Footabrough to Wick of Watsness, Shetland

[HU 179 502]–[HU 201 495]

P. Stone

Introduction

This section was originally named 'Fidlar Geo to Watsness' in the GCR archive. However, Fidlar Geo is in the middle of the section, and the south-east end of the site is better described as 'Voe of Footabrough', or simply as 'Footabrough'. At the north-west end of the site 'Watsness' should be either 'Wats Ness' (a location that is actually beyond the site boundary) or Wick of Watsness'.

The sea cliffs between Wick of Watsness and Voe of Footabrough on the west coast of the Walls Peninsula, Shetland Mainland, provide excellent, continuous exposure through folded strata of the Middle Devonian (Givetian) Walls Formation. Fidlar Geo [HU 190 493] is a prominent inlet in the central part of this section. The Walls Formation is part of the sequence lying between the N–S-trending Melby and Walls Boundary faults, and so forms part of the central Devonian structural tract within Shetland. Interpretation of the lithofacies present has proved difficult and controversial. The sequence is dominated by intercalated sandstone and shale that have been interpreted as turbidites deposited in a deep, lacustrine environment. However, a broad consensus from the most recent work (Melvin, 1985) is that a range of alluvial, braided stream, shoreline and shallow lacustrine environments are represented.

The regional importance of the site lies in the correct interpretation of its enigmatic lithofacies, thus allowing elucidation of depositional geometry within an otherwise poorly understood part of the Orcadian Basin. In this respect the site has an important role in characterizing the central north–south Devonian structural tract in Shetland. Detailed descriptions of the Walls Formation in the GCR site area are provided by Melvin (1976, 1985), Mykura and Phemister (1976) and Astin (1982). An overview of the geology is provided by Mykura (1976, 1991).

Description

Spectacular sea-cliffs along the coastline of the Walls Peninsula form the western extremity of Shetland Mainland. The cliffs expose an extensive section through part of the Walls Formation between Wick of Watsness and Voe of Footabrough (Figure 2.13). The sandstone-dominated formation was formerly thought to exceed 9000 m in thickness (Mykura, 1976), but may be much thinner (as discussed below). Only a part of this is exposed within the GCR site, but faulting and locally intense folding make thickness estimation very difficult.

A sparse and fragmentary fish fauna, together with some indeterminate plant detritus, has been recovered from the Walls Formation (including three localities within the GCR site) (Mykura and Phemister, 1976), but is indicative only of a broadly Mid-Devonian age. Highly carbonized palynomorphs collected by Melvin (1985) suggest a Devonian age no older than Emsian, and a more recent study of miospores has confirmed a Givetian age (Marshall, 2000). An approximate upper age limit is provided by the 360 ± 11 Ma date (K-Ar) from the Sandsting Plutonic Complex, which intrudes the Walls Formation in the south-east part of its outcrop (Mykura and Phemister, 1976).

The Walls Formation lies between the Melby and Walls Boundary faults, and so forms part of the central of the north–south structural tracts that contain the Shetland Devonian succession (Figure 2.2). The strata are folded about a series of upright, open to close synclines and anticlines (Figure 2.14) that trend approximately ENE and plunge gently towards the WSW. Hence, bedding dips range from horizontal to sub-vertical and strikes are variable (Figure 2.15)a,b. A locally strong cleavage is developed broadly axial planar to the folds. At least some of the deformation has been related to the intrusion of the Sandsting Plutonic Complex (Mykura, 1991).

Mykura and Phemister (1976) noted the vertical and lateral lithological uniformity of the Walls Formation. It comprises stacked cycles, each consisting of a basal fine-grained, dark grey sandstone that passes up into a finer-grained, thinly bedded unit consisting, in varying proportions, of shale, siltstone and, rarely, impure limestone. Complete cycles range in thickness from 0.75 m to 20 m, with individual sandstones up to 18 m thick. The ratio of sandstone to shale and siltstone varies between different parts of the formation, as is well illustrated southwards along the coast from Wats Ness, where shale-rich cycles are dominant for up to about 20 m but then alternate with sandstone-rich cycles 25–45 m thick. Melvin (1976, 1985) estimated that various types of sandstone-rich cycles form almost 80% of the succession, with the shale-rich cycles making up the remaining 20%.

The sandstone beds generally have a sharp base, with flute and groove marks developed locally, resting on an erosion surface. Rip-up clasts of shale and siltstone are common, but nowhere abundant, in the lowest few centimetres of the sandstone. Cross-bedding of various types is widespread, ranging from large-scale, planar forms to small-scale, trough cross-lamination. In some places, concentrations of heavy minerals line the cross-bedding foresets. Convolute lamination is also widespread, and some examples are truncated at the base of the overlying sandstone bed. Texturally, most of the sandstone is fine- or medium-grained and fairly well-sorted, with a matrix content up to about 25% (much of which is carbonate). The main detrital components are mono- and polycrystalline quartz, potassium feldspar (mainly orthoclase) and some plagioclase; accessories include muscovite, biotite, granite and garnetiferous quartz-mica gneiss (Melvin, 1976, 1985; Knudsen, 2000). The approximate overall modal proportions are: 70% quartz, 25% feldspar and 5% lithic fragments, which classify the sandstone as a subarkose. Detrital heavy minerals are abundant in some of the sandstones and may comprise up to 17% of the grains. Zircon, tourmaline and epidote are the most abundant, with less common sphene, rutile, clinozoisite and apatite.

The shale-rich parts of the succession contain many beds with well-developed ripple cross-lamination (Figure 2.16), which is locally accentuated by the coincidence of ripple crests with the bedding–cleavage intersection lineation. In some cases, successive beds show markedly different ripple orientations. Load casts are widespread and locally form pseudonodule layers. Desiccation polygons have been reported on some bedding surfaces by Melvin (1985), although Mykura and Phemister (1976) commented on their apparent absence from the Walls Formation. A typical section through the shale-rich lithofacies is shown in (Figure 2.17)a (Melvin, 1985). Thin beds of limestone and calcareous mudstone occur sporadically and are invariably finely laminated, with some included carbonaceous films. Most are disrupted by soft-sediment deformation, with subsequent preferential deformation by tectonic processes.

Interpretation

Various interpretations have been proposed for the depositional environment of the Walls Formation, and the topic remains controversial. Mykura and Phemister (1976) preferred an origin as turbidity flows within a deep, subsiding lake basin, although conceding the possibility of fluvial deposition. They were strongly influenced by the uniformity of the sandstone–shale succession over a considerable thickness (apparently up to 9000 m) and the apparent absence of diagnostic indicators of fluvial or sub-aerial environments. Examples of the latter, such as desiccation crack polygons, were subsequently discovered, and later workers (Melvin, 1976; Astin, 1982) preferred a shallow-water to fluvial depositional interpretation. Astin questioned the apparently great thickness of the succession and demonstrated sedimentological continuity northwards across the Sulma Water Fault (Figure 2.14) into the Sandness Formation, where fluvial depositional features are well developed. Further doubt was cast on the thickness estimate of 9000 m when Marshall (2000) showed from miospore evidence that both the Walls and Sandness formations were entirely Givetian in age.

The coast section forming the GCR site was shown by Melvin (1976, 1985) to consist largely of thick, multi-storey sequences of channelized, trough cross-stratified sandstone. Relationships between the successive channel units are complex, with cross-cutting scour surfaces underlying the bases of many sandstones. The assemblage of features suggests that in-channel deposition dominated, probably within a braided stream environment. A few of the sandstone-rich cycles show a particularly marked fining-upward trend and these were interpreted by Melvin (1985) to represent a progression of depositional environments from channel to sandbar, levee and floodplain ((Figure 2.17)b). The shale-rich cycles were interpreted by Melvin as shallow-water, floodplain deposits. Some thin, rippled sandstone beds within this over-bank sequence were probably deposited from intermittent sheet floods, and the sporadic desiccation cracks suggest periods of subaerial exposure. More prolonged lacustrine deposition gave rise to the carbonate-rich beds, reflecting increased phytoplankton abundance.

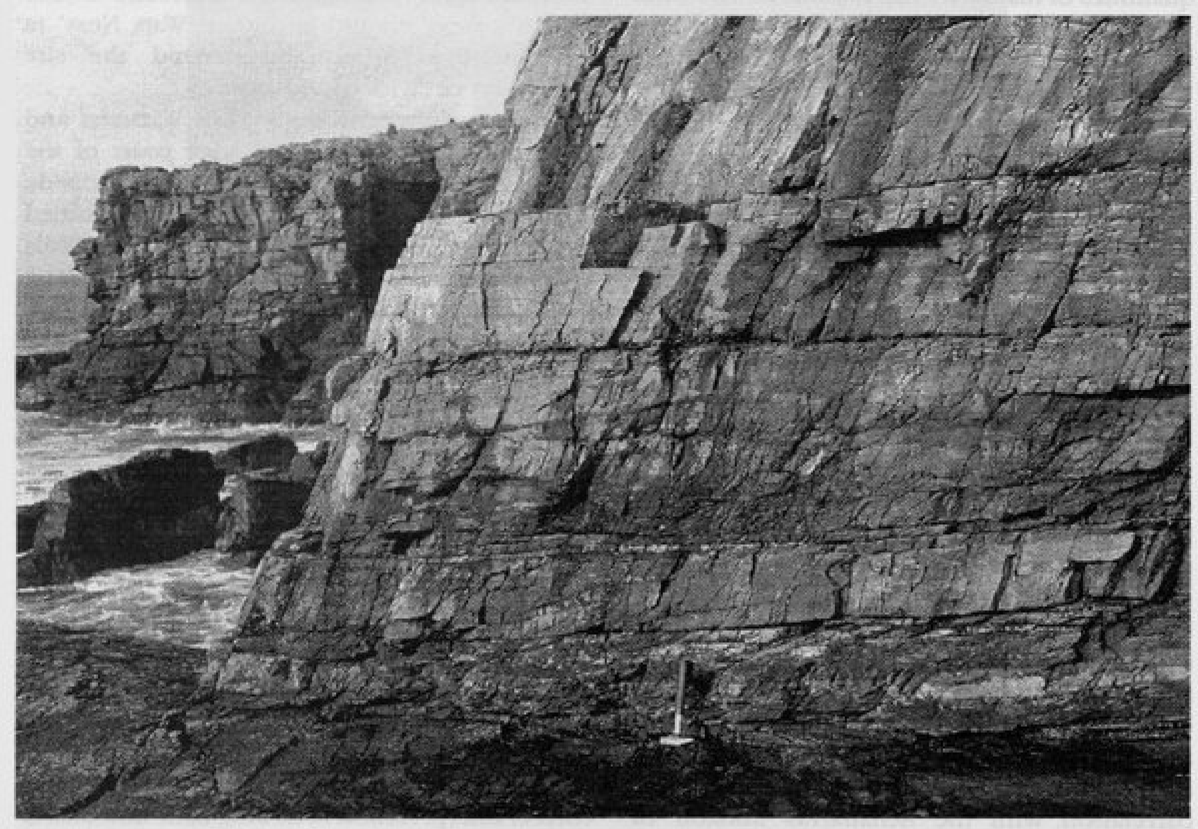
An important variation on a fluvial depositional interpretation was proposed by Astin (1982), who recognized a lateral facies transition from north-east to south-west. In his interpretation, the north-east part of the Walls Formation consists of an alluvial fan derived from the metamorphic rocks to the north (equivalent and probably contiguous with the Sandness Formation). Towards the south-west the alluvial fan merges with more distal, lacustrine deposits and, most controversially, with beach ridges, the latter well represented within the GCR site as parts of the channel-bar and bar-top sandstone assemblages of Melvin (1976, 1985). The correct lithofacies interpretation is important for an accurate assessment of basin geometry and regional tectonics. The current consensus view has moved away from a deep lacustrine, turbidity-flow origin for the Walls Formation and now favours braided alluvial plain to shallow lacustrine and beach environments.

The tectonic deformation of the Walls Formation, involving two separate folding episodes (Mykura and Phemister, 1976), makes it difficult to deduce palaeocurrent flow directions from the sedimentary features. However, both Melvin (1976, 1985) and Astin (1982) deduced a broad flow regime from north to south, with sediment provenance to the north. The suite of detritus, together with its isotopic characteristics (Knudsen, 2000), suggests that the source was a composite granitic and metamorphic terrane with characteristics similar to those of the basement rocks now seen between the Melby and Walls Boundary faults. Thus, Devonian strata now occupying the central of the Shetland structural tracts could have been derived by erosion of the basement rocks from that same structural tract.

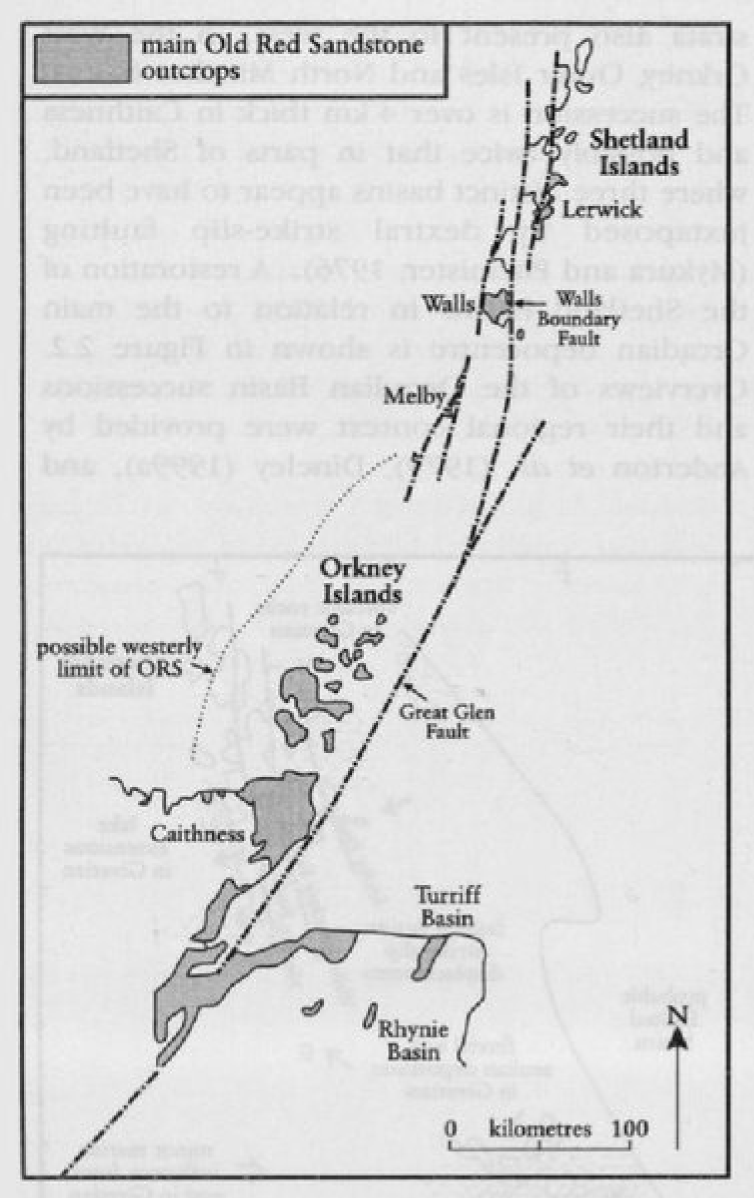
Conclusions

The Footabrough to Wick of Watsness GCR site provides a well-exposed section through part of the Walls Formation that is representative of the central of the Devonian structural tracts in Shetland. Sandstone, siltstone and shale combine in varying proportions to give broad alternations, over tens of metres, of sandstone-rich and shale-rich units with strong sedimentary cyclicity. The thick, sandstone-dominated units have a range of sedimentary features that have been interpreted in different ways. Turbidite deposition in a deep lake has been proposed, but the more recent consensus favours a combination of braided fluvial channel, littoral and shallow lacustrine environments. The interpretation of sedimentary depositional environments remains a subject of debate, but is of great importance in assessment of the regional basin geometry and tectonics.

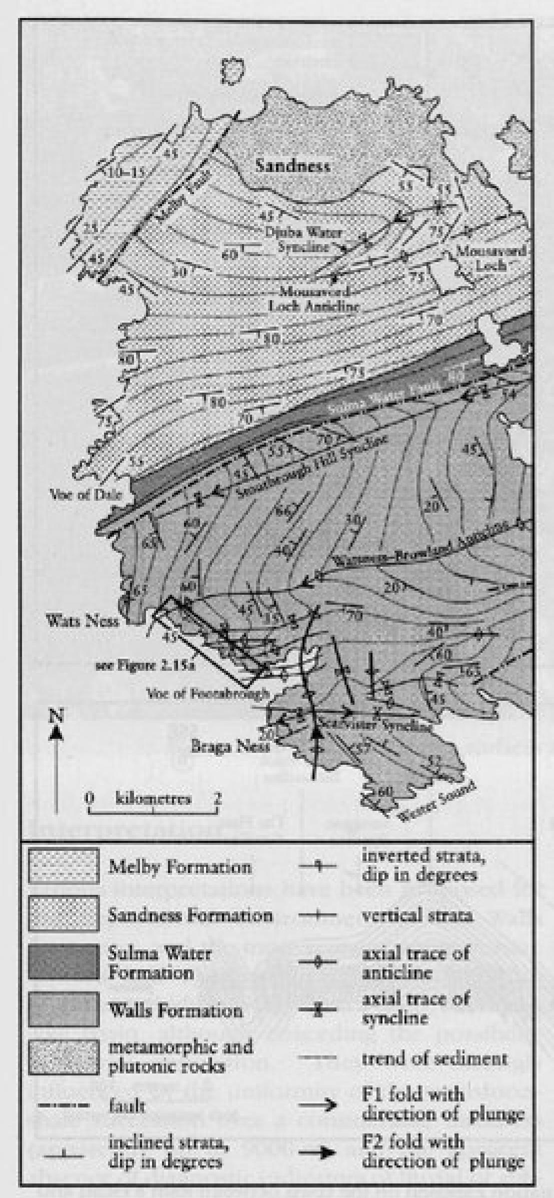
References



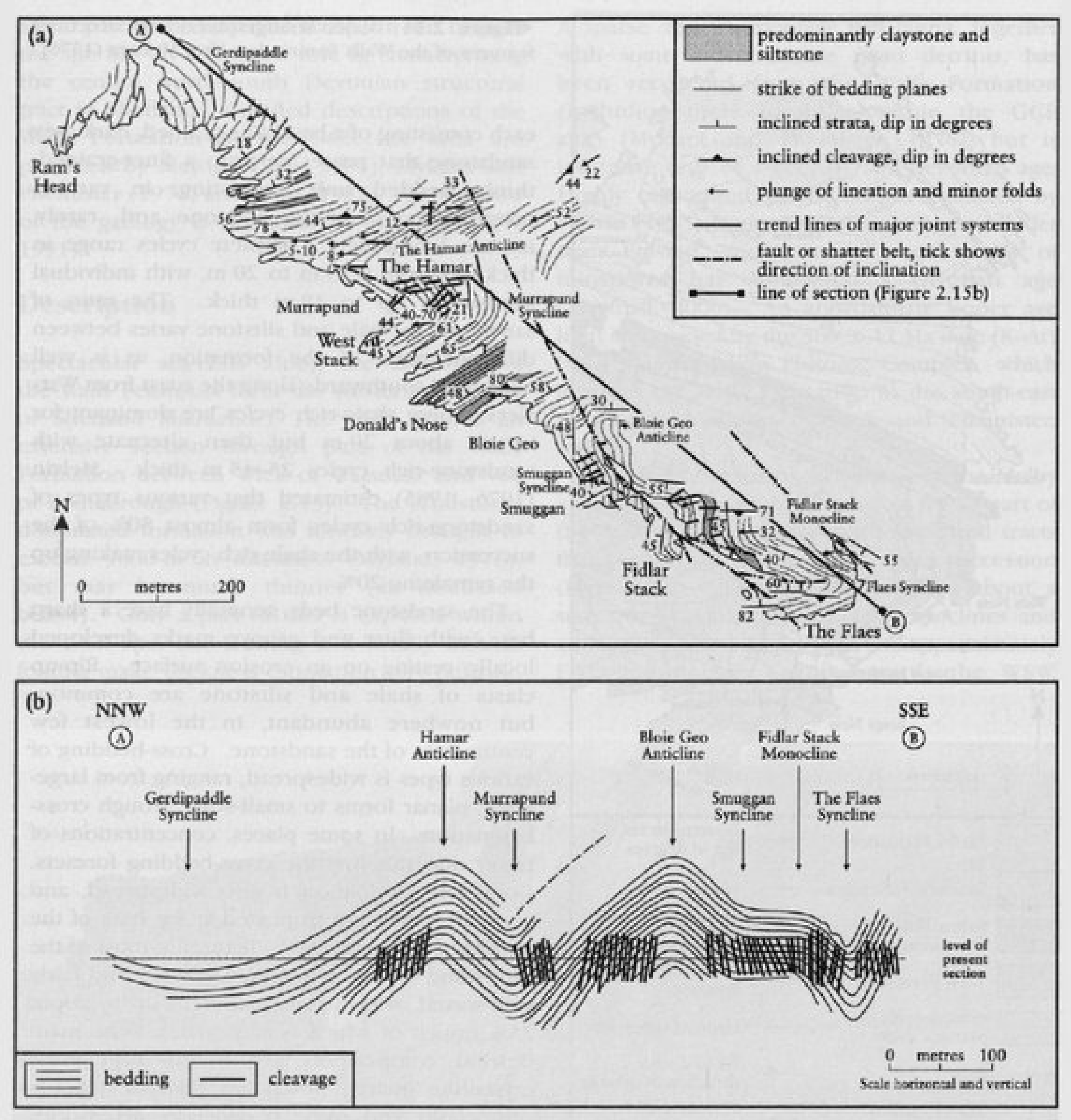
(Figure 2.13) The Walls Formation at Cotti Geo, Ram's Head. (Photo: P. Stone.)



(Figure 2.2) Old Red Sandstone outcrops in the Orcadian Basin and restoration of strike-slip displacements in the Shetland Islands. Based on Mykura and Phemister (1976) and Anderton et al. (1979).

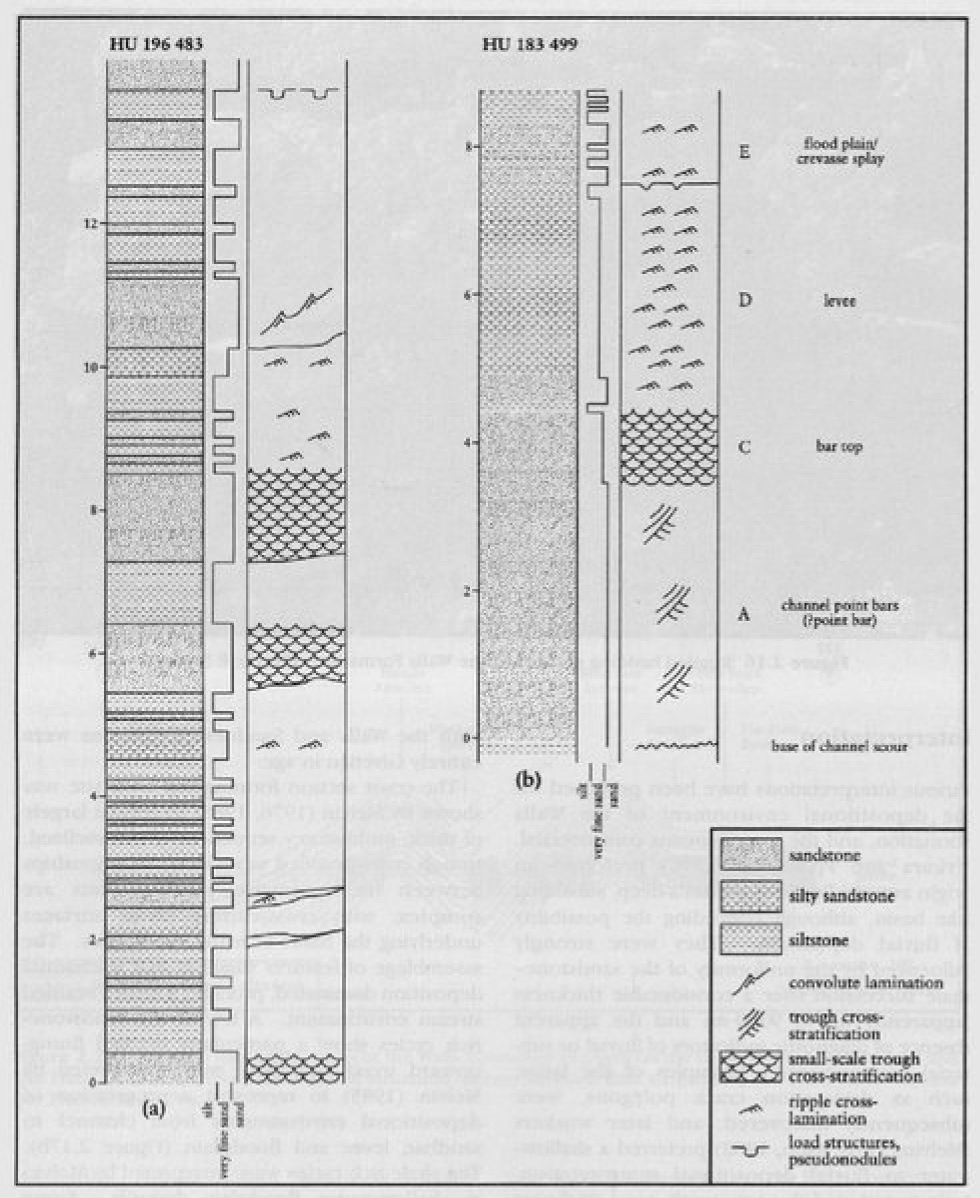


(Figure 2.14) Major stratigraphical and structural features of the Walls Peninsula. After Mykura (1976).



(Figure 2.15) (a) Sketch map of the rocks of the Walls Formation exposed on the coast between Ram's Head and The Flaes. (b) Cross-section showing the structural pattern between Ram's Head and The Flaes. After Mykura and Phemister (1976).

(Figure 2.16) Rippled bedding surfaces in the Walls Formation. (Photo: P. Stone).



(Figure 2.17) Examples of lithofacies associations in the Walls Formation. After Melvin (1985).