Corrie Shore to Brodick, Isle of Arran

[NS 026 422]–[NS 026 432]

Introduction

The coastline around the harbour at Corrie, on the east coast of Arran, exposes an excellent section through the Corrie Sandstone and the Brodick Breccia. The sandstones show fine examples of large-scale cross-bedding, often in three dimensions. Associated with the dunes are laminated interdune deposits and features, such as deflation lags; that are indicative of a desert environment. Fluvial sandstones, characterized by small-scale cross-bedding and desiccation cracks, are interbedded with the aeolian sediments. Also present at this locality are fulg-urites, created by lightning strikes that entered the sand and fused the grains. This is a key locality for the study of the Permian palaeoenvironments of Scotland.

The sediments exposed at Corrie Shore have been described by Gregory (1915), Piper (1970), Lovell (1971), Steel (1974b), Astin and MacDonald (1983), Clemmensen and Abrahamsen (1983), Clemmensen and Hegner (1991) , Clemmensen *et al.* (1994), and Frederiksen *et al.* (1998). Field guide accounts include MacDonald and Herriot (1983) and McKerrow and Atkins (1989).

Description

The sequence at Corrie Shore includes Carboniferous rocks, as well as the Corrie Sandstone (Figure 2.7)a and the overlying Brodick Breccia (Figure 2.7)c. The Carboniferous succession is unconformably overlain by the coarse-grained basal sandstones and breccias which are in the basal Corrie Sandstone, which is about 740 m thick, and comprises well-sorted, reddish-orange, flat- and cross-bedded sub-greywacke sandstones containing major bounding surfaces (Piper, 1970).

The major bounding surfaces are erosive surfaces that overlie cross-bedded draa or dune deposits (Clemmensen and Hegner, 1991). They are marked by a concentration of coarse sand grains, and are overlain by flat-bedded aeo-lian deposits. There are 33 such major bounding surfaces in the 740 m of the Corrie Sandstone, thus defining 34 phases of aeolian sand accumulation (Figure 2.8)a.

The flat-bedded aeolian sandstones comprise horizontal to low-angle sets bounded below by a major surface (Figure 2.7)a. Thicknesses vary from 0.5 to 7.0 m, with a mean of 2.9 m. Flat-bedded sets are generally tabular, but some taper out in the downwind direction. Sedimentary structures include wind ripples, lag layers, and straight or gently curved erosion surfaces. These units grade up into the cross-bedded aeolian sandstones that show a wide range of grain sizes. Cross-bedded sets are bounded above and below by sub-horizontal erosion surfaces, and range from 3 to 70 m in thickness, with a mean of 18 m. These sets are commonly composed of subsets, some 5 to 10 m thick, separated by erosion surfaces. Small-scale sedimentary structures include sandflow (especially common in the large dune deposits), inverse graded bedding, and ripple laminations (Clemmensen and Abrahamsen, 1983).

In places lamination is present, and occurs either as groups of very thin laminae with thin layers of silty sediment preserved at the bases of the sets, or as single thicker laminae with no internal structures (Piper, 1970). At higher levels, the sediments are generally finer-grained, commonly parallel-bedded, and red, yellow, or green in colour. In places nodular limestones have been reported (Lovell, 1971; Steel, 1974b).

The Corrie Sandstone at Corrie Shore, and farther north along the eastern coast of the island, contains fulgurites (Harland and Hacker, 1966; Piper, 1970; Turner, 1980), produced by lightning strikes fusing dry, subaerially exposed sediment (Figure 2.7)b.

The overlying Brodick Breccia is best seen near the bus shelter in Brodick [NS 020 360] and *c.* 100 m farther east [NS 021 359]. It comprises breccias and conglomerates interbedded with sandstones (Figure 2.7)c. The breccias contain clasts ranging in diameter from several millimetres to over 3 m in size and are clast-supported; sand is present interstitially. At Corrie, the boundary between the breccia and the underlying Carboniferous strata is highly variable, and may be vertical, inclined, or horizontal. The conglomerates incorporate clasts of vein quartz, schist, and quartzite, all originating locally from the Old Red Sandstone. The conglomerates form beds 1 to 2 m thick, which may be massive or may preserve horizontal or slightly inclined beds, cross-bedding, and lenses of finer-grained sandstone. Associated with the conglomerates are sandstones with trough cross-bedding or laterally extensive tabular cross-bedding. The sandstones are occasionally draped by mudstones that display mud cracks, and contain mudflake conglomerates (Astin and MacDonald, 1983).

Syndepositional faults are common along the Corrie Shore and Brodick Bay exposures. Those cutting through the Brodick Breccia formed small scarp faces and produced gaps between the blocks of sediment. In most cases the cracks were then infilled with sand, cobbles, and boulders that detached from the fault walls during tectonic activity. There is evidence that the breccia accumulated against the fault scarps during deposition (Astin and MacDonald, 1983).

Interpretation

The large-scale cross-bedding of the Corrie Sandstone is interpreted as having formed in dunes deposited in deserts, by a combination of aeolian (Gregory, 1915) and fluvial processes (Piper, 1970; Lovell, 1971). The presence of fulgurites indicates that the sands were dry, as opposed to the waterlogged sediments of river beds.

Much of the Corrie Sandstone succession is dominated by large-scale cross-bedding, consistent with an aeolian origin. Under the microscope, the sand grains have frosted surfaces, a feature indicative of aeolian transport. The nature of the dunes has been debated. Clemmensen and Abrahamsen (1983) suggested that the aeolian sediments accumulated as a series of large, compound crescentic dunes, with substantial interdune deposits (Figure 2.9), and with the prevailing wind coming from the northeast, as noted also by Piper (1970). Sneh (1988), however, argued that the sedimentary evidence from Corrie indicates a series of simple and complex oblique dunes, with a crest orientation and elongation from NNW to SSE; lateral migration was interpreted as towards the west, suggesting that the dominant wind direction was from the north. Clemmensen and Hegner (1991) disputed Sneh's (1988) re-interpretation and confirmed that the main direction of sediment transport was from the ENE.

Clemmensen and Hegner (1991) interpreted the Corrie Sandstone as a thick accumulation of some 34 cycles of erg deposits, with the erg sandstones interfingering with fluvial deposits around the basin margin. The cycles are separated by major bounding surfaces interpreted as erg-order deflation surfaces, where fine sand was blown off and the coarser material left behind as an armoured deflation lag. The flat-bedded sandstones are interpreted as amalgamated interdraa or interdune deposits. Each fining-upward bed is probably the result of a downwind migrating draa-interdraa or dune-interdune couplet at very low angles of climb. Only the lower parts of these structures are preserved, since the next migrating dune removed the upper parts. The cross-bedded sandstones are interpreted (Clemmensen and Hegner, 1991) as compound deposits formed by the downwind migration of several aeolian bed-forms. Some elements represent mainly draa deposits, while others are almost entirely composed of dune or draa slipface deposits. The amalgamated nature of these units, and their great thickness, implies that they represent erg deposits, not simple draa deposits. Clemmensen and Hegner (1991) used their measurements to define seven erg megacycles (Figure 2.8)a, representing seven phases of sand accumulation in a major sand sea.

Field measurements, combined with mathematical analyses, have identified a range of scales of cyclicity in the Corrie Shore sequence that Frederiksen *et al.* (1998) interpreted as Milankovitch cycles. These authors suggested that the long aeolian succession at Corrie shows evidence for short-term and long-term cyclicity of climate and of depositional patterns that reflect control by the orbital fluctuations of the Earth. Spectral analysis of the sedimentary logs and of geochemical measurements has yielded repeated patterns on the order of 25.7–29.3 m, 34.5 m, and 64.5m, and fieldwork has demonstrated cycles of 155 m and 675 m. These cycles were presumably produced by orbital climatic forcing, related to axial precession, orbital eccentricity, and obliquity, but Frederiksen *et al.* (1998) were not able to determine the precise causal relationship.

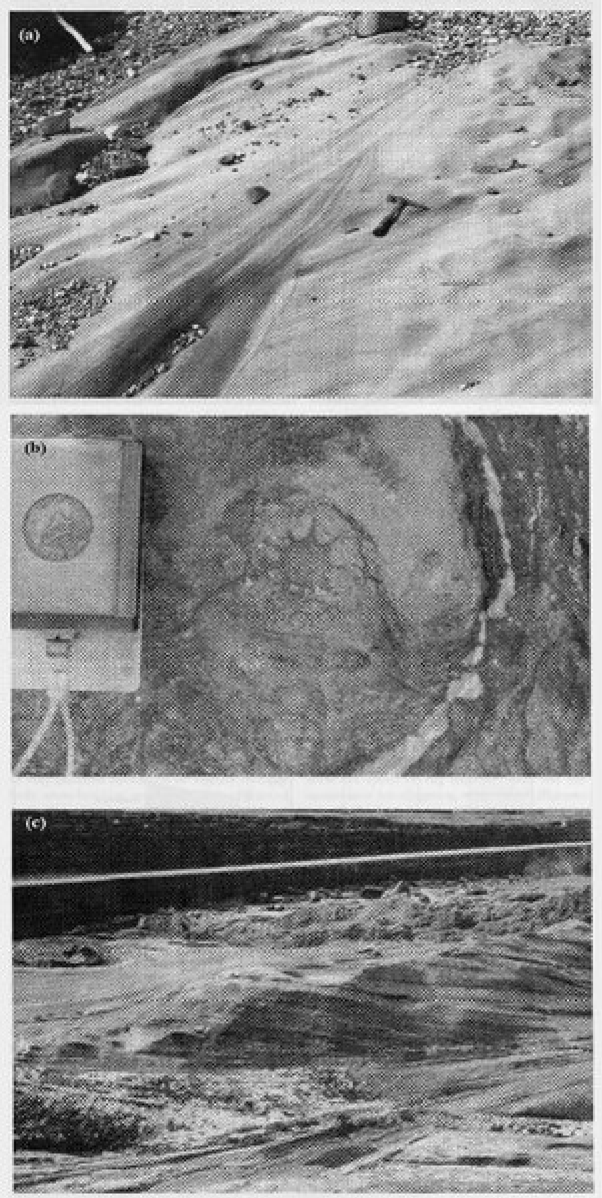
The poorly sorted laminated sediments, with pebbles, cross-bedding, and desiccation cracks, which are interbedded with the aeolian sediments, are interpreted as fluvial in origin (Piper, 1970), and possibly accumulated in interdune areas (Figure 2.9).

In places the Come Sandstone is interbedded with the overlying Brodrick Breccia, reflecting an interplay of aeolian and fluvial deposition (Turner, 1980; Astin and MacDonald, 1983). Tyrrell (1928) considered the Brodrick Breccia to be the result of volcanic activity. However, more recent studies cited above indicate that it formed under a range of depositional conditions, and accumulated in steep-sided valleys with stepped walls, incised into the slightly older underlying sediments. The valleys were formed when local tectonic uplift caused the rejuvenation of the rivers, resulting in down-cutting rather than fluvial deposition. The conglomerates were probably deposited by a braided river with a gravel bedload. The poorly defined stratification is characteristic of the internal structure of bars. The associated trough-cross-bedded sandstones accumulated in inter-bar channels or possibly on the downstream margins of bar complexes. The laterally continuous tabular or low-angle sheet sandstones were formed during single sheetflood events, probably during the transitional or upper flow regime. Trough cross-bedding associated with these sheet sandstones was formed in deeper water with lower-velocity currents. Smaller-scale ripples are indicative of declining current activity. These may have thin mudstone drapes characteristic of low-energy conditions. Palaeocurrent analysis of the troughand tabular cross-bedding suggests that the dominant flow direction was to the south (Astin and MacDonald, 1983).

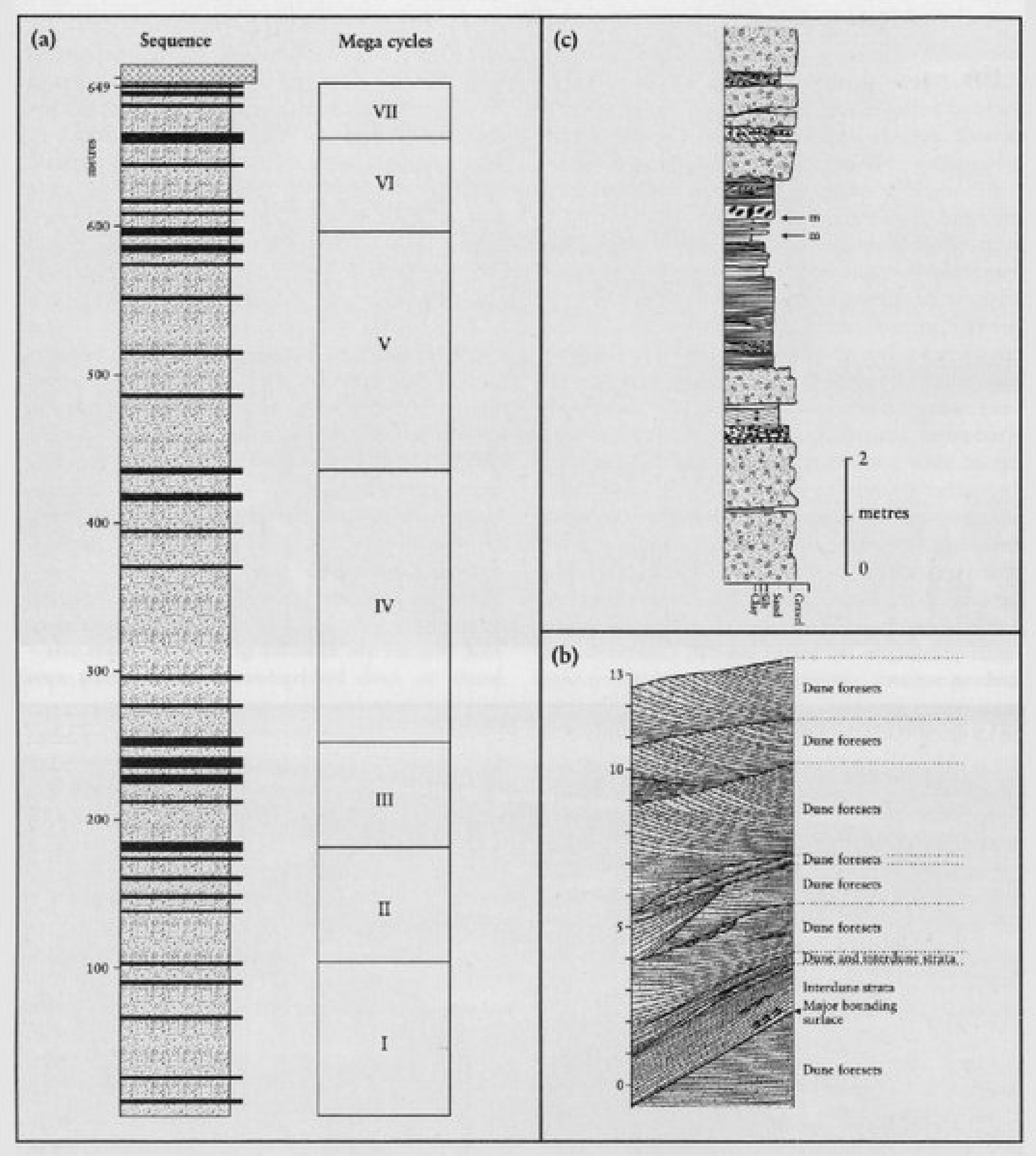
Conclusions

Corrie Shore is a key locality for the understanding of Permian palaeoenvironments and palaeogeography. The Corrie Sandstones formed in a marginal desert environment where fluvial sediments were reworked by aeolian processes, and the overlying Brodick Breccia was the result of major high-energy transfer of sediment from surrounding uplands, perhaps assisted by syndepositional faulting and basinal subsidence. The fulgurites, recording lightning strikes, are an added novelty of the site, and provide a rare vignette on contemporary meteorological conditions.

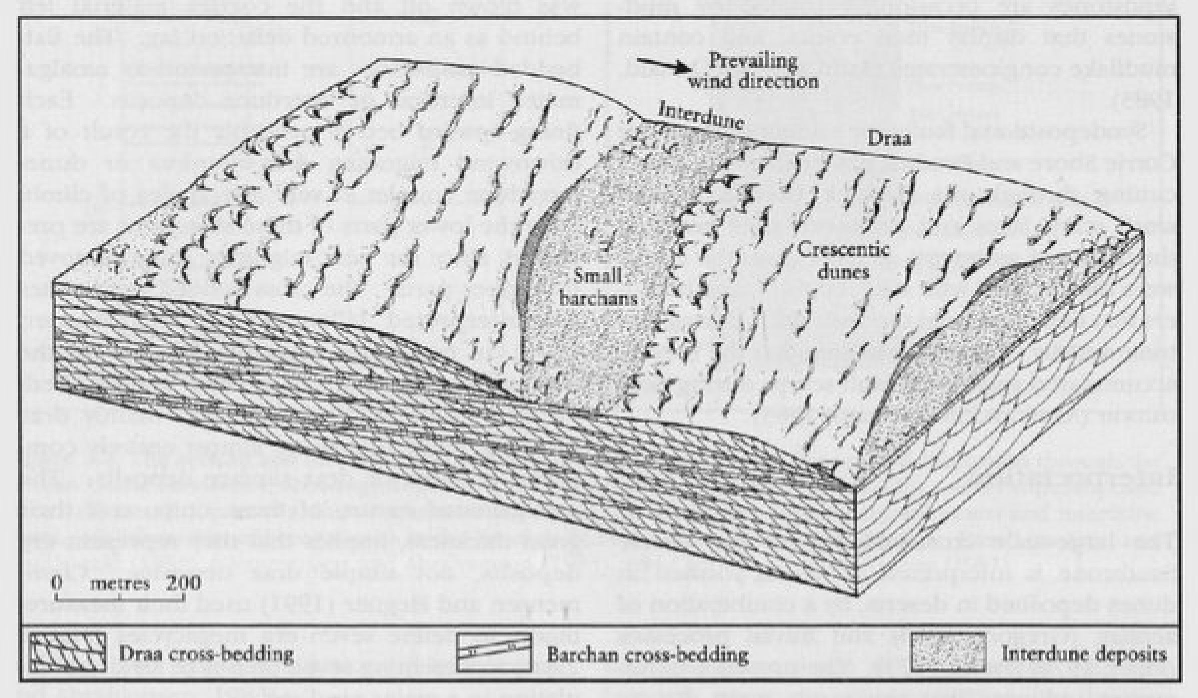
[References](#)



(Figure 2.7) Aeolian deposits at Corrie Shore, Arran. (a) Coastal exposure showing cross-bedding indicative of aeolian dunes. (Photo: C. MacFadyen.) (b) A fulgurite, top view of the site of a lightning strike. (c) Dune cross-bedded Corrie Sandstone overlain unconformably by the Brodick Breccia. The compass is 100 mm long. (Photos b,c: D.E.G. Briggs.)



(Figure 2.8) The aeolian and fluvial successions at Corrie Shore, Arran. (a) Generalized succession through the aeolian Corrie Sandstone, showing proposed division into seven erg megacycles (1—VII), and 34 superimposed units. (b) Detail of part of a dune sequence from low in the succession, showing dune foresets and interdune strata. (c) Succession of breccia units in the Brodick Beds at Corrie Shore; m, mudcracks. Based on Astin and MacDonald (1983), Clemmensen and Abrahamsen (1983), and Clemmensen and Hegner (1991).



(Figure 2.9) Palaeoenvironmental reconstruction for the Corrie Sandstone erg. Mainly slipfaceless draas with superimposed crescentic dunes alternated with interdune flats, the latter associated with small barchans. (From Clemmensen and Abrahamsen, 1983.)