Middle Old Red Sandstone, Northern Highlands of Scotland

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Middle Old Red Sandstone

Caithness and north Sutherland

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The greater part of Caithness is underlain by grey, fissile, thinly bedded flagstones which may be up to 4 km thick. They have been extensively quarried in the past for use as paving slabs, roofing slates and building stones. The flagstone sequence is divided into the Lower and Upper Caithness Flagstone Groups (Donovan and others, 1974), the boundary between which is drawn at the horizon of the Achanarras Limestone (P915488, P915492). The Achanarras Limestone is a distinctive, thinly laminated, calcareous bed with a characteristic fish assemblage similar to those found in the Niantd Limestone of east Caithness, the Sandwick Fish Bed of Orkney, the Melby Fish Beds of west Shetland, and the Cromarty and Edderton Fish Beds of Easter Ross.

The base of the Middle Old Red Sandstone of Caithness is diachronous, being oldest at Sarclet, where there is no stratigraphic break between Middle and Lower Old Red Sandstone. It becomes progressively younger along the western margin between Berriedale and Reay. In south-east Caithness there are nearly 2.5 km of sediment below the Achanarras horizon; at Reay the base of the Middle Old Red Sandstone is just below the Achanarras Limestone, and further west at Strathy it is just above this horizon.

**Lithology and depositional environment of the flags**

At first sight the Caithness Flags appear to consist of a monotonous sequence of laminated, carbonate-rich siltstones and shales with subordinate fine-grained, thinly bedded sandstones. Closer examination shows the sequence to be made up of well defined rhythmic units or cycles; these are generally 5 to 10 m thick, but reach 60 m in the Achanarras Limestone cycle. The flags were deposited in an extensive shallow lake (P915490) which extended from Caithness northwards, across and beyond Orkney and eastwards into the present North Sea. Every cycle represents a sequence of
events caused by the very frequent, repeated fluctuations in the lake level (Fannin, 1970; Donovan, 1980). Five distinct lithological associations (Facies A to E) can be recognised in many cycles.

**Facies A** The cycle commences with a bed of ‘laminite’, a dark grey or black, thinly laminated siltstone, generally carbonate- and bitumen-rich, which in many instances contains fish remains. Individual laminae are on average 0.5 mm thick and consist of triplets comprising micritic carbonate → organic carbon → fine silt. The laminite was laid down when the lake was at its deepest, when its waters were undisturbed by waves and when for most of the year little or no sediment entered the lake. The triplets have been interpreted as non-glacial varves formed by sequential deposition in a eutrophic lake whose waters were thermally stratified to some extent (Rayner, 1963). Seasonal algal bloom led to carbonate precipitation by increasing the pH of the lake water during photosynthesis. When the plankton died they fell to the (anaerobic) lake bottom to form a thin skin of organic carbon on top of the carbonate lamina. The final clastic lamina of the cycle is thought to represent a seasonal influx of fine sediment into the lake.

**Facies B** The laminite is followed by a slightly more coarsely interlaminated (0.5 to 3 mm scale) facies of dark grey, carbon-rich shale, siltstone and carbonate. This has some very small-scale ripple lamination, and some laminae may be turbidites. Mound structures are common; they may have been formed by gas bubbles rising from decaying vegetation in the sediment (Donovan and Collins, 1978). Sub-aqueous shrinkage cracks (syneresis cracks) also occur. These beds were formed below wave base in a quiescent lake which still received very little sediment.

**Facies C** The succeeding facies consists of coarser alternations (up to 10 mm) of carbonaceous shale and coarse siltstone with ripple cross-bedding, indicating shallow water and some wave action. Syneresis cracks, which may be due to seasonal changes in salinity, are common (Donovan and Foster, 1972).

**Facies D** This comprises successive beds of shale, siltstone and fine sandstone, and is up to 10 cm thick. Flaser bedding and surfaces with symmetrical ripple marks appear. Large subaerial shrinkage cracks are common; pseudonodules and convolute bedding are also found. At this stage the lake had become so shallow that its floor was periodically exposed, giving rise to extensive mud-flats.

In the Clyth Subgroup and in the basin-marginal deposits of higher subgroups these shallow lake and mudflat deposits are interbedded with, and channelled by, thicker lenticular cross-bedded sandstones (Facies E), which represent the filled-in channels of either rivers crossing the mudflat or delta- distributaries in the shallow lake. The sandy phase is overlain by mudflat deposits of interbanded siltstones and mudstones with sun cracks and syneresis cracks (Facies D and C) followed by an abrupt change to the dark, laminated fish-bed facies (A) of the next cycle, representing the onset of the next period of quiescent, deeper water conditions.

The thickness of the various lithological components within the cycle varies according to their stratigraphical position in the Caithness Flagstone sequence and their geographical position within the original lake. Thus the sandstone phases are relatively thick and laterally persistent in the Clyth Subgroup (the Helman Head beds of the original classification) but are thin and even absent in most areas within the succeeding subgroups. In the Mey Subgroup thick channel sandstones are again present. An even more characteristic feature of the Mey Subgroup is the common occurrence of slumped or foundered beds (with ‘pseudonodules’ or ‘ball and pillow’ structures) within the fluvial phase of the cycles. These beds were termed ‘nodule-beds’ by Crampton and Carruthers (1914). The quiet-water, ‘fish-bed’ facies are locally very carbonate-rich in the Clyth and Lybster subgroups, where some approach dolomitic limestone in composition. In the Achanarras cycle the fish-bed horizon is very thick and so finely laminated that it has been worked as a roofing slate. Other features of local significance are the presence of thick beds of pale grey,
unlaminated mudstone and silty mudstone in the cycles overlying the Achanarras Limestone at Halkirk and Achanarras, the presence of thin, black, highly bituminous beds within the Ackergill Beds (lower part of Mey Subgroup) just west and south of Sinclair Bay, and the presence of thick beds of fine-grained, flaggy sandstone in the Field Beds (a local facies of the Latheron Subgroup exposed on the coast just north of Wick).

Disseminated carbonate forms an appreciable percentage of all flagstones and its composition determines the colour of the weathered rock faces. Thus the flags below the Achanarras horizon are usually dark grey or black when fresh but weather to drab or buff colour (calcite), and those above are lighter coloured when fresh and weather to an ochre and bluish colour (ferroan dolomite). Algalstromatolites, which are common in the Stromness and Rousay Flags of Orkney, are rare in the Caithness Flags.

The western margin of the Orcadian lake appears to coincide roughly with the western edge of the present-day outcrop of the Caithness Flags (Donovan, 1975). Within this area the lake floor was uneven and locally rocky. In some areas, such as Dirlot Castle [ND 127 488], Red Point [NC 930 660], Portskerra [NC 876 667] and Balligill (NC 856 663), the remains of rocky islets of Moine basement are preserved. These islets are surrounded by thin fossil scree fans of breccia and conglomerate and, at Dirlot, individual pebbles are coated with algalstromatolites (Donovan, 1973). At Cnoc nan Airidhe (5 km south-east of Reay, (NC 989 608)) and Red Point there are thin beds of limestone close to the unconformity (Donovan, 1975).

In the Berriedale Outlier and along the northern margin of the main outcrop just north of Berriedale (P915486) the lowest member of the Middle Old Red Sandstone is a basal breccia or conglomerate, known as the Badbea Breccia at Ousdale. It is overlain by red arkosic sandstone (the ‘Berriedale Sandstone’) which is, in turn, succeeded by red and grey rhythmically bedded flags of Caithness Flagstone type (the ‘Berriedale Flags’). The Hags contain thick red channel-sandstone phases and well-developed interbanded sandstonesiltstone ribs with syneresis and sun cracks. South of the Berriedale Outlier the only lacustrine flagstones of Caithness type are the clasts forming the ‘Fallen Stack’ and other boulders in the coastal strip of Kimmeridgian beds between Ord Point and Kilmote (p.158). Most of the Lower Caithness Flags succession appears to have passed southward via a lake marginal facies into fluvial sandstones.

**Flora and fauna of the Caithness Flags (P915492 and P916027)**

Fish remains have not as yet been found in the lower part of the Clyth Subgroup; they are rare and fragmentary in the upper part of the Clyth Subgroup and in the Hillhead Red Bed Subgroup, but are relatively abundant and, in places, well-preserved in the ‘laminites’ (p.130) of the higher subgroups. The range of diagnostic fish fossils within the flagstone sequence is shown in P915492. This table shows that *Coccosteus cuspidatus* is confined to the Lower Caithness Flagstone Group and that the small, tadpole-like fish, *Palaeospondylus gunni*, has been recorded only at the horizon of the Achanarras and Niandt Limestones. *Dickosteus threiplandi* (a species easily confused with *C. cuspidatus*) occurs only in the Latheron and Ham-Scarfskerry subgroups; it has not been found below the Achanarras horizon. The two species confined to the Mey Subgroup are *Millerosteus minor* and *Thursius pholidotus*.

The only other fossil animal commonly recorded in the Caithness Flags is the conchostracan branchiopod, *Asmussia murchisoniana* (formerly *Esthena membranacea*), which occurs in the two highest subgroups only. Plant remains are scattered throughout the sequence, but these are not diagnostic for correlation. Miospores are present in many siltstones, but have not yet proved useful as detailed stratigraphic indicators.
John o’Groats Sandstone Group

The lacustrine flagstones of north-east Caithness are succeeded by a Predominantly fluvial sequence which forms the John o’Groats Sandstone Group of Caithness and the Eday Beds of Orkney (P915488). Most of the John o’Groats Sandstone is composed of predominantly medium-grained, red sandstones with pebbly lenses, trough cross-bedding and some convolute bedding (P219077). Most of the sandstones appear to have been laid down by braided rivers; fining-upward cycles (with red overbank siltstones and mudstones) of the type formed on alluvial plains of meandering rivers are present near the base. Palaeocurrent indicators suggest deposition by rivers flowing mainly from southwest to north-east. The deep-water laminites of the cycles contains fish remains which include Microbrachius dicki, Pentlandia macroptera, Tristichopterus alatus and Watsonosteus fletti.

East Sutherland

In the Brora Outlier the basal conglomerate of the Middle Old Red Sandstone rests on the underlying Lower Old Red Sandstone sediments with a marked angular unconformity, best seen along the margins of the syncline (P915489a). The basal beds (Smeorail Formation) are of alternating lenses of conglomerate and pebbly sandstone, which pass upwards into massive conglomerate (P915488). The pebbles are of porphyritic granites and schists derived mainly from the north or north-west. The overlying sandstones of the Col-Bheinn Formation occupy the centre of the outlier; they are generally fine-grained, brick-red and predominantly flaggy. They have been correlated with the Berriedale Sandstone of the Lower Caithness Flagstone Group. No sediments with a lithology similar to the Berriedale Flagstone or Caithness Flagstones are found in the outlier; however, the presence of many boulders of Caithness Flagstone in the northern outcrops of the Kimmeridgian Helmsdale Boulder Bed (p.158) indicate that flags of Caithness type must originally have been present above the highest exposed strata seen today, in the northern part of the outlier.

A narrow strip of coarse conglomerate with rounded boulders forms an outcrop 6.5 km long along the south side of Strath Fleet. Sandstone and sandy marl, which rest directly on the igneous and metamorphic basement, have been recorded beneath the conglomerate.

South-west of Helmsdale, a narrow strip of Old Red Sandstone separates the Helmsdale Granite from the coastal strip of Mesozoic sediments; it is bounded by faults on both sides. It consists of white and yellow sandstone with bands of shale and ‘limestone’ which have yielded fragmentary fish remains. The age of these beds has not yet been determined.

Ross and Cromarty

The Middle Old Red Sandstone of Ross and Cromarty, termed the Strath Rory Group by Armstrong (1977), consists of fluvial sandstones with thick conglomerates, and subordinate calcareous fish-bearing shales. The lenticular basal conglomerates are up to 500 m thick and form conspicuous hills, including escarpments along the western limb of the Black Isle Syncline. On the east limb of the syncline conglomerates reappear at the base of the sequence. The Black Isle (Cnoc Fyrish) conglomerates contain pebbles of biotite granite and pink felsite in addition to Moine clasts. There are also some small quartzite pebbles which may have been derived from the Dalradian quartzites of Banffshire. The presence of Torridonian and Cambrian pebbles in the western conglomerates indicates that large rivers from both east and west entered the alluvial plain which occupied the site of Easter Ross and the inner Moray Firth (P915490).

The conglomerates throughout the area are interdigidated with, and overlain by, over 2.5 km of medium-grained yellow and red trough cross-bedded and locally convoluted fluvial sandstone; this is
termed the Strath Rory Group north of the Cromarty Firth (Armstrong, 1977) and the Millbuie Sandstone Group in the Black Isle (Home and Hinxman, 1914). In the Black Isle some sandstones contain pebbles of basic lavas. The sequence contains a number of grey calcareous, locally slightly bituminous shales and siltstones with concretionary nodules of limestone. The nodules contain fish remains, and well known fish beds are present at Black Park (the Edderton Fish Beds), along the east coast of the Tarbat Ness peninsula at and just north-east of Balintore, and in the Killen Burn within the Black Isle. Species recorded in the Black Park (or Edderton) Fish Bed include *Cheiracanthus murchisoni, Cheirolepis trailli, Diplacanthus striatus,* and *Osteolepis macrolepidotus.* A similar faunal assemblage has been recorded from the other fish beds. This assemblage has certain species in common with those of the Achanarras Limestone of Caithness (p.134), suggesting that the sandstones of Easter Ross can be roughly correlated with the middle part of the Caithness flagstone sequence.

The Middle Old Red Sandstone of Ross and Cromarty is primarily of fluvial origin, the sandstones and conglomerates having been deposited by swiftflowing, predominantly braided rivers which converged on the area now occupied by the Inver-Black Isle Syncline both from the west and the south-east and then flowed to the north-east ([P915490](#)). The fish-bearing calcareous siltstones represent temporary transgressions of a lake across the alluvial plain.

This lake was probably a south-westward extension of the Orcadian lake. The Moine inliers along the Moray Firth shore appear to have been hills which projected through the alluvial plain.

**Selected bibliography**

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