TRACE FOSSILS IN THE ECCA OF NORTHERN NATAL AND THEIR PALAEOENVIROMENTAL SIGNIFICANCE

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ABSTRACT

Because of the rarity of body fossils in the Ecca Group fossil burrows, tracks and trails are of potential value in supplementing primary sedimentary evidence concerning the palaeoenvironmental factors of bathymetry, energy level and food supply. The three most important ichnogenera are *Skolithos, Corophioides* and *Scolicia*. The first two are restricted to the upper portions of Middle Ecca upward-coarsening regressive cycles attributed to delta progradation. They are representatives of Seilacher's (1967) *Skolithos* and *Glossifungites* communities, indicating shallow water conditions with diastems. *Scolicia* occurs at lower levels in the cycles and corresponds to Seilacher's deeper water *Cruziana* community. Meandering trails *Helminthopsis* and *Taphrhelminthopsis* in the Lower Ecca belong to Seilacher's deep water *Nereites* community. Less common ichnogenera include the U-burrows *Diplocraterion* and *Rhizocorallium*. It has proved impossible positively to identify many trace fossils such as short ramifying burrows, chevron trails, dumbell-shaped surface impressions, digitate tracks and problematic elliptical casts. Trace fossils have not been recognised with certainty in the fluviatile deposits which comprise the bulk of the coal-bearing strata of northern Natal.

INTRODUCTION

The Ecca Group of the Karroo Supergroup (provisional stratigraphic nomenclature pending recommendations of S.A.C.S.) has been studied in the region extending northwards from Pietermaritzburg to the Transvaal border (Hobday, 1973; Hobday, Tavener-Smith and Mathew, in press; Hobday and Mathew, in press). In the course of these investigations it has become evident that a significant relationship exists between some of the trace fossils and the lithology and sedimentary structures with which they are associated. Body fossils have rarely been encountered in these rocks (see Rilett, 1963; McLachlan, 1973), and apart from these few specimens further biological indications of the nature of the palaeoenvironment are dependent entirely upon trace fossils which are fortunately common.

The Middle Ecca has been attributed by Hobday and co-workers to the southward progradation of deltaic and fluviatile complexes. These clastic wedges apparently overrode the Lower Ecca epicontinental platform facies of mud and silt. The deltaic deposits are distinguished, among other characteristics, by the presence of numerous trace fossils. The regressive deltaic sequences are vertically repetitive, and certain varieties of burrows and trails tend to recur at particular levels within a given cycle. Except for occasional rootlet markings and fragments of lithified wood, biogenic structures are absent from most fluviatile deposits.

It follows from the above statement that trace fossils in the Middle Ecca are not only of intrinsic descriptive interest, but may also be used for predictive purposes. In limited exposures of incomplete cycles they can be used, in conjunction with other sedimentary criteria, to recognise the position of the strata within the modal cycle (Figure 1).

THE MODAL UPWARD-COARSENING REGRESSIVE CYCLE

These cycles vary in thickness from 30 to over 150 metres. At the base of the lowermost cycle, which extends into the Lower Ecca, are shelf mudstones. Above these, and forming the basal component of each succeeding cycle, are considerable thicknesses of alternating thin beds of siltstone and sandstone in roughly equal proportions. A prodelta environment, in which gentle tractional processes alternated with suspensional settling of fines, is envisaged for these rocks. Overlying them are cross-laminated and/or horizontally-laminated sandstones of the distal distributary mouth bar facies. These pass upward into coarse-grained, cross-bedded and massive sandstones of the proximal mouth bar and distributary channel.

In addition to the above pattern of beds there are thinner, less regular upward-coarsening cycles averaging under 10 metres in thickness. These are attributed to deposition in interdistributary embayments and delta plain depressions. In these cases the siltstones are highly carbonaceous and coarsen upward by the progressive intercalation of erosively-based, cross-laminated to massive, lenticular sandstones of crevasse origin. These sequences may include finely-laminated, oxidised, root-penetrated levee splay sandstones.

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LITHOLOGY	PRIMARY STRUCTURES	TRACE FOSSILS	COMMUN.
Conglomeratic sandstone	Scour and fill	Skolithos	Skolithos
Medium to very coarse-grained arkosic sandstone	Cross-bedding	Diplocraterion	Skolithos
Medium-grained sandstone	Cross-lamination and flat-bedding	Corophioides	Glossifungites
		Bifungites (?)	Glossifungites
		digitate tracks	
Alternating siltstone and fine to very coarse-grained sandstone	Cross-lamination	Scolicia	Cruziana
		chevron trails	
		Rhizocorallium	
	Graded bedding	ramifying burrows	
Siltstone and mudstone	Horizontal lamination	Helminthopsis	Nereites
		Taphrhelminthopsis	

MIDDLE ECCA

LOWER ECCA

Figure 1. The top of the Lower Ecca and the modal regressive cycle of the Middle Ecca with associated primary structures, trace fossils and Seilacher community.

TRACE FOSSILS

Description and Possible Mode of Origin

(i) Ichnogenus *Skolithos* Haldeman, 1840

These structures are vertical, unbranching tubular burrows between 6 and 20 mm in diameter, and up to 30 cm long. Two subtypes are recognised in the Middle Ecca. The first is circular in transverse section with an axial filling of structureless sandstone which is surrounded by one or more dark bands of sandy carbonaceous mustone (Figure 2). An outer concentric band of light coloured sandstone is also commonly present. The burrows are closely spaced and more or less equidistant. They bear strong resemblance to the well-known "pipe-rock" in the lower Cambrian of north-west Scotland. The second variety may be circular to irregularly elliptical in transverse section. Concentric banding is only weakly developed or absent. The tubes are very closely spaced, and may be mutually interpenetrant.

Skolithos tubes were recognised as *domichnia* by Seilacher (1964), in that they afforded permanent shelter to animals which procured food from above the water-sediment interface. Hallam and Swett (1966) attributed such burrows to suspension-feeding worm-like organisms.

(ii) Ichnogenus *Corophioides* Smith, 1893

Vertically disposed U-shaped burrows corresponding to this ichnogenus have a width between the two arms of the burrow approximately equal to its depth (6–10 cm). The tube limbs are parallel in some cases, but in others are symmetrically inclined. The latter may have resulted from erosion of the sediment containing the upper vertically-disposed portions of the limbs. Spreiten are well developed (Figure 3). According to Seilacher (1967) the growth of these structures represents an adjustment to the increasing size of the inhabitants of the *domichnia*. Alternatively, vertical migration of the burrow through the sediment may have been accompanied by backfilling.

(iii) Ichnogenus *Diplocraterion* Torell, 1970

These long narrow vertical U-tubes have been positively identified only in cores from the Middle Ecca. It is likely that the very fine spreiten are rapidly obliterated in outcrop by weathering.

(iv) Ichnogenus *Rhizocorallium* Zenker, 1836

Narrow U-tubes of this type, oblique or parallel to the bedding (Figure 4), are seldom well preserved. Faint spreiten are the product of feeding activities (Häntzschel, 1962, p. 210) which involved the excavation of sediment which was subsequently repacked in the apex of the U-bend. These burrows therefore correspond to Seilacher's (1967) *fodinichnia*.

(v) Ichnogenus *Scolicia* de Quatrefages, 1849

These trails occur in a variety of forms preserved in convex epirelief (on the top of a sandstone bed). Some show well-developed lateral lobes (Figure 5). Others appear as relatively featureless bands with faint laterally convex striations extending across the entire width (Figure 6). The trails range between 2 mm and 4 cm in width.

The grain size of the material comprising the trail is usually somewhat coarser than that of the surrounding sediment. These traces are probably the sole trails of gastropods which ploughed through the sediment in search of food.

(vi) Ichnogenus *Helminthopsis* Heer, 1877

According to Ksiazkiewicz (1970) this ichnogenus, as amended by Sacco (1888, p. 174), includes irregularly meandering sole trails. Such forms occur infrequently in the Lower Ecca as semi-cylindrical tubes up to 3 mm in diameter (Figure 7). Some are partly pyritised.

(vii) Ichnogenus *Taphrhelminthopsis* Sacco, 1888

This group includes all meandering trails with a central furrow. Good examples have been documented in the Ecca by Hosking (1973).

(viii) Other trace fossils of unknown ichnogenera

It has proved impossible to classify many of the biogenic structures encountered. Some traces display no distinctive features while others are rendered unidentifiable as a result of interpenetration. Intense bioturbation has rendered certain sandstones almost structureless. Such activity belies the generally held impression that Ecca sediments contain little evidence of the former existence of animal life. Nondescript endichnial burrows and exichnial casts (nomenclature of Martinsson, 1970, p. 327) are particularly common. Some of these have a distinct spiral form (Figure 8). Short near-vertical tubular burrows in arenaceous material are in many cases seen to ramify on reaching fine-grained organic rich sedimentary laminae to form an extensive complex of horizontal burrows.

Chevron trails, seldom exceeding 2 mm in width and 8 cm in length, occur as traces on the upper surfaces of sandstone beds. The trails are straight or slightly curving, with angular intersections and random orientation. Sole trails, preserved in positive hyporelief (on the base of a sandstone bed) are sometimes bunched after the manner of *Phycodes* (see Häntzschel, 1962, p. 206).

Dumb-bell-shaped surface impressions, superficially resembling *Bifungites,* occur in large numbers on certain sandstones (Figure 10). The spheres at the extremities of the dumb-bell are, however, much smaller than those illustrated by Häntzschel (1962, p. 186). Excellent examples from the Ecca have been illustrated by Hosking (1973, Figure d. vi.).

Digitate tracks in positive hyporelief (Figure 11) appear to be crawling impressions or repichnia, possibly to be associated with arthropod-type

animals. The tracks are occasionally paired, with a spacing of between 2 and 4 cm, but most have an apparently disordered arrangement. Each impression consists of 3 to 5 divergent rays between approximately 0,5 and 2 cm long.

Problematic casts in mudstone, illustrated in Figure 9, are possibly of biogenic origin. They take the form of flattened triaxial ellipsoids lying in the plane of the bedding. A longitudinal depression is commonly present in both the upper and lower surfaces. This axis is the origin of very large numbers of closely-spaced radiating striae which cover the entire surface of the cast. These structures were first interpreted as concretionary bodies, but this seems unlikely since those examined were compositionally identical with the surrounding mudstone. Neither are they fossilised vegetal material.

Distribution of Trace Fossils in the Modal Upward-Coarsening Regressive Cycle

All the forms described, apart from *Helminthopsis, Taphrhelminthopsis* and the problematic elliptical casts, were encountered in the upward-coarsening sequences of the Middle Ecca. The three exceptions are all from the Lower Ecca, but these are of infrequent occurrence and sporadic in their distribution.

The vertical distribution of trace fossils within a cycle follows a particular pattern. There is a predominance of horizontal types such as *Scolicia*, chevron trails, *Rhizocorallium* and *Bifungites* (?) in the lower prodelta alternations of siltstone and mudstone. These strata also contain occasional digitate tracks and the vertical burrows with ramifying horizontal extensions.

Corophioides occurs within the uppermost alternating beds, but is more common within the cross-laminated and horizontally-laminated sandstones above. These trace fossils are generally concentrated at particular horizons. There is an upward increase in the abundance of *Skolithos* from the alternating beds to the cross-bedded sandstones at the top of a cycle. The upper limit of the cycle, where sandstone is succeeded by siltstone of the overlying cycle, is commonly riddled with these burrows. *Diplocraterion* appears to be confined to the cross-bedded sandstones.

Palaeoenvironmental Significance of Trace Fossil Distribution

As pointed out by Seilacher (1967) trace fossil morphology is controlled by the behavioural rather than the anatomical characteristics of organisms. Almost identical trace fossils may be produced by quite different animals, representing a similar response by these animals to the same environment. Seilacher (op. cit.) stressed the bathymetric significance of trace fossil assemblages. He maintained that the *Skolithos* and *Glossifingites* communities are associated with littoral sands and omission surfaces respectively, that the *Cruziana* community reflects epicontinental platform deposits, and that the *Zoophycos* and *Nereites* communities occur in progressively deeper water facies.

Representatives of the *Skolithos, Glossifungites* and *Cruziana* communities are present in the Middle Ecca, while the *Nereites* community is recognised in the Lower Ecca, which was of deeper water origin. Deep vertical burrows such as *Skolithos* and *Diplocraterion* are characteristic of shallow water. Their position near the top of each of the Middle Ecca regressive cycles confirms the contention that these sediments were deposited on proximal, shallow water, distributary mouth bars.

Burrows such as *Corophioides* were the shelters of filter-feeding organisms of the *Glossifungites* community. These burrows were not subjected to appreciable erosion or sedimentation and their concentration at certain levels is in each case indicative of a depositional hiatus. Such horizons are common in the lower distal distributary mouth bar facies where there was a seasonal reduction in sediment influx and little reworking of the material by waves or currents.

The ramifying feeding burrows associated with the *Cruziana* community indicate that the organisms burrowed vertically until they encountered nutrient-rich organic layers, which they followed laterally. Other feeding furrows, such as *Scolicia* and chevron trails, were produced by the reworking of surface layers. Seilacher (op. cit.) pointed out that a greater volume of sediment can be processed if the furrowing follows a winding, digitate or helicoid pattern. All these trace fossils belonging to the *Cruziana* community occur most abundantly in the fine-grained prodelta facies, generally between 20 and 80 metres below the top of a cycle.

Crimes (personal communication) commented that he has observed *Scolicia* very similar to the example shown in Figure 5 in the Eocene flysch of northern Spain. It is possibly unusual to find these traces in relatively shallow water deposits of the Ecca.

The *Nereites* traces of the Lower Ecca are also somewhat anomalous in this respct although these shales have been ascribed to a deep water environment by Ryan (1967, p. 199). However, a maximum water depth of no more than a few hundred metres at most is indicated by the thickness to the top of the lowermost delta-front sandstone. Even allowing for the effects of sediment compaction and possible shallowing, water depth was certainly only a small fraction of that usually occupied by this community.

As Crimes (1970) has pointed out, however, the factors which control behavioural responses in organisms are energy conditions, substrate type and the nature of the food supply. While these parameters are to a large degree depth-dependent

there may be exceptions, as in sheltered shallow water, where conditions strongly resemble those of deeper water environments. This is consistent with the observation that in the north-eastern part of the Karroo Basin the only evidence of high energy processes is that which is associated with fluvial discharge. We have encountered no features indicative of even weak wave activity. Furthermore there is no evidence of tidal processes, and the effects of offshore currents appear to have been negligible.

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Explanation of Figures 2—11 (see next page).

Figure 2. Bedding plane exposure of *Skolithos.*
Figure 3. *Corophioides* with well-developed spreiten.
Figure 4. *Rhizocorallium*, a horizontal U-tube.
Figure 5. *Scolicia* with clearly defined lateral lobes. x1.
Figure 6. Bedding plane exposure of intersecting *Scolicia* trails.
Figure 7. *Helminthopsis* preserved in convex epirelief on sandy parting near top of Lower Ecca.
Figure 8. Vertical spiral burrow. x2.
Figure 9. Problematic elliptical cast preserved in convex epirelief in Lower Ecca mudstone.
Figure 10. Dumb-bell-shaped surface impressions on bedding plane.
Figure 11. Digitate scratch marks preserved in positive hyporelief with *Skolithos.*