

TRACE FOSSILS IN PLEISTOCENE SANDY DEPOSITS FROM GRAVINA AREA SOUTHERN ITALY

A. D'ALESSANDRO* & R.G. BROMLEY**

Key-words: Ichnofossils, Pleistocene, Southern Italy.

Abstract. The ichnology of the Pleistocene sand sequence of Gravina is described. The trace fossils provide evidence for marine coastal environments, ranging from the lower infralittoral to intertidal. The study is based on two sections, at Lama La Noce and at Notargiacomo's Quarry respectively. Meniscate backfill structures produced by echinoids (*Schizaster canaliferus*) occur in thin clay horizons. Sand substrates are dominated by *Ophiomorpha*, *Thalassinoides*, *Cylindrichnus* and vertical equilibrium traces. Two new ichnospecies are erected: *Cylindrichnus errans*, which has lateral spreite-like displacement of the shaft: and *Dactyloidites peniculus* for finely branched, radiating spreite structures.

Riassunto. Evidenze di ambienti deposizionali marini, compresi fra l'infralitorale inferiore e l'intertidale sono fornite dalle numerose strutture sedimentarie biogeniche presenti in una sequenza pleistocenica prevalentemente sabbiosa, affiorante presso Gravina in Puglia. In sottili orizzonti argillosi sono frequenti le strutture a menisco prodotte da *Schizaster canaliferus*, mentre i substrati sabbiosi sono caratterizzati da *Ophiomorpha*, *Thalassinoides*, *Cylindrichnus* e da tracce di equilibrio. Due nuove ichnospecie sono istituite: *Cylindrichnus errans* che presenta spostamenti laterali della galleria verticale e *Dactyloidites peniculus* con strutture radiali, ramificate e con *Spreiten*.

Introduction.

Rich and moderately diverse trace fossil assemblages were discovered in the lower Pleistocene prograding sequences outcropping near Gravina in Puglia (Fig. 1). These assemblages occurred in two of the four lithostratigraphic units mapped by geologists in the official Italian map-sheet F° 188 «Gravina in Puglia» (2nd edn.) and named by them from bottom to top *Argille di Gravina* (Q_a^c) (Gravina Clay), *Sabbie di Monte Marano* (Q_s^c) (Monte Marano Sand), *Sabbie dello Staturò* (Q_s^1) (Staturò Sand), *Conglomerato di Irsina* (q_{cg}^1) (Irsina Conglomerate).

* Dipartimento di Geologia e Geofisica, Campus Universitario, Università di Bari.

** Institute for Historical Geology and Palaeontology, Øster Voldgade 10, Copenhagen, Denmark.

— With grants from the Italian C.N.R. and from Ministero della Pubblica Istruzione, 40%.

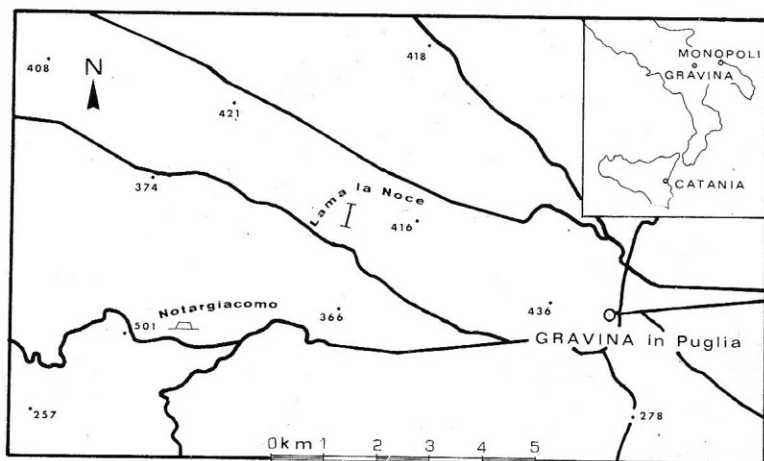


Fig. 1 — Location of the sections.

In the area under consideration the Gravina Clay, Pleistocene in age, is a bluish-grey clayey silt, locally containing episodic concentrations of mainly autochthonous megafossils. It grades up rapidly into the lower Pleistocene Monte-Marano Sand, which consists of a quartzose and calcareous sand containing fossiliferous fine muddy-sand horizons and trace fossils at some levels. The Staturo Sand has been described as a red to ochre and yellow quartzose-micaeous fine sand having clear cross-stratification and including conglomeratic and clayey lenses; it is tentatively attributed to Upper Villafranchian (Azzaroli et al., 1968). Although this continental formation is extensively mapped in the official sheet, in the study area it has not been identified for certain. The Irsina Conglomerate, questionably dated Upper Villafranchian or Emilian (Azzaroli et al., 1968), mainly consists of rounded or faintly flattened, medium-sized pebbles. The erosive contact with the underlying unit is locally characterized by sparse rhizoliths.

Detailed descriptions of this sequence and the inferred evolution of the environment are given in a forthcoming report by Caldara et al. The main purpose of this paper is to document the ichnofossils present in the sandy sequences and to infer the relationships between them and the palaeoenvironment.

Description of the sections

The trace fossils are observable in two artificial sections. The first exposure is in the small valley Lama La Noce (Section 1), the second in the Notargiacomo's Quarry (Section 2). The bases of the section lie at 372 m and 450 m above sea level respectively (Fig. 2). A direct correlation is believed to exist between the two sequences (Caldara et al., in prep.).

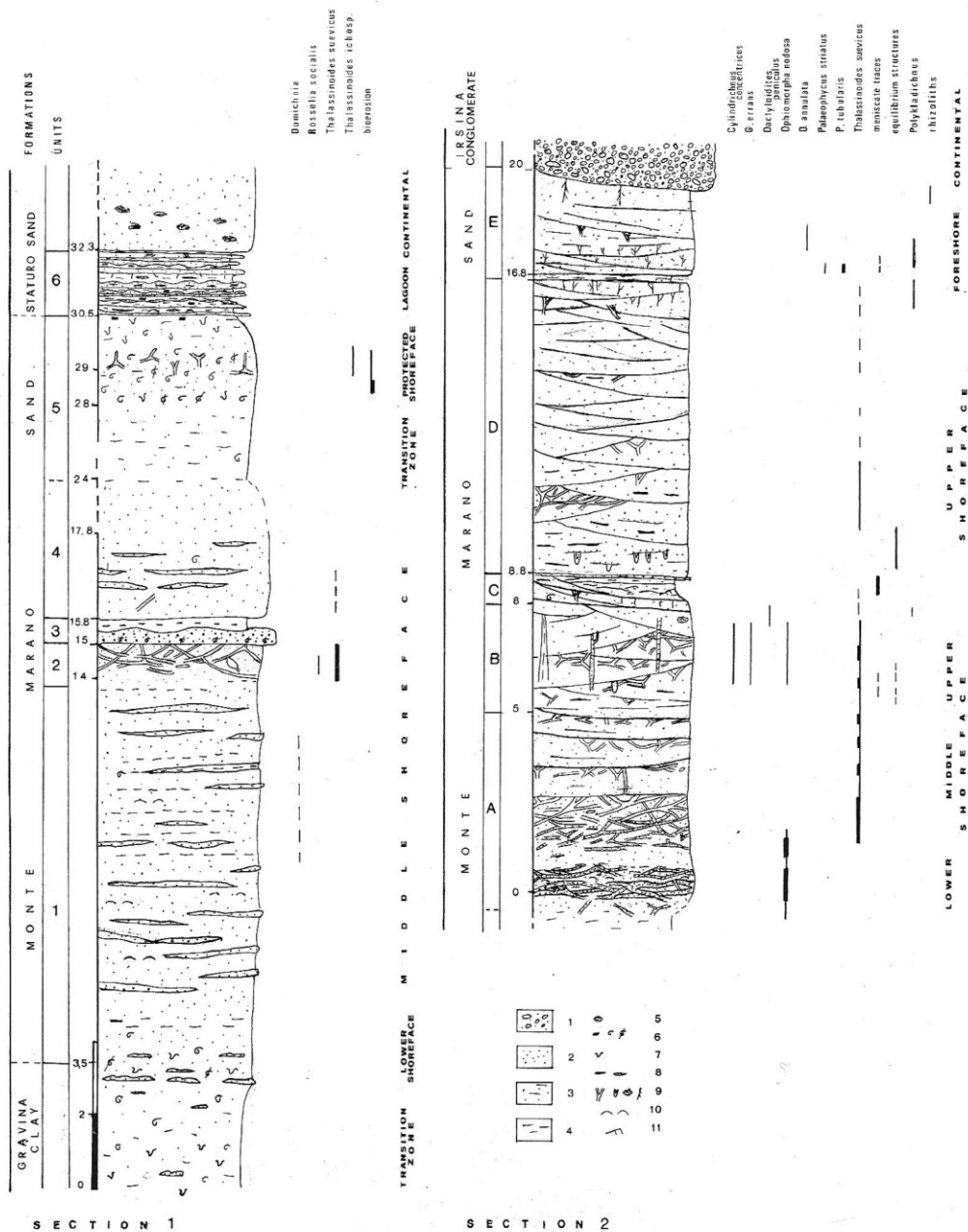


Fig. 2 — Schematic stratigraphic sections. The structures are not drawn to scale. 1) Conglomerate; 2) sand; 3) clayey silt; 4) clay; 5) carbonate concretions; 6) animal and plant body fossils; 7) bioturbate textures; 8) sand or clay lenses; 9) trace fossils; 10) shell pavements; 11) small scale ripple cross bedding.

Section 1 (Lama La Noce) (Fig. 2).

The sequence begins with 3.5 m of clayey silt that represent the upper part of the Gravina Clay. The overlying Monte Marano Sand has been divided into the following units, mainly on the basis of ichnofossils:

Unit 1 – 10.5 m of fine to medium grained sand having plane-parallel lamination and wavy bedded arenitic layers showing large-scale, low-angle cross stratification. Lenses of mud-clasts occur, most frequently and thickly developed in the upper part of the unit, where they may compose continuous mud layers of variable thickness. The bases of some clean, graded sand beds are formed by pavements of allochthonous body fossils. The only trace fossils present in this unit are uncommon domichnia associated with *in situ* *Panopea* specimens.

Unit 2 – a bed 1.2 m thick of fine silty sand, distinguished by a well developed *Thalassinoides suevicus* burrow-system, associated with *Rosselia socialis* (Pl. 11, fig. 2) having patchy distribution. The trace fossils are clearly related to the subsequent change in lithology; they are truncated above but not filled with material from the overlying bed. The trace fossils have suffered minimal compaction.

Unit 3 – a multiple coquina horizon up to 70 cm thick, grainsize from rudite to arenite. The flat-based bed preserves a symmetrical ripple bedform, being overlain by clay 10–40 cm thick.

Unit 4 – 2 m of muddy sand including large scale, cross bedded sandstones and sparse *Thalassinoides* elements;

– about 6 m of covered interval

Unit 5 – 4 m of poorly exposed mud, containing few bivalve shells, but apparently no trace fossils;

– 50 cm of fine silty sand, which is given the appearance of lamination by abundant presence of horizontal ostreids, venerids and glycymerids. These skeletons show well developed bioerosion;

– the facies passes up into shell-bearing silty-sand containing small *Thalassinoides* ichnosp. Some shells are in life position; fragmented shell debris is cemented in small clusters. Upwards, in the mottled muddy sediment, complete specimens of *Schizaster canaliferus* (Lamarck) and *Venus multilamella* (Lamarck) occur, together with limited vegetal remains. Thickness 18 m.

Unit 6 – sandy intercalations appear within the clay, thin at first but increasing to become the dominating lithotype. This unit, 1.5 m thick, is basically unbioturbated, but contains few and small trace fossils descending from the erosional tops of sandy layers.

The overlying red sand containing carbonate concretions probably represents a continental environment (Staturo Sand).

Section 2 (Notargiacomo's Quarry) (Fig. 2).

Trace fossils begin to occur in significant numbers in about 20 m of calcareous and quartzose—micaceous sand, which is mainly cross-bedded.

Unit A— 5 m of flat bedded or low-angle cross-bedded sand. In the lowermost 2 m, successive, cross-cutting maze systems of *Ophiomorpha nodosa* (Pl. 9, fig. 1) have largely obliterated the primary structures. The wall of the burrows is strongly developed in the first metre, where the medium-sand is characterized by levels of chaotically arranged bivalve casts and thin horizons of flat-lying *Ditrupa* tubes. Above this, the wall decreases in thickness in the following metre of fine sand, and *Ophiomorpha* is replaced by *Thalassinoides suevicus* in the overlying part of the unit. Simultaneously the degree of bioturbation diminishes markedly to a few percent (Fig. 3).

Unit B— 3 m of fine grained sand characterized by large scale trough cross bedding, including flat muddy lenses. In contrast to the even distribution of the sparse *Thalassinoides* below, the burrows here are patchily distributed in erosional remnants between troughs and below trough scour surfaces. Towards the top the *Thalassinoides suevicus* is joined by *Dactyloidites peniculus* (Pl. 12, fig. 3; Pl. 13, fig. 3), and by long shafts of *Ophiomorpha nodosa* (Pl. 10, fig. 2),

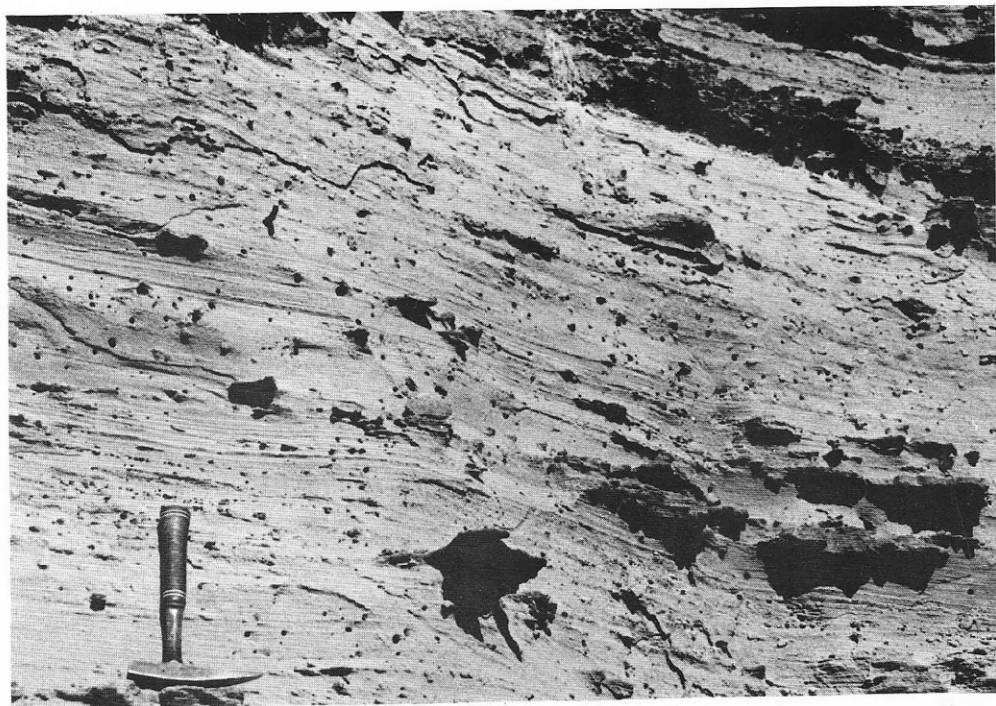


Fig. 3— Uppermost part of Unit A (Notargiacomo's Quarry) showing low density *Thalassinoides* burrows.

Cylindrichnus concentricus (Pl. 10, fig. 1) and *C. errans* (Pl. 11, fig. 1). These deep burrows cut across the *Thalassinoides* fabric.

Unit C – trough cross-bedded muddy sand, having rare *Thalassinoides* and small *Polykladichnus*. It grades upward in clayey flat lenticles and discontinuous thin layers overlain by a thin bed of medium to coarse sand; both the clay and the sand are intensely bioturbated with meniscus structures (Pl. 14, fig. 1). Overall thickness 80 cm.

Unit D – 8 m of large scale trough cross-bedded fine sand (Pl. 14, fig. 2), the scale of structures decreasing upwards. Equilibrium traces in the lower part, patchy *Thalassinoides*, as in Unit B but much less common, joined by numerous *Polykladichnus* are observable in the topmost metre.

Unit E – above a sharp base, 20 cm of clay follow, containing chalky nodules and 3 m of poorly sorted, fine sand, low-angle cross bedded. *Palaeophycus tubularis* and *P. striatus* occur on the sole of the sand bed in great abundance, with very rare meniscus structures. Multiple forked subvertical undersized *Polykladichnus* cross the lower 40–50 cm of the sands replaced upward by small and sparse *Ophiomorpha annulata* burrows.

The top is truncated by the Irsina Conglomerate and from the base of this, rhizoliths enter uppermost levels of Unit E (Pl. 15, fig. 1).

Palaeoenvironmental interpretation.

Autochthonous body fossils are well preserved in some levels of clayey-silt or fine muddy sand, but these are rare or absent in the sandy sediment. Consequently, information on environmental factors may be inferred either from body fossil benthic associations (*sensu* Fürsich, 1984) or from biogenic sedimentary structures. The trace fossils have low diversity, and commonly only a single ichnospecies occurs in a given unit, although density may be high, suggesting a biologically stressful environment. On this account true trace fossil assemblages cannot be identified and interpretations must be based on individual ichnospecies and their mode of development. Even where a few ichnospecies occur together in a bed, they clearly belong to different suites, emplaced at different times. Ethologically the burrows represent mainly domichnia and fodinichnia, indicating a low level of trophic differentiation which in turn further suggests a stressful environment.

Section 1.

The transition between the Gravina Clay and Monte Marano Sand is indicated by rapid gradational changes both in lithology and in composition of the faunal associations. Below this, the muddy bottom palaeocommunity (*Turritella*–*Venus* palaeocommunity) which corresponds to a facies of the «terri-genous mud» biocoenosis (*vases terrigènes cotières* – VTC – *sensu* Pérès & Pi-

card, 1964) developed in a biotope located below mean wave base. This is replaced above by an infralittoral (maybe lower shoreface) «heterogeneous association» (peuplement hétérogène — PE — *sensu* Picard, 1965; Di Geronimo, 1984) having high abundance values for the species indicative of sedimentary instability (Caldara et al., in prep.).

In Unit 1, physical structures and virtual absence of bioturbation suggest deposition in high energy middle shoreface. Evidence includes evenly laminated sand, thin pavements of oriented shells, and large scale low-angle cross bedding. The only biogenic structures are rare domichnia of the deeply infaunal bivalve *Panopea glycymeris* (Born), a species characteristic of «littoral (*sensu lato*) mud and sand of the Mediterranean Sea» (Ghisotti & Steimann, 1969). Turbidity and turbulence, possibly combined with a high rate of deposition and intermittent erosion, are conditions that could prevent the establishment of a benthic community, or allow preservation only of its deepest-burrowing elements. The unusually small size of *Panopea glycymeris* suggests an unfavourable environment, inhibiting normal benthic colonization.

In Unit 2, a colonization event is recorded by *Thalassinoides suevicus* and *Rosselia socialis*. The appearance of these trace fossils indicates a reduction in sedimentation rate and probably in the energy level. The modest density and lack of significant upward migration of the boxwork suggests that this interval was brief. The *T. suevicus* system is truncated by the bioclastic bed of Unit 3. This unit possibly represents storm layers, comprising several isolated events followed by the settling out of considerable amounts of suspended material.

The lower part of the poorly exposed Unit 4 resembles the facies of Unit 1 and probably represents a similar depositional environment. Thus, after the upward movement of the sea floor that marked the initiation of sand deposition (Unit 1), an approximate balance was struck between subsidence and depositional aggradation.

The basal portion of the clayey silt of Unit 5 is poorly exposed. Nevertheless, its low diversity megafaunal association composed of few, scattered, shallow infaunal molluscs, once again indicates upper circalittoral or transitional zone conditions (*Venus-Turritella* palaeocommunity) and so testifies to a brief reversal of the general regressive trend.

This is followed by a marked and rapid shallowing of the depositional basin, expressed by the succeeding palaeocommunities (Caldara et al., in prep.). Current activity on the soft muddy bottom caused this to become firm and left a lag deposit of exhumed shells belonging to the infaunal organisms of the previous palaeocommunity. These conditions favoured the successful settlement of both infaunal, epifaunal and bioeroding animals. Practically all thick shells were colonised by *Gastrochaena dubia* (Pennant), both the shell and boring of which are preserved.

The palaeocommunities succeed each other so closely that environmental condensation is the result. Thus, for example, *in situ Solen marginatus* Pulteney from the *Spisula* community is found emplaced among the underlying *Ostrea* community.

The continuation of the regressive trend coupled with the increased influx of fine silty sand, explains the shift to a muddy facies of the *Spisula* community in a protected biotope, such as a bay, located within the upper infralittoral zone.

Vagile endofaunal activity is documented by small clusters of shell debris and by *Thalassinoides* ichnosp. maze systems that have the shaft necks preserved intact with narrow apertures to the sea floor. The internodal distances are short, probably as a reaction to shelly obstacles in the substrate. Decrease in energy, possibly related to the establishment of lagoonal conditions, caused increase in mud and the collapse both in abundance and diversity of the animal community. The muddy sediment appears mottled but individual trace fossils are not identifiable. The survival of *Schizaster canaliferus*, specimens of which are perfectly preserved, complete with spines *in situ*, strongly suggests that this deeply burrowing form was largely responsible for the bioturbation.

The interbedded clay and sand of unit 6, lacking megafossils except for thin lenses of shell debris, and feebly bioturbated in the lower part, may represent a coastal, scarcely oxygenated lagoonal, transitional to continental environment.

Section 2.

Overlying the clay, which has been correlated with the base of Unit 5 (section 1) on field evidence, Unit A commences with a bed heavily bioturbated with *Ophiomorpha nodosa* increasing in density upwards. The relationships of the bed with the sequence above and below were not clearly visible. It is suggested that the horizontal cross cutting networks of *Ophiomorpha nodosa* here represent a response to an extremely unstable shifting substrate, necessitating heavy wall support of the burrows. The coquinas indicate arrival of the sediment under storm conditions, the *Ditrupa* layers demonstrating current activity. Consequently, the bed may be interpreted as a storm-deposited sand body, possibly involving several tempest events owing to its thickness, and deposited in the lower shoreface environment.

Above this bed, laminated sands at first have little bioturbation but this increases to total bioturbation in the following metre, suggesting slow sedimentation. The fabric consists of crowded cross-cutting, weakly walled *Ophiomorpha nodosa* elements. Reduction of walling in respect to the burrows below may be related to substrate consistency, the sand here having finer grain size. This tendency continues upwards, bioturbation remaining complete as far as

2.5 m above base, the *O. nodosa* being replaced by *Thalassinoides suevicus*. These sediments apparently also belong to the lower shoreface. In the final 2.5 m of the unit, the low angle cross bedded sand bodies are burrowed (*T. suevicus*) only at the upper parts, suggesting shorter periods of bioturbation. This in turn may be explained by an increase in rate of deposition, each pulse preceded by slight erosion. We may interpret this as indicative of gradual shallowing towards the middle shoreface environment.

The cross bedded interval, Unit B, documents further increase in energy. The bioturbated beds represent erosional fragments cut by trough scouring. The cross bedded sand bears rare lenses of clay, some disturbed by meniscate burrows, whereas the sand itself locally contains *Thalassinoides suevicus* and rare vertical, equilibrium traces. From the higher reactivation surfaces, vertical *Cylindrichnus* and *Ophiomorpha* shafts cut down across the fabric below. This is a classical upper shoreface association.

Dactyloidites peniculus has been emplaced in topmost Unit B sediments and indicates a quiet, time-consuming, deposit-feeding activity. Energy decrease is also implied by the presence at the same horizon of body fossils of *Atrina pectinata* (Linneus). The overlying clay and sand of Unit C are well bioturbated, dominated by meniscate backfills produced by echinoids, again suggesting low or medium energy. This evidence supports the trough or channel floor environment indicated also by the lenticular form of the unit, and its lithology.

In Unit D, the vertical retrusive and protrusive equilibrium traces, common at two levels at the base, indicate rapid sedimentation and erosion. *Thalassinoides* occurs at several levels, but the bioturbation degree is generally lower than in previous units. Physical structures dominate and an upper shoreface environment may be suggested. The top portion of Unit D, containing sparse *Thalassinoides* and *Polykladichnus* in the trough cross bedded sand, may represent a slightly different environment within the upper shoreface or lower foreshore.

There is then clearly a return to low energy conditions, the clay and sand lithology and bioturbation of the basal part of Unit E suggesting this. However, the discovery of a single fragment of meniscus backfill structure possibly may be taken to indicate echinoid activity and thus the persistence of marine conditions. The small branched burrows resembling diminutive *Polykladichnus*, possibly representing fodinichnia of worms, reveal little about the environment beyond a low or moderate depositional rate. The thin walled *Palaeophycus* likewise undiagnostic of environment, give the same indications. Upwards Unit E contains sparse, strongly walled small vertical *Ophiomorpha annulata* that together with the bedding type indicate shifting bottom in a foreshore environment.

The plant roots from the erosion surface terminating this unit demonstrate the non marine nature of the overlying sequence and possibly of the top-most part of this unit.

Conclusions.

The very poor degree of exposure in the Gravina area of the marine sandy sequence, and its complex lateral changes and interfingering of facies, prevent detailed stratigraphical correlation. The two sections studied here are tentatively correlated on field evidence: the four metres of clay of Unit 5 represent the clay at the base of section 2.

In section 1, the environmental indications are chiefly provided by sedimentological and palaeoecological evidence (based on body fossils). The trace fossils, where they occur, support the interpretations of environmental evolution through this sequence of coastal sediments from shallow marine shelf (transition zone) to continental conditions. A moderate, temporary deepening, coinciding with the lithological change at the base of Unit 5, interrupts the regressive trend; there follows the establishment of depositional environments of decreasing low energy (bay to lagoon). At certain horizons the trace fossils provide details of depositional rate and substrate consistency that enhance this picture.

In section 2 there is a general lack of body fossils but a more continuous trace fossil record. Details of *Ophiomorpha* and *Thalassinoides* distribution document the stability of the substrate at different levels; the shapes of these systems reveal rates of deposition and to some extent hydrodynamic energy levels. *Dactyloidites peniculus* ichnosp. n. indicates quiet conditions (in shallow water) suitable for deposit feeding activities. *Cylindrichnus concentricus*, *C. errans* ichnosp. n. and long vertical *Ophiomorpha nodosa* shafts indicate relatively high energy conditions, whereas vertical equilibrium traces record intermittent rapid deposition. Thin, clayey horizons, even where restricted to lenses a few metres in extent, are characteristically dominated by meniscate backfill structures attributable to the echinoid *Schizaster canaliferus* (body fossils found *in situ*). The thin clay bed at about 17 m and the basal part of the overlying sand, dominated by *Palaeophycus* and *Polykladichnus* probably represent water too shallow for *S. canaliferus*.

The trace fossils indicate a general and gradual shallowing of the bottom passing from lower shoreface, where storm deposits accumulated, up to the foreshore zone. Compared with the sediments of Unit 5, 6 (Section 1), here the biogenic and physical features indicate more open nearshore conditions and moderately higher hydrodinamism. In neither section is tidal influence documented.

Truncated rhizoliths record a continental continuation largely removed by erosion. Although section 2 has been indicated as non-marine Staturo Sand on

the geological map, the trace fossil assemblage demonstrates its marine origin (except, perhaps, for the uppermost part) and this sequence must therefore be considered to belong to the Monte Marano Sand.

Systematic ichnology

In the following, little-known or new trace fossils are given detailed systematic treatment whereas only brief descriptions are provided for the well known biogenic structures. All figured material is housed in the Department of Geology and Geophysics, University of Bari, Italy, bearing the prefix DGGB.

Ichnogenus *Cylindrichnus* Toots in Howard, 1966

Cylindrichnus concentricus Toots in Howard, 1966

Pl. 10, fig. 1; Pl. 15, fig. 2

1984 *Cylindrichnus concentricus* — Howard & Frey, p. 203, fig. 8A.

Description. Rare vertical, straight cylindrichnian burrows, associated with the new ichnotaxon *C. errans* and *Ophiomorpha nodosa*, have externally smooth wall or bear a faint xenoglyph of surrounding lamination (Pl. 10, fig. 1). In one specimen, the burrow fill was delimited by one or two thin, yellow laminae and surrounded in turn by a thick, massive, brown wall. At the boundary, the yellow laminae send a few small flame-like extensions into the walling material (Pl. 15, fig. 2). Both the fill and wall material further differ from the host sediment in being more strongly cemented.

Cylindrichnus errans ichnosp. n.

Pl. 11, fig. 1, 4; Pl. 12, fig. 1, 2; Pl. 15, fig. 3, 4

1982 aff. *Ophiomorpha* D'Alessandro & Iannone, p. 631, pl. 1, fig. 3; pl. 2, fig. 2; pl. 3, fig. 3, 4; pl. 4, fig. 4; pl. 5, fig. 3, 4; pl. 6, fig. 6, 8.

Origin of name. Derived from the latin *errans*, wandering, referring to lateral shifting.

Type-series. Holotype no. DGGB 108, Pl. 15, fig. 3; paratypes no. DGGB 109; DGGB 110.

Horizon. Calcarene di Gravina, Plio-Pleistocene.

Type-locality. Cala Corvino (Fig. 4), Monopoli (Bari, Italy).

Diagnosis. Long, unbranched vertical or sub-vertical *Cylindrichnus* having lateral, randomly orientated, limited displacement of the causative shaft, producing vertical spreiten. Usually a few shafts are joined together to produce bundles.

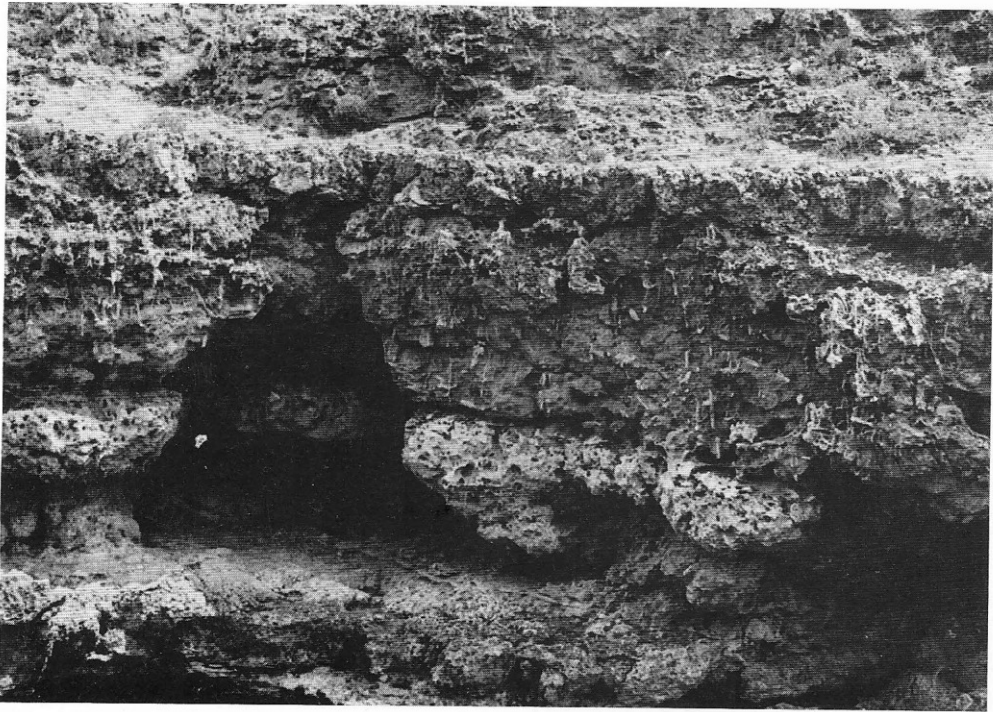


Fig. 4 – *Cylindrichnus errans* ichnosp. n. Cala Corvino (Monopoli), type-locality. Shafts are up to 80 cm long, seen in section at right angles to bedding.

Description. At the type-locality the very frequent structures are represented by cylindrical burrows up to 80 cm long, composed of a passive fill (1–2 cm wide) enveloped by a smooth multilayered wall. Lateral, randomly oriented displacement of the whole shaft produces spreiten; the degree of shift is normally greater at the base than at the top. Frequently, a few elements are joined together in small bundles, often arranged conically one beside the other, the whole structure wrapped around by smooth sheets of wall material.

In the Pleistocene sands outcropping to the west of Catania, these trace fossils are represented by single shafts (more than 1 m deep) showing wide lateral displacement (up to 10 cm) and surrounded by a massive envelope of wall material. In many examples, the spreite indicating the final position of the shaft protrudes from the envelope as a ridge (Pl. 11, fig. 4). The cross-section (max. diameter = 8 cm) appears subcircular to subelliptical in shape. Bundles of shafts have not been observed.

In Monte Marano Sand, *Cylindrichnus errans* is uncommon, found only in the top of Unit B, single or grouped in a conical bundle (Pl. 11, fig. 1), and generally showing poorly developed spreiten. The structures are preserved as endichnia.

Observations. These trace fossils were first described (D'Alessandro & Iannone, 1982) in detail under the name of aff. *Ophiomorpha* in the lower part of the Plio–Pleistocene Calcarenite di Gravina outcropping between Polignano and Monopoli (Bari province). The recent discovery of basically similar structures in two other localities (near Gravina, Apulia and Catania, Sicily), improving our knowledge of their morphological range of characters, permits the foundation of a new ichnotaxon. However, although they are here ascribed to *Cylindrichnus* on the basis of the multilayered walls, the remaining characters (mainly arrangement of the shaft and spreiten) are unknown in the ichnospecies at present included in this ichnogenus and in related taxa. There is a certain similarity with the vertical spreiten of *Heimdallia* Bradshaw. However, the limited degree of displacement, strongly developed wall and concentric wandering plan in *C. errans* serve to distinguish these forms.

C. errans could prove to be important in palaeoecological and environmental interpretation being found so far only in beach sediments. Indeed at the type–locality, the associated fossil assemblage is comparable to the recent biocoenosis of the well–sorted sand located in the upper infralittoral (D'Alessandro & Iannone, 1982). Near Catania, the same burrows have been observed in a Pleistocene biocalcarene deposited in a very shallow marine environment (Di Geronimo, pers. com. 1984). Lastly, in the Monte Marano Sand they are preserved in sediments interpreted as representing the upper shoreface. In all cases, *C. errans* is associated with *Ophiomorpha nodosa* maze systems connected to long shafts.

Ethologically, *Cylindrichnus errans* can be considered as domicinia of a suspension–feeding organism (see D'Alessandro & Iannone, 1982), maybe a crustacean, that adopted a strategy different from that of the *Ophiomorpha* makers, allowing it to live successfully in the same shifting bottom sediments.

Ichnogenus *Dactyloidites* Hall, 1886

***Dactyloidites peniculus* ichnosp. n.**

Pl. 12, fig. 3; Pl. 13, fig. 3

Origin of name. Derived from the latin *peniculus* meaning powder puff, referring to the burrow shape.

Type–series. Holotype no. DGGB 102, Pl. 12, fig. 3; Pl. 13, fig. 3; paratypes no. DGGB 103; no. DGGB 104.

Horizon. Sabbie di Monte Marano, lower Pleistocene.

Type–locality. Notargiacomo's Quarry (Spinalva), 7 km west of Gravina in Puglia (F° 188 II NO).

Diagnosis. A *Dactyloidites* having numerous, regular, symmetrically radi-

ating branches, themselves apparently unbranched and containing a limited retrusive spreite.

Description. Powder-puff-shaped burrow-system preserved in full relief. It is composed of long, thin, bundled galleries (5–6 mm in diameter) branching in a radial pattern from a short central shaft vertical to bedding. In the proximal part, the radial tunnels are obliquely oriented downward passing toward the distal part where they clearly curve upward; therefore in top view the entire structure appears faintly convex, whereas in bottom view it is deeply concave at the centre. The single tunnels, unlined or thinly lined, show retrusive spreiten in the marginal area; menisci, concave toward central area, are poorly developed within the galleries. In thin section the boundary between the galleries and the surrounding sediment appears sharp owing to local compaction, but without wall structures. The trace fossil, pale yellow in colour, is composed of clayey mudstone including loose, small clasts of quartz: the host sediment is composed of very fine quartzose-lime sand (angular grains) almost lacking in matrix (grainstone texture). In rare cases, thin sections show oval pellets to be sparsely present within the galleries.

Observations. The examined trace fossil superficially resembles the Palaeozoic structure that Desio (1940) described as a new form of the algal genus *Eoclathrus* Squinabol. *Dactyloidites peniculus* is distinguished from *Eoclathrus balboi* Desio mainly by its burrow lithology that differs from the host sediment, and by the pattern of the burrow-system in the marginal area. Indeed, the relief of *E. balboi* diminishes rapidly toward the periphery, beyond which a sort of roughness of sandstone surface is observed (Desio, 1940, p. 62: "Verso la periferia il rilievo si va rapidamente attenuando e dove cessa si nota esternamente una specie di scabrosità sulla superficie dell'arenaria..."). In agreement with Häntzschel (1975), after examination of Desio's specimen, it would seem reasonably safe to regard *E. balboi*, as having an inorganic origin.

The present material apparently belongs to the ichnogenus *Dactyloidites* Hall as redescribed by Fürsich & Bromley (1985), having radiating branches around a central shaft and a spreite structure. However, it is more densely and finely branched than the ichnospecies at present included in *Dactyloidites*, and therefore appears to represent a new ichnospecies.

A superficial resemblance to *Stelloglyphus turkomanicus* Vialov is striking, but inadequate knowledge of the structure of that ichnospecies and in particular of its internal organization prevent closer comparison with the present material.

Ethologically, the modified lithology of the burrow, menisci and pellets support the hypothesis that *D. peniculus* was a backfilled burrow-system of a stationary deposit-feeding organism. The branched structure appears to have been produced by successive probings after each of which the previous probe

was backfilled. The discovery of one specimen having relatively uncrowded galleries suggests that the radial pattern of the structure was established at an early stage and the organism then systematically increased the number of branches to better exploit the nutriment-rich sediments.

Ichnogenus *Ophiomorpha* Lundgren, 1891

***Ophiomorpha nodosa* Lundgren, 1891**

Pl. 9, fig. 1, 2; Pl. 10, fig. 2; Pl. 12, fig. 4; Pl. 15, fig. 5

- 1978 *Ophiomorpha nodosa* – Frey, Howard & Pryor, p. 224, fig. 1A, C, 2A, C–G, 3, 4B, C, 5, 6, 8C, 11 (*cum syn.*).
 1982 *Ophiomorpha nodosa* – D'Alessandro & Iannone, p. 629, fig. 8, 9, 11, 12, 17, 21; pl. 1, fig. 1; pl. 2, fig. 5.

Description. At the base of Unit A the *Ophiomorpha* system is dominated by horizontal development and is composed of long, weakly sinuous, occasionally slightly spiral, thickly walled galleries (2–3 cm in diameter): generally only the smooth fill and external impression of the nodose lining are preserved; large swellings occur at branching points (Pl. 15, fig. 5). The overlying fine sand contains very dense boxwork-systems; the galleries (average diameter about 1 cm) are constant in size, and have a thin wall preserved as a coloured halo, lacking in places. Upward in the same interval, the well developed burrow systems of *Ophiomorpha* are gradually replaced by *Thalassinoides*. However, in the next Unit B, *O. nodosa* is mainly represented by single, well-pelleted shafts, some of them truncated by scour and having lateral limbs (Pl. 10, fig. 2).

***Ophiomorpha annulata* Ksiazkiewicz, 1977**

- 1984 *Ophiomorpha annulata* – Howard & Frey, p. 205, fig. 11A (*cum syn.*).

O. annulata is encountered in Unit E, represented by a few, scattered, small Y-branched shafts, about 5 mm wide, strongly walled with pellets arranged in regular rings. No other trace fossils occur in this unit.

Ichnogenus *Palaeophycus* Hall, 1847

***Palaeophycus tubularis* Hall, 1847**

- 1982 *Palaeophycus tubularis* – Pemberton & Frey p. 856, pl. 1, fig. 1, 2, 5, 6, 8, 10; pl. 2, fig. 1; pl. 3, fig. 3, 6; pl. 4, fig. 5 (*cum syn.*).

Description. Straight to sinuous, thinly lined or apparently unlined endogenic burrows bearing rare, discontinuous, irregular striae which are probably diagenetic. The sparse single burrows, oriented prevalently parallel to or weakly

inclined to the bedding plane, are variable in diameter ranging from 3 to 8 mm. The size is not always constant along the length of the burrow, which in places shows irregular swelling; crossovers and interpenetrations are common. The fillings, essentially structureless, locally reveal faint differences in colour but their lithology seems comparable to the host sediment. Only a covering of red-brown mud drape emphasizes the trace fossils, which are preserved as convex hyporelief and in full relief.

Similar features characterize some associated burrows that can be differentiated exclusively on the basis of their size being less than 1 mm.

Palaeophycus tubularis occurs at bottom of Unit E.

Palaeophycus striatus Hall, 1852

1982 *Palaeophycus striatus* – Pemberton & Frey, p. 861, pl. 1, fig. 3; pl. 4, fig. 2, 3 (*cum syn.*).

Description. Endogenic cylindrical, straight to sinuous thinly lined burrow, ornamented by fine longitudinal parallel striae. This trace fossil, preserved in full relief originating from the bottom of a poorly cemented sand bed, is associated with *Palaeophycus tubularis*.

Ichnogenus *Polykladichnus* Fürsich, 1981

Polykladichnus ichnosp.

Description. Straight to gently curved vertical burrows, constant in diameter (1–2 mm), usually branched in Y-shape at several levels, rarely exhibiting downwards bifurcations. The length is normally 4 to 5 cm, although the maximum observed was 8 cm. A sharp discontinuity separates the muddy filling sediment (greenish in colour) from the surrounding silty-sand reddish substrate.

Observations. The lack of evident lining and the small size differentiate these burrows from type ichnospecies *P. irregularis* Fürsich. Their striking resemblance to feeding structures produced by *Heteromastus filiformis* (Howard & Frey, 1975, fig. 5 A–D, 6 D, E, G) suggests that these burrows were made by an ethologically similar worm.

- 1955 cf. *Rosselia socialis* — Seilacher, p. 389, pl. 23, fig. 8.
 1971 *Rosselia socialis* — Chamberlain, p. 240, pl. 30, fig. 16, 17 (cum syn.).
 1975 *Rosselia* — Häntzschel, p. 101, fig. 63.2
 1984 *Rosselia socialis* — Howard & Frey, p. 209, fig. 18 A–H.
 1984 *Rosselia socialis* — Pemberton & Frey, p. 297, fig. 12A.

Description. Bulbous burrows several cm in diameter, preserved in full relief. The structures, generally oblique to steeply inclined to stratification, are connected by a smooth, thick-walled tube (\cong 1 cm in diameter). The bulbous elements are composed of numerous imbricate laminae, concentric in cross-section, arranged in a spindle shape; the final form is asymmetrical owing to much more rapid tapering of one end, usually the upper one. The laminae are composed of whitish silty lime-mud alternating with yellow silt lithologically comparable to the host deposit. The whitish laminae continue at both ends as a silt-filled tube comprising the thick wall. In section, the fill of the tube appears continuous, passing longitudinally through the bulbous structure more or less at the centre. Rarely, one cylindrical element as it leaves one end divided into two smaller tubes. In most cases, the «bulbs» are isolated or only a few of them appear randomly and as loose clusters; exceptionally they are crowded but a stellate pattern as seen in *Asterosoma*, has not been observed.

Observations. At first sight the trace fossil seems to be comparable with Frey & Howard's «helicoïdal funnel» (1970). Nevertheless the former did not originate as a helicoidally wound tunnel (see *Rosselia* spp. in Frey & Howard, 1982, p. 5; *Rosselia chonoides* Howard & Frey, 1984, p. 208) and the galleries are arranged as a loose boxwork, in contrast to the more vertical shafts of Frey & Howard's material. In addition, the trace fossil differs from *Asterosoma* in lacking the characteristic stellate pattern.

Ichnogenus *Thalassinoides* Ehrenberg, 1940

Thalassinoides suevicus (Rieth, 1932)

Pl. 13, fig. 1

1984 *Thalassinoides suevicus* — Howard & Frey, p. 213, fig. 24 (cum syn.).

Description. *Thalassinoides suevicus* occurs as boxwork systems comprising unlined, cylindrical elements of constant diameter except at branching points, which are weakly enlarged. Branching is dichotomous. In Unit 1 (section 1) the horizontal or subhorizontal elements are prevalent, but subvertical elements are not uncommon. The horizontal elements are noticeably curved within the horizontal plane, and tunnels anastomose to produce a large, open, irregularly oval network. At section 2, *T. suevicus* occurs as well developed boxworks in fine to medium sand of Unit A and B.

Thalassinoides ichnosp.

Description. This burrow-system is smaller than *T. suevicus*. The tunnels have short internodal distances and variable diameter at swollen forking points. The preserved apertural necks terminate the vertical shaft, which are about 10 cm deep.

Thalassinoides ichnosp. occurs in Unit 4.

Equilibrium structures

Pl. 13, fig. 1; Pl. 14, fig. 2

1975 *Conostichus* Boyer & Warne (non Lesquereux), p. 85, fig. 8D.

Description. Vertical unwallled, subcylindrical burrow approximately 2–3 cm wide and up to 18 cm long, truncated by penecontemporaneous erosion; lower termination hemispherical. In axial section, the fill of some structures appears to contain successive terminations (menisci) following vertically above each other, the diameter weakly enlarged in correspondence to the lower rounded ends. Other examples have a simple U-shaped section. Normally the marked contrast in colour (red–brown) enhances the internal menisci and the sharp boundary between fill and surrounding sediment, which are similar in lithology. Only one specimen is associated with a *Thalassinoides suevicus* boxwork, which the equilibrium structure postdates, and is rendered visible by slight cementation of the laminae (Pl. 13, fig. 1).

Observations. These numerous trace fossils can be interpreted as equilibrium structures *sensu* Frey & Pemberton (1985, pp. 85–86), produced by vertical movements of animals, probably burrowing sea anemones, in response to minor depositional or erosional events. The simple cylindrical burrows are considered to represent a deepening phase (protrusive), the more complex forms, an upward migration (retrusive). The two kinds of structures occur exclusively at two different levels of cross-bedded sand (Unit D) and suggest that each represents the record of a single episodic population of gregarious suspension-feeders, the one adjusting its position upwards, the other downwards.

Among conical ichnogenera, *Conostichus* Lesquereux is ornamented, unlike the *Gravina* trace fossils, and both *Conostichus* and *Conichus* Myannil are more conical.

Domichnia of *Panopea glycymeris* (Born)

Description. The large body fossils of *P. glycymeris* are in life position in Unit 1 (section 1), preserved as empty moulds after dissolution of the shell material. These moulds occur in concentrations of coarse sand which make them conspicuous in the surrounding silty, fine sand, and represent a thin bur-

row fill outside the *Panopea* shell, and conforming to its shape. Above this, no traces have been seen representing activity or positioning of the siphons of this deeply burrowing mollusc. At Cerignola (Foggia), in lower Pleistocene silt, a similar situation occurs with different preservation. Here the shells of the *Panopea* are preserved, and the burrow fill, in the absence of coarse sand, consists of shell fragments. The reasons for the concentration of coarser material within the *Panopea* burrows are not understood. In the Mediterranean, *P. glycymeris* lives in littoral sand and mud (Ghisotti & Steinmann, 1969).

Meniscate trace fossils

Pl. 11, fig. 3; Pl. 14, fig. 1

Description. Endogenic meniscus backfilled echinoid repichnia, gently winding, lying parallel/sub-parallel to bedding. Generally the burrows, about 3 cm wide, have a circular cross-section; in a few longitudinal sections the menisci appear bilobed (Pl. 14, fig. 1).

Observations. Commonly these traces occur in three situations: 1) within the rare mud lenses included in large-scale cross-bedded sand (Unit B); 2) in clayey lenticles and in the overlying sand bed (Unit C) which, as in the lenticles of Unit B has been intensely bioturbated by echinoids throughout. In the mud and clayey sediments the burrows are revealed by faint contrast in colour, whereas in the poorly cemented sand they remain almost invisible except on the top-surface, where the menisci have been emphasized by a differential covering by a lime mud drape; 3) extremely rarely, this structure has also been seen on the sole of a thin sandy bed together with several *Palaeophycus* (Unit E).

The ridges, strings or grooves below or within the meniscate backfill that are characteristic of *Scolicia*, are not apparent and so it is uncertain whether this echinoid burrow should be referred to *Taenidium* (D'Alessandro & Bromley, in press) or to *Scolicia*. One specimen of *Schizaster canaliferus*, complete with spines, was found at the end of its burrow in a mud lens; this discovery indicates that animals belonging to this taxon were the trace makers. *Schizaster canaliferus*, endemic species in the Mediterranean, burrows in sand and mud bottoms ranging from a few metres to about 100 m deep. It is a characteristic element of the muddy bottom biocoenosis that largely occurs in the Adriatic Sea, 5–60 m deep, typically associated with *Amphiura chiajei* (Vatova, 1949). This biocoenosis corresponds to the Danish Skaggerak and Kattegat *Brissopsis*–*A. chiajei* community (Tortonese, 1965).

Rhizoliths

Pl. 15, fig. 1

Description. Sparse, irregularly orientated, tending to the vertical, biogenic

structure (5 to 15 mm in diameter and up to 40 mm in length), faintly tapering downward (Pl. 15, fig. 1), the fills composed of poorly sorted uncemented silt to fine-grained sand and lined by a rough whitish «wall» of lime-sand and isolated micritic grains. Small protuberances, presumably rootlets, diverge from the rough external surface.

Acknowledgments.

We thank Prof. I. Di Geronimo, University of Catania, as well as Prof. N. Walsh, University of Bari who first pointed out the trace fossils; we are grateful to Dr. M. Caldara for his help in collecting the specimens.

REFERENCES

- Azzaroli A., Perno U. & Radina B. (1968) - Note illustrative della Carta Geologica d'Italia, F° 188 «Gravina in Puglia». *Servizio Geologico*, Roma.
- Boyer J.E. & Warme J.E. (1975) - Sedimentary facies and trace fossils in the Eocene Dalmar Formation and Torrey sandstone, California. In Weaver D.W., Hornaday G.R. & Tipton A. (Eds.) - «Future Energy Horizons of the Pacific Coast». Paleogene Symposium and Selected Technical Papers. *AAPG-SEPM-SEG, Pacific sections*, pp. 65-98, Long Beach, California.
- Caldara M., D'Alessandro A. & Loiacono F. (in prep.) - Regressive Pleistocene sequence near Gravina in Puglia, Southern Italy: sedimentological and palaeoecological analyses.
- Chamberlain C.K. (1971) - Morphology and ethology of trace fossils from the Ouachita Mountains, Southeast Oklahoma *Journ. Paleont.*, v. 45, pp. 212-246, Tulsa.
- Dahmer G. (1937) - Lebensspuren aus dem Taunusquarzit und den Siegener Schichten (Unterdevon). *Preuss. Geol. Landes., Jahrb.* 1936, v. 57, pp. 523-539, Berlin.
- D'Alessandro A. & Bromley R.G. (in press) - Meniscate trace fossils: the *Muensteria-Taenidium* problem. *Palaeontology*.
- D'Alessandro A. & Iannone A. (1982) - Pleistocene carbonate deposits in the area of Monopoli (Bari Province): Sedimentology and Palaeoecology. *Geol. Romana*, v. 21, pp. 603-653, Roma.
- Desio A. (1940) - Vestigia problematiche paleozoiche della Libia. *Ann. Museo Libico St. Nat.*, v. 2, pp. 47-92, 13 pl., Milano.
- Di Geronimo I. (1984) - Stabilité des peuplements benthiques et stabilité des bassins sédimentaires. *Géobios*, Mém. spécial n. 8, pp. 145-150, Lyon.
- Frey R.W. & Howard J.D. (1970) - Comparison of Upper Cretaceous ichnofaunas from siliceous sandstones and chalk, Western Interior Region, U.S.A. In Crimes T.P. & Harper J.P. (Eds.) - «Trace fossils». *Geol. Journ.*, spec. iss. 3, pp. 141-166, Liverpool.
- Frey R.W. & Howard J.D. (1982) - Trace fossils from the Upper Cretaceous of Western interior: potential criteria for facies models. *The Mountain Geologist*, v. 19, pp. 1-10.

- Frey R.W., Howard J.D. & Pryor W.A. (1978) - *Ophiomorpha*: its morphologic, taxonomic and environmental significance. *Palaeogeogr. Palaeoclim. Palaeoecol.*, v. 23, pp. 199–229, 14 fig., Amsterdam.
- Frey R.W. & Pemberton S.G. (1985) - Biogenic structures in outcrops and cores. I. Approaches to ichnology. *Bull. Canadian Soc. Petrol. Geol.*, v. 33, pp. 72–115, Ottawa.
- Fürsich F.T. (1984) - Palaeoecology of boreal invertebrate fauna, from the Upper Jurassic of Central East Greenland. *Palaeogeogr. Palaeoclim. Palaeoecol.*, v. 48, pp. 309–364, 25 fig., Amsterdam.
- Fürsich F.T. & Bromley R.G. (1985) - Behavioural interpretation of a rosetted spreite trace fossil: *Dactyloidites otto* (Geinitz). *Lethaia*, v. 18, pp. 199–207, Oslo.
- Ghisotti F. & Steinmann E. (1969) - Schede malacologiche del Mediterraneo. *Panopea glycymeris* (Born, 1778). *Soc. Mal. It.*, 4 pp., Como.
- Häntzschel W. (1975) - Trace fossils and Problematica. In Teichert C. (Ed.) - Treatise on Invertebrate Paleontology. Part W, suppl. 1. *Geol. Soc. America Univ. Kansas*, 269 pp., Lawrence, Kansas.
- Hall J. (1847) - Palaeontology of New York. V. 1, 338 pp., C. Van Benthuyzen, Albany, N.Y.
- Hall J. (1852) - Palaeontology of New York. V. 2, 362 pp., C. Van Benthuyzen, Albany, N.Y.
- Hall J. (1886) - Note on some obscure organism in the roofing slate of Washington County, New York. *Trustees New York State Mus. Nat. Hist.*, 39th Ann. Rept., v. 160, 11 pl.
- Howard J.D. & Frey R.W. (1975) - Estuaries of Georgia Coast. U.S.A.: Sedimentology and Biology. II. Regional Animal–Sediment Characteristics of Georgia Estuaries. *Senckenb. Marit.*, v. 7, pp. 33–103, 14 pl., Frankfurt a M.
- Howard J.D. & Frey R.W. (1984) - Characteristic trace fossils in nearshore to foreshore sequences, Upper Cretaceous of East–Central Utah. *Canadian Jour. Earth Sc.*, v. 21, pp. 200–219, Ottawa.
- Pemberton S.G. & Frey R.W. (1982) - Trace fossil nomenclature and the *Planolites*–*Palaeophycus* dilemma. *Journ. Paleont.*, v. 56, pp. 843–881, Tulsa.
- Pemberton S.G. & Frey R.W. (1984) - Ichnology of storm–influenced shallow marine sequence: *Cardium* Formation (Upper Cretaceous) at Seebe, Alberta. *Canadian Soc. Petrol. Geol.*, Mem. 9, pp. 281–304, Ottawa.
- Péres J.M. & Picard J. (1964) - Nouveau manuel de biologie benthique de la Mer Méditerranée. *Bull. Réc. Trav. Stat. Mar. Endoume*, v. 31, 137 pp., Marseille.
- Picard J. (1965) - Recherches qualitatives sur les biocoenoses marines des substrates meubles dragables de la région marseillaise. *Bull. Réc. Trav. Stat. Mar. Endoume*, v. 36, 160 pp., Marseille.
- Rieth A. (1932) - Neue Funde spongeliomorpher Fucoiden aus dem Jura Schwabens. *Geol. Palaeont. Abhandl.*, N.S., v. 19, pp. 257–294, Jena.
- Seilacher A. (1955) - Spuren und Fazies im Unterkambrium. In Schindewolf O.H. & Seilacher A. - Beiträge zur Kenntnis des Kambriums in der Salt Range (Pakistan). *Akad. Wiss. Lit. Mainz., Math. Nat. Kl., Abhandl.*, n. 10, pp. 117–143, 6 pl., 6 fig., Wiesbaden.
- Tortonese E. (1965) - Echinodermata. V. of 413 pp., Ed. Calderini, Bologna.
- Vatova A. (1949) - La fauna bentonica dell'alto e medio Adriatico. *Nova Thalassia*, v. 1, 110 pp., Venezia.

PLATE 9

Fig. 1 — *Ophiomorpha nodosa* Lundgren. Top view of cross-cutting maze systems in the lowermost part of Unit A; ring for scale.

Fig. 2 — *Ophiomorpha nodosa* systems having strongly developed walls in Unit A; x 0.75.



PLATE 10

Fig. 1 — *Cylindrichnus concentricus* Toots in Howard. Externally showing faint xenoglyph of bedding lamination. Unit B.

Fig. 2 — *Ophiomorpha nodosa* shaft having lateral limb. Unit B.

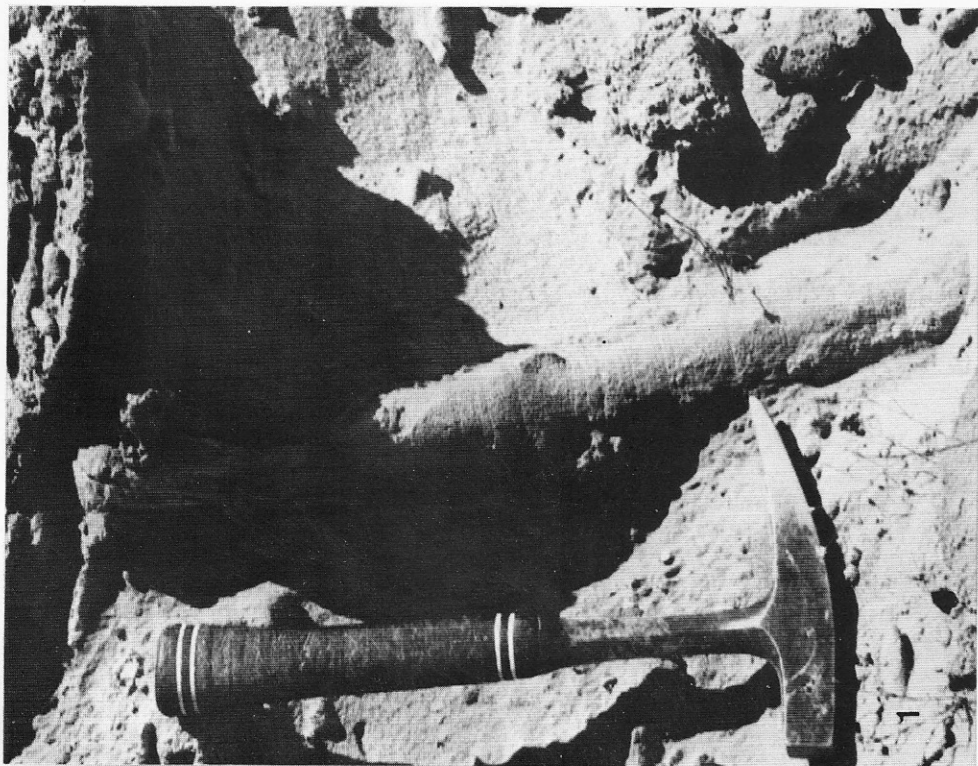
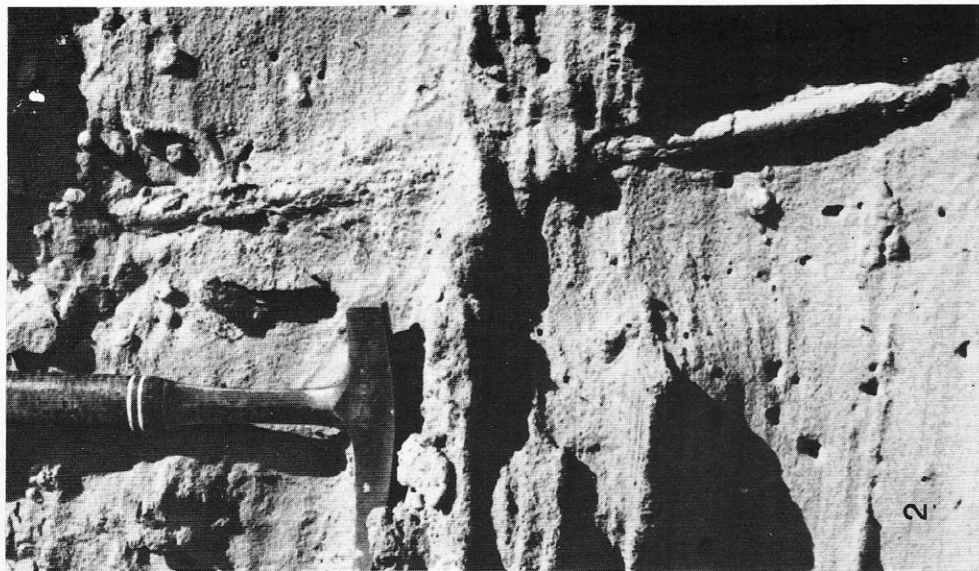


PLATE 11

- Fig. 1 — *Cylindrichnus errans* ichnosp. n. Vertical section; Unit B, Notargiacomo's Quarry; x 0.35.
- Fig. 2 — *Rosselia socialis* Dahmer. Bulbous element; Lama La Noce, Unit 2; no. DGGB 101; x 0.73.
- Fig. 3 — *Schizaster canaliferus* specimen (arrow) at the end of its meniscate trace fossil; x 0.5.
- Fig. 4 — *Cylindrichnus errans* ichnosp. n. Trace fossil from Pleistocene biocalcarenite. West of Catania. Coin diameter = 24 mm. Note vertical development and transversal section.

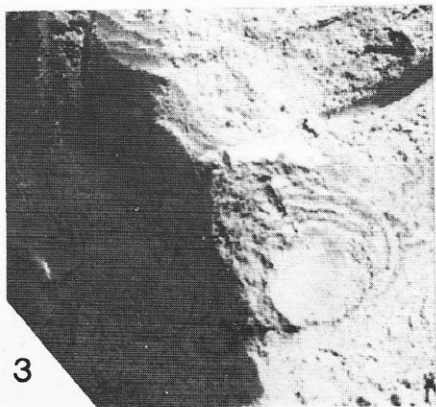
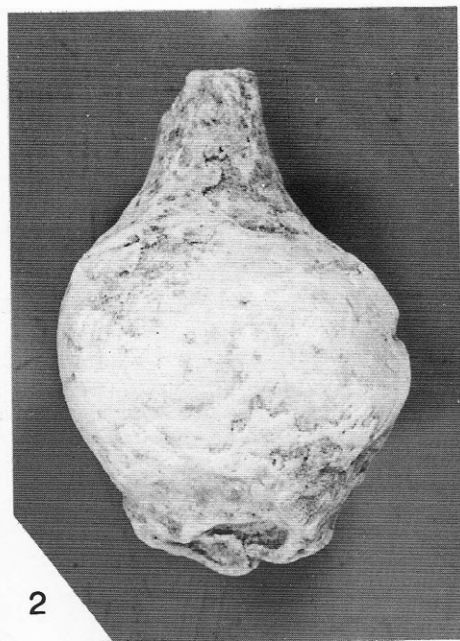
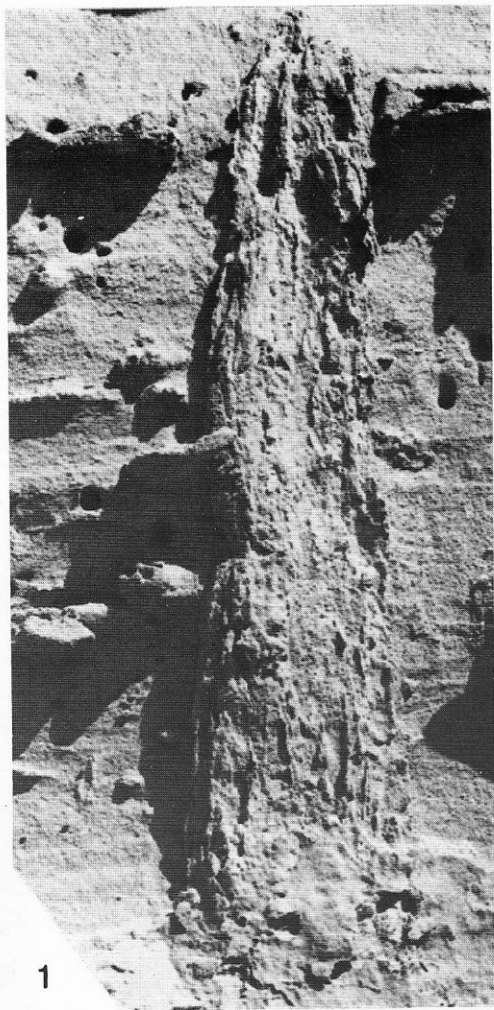


PLATE 12

- Fig. 1 – *Cylindrichnus errans* ichnosp. n. Transversal section; Cala Corvino, Monopoli; x 0.5.
- Fig. 2 – *Cylindrichnus errans* ichnosp. n. Cala Corvino, Monopoli. Max length 80 cm.
- Fig. 3 – *Dactyloidites peniculus* ichnosp. n. Holotype no. DGGB 102, Notargiacomo's Quarry, Pleistocene. In bottom view; x 0.4;
- Fig. 4 – *Ophiomorpha nodosa* fill. Unit A. Finger ring for scale.

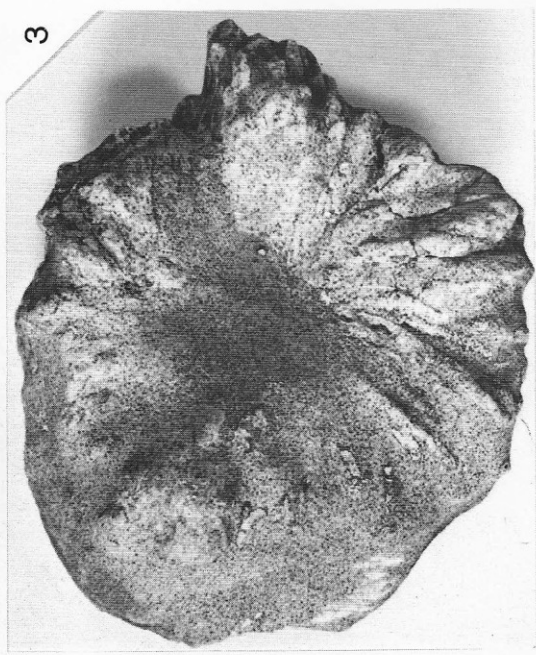
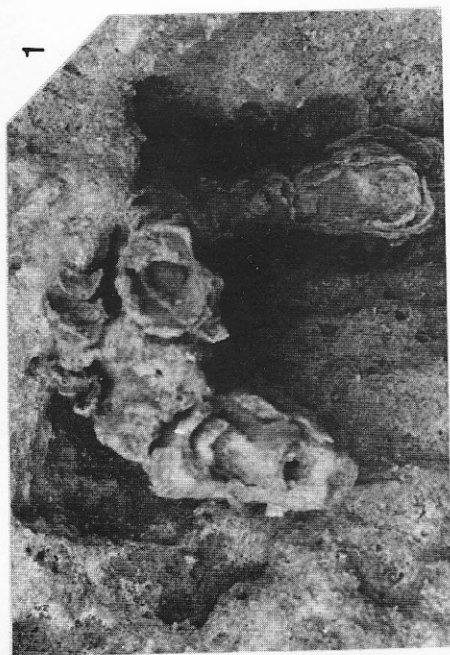
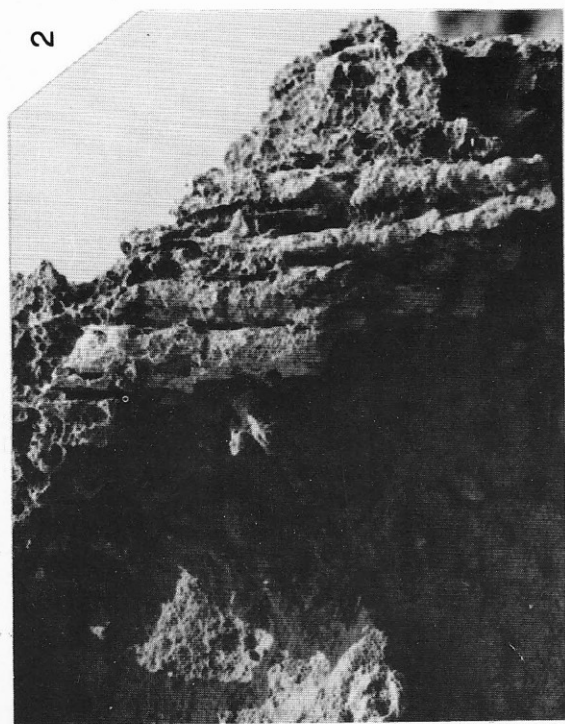


PLATE 13

- Fig. 1 — Equilibrium trace postdating *Thalassinoides suevicus* (Rieth) boxwork. Vertical section; Notargiacomo's Quarry; x 0.35.
- Fig. 2 — *Rosselia socialis* Dahmer. Bulbous element showing the imbricate laminae; Lama La Noce, Unit 2; no. DGGB 105; x 0.7.
- Fig. 3 — *Dactyloidites peniculus* ichnosp. n. Holotype no. DGGB 102. In top view. Notargiacomo's Quarry; x 0.4.

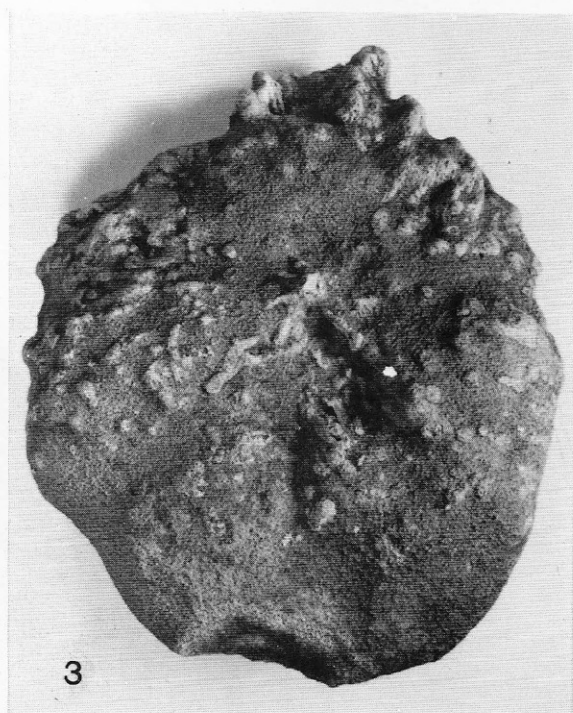
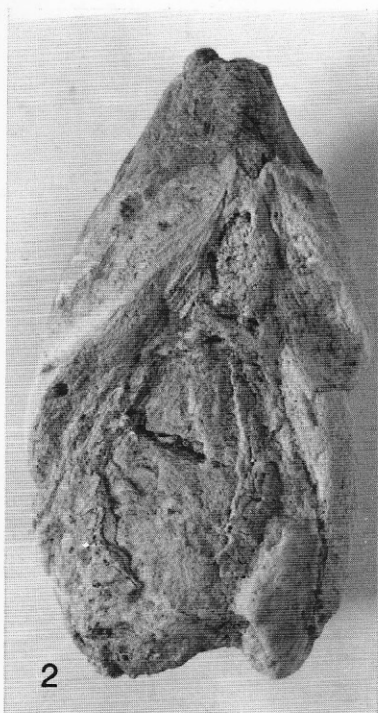


PLATE 14

Fig. 1 — Meniscate trace fossils bilobed at centre. Sole of sandy bed (Unit C). Natural size.

Fig. 2 — Vertical equilibrium structures in Unit D.

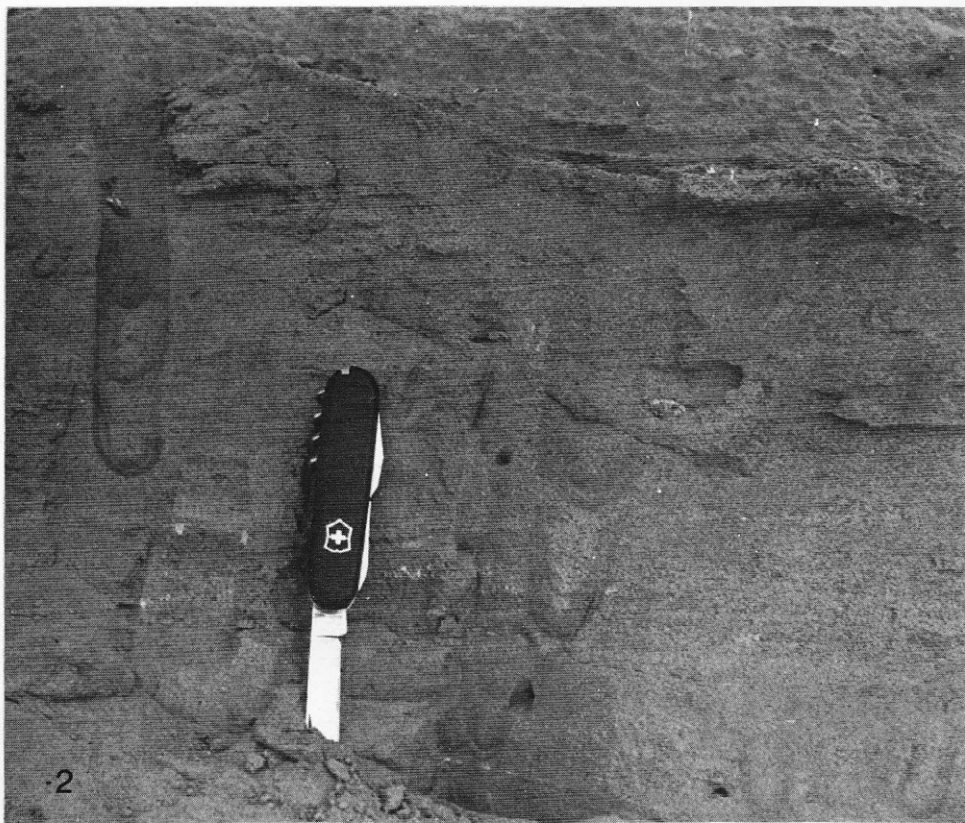
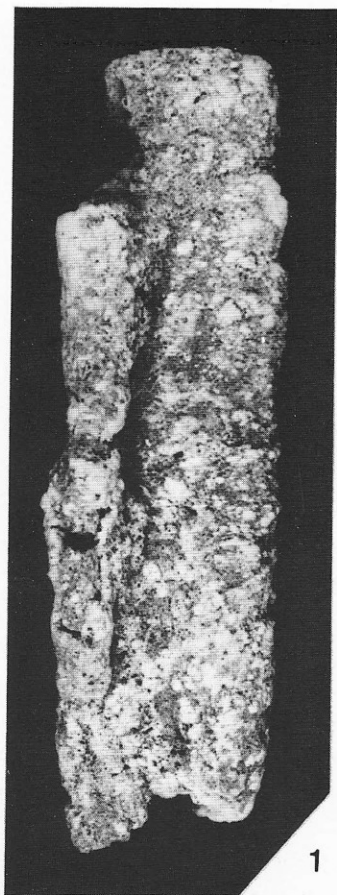
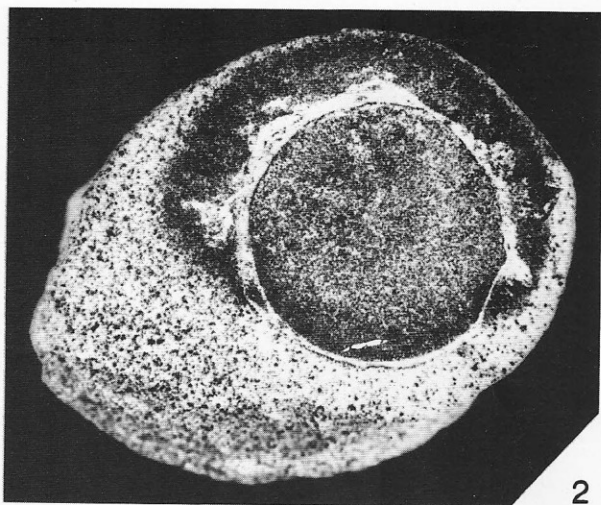


PLATE 15

- Fig. 1 – Rhizoliths in the topmost part of Unit E; no. DGGB 106. Natural size.
- Fig. 2 – *Cylindrichnus concentricus* Toots in Howard. Transversal section. Yellow laminae send small extensions into the brown wall; no. DGGB 107. Natural size.
- Fig. 3 – *Cylindrichnus errans* ichnosp. n. Transversal section. Holotype no. DGGB 108, Cala Corvino (Monopoli), lower Pleistocene. Natural size.
- Fig. 4 – *Cylindrichnus errans* ichnosp. n. Transversal section; no. DGGB 111. Notargiacomo's Quarry. Natural size.
- Fig. 5 – *Ophiomorpha nodosa* Lundgren. Systems having large swellings. Unit A.



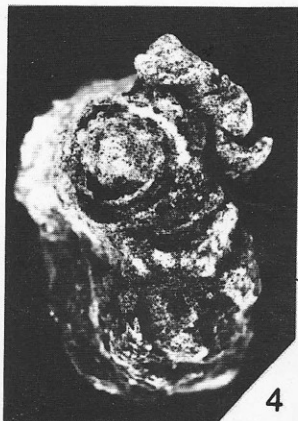
1



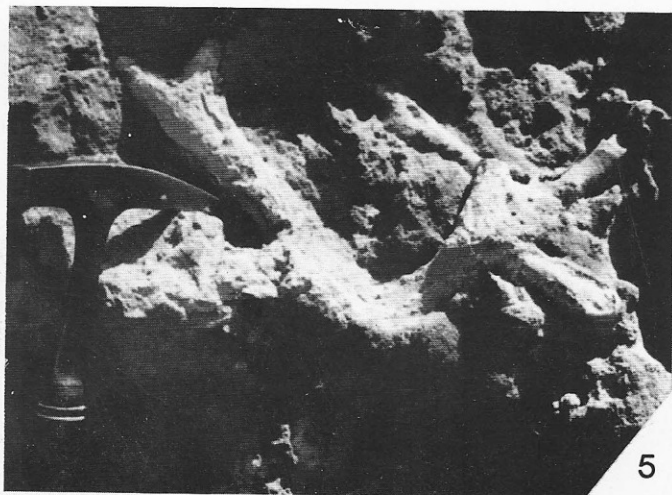
2



3



4



5