of thick, extensive spreads of glaciomarine or glaciolacustrine sediment in the immediate vicinity of Mosstowie.

Figure 57. Interbedded gravels and weakly laminated maroon and red brown silts, exposed at the base of a transverse ridge near Mosstowie.

The ridges at Mosstowie have been compared with similar, particularly well-preserved transverse ridges on the Tarbat Ness peninsula (Fig. 58), on the northern coast of the Moray Firth (Finlayson et al., 2007). Those closely spaced ridges traverse topographic undulations of up to 30 m and also occur inland, and at significantly higher elevations than Late Devensian raised marine deposits and related shoreline features on the peninsula. Originally interpreted as 'long drumlins' by Peach (1913), they are up to 6 m high, 40 to 90 m wide and 140 to 1120 m long. Ridge spacing ranges from 80 to 280 m (average of 147 m; n = 54).

The ridges at Mosstowie and Tarbat Ness lie at a similar altitudinal ranges of 25 and 55 m OD.

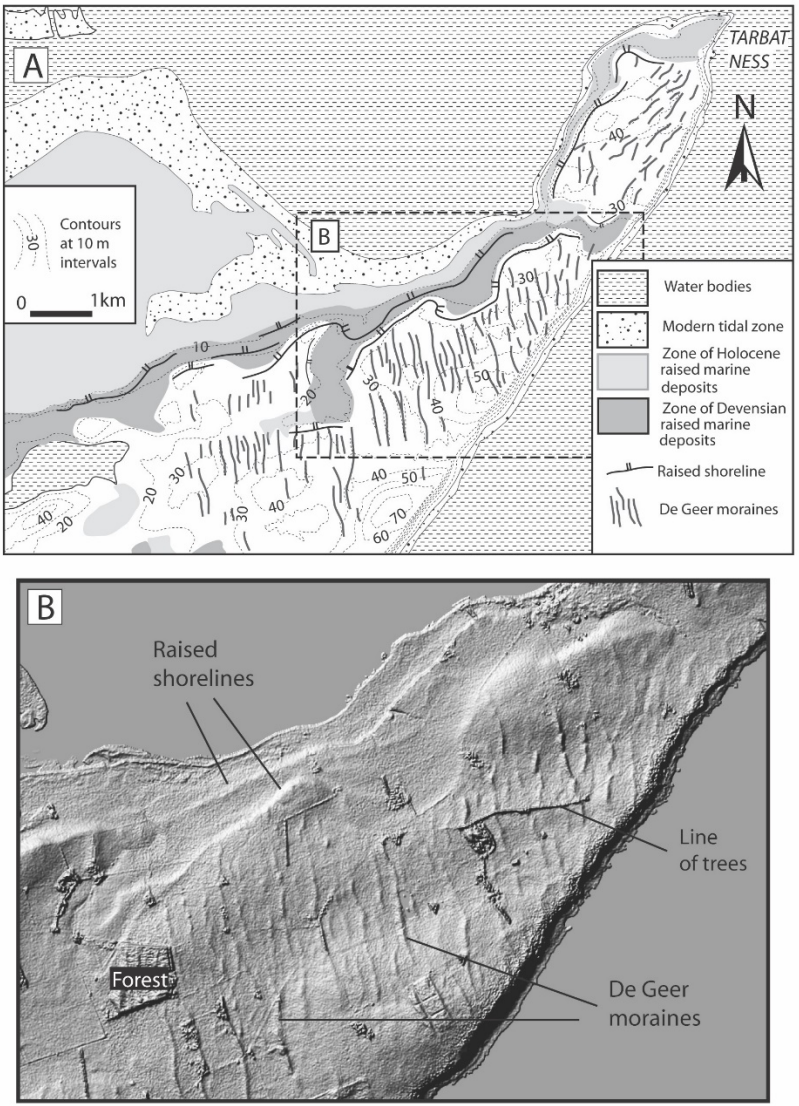

Figure 58. A) Geomorphological map of the Tarbat Ness area with superficial geology simplified from Institute of Geological Sciences (1972). B) Hill-shaded digital surface model showing transverse ridges and raised shorelines on the Tarbat Ness peninsula. Surface model built from NEXTMap Britain topographic data with illumination from the north-west.

Cross-profile analysis of a selection of ridges reveals a generally symmetrical to slightly asymmetrical profile with a tendency for east-facing slopes to be steeper (Finlayson et al., 2007). Networks of narrow, sometimes anastomosing, transverse ridges have been observed in the forelands of surging glaciers (Boulton et al., 1996; Evans et al., 1999; Evans and Rea, 2005). 'Crevasse-fill' or 'squeeze' ridges such as these are believed to form as sediment is squeezed into basal crevasses in highly fractured glaciers following surging. The ridges on Culloden Moor are tentatively interpreted thus by Fletcher et al. (1996), although Merritt et al. (1995) had suggested that they represented winter push moraines (cf. Boulton, 1986). However, the length, height and spacing of the ridges on Tarbat Ness and around Mosstowie are more characteristic of De Geer moraines that have been observed elsewhere to have formed in a subaqueous environment at, or near retreating ice margins (Larsen et al., 1991; Blake, 2000; Linden and Moller, 2005; Todd et al., 2007). Interestingly, Todd et al. (2007) report De Geer moraines traversing bathymetric ranges of up to 25 m, which is compatible with the ridges described here that trend across topographic undulations of up to 30 m.

Despite varying interpretations of their mode of formation, a regional view of the ridges between Culloden Moor, Easterton and Mosstowie shows that they all display a transverse alignment to former ice flow. It is also evident that the features generally increase in height and length in an easterly or east north easterly direction, i.e. away from the direction of ice front retreat within the Moray Firth.

Finlayson et al. (2007) concluded that the ridges on Tarbat Ness mark successive former marine grounding line positions, whereas those around Mosstowie alternatively could have formed when the ice margin terminated in an ephemeral ice-marginal lake (Fig. 13). If the tidewater interpretation is correct, the altitudes of both sets of the ridges (< 55m OD) would provide one of highest indicators of former relative sea-level in the British Isles (Fig. 59). The remarkable preservation of the ridges may then be explained if a rapid fall in relative sea level occurred whilst sea-ice remained throughout much of the year and before open water coastal processes could erase the features (Finlayson et al., 2007). A similar environment has been inferred for the deposition of the Errol Clay

Formation (Peacock, 1999) and would explain the rhythmic, graded bedding observed in the Ardersier Silts.

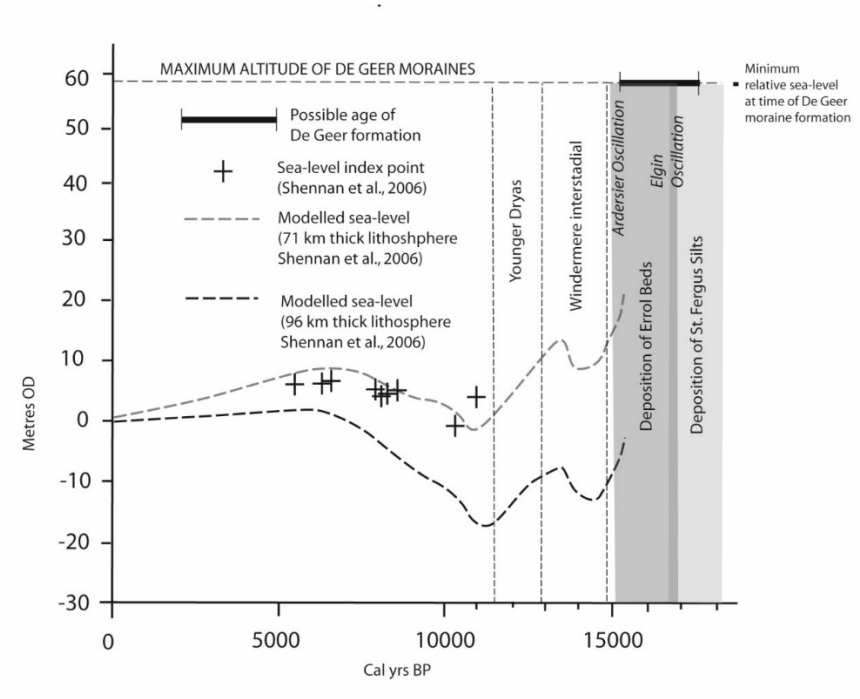

Figure 59. Observations (sea-level index points) and model predictions for relative sea-level change in the Moray Firth area (from Shennan at al., 2006), the altitude and suggested age range of De Geer moraines and ages of raised glaciomarine formations in north-east Scotland (after Merritt et al., 2017).

Viewpoints: In the area of this field guide, the transverse ridges to the west of Elgin occur on cultivated land and are best viewed in low angled light conditions from the road linking Whitefield [NJ 173 604] and Garrowslack [NJ 149 603]. On the other side of the Moray Firth, the De Geer moraines at Tarbat Ness can be viewed from the B9165 road, a few kilometres to the west of Portmahomack.