Bedrock Geology UK North: Mesoproterozoic and Neoproterozoic

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This topic provides descriptions of the rock types appearing on the British Geological Survey 1:625 000 scale map of the UK North and gives a brief explanation of their origins.

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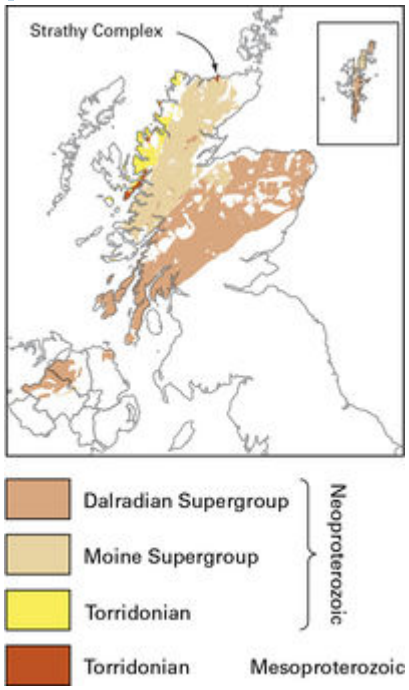

P785806.

1600 to 542 million years ago

In Mesoproterozoic times, by about 1200 million years ago (Ma), the deeply eroded Lewisian Gneiss Complex was becoming buried by a thick fluvial and lacustrine sequence of red, arkosic sandstones, informally referred to as the Torridonian. Despite lithological similarity throughout the sequence, there is little geological connection between its older and younger parts, an orogenic event intervening between their respective depositions. That was the Grenville Orogeny, which was brought about by the series of continental collisions that assembled the Rodinia 'supercontinent' between about 1100 and 1000 Ma (**Figure P785799a**). Its effects are now mainly preserved in Canada but a Scottish relict from this tectonic episode might be the enigmatic Strathy Complex, which now forms part of the north-east coastal region of Sutherland. Though dominantly made up of psammitic gneisses the complex also contains a variety of unusual rock types, including some that have a very high magnetite content, and all have experienced high-grade metamorphism between about 1100 and 1000 Ma.

At about the same time as the younger, Neoproterozoic Torridonian was accumulating, a marine, clastic shelf sequence of sandstone and mudstone also built up which now comprises the Moine Supergroup. Thereafter, the acceleration of rifting and the beginning of sea-floor spreading, which would eventually create the Iapetus Ocean, allowed passive margin and oceanic sedimentation accompanied by igneous activity. These events are recorded by the late Neoproterozoic to Cambrian,

shallow- to deep-marine strata and volcanic rocks of the Dalradian Supergroup, and the Cambro-Ordovician marine shelf strata of the north-west Highlands.

Torridonian

The Torridonian sandstones, conglomerates and mudstones are the oldest, largely unmetamorphosed sedimentary rocks in Britain. They are mainly red-brown in colour, and are exposed along the north-west coast of Scotland from Cape Wrath to the islands of Skye and Rum, west of (but also within) the Moine Thrust Belt. They form dramatic mountain scenery across the Torridon area and spectacular isolated peaks such as Suilven, Quinag and Cul Mor in Assynt (**Plate P000857**).

Beds of Torridonian sandstone form the stepped outcrop in the foreground and the more distant isolated mountain of Cul Mor. P000857.

Ben Hope looking north-north-east from Alltnacaillich, Sutherland. The coarde-grained Moine psammites have been intruded by a substantial basic sill, now an amphilbolite, which forms the prominent escarpment on the right of the picture. P002763.

The Mesoproterozoic part of the Torridonian succession, the Stoer Group (Y3), was deposited by large river systems, flowing into a rifted, continental graben. It was deposited as much as 1200 million years ago and consists of up to 2000 m of breccia, red arkosic sandstone, conglomerate and siltstone; there is a single but widespread bed, 10 m thick, of volcaniclastic sandstone.The lowest rocks are breccias which infill the undulating Lewisian surface. Sedimentary features in the Stoer

Group indicate deposition in an arid environment of seasonal braided rivers, shallow ephemeral lakes and dune fields. The Stoer Group is separated by an unconformity from the overlying, Neoproterozoic red sandstones.

In the south of the Torridonian outcrop area the Sleat Group (X1) consists of 3500 m of coarse-grained grey sandstone deposited by major river systems, and mudstone formed in lake or shallow marine environments. These rocks were affected by low-temperature, Palaeozoic metamorphism that reduced their colour from red to grey. The Sleat Group is not seen in contact with the Stoer Group but is conformably overlain by the Torridon Group (X1), which elsewhere rests unconformably on both the Stoer Group and on Lewisian gneisses. The Torridon Group was probably deposited around 1000 million years ago and ranges up to about 5000 m thick. At the base are discontinuous breccias, which formed as alluvial fan deposits, and lacustrine mudstone, but the bulk of the Torridon Group consists of coarse, red arkosic sandstone deposited on broad alluvial plains by large rivers. The Sleat and Torridon groups were probably deposited in basins formed peripherally to the mountain belt generated by the Grenville Orogeny.

Moine Supergroup

In the Moine succession of the Northern Highlands terrane, metapsammite (the dominant rock type), metapelite and quartzite form either thick homogeneous units or banded units characterised by rapid alternations of these lithologies. The depositional environments ranged from tidal shelf to shallow marine across a series of extensional basins, but the original sedimentary strata have been variably and repeatedly metamorphosed. Amphibolite sheets, locally common, have been produced by the metamorphism of originally intrusive mafic igneous rocks (**Plate P002763**).

Folded metapsammite and metapelite of the Glenfinnan Group, Moine Supergroup, north side of Loch Quoich, Lochaber. P219662.

Deformed micaceous

metapsammite within the Dava-Glen Banchor succession (formerly known as the Central Highland Migmatite Complex) at Auchterteang, Inverness. P008633.

The uniform, siliciclastic sequence contains few distinctive horizons that can be readily correlated over long distances, but three lithostratigraphical groups are recognised. The oldest of these, the Morar Group (X1) comprises a 5000 m-thick tripartite metapsammite-metapelite-metapsammite succession. The Glenfinnan Group (X2) is characterised by striped units of thinly interbanded metapsammites, metapelites and quartzites together with thick metapelite formations. The rocks show spectacular fold patterns at all scales (**P219662**) but this high level of deformation means that estimates of original sedimentary thickness vary from 1000 to 4000 m. The youngest and largely psammitic Loch Eil Group (X3) may be up to 5000 m thick. A separate sequence of metapsammites and metapelites occurs in the south of Skye where the strata are sliced within the Moine Thrust Zone. This sequence forms the Tarskavaig Group (Y2) and it appears in some respects to be intermediate in character between the Torridonian and the Moine rocks of the mainland; it is also less metamorphosed than the latter.

South-east of the Great Glen Fault, psammitic rocks lithologically similar to those of the Moine form a basement to the younger Dalradian Supergroup and are exposed in several inliers. In mainland Scotland, the inliers comprise the Dava–Glen Banchor succession (X1–3) of mainly gneissose metapsammite and some metapelite with quartzite (**Plate P008633**). On Colonsay and Islay, two enigmatic but Moine-like metasedimentary sequences (X) are inferred to overlie the Palaeoproterozoic Rhinns Complex: the Colonsay Group seen on both islands comprises up to 6000 m of siliciclastic strata with minor limestone, whilst on Islay (east of Loch Indaal) the arkosic and coarse-grained Bowmore Sandstone Group may exceed 4000 m in thickness. The stratigraphical correlation of both of these units is highly uncertain and whilst they are similar to some Moine lithologies there is also similarity with parts of the Dalradian sequence, notably the Grampian Group. An equally ambiguous and lithologically comparable sequence forms the Iona Group (X), but although Iona is only about 30 km north-north-west of Colonsay it lies to the north-west of the Great Glen Fault close to the Moine Thrust Zone.

Moine-like rocks are also seen in the Northern Isles. In Orkney, small inliers near Stromness consist of gneissose metapsammite with sporadic amphibolite sheets. Farther north, in Shetland, a thick sequence of gneissose, feldspathic psammite forms the island of Yell, whilst the Northmaven Complex (an assemblage of Caledonian plutonic rocks) at the northern extremity of Mainland separates two contrasting psammitic sequences, both gneissose, the general character of which invites correlations, from the east and west respectively, with the Glenfinnan and Morar groups.

Two inliers in Northern Ireland contain Moine-like rocks, though the correlations are not secure. The Central Inlier is a fault-bounded enclave of gneissose metapsammites, with some metapelitic schist, that stands in stark geological contrast with the surrounding igneous rocks of the early Palaeozoic Tyrone Complex. Farther west, straddling the border of County Fermanagh with the Republic of Ireland, the Lough Derg Group comprises metapsammites and mica schists cut by mafic dykes, the latter now metamorphosed to amphibolite. Despite some lithological similarity with the Moine succession, there is evidence of a long metamorphic history and the rocks of the Lough Derg Group (X1–3) may be significantly older than those of the Moine Supergroup.

Within the Moine sequence of the Scottish mainland, at about 870 Ma, parts of the Glenfinnan

and Loch Eil groups were intruded by granitic sheets and associated mafic bodies generated during a period of crustal thinning and extension. The Moine Supergroup and the intrusive igneous rocks were then deformed and metamorphosed during tectonothermal events at about 800 Ma (the Knoydartian Orogeny) and 740 Ma. Further intrusion of both mafic and granitic rocks followed at about 600 Ma, before episodes of Caledonian folding and metamorphism between about 470 and 410 Ma. The tectonic history of the Moine Supergroup remains controversial and it is usually difficult to associate specific structures with dated orogenic events; stratigraphical correlation between different parts of the outcrop is equally uncertain.

Dalradian Supergroup

Tight, irregular folding of Dalradian banded metapsammite from the Grampian Group, Ben Alder. P104211.

The gorge of the River Spean, cut through Dalradian metapsammite of the Grampian Group, at Inverlair, Grampian. P001153.

The late Neoproterozoic to early Ordovician rifting of Rodinia led to the deposition of shallow-

and deep-water sedimentary rocks and culminated in the eruption of associated lavas. Rifting presaged development of the Iapetus Ocean and the resulting rocks now form the Dalradian Supergroup, which dominates the Grampian terrane and forms the southern part of the Scottish Highlands. The Dalradian succession is a relatively well-differentiated sequence of marine sandstones, siltstones, mudstones and carbonate rocks with a cumulative total thickness of about 16 000 m; basalt lavas appear in the upper part of the sequence. It is unlikely that the full thickness was ever present as a single continuous succession and deposition probably occurred within a series of linked, north-east-trending marine basins controlled by major, rift-margin faults. Despite many phases of Caledonian deformation and metamorphism (**Plate P104211**) the stratigraphical integrity and overall geometry of these basins has been preserved and the Dalradian succession remains stratigraphically and structurally coherent. The age is not known precisely but the strata must be younger than the minimum age obtained from the underlying basement: that is about 800 Ma from pegmatite cutting psammitic gneiss of the Dava–Glen Banchor succession. The youngest Dalradian strata contain mid-Cambrian fossils.

The Dalradian succession is divided into four groups, each recording one or more cycles of subsidence, marine transgression and basin infilling at the evolving continental margin. Deposition of the oldest sequence, the Grampian Group (X5), was initiated by middle to late Neoproterozoic extension and basin development; it comprises three main facies that represent distinct phases of rifting and subsidence. The basal strata are shallow marine and fluvial, arkosic psammite and conglomerate with some limestone. Rapid subsidence then accommodated deposition of distal turbidites and sand that later formed metapelites and thinly bedded metapsammite before an increase in the rate of sedimentation filled the basin with proximal turbidites that now form a thick metapsammite succession (**Plate P001153**).

Dalradian quartzite of the Appin Group forming the Grey Corries' ridge, looking towards Aonach Beag, Glen Roy, Lochaber. P001157.

Stratiform baryte from the Dalradian Argyll Group in the Foss Mine at Aberfeldy,

Perthshire. P001560.

During deposition of the succeeding Appin Group (X6) an alternation of subsidence and basin filling episodes maintained nearshore and shallow marine shelf environments, and the sediments that accumulated therein later formed mostly quartzites and metapsammites (**Plate P001157**). A major marine transgression is recorded in the middle of the group but the widespread subsidence was short-lived and was followed by tidally influenced shallow shelf and anoxic lagoonal conditions. The resulting rock sequence includes quartzite and a graphitic schist, metapelite and limestone assemblage that can be traced with remarkable continuity, almost on a bed for bed basis, for some 300 km across the Scottish Highlands. Towards the top of the group, tuff layers and an influx of detrital volcaniclastic material record basin instability and volcanic activity as continental rifting presaged the opening of the Iapetus Ocean.

The succeeding Argyll Group (X7) reflects increasing basin instability and its rocks indicate several cycles of rapid basin deepening. A distinctive glaciomarine tillite marks the base of the group (and a major ice age) and thereafter variable and locally thick sedimentary units, mostly of quartzite, indicate that sediment input kept pace with basin subsidence to maintain deposition in a tidal shelf environment. Localised but rapid basin subsidence then followed, with deposition of finer grained lithologies including graphitic black pelite, calcareous semipelite and limestone, sporadically associated with pebbly quartzite; conformable sheets of mafic igneous rock may have originated as either lavas or sills. Exhalative saline brines gave rise to a locally persistent bed of stratabound sulphide minerals and baryte (**Plate P001560**) before the basin was swamped by the influx of deep-water turbidite sandstone. The uppermost part of the Argyll Group is dominated by limestone with thick accumulations of mafic volcanic lavas and subvolcanic sills. These mark the complete rupture of the continental crust during rifting and have been dated at about 600 Ma. Typical of this part of the sedimentary succession are abrupt lateral variations in facies and thickness with unconformities, overstep and pebbly beds. Significant volumes of granitic magma were generated about the same time as the mafic lavas and sills, and a number of substantial granite plutons were intruded at this time.

The uppermost part of the Dalradian Supergroup is the Southern Highland Group (X8); a succession that is about 4000 m thick and consists of coarse-grained turbidites with subsidiary volcaniclastic strata. These coarse-grained sediments were probably laid down via channels feeding deep-water submarine fans. Volcaniclastic units (the so-called ‘Green Beds’) are most prevalent in the lowermost 1000 m and may have been derived either by erosion of the underlying mafic volcanic rocks, or from contemporaneous volcanism. The sequence reflects a continuation of widespread and rapid basin subsidence as growth of the Iapetus Ocean accelerated and the developing continental margin foundered. Fossil evidence for the age of the Dalradian Supergroup is only preserved in the uppermost parts of the Southern Highland Group where, locally, metamorphosed limestone contains mid Cambrian trilobites.

Coarse-grained turbiditic sandstones of the Southern

Highland Group exposed in
the River Roe near Limavady,
County Londonderry.
P225420.

Farther north, in Shetland, probable Dalradian sequences are mostly separated from Moine-like rocks by the Boundary Zone Complex (X4), a tectonic intercalation of gneisses, schists and metapsammites of uncertain affinity. The Dalradian strata crop out on both sides of the Walls Boundary Fault. Those to the west, forming the Queyfirth Group (X), are metasedimentary and metavolcanic schists in a highly disrupted sequence that has been thrust westward over possible Moine rocks. To the east of the fault a more coherent sequence has a lower (Scatsta) division of quartzites, pelitic schists and gneisses and has probable affinity with the lower part of the Appin Group and with part of the Grampian Group. A middle (Whiteness) division of thick limestone units separated by mainly metapsammitic sequences probably correlates with the upper part of the Appin Group and lower part of the Argyll Group. The upper (Clift Hills) division of the Shetland Dalradian comprises the infill of a major extensional basin: mafic volcanic breccia and pillow lava are interbedded with phyllite and metapsammite, whilst the highest preserved strata are apparently interbedded with serpentinised ultramafic rock that may have originated as a lava. A general correlation with the upper part of the Argyll Group and the Southern Highland Group seems likely.

The Grampian terrane extends south-westward across Jura and Islay. On Islay, the enigmatic Colonsay and Bowmore Sandstone groups may have affinity with the Grampian Group or may be older and more appropriately viewed as part of the Moine Supergroup. Farther south-west, in Northern Ireland, Dalradian rocks form the high ground of the Sperrin Mountains and their continuation into north-east County Antrim. Only the higher part of the Dalradian Supergroup is preserved there, the succession correlating lithologically with the upper part of the Argyll Group and much of the Southern Highlands Group (**Plate P225420**).

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