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Pp. 125–167; 9 *Plates*; 7 *Text-figures*

BULLETIN OF
THE BRITISH MUSEUM (NATURAL HISTORY)
GEOLOGY Vol. 15 No. 3
LONDON: 1967

THE BULLETIN OF THE BRITISH MUSEUM (NATURAL HISTORY), *instituted in* 1949, *is issued in five series corresponding to the Departments of the Museum, and an Historical series.*

Parts will appear at irregular intervals as they become ready. Volumes will contain about three or four hundred pages, and will not necessarily be completed within one calendar year.

In 1965 *a separate supplementary series of longer papers was instituted, numbered serially for each Department.*

This paper is Vol. 15, *No.* 3 *of the Geological (Palaeontological) series. The abbreviated titles of periodicals cited follow those of the World List of Scientific Periodicals.*

World List abbreviation :
Bull. Br. Mus. nat. Hist. (Geol.).

TRUSTEES OF
THE BRITISH MUSEUM (NATURAL HISTORY)

Issued 24 *November,* 1967 *Price* £2 2s.

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CONTENTS

SYNOPSIS

The Lower Chalk of Southern England comprises between 17 and 80 m. of rhythmic alternations of more or less calcareous marly chalk. The whole sequence is intensely burrowed, the following burrow types are named: *Thalassinoides saxonicus* (Geinitz), *T.* cf. *suevicus* (Rieth), *T. ornatus* ichnosp. nov., *T. paradoxica* (Woodward), *Spongeliomorpha* sp., *Spongeliomorpha? annulatum* ichnosp. nov. and *Chondrites* sp. Several other forms are discussed, including " *Terebella* " *cancellata* Bather and *Keckia* (?) sp. Five burrow types too poor for detailed description are noted and discussed. Two other trace-fossils, " laminated structures ", regarded as related to *T. saxonicus* and *Pseudobilobites jefferiesi* ichnosp. nov. (the " problematicum " of Jefferies (1961, 1963)) are also described.

The Eocene form " *Terebella* " *harefieldensis* White is briefly discussed and interpreted as a crustacean boring. *Thalassinoides, Spongeliomorpha* " laminated structures ", *Pseudobilobites,* " *Terebella* " *cancellata* and two of the un-named burrows are regarded as the product of crustaceans, *Chondrites* and the other un-named burrows are attributed to " worms ".

Other trace fossils—borings and micro-coprolites-are also noted.

I. INTRODUCTION

(a) General Features. The Lower Chalk of Southern England comprises between 17 and 80 m. of marly blue or buff chalk, ranging in age from Lower to Upper Cenomanian. The present account is based chiefly on exposures along the North and South Downs, the Chilterns and the Isle of Wight, although sections to the north, at Hunstanton (Norfolk) and south-west (Dorset, Somerset and Devon) have also been examined.

Apart from the valuable coastal exposures, there are useful working sections around Lewes (Sussex), Burham and Holborough in the Medway Valley (Kent) and in the large pits at Barrington (Cambridgeshire), Houghton Regis and Totternhoe (Bedfordshire), Pitstone (Buckinghamshire), Chinnor and Childrey (Oxfordshire).

By far the best general account of the formation is still that given by Jukes-Browne (1903), whilst a brief outline of some of the depositional and post-depositional features has been given elsewhere (Kennedy, 1967).

In the Weald, Hampshire and the Chilterns, the base of the formation is generally marked by a sharp lithological break and a line of piping, the basal Glauconitic Marl being let down into the Gault or Upper Greensand below, generally without signs of marked erosion, and with occasional indications of continuous deposition from the Albian below. The basal few feet, rich in glauconite and phosphates, clearly indicates slow deposition; similar features appear occasionally in the lower part of the Chalk Marl above, as at Eastbourne (Sussex) and in the Isle of Wight. Above, the whole thickness can be interpreted as a sequence of rhythmic alternations of more and less calcareous (or marly) chalks, with carbonate contents varying between approximately 40 % at the base, increasing upwards to 90–95 % at the top of the Lower Chalk. Insoluble residue determinations suggest that these rhythms are visible when the difference in carbonate content is as low as 4–5 %.

There is much variation in thickness of the " limestone " and " marl " members of rhythms, although in a general way, in the lower part the " marls " are 45–60 cm. thick, the " limestones " 15–30 cm. thick. In the middle part the alternations are 15–30 cm. thick, whilst in the upper part, there is great variation, made difficult to interpret by the low mud content which renders the alternations only faintly discernible. A general, although not invariable feature of these rhythms is that the " marl " to " limestone " contact is transitional, whilst the contact at the base of the marls is very sharp.

The following features indicate that the alternations are, at least in part, primary:

(i) The piping of " marls " into " limestones " and vice-versa, in a wide variety of burrows.

(ii) The occurrence of " limestone " pebbles, phosphatized, glauconitized and otherwise, in " marls ".

(iii) The cutting of " marl "–" limestone " junctions by erosion hollows.

Evidence of secondary segregation is suggested by the nodular appearance of some " limestones " and the occurrence of calcareous concretions in some of the " marls ". In addition, sponges, ammonites and other fossils in " limestones " are often undistorted whilst the same forms are crushed flat in " marls ", suggesting the pre-compactional deposition of carbonate in the more calcareous parts of rhythms.

The upper limit of the Lower Chalk in this region is marked by a sharp change in lithology at the base of the *plenus* Marls, associated in some areas with obvious signs of erosion, the sub-*plenus* erosion surface of Jefferies (1962, 1963).

Traced northwards, the Lower Chalk loses these features, thins considerably and in Norfolk at Hunstanton is clearly condensed, with signs of erosion at many levels. It rests, with a sharp break and obvious signs of erosion on the Red Chalk (Albian). The Chalk here is hard, and as pointed out by Peake & Hancock (1961) probably winnowed. These features, and a similar thinning and condensation in the underlying Albian suggest the presence of a stable massif in this region during part, at least, of the Cretaceous. The influence of this massif may, in part be responsible for the development, in the Chilterns and northwards, of the " gritty " phosphatic Totternhoe Stone (Middle Cenomanian).

Traced westwards, the Lower Chalk maintains its general features to the western limits of outcrop at Membury (S. Devon), where rhythms are still present in the chalky part of the sequence. Faunal evidence indicates that the base of the Chalk is diachronous in the south-west.

(b) THE CHALK. The general composition of the Chalk was first noted by Ehrenberg (Sorby 1861) and later by Sorby (1861), Hume (1893) and Jukes-Browne & Hill (1903, 1904). More recently Black (1953), Black & Barnes (1959) and Hancock (1963) have given additional information. The carbonate portion of the Chalk is now wholly calcite, and it is generally accepted that most was deposited as such, and that it is wholly biogenic in origin. The finer fractions are largely composed of coccoliths, both whole and fragmentary, whilst the coarser fractions consist of *Oligostegina*, foraminifera, sponge fragments, the broken-down prismatic layers of *Inoceramus* and echinoderm debris. Abundance of the latter gives rise to the " gritty " chalks such as the Totternhoe Stone and Melbourn Rock. The insoluble fraction, discussed previously by Hume (1893) and Hill (1903, 1904) includes, in addition to the clay fraction, detrital silt and sand grade quartz as the most obvious mineral, accompanied by authigenic glauconite, collophane and feldspar.

(c) BOTTOM CONDITIONS. Current activity is indicated by the presence at many levels of winnowed chalks and rolled, glauconitized and phosphatized pebbles and fossils. The body chambers of large ammonites are often full of small fossils, including ammonites up to 10 cm. in diameter, presumably swept in by bottom currents. Fragmentation of *Inoceramus* shells and echinoid tests may be due to current activity.

Intraformational conglomerates suggest local erosion, as do what appear to be large scour hollows, sometimes associated with large ammonites (Kennedy, 1967).

The presence of burrowing bivalves such as *Pholadomya*, *Cucullaea*, and *Panopea* suggest soft bottoms, as does the presence of *Teredina amphisbaena* (Goldfuss), a form which I have never seen associated with wood (although *Teredo* bored wood occurs). Like the recent *Teredo* (*Furcella*) *polythalamia* (Linné) (Oosting 1925) this form appears to have lived in mud. Although soft, the bottoms must have been in the form of a stiff mud, since the small solitary corals and serpulids which are so common would not survive in a fluid mud, nor would larger epifaunal forms such as the limid and pectinid bivalves and *Inoceramus*, the latter possibly byssally attached to the sea floor. Equally, the lobster-like crustacean *Enoploclytia* presumably needed a firm bottom to walk across. Intense burrowing suggests bottoms rich in organic debris.

There is little evidence of rock bottoms (hardgrounds) in the Lower Chalk, erosion surfaces, when they occur, lacking the epifauna of bryozoa, serpulids and cemented bivalves present on the Chalk Rock hardgrounds. Borings in, and epifaunas on, the phosphatized top of the Upper Greensand in the south-west indicate hard bottoms here at least.

(d) DEPTH OF DEPOSITION. The abundance of coccoliths suggests deposition below the upper limit of present day coccolith abundance (60 m.): study of the sponges indicates a depth of 280 m. (Cayeux 1897: Turonian–Senonian) or 300 m. (Gignoux 1926: Campanian). Since it is generally agreed that the Chalk Marl, like the Chalk Rock (U. Turonian) represents shallower conditions than the rest of the Chalk (Jukes-Browne & Hill 1904), a depth lower than the maximum is implied for this part of the Lower Chalk. Burnaby (1962) has discussed depth variation in the Lower Chalk sea, on the basis of the foraminifera.

II. THE TRACE FOSSILS

Two types of trace fossil are described from the Lower Chalk; burrows and surface traces. Of these, burrows are by far the most important, and are one of the most prominent features of the sediment (Pls. 1, 2).

(a) Burrows. In modern marine environments a great variety of organisms utilize the region below the sediment–water interface for refuge, nourishment and habitation. Arthropods, echinoderms, molluscs, coelenterates, many groups of worms (particularly annelids) are amongst the most important groups of invertebrates, whilst many higher animals burrow. In addition, the interstitial fluid between sedimentary particles supports a large fauna and flora (Purdy, 1964). Particles of sediment themselves have a coating of bacteria, utilized by detritus feeders; total content increasing as particle sizes decrease (Newell 1965).

The influence of these organisms on the sediment is considerable. Davidson (1891) described the activities of lobworms in the Holy Island Sands, between Holy Island and the Northumberland coast, suggesting nearly two thousand tons of sand was ingested per acre per annum, and that the top 60 cm. of sediment passed through the worms' bodies every 22 months. Taylor (1964) quotes data suggesting 80–90% of the sands in the Bermudas is made up of ground shell matter that has passed through the intestinal tracts of echinoderms. Both indicate the importance of biological destruction of sedimentary structures. Local topography can be influenced by burrowing organisms; the hummocky bottom topography of the Bahaman platforms is attributed to organic activity (Taylor 1964), whilst erosion of callianassid burrows produces the characteristic sand-pipe topography of some intertidal regions (Weimer & Hoyt 1964). Many of the problematic mounds and depressions seen in deep-sea photographs are probably organic in origin.

Many burrows are lined with mucus, whilst *Callianassa major* Say lines its burrow with collophane-cemented sand pellets (Weimer & Hoyt 1964). Many sediment eaters form durable faecal pellets (Moore 1939). These features indicate the importance of burrowing organisms in stabilization and aggregation of sediments.

Taylor (1964) has pointed out the chemical effects of bottom dwelling organisms on both Eh and pH, particularly where the release of organic and inorganic acids is concerned, suggesting great importance in diagenesis at the early burial stage.

Burrowers are also responsible for the creation of refuges for many commensals. The burrow of the worm *Urechis*, for instance, is inhabited by a gobie, polynoid worm and pinnotherid crab (Fisher & MacGinitie 1928). Dales (1957) gives details of similar associations in other burrowing organisms.

(b) Burrows in the Lower Chalk. The whole of the Lower Chalk studied is intensely burrowed (Pl. 2, figs. 2–4), often many times over (Pl. 2, fig. 4). In general, these structures can be studied in section only, in the form of sedimentary mottling.

Only rarely can the pattern and form of systems be made out. Burrowing, often equally intense to that in the Lower Chalk, can be seen, in suitable lithologies, in the overlying Middle and Upper Chalk.

Simpson (1957), Häntzschel (1962) and Seilacher (1964) have discussed the various conditions of preservation of trace fossils; in the Lower Chalk the following modes of preservation of burrows can be distinguished:

(i) Differences in composition and colour of burrow filling and matrix.
(ii) Pyritization (an example of a pyritized burrow, overgrown by a pyrite nodule was figured by Mantell (1822, pl. 16, fig. 16)).
(iii) Coating of the outer surface of the burrow by iron sulphide (often altered to Limonite), perhaps influenced by the former presence of a mucus lining.

Burrowing in the English chalk has been mentioned only briefly by previous authors, generally as " mottling " or " piping ", or by reference to them as sponges (Webster 1814) or " Zoophytes " (Taylor 1823). More recently, Wood (1965), discussing the Lower Chalk at Dover, mentions " extensive reworking " by " bottom living organisms, the infilling of the burrow traces being a lighter colour than the main mass of the sediment ".

The only previous work on trace-fossils from the Lower Chalk is that of Davies (1879) and Bather (1911). The terebellids described by these authors are, in part, burrows, whilst the latter described a single fragment referred to as *Keckia* (?) sp.

III. LOCATION OF SPECIMENS

The author's collection and the types of " *Terebella* " *cancellata* Bather and " *T.*" *harefieldensis* White are in the collections of the British Museum (Natural History), Dr. R. P. S. Jefferies' collection is in the Sedgwick Museum, Cambridge. These are abbreviated to B.M. (N.H.), and S.M.C. respectively in the following account.

IV. SYSTEMATIC DESCRIPTIONS

Ichnogenus *THALASSINOIDES* Ehrenberg 1944

Type species. By the original designation of Ehrenberg (1944) *Thalassinoides callianassae* Ehrenberg, from the Miocene (Burdigalian) of Burgschleinitz, Eggenberg, Austria.

Discussion. This trace fossil genus was erected for a ramifying system of cylindrical burrows from Miocene sands, intimately associated with, and probably formed by crustaceans (identified as *Callianassa* sp.) described by Ehrenberg six years previously (1938). The original diagnosis is as follows: " Die Gattung „*Thalassinoides* " wäre wie folgt zu kennzeichnen: Gänge und Gangsysteme oder bzw. deren Ausfüllungen (Kerne) mit mehr oder weniger Y-förmigen Gabelungen oder Verzweigungen, meist ohne wesentliche Oberflächenskulpturen: sonstige Form und Durchmesser merklich wechselnd.

"Typus-„ Art " Th. *callianassae* mit den Charakteren der „ Gattung " aus dem Burdigal von Burgschleinitz bei Eggenberg. N : D. Typusexemplar das im Paläontolog. u. Paläobiolog. Institut der Universitat Wien verwahrte Urstück zu Ehrenberg 1938 Tafel 28,5."

A brief diagnosis in English has been given by Häntzschel (1962). On the basis of the present material it may be emended as follows:

Extensive burrow systems with both vertical and horizontal elements. Burrows cylindrical, between 2 and 20 cm. in diameter. Branching regular, characterized by Y-shaped bifurcations, swollen at point of branching. Horizontal elements joining to form polygons. Burrow dimensions variable within a system. Horizontal systems connecting to surface by vertical or steeply inclined shafts, widely associated with callianassid remains.

Häntzschel (1962, 1965) regards *Vomacispongites* de Laubenfels (1955 : 108) as a synonym of *Thalassinoides*. *Vomacispongites* was introduced by de Laubenfels as an " unrecognizable supposed sponge ", as follows:

" *Vomacispongites* de Laub. nom. nov. (pro *Spongites* Schloth. 1820 (non. Oken 1814)) ", the type species is *Spongites pertusus* Schlotheim (1820 : 369) based on a specimen from a Cretaceous chert from Amberg (W. Germany), compared by von Schlotheim to *Spongia pertusa* Esper (Esper 1799 : 246–7, pl. 26, figs. 1, 2). Esper's figure is clearly a sponge, and I can only presume that Häntzschel has examined the original specimen, since the original description does not suggest a *Thalassinoides*. The genus *Aschemonia* Dettmer (1914) is too poorly defined for comparison, but may well be a *Thalassinoides*.

In addition to the association of *Thalassinoides* with *Callianassa* sp. recorded by Ehrenberg (1938), Glaessner (1947) describes what are clearly *Thalassinoides* in association with callianassids from the Eocene of Victoria (Australia), whilst Mertin (1941) records *Protocallianassa* in association with what are probably *Thalassinoides* in the Upper Cretaceous of Germany. Häntzschel (1965), Seilacher (1955, 1964), Farrow (1966) and Hallam (1961) all regard *Thalassinoides* as a crustacean burrow.

Thalassinoides is very widespread, and has been recorded from the Trias (Reis 1910, Fiege 1944), Lias (Rieth 1932, Seilacher 1955, Hallam 1961), Oxfordian (Wilson 1949), Portlandian (Pruvost & Pringle 1924, Arkell 1935), Cretaceous (Geinitz 1842 etc.) and Tertiary (Ehrenberg 1938, Glaessner 1947). The geographical range of this form covers Europe, Asia and Australia.

In Britain, this trace fossil has been recorded from the Lower Lias by Hallam (1961), whilst the fucoids recorded by Blake & Hudleston (1877 : 271) and Arkell (1936 : 63) from the Oxfordian (Corallian, Nothe Grits) of the Dorset coast, and figured from a similar horizon in Yorkshire by Wilson (1949 : 256, pl. 10) are clearly *Thalassinoides*, as are the fucoids figured by Arkell (1925 : pl. 22, *a*) from the Portlandian (Portland Sand, Black Sandstones) of the Dorset coast. Farrow (1966) records it from many levels in the Yorkshire Jurassic.

I have noted this trace fossil at many horizons and localities: Triassic: Rhaetic, South-Devon coast between Seaton and Lyme Regis, piping the basal bone bed into the underlying Keuper (Text-fig. 2, G.). Jurassic: The whole of the Dorset Lias (Text-figs. 1, G–J; 2, F). Cretaceous: Lower Greensand, Folkestone beds at Folkestone (Text-fig. 2, I–K) associated with *Gyrolithes* type structures; Upper Greensand of Southern England and throughout the whole of the Lower Chalk and in the Middle

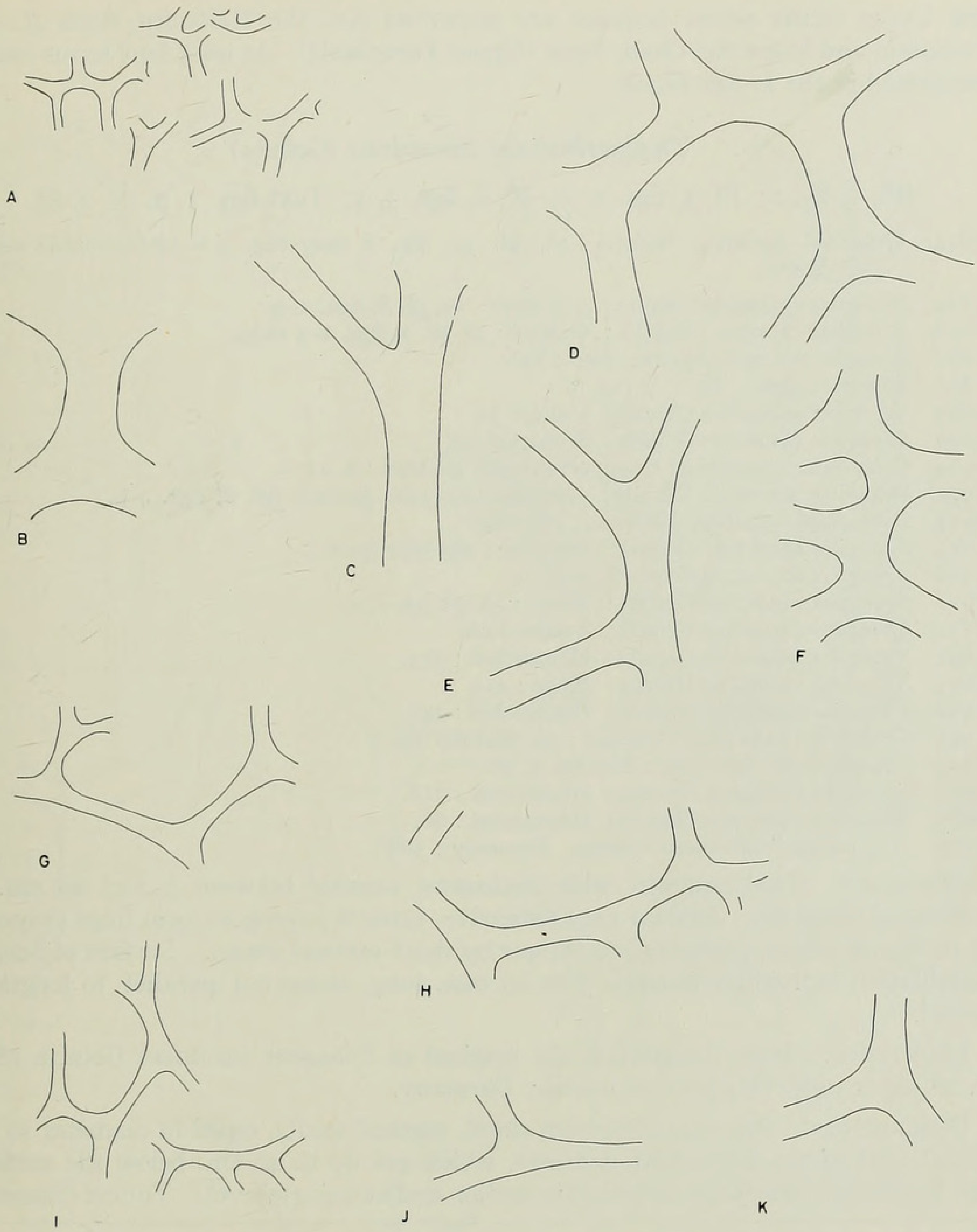


FIG. 1. A. *Thalassinoides* sp. Lower Chalk, ?Upper Cenomanian; White Nothe, Dorset. Plan, $\times \frac{1}{16}$. B, C. *Thalassinoides saxonicus* (Geinitz). Lower Chalk, Middle Cenomanian, Chalk below Totternhoe Stone; Houghton Regis, near Dunstable, Beds. Plan, $\times \frac{1}{16}$. D, F. Laminated structures. Lower Chalk, Middle Cenomanian; near Beachy Head, Eastbourne, Sussex, Plan, $\times \frac{1}{16}$. E. Laminated structure. Lower Chalk, Middle Cenomanian, bed 7; Folkestone, Kent. Plan, $\times \frac{1}{16}$. G–J. *Thalassinoides* sp. Upper Lias, Toarcian; near Seatown, Dorset. Plan, $\times \frac{1}{16}$. K. *Thalassinoides* sp. Upper Greensand; Foxmould, Humble Point, South Devon. Plan, $\times \frac{1}{16}$.

and Upper Chalk where burrows are preserved (i.e. the Melbourn Rock (Lower Turonian) and below the Chalk Rock (Upper Turonian)). At least four forms can be recognized in the Lower Chalk.

Thalassinoides saxonicus (Geinitz)

(Pl. 1, fig. 1; Pl. 5, figs. 2, 3; Pl. 6, figs. 3, 4; Text-figs. 1, B, C; 2, E)

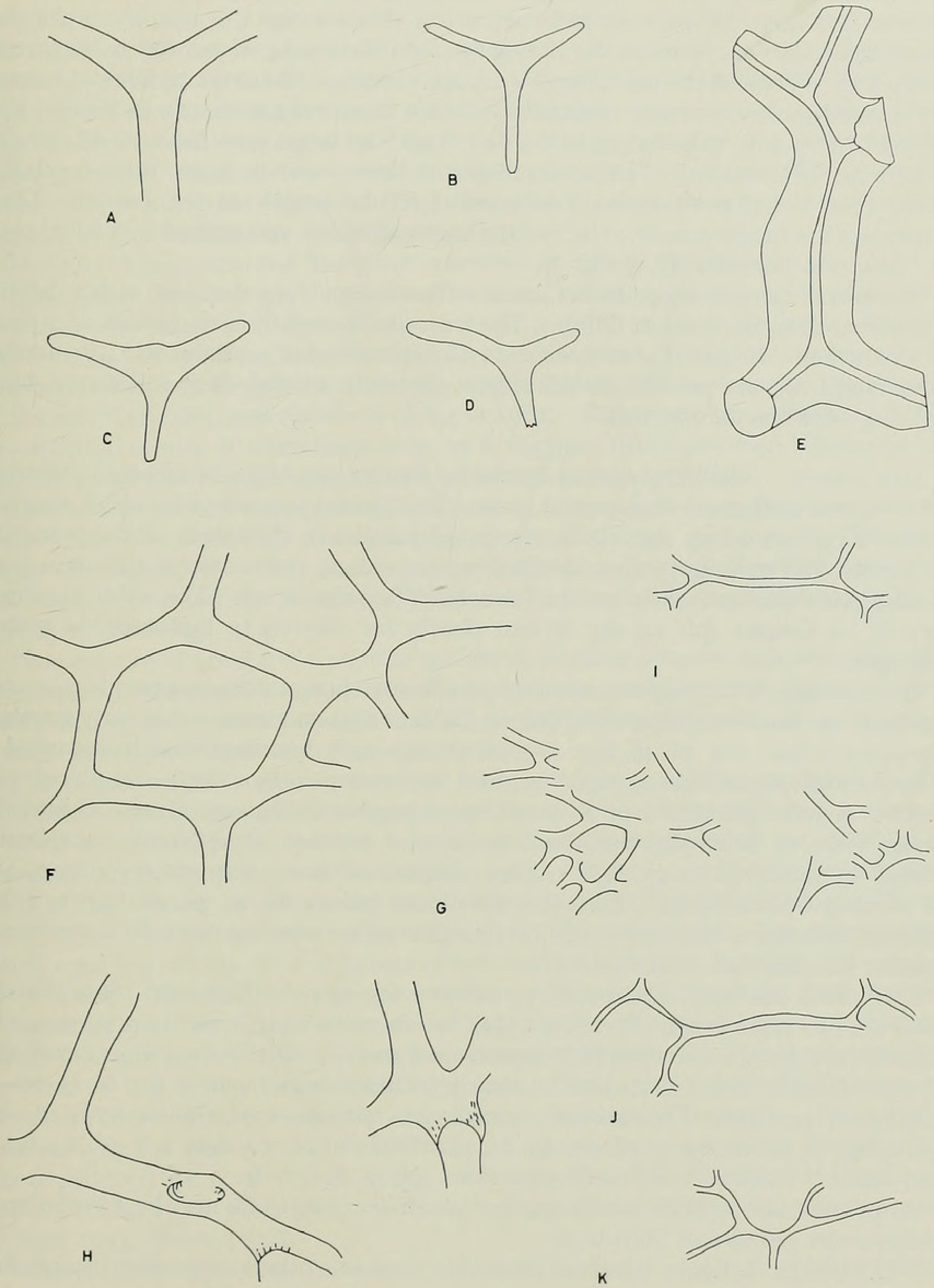
1842 *Spongites saxonicus* Geinitz : 96, pl. 12, fig. 1 only (fig. 2 = *Ophiomorpha nodosa* Lundgren).
1852 *Spongites saxonicus* Geinitz; von Otto : 20, pl. 6, figs. 2, 3.
1871 *Spongites saxonicus* Geinitz; Geinitz : 21, pl. 1, figs. 1–5 only.
1878 *Spongia saxonica* Geinitz; Frič : 149.
1878 *Spongites gigas* Frič: 75, 149.
1885 *Spongites saxonicus* Geinitz; Počta : 30.
1899 *Spongites saxonicus* Geinitz; Semenow : 6.
1909 *Cylindrites spongioides* Goeppert emend. Richter : 8, 11.
1912 *Spongites saxonicus* Geinitz; Dettmer : 114–126 (pars.), ?pl. 8, figs. 4–6.
?1914 *Aschemonia gigantea* Dettmer : 287, fig.
1915 *Spongites saxonicus* Geinitz; Dettmer : 285–287 (pars.).
?1928 *Spongites* sp. Lamprecht : 8, 9, pl. 2.
1932 *Spongites saxonicus* Geinitz; Rieth : 30, pl. 5*a*, 1, 2.
1934 *Spongites saxonicus* Geinitz; Andert : 68.
1934 *Spongites saxonicus* Geinitz; Häntzschel : 313.
1944 *Spongites saxonicus* Geinitz; Fiege : 419.
1952 *Spongites saxonicus* Geinitz; Häntzschel : 146.
1954 *Cylindrites saxonicus* Prescher : 59, text-fig. 19.
?1955 *Spongites* sp., Seilacher : text-fig. 5, 98.
1962 *Spongites saxonicus* Geinitz; Häntzschel : 218.
1965 *Spongites saxonicus* Geinitz; Häntzschel : 88.
1967 "*Spongites*" *saxonicus* Geinitz; Kennedy : 368

DIAGNOSIS. *Thalassinoides* with horizontal tunnels between 5 and 20 cm. in horizontal diameter. System very extensive, tunnels joining to form huge polygons up to 60 cm. across, connected to surface by short vertical shafts. Surface of burrow mamillated, individual mounds 5 to 10 mm. long, elongated parallel to length of tunnel.

LECTOTYPE. Here designated, the original of *Spongites saxonicus* Geinitz 1842, pl. 22, fig. 1 only: Upper Cretaceous; Germany.

DESCRIPTION. Systems arise from short, vertical shafts, equal in diameter to the widest part of the horizontal elements, which are up to 40 cm. below the surface. The horizontal tunnels are elliptical in section and at a single level. Tunnel diameters

FIG. 2. A–D. *Thalassinoides visurgiae* Fiege (after Fiege 1944) $\times \frac{1}{8}$. E. *Spongites saxonicus* Geinitz, Sketch of lectotype (after Geinitz 1842) $\times \frac{1}{4}$. F. *Thalassinoides* sp. Lower Lias; Pinhay Bay, S. Devon. Plan, $\times \frac{1}{16}$. G. *Thalassinoides* sp. Top of Keuper, full of Rhaetic Bone Bed; Charlton Bay, S. Devon. Plan, $\times \frac{1}{8}$. H. *Thalassinoides* sp. Upper Chalk, Upper Turonian, Chalk Rock; Hitch Wood, near Hitchin, Herts. Plan view of 3-dimensional tunnel system beneath the Chalk Rock hardground. $\times \frac{1}{4}$. I–K. *Thalassinoides* sp. Lower Greensand, Folkestone Beds, Lower Albian; Copt Point, Folkestone, Kent. Plan, $\times \frac{1}{16}$.


A
B
E
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K

vary between 20 by 13 cm. in the centre of systems, to 5 by 3·5 cm. at the extremities. Branching is very regular, at intervals of about 30 cm. tunnels bifurcate, with a symmetrical Y-shaped junction, slight widening giving rounded angles. The overall pattern is of large polygons up to 60 cm. across (Plate 1, fig. 1). Specimens showing terminations are uncommon; the ending figured (Plate 5, fig. 2) is swollen, measuring 12 by 5 by 3·5 cm. at the end of a 3 by 2·5 cm. tunnel. The outer surfaces of tunnels are covered by low mounds: on small specimens these vary from 17·5 to 18 mm. long by 7·5 to 11·5 mm. wide by 3·5 to 6·5 mm. high: on larger specimens 16–18 mm. by 9–12 mm. by 4–6 mm. The arrangement of these mounds shows little regularity other than a preferred orientation parallel to the length of the tunnel. These structures are rarely preserved on bottom surfaces, which are covered by a felted mass of *Chondrites* burrows (Pl. 5, fig. 3).

Sections of tunnels suggest that some of these mounds are discrete, with a definite separation from the burrow filling. The majority have only a suggestion of a plane of separation. In addition to mounds, oval depressions of a similar size, surrounded by a raised rim are present, as are ridges, generally 20 mm. long and 2 mm. high, running between the mounds.

DISCUSSION. The lectotype, as figured by Geinitz, is a large, branching cylindrical body with a maximum diameter of 5 cm. The surface is covered by small mounds, 5 mm. long and 2 to 3 mm. wide, elongated parallel to the length of the branches. A smooth half cylinder 5 mm. in diameter runs along the centre of the main part, joining with similar bodies on the branches (Text-fig. 2, E). The other specimen figured by Geinitz (pl. 22, fig. 2) can clearly be referred to *Ophiomorpha nodosa* Lundgren.

Geinitz regarded *Spongites saxonicus* as a horny sponge (Ceratospongidae), a view also held by von Otto (1854), Frič (1878), Počta (1885) and many other early workers. Goeppert (1842 : 115, pl. 46, figs. 1–5, pl. 48, figs. 1, 2) described what he regarded as a fossil alga, *Cylindrites spongioides*, and he subsequently (1847) considered this species to have priority over *S. saxonicus*, and that both were algae. *Cylindrites spongioides*, as originally proposed, includes a number of different trace-fossils. Forms figured on plate 46, figs. 1–4 are simple crustacean burrows (type B, p. 47), or possibly *Ophiomorpha*. The other specimens (pl. 46, fig. 4; pl. 48, figs. 1, 2) are smooth cylindrical burrows with swollen portions, differing from *S. saxonicus* in smaller size and lack of ornament.

Cylindrites has been used by many authors for fucoids (Eichwald 1865, Watelet 1866 etc.) or trace fossils (Prescher 1954), but is not available due to prior usage by Gmelin (1793) and Sowerby (1825) as gastropod genera. Richter's (1909) emendation of *Cylindrites* is unfortunate, for he clearly includes large burrows (up to 15 cm. in diameter), probably *Thalassinoides saxonicus*, specimens of *Ophiomorpha nodosa* (pl. 9, fig. 7, pl. 12, fig. 5, pl. 13, fig. 6), plant debris (pl. 12, figs. 1, 2, pl. 13, fig. 6) and smooth burrows with swollen portions (pl. 9, figs. 1–2).

As pointed out by Häntzschel (1952), *Cylindrites spongioides* may be a synonym of *Halymenites cylindricus* Sternberg:

"H. fronde fistulosa terente pinnatim ramosa, ramus opposites simplicibus patenibus cylindricus obtusis, terminale longiors . . . In schisto saxi arenaci Pirnensis (Greensand anglorum) prope Tetschen ad albim Bohemae." (Sternberg 1833.)

Until the branching pattern of *C. spongioides* is described, it is not possible to decide if it is a form of *Thalassinoides*, although it is clear that it is a smooth crustacean burrow, the swollen portions representing " turn-arounds ", comparable to the burrows produced by the living crustaceans *Upobegia pugettensis* (Dana) (MacGinitie 1930) and *Callianassa californiensis* Dana (MacGinitie 1934, Stevens 1928). These burrows were noted as early as 1760 by Schulze (41–46, pl. 2, figs. 1–5) who regarded them as crinoid remains. In view of their interpretation as callianassid burrows it is interesting to note that Goeppert (1854) recorded *C. spongioides* in association with remains of *Protocallianassa antiquua* (von Otto).

Dettmer (1912) regarded *Spongites saxonicus* as a giant foraminiferan!

Häntzschel (1934, 1935) records *Xenohelix saxonica* Häntzschel (=*Gyrolithes* Saporta) associated with *Spongites saxonicus*; spiral structures, perhaps *Gyrolithes* occur in the Folkestone beds (L. Albian) at Folkestone, Kent in association with *Thalassinoides*, and have been recorded associated with *Ophiomorpha* in the Miocene of Borneo (Keij 1965) and elsewhere (Kilpper 1962). This type of association indicates the artificial nature of trace-fossil taxa, as it suggests that *Gyrolithes*, *Thalassinoides* and *Ophiomorpha* are all synonymous, the first having priority.

The best preserved examples of *T. saxonicus* I have found are from beneath the Totternhoe Stone (Middle Cenomanian) of the Chilterns, particularly Houghton Regis (Bedfordshire). Here, hard, gritty Totternhoe Stone is piped into the very soft chalk below and the burrows so filled can be completely freed of matrix (Pl. 5, figs. 2, 3; Pl. 6, figs. 3, 4).

The presence of phosphatic pebbles and shells in these burrows indicates that they were open on the sea floor, and were filled passively, probably after being vacated. Individual systems extend over several square metres and indicate firm sediment, as I have never seen signs of collapse into them.

The ridges on the outer surface are interpreted as scratches produced by the inhabitant whilst digging or moving through the system; the mamillated surface as a result of worked pellets pushed into the wall of the tunnel and smoothed off or worn smooth by the passage of the animal's body. Pellets are impressed into burrow walls in this manner by the crustacean *Callianassa major* Say (MacGinitie *in* Häntzschel 1952, Weimer & Hoyt 1964). The oval depressions with their surrounding ridges appear to be the sites of pellets of soft chalk which have been washed away in preparation. The most likely purpose of these pellets is to support the burrow walls, a procedure used by living callianassids (Pohl 1946); swollen portions at points of branching and burrow terminations are comparable with the " turn arounds " of burrows of this group (MacGinitie 1930, 1934, Pohl 1946). All the features of *T. saxonicus* are thus comparable with Recent callianassid burrows. This view is enhanced by the presence, in the infilling of *T. saxonicus*, of rod-like phosphatized faecal pellets (type A of Wilcox 1953), more abundant than elsewhere in the Lower Chalk, which, from the presence of internal canals, are diagnostic of anomurans (Wilcox 1953, Moore 1932).

Internally, these burrows show intense re-working (see p. 149). A puzzling feature of previously described specimens of *T. saxonicus* is the small burrow running down the centre of the lower surface of the system. In the lectotype this is very regular, but in other specimens it clearly strays from the mid-line. Geinitz (1842) interpreted this as a juvenile sponge. My own material suggests that this is another, smaller species of *Thalassinoides*, which sometimes follows the mid-line of the bottom of the larger burrow, but which often leaves, passing out into the surrounding sediment (Pl. 6, fig. 4). These smaller burrows may be the products of the juveniles of the *T. saxonicus* animal, but as I have never seen transitions it is regarded as a distinct form, *T. ornatus* nov. (p. 141).

Whilst most systems correspond to the above description, occasionally tunnels are found filled with coarse, sandy chalk made up of shell fragments and microfossils. This material represents the remains of the burrow filling after the inhabitant has

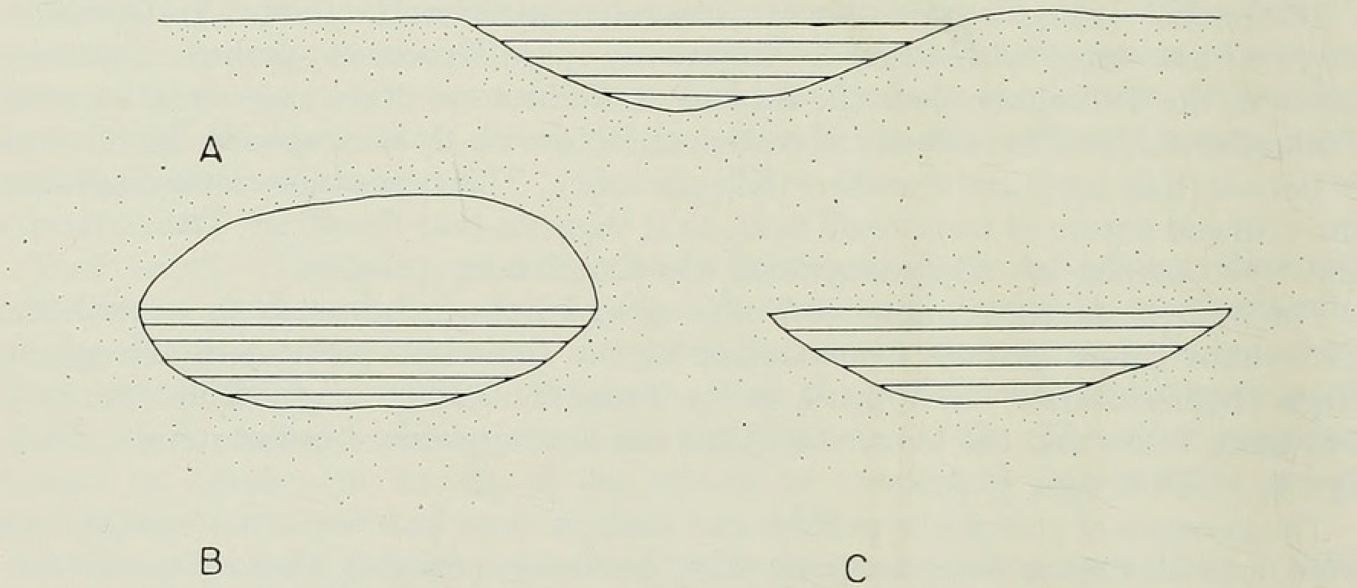

FIG. 3. Alternative interpretations of laminated structures. A. As surface trace; B. As partially filled burrow; C. As totally filled burrow with semi-circular section. All $\times\frac{1}{4}$.

sifted out the finer portion for ingestion; the faecal pellets associated with these burrows show only fine-grained material when sectioned (Wilcox 1953), suggesting this mode of feeding. Presumably the coarser debris was normally removed from the system and washed away by bottom currents, being only occasionally packed into a disused part of the burrow. In a single instance, from the Upper Cenomanian at Dover, a large mass of this coarse debris, lying above a *T. saxonicus* system seemed to represent material dumped outside the burrow opening adjoining the entrance shaft.

Thalassinoides saxonicus and " Laminated structures ". I have used the name " laminated structures " (Kennedy 1967) for problematic structures occurring throughout the Lower Chalk which, in section, show fine, horizontal laminations made prominent by their resistance to weathering (due to a calcite cement) and brown colour (due to disseminated limonite). In plan, these structures show a form identical in size-range and mode of branching with *T. saxonicus* (Text-fig. 1, D–F). In section they can be described in terms of a continuous series defined by two end members:

(i) Horizontal bands, up to 60 cm. long and 5–10 cm. deep, laminated throughout, the laminations essentially parallel.

(ii) Semi-circular sections, the curved surface downwards, with diameters from 10 cm. upwards. With increasing diameter the radius of curvature of the lower surface increases, passing into form (i). Laminations are essentially parallel, with a tendency to dip towards the centre of the section.

In both cases, weathered and cut sections show that the laminations consist of alternations of normal chalk and coarse debris of shell and echinoderm fragments, foraminifera and other sand grade microfossils, cemented by calcite and coloured brown by small quantities of limonite, perhaps after pyrite. The laminations are between 2 and 20 mm. thick, and may vary laterally (Pl. 8, fig. 3). In thin section, these structures show very ill-defined graded bedding, the coarse material grading up into the normal chalk above.

These laminated structures are cut by burrows (Pl. 8, fig. 3; Pl. 5, fig. 1) indicating a primary origin. Whilst the general sense of the laminations is horizontal and parallel, corrugations and other disturbances are common (Pl. 8, fig. 3). Some of these structures are clearly the result of subsequent burrowing (Pl. 8, fig. 3), whilst other irregularities appear to be the result of slumping of the layers (Pl. 8, fig. 3). Bottom surfaces are rather irregular (Pl. 8, fig. 3), in part as a result of burrows along the basal interface.

Interpretation. In view of the similarity in size-range of these structures and *Thalassinoides saxonicus* and the identical branching pattern, they are clearly the result of the activities of the same organisms; crustaceans. Whereas *T. saxonicus* is clearly a burrow, elliptical in section, laminated structures generally have a flat top. Three interpretations are possible (Text-fig. 3).

(i) They are the filling of the lower parts of burrows.
(ii) They are completely filled burrows semi-circular in section.
(iii) They are a surface trace.

I have examined many examples in the field; most show no indications of an associated burrow. A few show what could be interpreted as the upper part of a burrow, but at present the evidence suggests they were a surface trace, although the relationship seen in Plate 8 could be interpreted as the intersection of two burrows with a semicircular section, completely full of laminated sediment.

The laminations are interpreted as the result of sifting of the sediment by the animals producing these structures. As already indicated (p. 137) faecal material suggests they lived on the finer fractions; the coarse layers are the remains left after this sifting. Whilst this can explain the formation of one layer, I can offer no explanation of the repeated alternation of coarse and fine layers.

Explanation of these structures as a feeding trace of *Teichichnus* type (Seilacher 1955, Häntzschel 1962) is unsatisfactory due to the absence of an obvious burrow in association, unless the initial burrow were very shallow and invariably broke the sediment-water interface. An inorganic origin—that these are *Thalassinoides*, exposed by erosion and filled by swept-in coarse material alternating with fine mud deposited by gravitational settling or other currents—is rejected; other hollows on the sea floor lack a laminated fill, whilst one would expect to find truncated *Thalassinoides* without a laminated fill, which I have never seen.

OCCURRENCE. Solid specimens of *T. saxonicus* occur abundantly beneath the Totternhoe Stone in the Chilterns. Large *Thalassinoides*, identical in size and mode of branching are common in all coastal sections whilst large oval burrow sections are abundant in all sections and are regarded as identical with *T. saxonicus*. A large species of *Thalassinoides* occurs beneath the Chalk Rock (Text-fig. 2, H) but differs from *T. saxonicus* in having three-dimensional tunnels. These were described by Billinghurst (1927) as " solution channels ".

T. saxonicus is widely recorded from the Cretaceous of Germany and Central Europe. The specimen of *Thalassinoides* figured by Seilacher (1955) from the Tertiary may belong to this form. " Laminated structures " are common throughout the whole of the Lower Chalk, particularly in the Middle Cenomanian. At Folkestone (Kent) bed 7 (Jukes-Browne & Hill 1903) can be traced all along the coast, even when high in the cliffs, because of the abundance of these structures.

Thalassinoides cf. ***suevicus*** (Rieth)

(Pl. 1, fig. 2)

1932 *Spongites suevicus quenstedti* Rieth : 274.
1932 *Spongites suevicus* Quenstedt; Rieth : 292.
1932 *Cylindrites suevicus* (Quenstedt) Rieth, pl. 13*a*, *b*.
?1944 *Thalassinoides visurgiae* Fiege : 416–421, 424, text-fig. 4.
1955 *Spongites suevicus* Quenstedt; Seilacher, text-figs. 5, 57.
?1964 *Thalassinoides* sp. Häntzschel : 302, pl. 14, fig. 3.
1964 *Thalassinoides suevicus* (Rieth); Häntzschel : 302.

A *Thalassinoides* with tunnel diameters between 2 and 5 cm. is occasionally seen in allen blocks of Upper Greensand and Lower Chalk at many coastal sections (Eastbourne, Compton Bay, etc.). Those in the Upper Greensand in part arise from the base of the Glauconitic Marl.

In size, mode and angle of branching these are comparable with " *Spongites* " *suevicus* Rieth, from the Lias and Dogger of Germany (as pointed out by Häntzschel (1964 : 302) this name must be attributed to Rieth). There is also a strong resemblance to the fragment figured by Häntzschel (1964) from the Campanian of Beckum (Westphalia).

Thalassinoides visurgiae Fiege, from the Trias (Muschelkalk) of North Germany, is based on branching portions (Text-fig. 2, A–D) and appears identical with *T. suevicus*.

T. cf. suevicus differs from *T. saxonicus* in its much smaller size and absence of ornamentation. It is not referred definitely to *T. suevicus* because of the poor preservation. The systems are horizontal as far as has been seen. It is not clear how much of the piping beneath the Glauconitic Marl is due to this form (Pl. 1, fig. 3), but attitude and tunnel diameters are comparable.

Specimens of *Thalassinoides* from the Upper Greensand and from beneath the

Totternhoe Stone at Hunstanton, agreeing in size with this form occasionally show internal structure, seen in section as concavo-convex laminations (Text-fig. 6, D). This type of burrow filling is discussed on page 161.

OCCURRENCE. Fairly frequent in the whole of the Lower Chalk of southern England. Comparable forms occur in the Lias and Upper Greensand: Lias and Dogger of Germany and Campanian of Bochum, Germany.

Thalassinoides ornatus ichnosp. nov.

(Pl. 6, fig. 4; Pl. 7, fig. 6)

DIAGNOSIS. Small *Thalassinoides*, tunnel diameters between 16 by 8 mm. and 22 by 10 mm. System largely horizontal, surface of tunnels covered in reticulate ridges.

HOLOTYPE. B.M. (N.H.) T.559. Paratype B.M. (N.H.) T.551.

LOCALITY AND HORIZON. The holotype (associated with *T. saxonicus*) is from the Lower Chalk immediately beneath the Totternhoe Stone at Houghton Regis (Bedford shire) (National Grid Reference T.L.013233) and is Middle Cenomanian in age. The paratype is from the same horizon and locality. This species is not uncommon beneath the Totternhoe Stone elsewhere in the Chilterns: poorly preserved material from the Lower Chalk of the Weald may also belong to this form.

DESCRIPTION. The tunnels are generally horizontal or gently inclined, with typical *Thalassinoides* branching pattern. Individual tunnels are oval in section, dimensions varying between 16 by 8 mm. to 22 by 10 mm. The whole surface is covered in delicate intersecting ridges (Pl. 7, fig. 6); some tunnels are gently curved. Branching points are swollen, whilst swollen portions with diameters of about three times that of the adjoining tunnel are present.

DISCUSSION. This form is quite common beneath the Totternhoe Stone in Bedfordshire, often following the mid-line of the lower surface of *T. saxonicus* burrows (Pl. 6, fig. 3). As already suggested (p. 138) this may be the explanation of the cylindrical central body figured by previous workers (Geinitz 1842, 1871, von Otto 1854, Seilacher 1955 etc.). This pattern is not regular, the smaller burrows often passing through the larger burrows and occurring in the surrounding sediment.

Interpretation of *T. ornatus* as the work of juveniles of *T. saxonicus* is considered unlikely in the absence of intermediate forms.

As with the forms of *Thalassinoides* already discussed, the features of *T. ornatus* agree with an interpretation as crustacean burrows: reticulate surface ridges are scratches on the inside of the burrow produced during digging or when moving through the system, the swollen portions are clearly " turn-arounds ".

The surface ornament of *T. ornatus* resembles that on *Spongeliomorpha* (p. 151), also regarded as a crustacean burrow. The two forms are distinguished by the more regular ornamentation and branching of *T. ornatus*. This form differs from *T.* cf. *suevicus* by the presence of a reticulate ornamentation and swollen " turn-arounds ". Clearly, with poorly preserved material the two forms may be confused.

Thalassinoides paradoxica (Woodward)

(Pl. 3; Pl. 4; Pl. 8, fig. 5; Pl. 9, fig. 2; Text-figs. 4, 5, A–B)

1814 . . . singular organic body . . ., Webster, pl. 27, fig. 1.
1823 . . . a remarkable ramifying zoophyte . . ., Taylor : 82.
1830 *Spongia paradoxica* Woodward : 5.
1833 *Spongia paradoxica* Woodward; Woodward : 29, 30, 54.
1835 . . . a ramose zoophyte . . . Rose : 54, 275, 276.
1859 *Spongia paradoxica* Woodward; Wiltshire : 275, 277, pl. 1, figs. 1, 2.
1864 *Spongia paradoxica* Woodward; Seeley : 331.
1869 *Siphonia paradoxica* (Woodward) Wiltshire : 176.
1871 Problematicum, Geinitz, pl. 38, fig. 8.
1884 *Spongia paradoxica* Woodward; Hughes : 273–279.
1899 *Spongia paradoxica* Woodward; Whitaker & Jukes-Browne : 36, 55.
1900 *Spongia paradoxica* Woodward; Jukes-Browne & Hill : 303.
1903 . . . stems of *Siphonia* . . . , Jukes-Browne & Hill : 209.
1932 Problematicum, Rieth, text-fig. 35 (after Geinitz).
1961 "*Spongia paradoxica*" Woodward; Peake & Hancock : 301, 330.
?1961 "*Spongia paradoxica*" Woodward; Rios & Hancock, pl. 16.
1962 *Spongia paradoxica* Woodward; Häntzschel : W 242.

Diagnosis. Medium sized *Thalassinoides*, with irregular, very extensive horizontal burrow network, occurring at several levels, connected by vertical shafts. Diameter of tunnels variable, between 7 and 60 mm., short blind tunnels very common. Surface covered with longitudinal ridges. Generally occurs associated with erosion surfaces.

Neotype. Here designated, B.M. (N.H.) T.545 from the *Paradoxica* bed, base of Lower Chalk (Lower Cenomanian); Hunstanton Cliff, Hunstanton, Norfolk.

Description. This is the most irregularly branching *Thalassinoides* I have seen. The burrows have an irregular section, and may be depressed or rounded-angular, varying in a single system between 7 and 60 mm. in diameter. A large tunnel may give rise to a side branch less than a quarter of its own diameter. As in other species of *Thalassinoides*, the principal element of branching is a Y fork, with an increase in diameter around the point of branching, the tunnel tending to widen between the forks of the Y. Distance between branching points is very variable, between 1 and 20 cm. Many of the branches terminate after short distances, giving the system an antler-like appearance, whilst at every point on the system there are small blunt protuberances varying from a few millimeters to several centimetres long, representing abandoned or unfinished tunnels. Even smaller knobs are also present. Where several branches occur close together the tunnels may widen to form a flat chamber (Pl. 8, fig. 5) up to 10 cm. long and 5 cm. wide with five or six tunnels leading off.

The most striking feature of the branching pattern is that the Y-forks occur in three dimensions, whilst most of the elements of the system are horizontal, joining into small irregular polygons (Text-figs. 4, 5, A–B). An individual system can exist at several levels, connected by short vertical shafts. At Hunstanton, these levels are 5–6 cm. apart, running along the minor erosion surfaces within the *Paradoxica* bed, although elsewhere levels are up to 30 cm. apart (Text-fig. 4, A). The systems

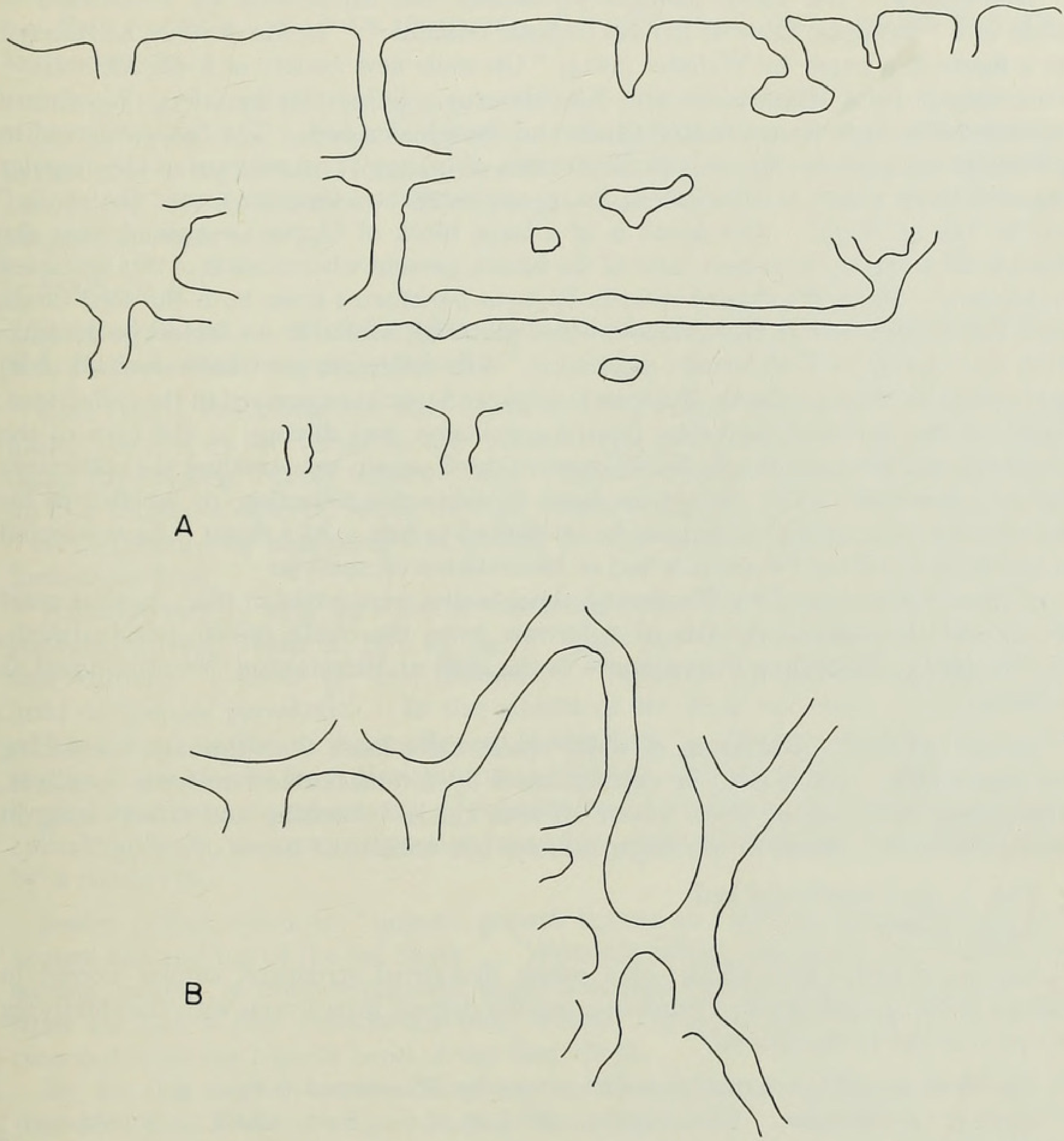

FIG. 4. *Thalassinoides paradoxica* (Woodward). A. Junction between Wilmington Sands and the overlying Middle Chalk; White Hart Sandpit, Wilmington, S. Devon. Vertical Section, ×⅛. B. Lower Chalk, Lower Cenomanian, Paradoxica bed; Hunstanton, Norfolk. Plan, ×⅛.

are connected to the surface by vertical or steeply inclined shafts 15–30 cm. long. On vertical faces, burrow densities are up to 20/1000 $cm.^2$

As pointed out by Hughes (1884) the surfaces of burrows have a green flakey coat; this appears to be glauconite. When cleaned, the surfaces of burrows are seen to be covered with rather poorly defined longitudinal ridges (Pl. 9, fig. 2).

DISCUSSION. The name *Spongia paradoxica* was introduced by Woodward in 1830 in a " Synoptic table of British Organic remains ". In illustration, he referred to a figure in a paper by Webster (1814) " On some new variety of fossil Alcyonia ", recording it from Hunstanton and Southbourne. Subsequently (1833) Woodward recorded this form from the Red Chalk and Paradoxica bed. The figure referred to (Webster 1814, pl. 27, fig. 1) is in illustration of (p. 377) " an account of the singular organic body which I observed in the green sandstone stratum under the chalk " of the Isle of Wight. The figure is of a large block of Upper Greensand from the Undercliff along the southern coast of the island, present whereabouts of this specimen unknown ! Since Woodward records *Spongia paradoxica* from both the Red Chalk and Paradoxica bed at Hunstanton, other material, available for lectotype designation was clearly in Woodward's possession. His collection (or what remained of it) passed to the Norwich Castle Museum in 1836, and was incorporated in the collections. Much of the material, including figured specimens, was missing at the turn of the century, and although Mr. B. McWilliams of the Museum has searched the collections for any specimens of *S. paradoxica* from Woodward's collection, or labelled in his hand, none now remains which can be attributed to him. As a result, I have selected a specimen from the *Paradoxica* bed at Hunstanton as neotype.

Although first named by Woodward, these bodies were noted in 1823, in what must be one of the earliest records of a burrow from the chalk (albeit misidentified). Taylor (1823), describing the sequence in the cliffs at Hunstanton, Norfolk, noted as follows:

" *No. 4.* 1½ feet. A stratum of white chalk, more loose than the last, containing no fossil shells: yet it is to be distinguished by a remarkable ramifying zoophyte, resembling the roots of trees; about an inch thick, branching and intertwining in every direction. Some of the fragments are not unlike the horns of a stag."

This is the *Paradoxica* bed.

Again, later:

" *No. 6.* 2 feet. Red Chalk, of a rough disjointed structure, similar except in colour to No. 4, and like it, though in a smaller degree, interwoven with the ramifying zoophytes before mentioned."

The first use of the name *paradoxica* was by Woodward (1830: 5):
" *Spongia paradoxica.* Geol. Trans. ii. t.27, f.1. Red Chalk. Southbourn; Hunstanton."

The Southbourne occurrence would appear to be the same as that given by Mantell (1833), in a list of " Fossils from the chalk formation ", where a *spongia* from Southbourne (Sussex) is noted. In a footnote stating, " the inferior bed of marl which is in contact with the Firestone at Southbourne is almost entirely composed of zoophytes, milleporites, madreaporites etc., so as to form coral reefs "—presumably the Glauconitic Marl.

The specimens figured and described by Webster (1814) include a number of forms, both burrows and fossil sponges. Plates 27 and 29 represent burrows, plate 28, figures 3 (in part), 4, 8, 9, 10 and 11 represent the " tulip alcyonidium " (*Siphonia* *tulipa* Zittel). The nature of the specimens figured as pl. 28, figs. 5–7 is not clear, but they resemble *Cylindrites spongioides* (Goeppert 1842), here regarded as a crustacean burrow.

The next reference to " Spongia paradoxica " is by Woodward (1833 : 29):
" Chalke Marle. This bed reposes upon the red chalk, and is seen to great advantage in that interesting section, Hunstanton cliff. It is of a grayish color, and at that place about four feet in thickness. The Spongia paradoxica, as we have named it *pro tempore*, abounds in it " . . .

Again, (p. 30):

" The Red Chalk . . . it is about two feet in thickness, and, like its superincumbent bed, abounds with Spongia paradoxica."

Rose (1835), describing the Red Chalk at Hunstanton speaks of " a ramose zoophite, the nature of which is not satisfactorily determined ". Again (p. 275), under the heading " Chalk without flints ", describes the lowest bed as being " made up of a ramose zoophyte, which strongly characterizes it ", regarding it (p. 276) as " best explained by supposing it originally a coral reef and its interstices filled with Cretaceous Mud."

Wiltshire (1859: 275), in a list of fossils from the Red Chalk records " Spongia paradoxica Geol. Trans. 2, tab. 27, fig. 1. page 377 (In the collections of Mr. Rose and Author.) ". Later (p. 277, footnote): " Siphonia pyriformis is probably the head of Spongia paradoxica. In the cabinet of Mr. Rose is a mass of the latter, to which a head similar to the one figured is attached ". The figures referred to are the first of *S. paradoxica* from Hunstanton published. Wiltshire's pl. 1, fig. 1, shows a typical branching fragment, fig. 2, referred to as *Siphonia pyriformis* is a swollen cylindrical body, the terminal portion being flat, with a circular depression surrounded by a raised rim.

Seeley (1864), refers to " organic growth known as ' spongia paradoxica ' in the sponge bed and top of the red chalk ". Wiltshire (1869), describing the Hunstanton section, notes " a meandering and many-branched sponge, *Siphonia paradoxica* " from his bed b (the Paradoxica bed), whilst " *Spongia paradoxica* Webster ", is recorded from the highest band of the Red Chalk.

By far the most extensive discussion is that of Hughes (1884) who concludes (257–277) that Webster's figure is a different fossil, the " tulip alcyonidium ", and that the fossil *Spongia paradoxica* is in fact an inorganic body, as sponge structure is preserved in the surrounding rock, but never in *S. paradoxica*. Large shell fragments in the matrix indicate conditions unsuitable for a delicate sponge, fragments of the *Spongia* are never found in the matrix, whilst shell fragments are avoided and never encrusted as would be expected in the case of a sponge.

This inorganic origin is accepted by Whitaker & Jukes-Browne (1899) who repeat Hughes' views, and Jukes-Browne (1900, 1903), who refers to " curious cylindrical bodies . . . which resemble the stems of *Siphonia* but which do not contain any sponge structure ". The most recent account of this " organism " is that of Peake & Hancock (1961), describing the *Paradoxica* bed:

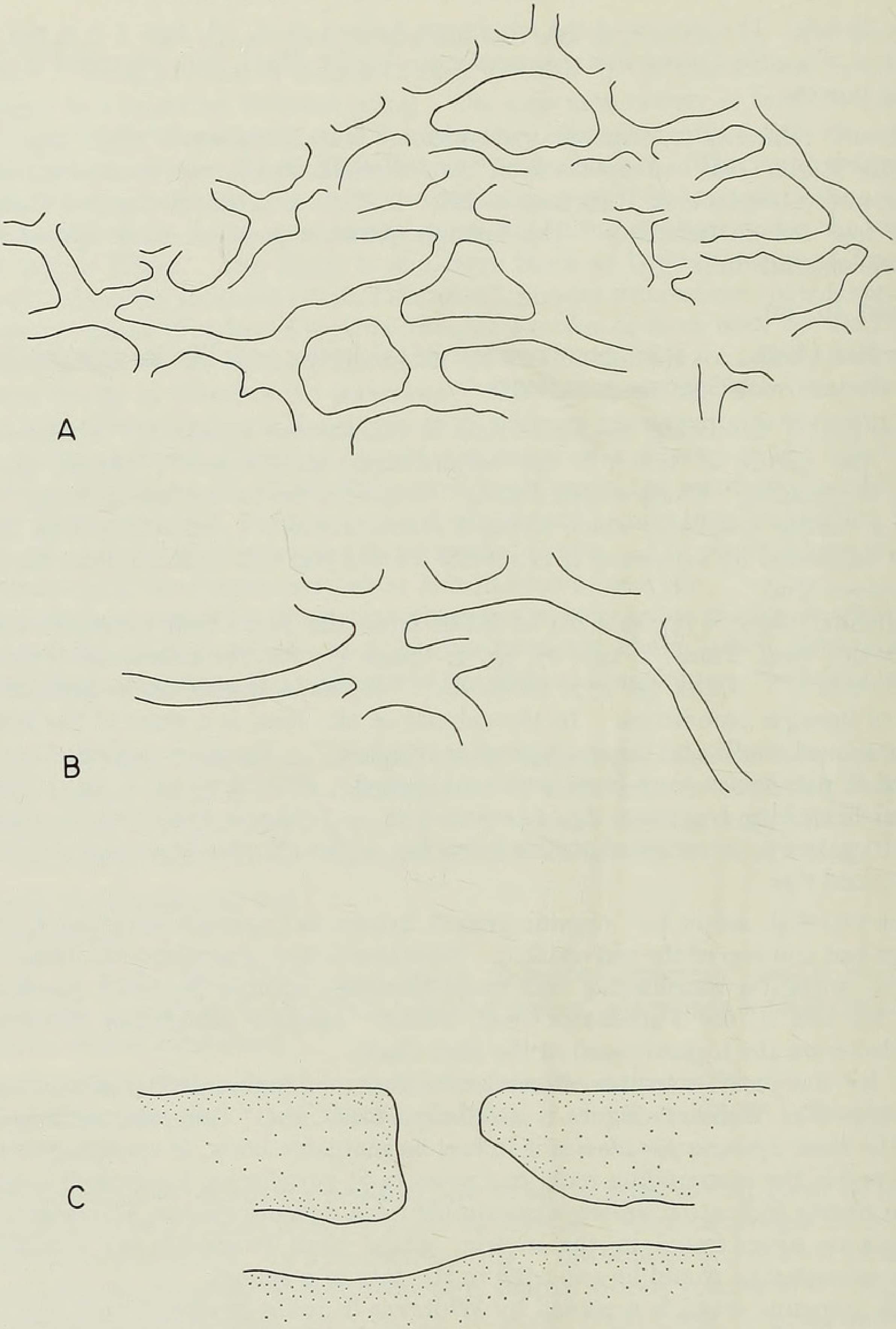

FIG. 5. A, B. *Thalassinoides paradoxica* (Woodward). A, Lower Chalk, Lower Cenomanian, Paradoxica bed; Hunstanton, Norfolk. Plan, $\times\frac{1}{8}$. B, Middle Chalk, Lower Turonian, Melbourn Rock; Brockham Limeworks, Betchworth, Surrey. Plan, $\times\frac{1}{4}$. C. *Thalassinoides* sp. Lower Chalk, Middle Cenomanian; cliffs below Whitbred Hole, Eastbourne, Sussex. Vertical section showing entrance shaft, $\times\frac{1}{2}$.

" soft-bodied organisms have left casts of their burrows which now form radiating, cylindrical branching and intertwining masses; they were once thought to be sponges, and actually named *Spongia paradoxica* ".

Häntzschel (1962) includes "*Spongia paradoxica* Woodward 1833 (=*Siphonia paradoxica* AUCTT.) " in a list of unrecognized and unrecognizable genera of trace fossils, giving Taylor's description and Hughes' views on its inorganic origin.

I have no doubt that this is a *Thalassinoides*, from both mode of branching and scratches; and that it is a crustacean burrow. The irregular three-dimensional branching makes it readily separable from other forms of *Thalassinoides*. The short blind burrows give a superficial resemblance of some parts to *Spongeliomorpha*.

Apart from its record in the English literature, already discussed, this type of burrow was described as early as 1760 by Schulze, who regarded them as crinoid remains. Problematic structures figured by Geinitz (1871) from the German Upper Cretaceous are clearly *T. paradoxica*. *Spongia sudolica* Zareczny (1878), regarded by Raciborski (1890) as a *Spongeliomorpha*, resembles *T. paradoxica* in size, but has rather different ornament; it is clearly a *Thalassinoides*.

In Britain, *T. paradoxica* has a very limited distribution, occurring only in association with minor erosion surfaces and signs of early lithification-hardgrounds. At Hunstanton the burrows occur associated with the erosion surfaces at the top of the *Paradoxica* bed, the Red Chalk and a minor erosion surface within the *Inoceramus* bed. The burrows in the *Paradoxica* bed tend to spread out along the minor erosion surfaces within the bed, but often pass through them. At the base, they follow the undulating irregular surface of the Red Chalk, but never pass into it. Those in the overlying *Inoceramus* bed follow the surface of the *Paradoxica* bed in like fashion. In both cases, the burrows always avoid pebbles, large shell fragments and echinoid tests, indicating that the animals could not bore into hard objects. That the erosion surfaces at the top of the Red Chalk and *Paradoxica* bed are never penetrated, likewise indicates that these were lithified when the burrowers were active in the sediment above. In the burrows beneath the Chalk Rock, here preserved as empty cavities, brachiopods, echinoids and *Inoceramus* fragments protrude into *Thalassinoides* burrows, the surrounding sediment having been removed, whilst the hard shell was left, again indicating inability to deal with hard objects.

In the south, the top of bed B. in the Wilmington outlier is penetrated by *T. paradoxica* (Text-fig. 4, A), here to a much greater depth, as there is no lower hardground to limit penetration. The burrows are excavated in sandstone, and are full of glauconitic chalk with small phosphates, identical with that in the base of the overlying Middle Chalk (equivalent to bed C. of the coastal sections). The walls of these burrows have a phosphatic veneer, as does the overlying erosion surface, whilst the sediment immediately around the burrows is impregnated with glauconite; this suggests that the lithification prior to these processes occurred either whilst the burrows were still occupied, or in the period before they were filled by drifted material.

This same trace-fossil occurs, associated with hardgrounds, at the top of beds A_2 and B of the Cenomanian Limestone on the Devon coast. It is also present, associated with hardgrounds, in the Middle Chalk above, and elsewhere in Southern England in the Melbourn Rock, again associated with hardgrounds. In the Lower

Chalk, it occurs below a hardground 11 m. below the *plenus* Marls at Culver Cliff (Isle of Wight).

In every case there is evidence that the burrow was excavated in soft sediment, and that the hardening, phosphatization and glauconitization, some or all of which occur in the associated hardground, post-date burrowing, but seem to have occurred prior to their silting up.

I have never seen any comparable burrow systems in chalk away from hardgrounds, and believe the association to be a valid one.

The " tubulures " of many continental authors, occurring associated with hardgrounds, variously interpreted as tree-roots, algae, annelid, terebellid or crustacean burrows (Schroeder & Böhm 1909, Ellenberger 1946, 1947, Marlière 1933 etc.), are clearly burrows of a similar type.

OCCURRENCE. The distribution and occurrence of *T. paradoxica* is fully dealt with in the discussion above.

Ichnogenus ***CHONDRITES*** Sternberg 1833

DIAGNOSIS. " Very plant-like, regularly ramifying tunnel structures which neither cross each other nor anastomose; should be interpreted as dwelling burrows or feeding burrows; width of tunnels remaining equal within a system, otherwise varying from large (i.e. *Buthrotrephis*) to small (e.g. *Chondrites*) very common trace fossil, usually named fucoid . . . surface pattern commonly very regular, effected by phobatactis . . . (probably made by marine worms). Cambrian to Tertiary. Cosmopolitan " (Häntzschel 1962 : 187–188).

TYPE SPECIES. *Fucoides targionii* Brongniart, by the subsequent designation of Andrews (1955).

DISCUSSION. The synonymy of *Chondrites* is given by Häntzschel (1962). Scott Simpson (1957) has discussed this trace fossil at length, reviewing early interpretations and concluding that it is the feeding-trace of some worm-like organism.

The following features have been indicated as diagnostic (Simpson 1957):

(a) Circular cross-section.
(b) Constant diameter (in some cases with constrictions at the point of branching).
(c) Smooth wall.
(d) Regular branching pattern:
  (i) Branching tends to be pinnate, especially at the periphery of the system, when not interfered with by neighbouring systems.
  (ii) Branching is always lateral, never equal.
  (iii) A large number of orders of branching may be present.
  (iv) The pattern lacks symmetry other than a radial tendency.
(e) Attitude, with both vertical and horizontal elements, the latter undergoing extensive ramification.
(f) Phobotactic pattern.

Chondrites sp.

(Pl. 2, figs. 2, 4; Pl. 5, fig. 3; Pl. 9, fig. 1)

A small species of *Chondrites* with tunnel diameters between 1 and 2 mm. is common throughout the whole of the Lower Chalk.

Many of the small, horizontal or gently inclined burrows present can be referred to this genus; every section I have examined contains this form, which is also occasionally encountered in the Glauconitic Marl.

Horizontal sections show that the vertical elements of these systems have a circular cross section; vertical sections show that the horizontal or gently inclined elements have an elliptical section, presumably as a result of compaction (which can be demonstrated by the crushing and deformation of associated fossils). Diameters are very constant, varying between 1 and 2 mm. in specimens from many horizons and localities. Individual branches and systems show a constant diameter throughout. Tunnel walls are smooth, tunnel fills structureless. Tunnels are always straight, except at the point of branching.

Vertical elements are less abundant than horizontal or inclined parts. No example of the two joining up has been observed but a sharp change of direction is implied. Sections give only limited information about branching but show this to have been lateral, never equal and at an acute angle. Horizontal and inclined elements branch frequently, vertical elements rarely.

Burrows never intersect, suggesting a phobotactic behaviour pattern: more positive evidence is seen in sections which suggest a " wrapping around " of tunnels, embracing on close encounter, then continuing in the original direction. " Solid " specimens—chance fracture surfaces (Pl. 9, fig. 1) or the cleaned surfaces of larger burrows from beneath the Totternhoe Stone (Pl. 5, fig. 3) give a better picture of the mode of branching. All the features already noted are present. There is no obvious symmetry; first and second order branches are present, branching at acute angles; pinnate branching is occasionally seen. Phobotactis is expressed in terms of " embracing " and stopping short. From these features, reference to *Chondrites* is clearly justified.

There are a wide variety of names available for forms of this size and it seems pointless to name the present material.

As noted above, every section contains these burrows: the maximum observed density is about 20 sections per square centimetre. A very characteristic occurrence of *Chondrites* is in the filling of larger burrows (Pl. 2, fig. 4). In nearly every instance, *Chondrites* is far more abundant in these than in the surrounding sediment; *Thalassinoides* is particularly prone to this re-working. Beneath the Totternhoe Stone at Houghton Regis, the filling of *T. saxonicus* burrows is completely re-worked and the bottom surface of the burrow converted to a felted mass of *Chondrites* (Pl. 5, fig. 3), whereas this form is uncommon at the base of the Totternhoe Stone and penetrates only a few centimetres. *Chondrites* penetrates to a much greater depth in burrow fillings than the surrounding sediment; a similar feature has been noted by Seilacher (1964 : 302, text-fig. 3, right-hand figure), *Chondrites* penetrating to a greater depth in the septum of a *Corophioides* than in the surrounding sediment (Lias γ, S. Germany).

A number of alternative explanations can be offered:

(i) The filling of the larger burrows is richer in nutrients than the surrounding sediment.
(ii) Re-worked sediment is better oxygenated.
(iii) Re-worked sediment is softer and thus more readily penetrated.

Of these alternatives, I would favour (iii) in view of the occurrences beneath the Totternhoe Stone where the presence of other burrowers, feeding on sediment, suggests it contained nutrients and was suitable for burrowing.

The abundance of *Chondrites* on the lower surface of larger burrows suggests that there is a geotropic control on the direction of burrowing, and that the sediment surrounding the burrows is not penetrated suggests that it was too stiff for the *Chondrites* animal. The surfaces of *Gyrolithes*, as figured by Saporta (1884) are covered by *Chondrites* in a similar fashion. An alternative may be that the *Chondrites* animal was feeding on mucus lining the burrow.

Ferguson (1965) has suggested that the filling of *Chondrites* tunnels was by the sucking-in of sediment from the surface-opening of the system as soon as the proboscis (or whatever part of the animal produced the burrow) was withdrawn from a branch. The arguments for this mode of filling are very reasonable, but it should be noted that ammonite siphuncles, borings and echinoid stereomes are sometimes sediment filled, indicating that passive filling of such structures can occur.

Occurrence. *Chondrites* sp. occurs in all sections of Lower Chalk examined. Comparable forms occur occasionally in the Glauconitic Marl and are common in the *plenus* Marls.

Ichnogenus ***SPONGELIOMORPHA*** Saporta 1887

1887 *Spongeliomorpha* Saporta : 299, pl. 6, figs. 2, 3.
?1913 *Rhizocorallium*; Felix : 21 (non Zenker).
1945 *Spongiliomorpha*; Darder, plate 8 (errore).
1955 *Spongeliomorpha*; de Laubenfels : E 36.
?1955 *Felixium*; de Laubenfels : E 36.
1962 *Spongeliomorpha*; Häntzschel : W 216.
?1965 *Felixium*; Häntzschel : 35.
1965 *Spongeliomorpha*; Häntzschel : 87.
1965 *Spongiliomorpha*; Häntzschel : 87.

Diagnosis. Medium sized, elongate, cylindrical, branching tunnel system, surfaces covered with network of fine ridges, interpreted as scratch marks; probably produced by crustaceans. Range: Triassic to Miocene.

Type species. *Spongeliomorpha iberica* Saporta 1887 (299, pl. 6, figs. 2, 3) from the Miocene of Alcoy, Spain, by monotypy.

Discussion. Saporta (1887) described what he believed to be a new form of keratosid sponge, *Spongeliomorpha iberica*, based on material from the Miocene of Alcoy (Spain), comparing it with *Spongelia* Nardo (in fact a synonym of *Dysidea*

Johnson: see de Laubenfels 1955: E 536), a form ranging from Eocene to Recent. In addition to the type material, Saporta mentions other material from the Calcaire Grossier and the United States. The fossil is indicated as resembling the horns of a deer, and being associated with *Taonurus* Saporta (=*Rhizocorallium* Zenker), a " fucoid ". Meunier (1889) described, without figuring, the material noted from the Calcaire Grossier. This new form, *Spongeliomorpha saportai* Meunier, from the " Sables du Beauchamp ", above the Calcaire Grossier, differs from *S. iberica* in its more elongate form and tendency to dichotomous branching (the specimen is 22 cm. long with a diameter of 2 cm.; lateral second and third order branches are present). The surface is said to be covered by ridges more regular, parallel and uniform than in *S. iberica*. Interpretation of *Spongeliomorpha* as a sponge is supported by Reis (1910), who describes Triassic forms, and de Laubenfels (1955) who compares it to the Jurrassic form *Spongelites* Rothpletz, a genuine sponge. Darder (1945) figures " *Spongiliomorpha* " *iberica*, again from the Miocene (Burdigalian) of Alcoy, but regards it as algal, and a sexual dimorph of *Taonurus ultimus* (i.e. a *Rhizocorallium*) ! The most satisfactory explanation is that of Reis (1922) who interpreted *Spongeliomorpha* as a burrow system.

The genus *Felixium* de Laubenfels (1966), proposed to replace *Rhizocorallium* Felix (1913, non Zenker) with *R. glaseli* Felix (*gläseli* recte = *glaeseli*) as type species, appears to be a burrow, perhaps a *Spongeliomorpha*, perhaps a *Thalassinoides* fragment or even the " arm " of a *Rhizocorallium*.

Scratched burrows for which the name *Spongeliomorpha* seems suitable have been discussed and figured by Lessertisseur (1955) from the marine Hauterivian of Andon (Alpes-Maritimes, France) and Weigelt (1929) from the Jurassic and Cretaceous of Germany. Raciborski (1890) regarded *Spongia sudolica* Zareczny (1878) as a *Spongeliomorpha*; from the branching pattern it is clearly a *Thalassinoides*, possibly a synonym of *T. paradoxica* (vide p. 147).

The figured material of *Spongeliomorpha* is all in the form of small fragments. The original figured specimen agrees closely with some fragments of *Thalassinoides paradoxica* in general form, whilst the ornament of *Spongeliomorpha* and *Thalassinoides ornatus* suggests that when the branching form of *Spongeliomorpha* is better known the two names may prove synonymous. *Spongeliomorpha* is used in the present account for scratched burrows which do not show a *Thalassinoides*-like branching.

The surface ridges of *Spongeliomorpha* are regarded as having the same origin as those of *Thalassinoides*—as a result of the inhabitant digging or moving through the system. Once more, only two groups of animals seem likely to produce these markings, crustaceans and annelids. Since Weigelt (1929) has figured similar scratches on Recent crustacean burrows whilst the same ornamentation is present on the fossil crustacean burrow *Rhizocorallium* (Weigelt 1929, Abel 1935, Häntzschel 1962), a crustacean origin for *Spongeliomorpha* is clear. Similar ornamentation is also seen on the undoubted crustacean burrow *Ophiomorpha* (personal observation based on material from the English Weald Clay (Lower Cretaceous, Barremian)).

Spongeliomorpha sp.

(Pl. 7, fig. 7)

Fragments of a *Spongeliomorpha* are not uncommon in the Lower Chalk at every locality examined. By far the best locality is beneath the Totternhoe Stone at Houghton Regis. The cross section is elliptical (presumably as a result of compaction), varying between 30 by 18 mm. to 16 by 12 mm. Straight or slightly curved fragments are commonest and occur in both vertical and horizontal positions. Occasional narrow lateral branches may be present. The surface is covered by small, sharp reticulate ridges intersecting at 80 and 100 degrees. No internal structure; surface often covered with small *Chondrites* and other burrows.

In size and general form these fragments are closely comparable to *S. iberica*, differing in their less continuous ridges intersecting at a higher angle. None of the material I have seen shows the antler-like branching of the figured specimens.

OCCURRENCE. Frequent in all sections of the Lower Chalk examined.

Spongeliomorpha? annulatum ichnosp. nov.

(Pl. 2, fig. 1; Pl. 5, fig. 5; Text-fig. 6, E)

DIAGNOSIS. Cylindrical branching burrows consisting of a marl cylinder 1–2·5 cm. in diameter with a glauconitic core 5 mm. in diameter; outer surface covered by longitudinal ridges. Occurring in glauconitic sediments.

HOLOTYPE. B.M. (N.H.) T.554 from the Glauconitic Marl (Lower Cenomanian); section below the Martello Tower No. 3, Folkestone, Kent.

MATERIAL. In addition to the holotype, I have examined many hundreds of specimens from the Glauconitic Marl and Upper Greensand of Southern England.

LOCALITY AND HORIZON. Abundant in the Glauconitic Marl at all localities examined. Occurring also in glauconitic bands above the base of the Chalk and in the glauconitic basement bed of the Lower Chalk in the south-west. Very common at many localities and horizons in the Upper Greensand. Widespread in glauconitic facies of Cretaceous age all over north-west Europe (J. M. Hancock, personal communication).

DESCRIPTION. Largely horizontal, cylindrical in section with diameters between 1·0 and 2·5 cm. Branching poorly known, apparently alternate and at an acute angle (fig. 6, E). Occurring only in glauconitic sediments, the burrow consists of a glauconite-free marl cylinder with a central glauconitic core about 5 mm. in diameter. The outer surface of the marl cylinder is covered in longitudinal ridges.

DISCUSSION. For over 150 years geologists in this country have noted the presence of " stem-like " markings in the Glauconitic Marl and other glauconitic Albian and Cenomanian sediments. Webster (1814) regarded these structures as alcyonites (sponges). Reid (1898), describing the Upper Greensand near Beachy Head, Eastbourne (Sussex) mentions . . .

" curious cylindrical cavities filled with material differing somewhat from the surrounding matrix. These are perhaps made by some boring animal, though the horizontal position and closed ends often suggest rather the disappearance of buried sand-eating Holothurians."

They are perhaps the " irregular spots and veinings of white marl " noted by Jukes-Browne & Hill (1903 : 38) from the Glauconitic Marl at Folkestone (Kent), later (p. 265) described as being . . . " areas of small size—seen in the hand specimen as whitish markings or pipings are filled with fine amorphous calcareous material to the exclusion of the larger glauconite grains ". What are probably the same burrows are noted by Thomel (1961) from an Upper Albian greensand from the Alpes-Maritimes, France.

Although extremely abundant in most sections of Glauconitic Marl and Upper Greensand (tunnel densities up to 80 per 1,000 cm.^{2}), the branching pattern is poorly known. The surface ornamentation of ridges suggests reference to *Spongeliomorpha*, but because of the peculiar internal structure a new generic name may be useful for this type of burrow.

INTERPRETATION. For reasons already stated, the surface ridges of these burrows are interpreted as scratch marks produced by crustaceans. The peculiar internal structure can be interpreted as a result of the sifting of sediment into clay, silt and sand grade materials during feeding, the animal presumably living on small organisms in the coarse fraction.

Ichnogenus ***PSEUDOBILOBITES*** Lessertisseur 1955

1882 Pseudobilobites, Barrois : 175, pl. 5, fig. 5*a*, *b* (not intended as a generic name).
1955 Pseudobilobite, Lessertisseur, text-fig. 25, G.
1955 *Pseudobilobites* Barrois; Lessertisseur : 45.
1965 ,, Pseudobilobites " Barrois; Häntzschel : 75.

DIAGNOSIS. Medium sized (3–7 cm. long) rounded or oval masses of sand-grade microfossils (largely foraminifera) and shell fragments cemented by calcite, generally ironstained, due to oxidation of small quantities of pyrite present. Upper surface flat or concave, smooth or slightly granulated. Lower surface convex, convoluted, covered by groups of short parallel ridges inclined at an angle to the axis of the structure.

TYPE SPECIES. *Pseudobilobites jefferiesi* ichnosp. nov., here designated. Lower Chalk, Middle Cenomanian; Pitstone (Bucks).

DISCUSSION. The term " pseudobilobite " was first used by Barrois (1882), in a discussion of *Bilobites* (=*Cruziana*)—resting trails of trilobites, from the Palaeozoic of Northern Spain. Clearly intended as a vernacular name, he applied it to small oval masses of microfossils, the lower surfaces of which are covered in ridges, from the Lower Turonian of Séry in the Ardennes.

Lessertisseur (1955) uses the term rather ambiguously: in the explanation of his figure 25 G (a copy of Barrois 1882, pl. 5, fig. 5*a*) he uses the name in the vernacular, on page 45, the name is italicized, as are the other generic names in Lessertisseur, and Barrois is given as author, together with the reference. Clearly, it is regarded as of generic status. As already noted, Barrois regarded Pseudobilobites as a vernacular name; Lessertisseur's use as a generic name, with Barrois as author is not justified. The genus *Pseudobilobites* is, therefore, attributed to Lessertisseur 1955.

The " problematicum " of Jefferies (1962, 1963) is clearly a trace fossil of this type. Similar forms occur in the Lower Chalk and are described as *Pseudobilobites jefferiesi* ichnosp. nov., here designated type species of *Pseudobilobites.*

Pseudobilobites jefferiesi ichnosp. nov.

(Pl. 6, fig. 1; Pl. 7, fig 3; Pl. 8, fig. 4; Pl. 9, figs. 3, 4, 6)

1961 *Problematicum* sp., Jefferies, text-fig. 2.
1961 Problematicum, Jefferies : 620, 623, 624, 644, pl. 77, fig. 5.
1963 Problematicum sp., Jefferies : 7, 12, 14, 16, 17, text-fig. 2 (pars.).

Diagnosis. As for Genus.

Holotype. B.M. (N.H.) T.565. Lower Chalk, Middle Cenomanian; Pitstone (Bucks.).

Material. Paratypes, B.M. (N.H.) T.556, 566, Lower Chalk, Upper Cenomanian, 10–15 ft. below base of *plenus* Marls; below Shakespeare Cliff, Dover, Kent. Numerous other specimens from the Lower Chalk and *plenus* Marls (Sedgwick Museum, Cambridge, Jefferies collection).

Description. Small ovoid masses of sand-grade microfossils (foraminifera) and shell fragments, cemented by crystalline calcite and stained brown by limonite, derived from the decomposition of the small quantities of pyrite present in unweathered specimens. In shape, specimens vary from elongate ovals, half as wide as long, to almost circular, ranging in length between 3 and 7 cm., although larger specimens probably also occur. The outline is fairly regular, although often broken up by subsequent burrowing. Upper surface smooth or slightly granular, flat or slightly concave, lower surface convex, convoluted and irregular, covered by groups of short, parallel ridges, inclined to the long axis of the structure.

Discussion. The original specimen figured by Barrois (1882) differs from *P. jefferiesi* in having longer more continuous ridges on the (presumed) under-surface. The figure is rather indifferent and re-examination of the material may indicate that it is the same as the present form.

These structures were first recorded from the English Chalk by Jefferies (1962, 1963) who briefly described and illustrated a " problematicum " from the top of the Lower Chalk and the *plenus* Marls. Subsequent collecting shows that they are common throughout the whole of the Lower Chalk, and also occur in the Melbourn Rock at the base of the Middle Chalk. Specimens show great shape variation in both outline, thickness and convexity, but form a quite distinctive group of trace fossils.

In thin section, the constituents are clearly the coarse fraction of the chalk. Foraminifera are abundant, ostracods, shell and echinoid debris plus small masses of collophane (? faecal pellets) make up the remainder, with a calcitic cement. Burrows passing through these structures suggest they were soft when buried, and that they are not of diagenetic origin (Pl. 9, fig. 6). Occasionally, internal laminations are present. *Pseudobilobites* clearly represents a type of activity like that which produced what I have called " laminated structures ". The prominent ridges on the base I would interpret here, as elsewhere, as scratch marks, indicative of crustaceans. Grouping in threes, fours or fives represents either the co-ordinated movement of appendages, or movement of a single appendage with several claws. From an examination of these structures in situ, they appear to be a surface trace. I have never seen a convincing example in a burrow, although the possibility cannot be overlooked.

This type of structure could result from the feeding activities of an animal sifting chalk for the fine fraction, ingesting this and leaving the coarse debris behind. The lower, scratched surface, represents the extent of foraging, the concave upper surface is perhaps an expression of the position of the body during feeding.

Not all the segregations of coarse debris in the Lower Chalk belong to this form, some (including, in part, some of the " problematicum " recorded by Jefferies (1961, 1963)) represent the partial or total filling of vertical and horizontal cylindrical burrows (a typical fragment is represented in Pl. 6, fig. 2). This type of filling probably represents the same type of activity. They sometimes occur closely associated with " laminated structures " (Pl. 8, fig. 3) and may be the product of the same animal, although separate occurrences show that these could be chance associations.

P. jefferiesi is widespread and common in the Lower Chalk and *plenus* Marls, also occurring in the Melbourn Rock (Lower Turonian).

***Keckia*(?) sp.**

1911 *Keckia* (?) sp., Bather : 553, pl. 24, fig. 1.

Bather's account of this form is excellent, as is his illustration. Having seen no other material, I can add nothing to his account. The nature and interpretation of *Keckia* has been discussed by Häntzschel (1938) and by Richter (1947).

" *Terebella* " *cancellata* Bather

(Pl. 8, figs. 1, 2)

1897 *Terebella lewesiensis* (Mantell) Davies; 145–148 (pars.).
1911 " *Terebella* " *cancellata* Bather : 551–553, 556, pl. 24, figs. 3, 4, No. 5.

Diagnosis. " Tube from which the (?gelatinous or mucilaginous) wall has disappeared, leaving on the internal cast an obscure cancellate ornament formed by transverse and longitudinal folds; with diameters from about 0·75 to 2 cm. and with a possible length of 19 cm. or more " (Bather 1911).

Holotype. B.M. (N.H.) 58253, Lower Chalk, Glynde, Sussex, figured here as Plate 8, fig. 1.

Discussion. Bather's description of this " Terebellid " is excellent, but I believe his interpretation to be erroneous. "*Terebella*" *cancellata* is clearly a burrow; material agreeing with the holotype and the holotype itself all appears to represent poorly preserved burrows of a type agreeing with what I have called *Spongeliomorpha* sp. The surface depressions described by Bather (1911) are the result of rather poorly preserved intersecting ridges (i.e. scratches). The paratype specimen, B.M. (N.H.) 1574 (Pl. 8, fig. 2) clearly belongs to a different form and is described below, as burrow type D.

From a re-examination of the holotype of "*Terebella*" *harefieldensis* White (White 1923), here figured for the first time, as Plate 7, fig. 2, it is clearly identical with crustacean " burrows " figured by Weigelt (1929), from a similar occurrence in Germany. *T. harefieldensis* is not a true burrow; excavated in hard chalk, below the sub-Tertiary erosion surface it is to be regarded as a boring. From its widespread distribution (Hester 1965, text-fig. 2) recognition as a crustacean boring may give this form value as a palaeogeographic indicator. No generic name appears to be available for this type of boring.

V. OTHER BURROWS

The forms described above constitute only a part of the trace fossil assemblage of the Lower Chalk. Some of the more obvious burrows, too poor for detailed study are noted below.

Burrow Type A

(Text-fig. 6, b, c)

Description. Burrow system made up of four vertical cylindrical shafts between 6 and 12 cm. long, widening downwards, connected by a horizontal tunnel 16–30 cm. long. Tunnel diameters about 2 cm.

Discussion. I have seen only two complete systems of this type. The systems originate at the bases of marls, piping down into the limestones below. The nature of the openings is not clear, but the vertical shafts increase in diameter away from the surface and are at their widest just above the junction with the horizontal tunnel. The spacing of shafts is identical in both examples I have seen: one shaft lies at each end, the other two are equidistant from each other, but one is separated from the end by nearly twice the distance separating the two inner shafts.

I have seen no descriptions or figures agreeing with these systems, and in view of the identical form of the two examples, I am inclined to regard this as a new form.

The most similar described system is that of *Pholeus abomasiformis* Fiege (Fiege 1944, Häntzschel 1962, 1965) from the Trias (Muschelkalk) of North Germany. *Pholeus* differs from the present form in the absence of intermediate shafts and the presence of a swollen horizontal chamber. *Pholeus* is regarded as a decapod crustacean burrow. The burrow of the living crustacean *Cambarus carolinus* Erichsen (Fiege 1944, fig. 3) is again similar but a swollen portion (" living chamber ") is present.

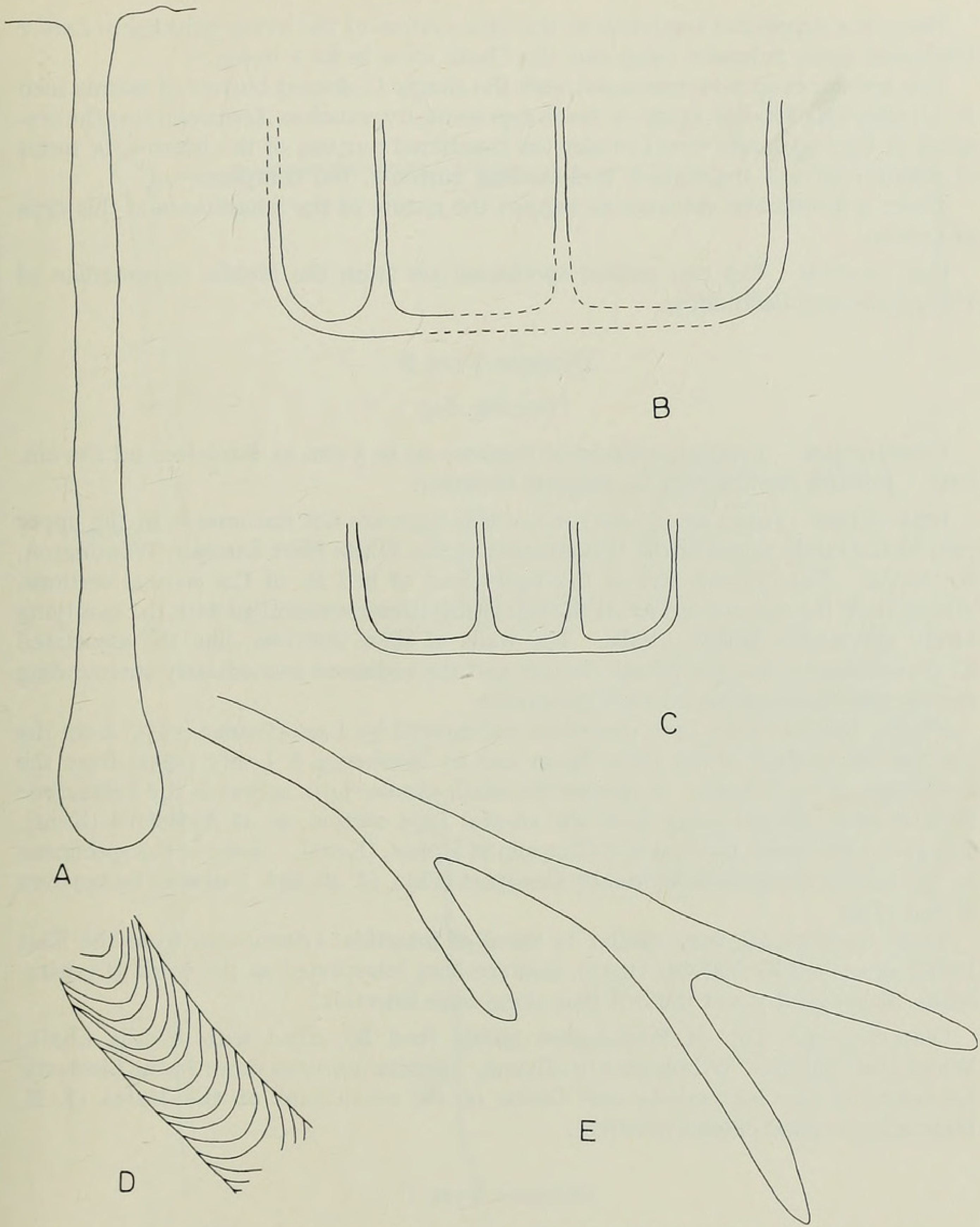

FIG. 6. A, Burrow type B, Top of Wilmington Sands, filled by the overlying Middle Chalk; White Hart Sandpit, Wilmington, S. Devon. Vertical section, $\times \frac{1}{8}$. B, C, Burrow type A, Lower Chalk, Middle Cenomanian. B, Folkestone, Kent, C, Eastbourne, Sussex. Both vertical sections, $\times \frac{1}{4}$. D, *Thalassinoides* sp. Lower Chalk, Middle Cenomanian; Hunstanton, Norfolk. Plan, showing septate internal filling. $\times$ I. E, *Spongeliomorpha? annulatum* ichnosp. nov. Upper Greensand; Cow Gap, Eastbourne, Sussex. Plan, $\times \frac{1}{2}$.

There is a superficial similarity to the tube system of the living polychaete *Lanice* (Seilacher 1951, Schaefer 1962) but the Chalk form lacks a lining.

This system cannot be compared with the simple U-shaped burrow of worms such as *Urechis* (MacGinitie 1928) or fossil representatives such as *Arenicolites*, as the presence of four openings would render the functional purpose of the burrow, in terms of maintenance of respiratory and feeding currents, too complex.

There is insufficient evidence to suggest the nature of the inhabitants of this type of system.

OCCURRENCE. The two perfect specimens are from the Middle Cenomanian of Folkestone and Eastbourne.

BURROW TYPE B

(Text-fig. 6A)

DESCRIPTION. Vertical, cylindrical burrows up to 5 cm. in diameter and 100 cm. long. Bottom swollen into an elongate chamber.

DISCUSSION. Large simple burrows of this type are not uncommon in the upper part of the sandy facies of the Cenomanian at the White Hart Sandpit, Wilmington, S. Devon. The burrows are in the equivalent of bed B. of the coastal sections, arising from the erosion surface at the top of this division and filled with the overlying sandy glauconitic Middle Chalk. The walls of these burrows, like the associated *T. paradoxica* have a phosphatic veneer and the sediment immediately surrounding the burrows is impregnated with glauconite.

Similar burrows have been described and figured by Lessertisseur (1955) from the Eocene (Bartonian) of the Paris Basin and by Maubeuge & Lanly (1952) from the Bathonian of the Vosges. A similar but much smaller form occurs in the Folkestone Beds (Lower Albian) away from the coastal type section, as at Aylesford (Kent), and in the Woolwich Bottom Bed (Eocene) at Upnor, (Kent). Some of the specimens of *Cylindrites spongioides* figured by Goeppert (1842, pl. 46, figs. 1–4) may be burrows of this type.

These burrows are very similar to those of intertidal crustaceans from the East Indies described by Verwey (1930), and are here interpreted as the work of crustaceans, although it is not implied that these were intertidal.

OCCURRENCE. Top of Wilmington Sands (bed B), filled with Middle Chalk; White Hart Sandpit, Wilmington, S. Devon. Similar burrows occur in the bioclastic Santonian of the Sudmerberg near Goslar on the north flank of the Hartz (J. M. Hancock, personal communication).

BURROW TYPE C

(Text-fig. 7)

DESCRIPTION. Long, straight or slightly flexed, very narrow cylindrical burrows up to 40 cm. long and between 1 and 10 mm. in diameter. Both vertical and horizontal elements occur, the latter often much narrower than the vertical part, from

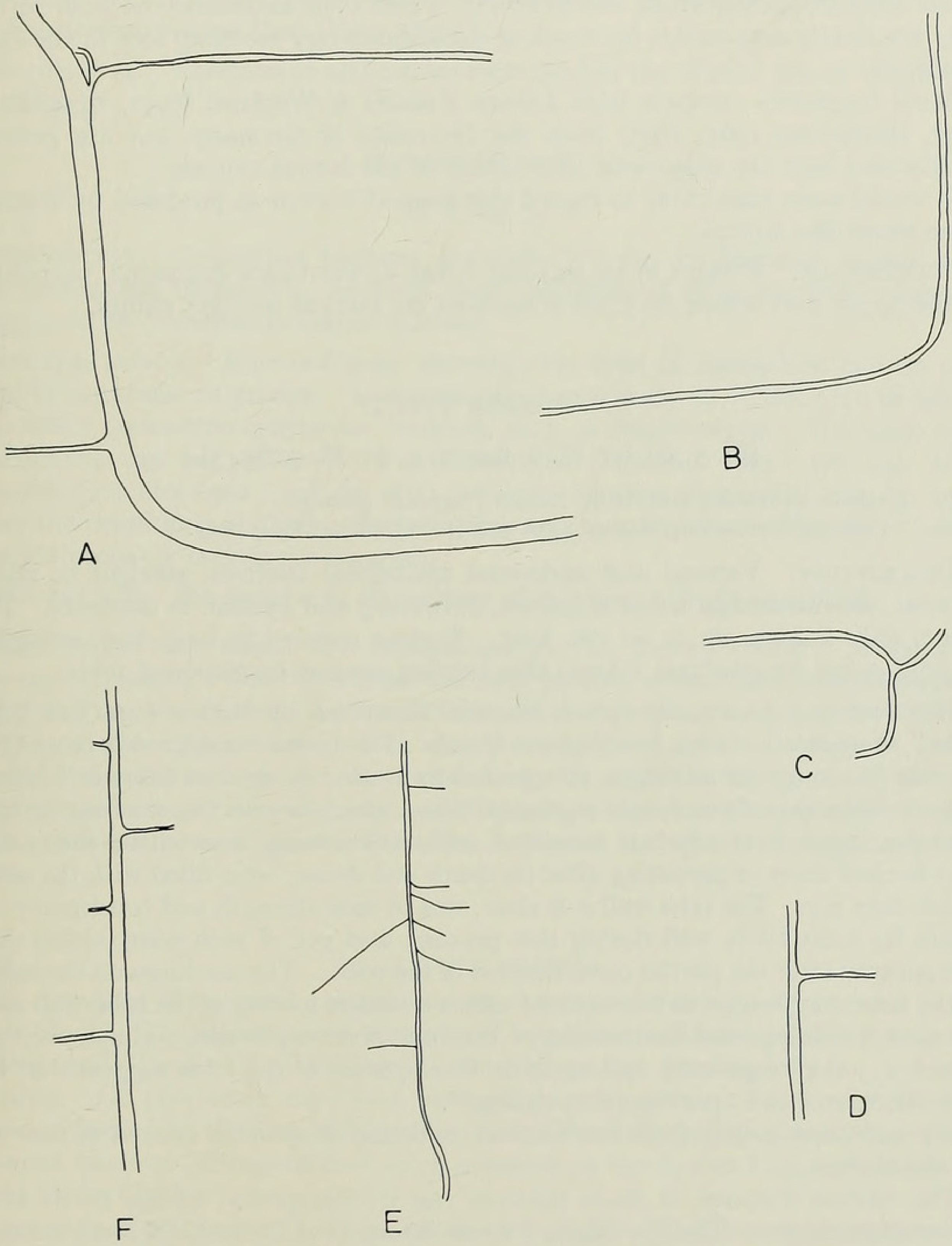

FIG. 7. Burrow type C. A–D, Lower Chalk, Middle Cenomanian; Glynde, Sussex. E–F, Lower Chalk, Upper Cenomanian; Dorking, Surrey. All specimens in relief on vertical solution planes. All $\times \frac{1}{4}$.

which they branch off at right angles. Some of these burrows curve round to a horizontal position and have tunnels 10–25 cm. long.

Discussion. Burrows of this type are best seen on vertical solution planes, where they frequently stand out in relief. From their abundance on such surfaces they are clearly responsible for much of the sedimentary mottling seen in the Lower Chalk.

Some fragments compare with *Lennea* Kräusel & Weyland (1932, 1934, Paulus 1957, Häntzschel 1962, 1965) from the Devonian of Germany, but are generally smaller and lack the diagnostic bifurcation of the lateral tunnels.

It would seem reasonable to regard this form of burrow as produced by worms or some worm-like animal.

Occurrence. Present in all sections in the Lower Chalk examined, particularly in the upper part where they are prominent on vertical solution planes.

Burrow Type D

(Pl. 5, fig. 4; Pl. 7, figs. 1, 4, 5; Pl. 9, fig. 5)

1897 *Terebella lewesiensis* (Mantell); Davies : 145–148 (pars.).
1911 "*Terebella*" *cancellata* Bather : 551–553 (pars.), pl. 24, fig. 5 only.

Description. Vertical and horizontal cylindrical burrows, straight or slightly sinuous, unbranched so far as is known, between 5 and 25 mm. in diameter. Fragments only known, up to 20 cm. long. Surface covered in long, fine, straight or slightly spiral longitudinal ridges, also bearing coarser longitudinal folds.

Discussion. As already noted, material described by Bather (1911) as "*Terebella*" *cancellata* includes two distinct forms. The forms considered here are those bearing fine longitudinal ridges, interpreted by Bather (p. 552) as follows: " It seems quite certain that these fossils represent tubes, which lay on the sea-floor or in the semi-floating ooze of which it consisted, and, either being deserted by the creature that formed them or persisting after its death and decay, were filled with the ooze in which they lay. The tube wall it is clear, was of such strength and consistency as to retain its form fairly well during this process, and yet of such composition that it disappeared after the partial consolidation of the ooze. The markings on the infilling of the tube may be due to two causes; either a similar folding of the tube-wall during life or a wrinkling and contraction of the tube after death and perhaps even after burial. . . . the irregularity and variable development of the folds suggest that they, at least, were due to post-mortem change ".

My own view is that these are burrows, and that they never existed as free tubes on the surface.

The surface features of these burrows can be interpreted as the result of two different processes. The fine ridges, I would interpret as the result of some worm-like animal passing through sediment, the ridges arising from bristles or appendages, or even grains of sediment stuck on the body. The longitudinal folds have a quite different origin and appear to be post-depositional compaction effects.

Clearly, there is no similarity to the reticulate surface ornamentation of the holotype of " *Terebella* " *cancellata*.

A rather similar ornamentation is present on the " fucoids " *Gyrolithes dewalquei* Saporta (Saporta 1884) *Codites neocomiensis* Saporta & Meunieur (Saporta 1882) and *Cylindrites rimosus* Heer (Heer 1877).

OCCURRENCE. Common in all sections examined in the Weald, Isle of Wight and Chilterns.

BURROW TYPE E

(Pl. 2, fig. 3)

DESCRIPTION. Cylindrical burrows, generally 1–2 cm. in diameter, known only from unbranched fragments. Sections show the filling of these burrows is septate, being made up of meniscus-shaped laminae.

INTERPRETATION. Burrow-fillings showing this type of lamination can be produced by a number of groups. *Thalassinoides* occasionally show this type of filling, as do other undoubted crustacean burrows, such as *Ophiomorpha*. The same type of structure can be produced by coelenterates (Schaefer 1962 : 326, fig. 165), echinoids (Schaefer 1962 : 348, fig. 183) and some bivalves (Schaefer : 424, fig. 223). Under the conditions of chalk sedimentation, and by comparison with other forms, these are probably crustacean burrows.

OCCURRENCE. Uncommon in all sections of the Lower Chalk examined.

Many other trace fossils are represented in the Lower Chalk. " *Terebella* " *lewesiensis* (Mantell), worm tubes lined with fish, plant or echinoderm debris should be interpreted as trace fossils, as should the micro-coprolites described by Wilcox (1953) from the Upper Chalk, which also occur in the Lower. Borings, in shells, pebbles and rock surfaces are very abundant. In addition to species of *Cliona*, other sponge borings (*Filuroda*), algal and fungal perforations (*Calcidelectrix, Dictyoporus*), cirripede bores (*Zapfella, Rogerella*), bryozoan borings and bivalve crypts all occur.

VI. CONCLUSIONS

The activities of burrowing organisms are shown to be universally present in the Lower Chalk. The most obvious are those of crustaceans (*Thalassinoides, Spongeliomorpha*) and " worms " (*Chondrites*). Several poorly known burrows are also described. Of previously described assemblages, the present one compares best with the Lower Lias (Hallam 1961), where both *Chondrites* and *Thalassinoides* occur. U-shaped burrows (*Rhizocorallium* etc.), common in the Lower Lias, are, however, absent in the Chalk.

A problem of the Lower Chalk fauna, in view of the abundance of burrows, is the absence or great rarity of the animals responsible. With worms, disappearance of the soft body is readily understood, but the absence of crustaceans demands explanation. The crustacean fauna of the Lower Chalk is very limited. By far the most abundant form is the large, lobster-like *Enoploclytia*, though the very massive claws and thick, thorny carapace suggest that it did not burrow. The only other macrurous crustacean I have seen is *Glyphea willeti* (Woodward), which, in view of the thin, rather delicate exoskeleton, could well have burrowed. In size, it would fit some of the larger *Thalassinoides*, but it is rare. Callianassids, recorded in association with *Thalassinoides* elsewhere, appear to be totally absent from the Lower Chalk facies of the Cenomanian, although a " *Callianassa* " sp. is present in division A of the Cenomanian Limestone of S. Devon. Hume (1897) records a *Callianassa* sp. as occurring commonly in the Upper Glauconitic Beds (Cenomanian) at Colin Glen, Co. Antrim. Callianassids also occur in the Upper Greensand of the Devon Coast (matrix of museum specimens suggests the Top Sandstones) and the Gault.

Brachyurous crustaceans are equally rare; a few specimens of *Diaulax* and *Necrocarcinus* are known from the Lower Chalk, whilst crabs are not uncommon in the sandy facies of the Cenomanian, particularly at Wilmington. In all, the known crustacean remains give few clues to the identity of the burrowers. A possible explanation of absence is suggested by recent burrowing forms which have a thin, sometimes even transparent exoskeleton, very poorly calcified. Sloughs are generally removed from burrows, whilst moribund individuals leave their burrows prior to death.

Under these conditions it seems possible that on the Lower Chalk sea floor the organically-rich remains were completely eaten or destroyed by scavengers and micro-organisms prior to burial.

VII. ACKNOWLEDGMENTS

I am grateful to Dr. J. M. Hancock and Dr. J. D. Taylor for reading the manuscript of this paper and for making many helpful suggestions. I have profited from discussions with Dr. R. Bromley, Dr. C. V. Jeans, Dr. R. P. S. Jefferies and many others; Mr. P. Palmer kindly provided me with photographs of the types of *Terebella cancellata* and *T. harefieldensis*; Mr. R. Cleevely has aided me greatly in finding some of the more obscure literature. Dr. H. W. Ball, Mr. S. Ware and Dr. C. L. Forbes have kindly allowed me to examine material in their care, whilst Dr. Jefferies has generously allowed me to work on his collection, now in the Sedgwick Museum. Mr. B. McWilliams of the Norwich Castle Museum searched the collections for type material of *T. paradoxica*. Preparation of illustrations by the Technical Staff of King's College, under the direction of Mr. E. O. Rowlands is acknowledged, particularly the assistance of Miss M. Baker in preparation of the plates. I am deeply grateful to my parents for their encouragement and assistance.

Part of the work was carried out under the tenure of a N.E.R.C. grant, which is gratefully acknowledged.

VIII. REFERENCES

Abel, O. 1935. *Vorzeitliche Lebensspuren*. 644 pp., 530 figs. Jena.

Andert, H. 1934. Die Kreideablagerungen zwischen Elbe und Jeschken. III. Die Fauna der Obersten Kreide in Sachsen, Böhmen und Schlesien. *Abh. preuss. geol. Landesanst.*, Berlin, **159** : 1–477, pls. 1–21.

ANDREWS, H. N. 1955. Index of Generic Names of Fossil Plants 1820–1950. *Bull. U.S. Geol. Surv.*, Washington, **1013** : 1–262.

ARKELL, W. J. 1935. The Portland Beds of the Dorset Mainland. *Proc. Geol. Assoc.*, London, **46** : 301–347, pls. 19–26.

BARROIS, C. 1882. Recherches sur les terrains anciens des Asturies et de la Galicie. *Mém. Soc. Géol. Nord*, Lille, **2** : 1–630, pls. 1–20.

BATHER, F. A. 1911. Upper Cretaceous Terebelloids from England. *Geol. Mag.*, London (5) **8** : 481–487, 549–556, pl. 24.

BILLINGHURST, S. A. 1927. On some New Ammonoidea from the Chalk Rock. *Geol. Mag.*, London, **64** : 511–518, pl. 16.

BLACK, M. 1953. The Constitution of the Chalk. *Proc. geol. Soc. Lond.*, **1499** : 81–86.

BLACK, M. & BARNES, B. 1959. The Structure of Coccoliths from the English Chalk. *Geol. Mag.*, London, **96** : 321–328, pls. 8–12.

BLAKE, J. F. & HUDLESTON, W. H. 1877. On the Corallian Rocks of England. *Quart. Jl. geol. Soc. Lond.*, **33** : 260–405, pls. 12–17.

BURNABY, T. P. 1962. The Palaeoecology of the Foraminifera of the Chalk Marl. *Palaeontology*, London, **4** : 599–608.

CAYEUX, L. 1897. Contribution à l'étude micrographique des terrains sédimentaires. II. Craie du Bassin de Paris. *Mém. Soc. Géol. Nord*, Lille, **4** : 206–563, pls. 9, 10.

DALES, R. P. 1957. Interrelations of organisms. A. Commensalism. *In* Hedgepeth, J. W. (Ed.) *Treatise on Marine Ecology and Palaeoecology*, **1**, Ecology *Mem. Geol. Soc. Amer.*, **67** : 391–412, pl. 1.

DARDER, B. 1945. Estudio geológico del Sur de la Provincia de Valencia y Norte de la de Alicante. *Bol. Inst. Min. Geol. España*, Madrid, **57** : 59–362, pls. 1–11.

DAVIDSON, C. 1891. On the amount of sand brought up by Lobworms to the surface. *Geol. Mag.*, London (3) **8** : 489–493.

DAVIES, W. 1879. On some Fish Exuviae from the Chalk, generally referred to *Dercetis elongatus*, Ag.: and on a New Species of Fossil Annelide, *Terebella Lewesiensis*. *Geol. Mag.*, London (2) **6** : 145–148.

DETTMER, F. 1912. *Spongites saxonicus* Geinitz und die Fucoidenfrage. *Neues Jb. Min. Geol. Paläont.*, Stuttgart, **1912** : 114–126, pls. 8, 9.

—— 1914. Die *Spongites-saxonicus*—Frage. *Sitz.-Ber. u. Abh. naturwiss. Gesellsch. ' Isis '*, Dresden, **1913** : 50–54.

—— 1915. Neus zum Fucoidenproblem. *Centralbl. Min. Geol. Pal.*, Stuttgart, **1915** : 285–287, 1 fig.

EHRENBERG, K. 1938. Bauten von Decapoden (*Callianassa* sp.) aus dem Miozän (Burdigal) bei Eggenburg im Gau Nieder-Donau (Niederösterreich). *Paläont. Z.*, Berlin, **20** : 263–284, pls. 27–29.

—— 1944. Ergänzende Bemerkungen zu den seinerzeit aus dem Miozän von Burgschleinitz beschriebenen Gangkernen und Bauten dekapoder Krebse. *Paläont. Z.*, Berlin, **23** : 354–359.

EICHWALD, E. D' 1865. *Lethaea Rossica* **2**, 1, *Periode Moyenne*. 640 pp. Stuttgart.

ELLENBERGER, F. 1946. Observations nouvelles sur la craie jaune à tubulures de Meudon. *C.R. Soc. Géol. Fr.*, Paris, **1946,** 11 : 202–204.

—— 1947. Le problème lithologique de la craie de Meudon. *Bull. Soc. Géol. Fr.*, Paris (5) **17** : 255–274.

ESPER, E. J. C. 1799. *Die Pflanzenthiere.* In *Abbildungen nach der Natur mit Farben erleuchtet nebst Beschreibungen*, **2**, 12 : 221–304, pls. Nuremberg.

FARROW, G. E. 1966. Bathymetric zonation of Jurassic trace fossils from the coast of Yorkshire, England. *Palaeogeography, Palaeoclimatol., Palaeoecol.*, **2** : 103–151, pls. 1–7.

FELIX, J. 1913. Über ein cretaceisches Geschiebe mit *Rhizocorallium Gläseli* n. sp. aus dem Diluvium bei Leipzig. *Sitz.-Ber. naturf. Ges. Leipzig*, **39** : 19–25, 37, pl. 1.

FERGUSON, L. 1965. A note on the emplacement of sediment in the trace-fossil *Chondrites*. *Proc. geol. Soc. Lond.*, **1622** : 79–82, fig. 1.

FIEGE, K. 1944. Lebensspuren aus dem Muschelkalk Nordwestdeutschlands. *Neues Jb. Min., Geol., Paläont.*, Stuttgart (B) **88** : 401–426, 6 figs.

FISHER, W. K. & MACGINITIE, G. E. 1928. The natural history of an echiuroid worm. *Ann. Mag. Nat. Hist.*, London (10) **1** : 204–213, pl. 1.

FRIČ, A. 1878. Studien im Gebiete der böhmischen Kreideformation. II. Die Weissenberger und Malnitzer Schichten. *Arch. naturw.Landesdurchf. Böhm.*, Prague, **4**, 1 : 1–151.

GEINITZ, H. B. 1839–42. *Charakteristik der Schichten und Petrefacten des sächsisch-böhmischen Kreidegebirges.* 116 pp., 24 pls. Dresden & Leipzig.

—— 1871–75. Das Elbthalgebirge in Sachsen. *Palaeontographica*, Stuttgart, **20** : 1–319, pls. 1–67.

GIGNOUX, M. 1926. *Géologie Stratigraphique.* vi + 588 pp., 124 figs. Paris.

GLAESSNER, M. F. 1947. Decapod Crustacea (Callianassidae) from the Eocene of Victoria. *Proc. R. Soc. Vict.*, Melbourne, **59** : 1–7, pls. 1, 2.

GMELIN, J. F. 1793. *C. a. Linne . . . Systema Naturae . . . Editio decima tertia aucta reformata cura J. F. Gmelin,* **3**. 476 pp., 3 pls. Lipsiae.

GOEPPERT, H. R. 1842. Über die fossile Flora der Quadersandsteinformation in Schlesien, als erster Beitrag zur Flora der Tertiärgebilde. *Nova Acta Caes. Leop.–Carol.*, Breslau & Bonn, **19**, 2 : 97–134, pls. 46–53.

—— 1847. Zur Flora des Quadersandsteins in Schlesien als Nachtrag zu der früher erschienenen Abhandlung über denselben Gegenstand. *Nova Acta Caes. Leop.–Carol.*, Breslau & Bonn, **22**, 1 : 356–365, pls. 35–38.

—— 1854. Quadersandsteinformation insbesondere über *Cylindrites spongioides* m. *Verh. nat. Ver. preuss. Rheinlande u. Westph.* (N.F.) **11** : 229–234, pl. 3.

HALLAM, A. 1961. A sedimentary and faunal study of the Blue Lias of Dorset and Glamorgan. *Phil. Trans. R. Soc.*, London (B) **243** : 1–44, pls.

HANCOCK, J. M. 1963. The hardness of the Irish Chalk. *Irish Nat. J.*, Belfast, **14** : 157–164.

HÄNTZSCHEL, W. 1934. Schraubenförmige und spiralige Grabgänge in turonen Sandsteinen des Zittauer Gebirges. *Senckenbergiana*, Frankfurt am Main, **16** : 313–324, 4 figs.

—— 1935. *Xenohelix saxonica* n. sp. und ihre Deutung. *Senckenbergiana*, Frankfurt am Main, **17** : 105–108.

—— 1938. Quer–Gliederung bei *Littorina*-Fährten, ein Beitrag zur Deutung von *Keckia annulata* Glocker. *Senckenbergiana*, Frankfurt am Main, **20** : 297–304, 6 figs.

—— 1952. Die Lebensspuren von *Ophiomorpha* Lundgren im Miozän bei Hamburg, ihre weltweite Verbreitung und Synonymie. *Mitt. Geol. Staats inst. Hamburg*, **21** : 142–153, pls. 13, 14.

—— 1962. Trace fossils and Problematica. *Treatise on Invertebrate Paleontology*, Part W : 177–245, figs. 109–149. New York.

—— 1964. Spurenfossilien und Problematika im Campan von Beckum(Westf.). *Fortschr. Geol. Rheinl. Westf.*, Krefeld, **7** : 295–308.

—— 1965. *Fossilium Catalogus* 1 : Animalia, Pars. **108**, Vestigia Invertebratorum et Problematica. 140 + 2 pp. s' Gravenhage.

HEER, O. 1877. *Flora Fossilis Helvetiae. Die vorweltliche Flora der Schweiz.* 182 pp., 70 pls. Zürich.

HESTER, S. W. 1965. Stratigraphy and Palaeogeography of the Woolwich and Reading beds. *Bull. Geol. Surv. G.B.*, London, **23** : 177–137, pl. 10.

HUGHES, T. M. 1884. On the so-called *Spongia paradoxica* (S. Woodward) from the Red and White Chalk at Hunstanton. *Quart. Jl. geol. Soc. Lond.*, **40** : 273–279.

HUME, W. F. 1893. *Chemical and Micro-mineralogical Researches on the Upper Cretaceous Zones of the South of England.* 103 pp. London.

—— 1897. The Cretaceous Strata of County Antrim. *Quart. Jl. geol. Soc. Lond.*, **53** : 540–606, pls. 44, 45.

JEFFERIES, R. P. S. 1962. The Palaeoecology of the *Actinocamax plenus* subzone (Lowest Turonian) in the Anglo–Paris Basin. *Palaeontology*, London, **4** : 609–647, pls. 77–79.

JEFFERIES, R. P. S. 1963. The Stratigraphy of the *Actinocamax plenus* subzone (Turonian) in the Anglo–Paris Basin. *Proc. Geol. Ass.*, London, **74** : 1–33, pls. 1, 2.

JUKES-BROWN, A. J. & HILL, W. 1900. The Cretaceous Rocks of Britain. Vol. I—Gault and Upper Greensand. *Mem. Geol. Surv. U.K.*, London. xiv + 499 pp., 5 pls.

—— 1903. The Cretaceous Rocks of Britain. Vol. 2.—The Lower and Middle Chalk of England. *Mem. Geol. Surv. U.K.*, London. xiii + 556 pp., 8 pls.

—— 1904. The Cretaceous Rocks of Britain. Vol. 3—The Upper Chalk of England. *Mem. Geol. Surv. U.K.*, London. x + 566 pp., pl. 9.

KEIJ, A. J. 1965. Miocene trace-fossils from Borneo. *Paläont. Z.*, Stuttgart, **39** : 220–228, pls. 28, 29.

KENNEDY, W. J. 1967. Field meeting at Eastbourne, Sussex. *Proc. Geol. Ass.*, London, **77** : 365–370.

KILPPER, K. 1962. *Xenohelix* Mansfield 1927 aus der miozänen niederrheinischen Braunkohlenformation. *Paläont. Z.*, Stuttgart, **36** : 55–58, pl. 7.

KRÄUSEL, R. & WEYLAND, H. 1932. Pflanzenreste aus dem Devon, II. *Senckenbergiana*, Frankfurt am Main, **14** : 185–190.

—— 1934. *Lennea schmidti*, eine pflanzenähnliche Tierspur aus dem Devon. *Paläont. Z.*, Berlin, **16** : 95–102, pls. 7–11.

LAMBRECHT, F. 1927. Schichtenfolge und Oberflächenformen im Winterberggebiete des Elbsandsteingebirges. *Mitt. Ver. Erdk.*, Dresden (N.F.) **1927** : 1–48.

LAUBENFELS, M. W. DE 1955. Porifera : *Treatise on Invertebrate Paleontology*, Part E : 21–112, figs. 14–89. New York.

LESSERTISSEUR, J. 1955. Traces fossiles d'activité animale et leur significance paléobiologique. *Mém. Soc. Géol. Fr.*, Paris (n.s.) **74** : 1–150, pls. 1–11.

MACGINITIE, G. E. 1930. The Natural History of the Mud Shrimp *Upobegia pugettensis* Dana. *Ann. Mag. Nat. Hist.*, London (10) **6** : 36–44, pls. 1–3.

—— 1934. The Natural History of *Callianassa californiensis* Dana. *Amer. Midl. Nat.*, Notre Dame (Indiana), **15** : 166–177, pls. 5, 6.

MANTELL, G. A. 1822. *The fossils of the South Downs.* 320 pp., 43 pls. London.

—— 1833. *The Geology of the South-East of England.* xix + viii + 415 pp., 7 pls. London.

MARLIÈRE, R. 1933. De nombreux bancs phosphatés dans la craie à *Actinocamax quadratus* du basin de Mons. *Ann. Soc. géol. Belg.*, Bruxelles, **56** : 289–301, pls. 1, 2.

MAUBEUGE, P. L. & LANLY, R. 1952. Sur un problématica du Bathonien moyen de la région de Neufchâteau. *Bull. Soc. Sci. Nancy*, **11** : 122–124, fig.

MERTIN, H. 1941. Decapode Krebse aus dem subhercynen und Braunschweiger Emscher und Untersenon sowie Bemerkungen über einige verwandte Formen in der Oberkreide. *Nova Acta Leop.-Carol.*, Halle (Saale), **10**, 68 : 149–262, pls. 1–8.

MEUNIER, S. 1889. Sur La *Spongeliomorpha saportai* espéce nouvelle parisienne *C.R. Acad. Sci. Paris*, **109** : 536–537.

MOORE, H. B. 1932. Faecal pellets of the Anomuran Crustacea. *Proc. Roy. Soc. Edinb.*, **52** : 296–308.

—— 1939. Faecal pellets in relation to Marine deposits. *In* Trask, P. D., *Recent Marine Sediments, A symposium* : 516–524, fig. 1. Tulsa.

OOSTING, C. H. 1925. Report on a collection of recent shells from Obi and Halmaher (Mollucas). *Meded. Landb. Hoogensch. Wageningen.*, **29** : 1–363.

OTTO, E. V. 1852. *Additamente zur Flora des Quadergebirges in der Gegend um Dresden und Dippoldiswalde, enthaltend meist noch nicht oder wenig bekannte fossile Pflanzen.* 29 pp., 12 pls. Dippoldiswalde.

PAULUS, B. 1957. Das Spurenfossil *Lennea schmidti* im Devon der Eifel. *Senckenberg. leth.*, Frankfurt am Main, **38** : 169–175, pl. 1.

PEAKE, N. B. & HANCOCK, J. M. 1961. The Upper Cretaceous of Norfolk. *Trans. Norfolk Norw. Nat. Soc.*, Norwich, **19** : 293–339, pl. 1.

POČTA, P. 1885. Beiträge zur Kenntnis der Spongien der böhmischen Kreideformation. *Abh. böhm. Ges. Wiss.*, Prague, **3** : 1–40.

Pohl, M. E. 1946. Ecological Observations on *Callianassa major* Say at Beaufort, North Carolina. *Ecology*, Brooklyn, **27** : 71–80.

Prescher, H. 1954. Sedimentpetrographische Untersuchungen oberturoner Sandsteine im Elbsandsteingebirge. *Freiberger Forschungsh.*, C **11** : 1–96, 28 figs.

Pruvost, P. & Pringle, J. 1924. Excursion to the Boulonnais. *Proc. Geol. Ass.*, London, **35** : 56–67, pls. 5–7.

Purdy, E. G. 1964. Sediments as Substrates. *In* Imbrie, J. & Newell, J. *Approaches to Palaeoecology* : 238–271, 16 figs. New York.

Raciborski, M. 1890. *Taonurus ultimus* Sap. in Galizien. *Verh. k. k. geol. Reichsanst.*, Wien, **1890** : 265–266.

Reid, C. 1898. The Geology of the Country around Eastbourne. *Mem. Geol. Surv. U.K.*, London. iv + 15 pp., 18 figs.

Reis, O. M. 1910. Beobachtungen über Schichtenfolge und Gesteinsausbildungen in der fränkischen Trias. I. Muschelkalk und untere Lettenkohle. *Geognost. Jahresh.*, München, **22** : 1–258, pls. 1–11.

—— 1922. Über Bohrröhren in fossilen Schalen und über *Spongeliomorpha*. *Z. deutsch. geol. Ges.*, Berlin, **73** : 227–237, pl. 7.

Richter, P. B. 1909. *Beiträge zur Flora der unteren Kreide Quedlinburgs. Teil II. Die Gattung* Nathorstiana *P. Richter und* Cylindrites spongioides *Goeppert.* 12 pp., pls. 8–12. Leipzig.

Richter, R. 1947. *In* O. Wilkens, Palaontologische und geologische Ergebnisse der Reise von Kohl-Larsen (1928–29) nach Süd Georgien. *Abh. senckenberg. naturf. Ges.*, Frankfurt, **474** : 75, 9 pls.

Rieth, A. 1932. Neue Funde Spongeliomorpher Fucoiden aus dem Jura Schwabens. *Geol.-Paläont. Abh.*, Jena, **19** : 257–294, pls. 13–17.

Rios, J. M. & Hancock, J. M. 1961. Summer Field Meeting in the Spanish Pyrenees. *Proc. Geol. Ass.*, London, **72** : 373–390, pls. 15, 16.

Rose, C. B. 1835–6. A sketch of the Geology of West Norfolk. *Phil. Mag.*, London (3) **7** : 171–182, 274–279, 370–376; **8** : 28–42.

Saporta, G. de 1882. *A propos des algues fossiles.* 82 pp., 9 pls. Paris.

—— 1884. *Les organismes problématiques des anciennes mers.* 100 pp., 13 pls. Paris.

—— 1887. Nouveaux documents relatifs aux organismes problématiques des anciennes mers. *Bull. Soc. Géol. Fr.*, Paris (3) **15** : 286–302, pls. 3–7.

Schaefer, W. 1962. *Aktuo-Paläontologie nach Studien in der Nordsee.* 666 pp., 36 pls. Frankfurt am Main.

Schlotheim, E. F. Baron v. 1820. *Die Petrefactenkunde auf ihrem jetzigen Standpunkte durch die Beschreibung seiner Sammlung versteinerter und fossiler Überreste des Thier-und Pflanzenreiches der Vorwelt erläutert.* 437 pp., 15 pls. Gotha.

Schroeder, H. & Boehm, J., 1909. Geologie und Paläontologie der Subhercynen Kreidemulde. *Abh. preuss. geol. Landesanst., Berlin* (n.f.) **56** : 1–64, pls. 1–16.

Schultze, C. F. 1760. *Betrachtung der versteinerten Seesterne und ihrer Theile.* iv + 58 pp., 3 pls. Warsaw & Dresden.

Seeley, H. 1864. On the Hunstanton Red Rock. *Quart. Jl. geol. Soc. Lond.*, **20** : 327–332.

Seilacher, A. 1951. Der Röhrenbau von *Lanice conchilega* (Polychaeta). Ein Beitrag zur Deutung fossiler Lebensspuren. *Senckenbergiana*, Frankfurt am Main., **32** : 267–280.

—— 1955. Spuren und Lebenweise der Trilobiten: 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.*, **10** : 86–143, pls. 16–27.

—— 1964. Biogenic sedimentary structures. *In* Imbrie, J. & Newell, D. *Approaches to Palaeoecology* : 296–316, 8 figs., 1 tab. New York.

Semenow, W. P. 1899. La Faune des dépôts crétacés de Mangychlak et de quelques autres localités de la province transcaspienne. *Trav. Soc. Imp. Nat. St. Pétersb.*, **28**, 5 (Géol., Min.) : 1–178, pls. 1–4.

Simpson, S. 1957. On the trace-fossil *Chondrites*. *Quart. Jl. geol. Soc. Lond.*, **112** : 475–499, pls. 21–24.

Sorby, H. C. 1861. On the organic origin of the so-called " Crystalloids " of the Chalk. *Ann. Mag. Nat. Hist.*, London (3) **8**, 193–200.

Sowerby, J. de C. 1823–25. *The Mineralogy Conchology of Great Britain; or coloured figures of those remains of Testaceous Animals or Shells, which have been preserved at various times, in the earth*, **5**, pls. 408–443 (1823), 444–485 (1824), 486–508 (1825). London.

Sternberg, K. M. Graf. v. 1833. *Versuch einer geognostisch-botanischen Darstellung der Flora der Vorwelt.* **5–6**. 80 pp. Leipzig & Prague.

Stevens, B. A. 1928. Ecological observations on the Callianassidae of Puget Sound. *Ecology*, New York, **10** : 399–405.

Taylor, J. H. 1964. Some aspects of diagenesis. *Advmt. Sci., Lond.*, **18** : 417–436, 7 figs.

Taylor, R. 1823. Geological section at Hunstanton Cliff, Norfolk. *Phil. Mag.*, London, **61** : 81–83.

Thomel, G. 1961. Sur la présence du genre *Schloenbachia* dans le Vraconien supérieur de Saint-Laurent de l' Escarène (Alpes-Maritimes). *C.R. Soc. Géol. Fr.*, Paris, **1961** : 37.

Verwey, J. 1930. Einiges über die Biologie ost-indischer Mangrovekrabben. *Treubia*, Buitenzorg, Bogor, **12** : 167–261, pls. 6–14.

Watelet, A. 1866. *Description des plantes fossiles du basin de Paris.* iv + 264 pp., Atlas 30 pp., 60 pls. Paris.

Webster, T. 1814. On some new varieties of fossil Alcyonia. *Trans. geol. Soc., Lond.* : 371–387, pls. 27–29.

Weigelt, J. 1929. Fossile Grabschächte brachyurer Decapoden als Lokalgeschiebe in Pommern und das *Rhizocorallium*-Problem. *Z. Geschiebforsch.*, Berlin, **5** : 1–42, pls. 1–4.

Weimer, R. J. & Hoyt, J. H. 1964. Burrows of *Callianassa major* Say, geologic indicators of littoral and shallow neritic environments. *J. Paleont.*, Tulsa, **38** : 761–767, pls. 123, 124.

Whitaker, W. & Jukes-Browne, A. J. 1899. The Geology of the Borders of the Wash: including Boston and Hunstanton. *Mem. Geol. Surv. U.K.*, London. iv + 146 pp.

White, E. I. 1923. Notes on a new Species of Terebelloid and other Phenomena in the Great Pit at Harefield, Middlesex, etc. *Proc. Geol. Ass.*, London, **34** : 43–46.

Wilcox, N. R. 1953. Some coprolites from phosphatic chalks in S.E. England. *Ann. Mag. Nat. Hist.*, London (12) **6** : 369–375, pl. 11.

Wilson, V. 1949. The Lower Corallian Rocks of the Yorkshire Coast and Hackness Hills. *Proc. Geol. Ass.*, London, **60** : 235–271, pls. 9, 10.

Wiltshire, T. 1859. On the Red Chalk of England. *Geologist*, London, **2** : 261–278 and *Geol. Ass. Spec. Papers*, **1859** : 1–18, pls. 1–4.

—— 1869. On the Red Chalk of Hunstanton. *Quart. Jl. geol. Soc. Lond.*, **25** : 185–192.

Wood, C. J. 1965. Field Meeting on the Lower Chalk between Folkestone and Dover. *Proc. Geol. Ass.*, London, **76** : 301–304.

Woodward, S. 1830 *A synoptic table of British Organic remains.* xiii + 50 pp., 1 pl. London & Norwich.

—— 1833. *An Outline of The Geology of Norfolk.* 54 + 1 pp., 6 pls. Norwich.

Zareczny, S. W. 1878. O średnich warstwach kredowych w krakowskim okregu. *Krakow Kom. Fizyogr. Spraw.*, **12** : 176–246, pls. 4–8.

PLATE 1

FIG. 1. ***Thalassinoides saxonicus*** (Geinitz). Lower Chalk, Middle Cenomanian; Houghton Regis, near Dunstable, Beds. Base of a fallen block of Totternhoe Stone with part of the underlying Chalk Marl attached, the burrow is filled by Totternhoe Stone. Plan view, hammer head 16 cm. long.

FIG. 2. ***Thalassinoides*** cf. ***suevicus*** (Rieth). Upper Greensand; Cow Gap, N.E. of Beachy Head, Eastbourne, Sussex. Burrow originates from the base of the Glauconitic Marl (Lower Cenomanian). Plan view, scale in inches.

FIG. 3. Burrows at base of the Glauconitic Marl, Lower Cenomanian; Compton Bay, Isle of Wight. Vertical section, hammer head 16 cm. long.

FIG. 4. Laminated structures. Lower Chalk, Middle Cenomanian, bed 7; foot of cliff 600 m. E. of Akers steps, Dover, Kent. Vertical section, pencil 9 cm. long.

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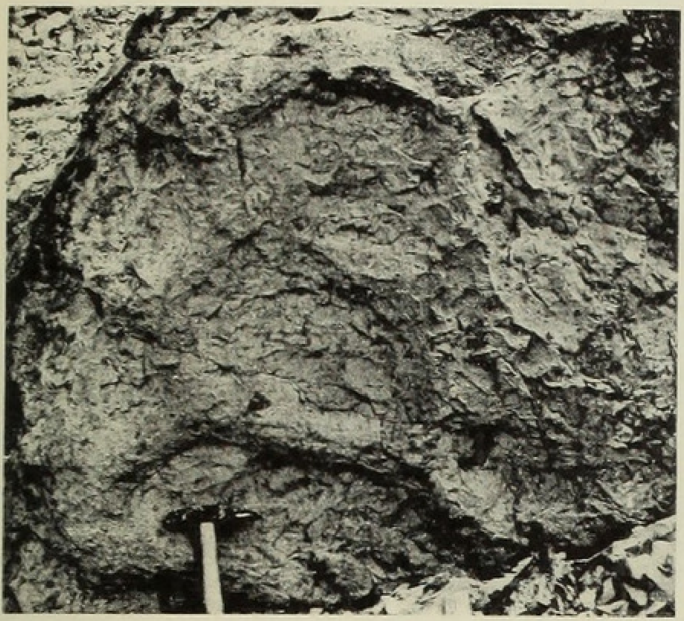


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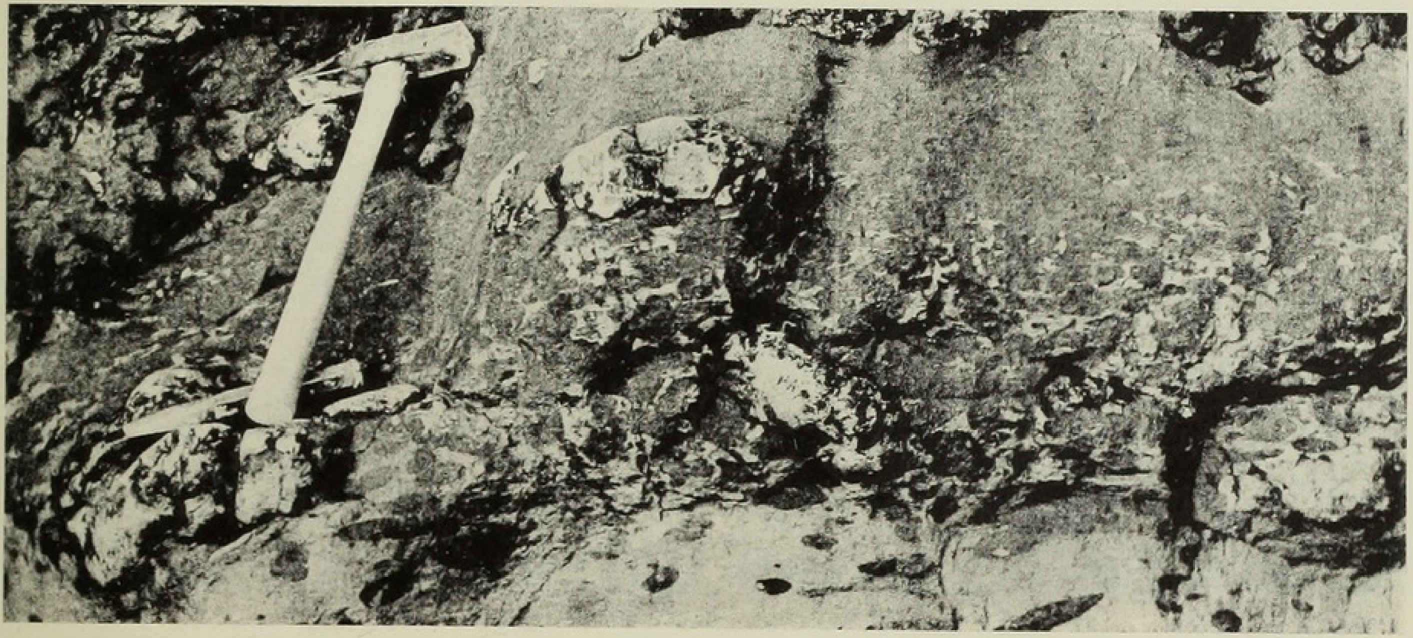
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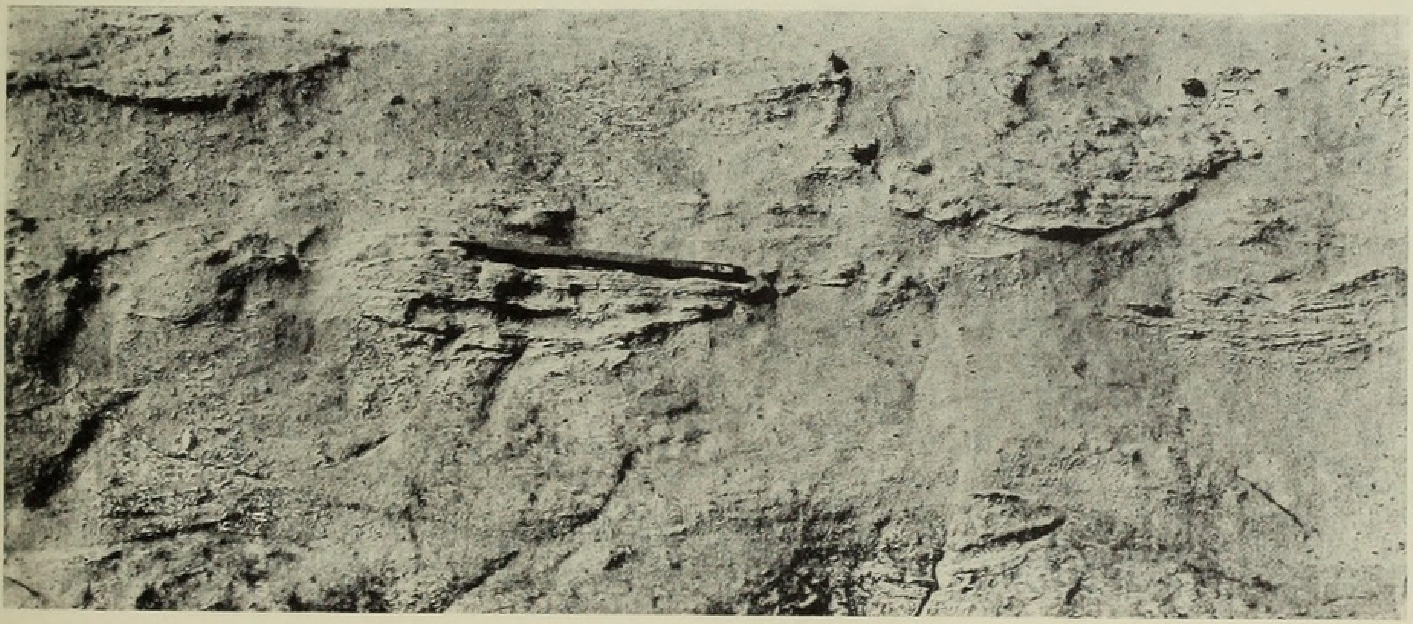
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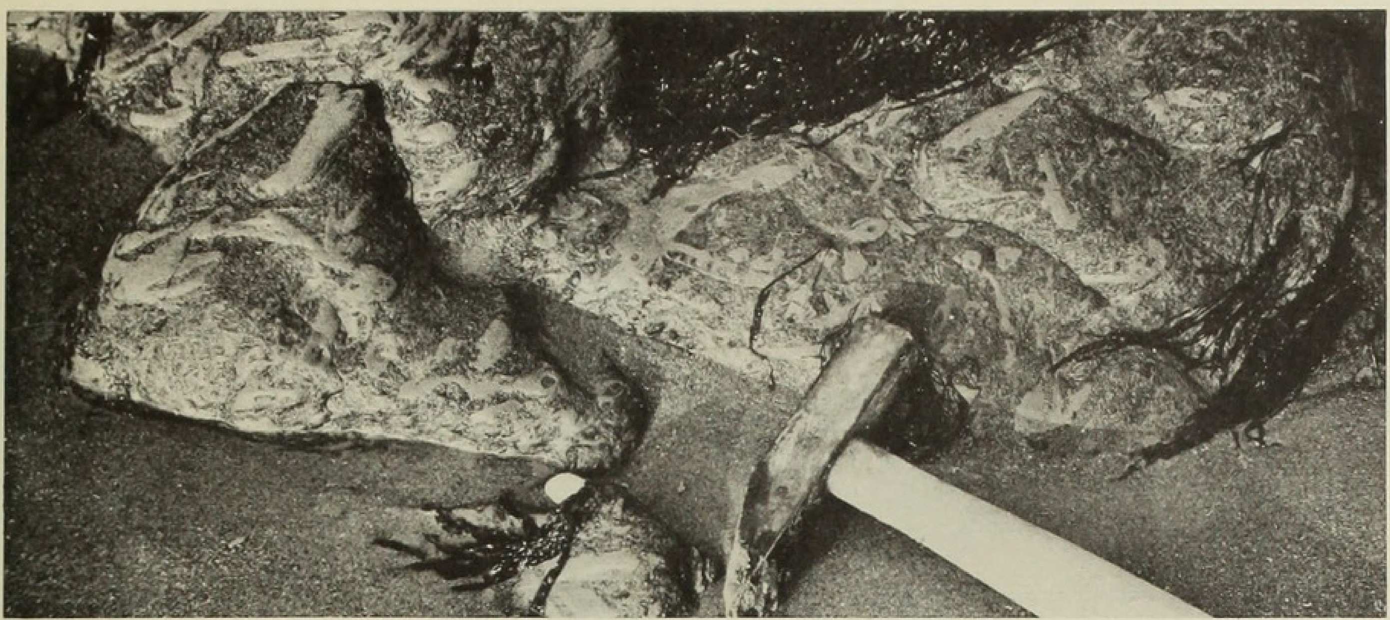
PLATE 2

FIG. 1. ***Spongeliomorpha? annulatum*** ichnosp. nov. Glauconitic Marl, Lower Cenomanian; foreshore, East Wear Bay, Folkestone, Kent. Oblique section, hammer head 16 cm. long.

FIG. 2. Vertical section of burrowed chalk with abundant *Chondrites* sp. Lower Chalk, Upper Cenomanian; Betchworth Limeworks, Betchworth, Surrey. ×1.

FIG. 3. Vertical section of burrowed chalk with *Chondrites* sp. and burrow type E. Lower Chalk, Middle Cenomanian; Eastbourne, Sussex. ×1.

FIG. 4. Vertical section of burrowed chalk. Lower Chalk, Upper Cenomanian; Dover, Kent. Note relative abundance of *Chondrites* sp. in larger burrows. ×1.



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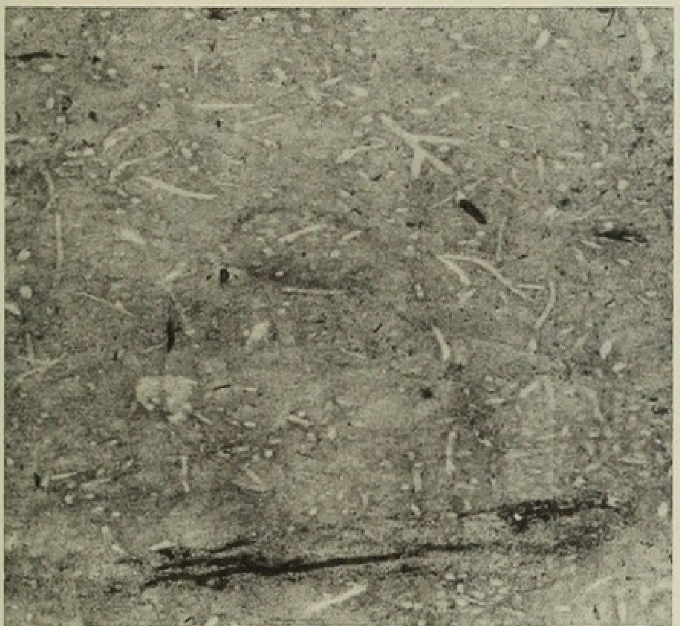

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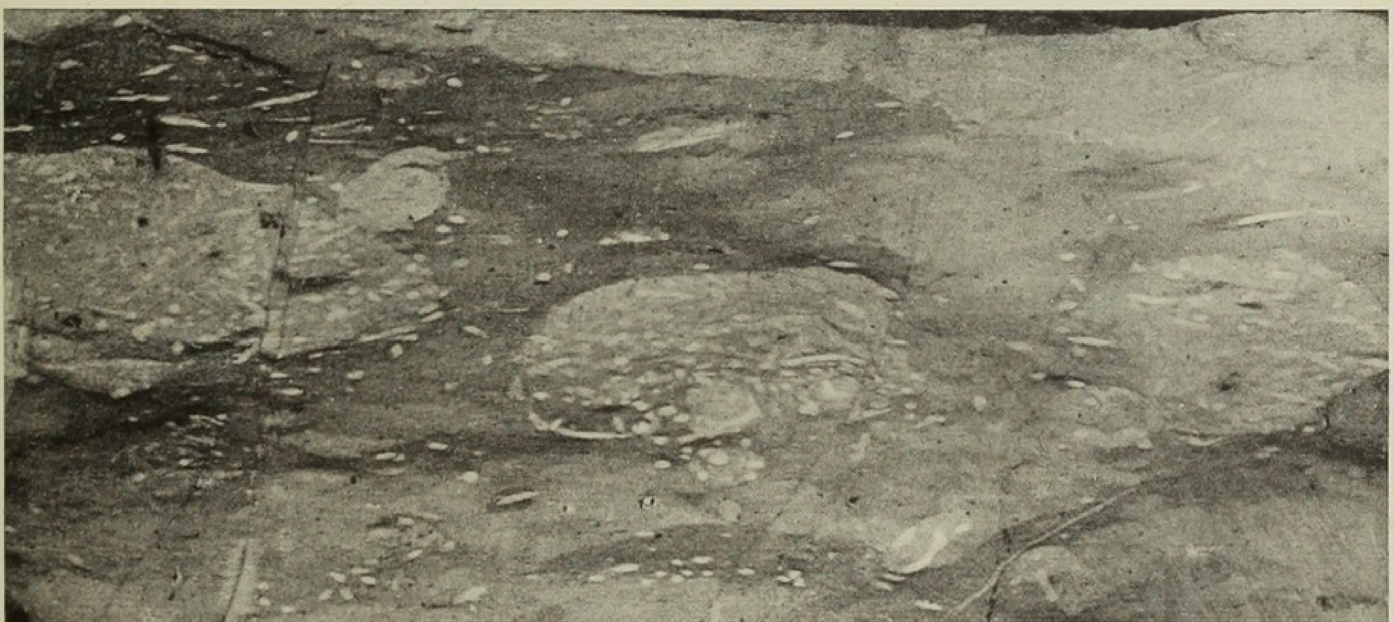

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PLATE 3

Thalassinoides paradoxica (Woodward)

Neotype, B.M. (N.H.) T.545. Lower Chalk, Lower Cenomanian, *Paradoxica* bed; Hunstanton, Norfolk. Oblique view, scale in centimetres.

PLATE 4

Thalassinoides paradoxica (Woodward)

Neotype, B.M. (N.H.) T.545. Lower Chalk, Lower Cenomanian, *Paradoxica* bed; Hunstanton, Norfolk. Plan view, scale in centimetres.

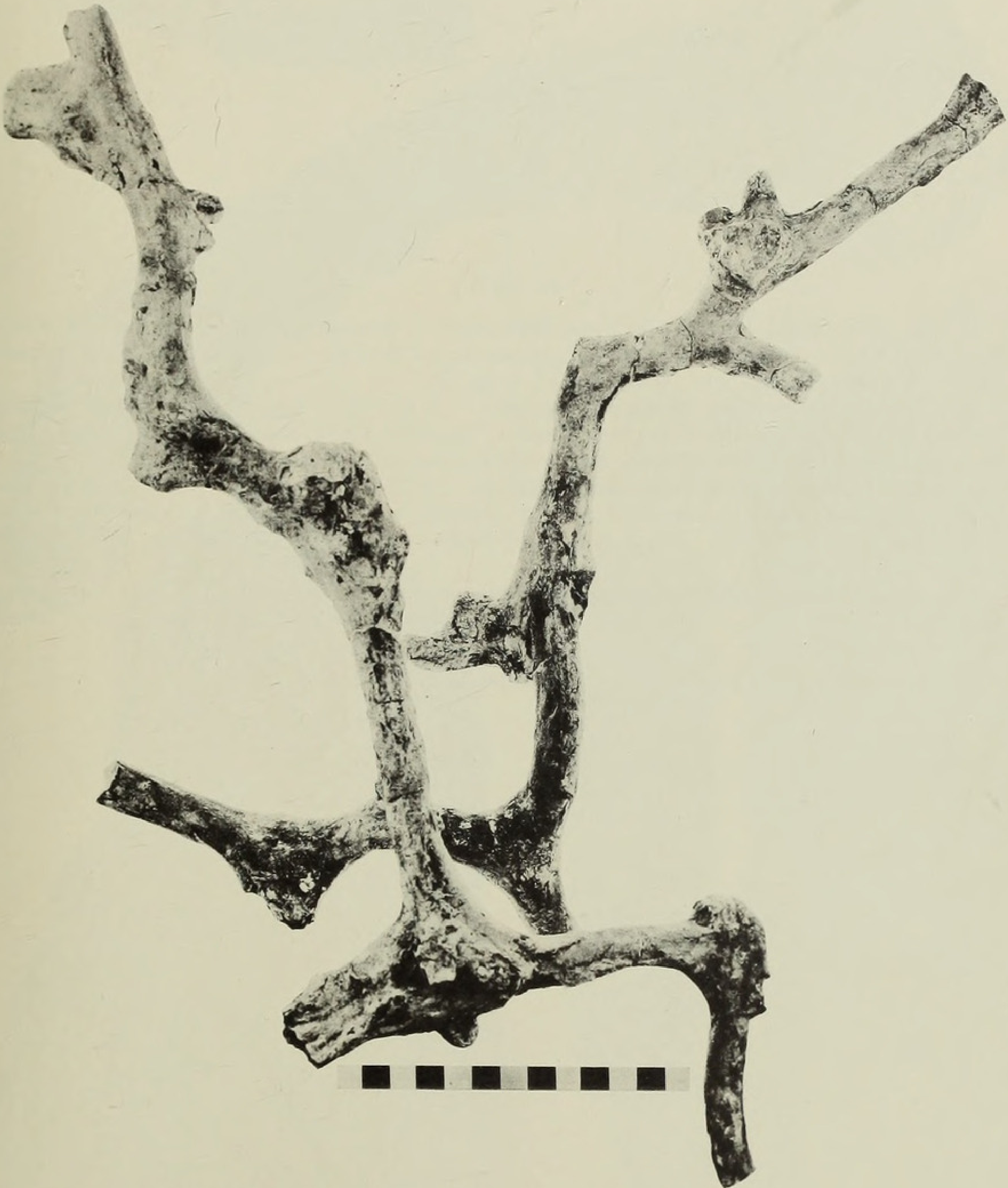


PLATE 5

Fig. 1. Laminated structure showing disruption of lamination by subsequent burrowing. B.M. (N.H.) T.550, Lower Chalk, Middle Cenomanian; Pit N.E. of Wouldham Hall, Wouldham, Kent. Vertical section, ×1. (Detail of Pl. 8, fig. 3).

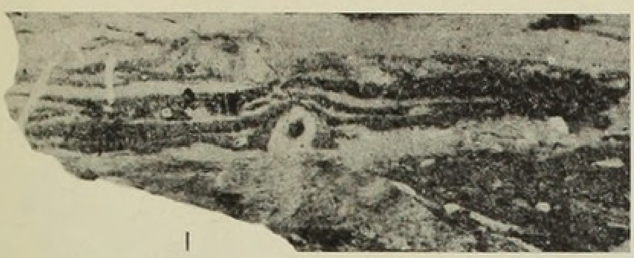
Fig. 2. ***Thalassinoides saxonicus*** (Geinitz). B.M. (N.H.) T.547, Lower Chalk, Middle Cenomanian, chalk beneath Totternhoe Stone; Houghton Regis, near Dunstable, Beds. Plan view of upper surface of termination showing ornamentation of elongate mounds. $\times \frac{1}{2}$.

Fig. 3. ***Thalassinoides saxonicus*** (Geinitz). B.M. (N.H.) T.548. Same horizon and locality, detail of figured specimen (Pl. 6, fig. 3), showing bottom covered with *Chondrites* sp. ×1.

Fig. 4. Burrow type D. S.M.C. b92473 (Jefferies collection). *Plenus* Marls, bed i; Merstham, Surrey. ×1.

Fig. 5. ***Spongeliomorpha? annulatum*** ichnosp. nov. Holotype, B.M. (N.H.) T.554. Glauconitic Marl, Lower Cenomanian; section below Martello Tower no. 3, Copt Point, Folkestone, Kent. ×1.

All specimens except Fig. 1 coated with ammonium chloride.



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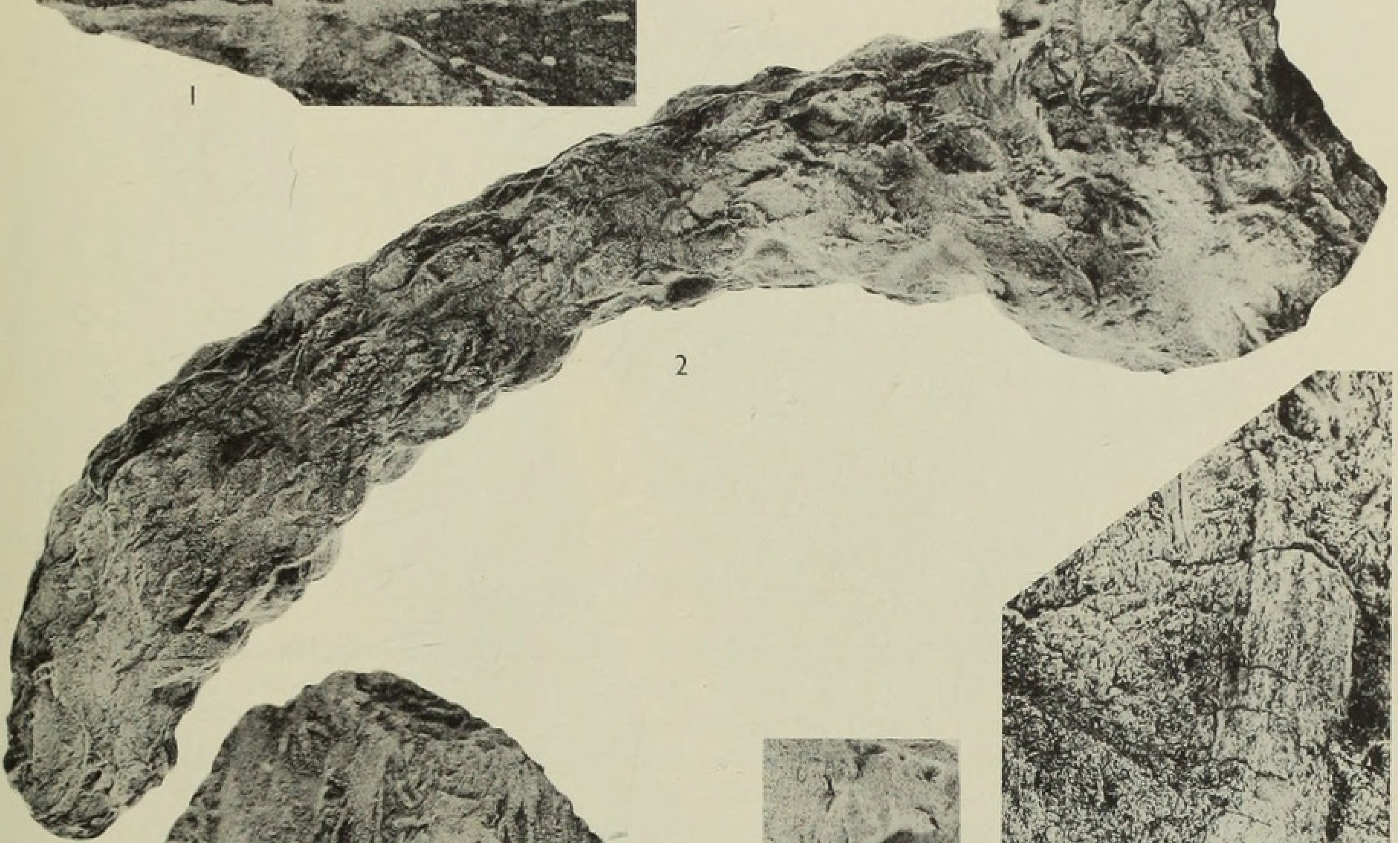

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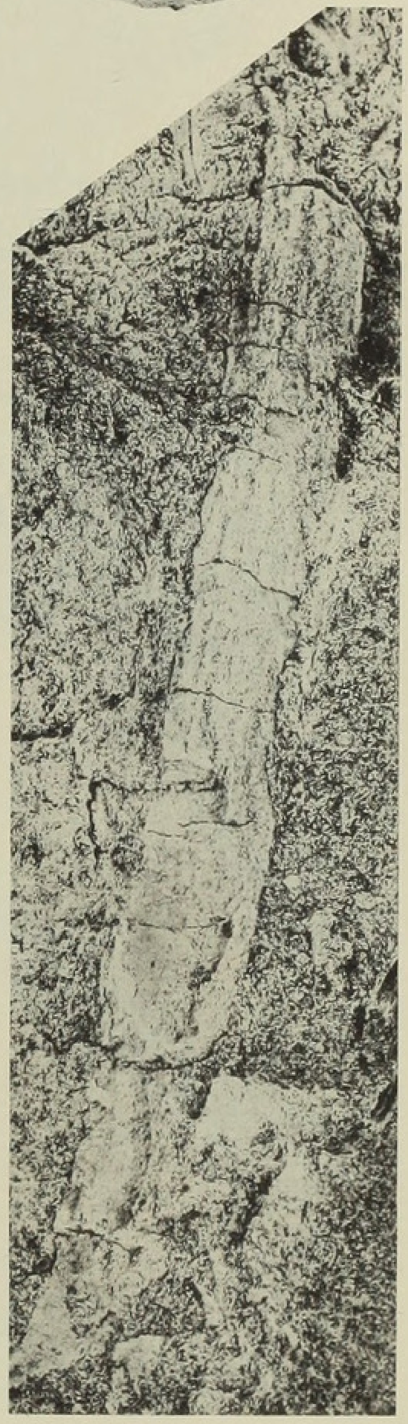

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PLATE 6

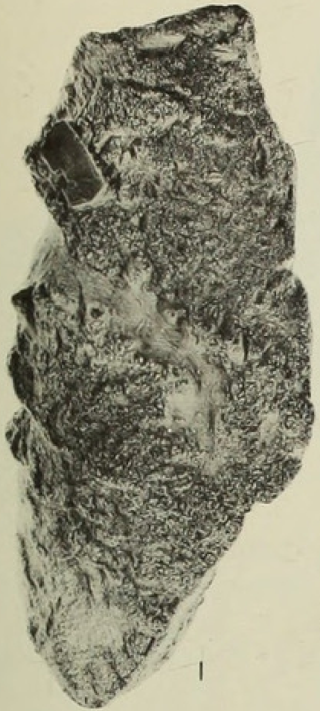
FIG. 1. ***Pseudobilobites jefferiesi*** ichnosp. nov. B.M. (N.H.) T.556. Lower Chalk, Upper Cenomanian; 7 m. below top of bed 8, base of Shakespeare Cliff; W. of Dover, Kent. Bottom surface, ×1.

FIG. 2. Cylindrical burrow full of coarse debris. S.M.C. B92827 (Jefferies collection). *Plenus* Marls, bed i; Merstham, Surrey. Listed by Jefferies (1963) as Problematicum sp. ×1.

FIG. 3. ***Thalassinoides saxonicus*** (Geinitz). B.M.(N.H.) T.548. Lower Chalk, Middle Cenomanian, chalk beneath Totternhoe Stone; Houghton Regis, near Dunstable, Beds. Bottom surface of typical branching fragment covered with *Chondrites* sp. ×1.

FIG. 4. ***Thalassinoides ornatus*** ichnosp. nov. associated with ***T. saxonicus*** (Geinitz). Holotype B.M.(N.H.) T.559. Same horizon and locality. Top surface, ×1.

All specimens coated in ammonium chloride.



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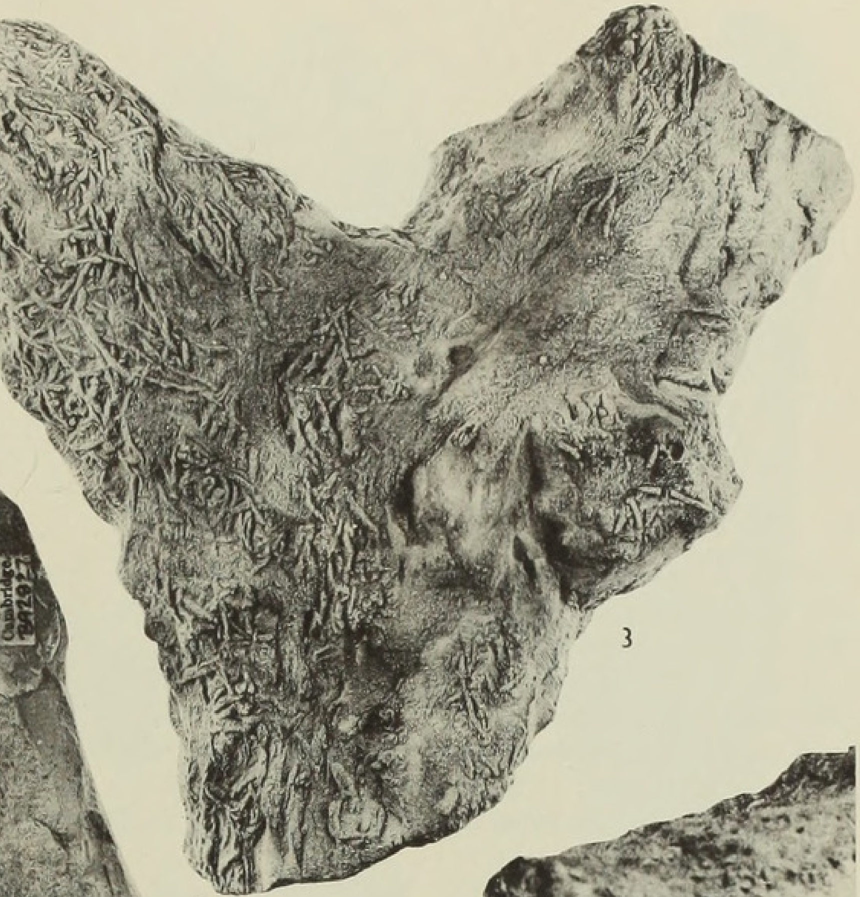

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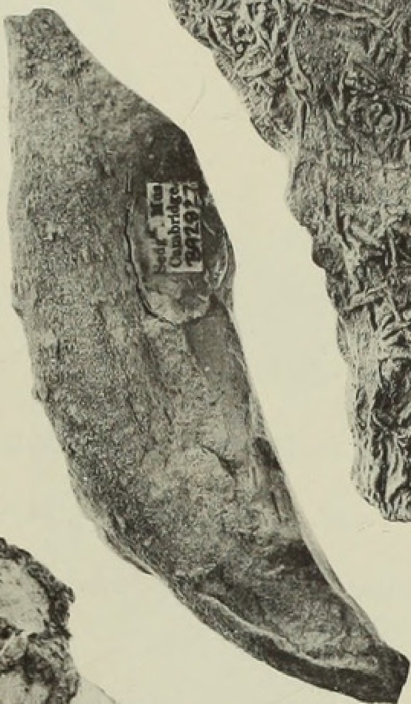

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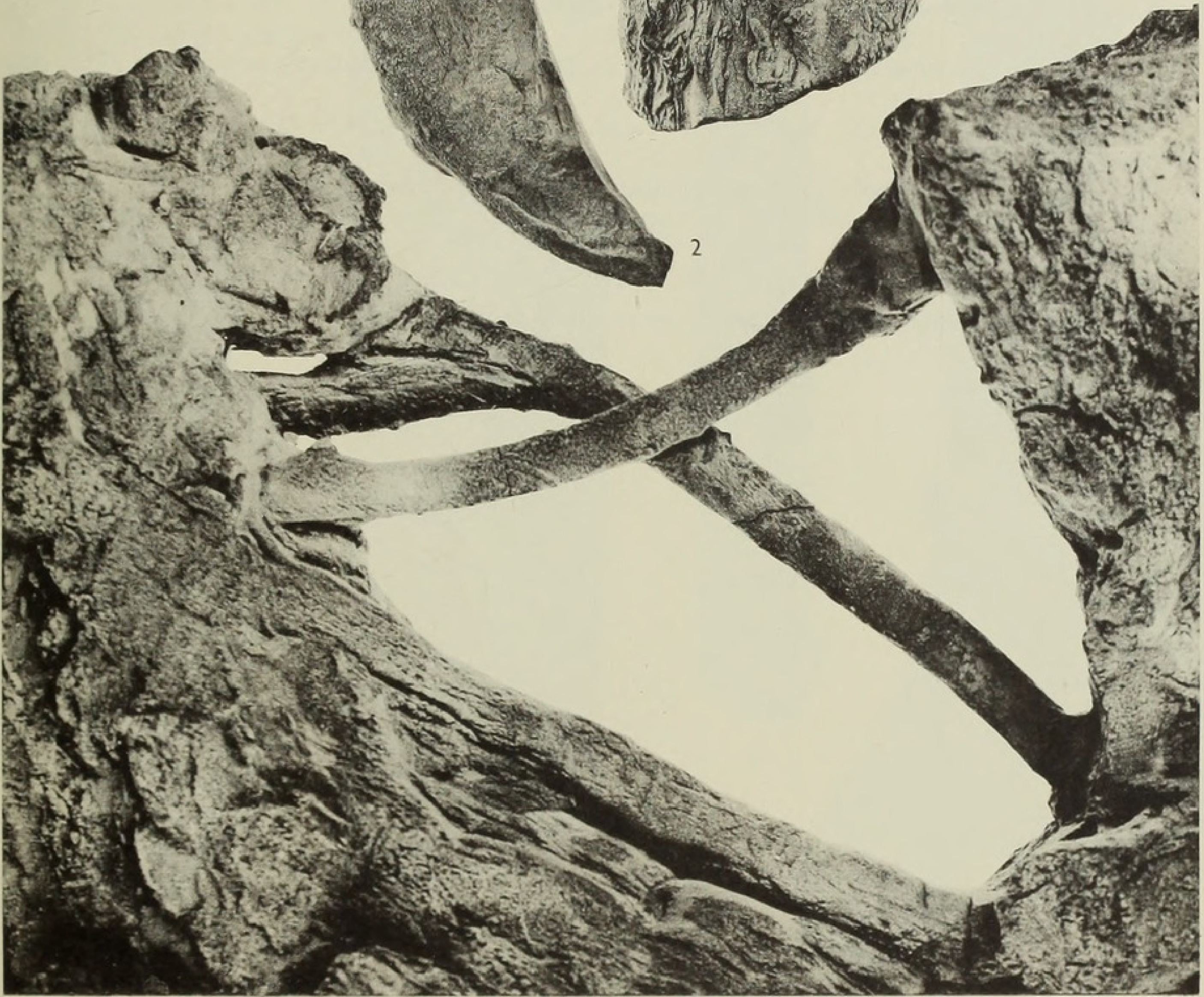

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PLATE 7

FIG. 1. Burrow type D. B.M. (N.H.) T.557. Lower Chalk, Middle Cenomanian, horizon of abundant *Orbirhynchia mantelliana* (Sowerby) and *Sciponoceras baculoide* (Mantell); Beddingham Limeworks, Beddingham, near Glynde, Sussex. ×1.

FIG. 2. "***Terebella***" ***harefieldensis*** White. Holotype, B.M.(N.H.) A.2445. Chalk/ Reading Beds junction; The Great Pit, Harefield, Middlesex. ×1.

FIG. 3. ***Pseudobilobites jefferiesi*** ichnosp. nov. S.M.C. B91035. *Plenus* Marls, bed i; Merstham, Surrey. Figured Jefferies (1963, pl. 77, fig. 5). Bottom surface, ×1.

FIG. 4. Burrow type D. B.M.(N.H.) T.569, Lower Chalk, Middle Cenomanian; Bluebell Hill, Burham, Kent, ×1.

FIG. 5. Burrow type D. B.M.(N.H.) T.558, Lower Chalk, Middle Cenomanian; Glynde, Sussex. ×1.

FIG. 6. ***Thalassinoides ornatus*** ichnosp. nov. Paratype, B.M.(N.H.) T.551. Lower Chalk, Middle Cenomanian, chalk below Totternhoe Stone; Houghton Regis, near Dunstable, Beds. ×1.

FIG. 7. ***Spongeliomorpha*** sp. B.M. (N.H.) T.553, same horizon and locality. ×1.

All specimens except Fig. 2 coated in ammonium chloride.

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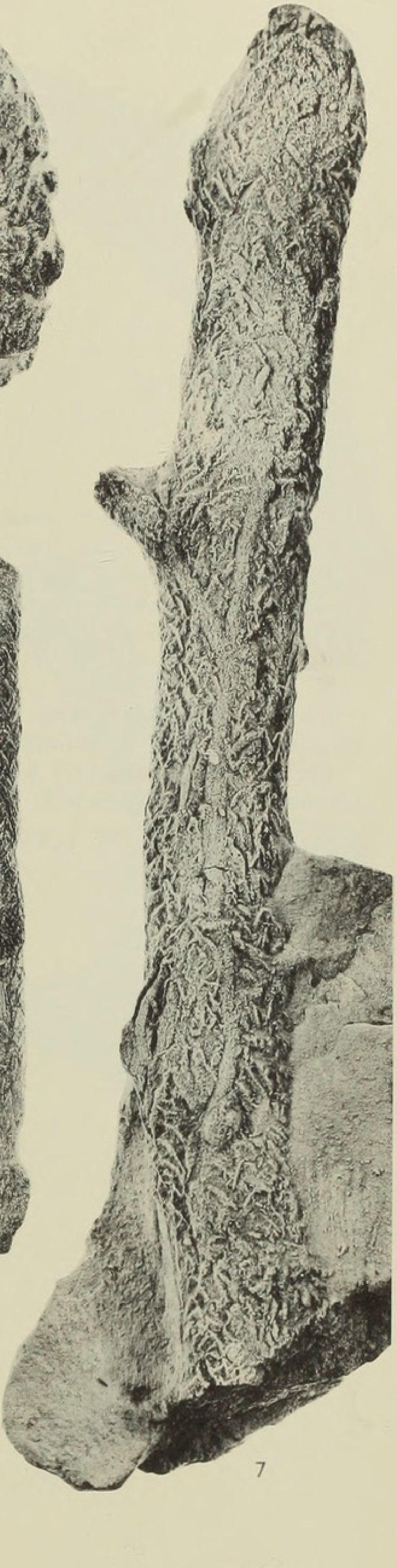

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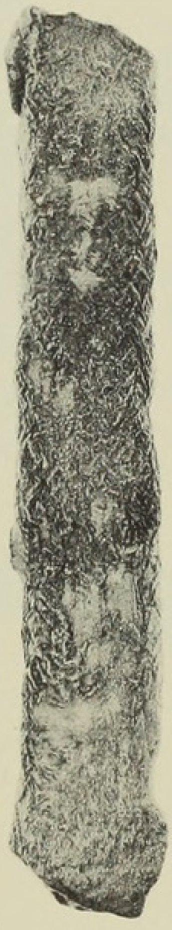

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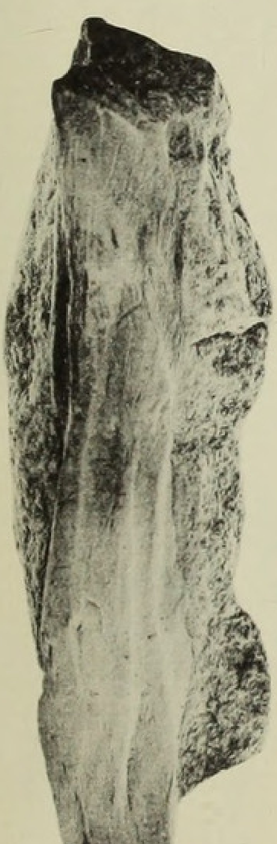

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PLATE 8

FIG. 1. " ***Terebella*** " ***cancellata*** Bather. Holotype, B.M. (N.H.) 58253 (Capron collection). Lower Chalk, *subglobosus* Zone; Glynde, Sussex. Figured Bather (1911, pl. 24, fig. 3). × 1.

FIG. 2. " ***Terebella*** " ***cancellata*** Bather. Paratype, B.M. (N.H.) A.1574 (Capron collection). Lower Chalk; Cowslip pit, near Guildford, Surrey. × 1.

FIG. 3. Laminated structure. B.M. (N.H.) T.550, Lower Chalk, Middle Cenomanian; pit N.E. of Wouldham Hall, Wouldham, Kent. Vertical section, upper surface at left margin. $\times \frac{2}{3}$.

FIG. 4. ***Pseudobilobites jefferiesi*** ichnosp. nov. S.M.C. B91557 (Jefferies collection). *Plenus* Marls, bed i; Merstham, Surrey. Lower surface, × 1.

FIG. 5. ***Thalassinoides paradoxica*** (Woodward) B.M. (N.H.) T.549. Lower Chalk, Lower Cenomanian, *Paradoxica* bed; Hunstanton, Norfolk.

Figures 1–3 uncoated, 4, 5 coated with ammonium chloride.


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PLATE 9

FIG. 1. ***Chondrites*** sp. B.M. (N.H.) T.562. Lower Chalk, Middle Cenomanian, horizon of abundant *Orbirhynchia mantelliana* (Sowerby) and *Sciponoceras baculoide* (Mantell); 300 m. west of Head Ledge, N.E. of Beachy Head, Eastbourne, Sussex. ×1.

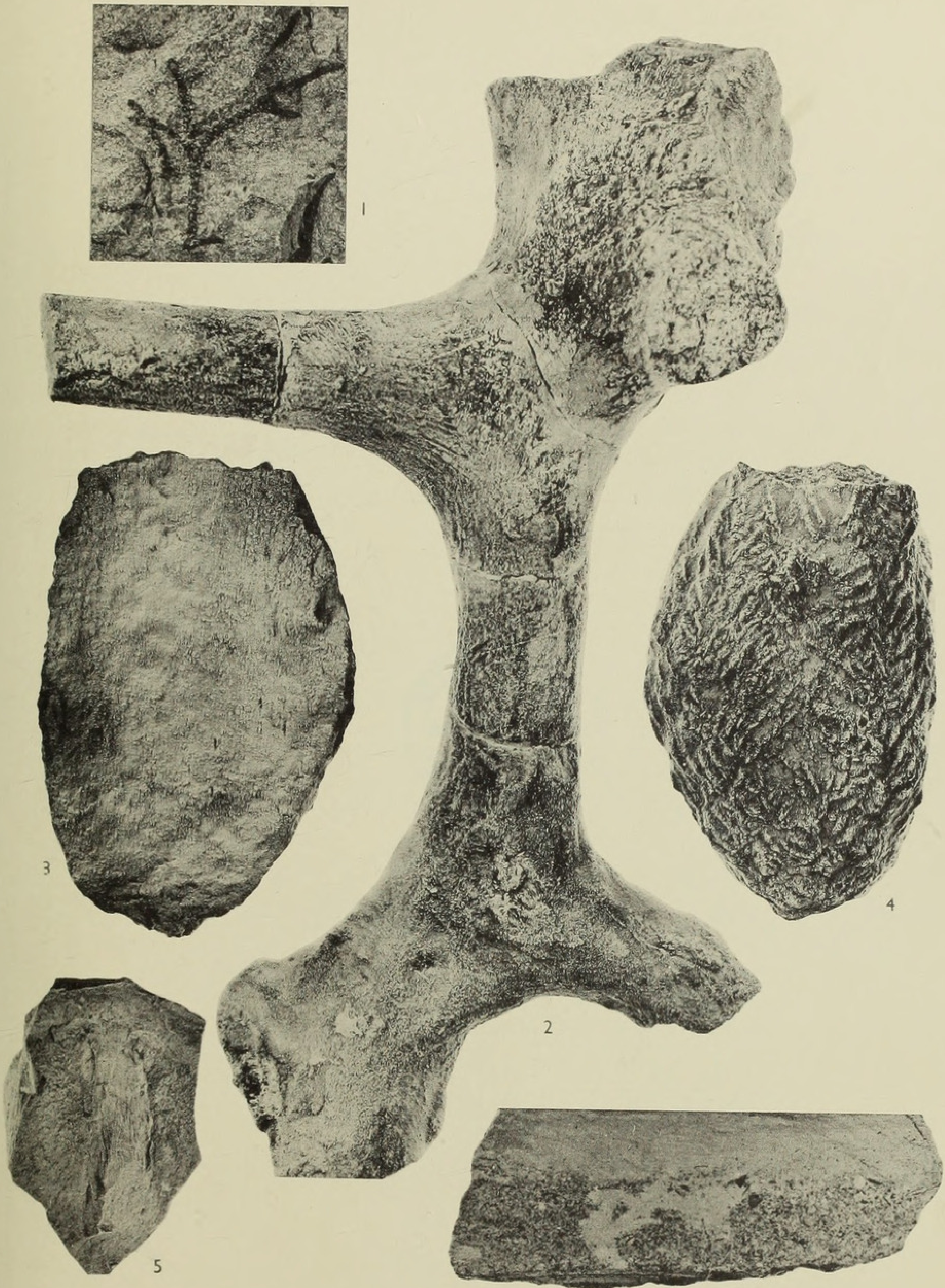
FIG. 2. ***Thalassinoides paradoxica*** (Woodward) B.M. (N.H.) T.546, Lower Chalk, Lower Cenomanian, Paradoxica bed; Hunstanton, Norfolk. ×1.

FIGS. 3, 4. ***Pseudobilobites jefferiesi*** ichnosp. nov. Holotype B.M. (N.H.). T.565. Lower Chalk, Middle Cenomanian, chalk below Totternhoe Stone; Pitstone, Buckinghamshire. 3, upper surface, 4, lower surface. ×1.

FIG. 5. Burrow type D. S.M.C. B92472 (Jefferies collection). *Plenus* Marls, bed i; Merstham, Surrey.

FIG. 6. ***Pseudobilobites jefferiesi*** ichnosp. nov. S.M.C. B91653b (Jefferies collection). *Plenus* Marls, bed 1; Lockinge, Berkshire.

All specimens except Figs. 1 and 6 coated with ammonium chloride.



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