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# Slioch–Heights of Kinlochewe

[NG 989 707]–[NH 089 649]

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## Introduction

The ground north of Kinlochewe (Figure 5.40) provided critical evidence used by both Murchison and Nicol during their early skirmishes in the mid-19th century as part of the 'Highlands Controversy' (Oldroyd, 1990). The transect to the south-west of the mountain of Slioch, along the north shore of Loch Maree and the continuation south-eastwards to Incheril and the glen containing the Abhainn Bruachaig (formerly known as 'Glen Logan' but here termed 'Glen Bruachaig') offer spectacular large-scale views (e.g. (Figure 5.41)) of the geometrical relationships between the main rock units of the North-west Highlands (Peach *et al.*, 1907). Murchison and Geikie (1861) interpreted this transect as forming a simple, E-younging rock sequence, while Nicol (1861) saw it as disrupted by faults. The edge of the Moine outcrop in Glen Bruachaig includes outcrops of crystalline rocks, termed the 'Logan Rock' by early workers and interpreted by both teams as being of igneous origin (e.g. syenite of Murchison and Geikie, 1861). Subsequent studies by Bonney (1880), in an early example of linked field and petrological descriptions (see Oldroyd, 1990), demonstrated the Lewisian origin of the 'Logan Rock', presaging the concluding act in the 'Highlands Controversy'. Work by Peach *et al.* (1907) established the 'Logan Rock' to be Lewisian gneiss and part of the far-travelled Kinlochewe Thrust Sheet.

This GCR site has more than historical significance. Offset Precambrian structures within the Lewisian of the Kinlochewe Thrust Sheet were used by Ramsay (1969) to deduce a slip in excess of 45 km on its basal thrust, one of few such estimates made in the southern Moine Thrust Belt. Furthermore, in the lower part of Glen Bruachaig, the footwall to the Kinlochewe Thrust Sheet is exposed in a window — one of very few such structures in the entire Moine Thrust Belt. Peach *et al.* (1907) described how the footwall is made of imbricated Cambrian strata. Based on these early studies, McClay and Coward (1981) initially interpreted the Kinlochewe Thrust as forming a simple roof to the imbricate zones. However, Coward (1982) later suggested that the Kinlochewe Thrust Sheet acted as a 'surge zone' which cuts gently down-section towards the west. Work by Matthews (1984; Butler *et al.*, 2007) suggested that the down-cutting of the Kinlochewe Thrust occurred before imbrication. The site is therefore important for establishing the geometrical relationships between the major thrust sheets and the underlying imbricated foreland strata.

The Caledonian Foreland to the west also includes spectacular geology. This includes arguably the most spectacular and famous demonstration of sub-Torridonian buried landscape, on the southern slopes of Slioch. The underlying Lewisian includes dramatic amphibolite-facies thrust zones that relate to Laxfordian crustal shortening (e.g. Droop *et al.*, 1998) and the thrust repetition of Archaean continental crust onto early Proterozoic supracrustal rocks of the Loch Maree Group. Although these field relationships have not received much attention in the specialist literature, they are important as the only places on the Scottish mainland where simple crustal thickening structures are exposed as part of the Lewisian Gneiss Complex (see Chapter 3 for an introduction to the Lewisian gneisses in northwest Scotland). This is one of only a few sites within this GCR volume that straddles two major geological elements of the North-west Highlands. It is therefore an excellent place for building up a geological history of the region, as recognized by the original workers in the mid-19th century.

## Description

The site area stretches south-east from the craggy Torridonian sandstone Heights of Slioch (980 m) across Loch Maree Group mafic metavolcanic and subsidiary metasedimentary rocks, to the NE-trending Glen Bianasdail, developed along the Fhasaigh Fault. South-east of this fault Cambrian quartzites overlie Torridonian sandstones, above which lie imbricated An t-Sron Formation and the Kinlochewe Thrust Sheet. The bulk of the thrust sheet is composed of Lewisian grey and subsidiary mafic gneisses, which are well exposed on Beinn a' Mhùinidh (692 m) and the surrounding cliffs and plateau. Torridonian rocks and Cambrian quartzites occur in the lower part of the thrust sheet that occurs around Meallan

Ghobhar (468 m; [NH 029 645]) and along the c. 250–400 m-high crags that overlook Kinlochewe to the north-east. The Moine Thrust lies farther south-east in Glen Bruachaig. The geology of this large GCR site is summarized on a simplified map and cross-section (Figure 5.42). The components of the site are described in order of their structural level, which broadly runs from west to east.

The Lewisian geology of the north-eastern side of Loch Maree forms part of a tract of supracrustal rocks that correlates with the metasedimentary and metavolcanic rocks of the Gairloch area (Park *et al.*, 1987; Park, 2002). These rocks constitute the Loch Maree Group and are described in Chapter 3; here they lie within a late (D3) Laxfordian structure, the Letterewe Synform. The group comprises a varied suite of schistose amphibolites, quartzose psanunites, semipelites and graphitic pelites, together with larger amphibolite sheets, all metamorphosed under amphibolite-facies conditions. Structurally overlying the supra-crustal rocks and forming the core of the Letterewe Synform is a tract of quartzofeldspathic gneisses intruded by amphibolite sheets. These rocks, the Letterewe Gneisses, have been interpreted as belonging to the older Archaean part of the Lewisian Gneiss Complex which pre-dates the Loch Maree Group. They were thrust over the Loch Maree Group, and the contact is marked by strong mylonitization that overprints the peak metamorphic fabrics in both hangingwall and footwall (Droop *et al.*, 1998). Stretching lineations plunge moderately to the south-east and asymmetrical structures imply a top-to-the-NW shear sense.

The Lewisian rocks are overlain unconformably by rocks of the Torridon Group. These form a 900 m-thick continuous section on the mountain of Slioch. The unconformity shows a remarkable palaeorelief of over 450 m, from a low at Smiorasair bothy (elevation 90 m; [NH 003 670]) to highs near Meall Riabhach (elevation 300 m; [NH 012 670]) and immediately beneath the western cliffs of Slioch [NG 997 693].

The western outcrops of the Torridonian, including small outliers of Diabaig Formation, contain breccias derived from the immediate substrate (chiefly amphibolite). However, most of the Slioch section is made up of the typical facies of the younger Applecross Formation, including dominantly well-rounded clasts of quartz and quartzofeldspathic aggregates. Across the palaeovalley, centred on Smiorasair bothy, the bedding in the Torridonian onlaps the gneissose basement.

The Fhasaigh Fault (Figure 5.42), a NNE-trending structure that throws down to the ESE, separates the Lewisian–Torridonian geology from the ground dominated by Caledonian thrust structures to the east (Peach *et al.*, 1907). The Kinlochewe Thrust Sheet is made up of Lewisian gneisses overlain by small erosional remnants of Torridon Group sedimentary rocks. Scourie dykes within the sheet trend north-west–south-east, parallel to those in the foreland Lewisian. This implies that the thrust sheet was emplaced without significant rotation about a vertical axis. There is little internal deformation of Caledonian age within the sheet and Scourian-type field relationships are preserved intact through large areas. However, the ground above the hamlet of Incheril contains outcrops of Torridon Group (chiefly Applecross Formation). Peach *et al.* (1907) considered that these form the sedimentary cover to the main outcrop of Lewisian gneisses within the Kinlochewe Thrust Sheet, which crops out farther north. However, Matthews (1984) showed that the Lewisian basement overlies the Torridonian sandstones, separated by a thrust. Consequently he defined an Upper and a Lower Kinlochewe Thrust Sheet, the upper one carrying chiefly Lewisian gneisses, the lower one Torridonian sandstones with locally its own Lewisian basement (Butler *et al.*, 2006). The upper sheet has small in-folded remnants of its cover of Diabaig Formation rocks (e.g. at [NH 058 635]), which lie in ENE-trending synclines. Similarly trending folds, containing small outliers of Cambrian quartzites are also found in the Lower Kinlochewe Thrust Sheet (e.g. at [NH 045 636]).

The Kinlochewe thrust sheets are bulged up and eroded to expose a small window into their footwall on the slopes 2 km north-east of Incheril in the lower part of Glen Bruachaig (Butler *et al.*, 2007). The window contains imbricated Cambrian strata, from the Pipe Rock, An t-Sron Formation and small amounts of the Durness Group carbonate rocks. These imbricate slices are well exposed along the Abhainn Bruachaig towards the hinterland side of the window. Here bedding and bounding imbricate thrusts dip moderately to steeply to the south-east. The Upper Kinlochewe Thrust caps these structures and is exposed (under low river-flow conditions) in small waterfalls at [NH 059 629]. The footwall to this thrust is in Durness Group carbonate rocks, and the thrust contact is marked by a few centimetres of fault gouge derived from the carbonate rocks. Moving north-west from the river, the Kinlochewe Thrust truncates imbricate zones in its footwall and thus cuts both up and down the stratigraphical section. The western side of the window shows no such truncation, with the footwall gliding at the top of the Salterella Grit. The thrust itself is decorated by small slices of quartzite and Fucoid Beds.

The bottom of Glen Bruachaig is largely filled with drift so that the eastern edge of the Kinlochewe Thrust Sheet is not exposed. Peach *et al.* (1907) considered it to be bounded by a steep fault that drops down Moine mylonites. This contact, marking the local western edge of the Moine outcrop, was critical in the mid-19th century when Nicol (1860) proposed tectonic disruption of the rock sequence. The preserved Lewisian rocks of what is now considered to be the (Upper) Kinlochewe Thrust Sheet are dominated by quartz-feldspar pegmatite, a feature that presumably led Nicol to propose that these igneous rocks (the mysterious 'Logan Rock' of the 19th century workers) were intruded up along the fault contact. However, there are outcrops of gneisses with clear banding, together with other attributes of Lewisian basement rocks, as recognized by Bonney (1879) and subsequently by Peach *et al.* (1907).

## Interpretation

The GCR site contains geology that encompasses a long and varied history. The oldest rocks in the area are the Letterewe Gneisses that lie in the hangingwall to a thrust above the Loch Maree Group supracrustal rocks. Park *et al.* (1987) considered these rocks to be of Scourian affinity and therefore of late Archaean age. The thrust itself is interpreted as an early-Laxfordian structure. Park *et al.* (1987) considered that this thrust sheet represents the base of the slab that buried and metamorphosed the Loch Maree Group rocks. Droop *et al.* (1998) estimated the peak metamorphic conditions in the supracrustal rocks as  $c. 600 \pm 25^\circ \text{C}$  at 8–10 kbar. However, they did not consider that this particular thrust was responsible for the burial as it is associated with retrogressive mylonites, which crystallized at temperatures of  $c. 475^\circ\text{--}500^\circ \text{C}$ . Nevertheless they regarded the metamorphism as reflecting crustal thickening by thrust stacking. Comparison with the Moine Thrust in certain localities may be pertinent as the mylonites on this major Caledonian structure ubiquitously show retrogression with time, which indicates that the tectonic overburden was reducing during progressive deformation. Indeed this is common for the thrust belt (e.g. see Foinaven, Eriboll and Sango Bay GCR site reports, this chapter). The Laxfordian structure at Letterewe may simply be another, albeit significantly older, example of the same processes.

The crustal thrusting model for Laxfordian tectonics (see also Park *et al.*, 2001) differs from many traditional interpretations (e.g. Park *et al.*, 1987) that invoke strike-slip deformation. Although there are parts of strike-slip systems, such as restraining bends, that can have associated high-grade metamorphism, Droop *et al.* (1998) pointed out that such special cases are unlikely to explain the regional extent of Laxfordian metamorphism. Indeed the present orientation of Laxfordian shear-belts on a regional scale, described elsewhere in this volume (Chapters 2 and 3), may simply be low-angle structures that have been folded during a late stage of Laxfordian reworking (Park *et al.*, 2001). The Letterewe structure shows such late folding (F3), with the thrust now preserved in a NW-trending synform.

Laxfordian deformation on the north-eastern side of Loch Maree can be correlated with the main outcrop areas of Loch Maree Group supracrustal rocks in the Gairloch area. Park *et al.* (2001) dated peak metamorphism (Laxfordian D1) at  $c. 1900 \text{ Ma}$ , with the later north-west–south-east folding (analogous to the F3 Letterewe Synform) occurring at  $c. 1700 \text{ Ma}$ .

The Torridon Group sedimentary rocks of Slioch that overlie the Lewisian of Letterewe are part of the Applecross Formation (Peach *et al.*, 1907; Park *et al.*, 1994), with local patches of Diabaig Formation. The highly irregular unconformity at the base of these sedimentary rocks has long been recognized as representing a subaerial palaeosurface (Peach *et al.*, 1907). The example at Slioch charts some of the greatest preserved relief on this surface.

The Caledonian structures on the site include the Kinlochewe thrust sheets. The offset Precambrian structures preserved in the Lewisian rocks of the Upper Kinlochewe Thrust Sheet were used by Ramsay (1969) to deduce displacement on the basal thrust. Using similar methods to those of Coward *et al.* (1980) in their analysis of the Glencoul Thrust Sheet in Assynt, a WNW-directed displacement on the Kinlochewe Thrust may be estimated to exceed 45 km. This value is important because, unlike in the Assynt district, the Moine Thrust Belt near Kinlochewe contains few imbricate zones. This might be taken to imply that the amount of displacement across the thrust belt is less in the south than in the Assynt and Eriboll districts. The estimate on the Kinlochewe Thrust suggests that displacements are actually maintained along the belt — at least by this amount.

The relationship between the Kinlochewe thrust system and its footwall is complex (Butler *et al.*, 2007) and cannot be explained by simple duplex formation (e.g. Boyer and Elliott, 1982). The essential problems are that the imbricate zones

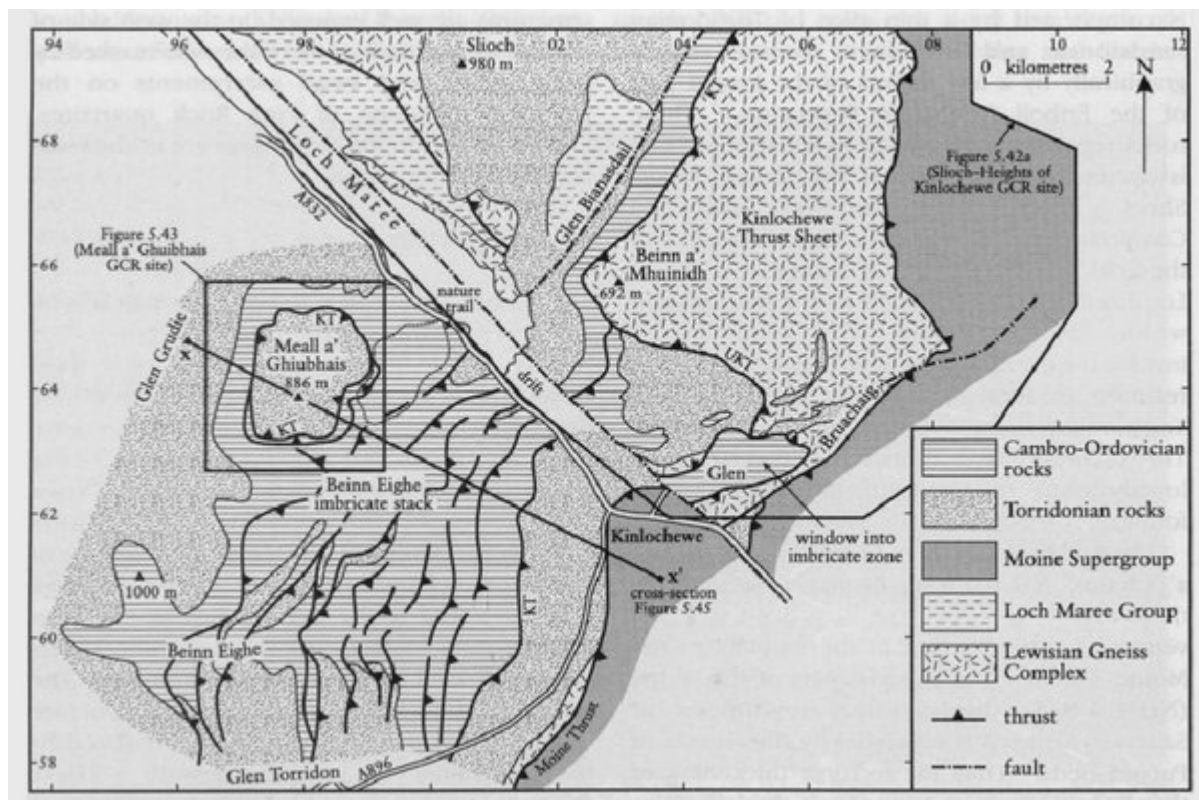
in the Incheril window contain Durness Group carbonate rocks, while the Kinlochewe Thrust to the west glides on Fucoid Beds. Hence the thrust cuts down-section towards the foreland. Coward (1982) interpreted this relationship as a low-angle extension fault, part of a rotational gravity slide system — or 'surge zone'. Matthews (1984) pointed out that an alternative interpretation is that the thrust cut down-section because the foreland rocks dipped towards the east prior to thrusting. A derivation of this could include low-angle faulting running across a series of down-to-the-E normal faults so that the hinterland parts of the footwall contain younger rocks than those to the foreland.

The sequence of thrusting is problematic, particularly the relative timing between the Kinlochewe Thrust and the imbricate zones in its footwall. Peach *et al.* (1907) showed the Kinlochewe Thrust to be folded, suggesting that it pre-dated imbrication ('piggy-back' thrusting, Boyer and Elliott, 1982). However, both Peach *et al.* (1907) and Matthews (1984) also showed the imbricate zones to be truncated by the Kinlochewe Thrust, suggesting overstep thrusting (in the sense of Butler, 1987). A compromise model may be more appropriate whereby the imbricate thrusts and the Kinlochewe Thrust developed simultaneously (Butler *et al.*, 2007). The result is both bulging and decapitation of structures. Hence, the small lenses of Cambrian strata along the Kinlochewe Thrust may represent the truncated tops of imbricate thrust slices.

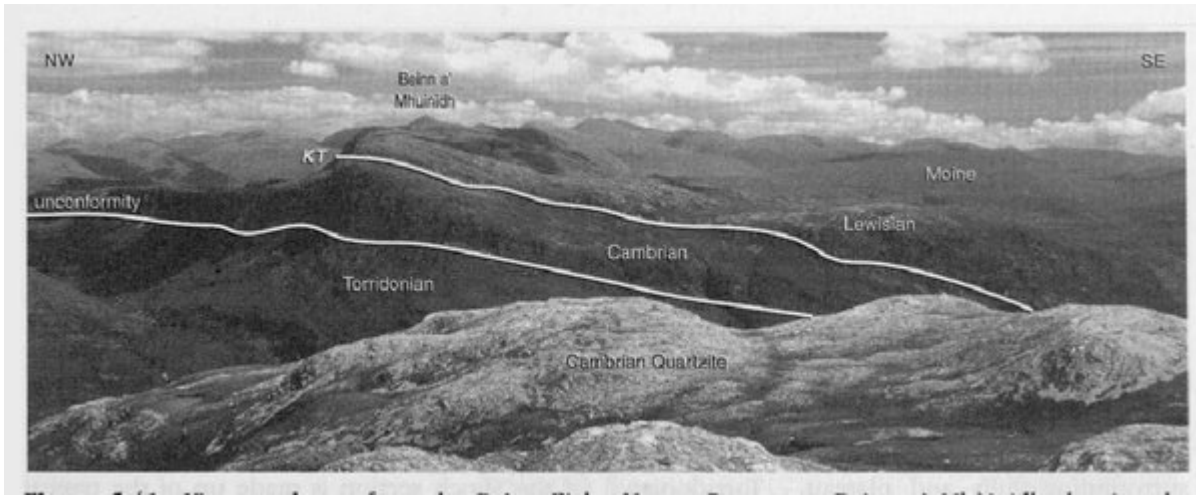
## Conclusions

The Slioch–Heights of Kinlochewe GCR site is undoubtedly of national importance in that it provides a very well exposed transect from the Lewisian Gneiss Complex and Torridon Group rocks of the foreland across the Moine Thrust Belt and into the Moine rocks in the east. As such it has received attention for over 150 years and contains the 'Logan Rock', which confused Victorian geologists for decades. Features include a putative Proterozoic thrust in the Lewisian outcrops, a magnificent demonstration of over 400 m of palaeorelief in the unconformity below the Torridon Group, and the thrusts and imbricate zones associated with the Kinlochewe and Moine thrust sheets that developed during the Scandian Event of the Caledonian Orogeny. Within a relatively short area many of the key aspects of North-west Highlands geology can be placed in their relative sequence. The site includes one of very few locations where, by matching basement structures, large displacements can be inferred in the southern part of the Moine Thrust Belt. It also displays significant complexity in the relative sequence of movements on major and minor thrusts as displayed in the unique Incheril window.

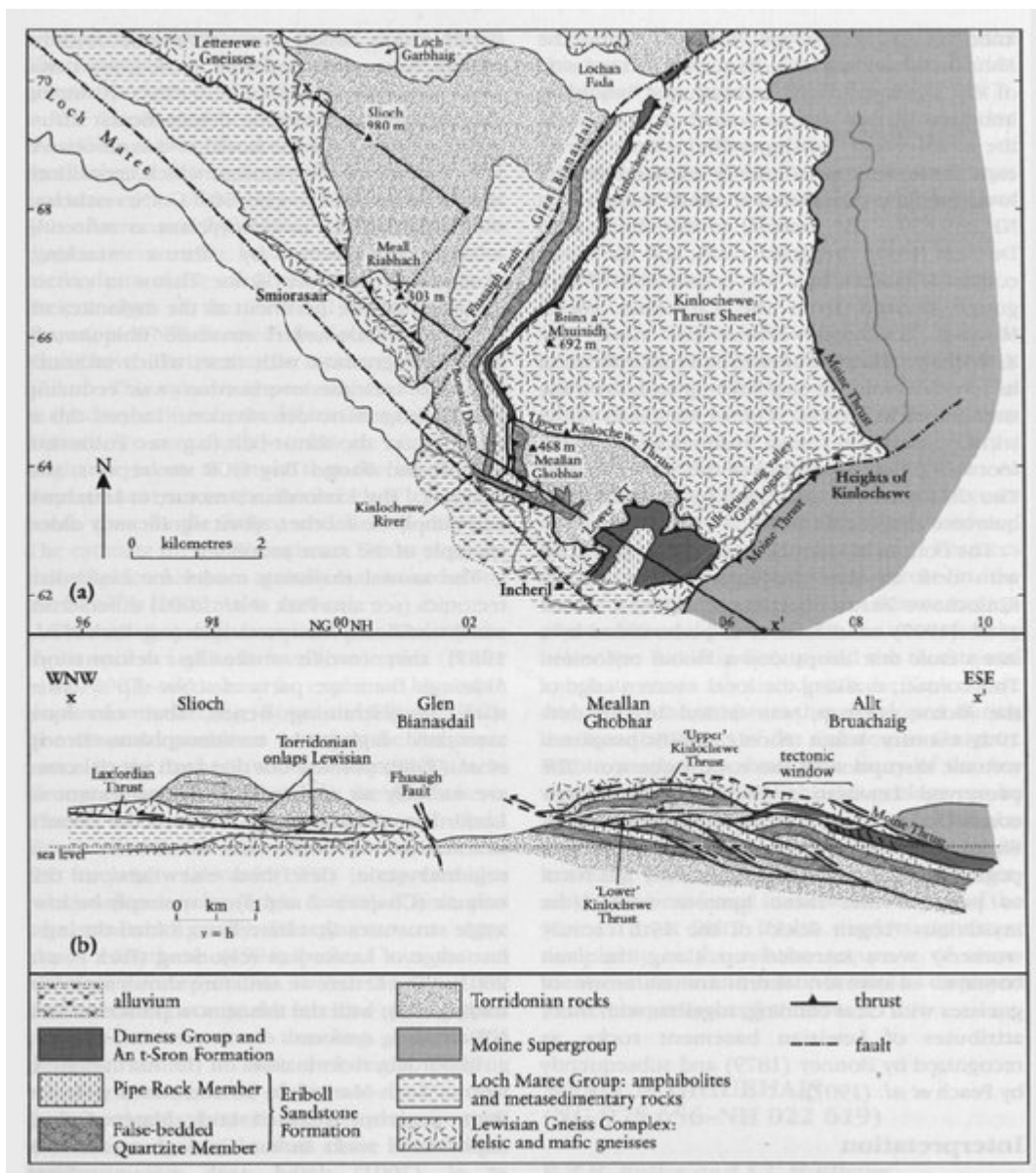
## References



(Figure 5.40) Map of the Slioch–Meall a' Ghuibhais–Beinn Eighe area, showing the regional geological setting of the Slioch–Heights of Kinlochewe GCR site (north-east of Loch Maree) and the Meall a' Ghuibhais GCR site. KT = Kinlochewe Thrust; UKT = Upper Kinlochewe Thrust. Locations of Figures 5.42a and 5.43 are indicated. Based on Geological Survey of Scotland (1913a) and Matthews (1984).



(Figure 5.41) View north-east from the Beinn Eighe Nature Reserve to Beinn a' Mhìlinidh showing the Kinlochewe Thrust Sheet. Lewisian gneisses are thrust WNW over the Cambrian rocks along the Kinlochewe Thrust (KT). Moine rocks form the hills to the north-east, including in the Fannich Mountains on the far skyline. The Moine Thrust is hidden from view. (Photo: R.W.H. Butler.)



(Figure 5.42) Map (a) and cross-section (b) of the Slioch–Heights of Kinlochewe GCR site. The part to the southeast of the Fhasaigh Fault is based on the work of Matthews (1984). Note that the section line is segmented and offset to the south-west at several points.