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The Late Cenomanian calcisphere global bioevent

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Calcispheres, tentatively identified as *Pithonella johnstoni* Bolli, are described in flood abundance from various localities of Early Turonian age. Their widespread occurrence at this level would indicate a widespread (near global) bioevent which is located immediately after the well known Late Cenomanian extinction event and carbon isotope excursion. Material from Membury (SE Devon) has (unusually for calcispheres) been investigated in three dimensions using a scanning electron microscope.

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Introduction

In a recently published dictionary of earth sciences (Allaby and Allaby 1990) calcispheres are defined as:

> "Small calcite spheres, up to 500µm in diameter, commonly found in Palaeozoic limestones and believed to be of algal origin. They consist of a micrite wall enclosing an interior which is hollow or filled with sparry-calcite".

Brasier (1980, pp. 51-57) also records these small calcareous spheres within the algae (Class Chlorophyceae), indicating that they are commonly found in lagoonal limestones from the Devonian onwards. Brasier indicates that calcispheres are best studied in thin sections or peels.

While it is true that spherical, calcareous bodies of algal origin do occur in reefal/lagoonal limestones they are also frequently encountered in pelagic sediments, especially those of Mesozoic age. These pelagic calcispheres are the subject of this paper and it is unfortunate that neither Allaby and Allaby (1990) or Brasier (1980) discuss, or even mention, this other occurrence. These calcareous, spherical bodies were first described *as Lagena ovalis* and *Lagena sphaerica* by Kauffman in Heer (1865) and these, together with many related forms, have become taxonomically "lumped" as *Pithonella* Lorenz (1902). The majority of occurrences are described from thin sections, an example of which is shown in Fig. 1.

The application of the scanning electron microscope (SEM), first used by Banner (1972) and Bolli (1974), has allowed detailed observations of morphology not recorded previously. Since that time (1974) a taxonomy of this group, officially placed in *Incertae Sedis,* has been proposed. During the same interval various views on their biological affinities have developed (Masters and Scott 1978).

In recent years IGCP 216 (Global Biological Events) has focussed attention on extinction levels and other widespread biological phenomena. It is clear that, in the latest Cenomanian and earliest Turonian, there is a very widespread occurrence of abundant calcispheres. This level of flood abundance is known from many regions, including the Middle East, Yugoslavia (Gusic and Jelaska 1990), the Alps (Fig. 1), Germany (Neuweiler 1989), Spain (Caus, *pers. comm.)* and the UK (Jarvis *et al.* 1988a, fig. 4 (d),(f),(g),(h)). In all these examples it is normal to use thin sections for the investigation of the calcispheres. In Devon, however, it is possible to locate this calcisphere-rich, Lower Turonian strata in an expanded succession at Membury (Hart 1975; Carter and Hart 1977). At this locality (Fig. 2) it has been possible to extract the calcispheres from the sediment, study them under the light microscope and also prepare them for SEM investigation.

The earliest Turonian level of widespread abundance is significant in that it immediately follows the Late Cenomanian global bioevent which (Jarvis *et al.* 1988a and references therein) appears to be the result of an expansion of the oceanic oxygen minimum zone (see Corfield *et al.* 1990 for a slightly different perspective). The extinction and faunal changes at this Late Cenomanian bioevent do, however, provide circumstantial evidence on the nature of calcispheres as they are quite clearly expanding into a vacant niche, or responding to a palaeoceanographic change.

Late Cenomanian stratigraphy

The Cenomanian/Turonian boundary succession has been investigated a many localities in southern and eastern England. In the majority of cases the identical succession of faunal changes can be identified, the only variation occurring in those places where parts of the succession can be shown to be missing. The "standard" succession is *currently* that near Dover (Jarvis *et al.* 1988a). Fig. 2 shows how the condensed succession of the Devon coast (Hooken Cliff, Beer) compares with the Dover succession in terms of lithostratigraphy, biostratigraphy and isotope stratigraphy. The Membury succession (Hart 1975) is not condensed and appears as a normal chalk sequence. Indeed it is so atypical that it was, for many years, regarded as the most westerly exposure of the Lower Chalk. In 1968 the author, in a series of excavations, cleaned up this succession although it is now badly degraded. The calcisphere flood abundances are also indicated in Fig. 2.

Data from Jarvis *et al.* (1988a) have also been used to record the changes in the plankton during the Late Cenomanian bioevent (Fig. 3). It is clear from these data that the flood abundance of calcispheres coincides with a distinct lack of dinoflagellate cysts and, perhaps, calcareous nannofossils.

Investigation of the calcispheres from Membury

The chalk samples from Membury were processed for foraminifers and, as a result, washed on a 63µm sieve. Many, if not most, of the calcispheres may have been lost as this sieve size is towards the larger end of their size range. Microscopical examination of *unwashed* material indicates that the smaller forms appear to be identical to the larger ones that have been isolated. Further work may be necessary with more material from these smaller size fractions. The 125µm-63µm size fraction was floated using carbon tetrachloride and this had the effect of separating the calcispheres and the planktonic foraminifers from the residue. The calcispheres were then mounted and photographed using a JSM 5300 scanning electron microscope. A range of specimens are shown in Fig. 4.

Individual specimens are described as:

Test spherical, consisting of one layer of 15µm average thickness. Crystals visible on outer surface, fairly regular in size, up to 3-4µm in diameter, sharply angular, fairly tightly packed with only small interspaces. Aperture small, circular. Average diameter 80µm with an aperture average diameter of which is 20-25µm.

Using the micropalaeontological data of Bolli (1974) the specimens from Membury would appear to belong *in Pithonella johnstoni* Bolli, which has a recorded range in the initial definition of the

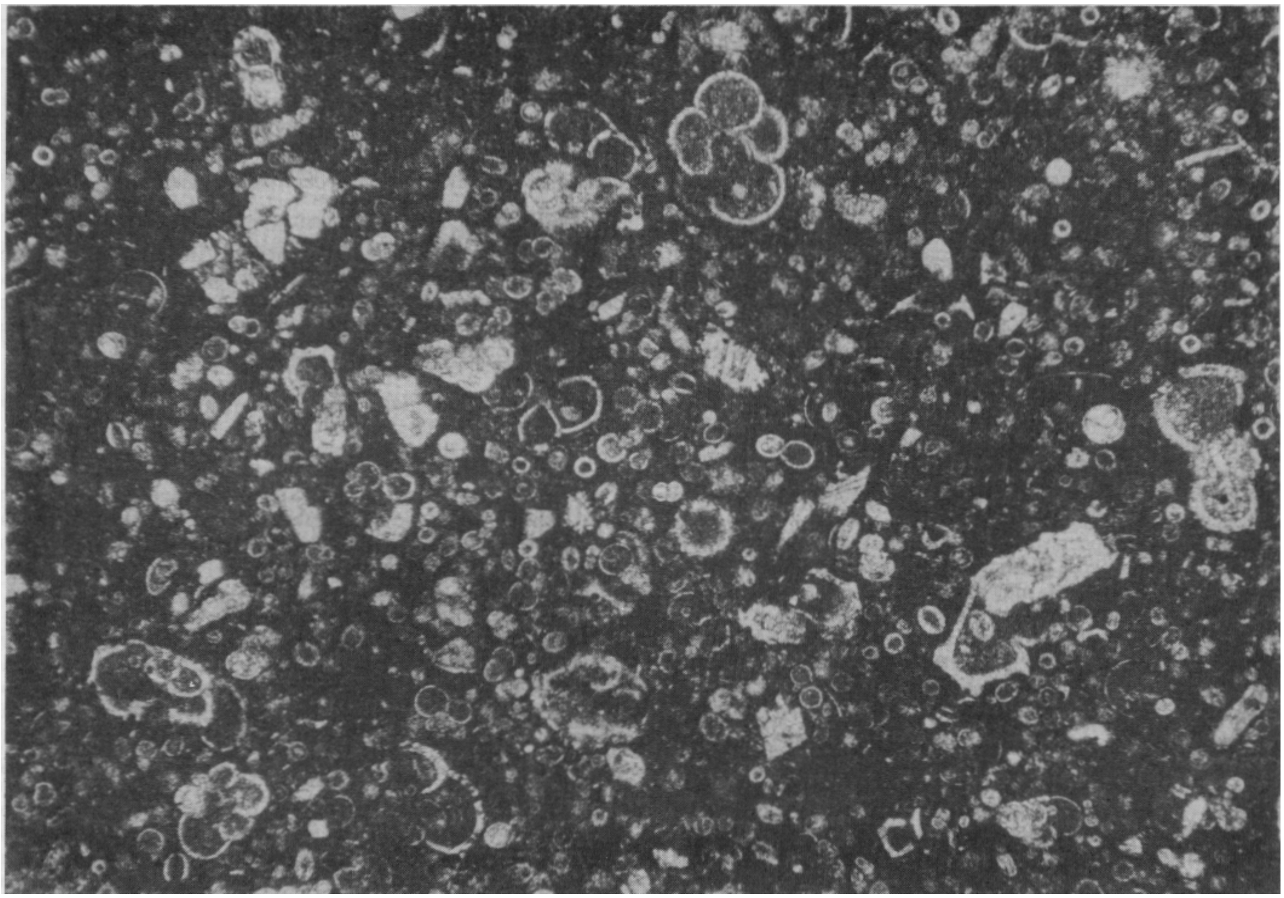

Figure 1. Thin section photomicrograph of the basal Seewen Limestone, Col de la Colombière, Haute Savoie, France. The co-occurrence of *Whiteinella* sp., *Praeglobotruncana praehelvetica* (Trujillo) and *Marginotruncana* spp. dates this sample as earliest Turonian. Field of view mm.

species as Late Cretaceous (? Coniacian to Santonian). It is worth recording that no Turonian or Cenomanian calcispheres were recorded on DSDP Leg 27 and Bolli's view of the range of *Pithonella johnstoni* was possibly incomplete.

In 1978 Masters and Scott hardly mentioned the status of many of Bolli's (1974) newly defined taxa, despite the paper being included in their reference list. It is clear from their emendations of the genera and families that many Cenomanian forms can also be referred to *Cadosina fusca* Wanner. Their emended diagnoses of these two genera highlight:

Pithonella - wall single-layered, constructed of radially elongated calcite prisms (4.4-12µm long), with prisms in adjacent rows normally being positioned in such a way as to create a helical spiralling effect.

Cadosina - wall single, homogenous layer of calcite platelets parallel to wall surface, which imparts a granular texture in cross-section. Wall may be 35-80µm in thickness.

Masters and Scott (1978, p.215) indicate that forms with "structurally undifferentiated spar calcite" are diagenetic end-products. In all the specimens examined in this study no organised wall structure has been seen and it is therefore impossible (using the emended definitions) to identify the Membury specimens to the generic level. The *only* guide is the thickness of the wall and this could be prone to change. Masters and Scott (1978, p.220) describe *Cadosina* as having a wall 35-86µm in thickness and this is far in excess of any of the Devon specimens. For the present they are therefore regarded as:

Incertae sedis - Family Stomiosphaeridae Wanner (19400 emend. Masters and Scott (1978). Genus *Pithonella* Lorenz (1902) emend. Masters and Scott (1978). *Pithonella sp. cf. P. johnstoni* Bolli (1974).

The forms illustrated in Fig. 1, which come from Haute Savoie, France, all appear to be identical to the forms described from Membury. Their overall size, relatively thin wall thickness and a small, simple, aperture make them very closely related, if not the same species. The same can be said for the material from Spain kindly provided by Dr E. Caus (Barcelona).

Environmental significance

The calcisphere assemblage from Membury is monospecific, a biological feature which usually implies an unusual set of environmental constraints. The planktonic foraminiferal fauna from Membury (Hart 1975) and that shown in Fig. 1 are relatively diverse with well-developed individuals. Fig. 1 shows good sections *through Marginotruncana* spp., *Whiteinella spp., Praeglobotruncana praehelvetica (Trujillo), Heterohelix* spp. And *Globigerinelloides* sp.. In the UK (eg. Dover) the earliest Turonian is haracterized by reduced benthonic foraminiferal faunas, presumably still affected by the reduced levels of dissolved oxygen in the water column (see Jarvis *et al.* 1988a). Clearly part of the plankton was affected (see Fig. 3) and this peculiar circumstance is important. There can, however, be no doubt that the pelagic calcisphere occurrences were taking place in open marine conditions of normal salinity and reasonable temperature (c. 20-25°C: Urey *et al.* 1951; Lowenstam and Epstein 1954).

Some authors (Bonet 1956; Adams *et al.* 1967; Bishop 1972) favour a deep open-sea environment while Villain (1981) favours

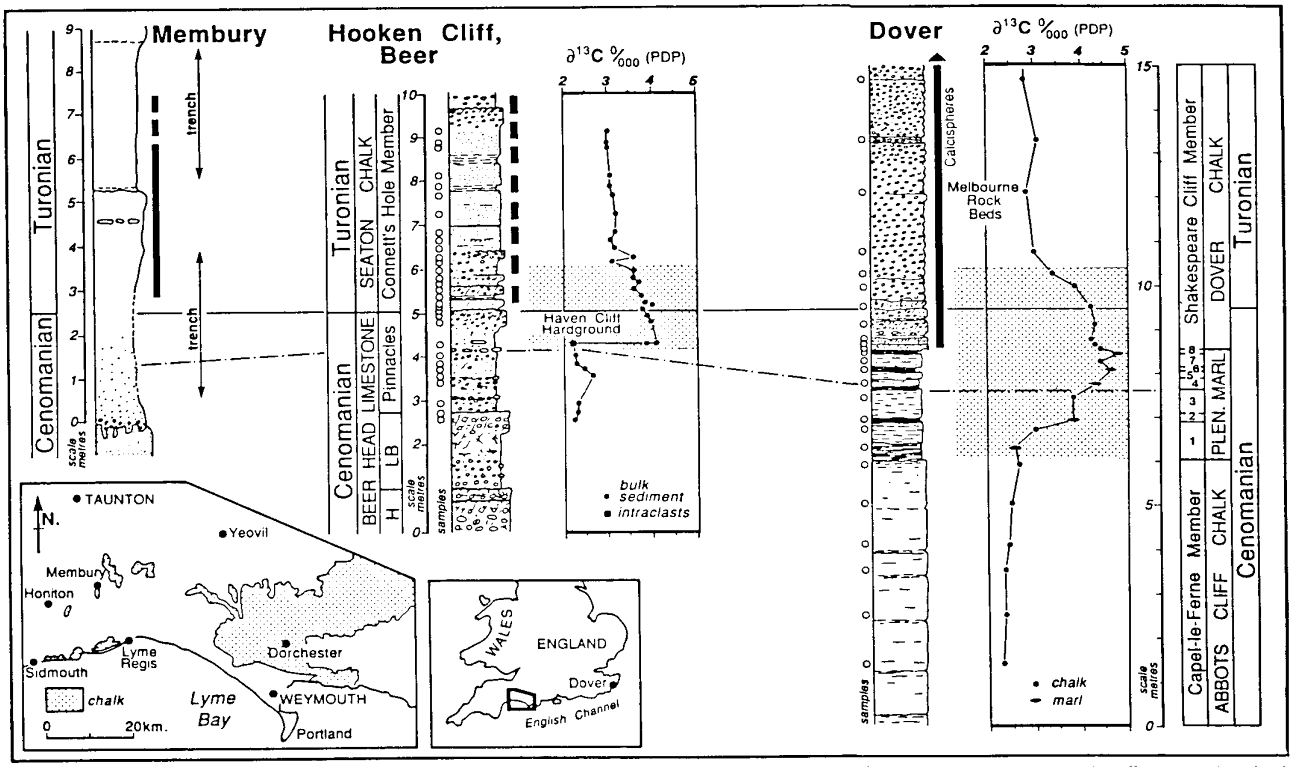

Figure 2. Correlation of the Late Cenomanian global bioevent across southern England. The successions and $\delta^{13}C$ curves for Hooken Cliff and Dover are described fully in Jarvis *et al.* (1988b) and Jarvis *et al.* (1988a) respectively. The dot-dash-dot line marks the extinction level of the *Rotalipora* sp., while the solid line indicates the Cenomanian/Turonian boundary (based on macrofossil data).

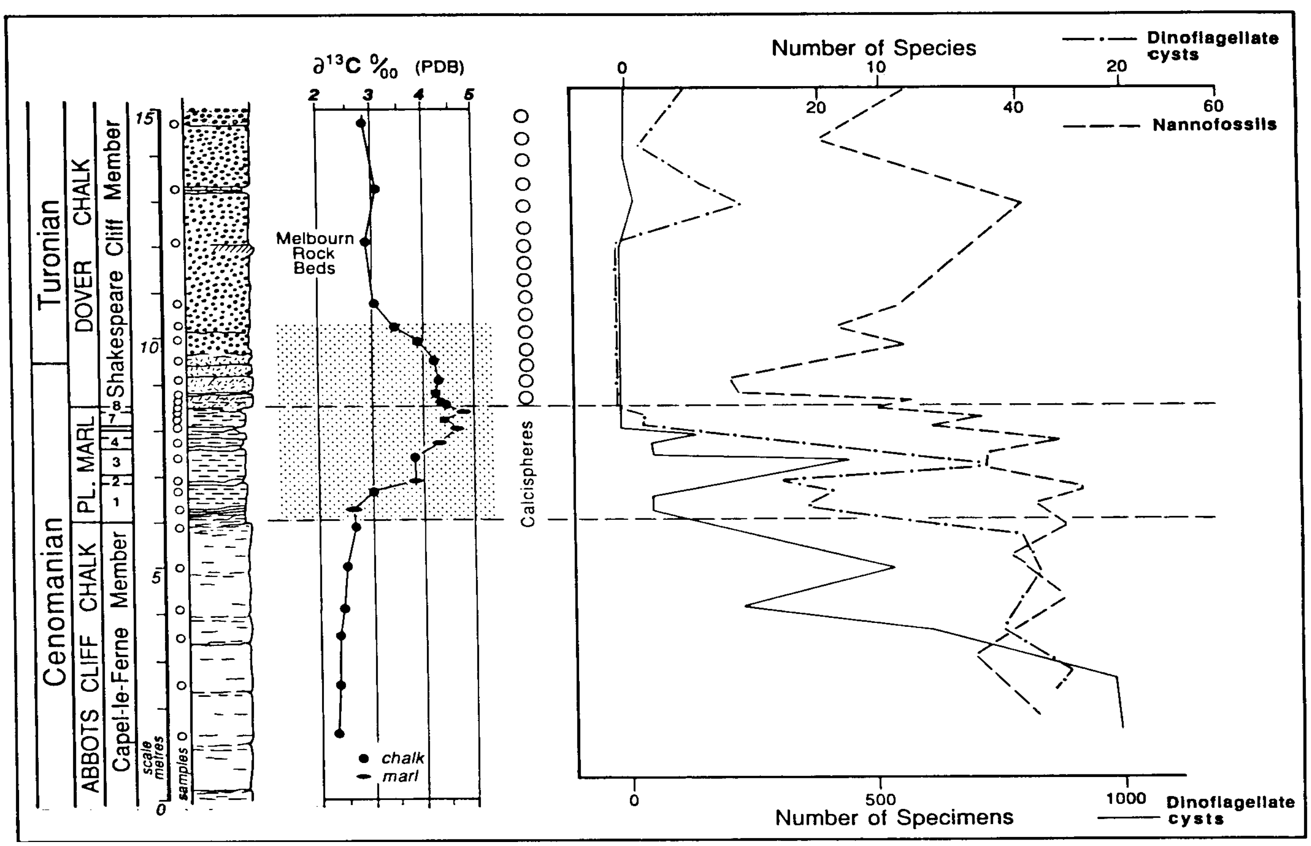

Figure 3. The Dover succession across the Late Cenomanian bioevent using data from Jarvis et al. (1988a). Note in particular the appearance of the floods of calcispheres immediately following the maximum $\delta^{13}C$ excursion. The nannofossil diversity recovers very quickly after the event while the diversity of the dinoflagellate cysts does not recover at all until well up in to the Turonian. Note also that the abundance (number of specimens in a set volume of material) of dinoflagellate cysts also remains at a low level throughout this interval.

and outer shelf environment for *Pithonella* throughout the Late Cretaceous. Bein and Reiss (1976) describe calcispheres from carbonate-rich inter-reefal environments while Masters and Scott (1978) describe rare calcisphere occurrences in back-reef lagoonal facies in the Lower Cretaceous of Arizona. Banner (1972) noted that they are generally more abundant in Tethyan environments, although views on the depth of the Early Cenomanian seaway in the UK may have changed slightly since his description of *Pithonella ovalis* from the Chalk Marl. The present work would indicate some sympathy with the views of Villain. Cretaceous shelves were probably slightly deeper water than the present day, the result of a generally higher global sea level (Hart 1990).

Biological affinities

A full discussion of this complex topic is beyond the scope of this paper, and further work is currently being undertaken. Banner (1972) and Adams *et al.* (1967) favour a protozoan relationship, while Bonet (1956) and Rupp (1968) prefer a link to algal cysts. Of critical importance in this respect is the work of Villain (1975) who has described a clustered life habit in some types of calcispheres as well as the presence of an organic lining reminiscent of cysts of *Acetabularia*.

Tappan (1980) in her major review of plant protists suggests two possibilities:

1. Thoracosphaeraceae - spherical calcareous forms with a terminal opening. Futterer (1976) has shown that *Thoracosphaera albatrosina* Kamptner has an opening strongly resembling a dinoflagellate archeopyle and this, together with other factors, have persuaded Keupp (1978) that *Pithonella* and related taxa are calcified dinoflagellate cysts.

2. Stomiosphaeraceae - associated with nannoconids and other calcareous nannoplankton, and possibly the calcareous spores produced by the dasyclad algae *Acetabularia.*

In the Early Turonian of southern England there are no known occurrences of dasyclad algae. There is, however, considerable circumstantial evidence (Fig. 3) to indicate that the calcispheres are most abundant in the interval where the dinoflagellate cysts are drastically reduced. Either they are some form of dinoflagellate response to a stressed environment or they are suddenly colonizing the niche left vacant by the collapse of the dinoflagellate cyst population. No internal or external structures have been seen in the course of this study that shed any light on the problem.

Summary

An Early Turonian flood abundance of calcispheres has been described from SE Devon and many other parts of southern England and Europe. The population appears to be monospecific and has been tentatively identified as *Pithonella sp. cf. P. johnstoni* Bolli. Circumstantial evidence would indicate that calcispheres may be calcareous cysts of dinoflagellates that are the direct result of abnormal conditions in the water column. Specimens from Membury appear to have no identifiable wall structure and may have suffered diagenetic replacement.

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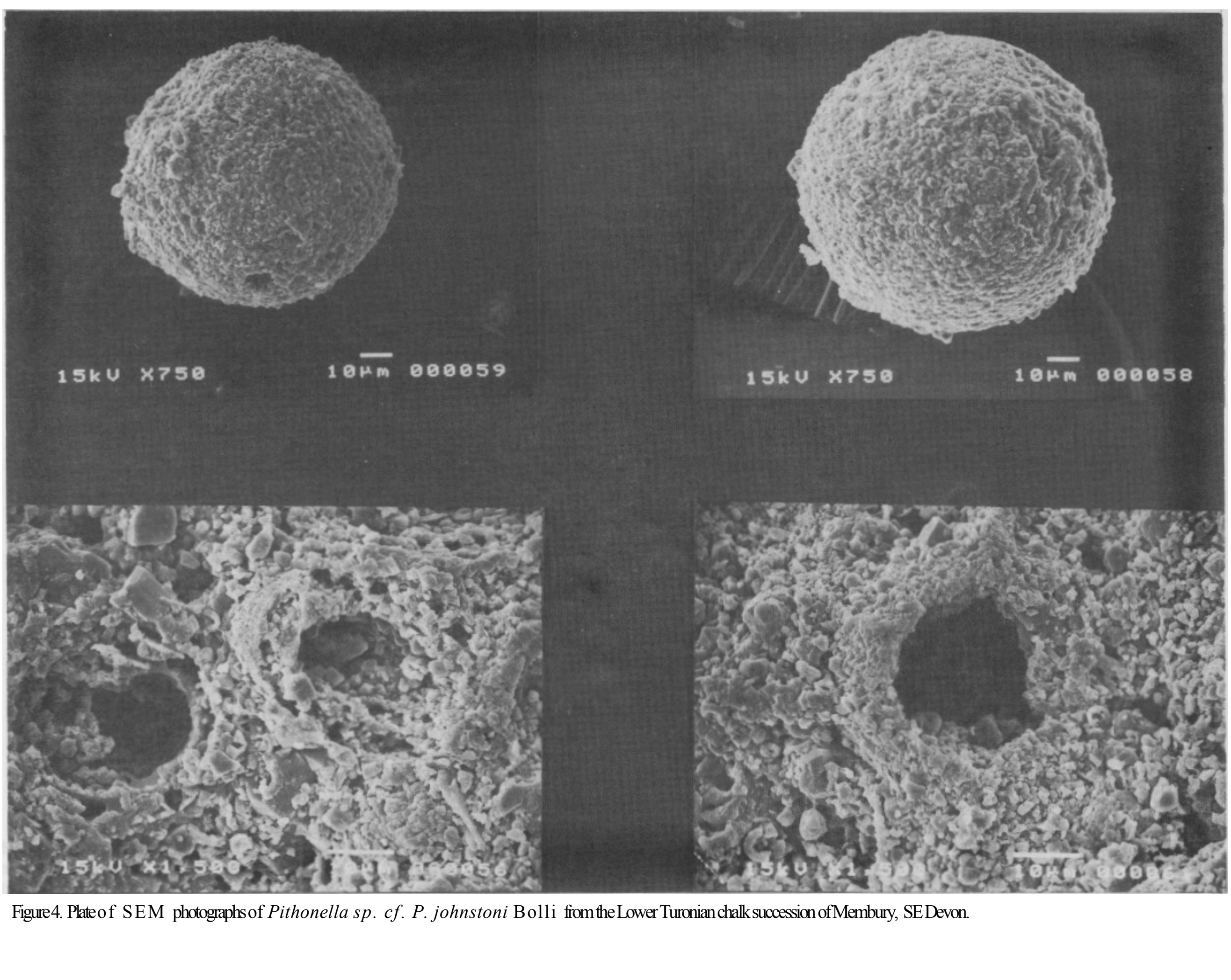

Figure 4. Plate of SEM photographs of *Pithonella sp. cf. P. johnstoni* Bolli from the Lower Turonian chalk succession of Membury, SE Devon.

for their advice on the distribution and biological affinities of calcispheres.

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