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# Bay of Berstane, Orkney

[HY 476 111]

Potential GCR site

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## Introduction

This potential GCR site lies in the north-west corner of the Bay of Berstane near Kirkwall on the Orkney Mainland. A short section of the Eday Marl Formation, including a mudstone containing a marine microfauna and pseudomorphs after halite, is exposed in a small, fault-bounded block. The mudstone is interpreted as representing a short marine incursion into the Orcadian Basin during mid-late Givetian (Mid-Devonian) times (Marshall *et al.*, 1996). If this interpretation is correct, this is the only record of a Devonian marine incursion onshore in Scotland, and the site is therefore of crucial importance for palaeoenvironmental and palaeogeographical interpretations of the Orcadian Basin. The site also provides the first onshore evidence to confirm the results of a BP/Chevron offshore well, drilled in the East Orkney Basin, which proved three intervals with marine microfossils in upper Givetian to lower Frasnian rocks (Marshall *et al.*, 1996).

## Description

The following account is based wholly on a description by Marshall *et al.* (1996). The site (Figure 2.39) exposes about 7 m of red and green, calcareous mudstones and argillaceous siltstones and sandstones, punctuated by cleaner red and buff sandstones up to about 50 cm thick. The most important feature is a 1 m-thick bed of grey-green, parallel-laminated, mudstone and siltstone, with red mudstone layers spaced at about 10 cm intervals (Figure 2.40), which contains evidence suggesting a brief marine incursion into the Orcadian Basin. Many of the siltstone laminae are trains of starved wave ripples, the troughs of which contain common hopper-crystal pseudomorphs after halite up to 2 cm across. Only the corners of many of the larger pseudomorphs are present, or they are truncated below the overlying siltstone. The smaller pseudomorphs are generally complete. The lamination in the red mudstone layers is disrupted and compressed into tepee structures.

The red mudstones above and below the grey-green unit are mostly apparently structureless and disrupted by successive polygonal arrays of desiccation cracks, or have a 'turbate', locally brecciated structure defined by contorted lenses and laminae of cleaner or coarser-grained sand. A diamict texture is present locally. Other less abundant structures include wave-rippled surfaces, deflation lags of coarse sand or granules (some with ripple form), gutter casts and water-escape structures. Traces of cross-lamination and flat lamination are preserved locally within the 'turbate' layers, and there are a few burrow-mottled horizons with tube-like, U-shaped, *Thalassinoides* and *?Beaconites* burrows. Common calcite nodules are either small calcrete concretions or more commonly sparite-filled vugs, giving the mudstones a vesicular appearance. Some are filled with dogtooth spar and others have geopetal fillings.

Samples of the grey-green mudstone contain a low-diversity palynomorph assemblage dominated by *Geminospora lemurata*, regarded as mid- to late Givetian in age. However, the main importance of this site lies in the discovery by Marshall *et al.* (1996) of two scolecodonts in the palynomorph assemblage. These are the chitinous jaw parts of polychaete worms, which are today restricted to marine environments, although all the sedimentological evidence at the site points to a non-marine origin.

This site is also important in providing an onshore link with offshore data obtained from the BP/Chevron offshore well 14/6-1, drilled in 1985 at the south-east margin of the East Orkney Basin (about 100 km ESE of Orkney). The well penetrated Devonian sedimentary rocks that are dated palynologically as late Givetian to early Frasnian in age (Marshall *et al.*, 1996), and three grey-green mudstone intervals, yielded marine microfossils, including an acritarch in the upper one and scolecodonts in the lower two.

## Interpretation

The red beds of the Eday Marl Formation are interpreted by Marshall *et al.* (1996) as the deposits of a muddy sabkha plain, the 'turbate' structures being caused by growth of evaporite crusts and nodules, deposition and erosion around them by wind and water, repeated desiccation, remobilization of saturated sediment and bioturbation by burrowing organisms. The sparite-filled vugs are probably the moulds of dissolved evaporite nodules.

The presence of scolecodonts and pseudo-morphs after halite in the grey-green mudstone in the Eday Marl Formation at the Bay of Berstane has been attributed to marine inundation of the sabkha plain (Marshall *et al.*, 1996). All living polychaete worms are found in marine environments and are accepted as indicators of similar environments in the geological past. Acritarchs would be expected to predominate over scolecodonts in a normal marine setting, and the dominance of scolecodonts in offshore well 14/6–1, as well as their restriction to simple forms such as *Micrhystridium* and *Veryhachium*, may be due to a 'stressed', marginal marine environment (Marshall *et al.*, 1996). This is supported by the fact that polychaete worms are common in the modern nearshore environment, where they can tolerate wide salinity variations.

The pseudomorphs after halite are also cited by Marshall *et al.* (1996) as important evidence for a marine incursion, although they also occur commonly in playa-lake deposits. Although evaporite pseudomorphs are widespread in the Orcadian Basin (e.g. Astin and Rogers, 1991) and the evaporitic crusts have been interpreted as causing the disrupted bedding and tepee structures in the Bay of Berstane section, the pseudo-morphs dominantly replace gypsum, indicating the presence of sulphate-rich brines. The pseudomorphs after halite are thought to indicate a short episode when NaCl-rich brines flooded the basin, and their large size and high concentration suggest that marine waters were the source of the brines. The absence of desiccation cracks suggests that any periods of emergence were short. Marshall *et al.* (1996) envisaged an extensive, low-relief sabkha plain that was episodically flooded by marine waters, analogous to the Ranns of Kutch today, which is flooded during the monsoon season and is a dry, evaporitic sabka plain for the remainder of the year.

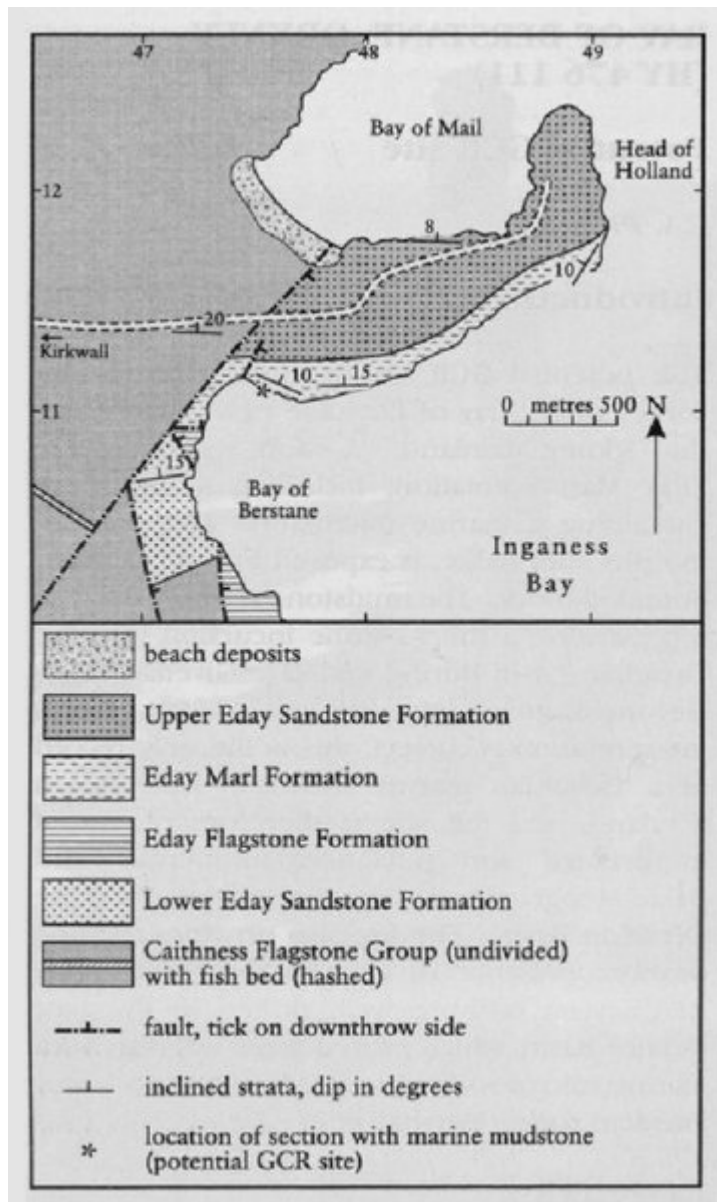
The evidence of the marine incursions in BP/Chevron Well 14/6–1 and in the Bay of Berstane section has led to a major revision of late Mid- and Late Devonian palaeogeography of the Orcadian Basin and North Sea. The discovery of marine Devonian rocks in the Argyll Field, farther south in the North Sea (Pennington, 1975) necessitated revision of the palaeogeographical model, incorporating a connection with the marine Devonian rocks of southern Britain and northern Europe along a narrow, probably fault-bounded zone. The discovery by Marshall *et al.* (1996) of the miospore *Archaeoperisaccus* in the marine beds in well 14/6–1, a genus restricted to the northern part of Laurasia to the north, indicates that the marine waters did not enter the Orcadian Basin through a southern connection. Marshall *et al.* (1996) suggest that the connection was from the east, along the Tornquist Zone, around the southern margin of the Fenno–Scandian High. When sea levels dropped, the connection was severed and continental sedimentation resumed in the Orcadian Basin.

The marine incursions represented at the Bay of Berstane and in well 14/6–1 were tentatively attributed by Marshall *et al.* (1996) and Marshall and Hewett (2003) to global sea-level rises, the Berstane occurrence being correlated with the Givetian Taghanic highstand of the 'standard' Devonian sea-level curve, as defined in New York State (House and Kirchgasser, 1993). Marshall *et al.* (1996) further speculated that the sea level was controlled by two orders of orbital cyclicity, at periodicities of 39.5 ky and 413.9 ky.

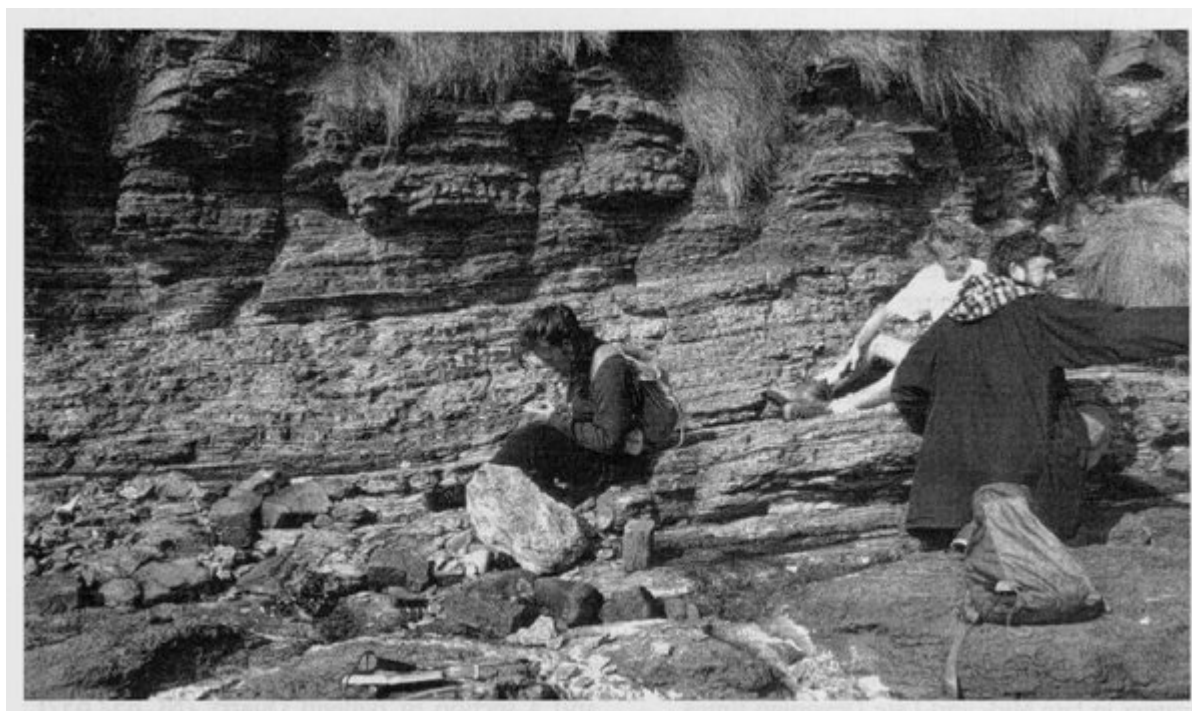
## Conclusions

This site's importance lies in providing what may be the first onshore record of a Devonian marine flooding event in Scotland. The marine interpretation is contentious, but if proved to be correct, there are important implications for the study of the palaeoenvironments and palaeogeography of the Orcadian Basin. A short section of the Eday Marl Formation contains a grey-green mudstone that has yielded marine microfossils and pseudomorphs of halite crystals. These, together with evidence from an offshore well drilled in the East Orkney Basin, may provide evidence that the sabkha plains of the Orcadian Basin were periodically inundated by marine waters in late Mid- and Late Devonian times.

## References



(Figure 2.39) Geological map of the Bay of Berstane area. After British Geological Survey (1999)



*(Figure 2.40) Grey-green mudstone unit within the Eday Marl Formation at the Bay of Berstane. (Photo: J.E.A. Marshall.)*