Cam Loch

[NC 225 148]–[NC 232 126]

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Introduction

The Cam Loch GCR site exposes an erosional remnant of Lewisian gneisses and Cambrian quartzites in a tectonic outlier of a thrust sheet (known as a ‘klippe'). The Cam Loch Klippe is the largest and best known of at least ten klippen in the Assynt Culmination (Figure 5.32), and lies the farthest west. Klippen can be useful in estimating thrust displacements, if they can be correlated with thrust sheets deeper in the thrust belt (as for example in the Faraid Head GCR site). However, whilst some klippen can be readily linked with larger thrust sheets, the correlation of the Cam Loch Klippe has been controversial. For Peach *et al.* (1907), the klippe represented the erosional remnants of a single, continuous sheet carried on the Ben More Thrust, a conclusion supported by Elliott and Johnson (1980) who correlated the structural content of the klippe with the main Ben More Thrust Sheet. However, Bailey (1935) considered them to be individual thrust-bounded 'parcels', and Coward (1985) proposed that the klippen represent other thrust sheets, in addition to the Ben More Thrust Sheet.

All of the klippen in the Assynt Culmination contain Cambrian quartzites, and four include the stratigraphically underlying Lewisian or Torridonian units. They may be grouped into four sets. The klippen of Beinn nan Cnaimhseag [NC 274 178] and Beinn an Fhuarain [NC 262 159] both contain Torridon Group strata and constitute the Assynt klippen of Elliott and Johnson (1980) (Figure 5.32). They are likely to be parts of the Ben More Thrust Sheet. An array of small outliers of False-bedded Quartzite and Pipe Rock form the Ledbeg klippen, distinct in turn from the main Cam Loch Klippe. The fourth set, the Cromalt klippen lie adjacent to the Moine Thrust in southern Assynt, and are described in the Knockan Crag GCR site report (this chapter).

The Cam Loch GCR site also provides crucial constraints in relating folding to thrusting processes. For Elliott and Johnson (1980) the folds within the Cam Loch Klippe are part of their 'Sgonnan Mòr family' (see Sgonnan Mòr–Dubh Loch Beag–Upper Glen Oykel GCR site report, this chapter), an interpretation central to linking the klippe with the Ben More Thrust Sheet. They interpret the folds as entirely predating the thrust upon which they have been carried and recognize no thrust-fold link. Alternatively, a thrust-fold causative relationship may be readily postulated.

The klippe is also important in establishing the relationship between thrusting and intrusion episodes associated with the Loch Borralan Pluton (Parsons and McKirdy, 1983). To the south-east of the designated GCR site, recently excavated exposures within the klippe show quartzites intruded by syenites and pyroxenites of the Loch Borralan Pluton (location 're on (Figure 5.32)). These relationships suggest that the Cam Loch Thrust has been cut by the intrusions, and therefore emplacement predates their intrusion at *c.* 430 Ma (van Breemen *et al.,* 1979a).

Description

Within the Cam Loch GCR site, the eponymous klippe consists of Lewisian basement together with its Cambrian cover of False-bedded Quartzite and, locally, Pipe Rock (Figure 5.33)a. These units are well exposed in a major fold, termed here the Innse–Ruaidhe Anticline', which faces north-west and has a strongly overturned forelimb (Figure 5.33)b. Cross-bedding in the quartzite gives younging directions away from the Lewisian in the fold core. Locally the quartzites contain minor rhyolitic dykes that have been sheared, presumably during folding; one such dyke at Creag na h-Innse Ruaidhe [NC 224 140] is described in the *Caledonian Igneous Rocks of Great Britain* GCR Volume (Parsons, 1999).

Although not shown on published maps (e.g. Geological Survey of Great Britain, 1923; Johnson and Parsons, 1979), the summit region of Cnoc an Leathaid Bhig lies in the Pipe Rock on the normal limb of the Innse-Ruaidhe Anticline. These strata can be traced around the fold onto the forelimb where they are overturned. The Innse-Ruaidhe Anticline is related

to the hangingwall ramp of Lewisian rocks against the thrust that carries the Cam Loch Klippe. As such it has the geometry of a so-called 'thrust-propagation fold' (Williams and Chapman, 1983) in which the formation of a thrust ramp is pre-conditioned by buckling.

The footwall to the Cam Loch Klippe is generally poorly exposed. Above Cam Loch itself, Lewisian gneisses overlie Pipe Rock (Johnson and Parsons, 1979). The thrust is not exposed, but nearby structurally higher Lewisian outcrops are mylonitic, with a SE-dipping foliation. The quartzites in the immediate foot-wall contain cataclasite seams. The continuity of this sheet of Pipe Rock in the footwall is obscure. There are no exposures in the region of Cul na h-Innse Ruaidhe (Figure 5.33)a save for isolated portions of the foreland succession. It is likely that the Pipe Rock forms a sheet carried with the Cam Loch Klippe onto Durness Group carbonate rocks (Johnson and Parsons, 1979).

On the east side of Cnoc an Leathaid Bhig, overturned Pipe Rock quartzites of the klippe overlie carbonate rocks of the Durness Group, at the top of the foreland succession. Thus here the thrust carrying the klippe has branched onto the regional Sole Thrust (NC 223 142; (Figure 5.32)). On the eastern side of the klippe, at Bad a' Ghille Dhuibh (NC 232 144 and [NC 231 141]), the deepest structural levels contain metamorphosed Durness Group carbonate rocks. These marbles have been folded so that the outcrops represent the crests of domal structures, and are structurally overlain by a thrust sheet of Pipe Rock. This thrust-bounded Pipe Rock unit underlies stratigraphically right-way-up False-bedded Quartzite of the klippe, but does not itself form part of the Cam Loch Klippe.

Interpretation

The importance of the Cam Loch GCR site stems chiefly from its status as a detached part of the Ben More Thrust Sheet (Peach *et al.,* 1907; Elliott and Johnson, 1980; Parsons and McKirdy, 1983). However, there are some problems with this interpretation. The approach of Elliott and Johnson (1980) assumes that thrusts developed in a regional 'piggy-back' fashion so that the structurally higher thrusts are earlier than the underlying ones. In addition, 'piggy-back' thrusts cut up-section in their transport direction. This means that strata within a thrust sheet are generally older towards the hinterland and younger towards the foreland. However, the main trace of the Ben More Thrust farther east on Sgonnan Mòr exposes Torridon Group and Cambrian rocks in its hangingwall, whereas the Cam Loch Thrust has Lewisian gneisses in its hangingwall. Hence, if the Cam Loch Thrust equates with the Ben More Thrust, it would have to cut drastically down-section. Normally, foreland-propagating thrusts that deform flat-lying strata are not expected to cut down-section, which would suggest that that the Cam Loch Klippe is not part of the Ben More Thrust Sheet, but part of a separate thrust sheet. There is further support for this interpretation; the slice of Pipe Rock that separates the klippe from the marbles at Bad a' Ghille Dhuibh (Figure 5.33)a is part of the Ledbeg klippen group, which themselves may be interpreted as part of the Ben More Thrust Sheet (Peach *et al.,* 1907). Thus the Cam Loch Klippe overlies the Ben More Thrust Sheet and presumably roots back farther to the east.

An alternative interpretation is that the Ben More Thrust cut previously folded rocks; thrusts that cut previously folded rocks can cut both up-section and down-section. This has been a traditional view of fold–thrust relationships in the Assynt area (e.g. Peach *et al.,* 1907; Johnson and Parsons, 1979), largely arising from correlations of the Sgonnan Mòr structures. As discussed in the Sgonnan Mor–Dubh Loch Beag–Upper Glen Oykel GCR site report (this chapter), these correlations are probably unsound, with the folds better interpreted as related to local thrusting processes. Exceptions exist within the Cromalt klippen, and these are discussed in the Knockan Crag GCR site report (this chapter).

For thrust correlations in southern Assynt it is also important to establish the relative timing of emplacement of thrust sheets and major igneous intrusions. Most intrusions in Assynt appear to be earlier than the (local) Scandian structures.

However, Parsons and McKirdy (1983) showed that pyroxenites of the Loch Borralan Pluton have intruded quartzites, which appear to be part of the Cam Loch Klippe (at 'ID' on (Figure 5.32)). Partly due to poor exposure, it is not clear to which thrust sheet the quartzites actually belong, nor whether the pyroxenites form a distinct intrusion within the thrust sheet. Certainly the easiest interpretation that may be reached from the field relationships is that the Loch Borralan Pluton intruded a thrust sheet (but not necessarily the Ben More Thrust Sheet *sensu stricto)* that had been emplaced onto Durness Group carbonate rocks. If so, thrusting in southern Assynt was active after the emplacement of the Loch Ailsh Pluton (439 ± 4 Ma, Halliday *et al.,* 1987) and both before and after the intrusion of the Loch Borralan Pluton (430 ±

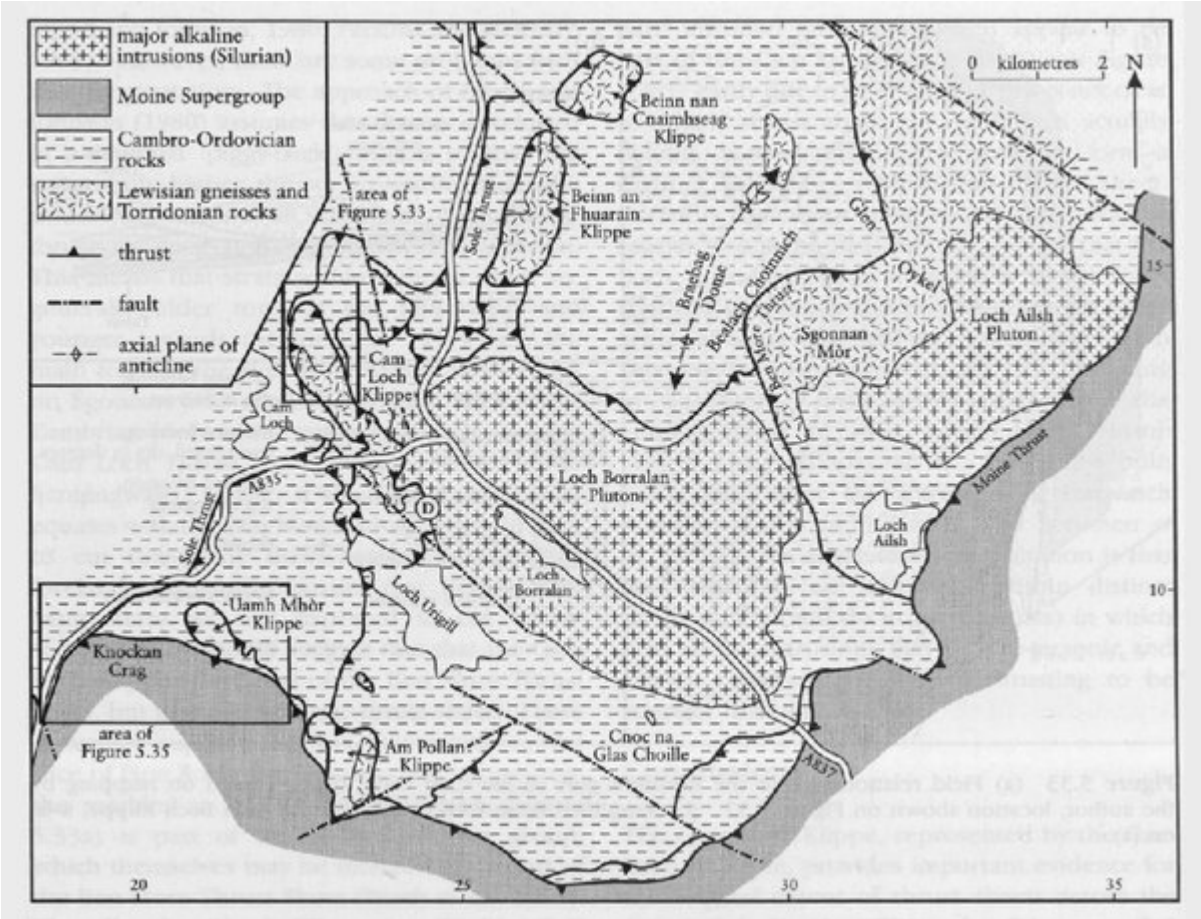
4 Ma, van Breemen *et al.* 1979a). An alternative interpretation is that the intrusions are contained within distinct thrust sheets (and do not cut thrusts) in which case all the intrusions may be pre-tectonic and merely constrain the age of thrusting to be younger than 430 ± 4 Ma.

Conclusions

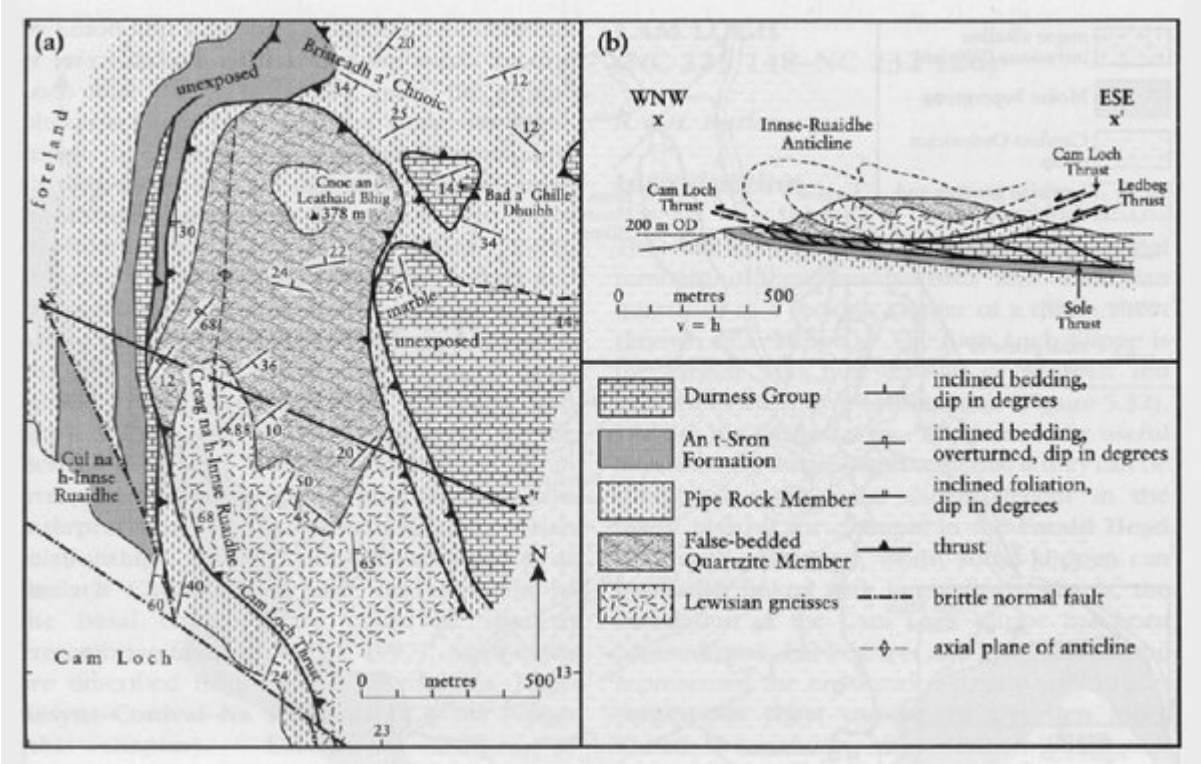
The Cam Loch Klippe, represented by the Cam Loch GCR site, provides important evidence for the original extent of thrust sheets across the Assynt Culmination. One school suggests that the klippe forms part of the Ben More Thrust Sheet, which originally enveloped almost all of central and southern Assynt. However, the interpretation favoured here is that the Cam Loch Klippe forms part of a sheet distinct from — and structurally higher than — the Ben More Thrust Sheet. Regardless of the validity of these conclusions, the site is important in providing a testing ground for methods of three-dimensional analysis of thrust structures (e.g. Elliott and Johnson, 1980; Coward, 1985).

The klippe itself contains a major anticline that faces WNW and has a strongly overturned forelimb. It is a good example of a style of deformation termed 'thrust-propagation folding', whereby thrust ramping is accompanied by a buckling component reflecting a rate of thrust propagation that was slower than that of thrust displacement. Historically this deformation style underpinned classic ideas of thrust formation developed in the Alps. However, in the Moine Thrust Belt the original surveyors rejected this requirement for thrusting to be necessarily preceded by folding, since many thrusts show very little such deformation. The Cam Loch GCR site, together with other examples of 'Sgonnan Mòr structures' within the Sgonnan Mòr–Dubh Loch Beag–Upper Glen Oykel GCR site, is important because it illustrates that both styles of thrusting, with or without preceding folding, may occur within the same thrust belt.

References



(Figure 5.32) The structural setting of the Cam Loch Klippe and other klippen in southern Assynt. LT — Ledbeg Thrust. Based on Geological Survey of Great Britain (1923), Elliott and Johnson (1980), Coward (1985) and British Geological Survey (2007).



(Figure 5.33) (a) Field relationships in the northern part of the Cam Loch Klippe (based on mapping by the author, location shown on Figure 5.32. (b) Simplified cross-section through the Cam Loch Klippe, x—x' on (a).