Site 4.7. Thornhill Drumlin
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Introduction

The drumlins in the West of Ireland represent some of the best exposed features in the whole of Britain and Ireland, and have been studied by numerous researchers (Close, 1867; Synge, 1968, 1969; McCabe, 1985, 1991; Hanvey, 1987, 1992; Coxon and Brown, 1991). The drumlins along the edge of Clew Bay (figure 1) and were thought to be formed during the Midlandian (Weichselian) Glaciation which had a low angled ice margin in Clew Bay (Synge 1963, 1968) although the maximum limit out to the west is not known.

Clew Bay is the seaward continuation of the Central Plain of Ireland, surrounded by mountains. It consists of a faulted syncline of Carboniferous rocks flanked by Old Red Sandstone and Dalradian metasediments. The most detailed recent study of these drumlins was carried out by Hanvey (1992). She suggested that there are approximately 630 drumlins which are found along the sides of the

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![Figure 4.7.1. Map of the area based on LANDSAT TM imagery and field observations (after Coxon and Browne, 1991).]
bay and also within the bay as islands (figure 4.7.2). They are found mostly on the limestone and below 70m a.s.l. (Hanvey, 1992). Lateral moraines are found around the bay (Synge, 1963) but drumlins are found both inside and outside of them.

![Figure 4.7.2. Profile of Clew Bay island drumlins.](image)

There are many theories for drumlin formation (Menzies, 1979; Shaw, 1983). Rose (1987) argues that drumlins are part of a subglacial continuum, from flutes to drumlins and megaflutes/mega-scale glacial lineations to streamlined hills. This is useful model as any theory to explain drumlins, must also be scalable. Boulton (1987) suggested that drumlins are associated with a subglacial deforming bed, and Hart (1997) outlined a drumlin structure continuum comprising depositional, deformational and erosional drumlins (with the later being the most extensive). More recently, Clark et al., (2003) have argued that mega-scale glacial lineations are cut by ice keels, that carve grooves in the deformable till, and plough up weak till into ridges. However, any model for drumlin formation needs to be related to the sedimentology and structural geology of the drumlins themselves.

**Sedimentology**

Three drumlins are described from the southern shore of Clew Bay, although only Thornhill will be examined on the excursion (figure 4.7.3). The fabric results are shown in Table 1 and figure 4.7.4.

*Turlin Drumlin (L805,820)*

The Turlin drumlin is located on the western end of Clew Bay, north of Louisburgh is found on the distal side of the Old Head peninsular formed over Old Red Sandstone. This drumlin is 24m high by 400m long and is oriented W/E (figure 4.7.3a). Most of the drumlin is composed entirely of homogeneous grey diamicton, with a weak fabric strength orientated W/E. On the lee-side there is a lower fine-grained stratified diamicton which has a medium strength fabric oriented to the NE/SW. This is overlain by the homogeneous grey diamicton which has either a sharp base, or a striated boulder pavement. On the stoss side, bedrock is exposed, immediately above this the diamicton is coarser with some very large clasts (a-axis 1m) dipping up ice and a high fabric strength. However, the grey homogeneous diamicton 1m above it has a
Figure 4.7.3. Drumlin profiles: a) Turlin, b) Fallduff, c) Thornhill
Figure 4.7.4. Eigenvalue data. HD = Homogeneous diamicton, SD = Stratified diamicton

much lower fabric strength.

Fallduff (L841 820)

The low relief drumlin at Fallduff also shows a number of different facies (figure 4.7.3b). The lee-side has three layers; a lower diamicton with ungraded fine (2mm thick) sand layers which drape clasts. The intermediate layer is a diamicton with graded sand layers and a low fabric strength. The upper layer is the homogeneous grey diamicton with a low fabric strength. This upper diamicton comprises most of the drumlin and a further fabric taken in the centre has a medium strength fabric. All the fabrics at this site are oriented NW/SE.

Towards the stoss-side of the drumlin the lower part is comprised of discontinuous folded, sheared and thrusted lenses of gravel rich diamicton, normal grey diamicton, and laminated sandy diamicton. In places these units appear to be deformed by glaciotectonic deformation (figures 4.7.5a and b), whilst in other places the relationship between the units is sedimentary. At the very stoss-side the drumlin has a series of large faults (average dip 13°; strike 78°). Slightly to the west of these there are some more faults running up through the till with an average strike of 101°, dip 17°.

Thornhill (L888 828)

The Thornhill Drumlin is situated below Croagh Patrick Mountain and overlies limestone bedrock. This drumlin is orientated east/west and has a maximum
Figure 4.7.5. Deformation of the homogeneous and stratified diamicton at Falduff: a) folding; b) shearing and hydrofracture.
Figure 4.7.6. Thornhill: a) lower stratified diamicton and upper homogenous diamicton, b) upglacier oriented shears through the Stratified Diamicton.
height of 26 m (figure 4.7.3c). The stoss-side and central part of the drumlin is composed of a grey clay-rich homogeneous diamicton.

On the lee-side of the drumlin there are two diamicton layers (figure 4.7.6a). Below the homogeneous diamicton described above, there is a lowermost unit of stratified grey clay-rich diamicton (stratified diamicton) which increases in clast density upwards through the sequence. Within this unit fine grained units and small scale onlapping units are found. The beds consist of fining upwards rhythmites of 20-60 cm. In places there are sand lenses and channel features, and interbedded units of homogenous and stratified diamicton. These have a weak fabric and the fabric is orientated NE/SW. Above the stratified diamicton there is a further unit of grey homogeneous diamicton. The drumlin is capped by a unit of sand and gravels. In the lee-side these contain very large angular (2 m x 2 m) clasts.

Within the stratified diamicton there are three styles of deformation. In places the beds have been folded into an anticline, and there are some small scale reverse faults which are oriented in the ice direction (average strike 138°, dip 11°). However the lee-side of the drumlin is dominated by faults, which orientated upglacier. There are approximately 40 such faults which only appear to effect the stratified diamicton. The average strike of these is 168° with an average dip of 43°. The throw on the faults is small (2 cm) but gravels and sands have moved up into them. In places the faulting shows propagation horizontally along the fine beds but at a high angle through the coarser beds (figure 4.7.6b).

**Facies Interpretation**

All three drumlins are composed of two types of till: a homogeneous grey diamicton and a stratified diamicton. figure 4.7.7 shows a composite of the three drumlins with mean fabric directions of the different facies and direction of shears. The homogenous diamicton is highly orientated at its base, and less well oriented throughout the rest of the sequence where it is oriented along the drumlin axis. It contains striated boulders, and evidence of folding and shearing. This sequence probably represents lodgement at the base and a deformation till elsewhere (Hart and Boulton, 1991; Hart, 1994). The results showed that the stratified diamicton tends to have a lower fabric strength, and the fabrics were oriented away from the drumlin direction. This unit is more likely to represent a subaqueous till formed by debris flows.

At Turlin the stratified diamicton is only found on the lee-side, and has a distinct erosional upper contact (and boulder pavement). At Fallduff the stratified diamicton is relatively undisturbed on the lee-side, and present but tectonically incorporated into the homogeneous diamicton in the rest of the drumlin. At Thornhill the stratified diamicton is relatively undisturbed on the lee-side (with a sharp upper contact), and present but deformed in the central part of the drumlin.
Drumlin forming process

These three drumlins have no significant carapace, but have deformation on the stoss-side. The lee-sides all have horizontal bedding which has been truncated by the drumlin form and show no deformation on the lee-side except at Thornhill.

It is suggested that subaqueous till was laid in proglacial water bodies during an initial advance, but this was later overrun by the glacier and a lodgement till and then a deforming till was deposited. Under conditions of increased velocity or decreased sediment supply, drumlinisation occurred (Hart, 1997). However this was not just a passive erosional process, because of the presence of internal deformation. The deformation included shearing, folding and tectonic mixing of the subglacial and subaqueous till. In places, the till is deformed by small scale hydrofracturing as water escaped from the section during deformation and transported sediment with along the shears (figure 4.7.5b) (Brown and Philips 2003). The stoss-side shears and lee-side down glacier shear reflect compressive deformation associated with the drumlin forming process. The lee-side upglacier shears at Thornhill probably also reflect larger scale hydrofracturing as water escapes away from the drumlin core.

In contrast, McCabe et al. (1992) suggested that the drumlins formed due to rapid ice wastage associated with glaciomarine conditions (Eyles and McCabe, 1989), which they suggested is supported by the glaciomarine sedimentary evidence and the low lying lateral moraines along he mountain slopes (Synge, 1968). Alternatively, it is suggested here that the subaqueous tills were formed either in a lacustrine or glaciomarine environment, associated with proglacial ponding during ice advance.
The drumlin event was associated with the glacier overriding the subaqueous tills, and forming deformational drumlins, because the drumlin core was relatively weak. The low slopes could be explained by low angled glacier moving over the deforming bed.

**Conclusion**

The drumlins of Clew Bay comprised two diamicton facies with complex internal deformation structures. There was a stratified till, with a low fabric strength and high directional variation which was interpreted as a subaqueous till, and an homogenous till with slighter higher fabric strength aligned with drumlin direction which was interpreted as a subglacial deformation till. However during drumlinisation, the stoss side of the drumlin was deformed, by both ductile and brittle deformation, to produce a series of deformational drumlins.