# Eilean Mòr and Camas Choire Mhuilinn

[NM 571 614]–[NM 599 608], [NM 521 630]

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## Introduction

The coastal sections along the southern shore of the Ardnamurchan peninsula provide clean sections through the thick Upper Morar Psammite Formation, which here preserves a range of sedimentary structures in a largely undeformed state. This is the uppermost unit of the Morar Group in the Moine Supergroup and is also described in the Loch Moidart Road Cuttings GCR site farther north, albeit in a more-deformed state.

The Moine rocks around the Eilean Mòr site are overlain to the west by near-horizontal Palaeogene basalt lavas, which preserve beneath them a thin unit of sandstone, mudstone and lignite beds (Figure 8.27). These units occur on Beinn Bhuithe [NM 570 630] and are down-faulted to form the peninsula of Ardslignish, immediately west of Rubha Dubh. Around Eilean Mòr the Moine psammites generally dip steeply to the south-west on the western limb of a large complex N-trending antiform, which itself lies en echelon to the Morar Antiform farther north.

At the Camas Choire Mhuilinn site, 6 km west of Eilean Mòr, the Upper Morar Psammite dips gently south-east. It is overlain to the west by a thick Palaeogene dolerite sill, the Ben Hiant Dolerite, and is truncated by a thick quartz-dolerite plug to the east. In the hinterland a down-faulted block contains Palaeogene lavas that overlie Jurassic (Lower Lias) sandstone, shale and limestone, and Triassic red sandstones and conglomerates.

Numerous Palaeogene dolerite and basalt dykes intrude all the above lithologies. The dykes belong to the Skye–Mull swarm, except in Camas Choire Mhuilinn, where they relate to the Ardnamurchan igneous centre.

The southern part of the Ardnamurchan peninsula was mapped by the Geological Survey between 1921 and 1923. O'Brien (1985) subsequently studied the Moine rocks and summarized the structural sequence in the central part of the peninsula. Glendinning's (1988) detailed study of the sedimentary structures and sequence within the Upper Morar Psammite included the Eilean Mòr and Camas Choire Mhuilinn localities.

## Description

The Eilean Mòr site stretches from the wooded, rocky eastern side of Glenmore Bay, westwards for some 1.5 km to include Eilean Mòr, Camas Fearna and Rubha Dubh [NM 574 613]. The small bay of Camas Choire Mhuilinn lies some 5 km farther to the WNW (see (Figure 8.27)). At the Eilean Mòr GCR site, the shoreline consists of clean glaciated rocky promontories separated by low-lying sandy bays. A prominent raised rock platform is present. Eilean Mòr is separated from the mainland only at high tide.

East of Eilean Mòr, the Upper Morar Psammite Formation is underlain by a semipelite–pelite sequence that forms the upper part of the Morar Pelite Formation (Figure 8.3). The folded contact is exposed on the east side of Glenmore Bay around [NM 5955 6132]. The dark-grey, blocky to massive, biotite-rich semipelite is coarsely schistose with abundant purplish-red euhedral garnets and quartz-feldspar segregation veins. The transition to psammite is rapid, and in cliffs east of the road, mid- to pale-grey, laminated feldspathic and micaceous psammites are locally cross-bedded. Individual psammite beds range in thickness from 10 cm to 1 m, and thin semipelitic and pelitic interbeds are common. Calc-silicate lenses up to 10 cm thick are locally abundant in these transitional lithologies. A late-stage weak crenulation cleavage is present. The Upper Morar Psammite and the Morar Pelite formations are infolded and thrust to form a complex outcrop pattern.

The typical feldspathic psammites of the Upper Morar Psammite are well exposed on Eilean Mòr, around Rubha Camp an Righ [NM 580 615], and farther west on Rubha Dubh. Glendinning (1988) made a detailed facies analysis of Upper Morar Psammite here and presented an overall interpretation of the palaeoenvironment. Much of the following account makes use of this work. The psammites are dominantly pink to pale grey, blocky, medium- to coarse-grained and arkosic. The beds commonly show gritty bases and include coarse-grained and gritty lenses. They exhibit abundant cross-bedding, and in parts graded psammitic units with micaceous and rarely semipelitic tops are seen. Individual beds are between 30 cm and 1 m thick and are laterally lenticular over some 10–50 m. Micro-conglomeratic units are present and attain between 1.2 m and 4 m in thickness. The cross-bedding foresets generally lie at 12°–14° to the bedding. Glendinning (1988) noted that trough-festoon sets (facies 1C) are dominant with abundant trough-parallel sets (facies 1B), and some tabular cross-sets (facies 2). The sets range from 20 cm to 2 m in thickness. Large-scale trough-cross-bedding (facies 3) is also present. Facies 2 and 3 units involve originally gravelly sands with clasts averaging 4 mm across and ranging up to 8 mm. Good examples are seen on Rubha Camp an Righ (Figure 8.28). Plane-laminated (facies 4) and cross-laminated fine-grained psammites (facies 5) are less common, as are interbedded psammites and semipelites (facies 6) and massive semipelite (facies 7). In the transitional zone into the underlying Morar Pelite sedimentary structures and lithologies include flaser bedding (Glendinning, 1988, fig. 2.20), cross-bedded psammite sheets (facies 1B and 4), interbedded psammite and semipelite (facies 6), and massive semipelite units (facies 7).

Magnetite-rich heavy-mineral bands up to 1 cm thick, and ovoid iron-rich nodules up to 10 cm across occur in the Upper Morar Psammite, notably in the thick, lenticular, arkosic, coarse-grained psammite units. In many units the cross-beds are strongly oversteepened and commonly may be disrupted and tightly folded. Glendinning (1988) documents extensive sheets of highly contorted psammite with large-scale convolute bedding structures, typically truncated by the overlying bed, signifying local erosion. On Rubha Camp an Righ cross-bedded psammites can be traced laterally over a short distance into asymmetrical slump-folded units, implying either rapid gravitational instability or strong current drag during deposition of the overlying unit.

At Camas Choire Mhuilinn higher stratigraphical levels of the Upper Morar Psammite are exposed. The limited shoreline exposures show flaggy, medium- to coarse-grained psammites locally with feldspar clasts. The upper parts of the formation are coarse grained and the sequence overall is upward-coarsening (Glendinning, 1988). Soft-sediment deformation structures are also notably abundant.

The Upper Morar Psammite Formation was estimated by Glendinning to exceed 4800 m in thickness in the western part of Ardnamurchan, its maximum development in the North-west Highlands. The rocks are metamorphosed to epidote-amphibolite facies, although the diagnostic mineralogies are best seen in the subsidiary pelitic units and in the underlying Morar Pelite Formation east of Glenmore Bay. The main foliation and associated recumbent folding at the site are attributed to D2. The later upright, open to tight folds that refold the earlier structures, are termed 'D3'. Note that O'Brien (1985), who recognized four phases of folding in central Ardnamurchan, terms the earlier structures 'D1' and the later structures 'D2', but the terminology used here is compatible with that used in the other GCR sites in Morar and Moidart. The notes below are based on O'Brien (1985). F2 folds are typically asymmetrical with sheared common limbs, which act as sites of dislocation. No consistent sense of vergence was noted and there are few areas of inverted rocks. Nevertheless it is probable that the complex interfolding pattern at the eastern edge of the site is largely a product of medium- to large-scale F2 folding. F3 folds are generally boxlike or step-like and trend NNW. A penetrative S3 foliation is locally present in pelitic units, but elsewhere S3 is a variably developed crenulation cleavage. D4 and D5 deformation events resulted in conjugate step-like folds.

## Interpretation

The Eilean Mòr and Camas Choire Mhuilinn GCR sites show examples of the typical sedimentary structures that occur in the Upper Morar Psammite Formation (Morar Group). This formation reaches its acme in this area, attaining some 5 km in thickness. Glendinning (1988) documented the sedimentary structures present and constructed a palaeoenvironmental model for the deposition of the unit. He interpreted the original sand sheets, interbedded sands and silts, and massive silts of the upper parts of the underlying Morar Pelite to be mostly of tidal origin with parts of the sequence as intertidal or

shallow sub-tidal. The movement of sand sheets may relate to local storms but the general lack of channelling and other features suggest relatively low energy conditions. The Upper Morar Psammite represents a transgression which overall coarsens upwards (regressive). Conditions remained tidal and shallow marine, as shown by the occurrence of thick units of planar laminated sands (facies 4), indicative of the upper flow regime and hence relatively high velocity currents. The upward appearance of thick tabular cross-bedded sands (facies 2) indicates an increase in water depth to > 5 m and this is confirmed by the shift to high-energy cross-bedded sands (facies 1B and 1C). Facies 1 sands, interpreted as a product of migrating sand waves, are locally interbedded with facies 6 and 7 silts, indicative of more-distal, waning flow under tidal and sub-tidal conditions. Allen (1984) illustrated that such associations can be generated by storm conditions with the return flow creating thin graded units. Glendinning (1988) postulated that tidal amplitude was enhanced, possibly as a result of the geography of the gulf in which the formation was deposited, as for example in the present-day Bay of Fundy in Nova Scotia. However, the progressive upward and lateral interfingering of proximal facies (1C and 2) with more-distal facies (1B, 6 and 7) in the Upper Morar Psammite is typical of a regressive shallow-marine sequence.

Palaeocurrent directions derived from foreset orientations are regionally very consistent, with a primary transport direction towards the NNE. Such directions are recorded from the Rubha Camp an Righ and Camas Choire Mhuilinn sections whereas the primary mode on Eilean Mòr is to the ENE (Glendinning, 1988). Secondary transport modes are recorded as towards the SSE at Rubha Camp an Righ and the south-west at Eilean Mòr. The direction of vergence of the slump or current drag folds also implies current flow to the NNE. Bimodal, bipolar palaeocurrents that are near-exclusive to trough-parallel sets (facies 1B) appear to have been dominant in the lower parts of the formation. The convolute bedding is interpreted mainly as a dewatering structure, with possible periodic seismic events occurring along a possible western graben-bounding fault. It is also indicative of the high rate of sand accumulation and a high water content.

Glendinning (1988) interpreted the Upper Morar Psammite Formation as having been deposited in a N-trending marine tidal gulf, formed by a half-graben structure during a regional extension event around 900 to 1000 Ma. The coarsest, pebbly psammites, the most proximal parts of the formation, occur in Ardnamurchan and the overall model implies that a bounding fault occurred a short distance to the west of the present outcrop. Fine-grained psammites and semipelites are more abundant both eastwards and northwards where the formation becomes markedly thinner, representing more-distal parts of the sedimentary basin. Soper *et* al. (1998) adapted the Glendinning (1988) model and extended it to interpret the palaeogeography of the whole Moine succession of the North-west Highlands.

In contrast, Bonsor and Prave (2008), working around Rubha Ruadh on the northern coast of the Ardnamurchan peninsula, documented five sandstone lithofacies types ranging from coarse to medium-fine, based on grain size, cross-bedding styles, bar forms, soft-sediment deformation features, and the incidence of gravel lags. They concluded that the formation represents a retrogradational braidplain fluvial environment. They interpreted the rocks as part of a foreland molasse formed by erosion of the Grenville Orogen to the north-west.

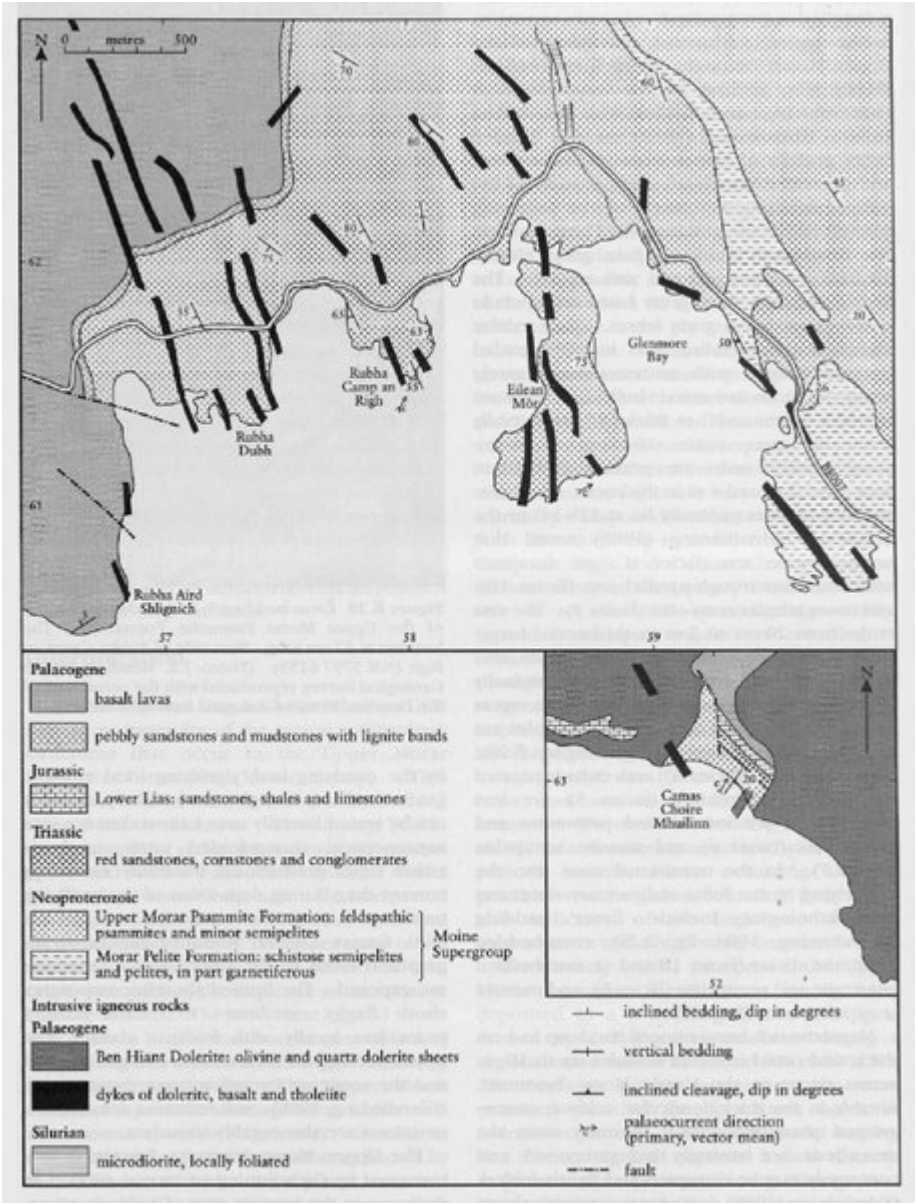
## Conclusions

The Eilean Mòr and Camas Choire Mhuilinn GCR site on the south side of the Ardnamurchan peninsula provides very good exposures of the Upper Morar Psammite Formation, comprising psammites and subsidiary semipelites. This originally immature, sand-dominated formation lies at the top of the Morar Group of the Neoproterozoic Moine Supergroup, and on Ardnamurchan it reaches its maximum exposed thickness of some 5 km. The rocks have been metamorphosed under epidote-amphibolite-facies conditions. They also show evidence of several phases of folding, related to the Grampian and possibly older orogenic events. The intensity of folding and degree of metamorphism diminish westwards on the Ardnamurchan peninsula, and around Eilean Mor the psammites exhibit abundant sedimentary features, notably cross-bedding and convolute and disturbed bedding structures.

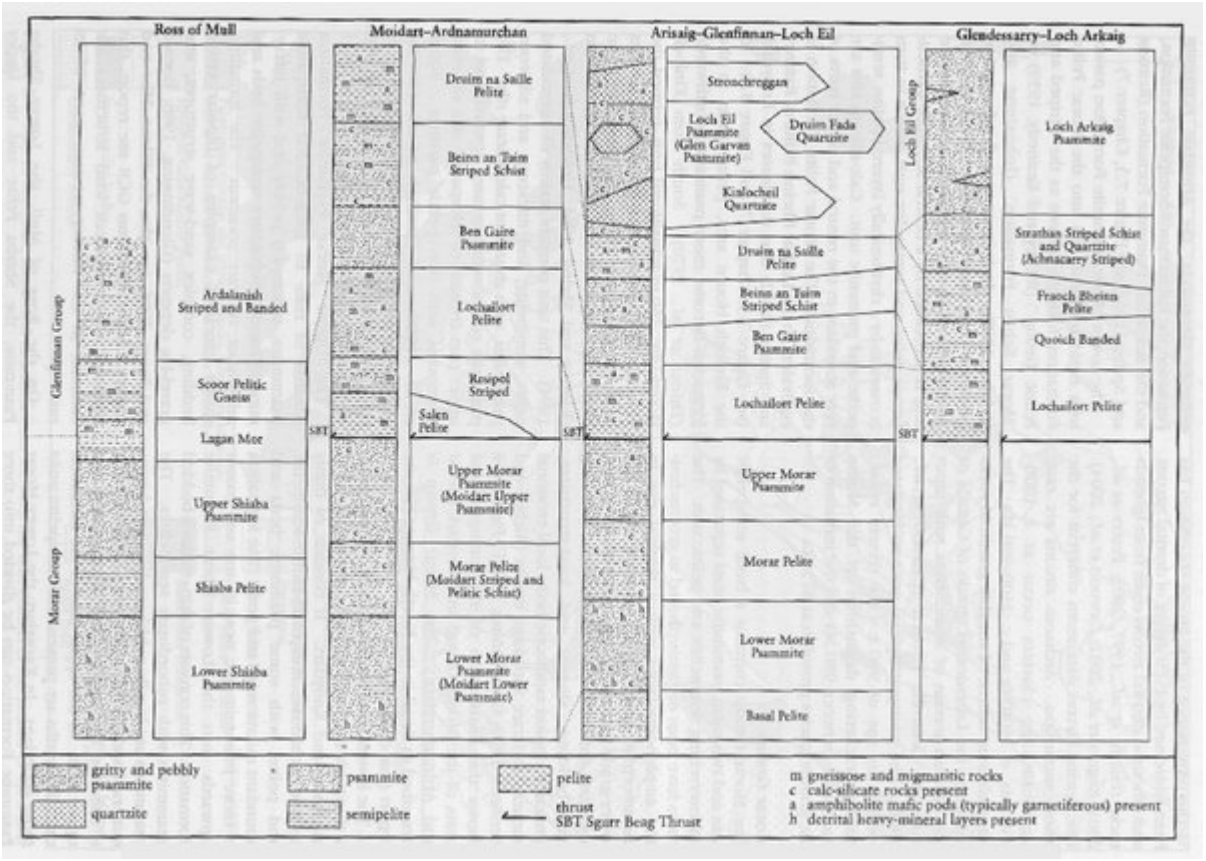
The GCR site is of national importance as it provides reference sections that enable the sedimentation conditions that prevailed during deposition of the Upper Morar Psammite Formation to be deduced. This formation is unique in that it is sufficiently undeformed in Mull, Ardnamurchan and Morar to enable its depositional conditions and palaeogeography to be reconstructed with some confidence. It can be identified as either a shallow-marine, tidally dominated, thick, sand infill of a restricted basin formed during regional extension, or as part of an extensive alluvial-fluvial foreland basin system

draining the eroding Grenville Orogen.

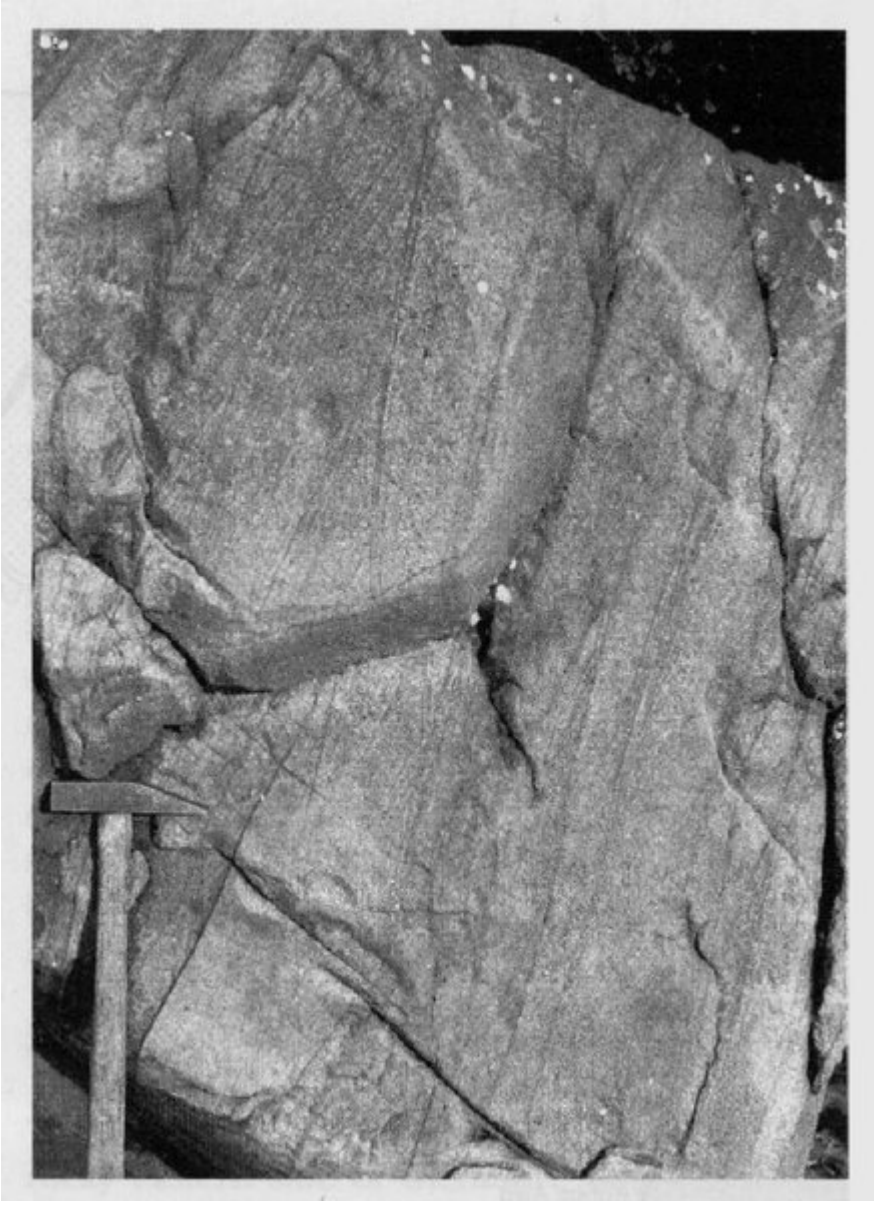
## References




*(Figure 8.27) Map of Eilean Mòr GCR site (based on British Geological Survey maps).*




*(Figure 8.3) Tectonostratigraphy of the Moine succession within the Moine (South) area, showing the main formations.*



*(Figure 8.28) Cross-bedding in feldspathic psammites of the Upper Morar Psammite Formation. The hammer is 37 cm long. West side of Rubha Camp an Righ [NM 5797 6153]. (Photo: J.R. Mendum, British Geological Survey, reproduced with the permission of the Director, British Geological Survey, © NERC.)*