Yesnaby and Gaulton Coast Section, Orkney

[HY 222 144]–[HY 224 166]

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Introduction

This impressive and extensive site extends from south of Neban Point to Row Head, comprising over 5 km of the western coast of the Mainland. The site contains superb cliff sections through the Lower Devonian Yesnaby Sandstone Group, which does not occur anywhere else in Orkney, and the Middle Devonian Lower Stromness Flagstone Formation. The Yesnaby Sandstone Group comprises two formations, the older Harra Ebb Sandstone Formation and the Qui Ayre Sandstone Formation (formerly known as the Yesnaby Sandstone Formation; Fannin, 1970; Clarke, 1990; Trewin and Thirlwall, 2002). These units are separated by the Garthna Geo Fault and both overlie crystalline basement. Importantly, the Qui Ayre Sandstone Formation includes aeolian sandstones (Fannin, 1970; Trewin and Thirlwall, 2002), a facies not found anywhere else in the Lower Devonian succession of the Orcadian Basin. Other aeolian sediments in the Lower Old Red Sandstone are known only in the Smerwick Group in the Dingle Peninsula, south-west Ireland (Richmond and Williams, 2000). The Yesnaby Sandstone Group is unconformably overlain by the Lower Stromness Flagstone Formation. This comprises a series of rhythmic fluvio-lacustrine units, representing a wide range of lake sediments, and includes the best stromatolite beds in the Orcadian Basin. Also exposed within the site is the Sandwick Fish Bed, which lies at the base of the overlying Upper Stromness Flagstone Formation and is an important marker horizon in regional correlation.

Description

The shore on the south side of the prominent inlet of Garthna Geo, which has been eroded along a fault, exposes extensive outcrops of the metamorphic basement (Figure 2.35). The basement includes large areas of siliceous schist, and, just north of Harra Ebb, some hornblende-and biotite-schist. The schist and gneiss are intruded by veins and sheets of pre-Devonian granite. The pre-Devonian land surface was a steep westward-sloping hillside with a flat plain at its foot. The basal part of the overlying Harra Ebb Sandstone Formation consists of less than 50 m of poorly sorted, coarse-grained breccias and conglomerates. A bed of basement (lasts with laminated carbonate (mixed calcite-dolomite) coatings rests directly on the basement, which has fractures up to 50 cm wide and 6 m deep, filled with similar laminated carbonate. Cavities within the carbonate fracture-fillings contain quartz, barite and fluid hydrocarbon. The breccias and conglomerates are overlain by up to 100 m of interbedded sandstones, dolomitic mudstones and red and green siltstones, with a few thin tabular beds of conglomerate. Trough cross-bedding and ripple cross-lamination are common in the sandstones; desiccation cracks are abundant in the interbedded siltstones and mudstones. There is an angular discordance of around 10° at the unconformable contact between the Harra Ebb Sandstone Formation and the overlying Lower Stromness Flagstone Formation at Kaellan Hellier [HY 219 145]. At Harra Ebb there are also several unusual vertical breccia masses, one of which forms a spectacular stack composed of angular to subrounded sandstone boulders in a matrix of comminuted carbonate-rich sand.

On the north side of the Garthna Geo Fault, the rocks of the Yesnaby Sandstone Group, formerly named the 'Yesnaby Sandstone Formation' by Fannin (1970), Mykura (1976) and Clarke (1990), are now known as the 'Qui Ayre Sandstone Formation' (Figure 2.36).

Although the Garthna Geo Fault separates the major outcrops of the Harra Ebb and Qui Ayre Sandstone formations, Clarke (1990) noted that the Qui Ayre Sandstone Formation rests directly and conformably on the Harra Ebb Sandstone Formation, with channels filled by the former incised into the latter ([HY 2179 1482]; [HY 2181 1488]). The Qui Ayre Sandstone Formation can be subdivided into two members, the lower of which comprises at least 30 m of rusty-weathering, grey, fine- to medium-grained, well-sorted sandstones with well-rounded grains. The sequence displays large-scale cross-stratification in sets up to 3 m, with steep foresets and planar truncation surfaces. The truncation

surfaces are spaced about 5–10 m apart.

The well-sorted, cross-bedded sandstones pass up into the upper member, which is best exposed in Old Millstone Quarry [HY 217 155] at the point of Qui Ayre. It consists of at least 25 m of massive, planar-bedded and ripple-bedded sandstones, which are locally trough cross-bedded and ripple cross-laminated with pebble trains. Siltstone interbeds have desiccation cracks. The sandstone is locally impregnated with bitumen, and black, bituminous sandstone can be observed on the cliff top near the sea stack known as the 'Castle of Qui Ayre'. At Old Millstone Quarry, the Qui Ayre Sandstone Formation is unconformably overlain by the Lower Stromness Flagstone Formation with an angular discordance of 10°. The unconformity surface is draped by a thin, matrix-supported conglomerate in which the clasts are subangular to subrounded and generally up to 10 cm by 6 cm. They include metaquartzite, siliceous mica schist, sparry dolomite and vein quartz, all set in a matrix of sandstone cemented by ferroan dolomite. Rarer clast types include banded gneiss, pegmatite and chert. The conglomerate is overlain by 1–2 m of ripple cross-laminated sandstone, followed by laminated, calcareous beds.

The Yesnaby Sandstone Group may contain lateral equivalents of the 61 m-thick Warebeth Red Bed Formation, which were encountered between basement and the Lower Stromness Flagstone Formation in a borehole at Warebeth, near Stromness (see South Stromness Coast Section GCR site report, this chapter).

The Lower Stromness Flagstone Formation is well exposed along the cliff tops northwards towards the Hill of Borwick and Ramnageo. It comprises a blue-grey, flaggy, rhythmic sequence in which laminated mudstones pass up into siltstones and fine-grained sandstones, forming a series of coarsening-upward sequences 1–8 m thick. The section includes stromatolites known locally as 'Horse Tooth Stone' [HY 220 161], of which there are particularly fine examples on the cliff top at Yesnaby, just to the north of the road end. A prominent bedding plane is covered with stromatolites, which locally form elliptical mounds with the heads inclined inwards. It is intruded by a camptonite dyke, and there are minor traces of galena mineralization at the contact. On the cliff top between Borwick and Ramnageo, 0.5 m of interbedded calcitic and dolomitic mudstones contain dark, laminated chert nodules that are concentrated in the calcitic layers and form polygonal arrays.

The top of the Lower Stromness Flagstone Formation is placed at the base of the Sandwick Fish Bed. This laminated mudstone is exposed in a small quarry at the head of Ramnageo, a spectacular, long inlet with parallel vertical walls, one of which is a fault plane. Shiny, black fragments of fossil fish are abundant on the exposed bedding planes. The quarry yielded a great quantity of fossil fish remains in the 1840s and 1850s. One of the best-known localities for the Sandwick Fish Bed is Cruaday Quarry, about 4 km north-east of the north end of the GCR site. The quarry has been a source of fossil fish specimens since the 19th century and is described in the *Fossil Fishes of Great Britain* GCR volume (Dineley and Metcalf, 1999). The fauna includes *Coccosteus cuspidatus* and *Osteolepis macrolepidotus* (both common as whole specimens) and *Mesacanthus* sp. (Dineley, 1999a). Detailed studies at this site have allowed a close correlation with the Niandt Limestone Member at Achanarras, Caithness (Trewin, 1976). An exposure of the Sandwick Fish Bed at the Bay of Skaill, about 2 km north-east of the north end of this GCR site, has yielded some of the best examples of Mid-Devonian plant fossils in Britain and is described in the GCR volume on *Palaeozoic Palaeobotany of Great Britain* (Cleal and Thomas, 1995). The flora includes the holotype of the oldest known progymnosperm *Protopteridium thomsonii.*

The overlying Upper Stromness Flagstone Formation comprises a sequence of rhythmic units similar to that of the Lower Stromness Flagstone Formation.

Interpretation

The sequence at Yesnaby is interpreted as recording a changing sequence of fluvial, lacustrine and aeolian environments which characterized the Orcadian Basin in Early to Mid-Devonian times. The aeolian facies is very important in being one of only two occurrences recognized in the Lower Old Red Sandstone of Britain and Ireland. Trewin and Thirlwall (2002) suggest that a drier climate prevailed during its deposition. The basal breccias of the Harra Ebb Sandstone Formation may represent talus deposits which accumulated on the slopes of the basement palaeotopography. Fannin (1969) interpreted the coated basement clasts as algal oncolites, although there seems to be a gradation from these structures to the fracture-fillings in the basement and the pebble coatings may therefore be travertine drapes. The

overlying sandstones, siltstones, mudstones and dolomicrites of the Harra Ebb Sandstone Formation are interpreted as representing alluvial-fan and sandflat deposits that prograded over a playa-lake system and its associated mudflats (Fannin, 1970; Clarke, 1990). Deposition was predominantly by sheet-flood, with some channelized flow, palaeocurrent directions suggesting south-westerly progradation of the alluvial-fan system (Fannin, 1970). The laminated carbonates probably had a biogenic origin as algal or microbial mats in the playa lake. The vertical breccia bodies have been interpreted as breccia pipes (cryptovents) produced by gas fluxion associated with Permian igneous activity (Mykura, 1976).

Clarke (1990) interpreted the basal part of the Qui Ayre Sandstone Formation as the deposits of a sandy braided river system that flowed southwestwards over the playa mudflats of the Harra Ebb Sandstone Formation. This was followed by a period of emergence and aeolian dune-field migration, when the predominant wind direction was towards the east or ESE (Fannin, 1970). Clarke (1990) interpreted the overlying facies as the result of renewed fluvial deposition by ephemeral streams and overbank sheet-floods, followed by development of sandy, low-sinuosity braided rivers flowing to the south-west and south-east. A different interpretation was presented by Fannin (1970) who tentatively suggested that the facies overlying the aeolian dunes represent a northward-encroaching, shallow, clastic shoreline that inundated and reworked the upper part of the dune deposits. He based this interpretation on analogy with modern marine shoreline environments, but pointed out that there is no evidence to show whether the advancing water body was fresh or marine.

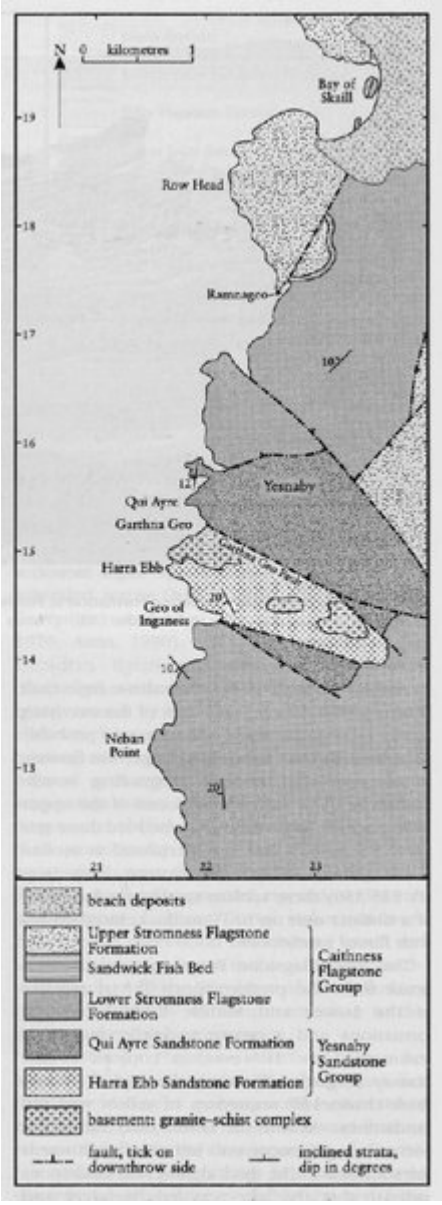
Fannin (1970) distinguished three sources for the pebbles lying on the unconformity surface at the top of the Qui Ayre Sandstone Formation the adjacent crystalline basement, the underlying Yesnaby Sandstone Group and an exotic source that lay outside the area and supplied a range of metamorphic and metasedimentary clasts.

The Caithness Flagstone Group, comprising the Lower and Upper Stromness Flagstone formations, marks a change to rhythmic, coarsening-upward lacustrine and alluvial cycles. Each cycle records a successive change in environment from deep-water lake to ephemeral shallow lake, lake-beach and alluvial fan. This cycle was repeated many times and may have been driven by a combination of cyclic climate change and tectonic activity (see South Stromness Coast Section GCR site report, this chapter, for a more detailed interpretation of the 'cycles' within the Caithness Flagstone Group).

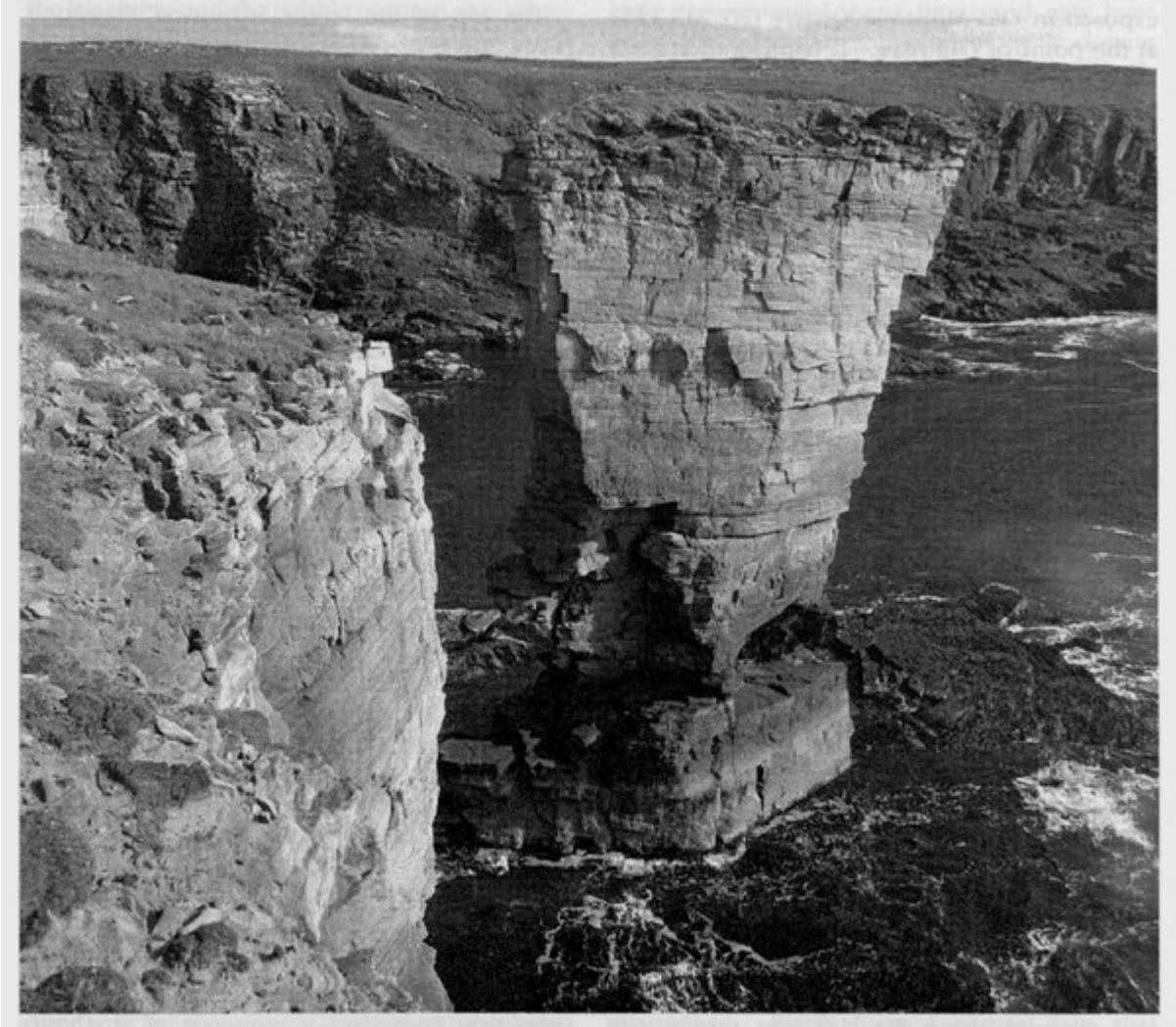
Conclusions

This site is important in exposing a thick succession of Old Red Sandstone strata, including the Harra Ebb and Qui Ayre Sandstone formations of probable Early Devonian age, the oldest sedimentary rocks exposed in the Orcadian Basin. These represent a combination of alluvial-fan, aeolian dune and lake–beach deposits and are of great importance in the interpretation of sedimentary environments in the early development of the Orcadian Basin. The aeolian sandstones are particularly important in the uniqueness of their occurrence and its implications for early Devonian climate and the palaeogeography of Britain, and Ireland. The well-exposed basement complex and its mantle of breccias and conglomerates also allow reconstruction of part of the pre-Devonian landscape. The Caithness Flagstone Group records the establishment of a lake environment and a cyclic pattern of sedimentation in which the lake deepened rapidly and shallowed slowly, with deep lake muds at the base of each cycle passing up into coarser-grained sediments containing evidence of shallowing and emergence. Rivers formed alluvial fans that built out over the dry lake-bed before becoming inundated as the cycle started again.

References



(Figure 2.35) Geological map of the Yesnaby coast, west Mainland. Based on Fannin (1970), Mykura (1976), Clarke (1990) and British Geological Survey (1999).



(Figure 2.36) Cliffs of large-scale cross-bedded sandstones of the Qui Ayre Sandstone Formation at Yesnaby. In the background is Garthna Geo with exposed basement. View towards the south. (Photo: BGS No. D1545, reproduced with the permission of the Director, British Geological Survey, © NERC.)