# Torridonian, Northern Highlands of Scotland

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Johnstone, G S and Mykura, W. 1989. British regional geology: Northern Highlands of Scotland. Fourth edition. Keyworth, Nottingham: British Geological Survey.
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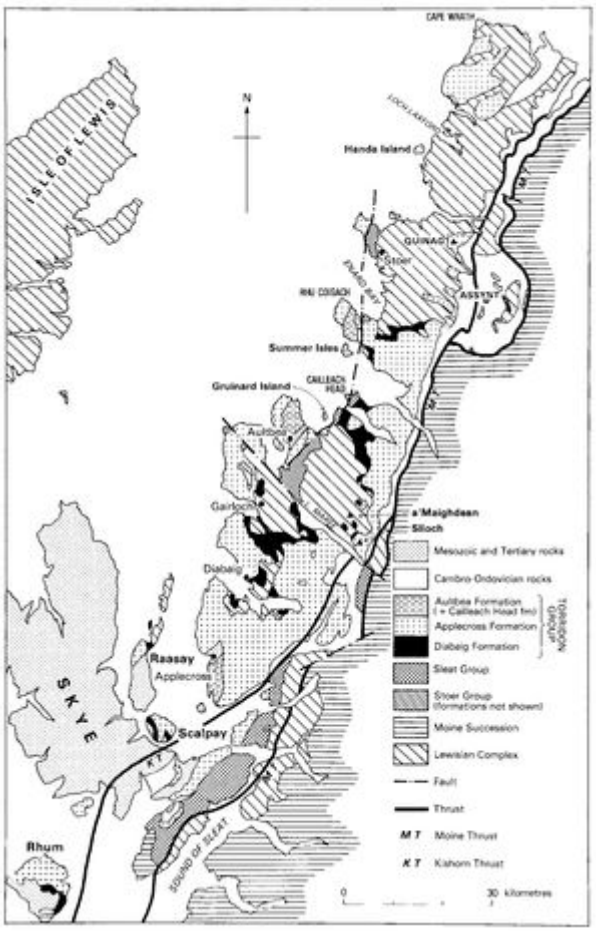
## Contents

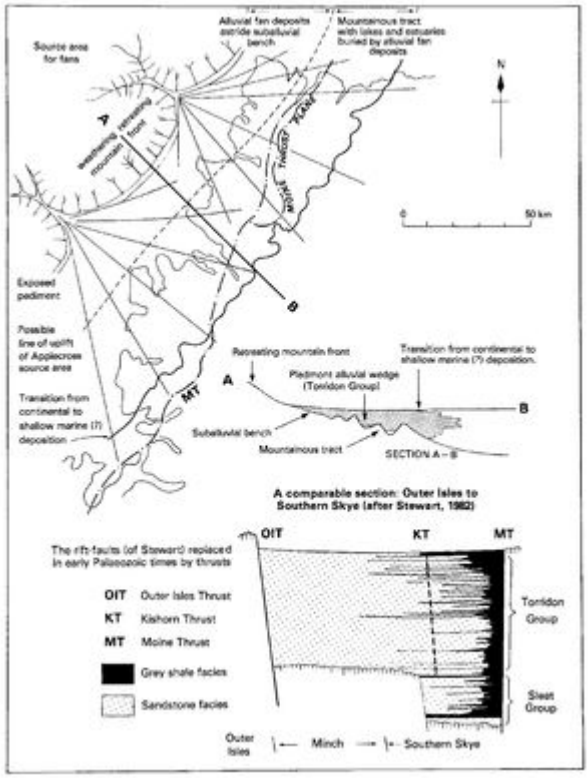


## Introduction

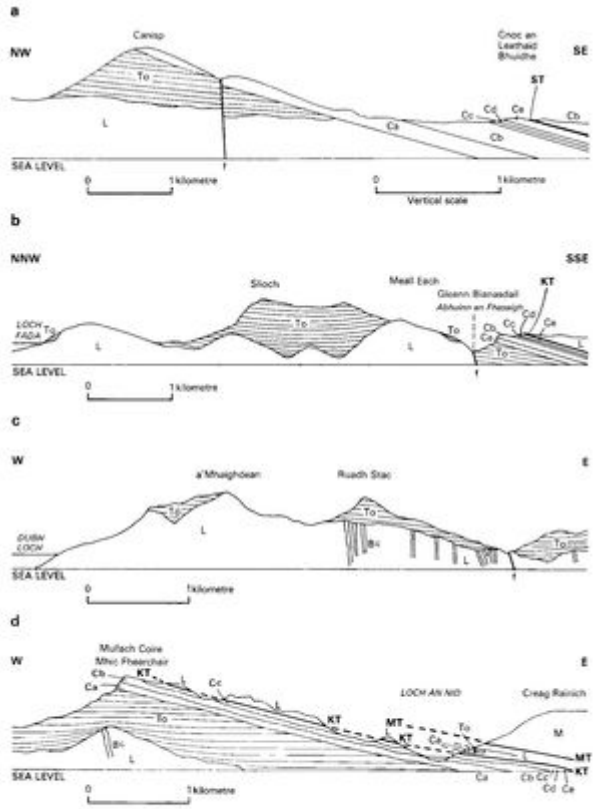
Beyond typical terrain of the Lewisian foreland north-east of Stoer we see relict mountains of Torridonian Sandstone. P000964.




Distribution of groups and formations of the Torridonian. P915464.

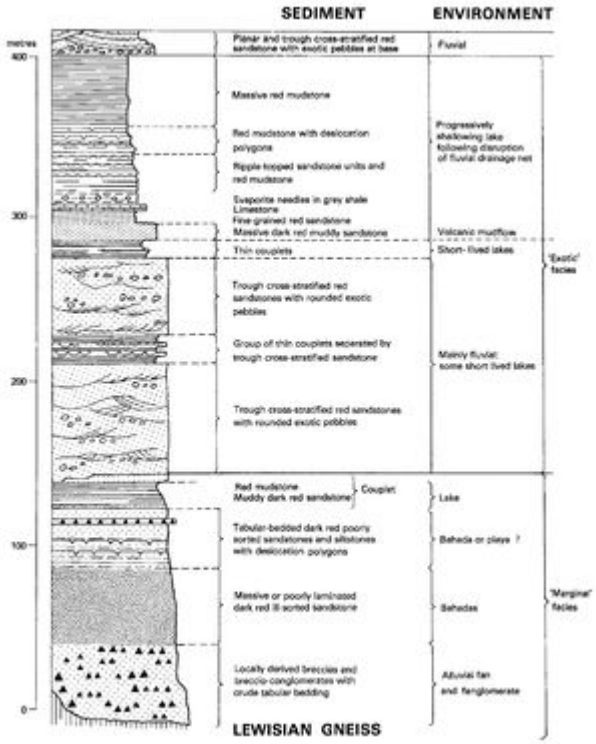



A hypothetical interpretation of the palaeogeography of the Torridon and Sleat Groups within a rift basin. P915465.




**a** Canisp to Cnoc an Leathaid Bhuidhe **b** Loch Fada across Slioch to Gleann Bianasdail **c, d** A'Mhaighdean by Mullach Coire Mhic Fhearchair to Creag Rainich
**L** Lewisian gneiss **B$^{D}$** Basic dykes in gneiss **M** Moinian schists **To** Torridonian sandstone
**C** Cambrian **Ca** Basal Quartzite **Cb** Pipe Rock **Cc** Fucoid Beds **Cd** Serpulite Grit **Ce** Durness Limestone
**MT** Moine Thrust **KT** Kinlochewe Thrust **ST** Sole Thrust **f** fault

Sections illustrating the unconformity of the Torridonian on Lewisian gneiss. P915466.




Graphic log of part of type section of the Stoer Group at Stoer. P915467.

In late Precambrian times (1000–750 Ma) the eroded land surface of Lewisian gneiss of the North-West Highlands was covered by a thick accumulation of sediments which, in the area of the

Caledonian Foreland, have never been deformed or regionally metamorphosed. It is possible that these sediments represent the last of several cycles of deposition and erosion since the gneisses first formed a land surface; within them there is a major unconformity, representing a long time-gap. The late Precambrian sediments are, in turn, unconformably overlain by Lower Cambrian strata.

The name 'Torridon Sandstone' was introduced by Nicol (1866), but sandstone, though the dominant rock type, is only one of several lithologies to be found. For this reason the rocks are usually collectively termed 'the Torridonian', a term coined by Geikie *(in* Peach and Horne, 1892). The name is derived from the Torridon area of the North-West Highlands, where mountains carved from the rocks of the sequence form some of the most spectacular scenery in the British Isles (Plate 7). Precipices of deeply eroded, generally flat-bedded strata rise 600–900 m, often from a valley floor in which the underlying gneiss is exposed. Individual peaks and ridges are commonly capped by small outliers of Cambrian quartzite, well to the west of its main outcrop. North of the type area, the Torridonian sandstone mountains become isolated, giving rise to characteristic 'inselberg' or 'island mountain' terrain; this is at its most spectacular in Assynt (P000964). There, the sandstone forms long narrow ridges separated by broad valleys of gneiss. Viewed from the east or west several of the mountains appear as tower-like, isolated masses, often with precipitous walls through which a way to the summit is not easily made.

Within the Northern Highlands the Torridonian (P915464) comprises, for the greater part, an assemblage of terrestrial sedimentary rocks. These are commonly reddish or reddish brown, laid down under fluviatile and, more rarely, shallow lacustrine conditions, with local accumulations of scree-breccias on or near the contacts with the Lewisian land surface. Certain grey-facies rocks were formerly taken to be marine, but Stewart and Parker (1979), by a study of palaeosalinity indicators, showed that this is unlikely to be the case. The great thickness of terrestrial deposits, and the palaeoenvironment indicators they contain, suggest that the rocks accumulated in subsiding basins which were probably fault-determined. Stewart (1982) considers that these basins were in the form of NNE-trending rifts cutting the Archaean and early Proterozoic crust, the rifts marking an early stage in the development of what later became the Iapetus Ocean separating Laurentia from Baltica. On this hypothesis the grey-facies shales, in broad terms, are distal representatives of proximally-deposited red beds in each rift (P915465). Direct evidence for the presence and extent of the rifts is obscured by later thrusting within the succession, and the over-riding of the Moine Nappe.

It should be clearly understood that the Torridonian is not a 'System'. In common with late Proterozoic sediments elsewhere, comparative studies have not reached the stage where it can be correlated world-wide. Nonetheless some comparisons have been made of its nannofossil content of acritarchs and cryptarchs (Diver and Peat, 1979), as several of the grey-shale beds of the Torridonian have a large and varied assemblage (e.g. Zhang, 1982). These fossils indicate that the rocks can be correlated with the Upper Riphaean of the Russian classification. It was formerly thought that the Torridonian rocks were laid down during one continuous period of deposition. It has now been established (e.g. Gracie and Stewart, 1977) that one notable unconformity exists within the sequence. Below it the rocks (termed the Stoer Group) have a radiometric (Rb-Sr isochron) age of c.960 Ma (Moorbath, 1969) and a palaeomagnetic age inferred to be about 1100 Ma (Smith and others, 1983). Above the unconformity the rocks on the mainland comprise the Torridon Group; their isotopic age is c.770 Ma and they have a palaeomagnetic age of c.1040 Ma. The palaeolatitude of the 'Upper' and 'Lower' Torridonian differs by some 45°.

Prior to the deposition of the Torridon Group, the Stoer Group was tilted to the north-west by up to 30° and extensively eroded, so that over much of the area the Torridon Group now rests directly on basement gneisses. It is thus clear that the regional sub-Torridonian surface is composite, comprising a pre-Stoer Group surface which was further modified during the long period of erosion

between the deposition of the Stoer and Torridon Groups. How extensive this modification was is not yet known. Taken as a whole, however, the sub-Torridonian land surface was gently undulating in north-west Sutherland, but south of the mountain Quinag it became more irregular and locally had a high relief. Striking examples of Torridonian-filled valleys can be seen at Quinag, a'Mhaighdean and Slioch (P915466) where hills of gneiss rise 400 m, 300 m and 600 m respectively above the pre-Torridonian valley floors. Pre- Torridonian valleys in the gneiss can be traced for some distance; the present drainage in south Assynt and north-west of Loch Maree may well follow lines established in pre-Torridonian times. Williams (1969) suggested that the relatively flat surface of the gneiss in north-west Sutherland is part of a large 'suballuvial bench', a planated piedmont surface lying below a retreating front of gneiss mountains (which lay to the west of the Minch) and from which most of the Torridonian sediments were derived. Sedimentary structures and currentbedding directions suggest that these were deposited in coalescing fans formed by E- to SE-flowing streams (P915465). On Stewart's hypothesis (above) these fans debouched over the western margin of the steadily subsiding rift-valley.

The Torridonian is absent from the Outer Hebrides, although its presence under the waters of the Minch has been shown by Chesher and Lawson (1983). According to the rift hypothesis of Stewart, the western bounding fault of the basin of deposition was in the position of the present Outer Isles Thrust, and the eastern fault was in the position of the 'root' of the Moine Thrust (now concealed under the Moine Nappe), both faults being reactivated as thrusts in Caledonian times. If this interpretation is true, Torridonian strata may never have covered the Outer Hebrides in great thickness.

| **Subdivisions of the Toridonian rocks** | | |
|---|---|---|
| **Groups** | **Formations, etc.** | **Thickness (m)** |
| Torridon Group | Cailleach Head Formation | 750 + |
| | Aultbea Formation | up to 2500 |
| | Applecross Formation | up to 3000 |
| | Diabaig Formation | 0–c.500 |
| Sleat Group (formerly part of the Diabaig Group) | Kinloch Formation | 900–1400 |
| | Beinn na Seamraig Formation | 1200–1500 |
| | Loch na Dal Formation | 800 |
| | Rubha Guail Formation | c.100 |
| **Unconformity on Foreland below Torridon Group** | | |
| Stoer Group | (No formation subdivision) | 2000 + |
| The Torridon and Sleat Groups make up the 'Upper Torridonian' of Smith and others (1983). The 'Lower Torridonian' comprises only the Stoer Group. | | |

Following the researches of the original surveyors (Peach and others, 1907) it was long held that the Torridonian comprised three main divisions — the Diabaig, Applecross and Aultbea groups (in ascending order); a fourth group — the Cailleach Head Group — was of doubtful status, as it was only seen in faulted contact with the Aultbea Group. The recognition of the intra-Torridonian unconformity and the reallocation of former Diabaig Group rocks in the Sleat of Skye to a separate group (the Sleat Group) has resulted (see P915507) in the formal redefinition of the groups by Stewart (1969, and 1975).

# Lower Torridonian

## Stoer Group

The Stoer Group was first recognised as lying beneath an unconformity at Enard Bay (Stewart, 1966a; Gracie and Stewart, 1967), and rocks of the Group were eventually shown to have a widespread, although not areally extensive, outcrop. The name was formalised by Stewart (1969).

The Group consists of unmetamorphosed red beds, over 2 km thick, resting on a land surface of Lewisian gneiss with up to 400 m relief. Stewart (1975) recognised a lower 'marginal' facies and an upper 'exotic' facies (P915467). The former contains breccia conglomerates, planar and crossbedded sandstones, and rare, playa-lake sediments with thin limestones. This facies is interpreted as a fanglomerate deposit. The 'exotic' facies contains locally cross-bedded red sandstones and mudstones. It contains rounded pebbles of gneiss and quartzite which are not found in the underlying basement gneiss. This facies is thought to be of fluvial origin, with sediments derived from both a westerly and, locally, southeasterly source. One important horizon within the exotic facies — the Stac Fhada Member — contains volcanic debris, glassy shards and accretionary lapilli; it is considered to be a volcanic mudflow (Lawson, 1972) derived from the east. If this is taken as a time-plane, then the variations in thickness of the 'exotic' facies indicate that the basin of deposition was deepest in the Loch Maree area, where the sediments beneath the volcanic horizon are thickest. In Stoer Bay, nannofossils have been obtained from limestone by Downie (1962), and from grey shale by Cloud and Germs (1971).

# Upper Torridonian

## Sleat Group

Rocks of the Sleat Group, which are only found within the Kishorn Nappe on the island of Skye and adjacent mainland, were first described by Clough *(in* Peach and others, 1907), and the subdivisions which he established are still accepted. More recent workers (Stewart, 1969; Sutton and Watson, 1964) are agreed, however, that Clough's estimates of the thickness of the various groups are too low; the thicknesses given in this account follow Sutton and Watson. The formation names are based on localities in Skye, but have also been applied to the equivalent beds in the Kyle of Lochalsh and Kishorn areas. The Rubha Guail Formation (c.100 m — formerly the 'Epidotic Grit Formation') is made up mainly of coarse 'gritty' or pebbly sandstone with abundant fragments and pebbles of epidote and epidotised feldspar, thought to be derived from the weathering of the underlying Lewisian gneiss. Trough cross-bedding is common. There are occasional bands of purple and green shale. The Loch na Dal Formation (800 m — formerly Loch na Dal Beds) comprises dark grey siltstones and sandy shales with bands of coarse sandstone and some calcareous lenticles. The Beinn na Seamraig Formation (1200–1500 m — formerly Beinn na Seamraig Grits) consists mainly of current-bedded sandstones or 'fine grained grits' with thin bands of grey laminated siltstone and sandstone. The Kinloch Formation (900–1400 m — formerly Kinloch Beds) is made up of dark grey siltstones, grey and buff sandstones and 'Fine grits' with thin calcareous lenticles. Cross-bedding is rare. Sutton and Watson point out that while the above grouping of strata into formations is valid on the basis of field characteristics, it depends as much on the variations of the proportions of lithologies common to several groups as it does on the presence, within any group, of a distinctive rock type.

Unlike the rocks of the Torridon Group the dominant colour of the Sleat Group sediments is grey or buff; they were formerly considered to be littoral or lagoonal deposits. As mentioned earlier, Stewart and Parker now consider them to have been laid down in a freshwater environment, the grey shales

possibly representing distal fluvial or lacustrine deposits. The predominant grey colour of the sandstone could be due to the alteration of hematite to magnetite during Caledonian metamorphism, the effects of which can be seen in the Loch Alsh Syncline where the Torridonian rocks reach the lower greenschist facies. Within the Kishorn Nappe of Skye (P915464) the Sleat Group is followed conformably by Torridon Group strata. Stewart (1969; 1982) discusses reasons for ascribing the Sleat and Stoer Groups to completely separate stratigraphical units.

## Torridon Group

The Torridon Group is the typical 'Torridonian Sandstone'. It is up to 7 km thick and comprises unmetamorphosed red beds with subordinate grey shales (P915468). Where it lies unconformably on Lewisian rocks, its basal beds are commonly fanglomerates, fossil screes and sandstones which can be seen filling old pre- Torridonian valleys and even small clefts in the Lewisian basement; spectacular examples are to be seen in the area south of a'Mhaighdean, east of the Fionn Loch. These basal beds pass upwards and laterally into grey shales which are thin or absent in the north but become thicker and more widespread south of Gairloch to form the redefined Diabaig Formation of Stewart (1975). This formation reaches its maximum thickness in Rhum and Scalpay (c.500 m). The Diabaig shales were formerly thought to be of marine origin, but are now more generally accepted as lacustrine. In Sleat the passage between the rocks of the Kinloch and Applecross Formations is marked by intercalcation with, lateral passage to, shales of 'Diabaig' type.

The Applecross Formation comprises over 2500 m of fluvial, strongly crossbedded, red-brown to pale red arkosic sandstone and pebbly sandstone, locally with conglomerate. During the deposition of the group the source area lay to the west, with two major alluvial fans spreading south-eastwards from a mountainous source area, the eastern margin of which occupied most of the presentday Outer Hebrides (P915465). Stewart (1982) suggested that the fans accumulated at the base of a fault along the east side of the present Outer Hebrides and that the cyclic nature of the sequence indicates periodic rejuvenation of the fault movements. The pebble content of the rocks (including quartzite, jasper, and feldspar porphyry) cannot be matched with the lithology of the Lewisian at present exposed in the Outer Isles; this indicates a provenance in a higher level of basement than that now exposed. The rocks providing the clasts could either have been entirely eroded away or, alternatively, lie to the west of the present Outer Hebrides.

The Aultbea Formation consists of red, cross-bedded, fine- to medium-grained arkosic sandstone which reaches 2500 m in Coigach. Like the Applecross Formation, it is of fluvial origin and its source area was to the WNW. Unlike the Applecross, however, pebbly sandstone and conglomerate horizons are sparse. The sandstones are interbedded with thin shales which have occasional sun cracks and rain pits. Stewart (1969 and 1975) shows a degree of diachronism between the upper part of the Applecross and lower part of the Aultbea Formation and this is confirmed by the palaeomagnetic studies of Smith and others (1982).

The position of the Cailleach Head Formation is not fully proved, as it is not seen in unfaulted contact with the (presumed) underlying Aultbea Formation*. Its outcrop is confined to the tip of the peninsula between Loch Broom and Little Loch Broom, where it is at least 750 m thick. It consists of a sequence of cycles each of grey shale grading upwards into red sandstone. A whole rock Rb/Sr isochron from shales near the bottom of the Applecross Formation gave an age of c.770 Ma (Moorbath, 1969). The Upper Torridonian time sequence of pole positions coincides with the Laurentian polar wandering path at about 1040 Ma according to Smith and others (1983).

Teall *(in* Peach and others, 1907) was the first to record possible organic remains in the Torridonian. He recorded minute spherical bodies and fibres within black phosphate nodules in the Cailleach Head Formation near Loch Broom. Nannofossils have since been recorded in several black shales

within the Torridon Group (Naumova and Pavlovsky, 1961; Sutton, 1962; Diver and Peat, 1979). Zhang (1982) has given a detailed description of a nannofossil assemblage from Aultbea Formation shales on the Summer Isles. These fossils belong to the * Dr W. Diver reports the presence of beds ascribed to the Cailleach Head Formation conformably overlying Aultbea Formation sediments on Gruinard Island (personal communication, sphaeromorphic acritarchs and cryptarchs, and include the sheaths of filamentous cyanobacteria. They are believed to indicate an Upper Riphean age.

The Torridonian strata and basement gneisses were tilted westward and planated prior to the deposition of the lower Cambrian rocks, the planar surface itself being tilted in post-Cambrian times to incline as much as 20° to the east, with the underlying Torridonian rocks more or less recovering their original horizontal disposition.

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