Knoydart Mica Mine

[NM 797 961]

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Introduction

The Knoydart Mica Mine, north of Loch Nevis in a remote part of the Knoydart peninsula, is one of the sample sites used in a pioneering geochronological study of metamorphic rocks from the Scottish Highlands by Giletti *et al.* (1961). Large muscovite crystals were obtained from a thick pegmatite in the Ladhar Bheinn Pelite Formation, part of the Morar Group succession ((Figure 7.3), Chapter 7). The muscovites provided Rb-Sr isotopic ages of 705–765 Ma, the first evidence for a Neoproterozoic tectonometamorphic event in the Moine rocks. These ages stimulated a long-running and still continuing debate on the geological history of the Scottish Highlands.

The Knoydart Mica Mine was one of the few sources of coarse mica in Britain, and it remains the most important source of beryl. Muscovite books and beryl crystals over 30 cm in size have been described. A single beryl crystal weighing over 4 kg collected from the mine dumps is in the possession of the Natural History Museum in London.

W.Q. Kennedy first mapped the Knoydart area for the Geological Survey in 1938 and delineated the prospective pegmatite veins ((Figure 8.13); see also (Figure 8.15), North Morar GCR site report, this chapter). The overall geology was summarized by Kennedy (1955) as part of his wider synthesis of the Morar Antiform. In the 1960s the Moine and Lewisianoid rocks of Knoydart and Morar to the south were subject to further detailed mapping and related structural and metamorphic investigations. This work has been fundamental to advancing the understanding of geology in the Northern Highlands (Poole and Spring, 1974; Powell, 1974). The overall geology is described more fully in the succeeding North Morar GCR site report, which covers a wider area south of Loch Nevis.

Description

The Knoydart Mica Mine is situated on the north side of Loch Nevis on the southern flank of Sgurr Coire nan Gobhar, at an altitude of 560 m. Kennedy *et al.* (1943) documented the mine area as part of a wartime evaluation of sources of mica in Scotland. Large muscovite books of high optical quality were described from a suite of pegmatites within the gneissose Moine pelites. As a result of extensive quarrying most of the larger pegmatite bodies have been removed, leaving sizeable spoil heaps. Smaller pegmatite veins remain *in situ* as clues to the original nature of the site. The Knoydart mine was worked as a source of sheet mica between 1943 and 1944; some 3600 tons of rock were processed yielding 33.3 tons of good quality mica.

The original description by Kennedy *et al.* (1943) is important as it provides the only detailed information on the site prior to quarrying (Figure 8.13). The quartz-rich muscovite pegmatites occurred as a series of concordant veins within a SW–NE-trending lens of 'saturated gneiss', some 30 m in length and 15 m in width. At its eastern end, a thin pegmatite-bearing sheet of gneiss extends for a further 30 m towards the north-east.

The zone of pegmatization lies within the Ladhar Bheinn Pelite Formation, the lateral equivalent to the Morar Pelite Formation (Holdsworth *et al.,* 1994), in a northern extension of the Morar Antiform (see North Morar GCR site report, this chapter). The formation here consists of interlayered gneissose pelite and psammite, with the lithological layering and foliation generally dipping steeply to the east. The gneissose pelite contains stromatic migmatitic leucosomes typically up to about 1 cm thick, bounded by thin biotite selvedges. Garnet porphyroblasts in the pelite show evidence of a complex tectonic history with an inner core retaining a discordant, relict early fabric surrounded by an outer inclusion-free rim, which in turn is wrapped by the main schistosity (Figure 8.14). The pegmatites that remain today are dominated by quartz, feldspar, muscovite and garnet, with mantles of biotite and garnet in the host rock. They are concordant with the layering and foliation, and vary from a few centimetres up to *c.* 1 m in length and up to *c.* 30 cm thick. Muscovite is

abundant, with large individual or intergrown books up to 30 cm long and about 10 cm thick. Large books occur even within small pegmatites that are only 10 cm thick. Muscovite is normally developed with its basal cleavage aligned parallel to the pegmatite margins, and is typically remarkably fresh, clear and undeformed with a distinctive smoky colouration. Garnet occurs as small euhedral crystals up to *c.* 1 cm across, and beryl is abundant as euhedral crystals several centimetres long. Material in the surrounding spoil heaps suggests that the quarried pegmatites were mineralogically similar, although large individual feldspar crystals > 30 cm in size imply that some of the pegmatite bodies were several metres in length.

The pegmatites have been deformed into boudins on the limbs of tight to isoclinal folds whose axes plunge steeply to the south-east, consistent with the F2 folds of the area (James, 1977). They are also clearly folded by the later upright, open F3 folds. In the psammites a penetrative schistosity, defined by muscovite and abundant quartz veinlets, is developed axial planar to the F2 folds. The F2 folding appears to be that referred to by Kennedy *et al.* (1943) as 'contemporaneous' with the pegmatites, as the bodies are rarely folded around hinges and appear to be generally axial planar to F2. Locally, pegmatite bodies are also rodded, parallel to the F2 axes.

Interpretation

The pioneering Rb-Sr isotopic age dates of 705–765 Ma obtained by Giletti *et al.* (1961), subsequently revised by Long and Lambert (1963) to 680–745 Ma, were used as evidence for a discrete Neoproterozoic orogenic event in the Moine assemblage, termed 'Knoydartian' (Bowes, 1968) or 'Morarian' (Lambert, 1969). Further isotopic evidence was provided by K-Ar dating of muscovite from the Knoydart Mica Mine by Fitch *et al.* (1969), which gave a cooling age of 744 ± 10 Ma. Since this time, other isotopic ages of *c.* 750–800 Ma have been reported widely from the Moine outcrop and also the Scottish Central Highlands (e.g. van Breemen *et al.,* 1974; Piasecki and van Breemen, 1983; Powell *et al.,* 1983; Noble *et al.,* 1996; Rogers *et al.,* 1998; Vance *et* al., 1998). Much debate has taken place as to the significance of these dates and the nature, cause and even occurrence of Neoproterozoic orogenesis in the Moine. This Neoproterozoic event, first revealed at Knoydart Mica Mine, has remained one of the most controversial aspects of Highland geology (see Tanner and Bluck (1999) and Oliver (2002) for recent summaries).

On the basis of the initial Sr ratios, Long and Lambert (1963) proposed that the pegmatites were locally derived from their surrounding Moine host rocks. This supports the conclusions of Kennedy *et al.* (1943) who noted that the pegmatites occur in a 'saturated' zone where the gneisses are particularly biotite rich, with strong mafic selvedges at the margins of the pegmatites. These features are consistent with the pegmatites having formed by in-situ segregation or partial melting.

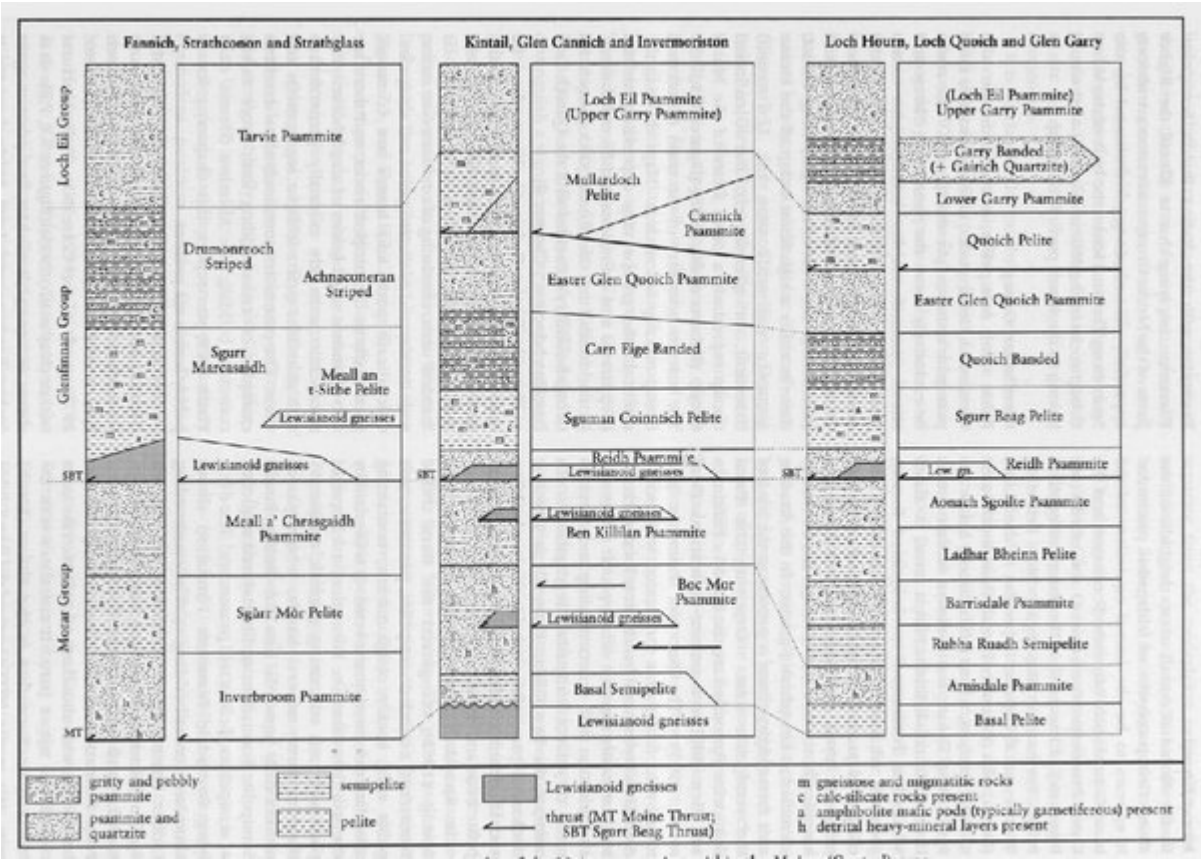
In a detailed structural study of the area, James (1977) interpreted the Knoydart pegmatites as being post-D1, and either pre- or syn-D2 in age, and correlated the first recognizable metamorphism (M1) with the Neoproterozoic Knoydartian event. MacQueen and Powell (1977) demonstrated that the early high-strain fabrics, preserved as internal inclusion trails within garnets, represented the M1 metamorphic event, which overlapped D1 and D2. However, the fabrics were typically deformed by the D2 deformation. In the gneissose pelitic rocks, the high-strain fabrics have been destroyed by the coeval migmatization, which generated pegmatitic segregations axial planar to the F2 structures (Dalziel and Johnson, 1963). Recent pressure–temperature calculations based on the mineralogy and Sm-Nd ages of 820–790 Ma for garnets in the Morar Group have been taken to indicate an episode of crustal thickening in the western Moine during the Neoproterozoic (Vance *et al.,* 1998). Indeed, there is now substantial evidence to support the proposal, first identified at Knoydart, that a Neoproterozoic 'ICnoydartian' tectonometamorphic or 'orogenic' event affected these rocks at *c.* 750–800 Ma.

Conclusions

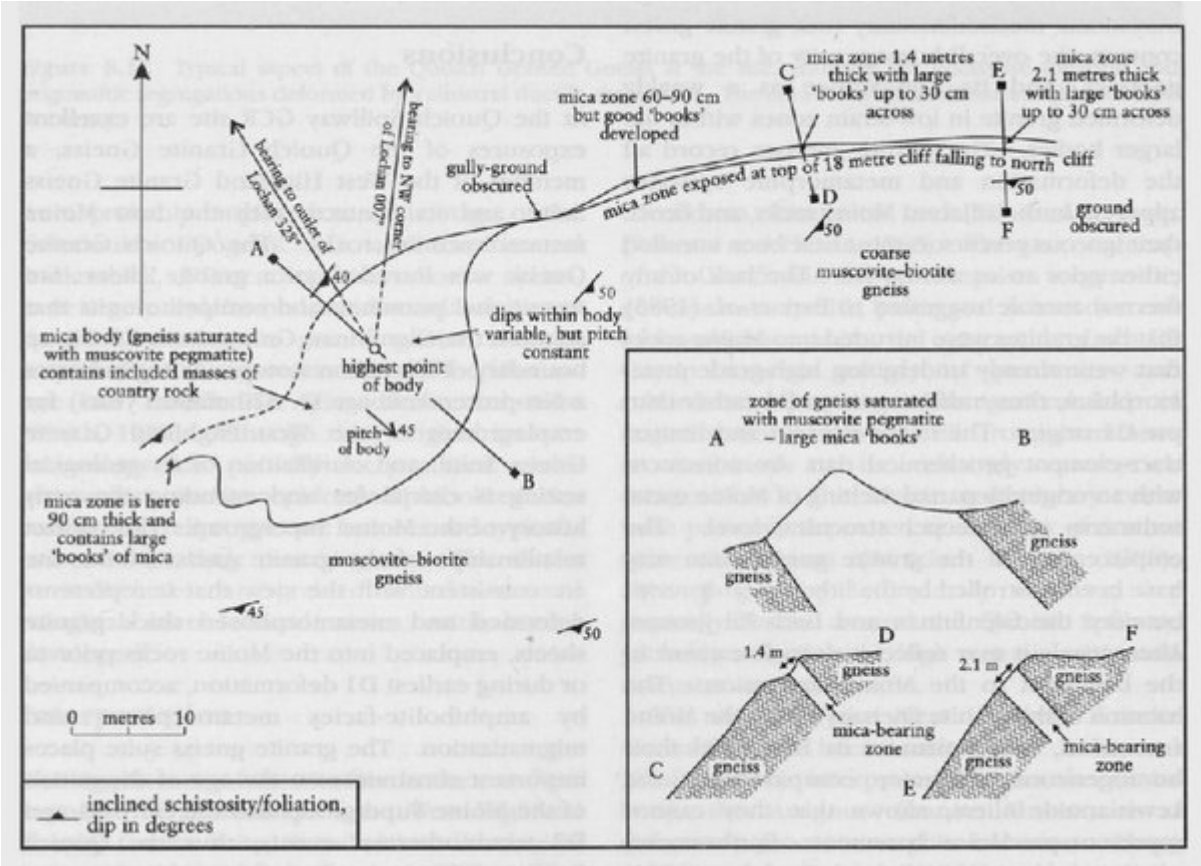
The Knoydart Mica Mine marks the occurrence of a suite of muscovite- and beryl-rich quartz-feldspar pegmatites, which have been of fundamental importance to the development of understanding the geological history of the Scottish Highlands. Samples from the site were used in a pioneering geochronological study in 1961 that obtained Rb-Sr mica ages of *c.* 750 Ma and provided the first evidence of a Neoproterozoic, Knoydartian tectonometamorphic event in Scotland. The character of this event is still being researched and debated. The site is of national importance. It is also of

historical significance as one of the few sites of limited commercial muscovite exploitation in the United Kingdom, and it remains the most significant resource of beryl in Britain.

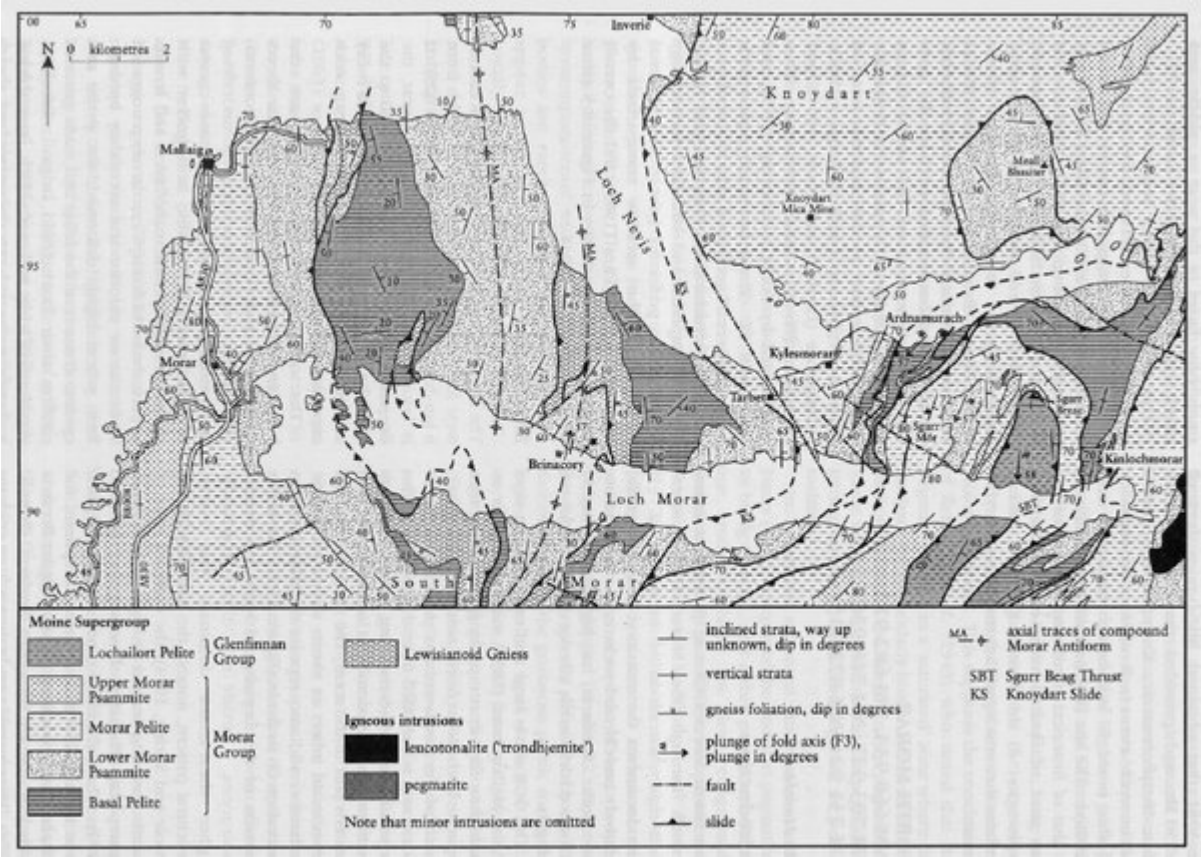
References



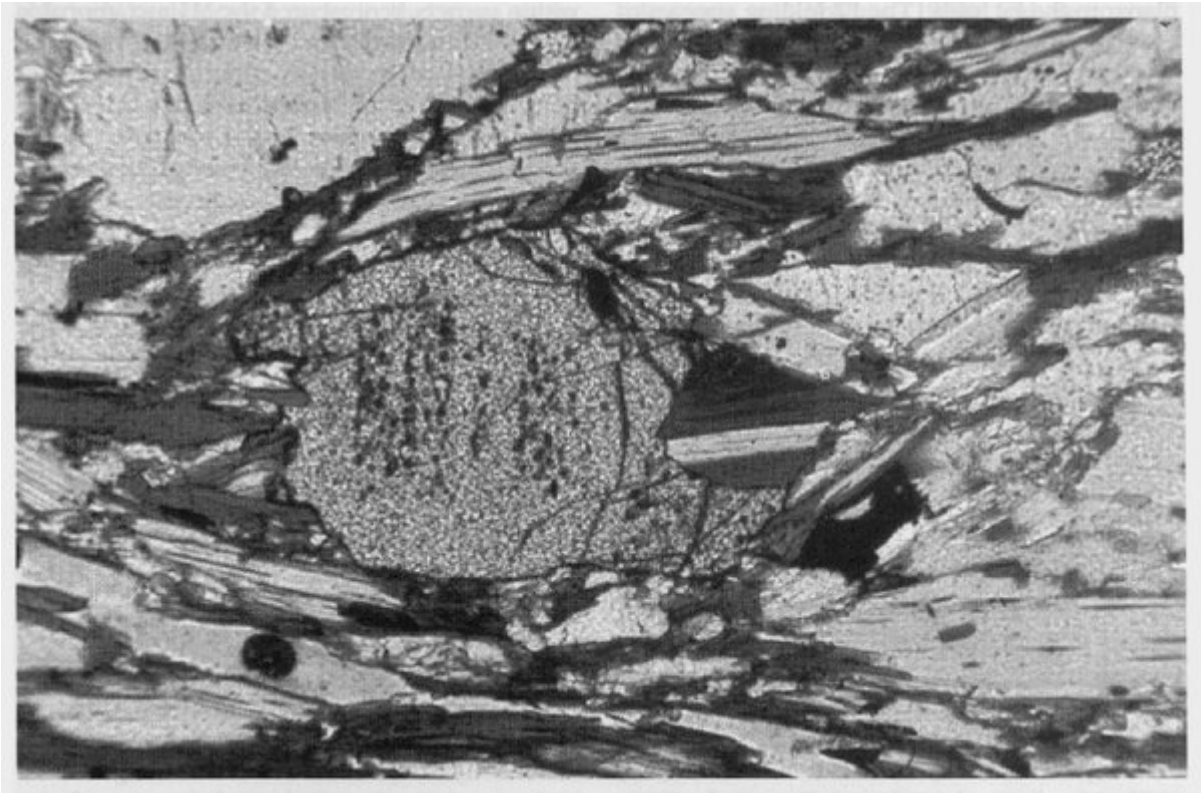
(Figure 7.3) Tectonostratigraphy of the Moine succession within the Moine (Central) area.



(Figure 8.13) Plan of the Knoydart Mica prospect prior to quarrying operations. Modified from original plan (Kennedy et al., 1943).



(Figure 8.15) Geology of the North Morar GCR site and surrounding area. Compiled from 1:63 360-scale Sheet 61(Arisaig) (Institute of Geological Sciences, 1971), and Powell (1974).



(Figure 8.14) Photomicrograph showing garnet within pelitic host rock to Knoydart pegmatites. Garnet core contains fine-grained inclusions aligned to give a planar fabric perpendicular to the main fabric, surrounded by a broad inclusion-free rim. The garnet is c. 1 mm across. (Photo: E.K. Hyslop, thin section N4940.)