# Wick Quarries, Caithness

[ND 377 498]–[ND 374 491]

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## Introduction

At South Head, Wick, good exposure through part of the Middle Devonian Lower Caithness Flagstone Group is provided by a series of disused flagstone quarries cut into the sea cliffs. The quarries were last worked almost 100 years ago, since when differential weathering of the cliff faces has revealed an extraordinary array of sedimentary features. These and the lithologies present comprise a series of lithofacies produced during the sequential shallowing and deepening of a large lake occupying part of the Orcadian Basin. Of particular note are the laminated lacustrine deposits, including a fish-bearing bed; the remarkable range of shrinkage cracks, which have been variously interpreted as subaqueous and/or subaerial in origin; and the soft-sediment deformation structures showing both compressional and extensional bed-parallel movement. Field guides to the site are provided by Donovan (1978), Parnell *et al.* (1990) and Trewin (1993).

The importance of the Wick Quarries site lies in its exceptionally well-displayed sedimentary features. This allows interpretation and characterization of an otherwise poorly exposed part of the stratigraphy of the Orcadian Basin. The site is also important for the broader tectonic, lithostratigraphical and palaeogeographical interpretation of the Orcadian Basin, as well as providing exposure of rocks that have a high total organic carbon content (TOG) and are a source for oil.

## Description

The South Head promontory forms the south side of Wick Bay. Between the coastguard station and the Castle of Old Wick (Figure 2.50), a sea cliff, modified by extensive quarrying, provides an outstanding section through lacustrine strata of the Lybster Subgroup of the Lower Caithness Flagstone Group. The strata are probably of Eifelian (Mid-Devonian) age. The beds dip consistently northwards by about 10°, so that just over 100 m of strata are present within the GCR site, although minor faulting at the northern end of the section disrupts continuity.

The southernmost of the old flagstone quarries within the site area, adjacent to the road-end (Figure 2.50), affords a fine section through thinly laminated mudstones and fine-grained sandstones (Figure 2.51)a,b. This transitionally overlies a sequence dominated by thicker sandstone beds, ranging up to about 10 cm, which are commonly disrupted by extensive desiccation polygons (Figure 2.52). The quarry face exposes hundreds of couplets of mudstone-fine sandstone, each between a few millimetres and several centimetres thick; it is an excellent example of 'B to C association' flagstones as defined by Donovan (1980) (see 'Introduction', (Figure 2.3) for further details). The sandstone layers commonly extend downwards into small shrinkage cracks that penetrate the underlying mudstone, the so-called 'fang structures' of Donovan (1980). Differential compaction strongly deformed many of the crack infills so that they are bulbous or sinuous in cross-section. It is understandable that they were originally interpreted as bioturbation (Crampton and Carruthers, 1914) and their origin remains controversial (see 'Interpretation' below).

Interbedded with the mudstone-sandstone couplets are abundant, thin dolomitic layers up to about 2 cm thick that weather to a distinctive orange-brown colour. During diagenesis, the dolostones were lithified earlier than the adjacent mudstone-fine sandstone couplets and so behaved in a more competent fashion during early deformation. As a result, the dolostones preserve a remarkable array of small-scale compressional and extensional, brittle and ductile structures (Figure 2.53). Recumbent folds and thrusts demonstrate considerable local shortening (Figure 2.53)a,b, but other beds in close proximity are boudinaged or offset by small arrays of en-echelon normal faults (Figure 2.53)c.

The main face of the quarry exposes a sandstone body above the laminites. About 2 m thick, in cross-bedded sets up to about 30 cm, the sandstone is the 'D association' of Donovan (1980). North from here, the central part of the GCR site spans a quarried area around Trinkie Pool, which is slightly higher in the sequence than that exposed in the southernmost quarry. The distinctive mudstone–fine sandstone laminites again dominate, but sporadic thicker (up to about 10 cm) sandstone beds are also present. There is one thicker development of laminated mudstone ('A association' of Donovan, 1980) from which fish remains have been recovered and which is reported to be cut by hydrocarbon-bearing veins (Trewin, 1993). To the north, and higher in the succession, the laminites are interbedded with increasing amounts of thin sandstone beds, which are generally internally cross-laminated and, in some cases, extensively and chaotically convoluted. Thin sandstone dykes cutting obliquely across 1 m or more of strata are further evidence of wet-sediment mobility. Exposed bedding surfaces of the sandstones are extensively rippled (Figure 2.54) and carry a range of cracks. Some are polygonal, but most are commonly lenticular and either randomly arranged or aligned. Locally, the crack patterns interfere to give complex, mixed arrays that are probably polygenetic.

## Interpretation

The strata exposed in the series of old quarries at South Head, Wick were originally laid down in a large lake. The lithologies reflect changes in lake conditions, primarily water depth, and these have been grouped together into four general lithofacies associations by Donovan (1980) (see 'Introduction', and (Figure 2.3) for further details). The South Head sequence shows two major deepening–shallowing cycles, on which bed-by-bed variations are superimposed.

The southernmost, oldest strata are sandstones, which were probably shallow-water deposits, with some polygonal desiccation cracks indicating sporadic emergence as the lake dried up. Stratigraphically above these sandstones, the laminated mudstone–fine-grained sandstone couplets CB to C association') seen in the southernmost quarry are the deposits of a shallow lake with a seasonally fluctuating water-level. Sporadic, thicker sandstone beds are probably turbidite units. Higher in the sequence, the significantly thicker and more massive sandstone body (the 'D association') is evidence for a return to very shallow water depths. It represents an increased clastic input to what had previously been a relatively distal lacustrine area, the shallower water allowing wave or fluvial reworking of the sediment in cross-bedded sets. Parnell *et al.* (1990) go further and suggest a partial aeolian origin for the cross-bedding, implying temporary emergence.

Subsequent deepening of the lake is shown by the re-appearance of the 'B to C association' laminites, a trend that reaches its fullest development with the fish-bearing mudstone laminite close to Trinkie Pool. In detail, this bed comprises sub-0.5 mm, alternating layers of fine, clastic sediment, carbonate and organic carbon probably derived from seasonal algal blooms. The whole assemblage is interpreted as 'a non-glacial varve recording sequential deposition in a tropical, eutrophic lake whose waters were subject to some degree of thermal stratification' (Donovan, 1980). The 'A association' unit is evidence for a deep lake environment remaining relatively stable for at least hundreds, and possibly thousands, of years. Thereafter, renewed shallowing of the lake is shown by the up-sequence (northward) return to 'B to C association' laminites and the increasing proportion of sandstone beds with polygonal desiccation cracks and rippled surfaces.

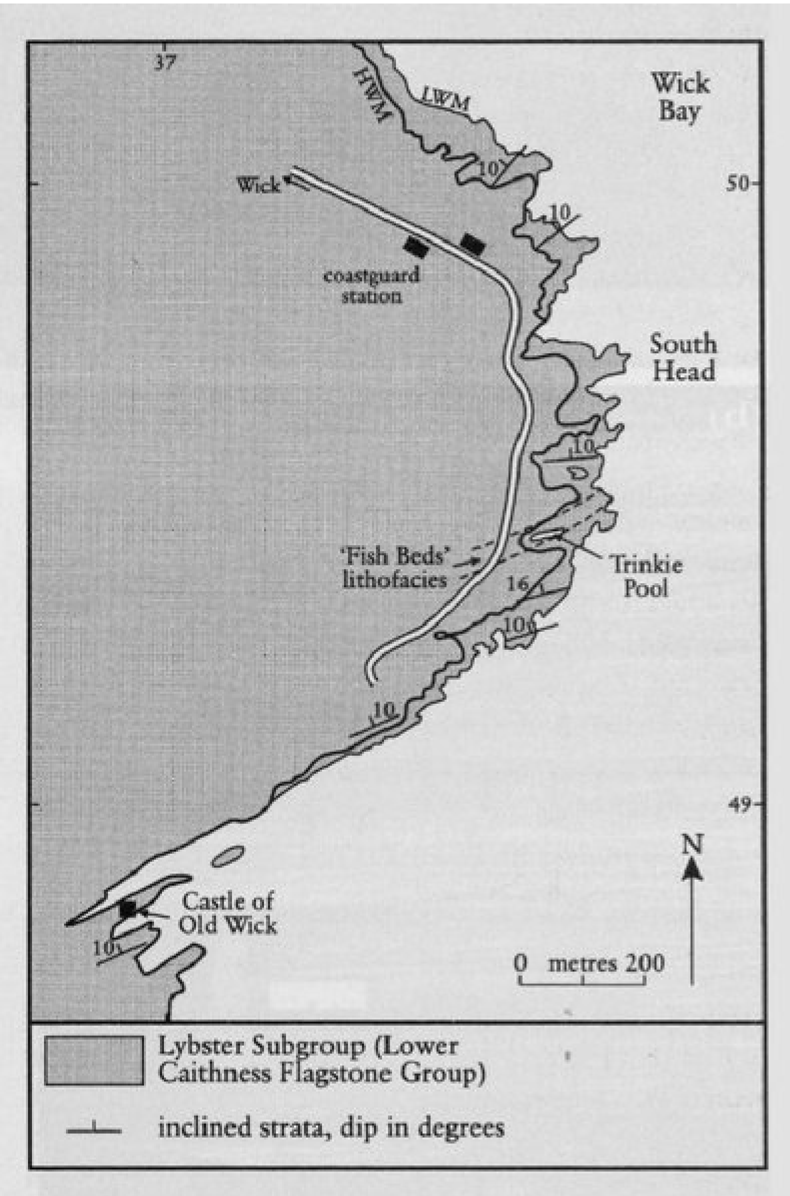
Polygonal crack patterns on bedding surfaces have been cited above as evidence for shallowing of the lake, with periodic emergence and desiccation of the sediments. However, most of the shrinkage cracks seen in the South Head section are isolated, curved and lenticular, and their interpretation is more controversial. Donovan and Foster (1972) considered them to be subaqueous in origin, and formed by a synaeresis-like process, perhaps linked to salinity changes in the lake. This interpretation has been supported by Trewin (1992, 1993), Barclay *et al.* (1993) and Trewin and Thirlwall (2002), and precludes subaerial conditions. Rogers and Astin (1991) and Astin and Rogers (1992, 1993) expressed a contrary view, suggesting that the formation of gypsum, and possibly halite, crystals during the drying out of the lake (with commensurate increase in salinity) was an important precursor to the formation of the lenticular cracks. The crack patterns and geometry were controlled by that of the crystals, the extent of desiccation and the thickness of sediment layer. During dry periods, wind-blown sand filled the open cracks and was deposited as thin lenses and laminae on the exposed playa-lake floor. The Astin and Rogers interpretation requires longer periods of subaerial conditions than the interpretation of Donovan and Trewin.

One of the most striking features of the 'B to C association' laminites is the widespread presence of small-scale, but intense compressional and extensional structures (Figure 2.43). The structures are picked out by the dolomitic layers that appear to have lithified before the enclosing mudstone, and so responded differently to early deformation. Compressional structures are more common than extensional features, but both are extensively developed and may occur in close proximity to each other, both vertically and horizontally. A complex, polyphase history of bed-parallel movement seems likely. This may have partly occurred during burial and loading, but may also be a result of adjustment during extensional faulting and subsidence of the Orcadian Basin.

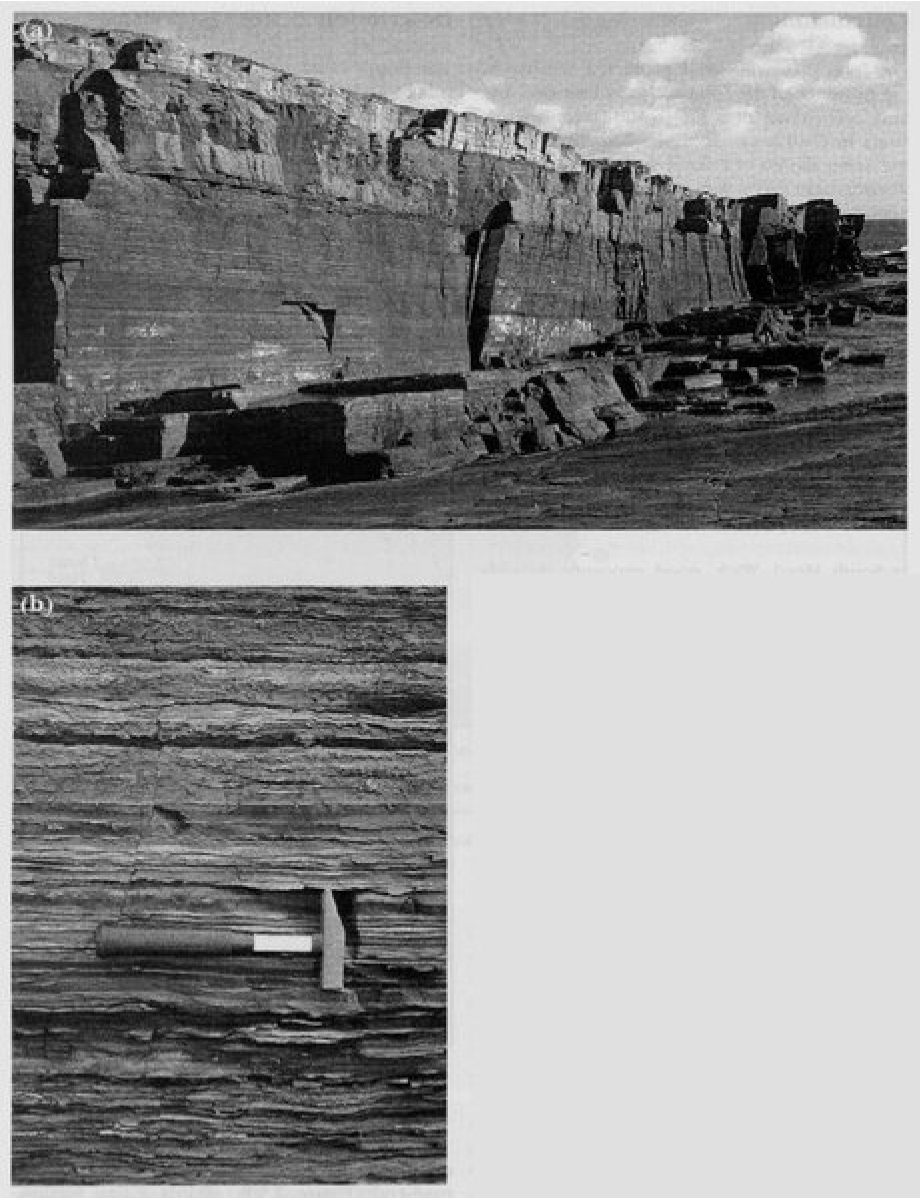
## Conclusions

The Wick Quarries GCR site provides an exceptionally well-exposed representative section of part of the Middle Devonian Lower Caithness Flagstone Group. Two lithofacies cycles are seen, representing the sequential shallowing and deepening of the Orcadian Basin lake. The site is of great importance in regional interpretation of the tectonics and palaeogeography of the Orcadian Basin. In addition, the excellent preservation of a spectacular array of shrinkage-crack styles provides pertinent evidence to current scientific debate concerning their origin. Polygonal crack patterns have traditionally been associated with desiccation, whereas lenticular cracks have been regarded as subaqueous. A recent re-interpretation of the lenticular cracks in the Wick Quarries section as the result of evaporite mineral formation and subsequent dissolution, subaerial desiccation and infilling by aeolian sand presents a radically different interpretation of lake chemistry and sedimentation in this part of the Orcadian Basin. A further aspect of the importance of the site lies in it being one of the few localities where potential hydrocarbon source rocks can be examined.

**References**

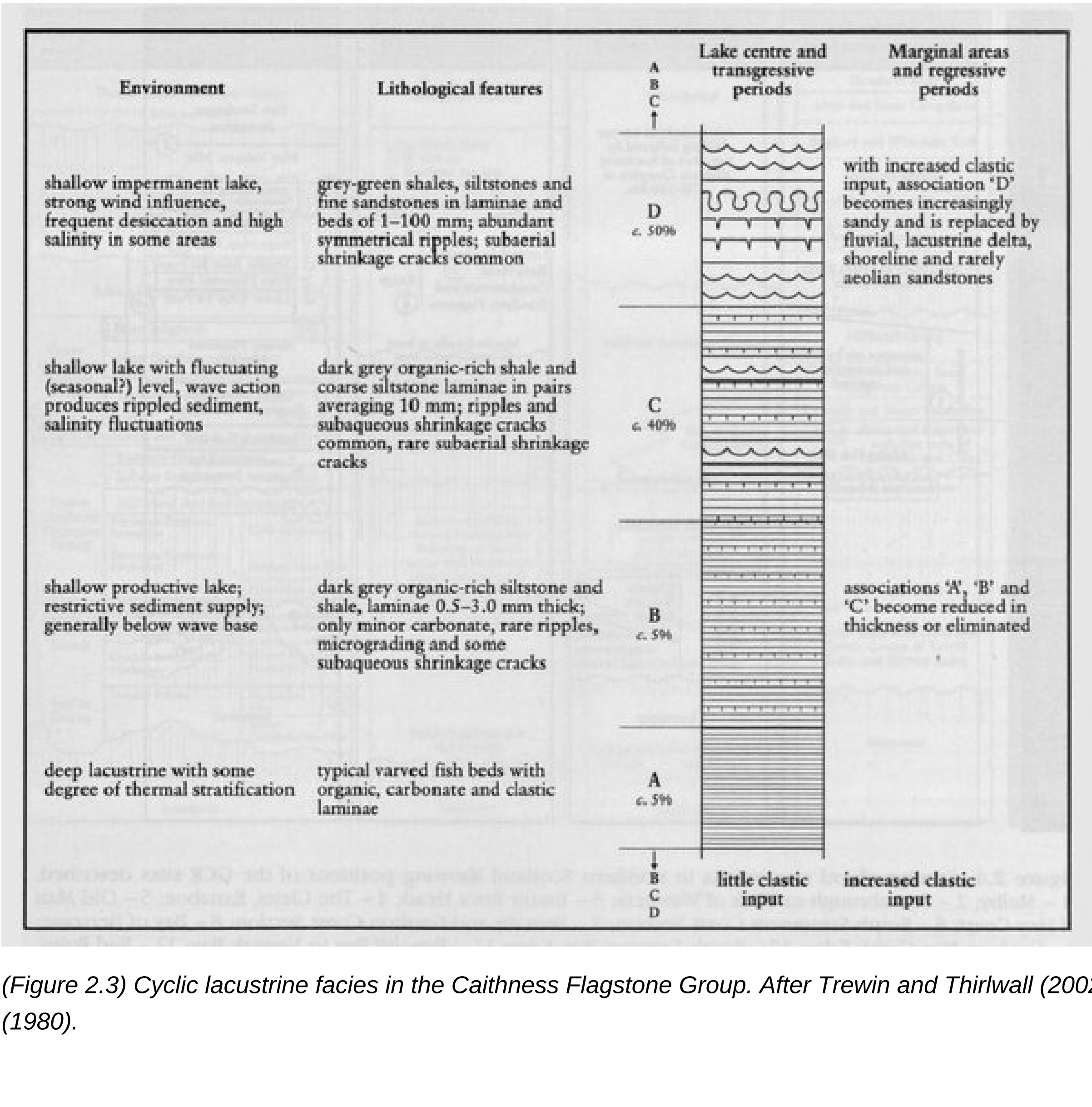


(Figure 2.50) Map of the Wick Quarries GCR site.

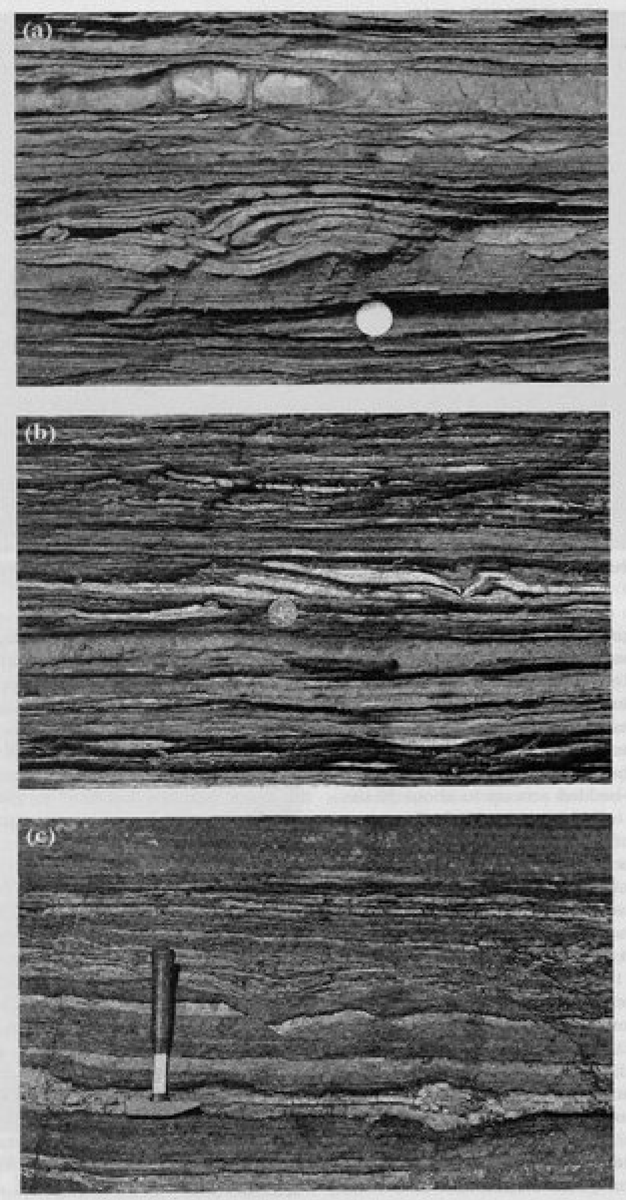



(Figure 2.51) (a) Laminated mudstones and thin sandstones of the Lower Caithness Flagstone Group, South Head. (b) Detail of laminites, Lower Caithness Flagstone Group, South Head. (Photos: P. Stone.)

(Figure 2.52) Desiccation polygons, Wick Quarries, South Head, Wick. (Photo: P. Stone.)




(Figure 2.3) Cyclic lacustrine facies in the Caithness Flagstone Group. After Trewin and Thirlwall (2002), from Donovan (1980).




*(Figure 2.53) Laminites of mudstone, sandstone and dolostone, Wick Quarries. (a,b) Small-scale recumbent shortening structures; (c) small-scale brittle extensional faults. (Photos: P. Stone.)*

*(Figure 2.54) Rippled sandstone surface, Wick Quarries. (Photo: P. Stone.)*

*(Figure 2.43) Coarse breccia of basement and limestone clasts in a sandy matrix, overlying massive limestone, Red Point. (Photo: P. Stone.)*