South Stromness Coast Section, Orkney

[HY 223 102]–[HY 254 078]

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Introduction

The South Stromness Coast Section GCR site lies on the south-west coast of the Orkney Mainland and extends along the coast from the Skerry of Ness, at the mouth of Stromness harbour, to Billia Croo, about 3 km WNW of Stromness. This stretch of coastline is excellently exposed and accessible, and provides the best section in Orkney through the Lower and Upper Stromness Flagstone formations. These formations make up the Middle Devonian Caithness Flagstone Group (approximately equivalent to the Middle Old Red Sandstone) in Orkney. At the eastern end of the site, the Lower Stromness Flagstone Formation rests unconformably, with a basal conglomerate, on Precambrian metamorphic rocks, exposed here in the largest of a few small inliers of basement in Orkney. Information from the overlying sequence has been critical in the recognition and palaeo-environmental interpretation of the rhythmic units or 'cycles' that characterize the Middle Devonian fluvio-lacustrine sequences of the Orcadian Basin (Fannin, 1970; Mykura, 1976). Features of particular sedimentary and palaeoenvironmental significance include impressive desiccation cracks, ripples, early diagenetic chert nodules, beds of algal debris, and large stromatolitic mounds.

The section also contains fault-repeated exposures of the Sandwick Fish Bed, the base of which is the junction between the Lower and Upper Stromness Flagstone formations (Astin, 1990). This horizon is important in regional correlation and justly famous for its fossil fishes (see also Yesnaby and Gau1ton Coast Section GCR site report, this chapter).

Description

At the Skerry of Ness, which lies at the eastern end of the site (Figure 2.27), the Lower Stromness Flagstone Formation overlies a granite-gneiss basement surface that slopes gently to the south. This is one of a few small inliers of pre-Devonian basement which lie along an axis stretching from the island of Graemsay (directly south of Stromness) through Stromness to Yesnaby on the western coast of the Mainland (see also Yesnaby and Gaulton Coast Section GCR site report, this chapter). The basement is composed of pink, foliated feldspar-phyric granite with enclaves of foliated metamorphic rocks that resemble rocks of the Lewisian inliers within the outcrop of the Moine Supergroup of the Northern Highlands (Wilson *et al.,* 1935).

Unconformably overlying the basement are 5–20 m of coarse, poorly sorted, clast-supported breccia and conglomerate. These form the basal part of the Lower Stromness Flagstone Formation and consist of subrounded to angular clasts of gneiss, granite, schist and quartzite set in an arkosic, sandy matrix. The clasts are generally cobble-sized (up to 20 cm by 10 cm), although some are up to 50 cm. Fannin (1970) noted that some of the clasts show a poorly developed imbrication, dipping westward off the crystalline mass. Some of the clasts have thin algal coatings of interlaminated dolostone and siltstone. Above the conglomerates, there are further examples of algal coatings, as well as stromatolitic mounds, mats and ridges. The basal fades passes up into finer-grained conglomerates and arkosic, pebbly sandstones. The sequence fines markedly upwards, with pebble content decreasing and with very few pebbles in the beds higher than about 25 m above the base.

The BGS Warebeth Borehole (Mykura, 1976; Clarke, 1990) lies in the site, providing a further point of interest. The borehole proved 61 m of red-purple siltstones, sandstones and breccias (the 'Warebeth Red Bed Formation'), which are absent from the succession exposed on the coast. They lie above the metamorphic basement and below the basal conglomerate of theLower Stromness Flagstone Formation and are tentatively assigned to the Lower Old Red Sandstone (Lower Devonian).

The Lower Stromness Flagstone Formation is about 250 m thick and the Upper Stromness Flagstone Formation at least 500 m thick. Both formations, with the exception of the basal sequence of the Lower Stromness Flagstone Formation, comprise a series of cyclic units, each unit or 'cycle' ranging from 2 m to 15 m thick. Fannin (1970) studied the sequence in detail and subdivided the units into the Lower Stromness Flags (24 cycles), the 'Sandwick Fish Bed Cycle' (1 cycle), the 'Hoy Cycles' (4 cycles) and the Upper Stromness Flags (20+ cycles). The classification was subsequently simplified so that the informally defined 'Sandwick Fish Bed Cycle' and 'Hoy Cycles' of Fannin (1970) now form part of the Upper Stromness Flagstone Formation (Astin, 1990). The facies of a typical cycle were described by Mykura (1976) and are summarized below.

The base of each cycle is taken at the appearance of dark grey to black, calcareous, silty mudstone interlaminated with siltstone. This facies generally contains graded laminae that may have either a high bitumen and pyrite content or a high carbonate (mostly ferroan dolomite) content. Fossil fish remains may also be present. The dark mudstones and siltstones pass up into thinly interbedded bituminous siltstones and fine-grained sandstones, together with some discrete beds of massive siltstone and fine-grained sandstone, which fill small eroded channels. This part of the sequence contains evidence of soft-sediment slumping and is also characterized by numerous small lenticular cracks, which were infilled by sand or silt and then compacted and contorted. Algal stromatolite sheets and mounds are common. The upper parts of many cycles are characterized by ripple cross-laminated sandstones and massive siltstones with well-developed sand-filled desiccation polygons. Locally, stromatolite sheets and mounds cover the cracked surfaces and stromatolitic debris occurs in the cracks. The stromatolites are overlain by further ripple-laminated sandstones and siltstones with desiccation cracks. The top of the cycle is generally characterized by thinly laminated siltstones and mudstones with desiccation cracks that are overlain abruptly by black laminated mudstones that form the base of the next cycle.

Much of the sequence is rich in ferroan dolomite, causing the beds to weather to distinctive yellow, orange and buff colours. Fresh surfaces are commonly dark grey owing to their organic content. One of the most impressive features of the section is the presence of extensive, gently dipping bedding planes (Figure 2.28) covered with wave- and current-ripple marks or infilled desiccation cracks.

The algal stromatolites are an interesting and important feature of this site. About 800 m west of the Point of Ness are large (metre-wide) stromatolite-covered mounds [HY 2510 0765], described in detail by Fannin (1969). The mounds were built around coarse sand cores on an irregular erosion surface. The sandy cores are coated with linked hemispheroidal stromatolites and flanked by breccias of stromatolitic debris. The stromatolite-bearing sequence is locally silicified, with chert layers occurring at the top of some mounds. The succession above and below the mounds is rich in stromatolitic debris and smaller stromatolite developments are common in the beds above the mounds. Most of the stromatolitic rocks are mineralized by galena and sphalerite.

Small shows of mineralization, particularly galena-sphalerite-barite, are common elsewhere throughout the section. Barite veins also cut the metamorphic basement. Lead was mined at Warebeth Beach around 1775 and an infilled adit is still visible. Below the adit on the beach, a brecciated zone of normal faulting that contains veins of galena–calcite–barite is one of a series of 2 m-wide, parallel, brecciated zones. Blebs of galena and sphalerite also occur within the rock surrounding the veins. The sequence also exhibits pseudomorphs after gypsum, some of which appear to have modified sand-filled mudcracks. Bedding planes on the shore by Stennigor exhibit pink barite pseudomorphs after gypsum and one west of The Noust contains calcite and quartz pseudomorphs after gypsum.

Towards the top of the Lower Stromness Flagstone Formation, about 50 m east of the east end of the Noust of Nethertown, an exposure cut by a minor fault contains numerous chert nodules (Parnell *et al.,* 1990). The relationship between the chert nodules and the lamination that passes through them shows that the nodules are replacive and developed before compaction, and that during compaction they were rotated and deformed. Rare sub-millimetre sized sphalerite crystals in the chert are thought to be syndiagenetic (Parnell, 1987).

The Sandwick Fish Bed, the base of which marks the junction between the Lower and Upper Stromness Flagstone formations, crops out at three localities in the site owing to fault repetition — two localities at the Noust of Nethertown, and one at The Noust (near Breck Ness). It is a white-weathering carbonate laminite, above which are black lenses of chert and fossil fish fragments. At the Noust of Nethertown the section is deformed by N–S-trending box folds. The fish bed is rich in fossil fish specimens, Cruaday Quarry GCR site yielding 14 or 15 specimens, including common *Coccosteus cuspidatus, Mesacanthus* sp. and *Osteolepis macrolepidotus* (Dineley, 1999a).

The Caithness Flagstone Group contains many features of use in local correlation. The fish-bearing laminites, such as the Sandwick Fish Bed, are distinctive and laterally persistent. Other marker horizons include the large chert nodules (described above) in two thinly laminated iron-rich beds of silty dolomite 14 m and 59 m below the Sandwick Fish Bed. A further marker horizon, just above the base of the Sandwick Fish Bed, is a 25 cm-thick calcite mudstone that weathers to a distinctive blue-grey colour.

Interpretation

This site has the best section in Orkney of the rhythmic units or 'cycles' that form the Caithness Flagstone Group. These cycles are interpreted as reflecting fluctuations in water-level and sediment input in a major lacustrine rift basin, the Orcadian Basin, that extended across Orkney and Caithness during Mid-Devonian times (e.g. Fannin, 1970; Mykura, 1976; Astin, 1990). The cycles reflect fluctuations between wetter periods when there was a permanent lake in the Orcadian Basin, and drier periods when there was net evaporation and the lake was ephemeral (Astin, 1990).

The calcareous, fish-bearing, thinly laminated siltstone and mudstone at the base of each cycle represent a period when the water, although still shallow, was at its deepest. The sediments were laid down in relatively quiet and sometimes stagnant waters, undisturbed by wave action. The lake waters may have been thermally stratified at times and some of the graded laminae may have been deposited by turbidity currents (Mykura, 1976). The overlying sequence of siltstones and fine-grained sandstones contains algal stromatolites, suggesting very shallow water. The mineralization of thestromatolites by galena and sphalerite may also have environmental implications, Muir and Ridgway (1975) suggesting that the degradation of algal material produced organo-metallic complexes that precipitated sulphides in the presence of sulphide-reducing bacteria. Numerous small cracks, originally interpreted as subaqueous synaeresis cracks (e.g. Fannin, 1970; Donovan and Foster, 1972) have been reinterpreted as pseudomorphs of gypsum (Astin and Rogers, 1991; Rogers and Astin, 1991), but this remains controversial (Astin and Rogers, 1992, 1993; Trewin, 1992; Barclay *et* al., 1993; Trewin and Thirlwall, 2002).

Progressive shallowing of the lake produced mudflats that periodically dried to produce polygonal arrays of desiccation cracks. The presence of barite, quartz and calcite pseudomorphs after evaporite minerals such as gypsum suggest a playa-lake setting. The lake muds were covered by fine-grained, rippled sands and silts of alluvial fans that prograded over the shallow or dry lake floor. These fluvial and deltaic sediments were succeeded by thin-bedded silts and sands with mud-filled desiccation cracks, abruptly overlain by deeper-water fish-bed facies at the base of the next cycle.

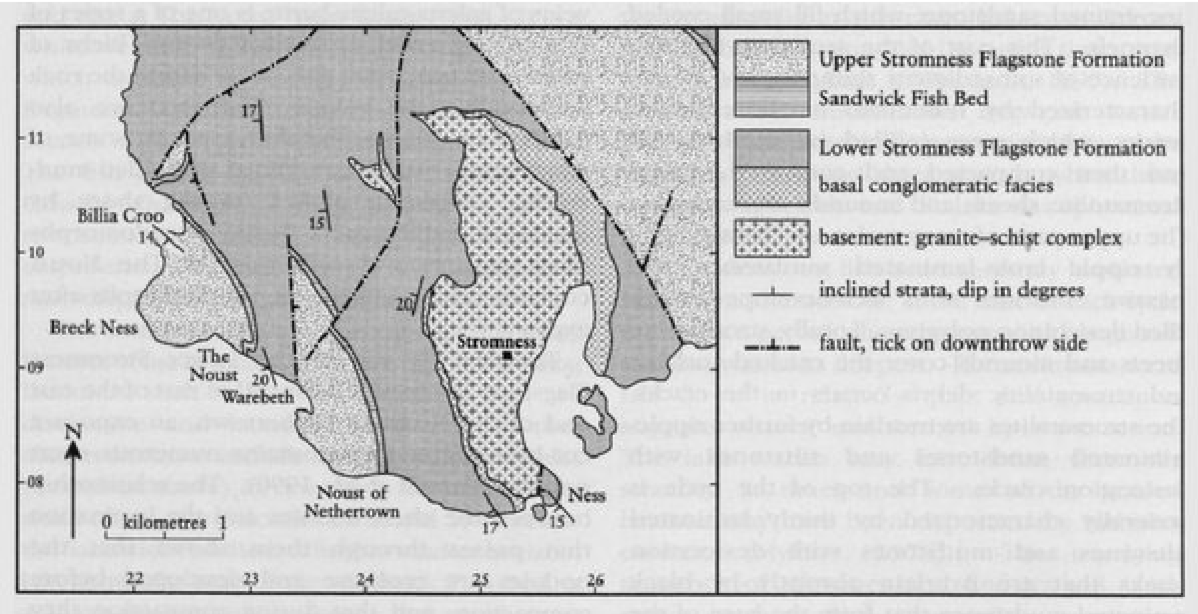
The cyclicity of the sequences, together with the presence of wave-reworked surfaces, pseudomorphs after gypsum and mudcracks, reflects the frequent oscillation between shallow temporary lake and desiccated lake basin, the former estimated to have lasted in the range of 100–200 years to 5000–10 000 years (Astin, 1990). Palaeocurrent analysis of the sequence indicates that there was a dominant current flow towards the south. Fannin (1970) suggested that the Orcadian lake had a roughly E-W-trending shoreline and was fed by rivers entering from the north. Astin (1990) measured palaeocurrent directions from current ripples in sheet-flood sandstones in the Upper Stromness Flagstone Formation on the northern coast of the Mainland (north of this GCR site) and found the predominant sheet-flood drainage direction to be towards the SSW.

In a detailed study of the cyclicity in the Upper Stromness Flagstone Formation across Orkney Astin (1990) recognized about 45 'first order' lake cycles between the Sandwick Fish Bed and the Lower Eday Sandstone Formation (which lies above the Upper Stromness Flagstone Formation). He interpreted these cycles as Milankovitch-type cycles controlled predomi nantly by orbital precession, causing long-term fluctuation in rainfall over about 1 million years. He also suggested that there is evidence for eccentric orbital cycles of longer timescale.

Conclusions

This site is of national importance as it is the best section in Orkney (and arguably the best anywhere) through the Caithness Flagstone Group, and its underlying metamorphic basement. The site provides a beautifully exposed section through a series of sedimentary 'cycles' that reflect the periodic oscillation between a shallow temporary lake and a desiccated lake basin. These cycles, together with the wide range of lithologies, sedimentary structures and biogenic structures that they contain, have been critical for the interpretation of sedimentary environments of the Orcadian Basin during Mid-Devonian times. The site also contains exposures of the well-known Sandwick Fish Bed, which separates the Lower and Upper Stromness Flagstone formations and is an important marker horizon in regional correlation.

References



(Figure 2.27) Geological map of the Stromness coast area. After British Geological Survey (1999).

(Figure 2.28) Upper Stromness Flagstone Formation at Warebeth. View south-west towards Hoy. (Photo: E.A. Pickett.)