

TRACE FOSSILS FROM THE NANKA FORMATION, SOUTHEASTERN NIGERIA¹C. S. NWAJIDE² & M. HOQUE³

ABSTRACT

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The Eocene Nanka Formation of the Anambra Basin of southeastern Nigeria is a thick, abundantly cross-stratified, flaser and lenticular bedded unfossiliferous unit; it is composed dominantly of medium to coarse grained quartz sand with shale and claystone at several horizons. Various kinds of burrows, confined to the sand beds, are the only evidence of past organic activity within the otherwise unfossiliferous formation. These burrows have been identified to be of the ichnogenera *Ophiomorpha* and *Skolithos*. The former occurs as both isolated and randomly oriented tubes and as dichotomously branching burrows possessing tuberculate ornamentation. The latter is seen as short and narrow vertical to steeply inclined straight to curvilinear burrows. A third unidentified burrow type occurs as horizontally oriented, unlined tubes probably constructed by sediment ingesting worms.

Trace fossils have proved to be reliable environmental indicators. Both *Ophiomorpha* and *Skolithos* have been known to occur mainly in a marginal marine environment. Their presence in the Nanka Formation is, therefore, indicative of the deposition of Nanka sands in an intertidal to shallow sublittoral zone. This interpretation, based on trace fossil study, finds support on other evidences independently obtained from the lithostratigraphic and sedimentologic features of the formation. It appears then that the presence of trace fossils in otherwise unfossiliferous strata could provide a reliable basis for environmental diagnosis.

INTRODUCTION

The Nanka Formation (Eocene) is a clastic unit about 305 metres thick. It underlies the marine Imo Shale (Palaeocene) and overlies the paralic Ogwashi-Asaba Formation (Middle Eocene). These formations are the major lithostratigraphic units of the Anambra depositional basin of southeastern Nigeria (Fig. 1).

The formation lacks body fossils, but is characterized by an abundance of trace fossils mostly in the form of burrows. The purpose of this paper is to describe the morphology of these ichnofossils, to discuss their origin and to evaluate their palaeoenvironmental significance.

THE NANKA FORMATION

An integrated stratigraphic and sedimentologic study of the Nanka Formation has recently been concluded (NWAJIDE,

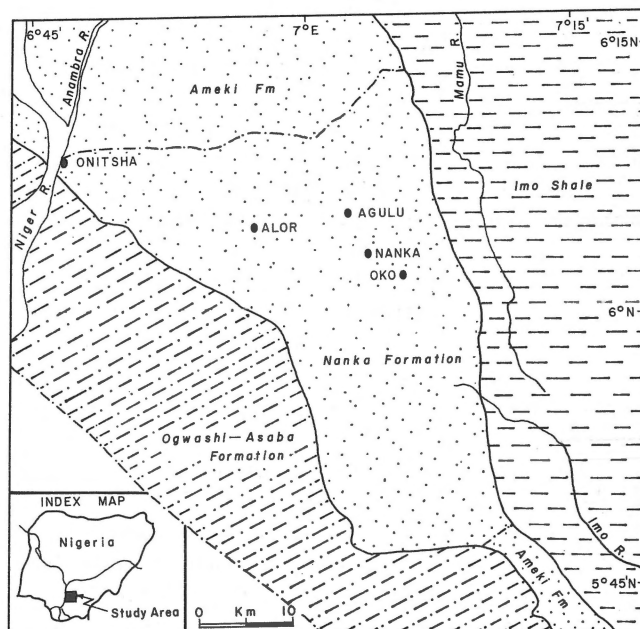


Fig. 1
Generalised geology of a part of the Anambra Basin, southeastern Nigeria.

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Age	Formation	LITHOLOGIC DETAILS		Environment
M. EOCENE	Ogushi-Asaba Fm.		Mainly Shale with lignite beds	Paralic
LOWER EOCENE	Nanka Formation		Thickly cross-bedded, m. to c., at places pebbly, sand; upper part lateritised, with Ss blocks and quartz pebbles	Sandflat / Subtidal
			Gypsiferous Sh with pyrite	Mudflat
			Cross-bedded, m. to c., sand, burrowed; beds of ferruginous Ss	Sandflat
			Glauconitic Sh with gypsum	Mudflat
			Cross-bedded, m. to c., at places pebbly, sand, burrowed; intercalations of clay and Sh	Mixed-flat
			Sh with fine sand beds	Mudflat
PALEO-EOCENE	Imo Shale Fm.		Mostly shale	Marine

Fig. 2 Stratigraphic relationship and lithologic summary of the Nanka Formation (after NWAJIDE, 1977). Not to scale.

1977). In the proposed unit stratotype in the Nanka town, the formation is found to be composed dominantly of loose or semi-consolidated quartz arenite with minor mudrocks and thin ferruginous sandstone bands at several horizons (Fig. 2). The sand is medium to coarse grained, occasionally pebbly, subrounded, generally positively skewed and mesokurtic to leptokurtic in distribution. The shale and claystone beds are relatively thin, averaging only about two metres thick. They separate the stratigraphic column into four sand subunits, each with an average thickness of about 73 metres. These subunits exhibit various inorganic and biogenic sedimentary structures which include horizontal stratification, planar and trough cross-bedding, flaser and lenticular bedding and various types of burrows.

The burrows are invariably confined to the sand subunits, and appear to be the only evidence of past organic activity within the otherwise unfossiliferous formation.

KINDS AND MORPHOLOGY OF THE BURROWS

Three kinds of burrows were observed in the Nanka Formation. These are *Ophiomorpha*, *Skolithos*, and an unidentified type.

The ichnogenus *Ophiomorpha* occurs both as isolated single burrows and as ramifying three-dimensional meshworks. At Oko and Alor, it is observed as a dense network of branching burrows spread out approximately parallel to stratification. Some branches appear to cut through one another.

Ophiomorpha has a circular cross-section ranging from 1.5 cm to 4 cm in diameter. Branching is normally dichotomous and occurs at irregular intervals, showing swellings at each point of branching (Fig. 3). Externally, this burrow has a

tuberculate ornamentation consisting of variously sized knobs that give it the appearance of a 'corn cob'. The wall is usually 4-6 mm thick, and has a smooth interior, contrasting sharply with the knobby exterior. It consists of coarse quartz grains firmly cemented by a dark brown or white material which is probably collophane, a cementing material observed by WEIMER & HOYT (1964). The cementation is firm enough for the wall to retain its form and stand in relief even after the surrounding sand has been eroded away. The burrow-fill is generally structureless, consisting also of coarse quartz grains in a scanty matrix of clay. The main distinction is that the burrow-fill is usually lighter in colour than both the wall and the host sediment. Hollow burrows have not been observed.

A variant of the form described above is one in which the burrow is almost elliptical in cross-section, with its underside a little flatter than the topside. The maximum diameter of the cross-section is normally horizontal to the bedding plane. The underside of the burrow is furrowed lengthwise and, except at the edges, generally lacks knobby ornamentation (Fig. 4). The upper side is densely tuberculate.

Skolithos occurs less frequently than *Ophiomorpha* in the Nanka Formation. It is observed in a sand quarry near Onitsha and in the Agulu gully as vertical to slightly inclined burrows. These are normally 2-10 cm long and 2-6 mm in diameter. They are single, unbranched, cylindrical to subcylindrical, straight to curvilinear. The wall, about a millimetre thick, is made up of firmly cemented quartz grains. The burrow-fill is structureless, and is composed of medium grained sand, usually lighter and finer than that of the wall and the host rock.

The third burrow type is observed in the flaser-bedded sand subunits. It is usually oriented parallel to bedding and is unbranched and unlined. Cross-sectional shapes range from circular to oval, with a maximum diameter ranging from 1.5 cm to 4 cm. The burrow-fill is structureless, and is often better sorted, slightly coarser and of more homogeneous lithology than the enclosing sediment.

ORIGIN OF THE BURROWS

Ophiomorpha nodosa Lundgren is the name given to the dwelling tubes constructed by the shrimps *Callianassa major*, *C. biformis* and *Upogebia pugettensis* (VAN DE GRAAF, 1972; FREY, 1975). These burrowers are decapod crustaceans which inhabit beaches and tidal flats (WEIMER & HOYT, 1964; SEILACHER, 1967; HOWARD & DORJES, 1972). The dwelling tubes belong to the ethologic group called domichnia by Seilacher (1953, cited in FREY, 1973), and are used as permanent domiciles for suspension feeding by semisessile animals. They are firmly constructed, and are usually found preserved in full relief, with an active fill (SEILACHER, 1964). The network of branching burrows reflects the crustaceans' search for food and is also suitable for shelter requirements (HÄNTZSCHEL, 1962).

Another ethologic feature is the presence of swellings at the

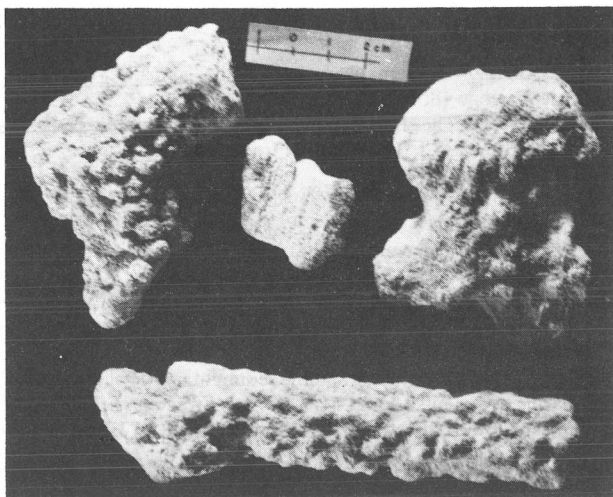


Fig. 3
Ophiomorpha: top-left and top-right: swelling at points of dichotomous branching. Top-centre: lighter burrow-fill and darker burrow-wall. Bottom: straight and cylindrical stem with tuberculate ornamentation and swelling at the left end.

points of branching. The swellings have been called 'turn-arounds' and are supposed to represent locations where the burrowing organism changed direction (KENNEDY & SELLWOOD, 1970).

Ophiomorpha nodosa from various locations and ages displays conspicuously similar modes of occurrence and morphological characteristics. This is why it is considered to be a distinct ichnospecies (RADWANSKI, 1970).

CRIMES (1975) reports that circular outlines of *Ophiomorpha* parallel to bedding may become elliptical after compaction of sediments. Those burrows of the Nanka Formation with their underside flatter, furrowed and virtually non-tuberculate, do not appear to have resulted from any post-depositional compaction or deformation. These burrows may rather belong to a different species of *Ophiomorpha* and perhaps were particularly suitable for an organism living on or very near to the sediment surface.

Skolithos is interpreted as the dwelling burrow type (domichnia) constructed by annelids or phoronids (SHROCK & TWENHOFEL, 1953, p. 258; ALPERT, 1974). GOLDRING (1964) suggests that these burrowers probably moved upward in the sediment as an adjustment to depth (sediment thickness), leaving behind burrows that were later passively filled by gravity. It is also conceivable that the burrowers kept pace with the sedimentation rate by abandoning the lower part of the burrow after filling it up. The organism thus always remained near to the accretion surface where the most nutrients were available.

The unidentified burrow type can be classified with the fodinichnia. These are unlined and may be actively filled ordinary feeding burrows of a vermiform organism foraging close to the sediment surface. This may explain their confine-

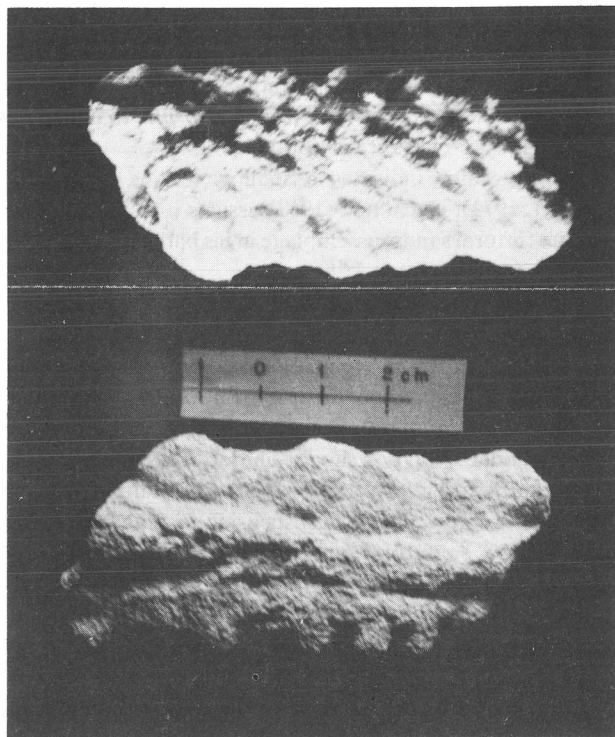


Fig. 4
Ophiomorpha: having an elliptical cross-section. Top: upper-side with dense tuberculation. Below: underside with lengthwise furrows and lacking ornamentation.

ment to bedding planes.

In all the above burrow types, the fill is usually lighter coloured than the host sediment. This probably resulted from biochemical alteration of sediment by the tracemakers (HALLAM, 1975).

PALAEO-ENVIRONMENTAL SIGNIFICANCE AND CONCLUSIONS

Trace fossils are useful environmental indicators as they are thought to reflect behavioural responses of animals controlled by physical, chemical and other ecological conditions of the environment. Since they cannot normally be transported and redeposited, they are usually more reliable than the associated shelly fossils. They are also of great value in a stratigraphic analysis of a sequence devoid of body fossils or with only poorly preserved ones. The geological significance of trace fossils has been reviewed by several workers (CRIMES & HARPER, 1970; FREY, 1973, 1975).

Ophiomorpha has been reported from a shallow marine, sublittoral environment (KENNEDY & SELLWOOD, 1970), a foreshore (REINECK & SINGH, 1973, p. 341) and from a beach environment (SEILACHER, 1967). SHINN (1968) reported callianassid burrows from a depth of 12 metres in the marine waters off

Florida and the Bahamas. KENNEDY & MACDOUGALL (1969) interpreted an association of *Ophiomorpha* with marine, brackish and fresh-water fossils as indicating a transitional environment. HOWARD (1972) also used *Ophiomorpha* to interpret an offshore/shore facies transition.

Skolithos also indicates a shallow marine environment (ALPERT, 1974). SEILACHER (1967) assigns it to the shallowest marine (littoral sands) assemblage in his bathymetric zonation of trace fossils.

Ophiomorpha belongs to both the *Skolithos* and the *Cruziana* assemblages of ichnofossils (FREY, 1975, table 2.1). In the former, vertical or steeply inclined burrows are common and indicate suspension feeding in littoral to very shallow sublittoral zones of relatively high energy conditions, e.g. beaches, tidal deltas and shoals. The latter assemblage is characterized by irregularly inclined to horizontal burrows, constructed by carnivorous and suspension feeding trace-makers in a shallow sublittoral environment below wave base and quieter offshore conditions. In both cases, the characteristic lithology is sand with beds of mudrocks.

In the Nanka Formation, there are both vertical and randomly disposed *Ophiomorpha* as well as vertical *Skolithos*.

From the foregoing analysis of the environmental significance of the burrows, it appears that sediments of the Nanka Formation were deposited in a zone which ranges from intertidal to sublittoral.

This palaeo-environmental diagnosis made only on ichnological evidences confirms an earlier conclusion based on an integrated study of the lithostratigraphy, petrography, geometry, and palaeocurrent system of the Nanka Formation (NWAJIDE, 1977). Such a sandy shoreline environment appears to be under the influence of relatively high-energy dynamics where only a few benthic organisms could have survived current and wave surges, desiccation, and rapid fluctuations of temperature and salinity; their survival appears to have been dependent largely on their ability to construct firmly lined burrows.

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