Tarbat Ness, Ross and Cromarty

[NH 929 873]–[NH 939 851]

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Introduction

The cliff and foreshore sections on either side of Tarbat Ness afford excellent exposure through parts of the Strath Rory Group (Middle Devonian) and the Balnagown Group (Upper Devonian). The site also provides evidence pertinent to the debate over the relationship between the Middle and Upper Devonian successions. A regional unconformity seems likely, but there appears to be a conformable succession at this site. A range of lithofacies is present, including fluvial pebble conglomerates and pebbly sandstones, aeolian sandstones, and a sabkha-type facies of sandstone and mudstone containing evidence of evaporitic deposition, desiccation, intermittent rainfall and subaerial animal activity. The most comprehensive description and interpretation of the site are by Rogers (1987), whose results were incorporated into a regional palaeogeographical analysis by Marshall *et al.* (1996).

The importance of the Tarbat Ness site is twofold. Firstly, it provides a complete section through the Upper Devonian succession, allowing interpretation and characterization of an otherwise poorly represented part of the stratigraphy of the Orcadian Basin. It also provides one of the few apparently conformable transitions between the Middle and Upper Devonian strata. The site thus has sedimentological value, and is important to the broader interpretation of the palaeogeography, development and tectonics of the Orcadian Basin.

Description

The Tarbat Ness GCR site consists of the cliff and foreshore exposures to the west and south of the lighthouse. It forms the extreme north-eastern promontory of Easter Ross between the Moray and Dornoch firths. The exposed strata span the Middle Devonian Strath Rory Group and Upper Devonian Balnagown Group, the contact between them being variously interpreted as faulted or conformable. The dip is fairly uniform towards the north-west, steepening in that direction from 10° to nearly 40°, within the south-east limb of the Black Isle Syncline. About 800 m of beds are seen within the site, although continuity is disrupted by faulting towards the top and the bottom of the section.

The oldest strata are preserved on the east coast of the promontory, as a strike section along the shore southwards from a point about 1.5 km south of Tarbat Ness (Figure 2.60). They are thickly bedded, yellow and red, fluvial sandstones with subordinate (but fairly common) thin interbeds of calcareous mudstone. The beds were assigned by Armstrong (1977) to the Strath Rory Group. The sandstones are generally cross-bedded on a fairly large scale and internal lamination is highly convoluted locally. The mudstone interbeds contain sporadic carbonate concretions, some of which have yielded fish fragments that support an early Givetian (Mid-Devonian) age. Elsewhere, the Strath Rory Group ranges down into the Eifelian Stage (Dineley and Metcalf 1999).

The top of the Strath Rory Group was placed by Armstrong (1977; see also Institute of Geological Sciences, 1973) at a fault on the south side of Port Tarsuinn, probably the same one identified by Rogers (1987) as the South Wilkhaven Fault (Figure 2.60). This interpretation allows for an unconformable relationship between the Strath Rory Group and the overlying strata, the unconformity itself being farther inland and unexposed. By contrast, Rogers (1987) proposed a complete and conformable succession, compiled in various fault blocks around Port Tarsuinn. He noted a thick sandstone body, probably of aeolian origin (the Port Tarsuinn Member of the Rockfield Formation in his informal stratigraphy), at the top of the Strath Rory Group conformably overlain by coarse, pebbly sandstones of the Balnagown Group.

Rocks of the Balnagown Group (Armstrong, 1977) form the headland of Tarbat Ness and are exposed from there along the north coast of the promontory. Red, pebbly sandstones with conglomeratic lenses and interbeds predominate at the base of the group, and are exposed northwards from Port Tarsuinn and around the headland itself. Rogers (1987) informally named these beds the 'Tarbat Ness Formation'. The pebbles are invariably well-rounded and mainly quartzose. They form conglomeratic beds up to about 20 cm thick, but more commonly occur as lenticular bodies (Figure 2.61)a or as isolated clasts strewn along bedding surfaces (Figure 2.61)b. The formation is cross-bedded on a large scale, with conglomeratic layers forming individual cross-sets and isolated pebbles lining foresets (Figure 2.61)c. The concentration of pebbles decreases up-sequence towards Tarbat Ness, but thereafter appears to increase again towards the top of the Tarbat Ness Formation. Around the lighthouse and headland, many of the thick, red sandstone beds contain only sporadic, isolated pebbles and many are pebble-free. The sandstones are cross-bedded on a large scale (Figure 2.62)a, and there are many examples of convolute bedding and post-depositional deformation, probably caused by slumping and de-watering, the latter phenomenon having produced sand volcanoes in places (Figure 2.62)b.

The top of the Tarbat Ness Formation, to the west of the headland, shows an irregular increase in the proportion of pebbles in the thick, cross-bedded red sandstones towards Port Albion and Canas Solais. There, pebble content and bed thickness abruptly decrease, above which the higher part of the Balnagown Group is dominated by thinly interbedded sandstone and mudstone. Rogers (1987) named these beds the Gaza Formation.

The characteristic lithologies of the Gaza Formation are very thinly bedded, argillaceous, fine-grained sandstones and rare mudstones (Figure 2.63)a. Colour ranges from red to yellow-green, with many beds having a mottled appearance. An irregular, wavy lamination, defined by colour variation or silty partings, is fairly ubiquitous in the thin sandstone beds, and very low-amplitude ripples are apparent on some bedding surfaces, particularly where they are picked out by a colour variation. Red mudstone flakes are common on some bedding planes and sporadic, thicker, sandstone beds also contain isolated mudstone lasts. The thicker sandstones may be either fluvial or aeolian, but higher in the Gaza Formation, towards the north-western boundary of the GCR site at Castlehaven, Rogers (1987) identified compound aeolian dunes (draas) forming sandstone bodies up to 14 in thick. These sandstones show large-scale, internal cross-bedding, described by Rogers in terms of three orders of bounding surface. He also noted the presence of small (0.5–3 mm) 'adhesion warts' within the cross-sets (Figure 2.63)b and interpreted them as clusters of grains held together by moisture from sparse rainfall. Rare examples of rain impact pits were also noted elsewhere in the sequence.

Rogers (1987) described a range of trace fossils from the Gaza Formation, mostly in the Castlehaven area. The forms include tetrapod tracks attributed to early amphibians, arthropod tracks and burrows, and zones of strata homogenized by bioturbation. Although compatible with a Late Devonian age, the trace fossils do not provide a more exact date for the formation, which is generally presumed to be Frasnian to Famennian in age (Mykura, 1991; Dineley and Metcalf, 1999).

Interpretation

The lower part of the sequence exposed within the GCR site comprises thick, cross-bedded, fluvial sandstones of the Strath Rory Group, deposited in response to the basin rejuvenation that accompanied early Mid-Devonian deformation and uplift (Armstrong, 1977). Thick conglomerate beds in the lower part of the Strath Rory Group, not represented within the GCR site, indicate derivation from uplifted areas of Moine and Dalradian rocks to the west and south; a similar provenance direction is indicated by the cross-bedding in the sandstones.

Within the fluvial sandstones of the Strath Rory Group, interbeds of red mudstone with calcareous laminae and concretions probably represent lacustrine episodes and indicate the of the bedded sandstones intermittent extension, into the Easter Ross region, of the main Orcadian Basin lake that was centred on Caithness. The thick aeolian sandstones (Port Tarsuinn Member) identified by Rogers (1987) at the top of the Strath Rory Group, provide evidence of temporary subaerial conditions prior to the re-establishment of a fluvial regime at the base of the Balnagown Group. This is marked by the appearance of conglomeratic lenses, pebbly sandstones and thick, cross-bedded fluvial sandstones, which, together with the absence of red mudstone interbeds, are characteristic of the Tarbat Ness Formation. The conglomerate pebbles are invariably well-rounded (Figure 2.61), suggesting some degree of reworking of the underlying Strath Rory Group. The fluvial sandstones show widespread internal convolute lamination and liquefaction phenomena such as sand volcanoes (Figure 2.62)b, indicating de-watering during rapid burial of water-saturated sand, probably in a large, braided river system.

The top of the Tarbat Ness Formation marks a major environmental change. The overlying non-pebbly, fluvial sandstones and thinly interbedded sandstones and mudstones (the Gaza Formation) were interpreted by Rogers (1987) as having formed in a sabkha-like environment. The presence of the fragmented remains of desiccated mud layers as mudstone flakes in the sandstones, and 'adhesion warts' produced by differential wetting of a dry sand surface support this interpretation. Rippled surfaces may have formed either by adhesion of blown sand to an irregularly damp surface or by sheet flooding, but Rogers (1987) speculates that, in either case, wind scour may have accentuated the features. Roughly polygonal to irregularly sinuous ridges rising up to 1 cm above some bedding surfaces caused localized disruption of the underlying sandstone laminae. Rogers (1987) interpreted them as a result of surface buckling during expansion due to evaporite formation. This interpretation supports a sabkha origin. Rain pitting, and the tetrapod and arthropod tracks add further evidence of predominantly subaerial environments during deposition of the Gaza Formation.

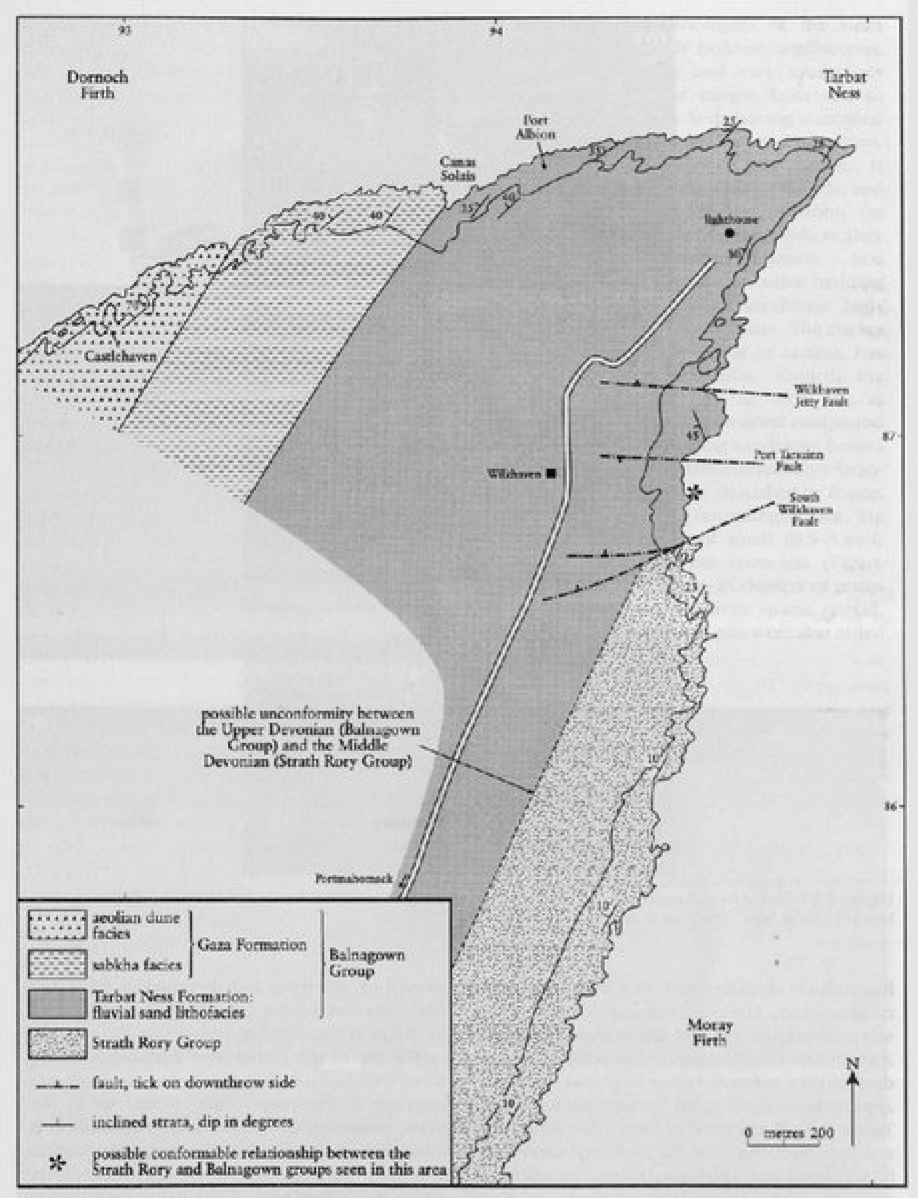
At the north-western extremity of the GCR site, the Gaza Formation is overlain by a thick, compound aeolian dune sequence identified as a draa by Rogers (1987). From measurements of the internal set and co-set relationships, Rogers calculated dune heights up to about 6 m, with interdune distances of up to 80 m. Most of the animal tracks were recorded in the dune sandstones, on surfaces strewn with 'adhesion warts'.

A palaeoenvironmental model for the Upper Old Red Sandstone of the Tarbat Ness area, after Marshall *et al.* (1996) is shown in (Figure 2.64). This envisages fluvially dominated marginal facies passing distally to sandy sabkha with migrating dunes.

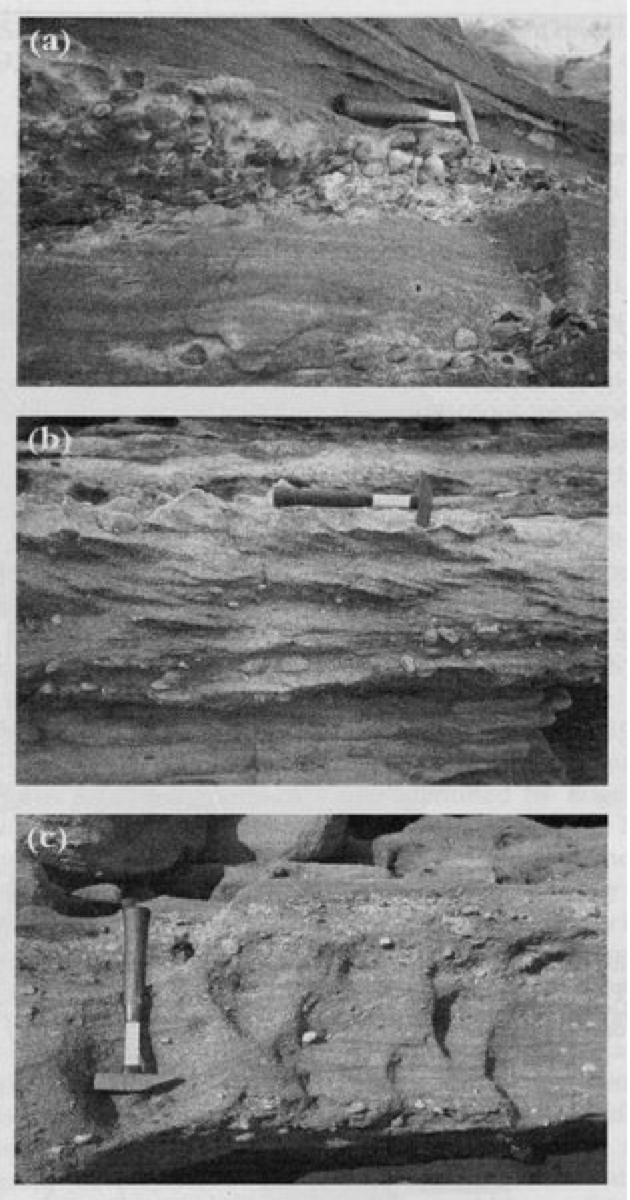
Conclusions

The Tarbat Ness GCR site provides an exceptionally well-exposed representative section of part of the Middle Devonian Strath Rory Group and its boundary with the overlying Upper Devonian Balnagown Group. This is one of the few localities where the Middle-Upper Devonian boundary can be examined, and here it appears to be conformable, in contradiction to the generally accepted model of a regional unconformity. The range of lithofacies exposed is unusually large. Fluvial sandstones with sporadic lacustrine mudstone interbeds are typical of the upper part of the Strath Rory Group. Two markedly different fades associations are seen in the Balnagown Group — a fluvial association of pebble conglomerate and cross-bedded sandstone forms the Tarbat Ness Formation at the base of the group; above this, a fluvial–aeolian–sabkha association forms the Gaza Formation. The latter contains striking examples of desiccation and evaporitic structures, features associated with sporadic rainfall in an arid environment, and evidence of subaerial animal activity. Overall, Tarbat Ness is a very important site, providing a rare insight into Mid- and Late Devonian environments and habitats at the margin of the Orcadian Basin.

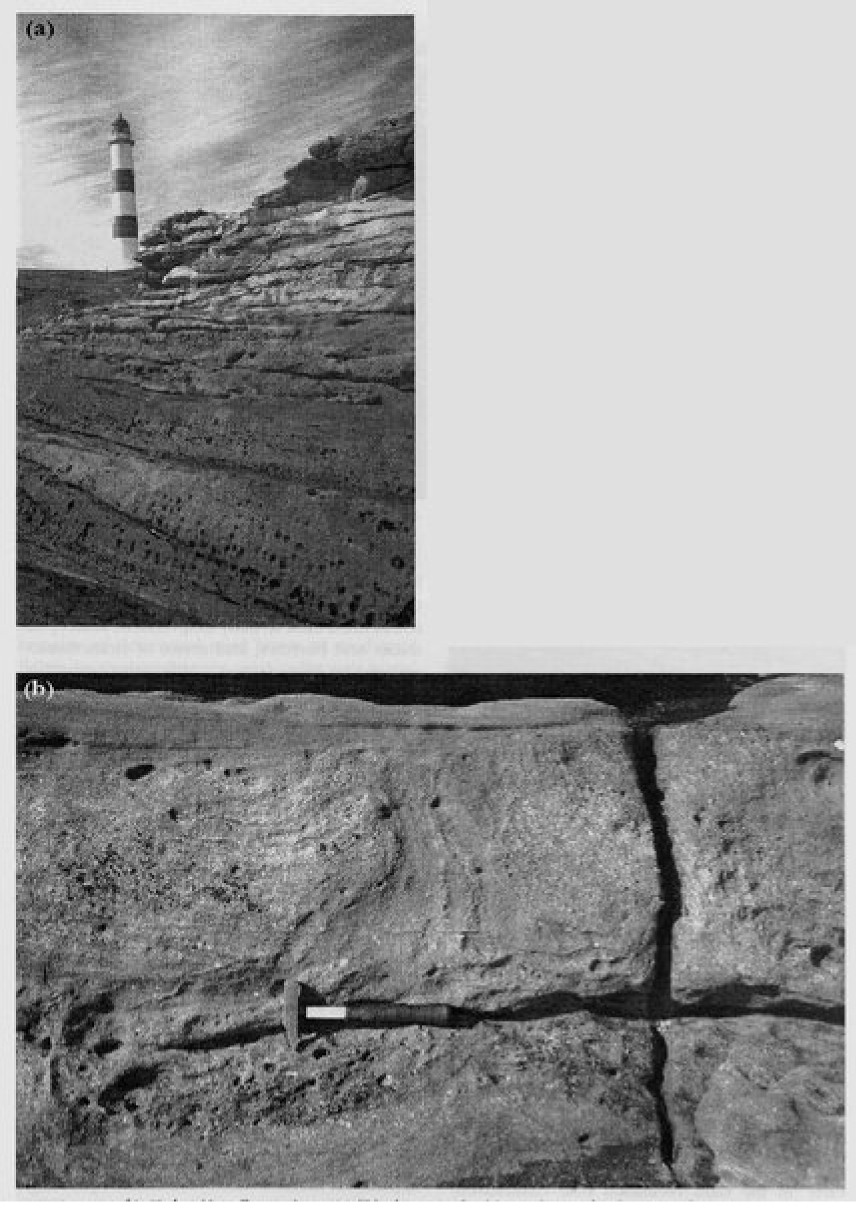
References



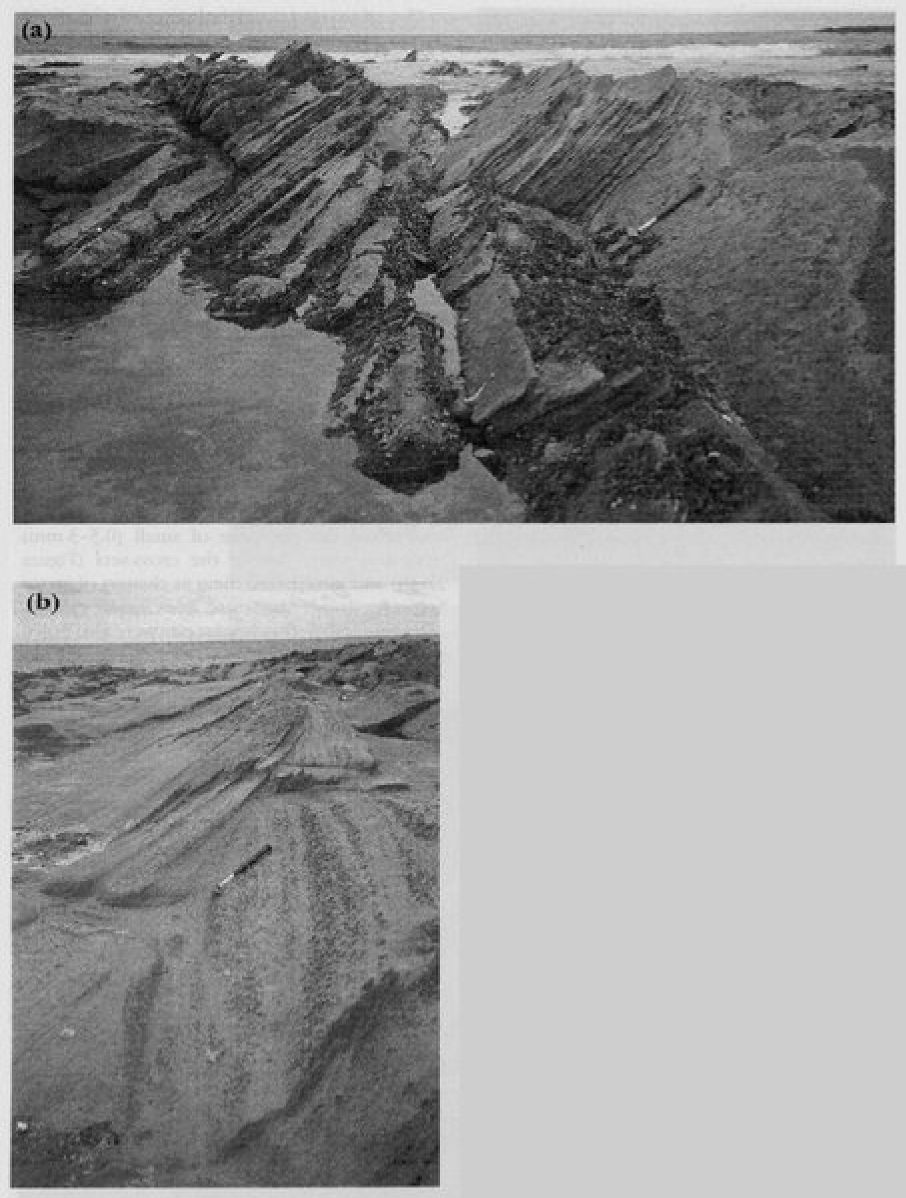
(Figure 2.60) Geological map of the Tarbat Ness area.



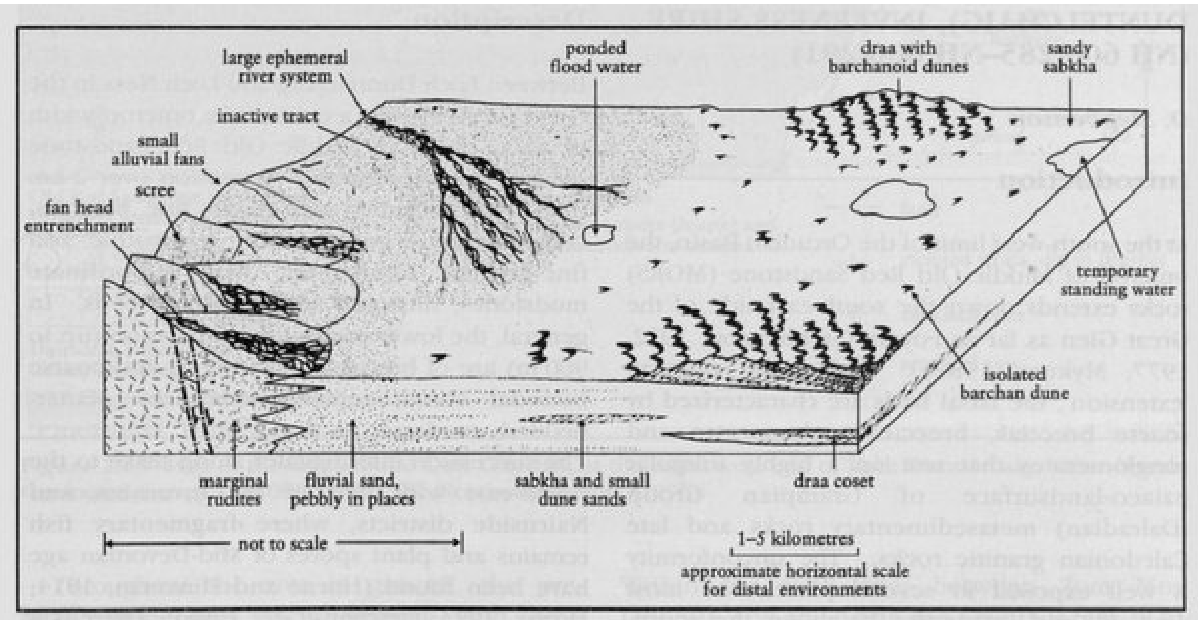
(Figure 2.61) Tarbat Ness Formation. (a) Conglomerate lenses; (b,c) pebbly layers and isolated pebbles in cross-bedded sandstones (Photos: P. Stone.)



(Figure 2.62) Tarbat Ness Formation. (a) Tabular cross-bedding; (b) sand volcano. (Photos: P. Stone.)



(Figure 2.63) (a) Thinly Gaza Formation west of Canas Solais. (b) 'Adhesion warts' in the Gaza Formation near Castlehaven. (Photos: P. Stone.)



(Figure 2.64) Palaeoenvironmental model for the Upper Old Red Sandstone of Tarbat Ness. After Marshall et al. (1996).