SEDIMENTARY STRUCTURES FROM THE KEUPER SANDSTONE OF ALTON, STAFFORDSHIRE

by

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Summary

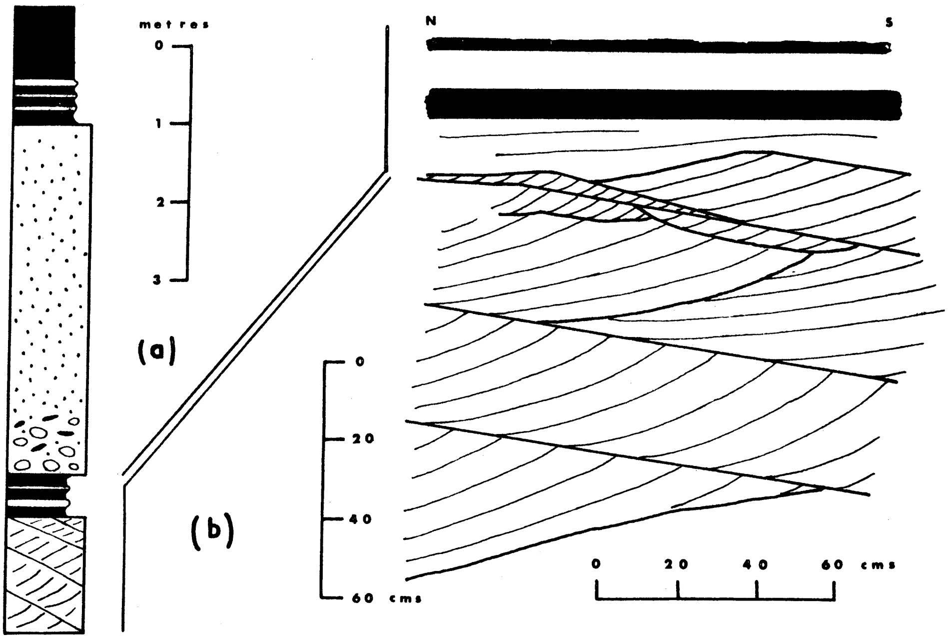
Sole markings, including flute casts, groove casts, ctenoid (prod) casts and transverse furrow casts, are associated with large and small scale cross bedding, parallel bedding with parting lineation, and current ripple marks. The sedimentary facies indicates deposition of the Keuper Sandstone of Alton in a fluviatile environment.

Introduction

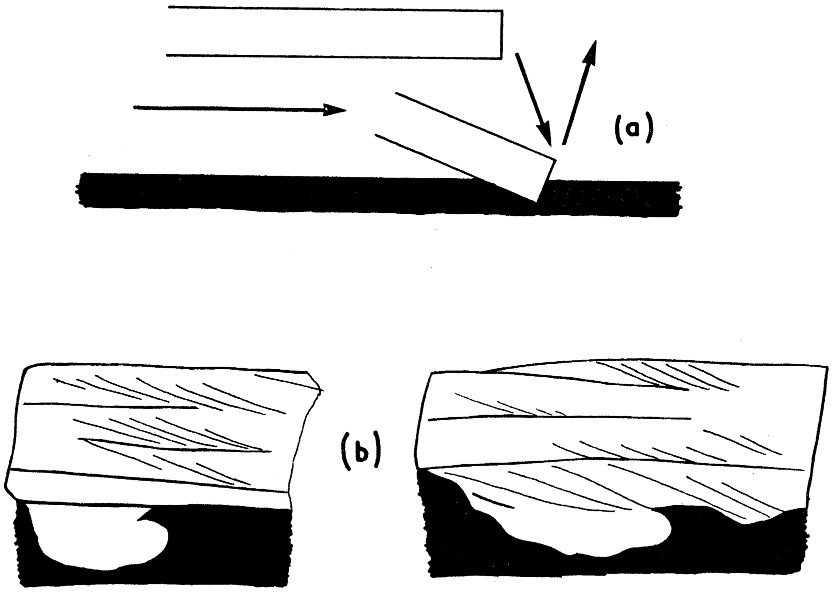
Sole markings from the Keuper Sandstone were first described over fifty years ago (Beasley, 1908, 1909, 1914), but have only recently attracted much attention (Cummins, 1958; Craig and Walton, 1962; Dzulynski and Sanders, 1962; Potter and Pettijohn, 1963; De Raaf, 1964). An up-to-date account of their occurrence is somewhat overdue.

One of Beasley's localities was the Townhead Quarry (National Grid Ref. SK 077425) at Alton in Staffordshire. Sedimentary structures have been collected here during several recent visits, and some of the original specimens * collected during Beasley's investigations have been re-examined.

* Now preserved in the Geology Department of the University of Leicester, where they have recently been acquired from Denstone College.



Text-fig. 1 (a) Vertical section of the rocks at present exposed in the Townhead Quarry. Marl - black; siltstone and fine sandstone - white; sandstone - with indication of cross bedding, pebbles and marl pellets; undifferentiated sandstone - dotted
(b) Detail of cross bedding in the lower sandstone.



Text-fig. 2 (a) Formation of ctenoid impressions by downward movement of forward end of equisetiform stem. Current direction from left to right.
(b) Sections through transverse furrow casts.

Townhead Quarry

The Townhead Quarry is sunk through a thin cover of marl into the Keuper Sandstone. Quarrying for building stone was still in progress in Beasley's time, but has long since ceased. The quarry now serves as a refuse dump and the original floor is no longer visible. The rock succession at present exposed is shown in Text-figure 1a.

The lower sandstone, of which little over a metre remains exposed, is pink and white and shows very clear large scale cross bedding. The cross strata dip to the north and the set boundaries (surfaces between the sets of cross strata) dip gently upstream (to the south) in relation to the parallel bedding in the overlying rocks (Text-fig. 1b). This observation supports the view that large scale cross bedding is produced by the migration of large scale current ripples under conditions of net deposition, whereby each sand ripple, advancing over the up-stream slope of the ripple in front, forms a set of cross strata (Allen, 1963a, and discussion by Hemmingway and Clarke, 1963; Allen, 1963b).

Red micaceous shales and red blocky marls overlie the lower sandstone. Interbedded with these are a few thin beds of green and white micaceous siltstone and a bed of fine red micaceous sandstone. The siltstones are minutely cross laminated, in sets only a few millimetres thick, and are not continuous for more than a few metres. The red sandstone bed, which varies from four to ten centimetres thick, shows ctenoid casts and other sedimentary structures, which will be described below. The current direction indicated by these structures is from south to north, as in the underlying cross bedded sandstone.

The upper sandstone is white and, at first sight, appears to be massive. Rather sinuous groove casts with a general north-south alignment are exposed on the base of this bed and, in one small area, there are the casts of straight small-scale ripple marks, indicating a current flowing slightly west of north. Quartz pebbles and mud pellets are abundant in the lower part of the bed and their orientation reveals the presence of large scale cross bedding with the cross strata dipping to the north, as in the lower sandstone. There are horizontal partings within the bed, at least one of which is associated with a layer showing small scale cross bedding.

Red marls and shales overlie the upper sandstone. Interbedded with these in their lower part are a few beds of red sandstone. These are inaccessible in the quarry face, but a slipped block from this level contained a bed of fine red sandstone, about nine centimetres thick, with flute casts and other structures.

Ctenoid casts

The ctenoid casts (Plate 8b) are found on the bottom of a bed of fine red sandstone in the marls between the upper and lower sandstones. With them are found transverse furrow casts (see below), small groove casts, and a prod cast formed by a sharp stick digging into the mud.

The upper surface of this sandstone bed shows linguoid current ripple marks (Plate 9a). Gently dipping laminae crop out on the eroded upstream faces of these ripple marks. The bed is cross laminated throughout. The individual sets of cross laminae rest on trough shaped erosion surfaces, consistent with their formation from migrating linguoid current ripple marks (Allen, 1963a, fig. 14). Set thicknesses range from over a centimetre at the base to a few millimetres at the top of the bed. The internal structure can be identified with the "nu-cross-stratification" of Allen (1963c).

The origin of ctenoid casts has been discussed by Beasley (1914), Linck (1956) and Cummins (1958, 1965). It is generally agreed that they are the casts of impressions made in mud by equisetiform plant stems. Rolfe (1961) and Craig and Walton (1962) have pointed out the similarity between ctenoid casts and the orthocone prod casts found in the Silurian of Scotland, which are the casts of impressions made by straight nautiloid shells on the mud of the sea floor. A significant difference is that the orthocone prod casts commonly occur in opposed pairs (Craig and Walton, 1962 Plate 5b), whereas the ctenoid casts are never paired and all face in the one direction. The orthocone shells probably travelled with the apertural end forward and downward. When this made contact with the muddy sea floor, the apical end, buoyed up by the gas chambers, turned right over in the plane of travel before the shell was freed (Craig and Walton, 1962, fig. 6). The equisetiform stems, on the other hand, probably floated almost horizontally, except in very turbulent water. The ctenoid impressions were probably made by almost vertical deflections of the forward end of the stem due to turbulence. The impact would be momentary, the stem immediately returning to its normal horizontal position (Text-fig. 2a).

Transverse furrow casts

The most prominent sole markings on the sandstone bed with the ctenoid casts are discontinuous ridges trending almost at right angles to the current direction (Plate 8a). These ridges are very variable in cross section. They range from less than a centimetre to more than eight centimetres across, and up to one and a half centimetres in elevation above the general level of the bedding plane. They are generally asymmetrical, having a steep, sometimes overhanging downstream face and a more gentle slope on the upstream side. Cross sections (Text-fig. 2b) show no deformation of the sandstone laminae above these ridges; they are thus not the result of load deformation. The ridges are the casts of transverse furrows, scoured out of the marl by current action.

Water flowing along these furrows, at a considerable angle to the general direction of flow in the water above, probably eroded the steep or overhanging downstream banks. That water did in fact flow along the transverse furrows can be demonstrated on one specimen, which shows the cast of a longitudinal channel joined by several transverse furrows as tributaries (Plate 8c). The longitudinal channel cast is finely fluted, some of the flutings showing the characteristic bulbous ends of typical flute casts.

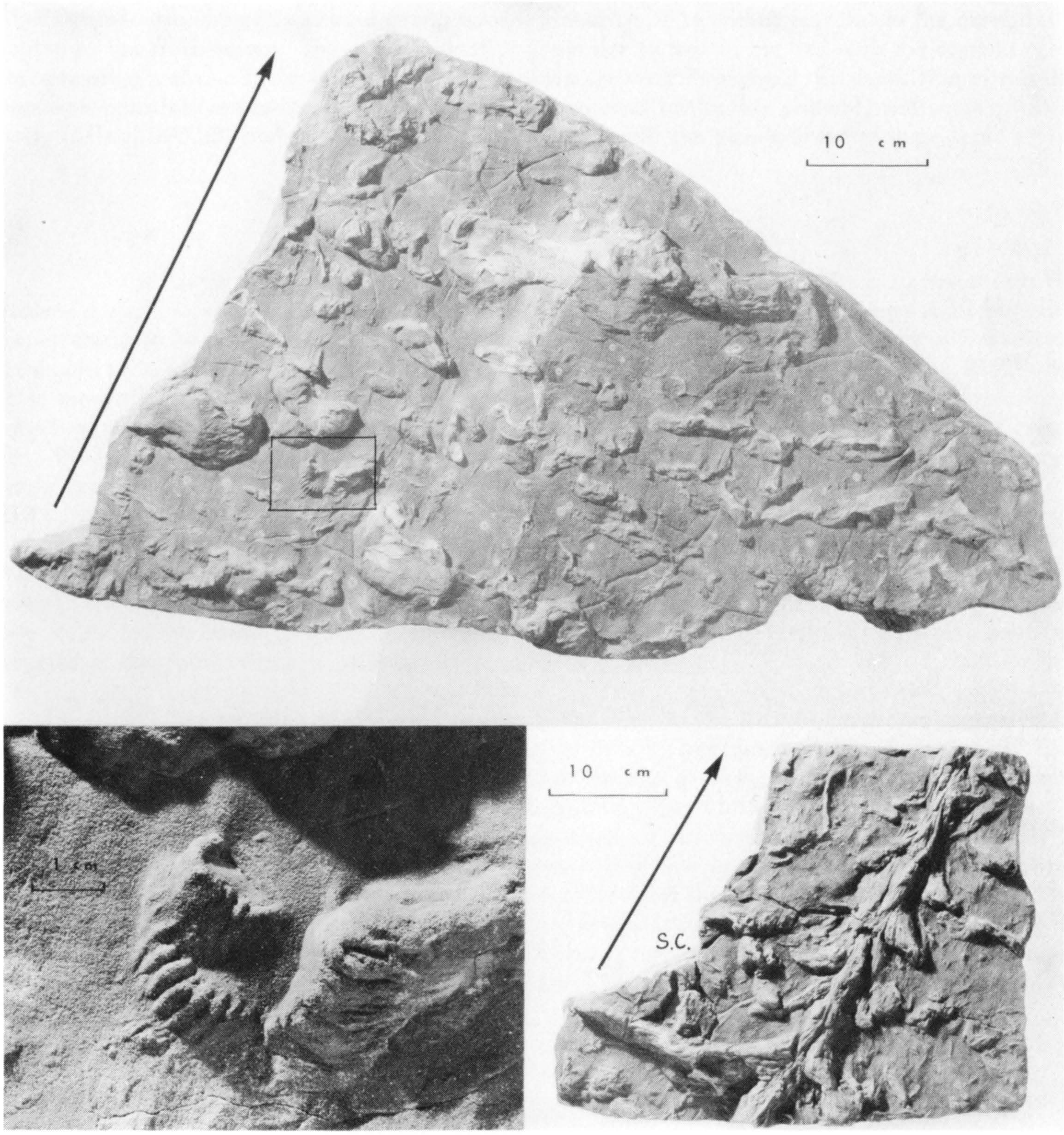
Sand cracks

A polygonal system of cracks is developed over a small area of the base of the sandstone bed with ctenoid casts (Plate 8c). The maximum depth of the cracks is about a centimetre. They are wedge-shaped in section, narrowing upwards into the sandstone and filled with marl from the underlying bed. The maximum width at the opening is about half a centimetre. They are the complete reverse of normal mud cracks (Shrock, 1948, fig. 148, p. 189), in which the cracks narrow downwards into mud and are filled with sand from the overlying bed. The cracks are clearly post-depositional, as narrow mud ridges could not have withstood the current which deposited the sand. There is vertical displacement of up to about half a centimetre across a few of the cracks. No satisfactory explanation for this structure has yet been suggested.

Flute casts

Flute casts have been found on a bed of fine red sandstone in a slipped block, probably from near the top of the quarry. The individual flute casts (Plate 9b) are rather variable in size, shape and orientation, although there is no doubt about their overall parallelism. Furthermore their grouping is rather irregular. These observations are consistent with the view that flute casts on shallow water sandstones are less regular than those on deep water turbidites (Kuenen, 1957, p. 241; Ksiazkiewicz, 1961, p. 45).

The upper surface of the bed shows rather indefinite current ripple marks. Internally, the lower six centimetres of the bed are parallel laminated and the top three centimetres cross laminated. The



(a) Top - Transverse furrow casts with ctenoid casts.

(b) Bottom left - Ctenoid cast: enlargement of enclosed area in (a).

(c) Bottom right - Transverse furrow casts joining longitudinal channel cast as tributaries. Note also pattern of sand cracks (s.c.) Current direction indicated by arrows.

parallel laminae are charactized by a strong parting lineation, * trending parallel to the current direction indicated by the flute casts. The cross lamination is similar to that in the bed with the ctenoid casts (p.155), but on a smaller scale. The current direction remained constant throughout the deposition of this bed. The change from parallel lamination with parting lineation to cross lamination probably indicates a fall in current velocity (Allen, 1963d), perhaps in water too shallow to permit the development of large scale current ripples.

Sedimentary environment

Large scale cross bedding, such as occurs in the Keuper Sandstones, has always been considered a shallow water structure. If this structure is due to the migration of large scale current ripple marks, as seems to be the case in the Townhead Quarry (see p.155), then the thickness of the sets of cross strata should be related to the height of the parent ripple marks (Allen, 1963a, fig. 9, p. 204). But Allen has also shown that the height of large scale current ripple marks bears a direct logarithmic relationship to the depth of water. Thus the depth of water can be estimated from the thickness of the sets of cross strata (Allen, 1963a, pp. 196, 198, 212, 213). On this basis the lowest sandstone exposed in the quarry was probably deposited in about three metres of water, though this must be taken as a minimum figure (Allen, 1963a, p. 213). The water got shallower upwards during the deposition of the lower cross bedded sandstone (thinner sets of cross strata, see Text-fig. 1b), presumably due to sand deposition. There is no evidence of exposure during sedimentation in this quarry, though footprints and mud cracks have been recorded from neighbouring quarries in the Keuper Sandstone (Beasley, 1906, p. xxi). The sequence of rocks exposed in the Townhead Quarry resembles the Lower Old Red Sandstone cyclothems of the Anglo-Welsh Basin, which have been interpreted as floodplain deposits (Allen, 1964).

The presence of current formed sole markings in the Keuper Sandstone suggested to the present author that such structures might be formed other than by turbidity currents (Cummins, 1958). The same structures, however, have also been interpreted as "examples of the activity of turbidity currents in an ancient lake deposit" (Dzulynski and Sanders, 1962, p. 91). Such lakes as may have been present on the flood plain must have been very shallow, a few metres deep at the most. It seems rather unlikely that a turbidity current capable of depositing a ten centimetre bed of fine sandstone could have been set in motion in such an environment; though it would certainly be difficult to show that a particular bed could not be a turbidite. The internal structures of the thin sandstone and siltstone beds are not particularly helpful. Small scale cross lamination and parting lineation may be found in turbidites and aqueites** alike. The small scale cross lamination, however, is not the gradational type (Allen, 1963c, p. 98), which may prove to be characteristic of turbidites (Walker, 1963).

* Parting lineation (Crowell, 1955, p. 1357) is preferred to primary current lineation (Stokes, 1947), which might be taken to include a wide range of linear sedimentary structures.

** Turbidite (Kuenen, 1957), meaning any sediment or sedimentary rock deposited by a turbidity current, has proved to be a most useful term. There is a need for a comparable term for the sediment by a water current other than a turbidity current. It is suggested here that a new term "aqueite" might be introduced to fill this gap.

Conclusions

The following conclusions seem to be justified by the evidence of the sedimentary structures:-

1. Deposition was entirely sub-aqueous.

2. Depth of water was never more than a few metres.

Also, by analogy with the Old Red Sandstone cyclothems described by Allen (1964), it seems likely that:-

3. The two main sandstone beds were deposited in river channels.

4. The red marls and shales were deposited in backswamp lakes on floodplains.

Thus the sole markings found here are of shallow water origin and have been formed in river channels and in shallow lakes. The beds of fine red sandstone, on which the best markings are preserved, may have been deposited at times of flood, when the river flowed as a great sheet of turbulent, sediment-laden water, across floodplain and channel alike. This is the sub-aqueous equivalent of the sheet floods, suggested earlier (Cummins, 1958). The alternative is that they may be the deposits of turbidity currents flowing independently of the standing body of lake water (Dzulynski and Sanders, 1962). Sheet floods travelling down an exposed floodplain and entering a lake might produce such currents.

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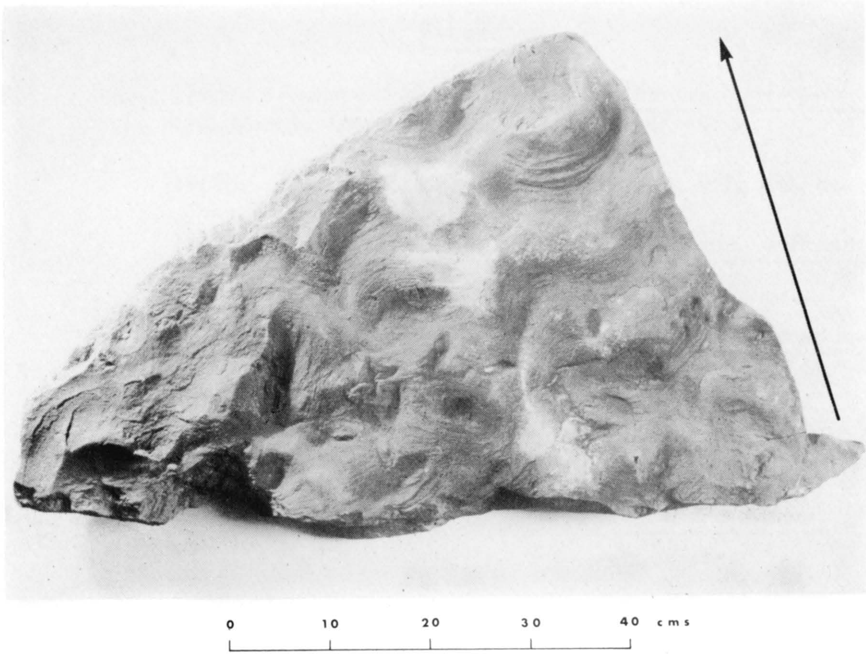

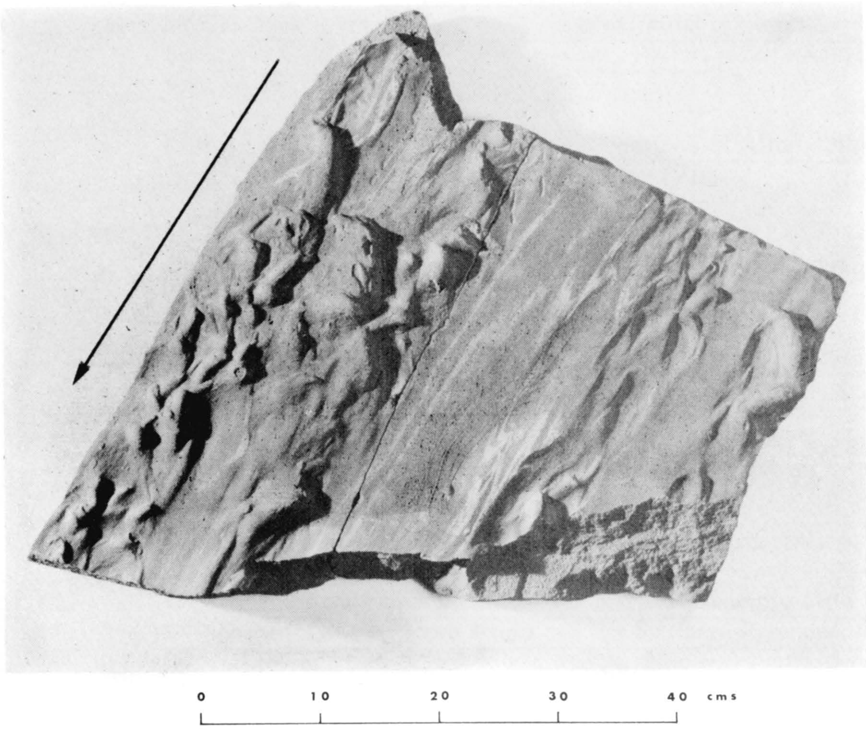

(a) Top - Linguoid current ripple marks. Upper surface of specimen shown in Plate 1a.

(b) Bottom - Flute casts.

Current direction indicated by arrows.

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