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INTERPRETIVE PROBLEMS IN A SEARCH FOR MICRO-INVERTEBRATE FOSSILS FROM A NEOPROTEROZOIC LIMESTONE IN NAMIBIA

by

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ABSTRACT

Attention is focussed on a carbonate sequence in the Auros Formation of the Otavi Group in northern Namibia, where several limestone layers are found to have been phosphatised. These contain an abundance of unusual objects, some of which suggest sponge-like microfossils, whereas others superficially resemble bivalved shells. Alternatively they may be pseudofossils - the deceptive products of a phosphatisation process and subsequent diagenetic effects in the limestone. Since this deposit antedates the ca. 590 million-year-old Ghaub or Marinoan glaciation, the presence of any potential metazoan fossils is worth investigating. The objects in question are described and alternative interpretations are discussed.

KEYWORDS: Neoproterozoic, Otavi Group, microfossils, pseudofossils

INTRODUCTION

For the last few years, one of the authors (C.K.B.) has been conducting a search for micro-invertebrate fossils in Proterozoic limestones of Namibia. Many samples of limestone from the Otavi Group in the Otavi-Tsumeb-Grootfontein area were examined in thin section and as acetic acid-treated residues, but recrystallisation of the limestones in the folded Otavi Mountainland appeared to militate against the finding of well preserved microfossils there. In fact, as Martin Pickford (1995) has pointed out, virtually no fossils other than stromatolites have thus far been found in Otavi Group sediments. But, north of the Otavi Mountainland lies the flat, calcrete-covered plain of the Etosha Basin, which apparently represented a Bahamas-type carbonate platform on the Congo Craton in Late Proterozoic times. About 50 km beyond the northern border of the Otavi Mountainland outcrops, and well away from the metamorphic folded belt, some isolated hills make their appearance, through the surrounding calcrete cover, close to the Halali restcamp in the Etosha National Park. Two km east of Halali are the twin peaks of Helio Hill and when C.K.B. examined acetic acid residues of samples of a black grainstone from the base of Helio Hill, he encountered microfossil-like objects that appeared to have been phosphatised. Such objects, referred to here as 'otavias', were later found in similar limestones from the Halali Hill itself and the Halali Quarry, 2 km further west. They are considered in detail in this paper, together with shell-like objects encountered in the Halali Quarry grainstones. Although the Halali outcrops appear on the 1 : 1 000 000 Geological Map of Namibia (1980) as 'Otavi Group – undifferentiated', it was clearly important to establish just where within the Group's stratigraphy the sequence is positioned. The outcrops were therefore examined in detail in the field by K.-H.H. and C.K.B. and samples were taken at close intervals for carbon isotope analysis and interpretation by A.R.P. and A.E.F. Comparable studies were made on the Abenab Subgroup sequence in the Kaokoveld by K.-H.H. and A.R.P., while confirmation of the presence of calcium phosphate in the microfossil-like objects from the Halali outcrops was provided by J.C. and A.J.B.

As has been pointed out by several specialists in the field of Proterozoic palaeontology who commented on the first draft of this paper, the interpretation of phosphatised objects in limestones of this age is by no means straightforward and is fraught with uncertainties. The purpose of the present paper therefore is to draw attention to, and to discuss such uncertainties in the the Halali context, with the hope that greater interpretive confidence will be possible in the future.

GEOLOGICAL CONTEXT AND CARBON ISOTOPE VALUES

As pointed out earlier (Hoffmann & Prave 1996, p. 77), "the Otavi Group is a thick succession of Neoproterozoic carbonates exposed within the Otavi Foreland fold belt of northern Namibia. It overlies predominantly coarse-grained terrigenous siliciclastic and local volcanic rocks of the Nosib Group and is overlain by fine- to coarse-grained Mulden Group siliciclastic sediments." The extent of Otavi Group outcrops in northern Namibia is shown in Figure 1, while a lithostratigraphic subdivision and correlation of the

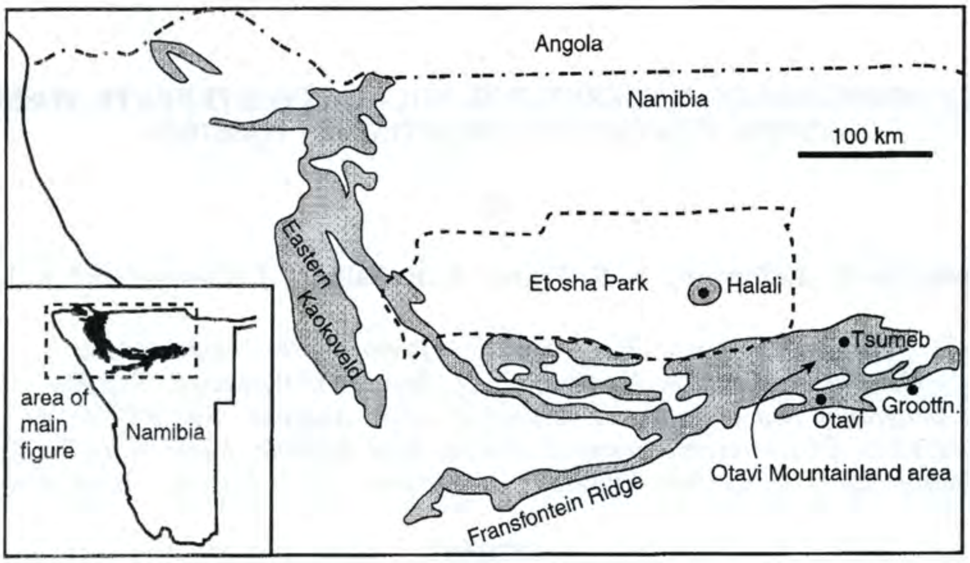


Figure 1. Map of northern Namibia showing the extent of the Otavi Group outcrops (shaded) in the Otavi Mountainland and Kaokoveld. The position of the Halali exposures, on the Etosha plain is also shown.

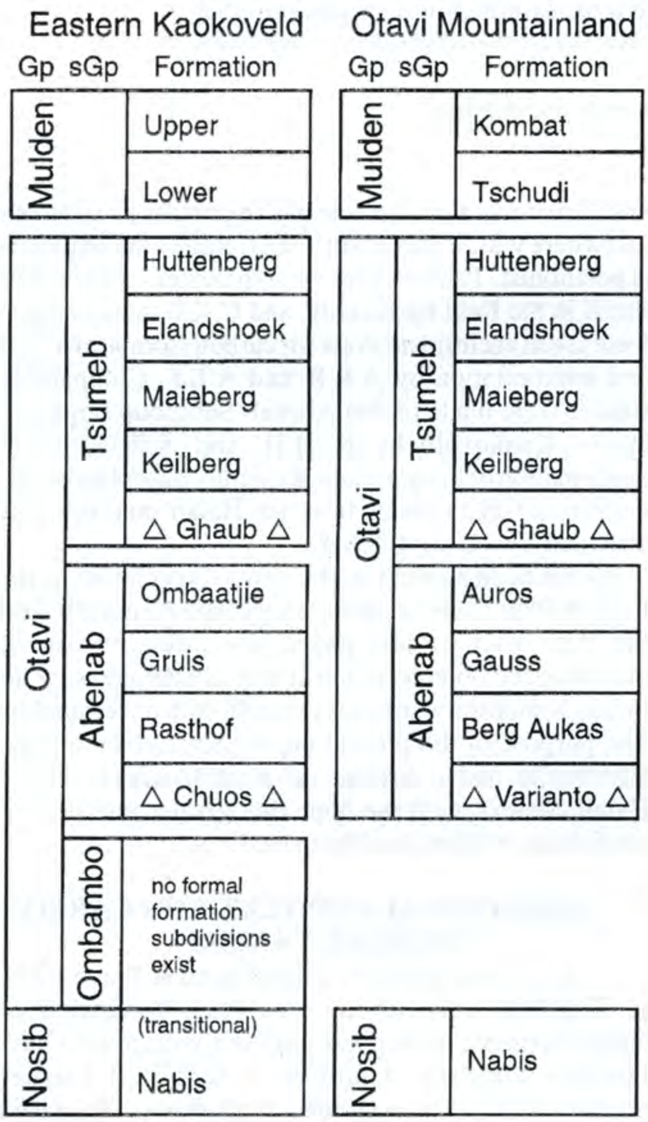


Figure 2. Simplified lithostratigraphic subdivision of Neoproterozoic rocks in northern Namibia (modified slightly from Hoffmann & Prave 1996). Triangles denote the two glaciogenic units. Gp = Group; sGp = sub-Group.

Group in the Otavi Mountainland and the eastern Kaokoveld, as was proposed by Hoffmann & Prave (1996), is given in Figure 2. Just prior to the publication of this subdivision, field studies along the Fransfontein Ridge to the east of the Otavi Mountainland, had demonstrated the presence of *two* stratigraphically and lithologically distinct glacial diamictite intervals, each succeeded by a unique cap-carbonate (Hoffmann 1994; Prave & Hoffmann 1995; Hoffmann & Prave 1996). Prior to this, a single glacial interval only, within the Otavi Group had been known for a considerable time (e.g. Le Roex 1941), but the presence of the two diamictites is now generally accepted.

Although evidence for very severe glacial conditions during Neoproterozoic time has been recognised for 37 years (Harland 1964) and the concept of a 'snowball Earth' was proposed by Kirschvink (1992) almost a decade ago, the application of the 'snowball Earth' scenario to the two glacial episodes reflected by Otavi Group diamictites is much more recent (Hoffman *et al.* 1998a, b). It postulates extreme glacial conditions, even in the equatorial regions, a cessation of continental runoff and virtual shutdown of biological activity. Such conditions would have had a dramatic effect on the evolution of early animals, whose lineages apparently go back considerably further in time on the basis of molecular evidence (Doolittle *et al.* 1996; Wray *et al.* 1996). It is therefore of interest to note that the Halali carbonate sequence with which we are concerned here is found to fall within the Auros Formation of the Abenab Subgroup, below the upper of the two glacial episodes, the Ghaub, which is thought to have occurred about 590 million years ago.

The continuity of the Halali carbonate sequence has been traced in four separate exposures. Where exposed, close to the Halali restcamp, these rocks are found to dip at a shallow angle towards the east, with the result that the oldest part of the profile outcrops in a low ridge at the Halali Quarry, 2 km west of the Halali camp, and this

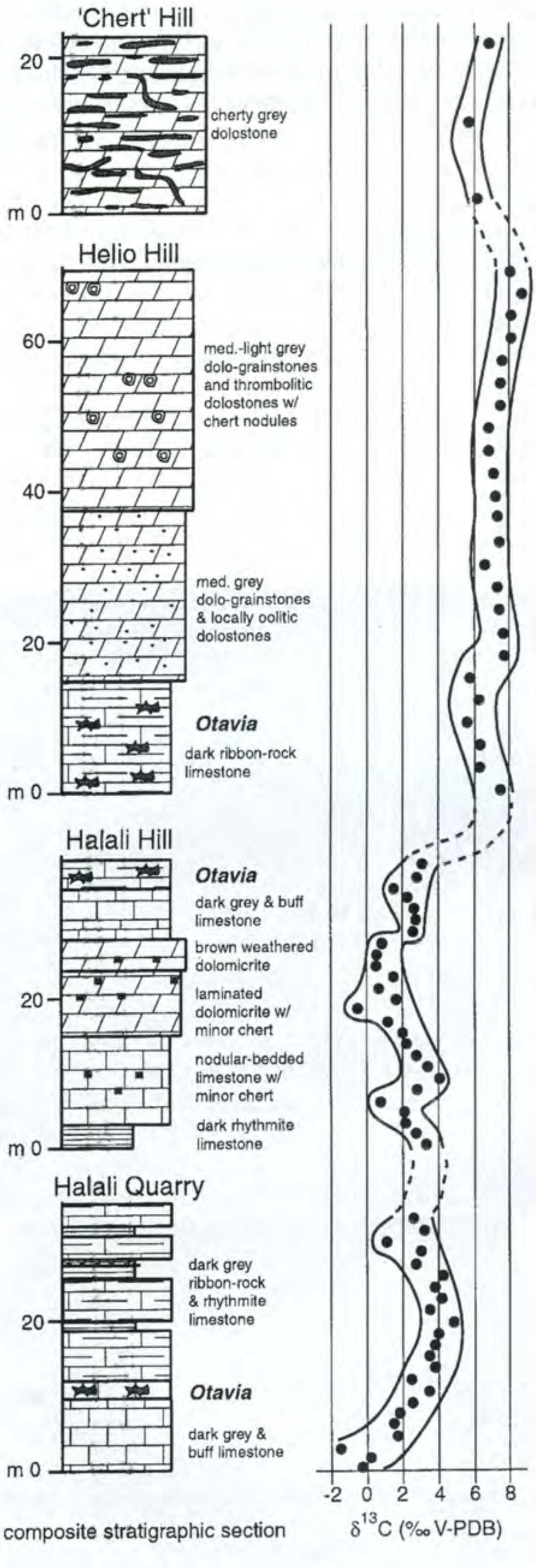


Figure 3. Composite stratigraphic section of the Otavi Group, Halali area, Etosha National Park. Each locality occurs in isolation but stratigraphic continuity is assured because the area is structurally simple and marked by shallow dips, thus the amount of stratigraphic omission between sections is minimal (no more than several metres between each section).

sequence is continued in the 40 m-thick layers of the Halali Hill, situated in the restcamp enclosure. Two kilometres to the east are the prominent twin peaks of Tweekoppies, or Helio Hill, where 60 metres of grey dolostones continue the sequence in this geographically isolated exposure of Otavi carbonates. Finally, about one km farther east is a low ridge of exposures referred to in this paper as "chert hill", which represents the stratigraphically youngest rocks reported upon here.

The lower parts of the Halali profile contain highly distinctive ribbon rocks, or nodular limestones, consisting of interfingered grey and buff layers. These outcrop again 45 km to the south, on the northern fringe of the Otavi Mountainland, just within the boundary fence of the Etosha National Park, opposite the farm Olifantslaagte. Here the ribbon rocks can be seen in stratigraphic context some distance below the Maieberg carbonate, that lies above the Ghaub diamictite elsewhere in the Otavi succession.

Lithological details of the composite Halali profile are shown in Figure 3, together with results of the carbon isotope analyses, the implications of which will now be considered.

The carbonate rocks exposed in the Halali area were measured and sampled by K.-H.H. and C.K.B. Subsequently, A.R.P., accompanied by C.K.B., field checked the sections and sample localities. A total of 77 samples was analysed for C-isotope signatures. Samples were processed following standard techniques and screening process. Samples were microdrilled (in order to minimise lithological differences, only micritic constituents were drilled) and the powders sent to the Scottish Universities Environmental Research Centre for stable isotopic analysis under the supervision of A. E. F. Approximately 1 mg of powder is loaded into a 4 ml glass tube that is sealed and heated at 70° C for 30 minutes. The sample is then placed in the Carbonate Acid Injector and a 3-way needle inserted which pumps He into the sample to purge all atmospheric gases. The He flow and vent are closed, phosphoric acid added and the sample is then allowed to react (at least 8 hours for calcite and at least 24 hours for dolomite). Once the reaction time is completed, the samples are transferred to the Gas Prep Interface Analyser linked to an AP 2003 triple-collector mass spectrometer in which the vented CO_2 is analysed. Calibrated standards are included at every run to check machine precision and reproducibility.

The resulting ^{13}C trend is shown in Figure 3 and, combined with the lithofacies character of the rocks, provides convincing evidence for correlating the isolated Halali exposures to the Auros-Ombaatjie Formations (see Figure. 2) of the Otavi Group. As discussed above, the dark grey limestones that are exposed at Halali can be observed to occur subjacent to the Keilberg cap carbonate near the Etosha border fence south of Halali. In addition, the dark grey, foetid ribbon-rocks and rhythmite limestones of the Halali successions are lithologically identical to the pre-Keilberg rocks of the Ombaatjie Formation in the eastern Kaokoveld. In the

Otavi Mountainland, the rocks immediately beneath the Keilberg cap carbonate are laminated dolomicrites and dolograinstones, facies in every respect similar to those of the Ombaatjie Formation and Halali rocks except that they are dolomitised and recrystalised. Thus, lithostratigraphically there is good evidence to conclude that the Ombaatjie, Auros and Halali rocks are correlatives.

This inference is corroborated by the ^{13}C data. The limestones exposed in the Halali Quarry and Halali Hill localities display a sharp rise from initially slightly negative values to mostly +2 to +4 values; several singular excursions to around 0 punctuate this trend. In the overlying Helio Hill and Chert Hill sections the ^{13}C values rise to +8 and remain uniform through the entirety of the exposed succession. Note that this rise is not attributable to dolomitisation because it initially occurs in the dark grey ribbon-rock limestones in the lower 15 m of the Helio Hill section (these limestones are identical to the underlying ones in the Halali Hill and Quarry sections). This overall trend (sharp rise from slightly negative to moderately positive and then uniformly +8) mirrors that known from the Ombaatjie Formation in the eastern Kaokoveld (e.g. Hoffman *et al.* 1988; Prave, Hoffmann & Fallick unpub. data) and the Auros Formation in the Otavi Mountainland (Prave, Hoffmann & Fallick unpub. data). Thus, the combined lithostratigraphic and chemostratigraphic data for the Halali rocks indicates that these, and any microfossils that they might contain, are pre-Ghaub glaciation in age.

EVIDENCE OF PHOSPHATISATION

As mentioned above, acetic acid dissolution of dark grey grainstone from the base of the Helio Hill revealed objects that superficially appeared to have been phosphatised. Examples of these objects, in the form of sponge-like 'Otavias' and shell-like 'Halalias', were mounted on SEM stubs and subjected to an EDS process (Energy-dispersive Spectometry), linked to a JEOL 5800LV Scanning Electon Microscope at the University of Pretoria's Electron Microscopy Unit, by two of the authors, J.C. and A.J.B. As a control, the same procedure was carried out on an Early Cambrian 'small shelly' tubular fossil, dissolved from a sample of Ajax Limestone from the Aroona area of South Australia. The phosphatisation of such fossils has been documented by Bengtson *et al.* (1990). The elemental composition of the three samples mentioned here is shown in Figure. 4 a - c, from which it can be seen that the peaks for Calcium and Phosphorus are virtually identical for the three samples. These results are taken to indicate that the the two kinds of Halali objects, be they micro- or pseudo-fossils, have been preserved as calcium phosphate. At the same time it should be emphasised that the heights of peaks for any particular element are not a reliable indicator of its actual abundance in the sample being investigated, though the presence of the particular element is documented beyond doubt.

It should be mentioned that this is not the first time that calcium phosphate has been demonstrated in Otavi Group carbonates. In his study of carbonates hosting the Tsumeb ore-body, Hughes (1987) remarked on the presence of calcium phosphate being present both as cryptocrystalline collophane and as crystalline apatite.

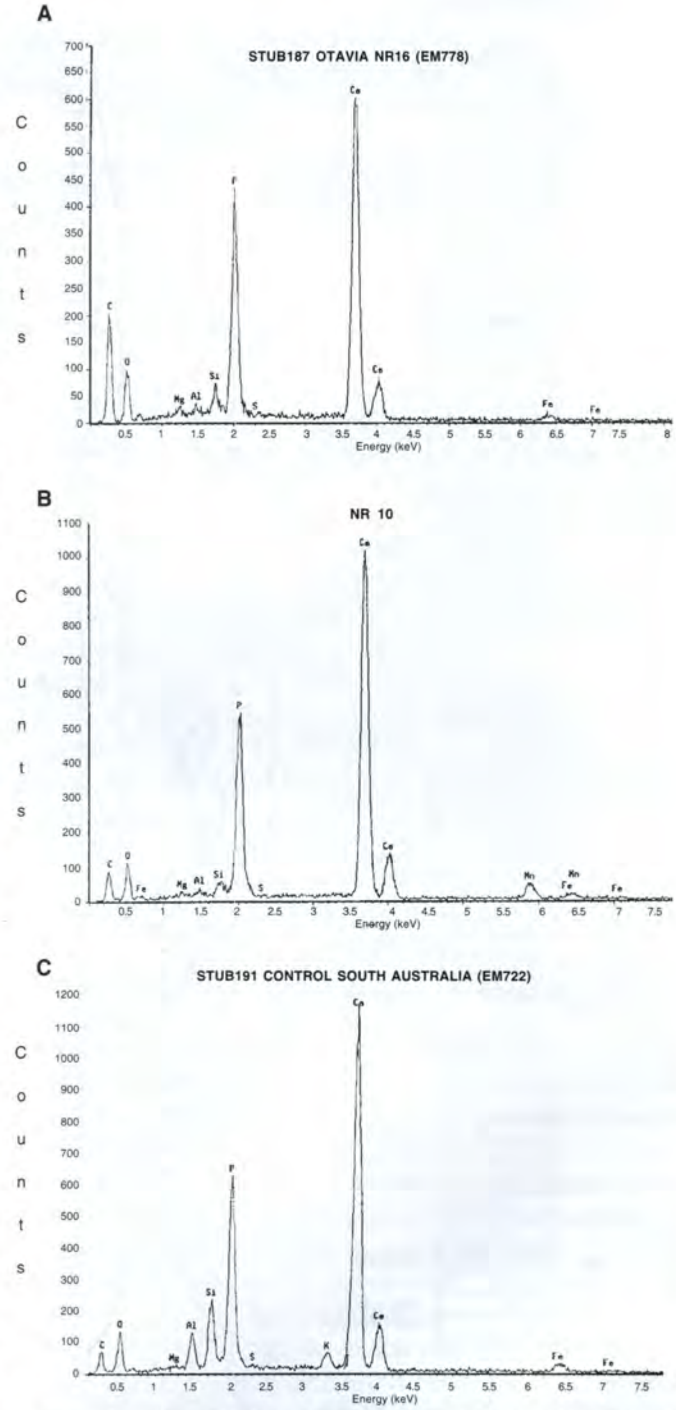


Figure 4. Energy-dispersive spectometry diagrams documenting the occurrence of elements in samples of : A. The outer envelope of an 'Otavia' specimen from the Halali Quarry section; B. A 'Halalia' shell from the same horizon and C. A control sample, consisting of a 'small shelly' phosphatised tube fossil from the Early Cambrian Ajax Limestone, Aroona, South Australia. It will be seen that Calcium and Phosphorus are represented in a comparable manner in each of the samples by this technique.

PHOSPHATIC "OTAVIA" OBJECTS WITH A SPONGE-LIKE APPEARANCE

For convenience, the objects discussed here are referred to informally as 'otavias', although no formal taxonomic designation is provided at this stage. In the Halali sequence, otavias have been found in three layers of black/grey foetid grainstones – in the Halali Quarry section, at the top of the Halali Hill and within the lowermost few metres of the Helio Hill sequence. They are extremely common in the Quarry section, less so on the Halali Hill and rare at Helio Hill, where the enclosing matrix has been partially dolomitised. In size, otavias vary from 300 micrometers to 3.5 mm in maximum dimension, with the largest specimens occurring in the Quarry section. From here a sample of 200 otavias were individually measured, as well as 90 from the Halali Hill. The greatest dimensions of these specimens were recorded after the individual objects had been manipulated under water over a micrometer scale with the aid of a stereo microscope. Most otavias from the Quarry section are 500-600 micrometers in their greatest dimension, while those from Halali Hill are typically 300-400 micrometers in length.

As shown in Figure 5, there is a good deal of variation in shape of otavia specimens, though they all share some features in common. When viewed as isolated objects sorted from acetic acid residues under a stereo microscope and then imaged with a scanning electron microscope (in this case, a Hitachi 510 at the Transvaal Museum), each otavia appears as a hollow bag, with one to five comparatively large openings, typically on raised, volcano-like mounds. These penetrate the phosphatic outer wall and lead directly into the internal cavity. The wall is also pierced by numerous smaller openings that generally lead into a "peripheral labyrinth' (for want of a better term), shown in Figure 6. This system of irregularly interlinked spaces is present beneath some parts of the outer wall and is variable in its extent; it also has connections with the internal cavity.

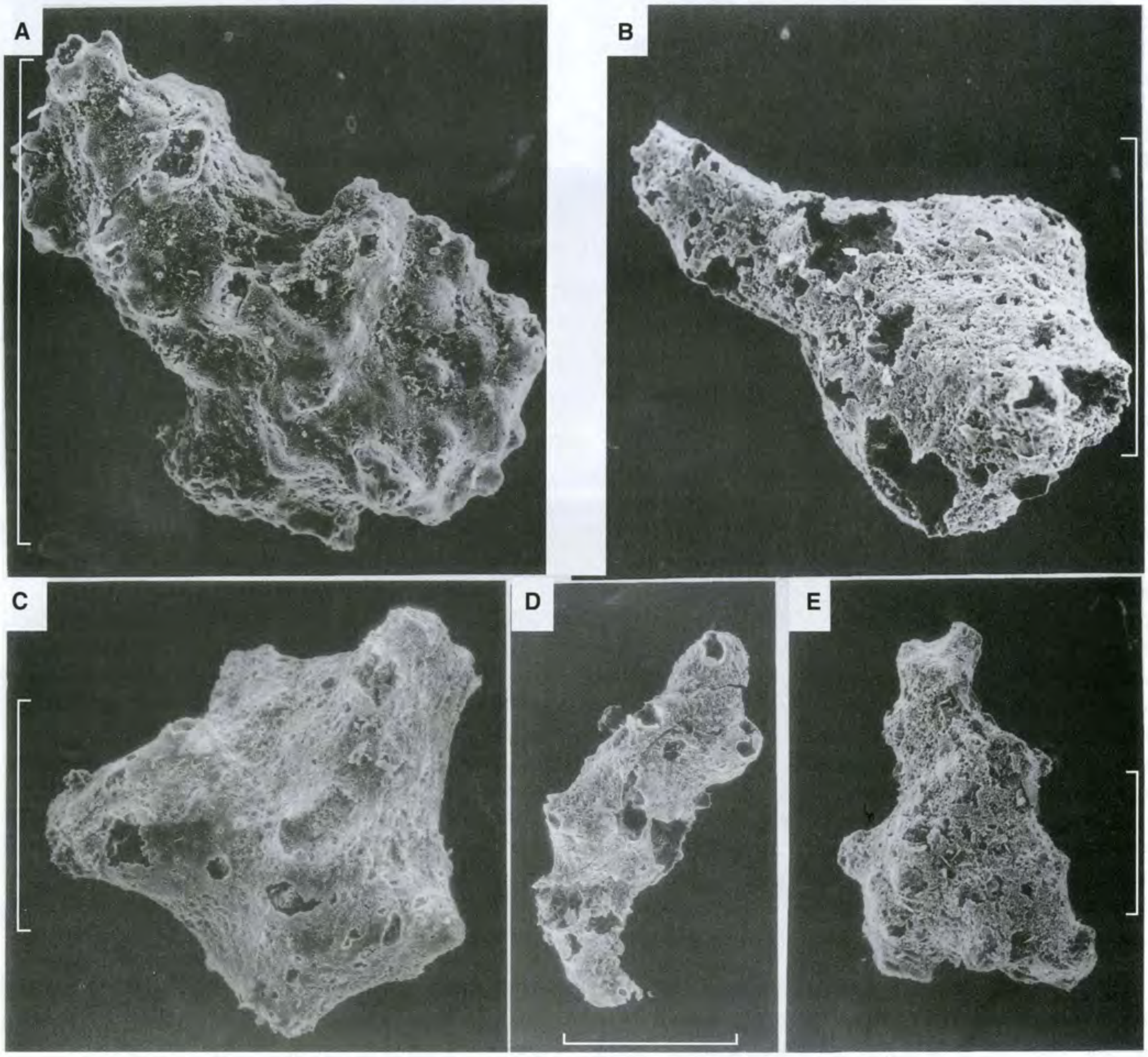


Figure 5. SEM images of 'otavia' objects recovered from acetic acid residues of Otavi limestone; A and B are from the base of Helio Hill, the others come from the Halali Quarry section. All scale bars represent 200 micrometres.

In thin sections, as shown in Figure 7, the outer envelope and peripheral labyrinth typically appear dark, or almost opaque; the walls of these structures are composed of calcium phosphate in an amorphous or cryptocrystalline form. Thin sections show the interior of the otavia structure to be filled with crystalline calcium carbonate, very similar to that of the surrounding matrix, which can perhaps best be described as a sparite.

In view of the superficial similarity in appearance of these objects to small sponges, special attention has been given to the outer walls for the possible presence of spicules, characteristic of many later sponges. Elongate crystals do occur occasionally in the walls, but they are not convincing as spicules and are more likely to be inorganic with a diagenetic origin.

In an earlier draft of this paper, one of the authors (C.K.B.) attempted an interpretation of the otavia structures, suggesting that they were phosphatised fossils of small calcareous sponges (Alternative A below). The draft was sent for comment to various specialists on Proterozoic palaeontology and valuable comments were received from Stefan Bengtson, Andrew Knoll and Bruce Runnegar, necessitating a

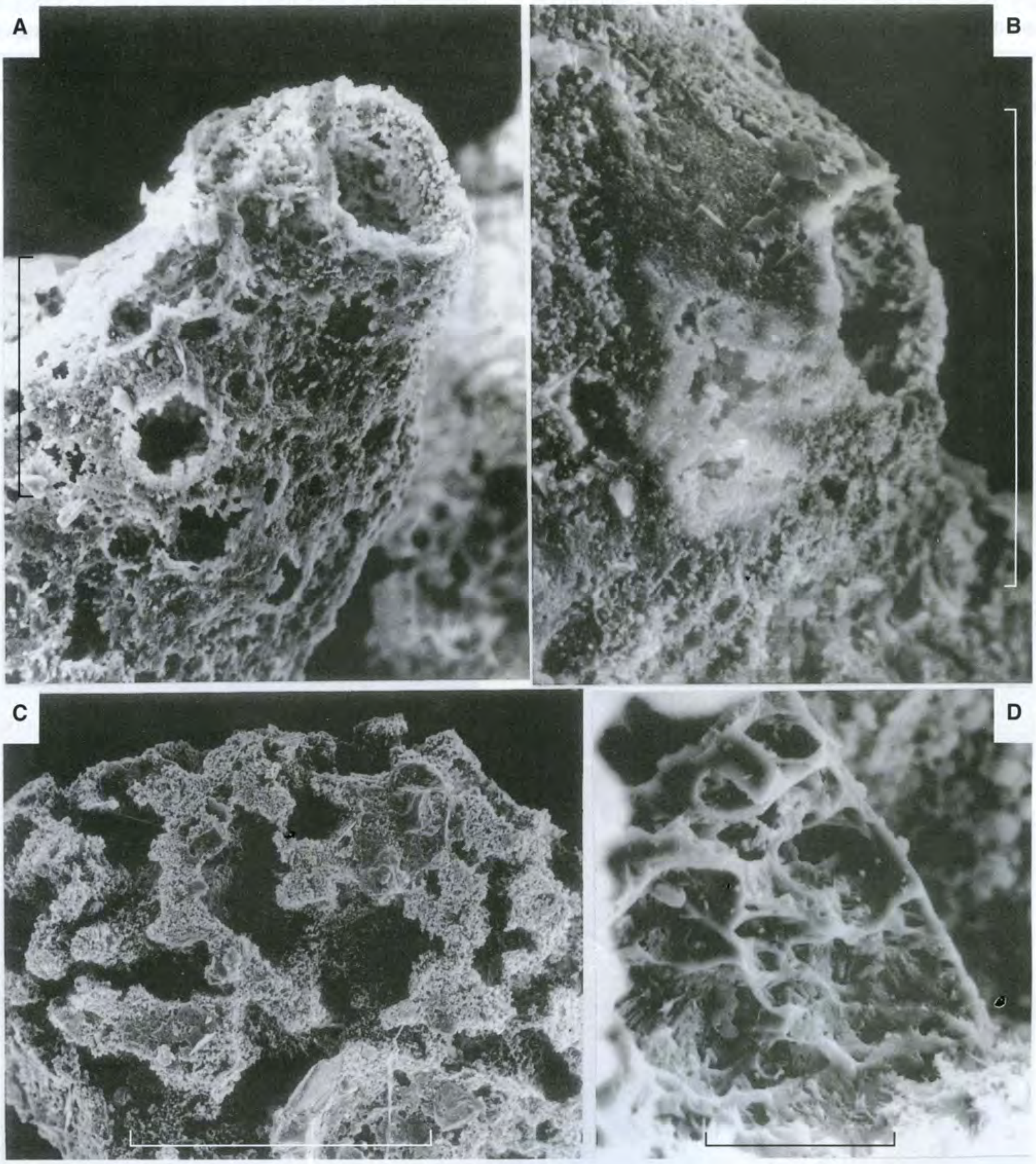


Figure 6. SEM images of 'otavia' objects from the Halali sequence. A & B show detail of openings through the outer envelope on raised eminences; scale bars each represent 50 micrometres. C & D show detail of the 'peripheral labyrinth', where the outer envelope has been removed; the scale bar for C represents 200 micrometres; that for D is 20 micrometres.

revision of some of the proposals made in the draft. These are taken into account in Alternative B, to be presented shortly, while a third possibility is expressed in Alternative C. Studies will continue on the otavias from the Halali sequence and a more firmly based interpretation may be possible in the future.

Alternative A

This interpretation assumes that an otavia existed originally as a multicellular sponge-like organism in the form of a hollow bag, the organic walls of which were penetrated by one or several larger openings, typically 25 - 200 micrometers in diameter and usually situated on raised eminences. These connected directly with the internal cavity and would have been the equivalent of the exhalent oscula of later sponges. Numerous smaller holes in the outer wall, representing incurrent pores or ostia, typically led into an irregular 'peripheral labyrinth' of interlinked chambers of variable extent, within some parts of the outer wall. These chambers in turn had connections with the internal cavity and could be interpreted as the paragastric cavities of sponges, in which flagellated collar cells were originally housed.

In his comment on this interpretation, Bruce Runnegar has reservations about the 'peripheral labyrinth' being of organic origin. He writes (pers. comm.): "The meshwork of phosphate is sponge-like but it is also the sort of structure one might expect to find in phosphate nodules formed inorganically". This is an observation that clearly needs to be taken seriously.

Another reservation, expressed by Stefan Bengtson (pers. comm.), is that the overall size of the otavias is too small for these to have functioned properly as sponges. In particular, he points out that there are critical lower limits for the size of incurrent pores or ostia, if these are to function effectively as the entry points of water streams carrying potential food items. He observes (pers. comm): "The force necessary to pump water through a tube is inversely proportional to the 4th(!) Power of its diameter (the Hagen-Poiseuille equation). In other words, resistance increases dramatically with diminishing size, and a 2 micrometer tube needs 5^4=625 times as much pressure as a 10 micrometer one to maintain the same flow, and 5^8=~400,00 times as much as a 50 micrometer one. Sponges are basically suspension feeders, and ostia this small (ie. about 10 microns across) would exclude most suspended cellular material from entering the system. Inhalent canals are typically lined with choanocytes, which are about 5-10 microns apart in diameter. Ostia down to 2 microns in diameter would be out of proportion with even the smallest inhalent canals."

Another reservation, expressed both by Bengtson and Knoll (pers. comm.), concerns the conclusion inherent in this interpretation, that the interior of the otavia "bag" was, in fact, empty prior to fossilisation. Bengtson suggests that the phosphatic 'skin' might have surrounded a solid structure. He writes (pers. comm.): "Looking at your thin sections and SEMs, I rather have the impression of irregular galleries of calcium carbonate that have been enveloped in calcium phosphate, and that the protruding necks with the "oscula" are places where the enveloped calcium carbonate has been sticking out".

This comment leads naturally to the consideration of 'microphytolites', central to Alternative B, a matter raised by Knoll and clearly critical to the understanding of Proterozoic objects of this kind.

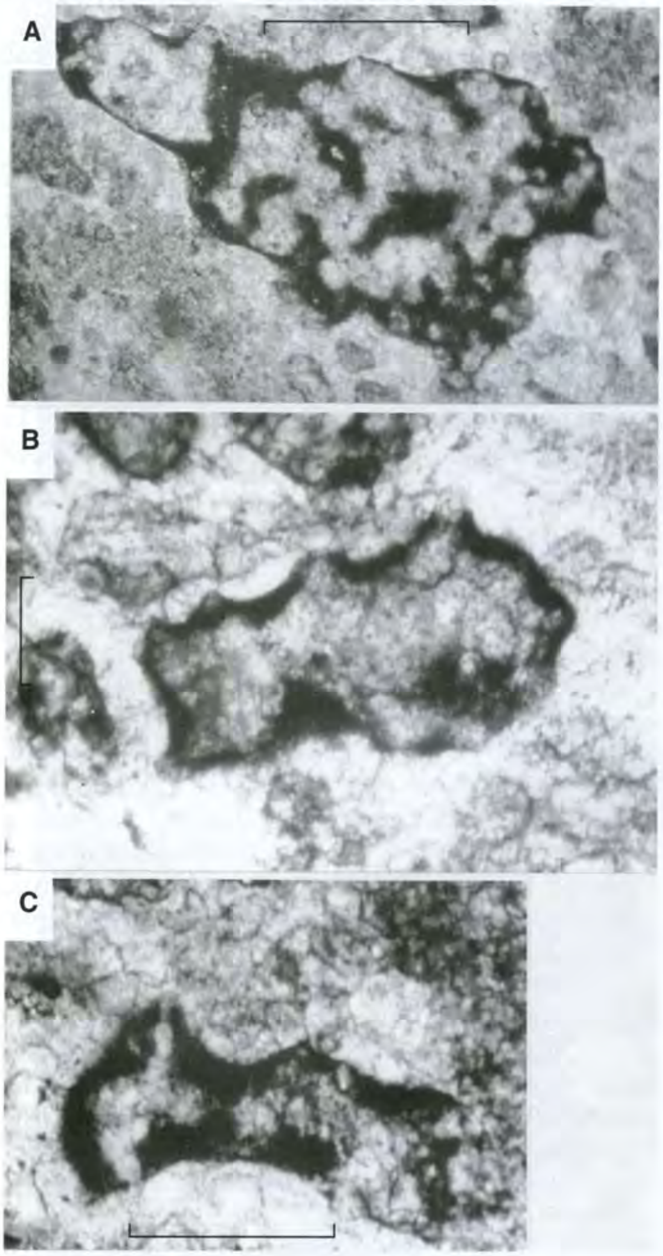


Figure 7. Thin sections of three 'otavia' objects. The black areas represent the extent of the 'peripheral labyrinths', which may fill depressions among composite microphytolite grains, according to one interpretive alternative. See text for details. Scale bars represent the following. A: 1 mm; B: 200 micrometres; C: 500 micrometres.

Alternative B

In their paper on Late Proterozoic sediments from Spitsbergen, Swett & Knoll (1985 p. 341) provide the following information about microphytolites: "In the Soviet palaeontological literature the term "microphytolite"is used to embrace a wide variety of carbonate grain morphologies ranging from fine sand to gravel in size and exhibiting highly variable shapes and internal structures. Morphologies that fall within this group include ooids, small oncolites, grapestones, algal lumps, and other, more problematic intraclasts; some have been assigned Linnean bionomials and used in biostratigraphy (e.g., Raaben and Zabrodin 1972)". They point out that microphytolites are known in various upper Proterozoic carbonates from many parts of the world and, although they do occur occasionally in modern carbonate environments, they are not common there. The reason for this is that, in a microphytolite, a variety of irregular grains is held together by a bacterial and/or algal film and, in the contemporary context, such a film tends to be consumed by grazing metazoans, causing the individual grains to separate. The overall shape of a composite microphytolite aggregate can be very irregular with projections and deep embayments in connection with which Swett & Knoll (1985) remarked: "As viewed in thin section, external shapes may be extremely elongate (L:W > 20:1) or compact (L:W ~ 1:1)".

It is of interest to note that microphytolite grains provide some information of the turbulence of the water in which they formed. Where water movement is sufficient to regularly roll carbonate grains around on the sea floor, oolitic or pisolitic grainstones can develop. In conditions of intermediate turbulence, microphytolites might well form, where the composite grains are occasionally moved, but not with sufficient regularity to acquire oolitic coatings. Finally, in tranquil aqueous environments, continuous microbial mats can develop to cover the sea floor, incorporating any microphytolites that may happen to be there. Adolf Seilacher (eg. 1999) has stressed the importance of biomats to the existence of the unusual 'Ediacaran' fauna that dominated shallow marine environments during terminal Neoproterozoic times. Such biomats disappeared with the advent of abundant surface-feeding and burrowing metazoans in Cambrian times.

Alternative B postulates that an otavia is essentially no more than a microphytolite that has acquired a phosphatic coating. Deep embayments between individual grains were originally filled with adhering bacteria, cyanobacteria or other algae and their substance was phosphatised at the time that the phosphatic envelope developed. The entire otavia structure is therefore biological only in the sense that calcium phosphate replaced the slime which served as the 'glue' for the component microphytolitic grains. Large openings in the phosphatic envelope were places where parts of grains protruded; small openings represented nothing more than defects in the envelope's continuity.

Alternative C

This interpretation takes into account the very considerable role that microphytolites played in Neoproterozoic grainstones and acknowledges that these were very likely the nuclei upon which otavia structures were built. However, in Alternative C it is speculated that the deep embayments, present in some of the microphytolite complex structures, could well have been the ideal microhabitats that promoted the evolution of the first encrusting proto-sponges. These rather loosely coordinated 'multicellular' organisms must have started as social choanoflagellates, such as still may be found in contemporary habitats, and it is suggested that these could have thrived in the deep recesses among microphytolite grains. Selective pressures may have favoured those colonies that increased their 'multicellular' tendency, promoting a coordinated flow of water, with its food particles, past the food-gathering collar cells. This would have involved the development of an outer envelope with incurrent and excurrent openings and a series of interlinked chambers in which flagellated cells were housed.

Close examination of otavia structure suggests that some of the large openings, on their raised mounds, are not simply places where microphytolite grains protruded, or where the phosphatic envelope was defective, but were biological structures. This possibility will be considered further in the future as the research project proceeds.

OOIDS WITH PHOSPHATIC RIMS AND THE GENESIS OF 'HALALIA' SHELLS

In the otavia-rich grainstone of the Halali Quarry section, complete ooids occasionally occur, typically 3 - 4 mm in diameter. These have laminated outer shells of calcium phosphate, a situation that has been described elsewhere previously, as, for instance, in Lower Cambrian sediments of Spitsbergen (Swett & Crowder 1982). As complete spheroids, however, they are rare in the Halali grainstones, when compared to the relatively common pieces of broken ooids such as those shown in Figure 8A, B. These pieces consist of an outer, often laminated shell of calcium phosphate, around the remains of the micritic 'ball' that the shell enclosed. Very frequently the pieces of outer shell have separated completely from their original cores and these phosphatic shell pieces are seen in abundance in some layers of the grainstone. In thin section, the micritic interiors of the ooids typically appear dark or opaque. What caused the ooids to break up is debatable, but there are indications that the pellet-like micritic cores of some ooids have been partially removed by diagenetic dissolution causing pieces of the outer shells to collapse inwards upon themselves. Results of this process can be seen in thin sections of oolites (Figure 9A) from the Ombaatjie Formation in the eastern Kaokoveld, of approximately equivalent age to the Halali carbonates. As shown in Figure 9B, pieces of the outer shells remain in various degrees of apposition to one another, even though the fine-grained filling has been partially removed. In the thin sections and acetic acid residues from the Halali Quarry grainstone it is not unusual to see shell pieces in bivalve-like apposition, as shown in Figure 8C, D and these are referred to (by C.K.B.) as halalias. Initially it was thought that some of these could have

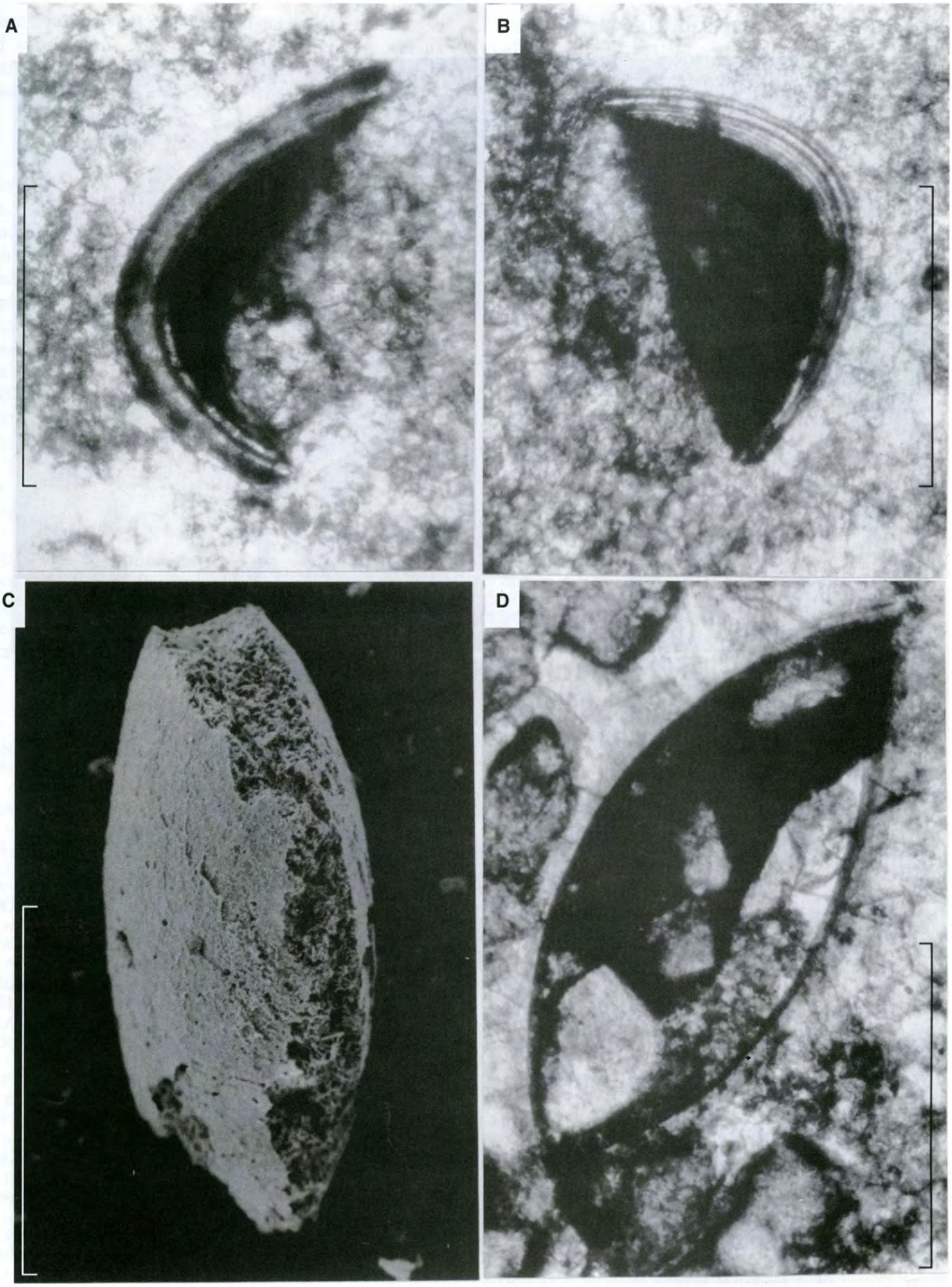
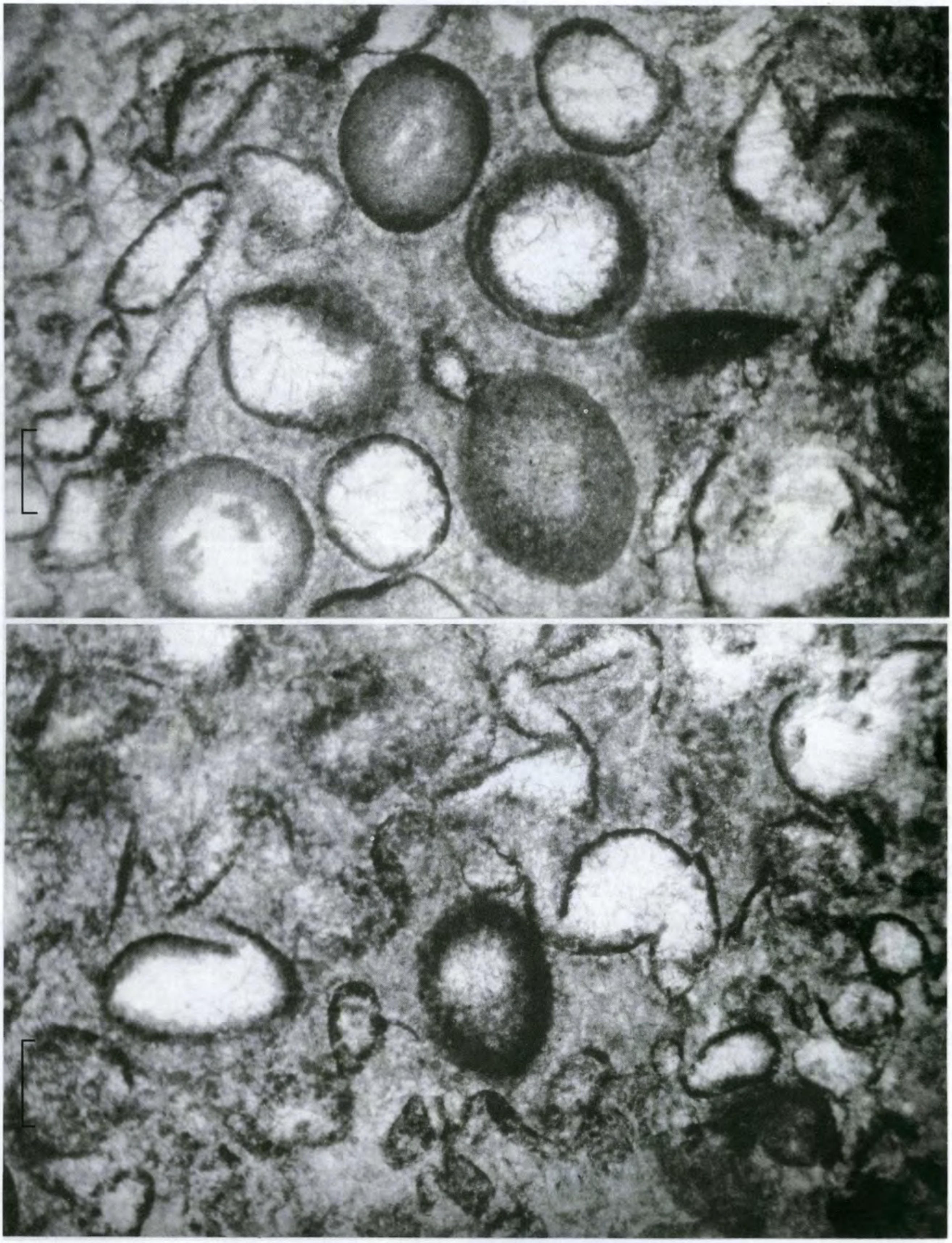


Figure 8. A & B: Pieces of broken ooid from the Halali Quarry section. Notice the laminated external shell of calcium phosphate and the dense micritic interior. Scale bars each represent 500 micrometres. C & D : collapsed ooids from the Halali Quarry section, showing a deceptive bivalve-like condition of 'halalia' shells. C is a SEM image showing the apposition of two shell pieces with remnants of their adhering interiors, while D shows two apposed shell pieces in thin section. Scale bars each represent 500 micrometres.

A



B

Figure 9 A& B: Thin sections of oolitic limestone from the Ombaatjie Formation in the eastern Kaokoveld, showing complete ooids with resistant rims in A, while B shows the effects of diagenetic dissolution of the interior of ooids and resulting collapse of the exterior shells. Each scale bar represents 1mm.

been true bivalved shells of biological origin, but in view of subsequent evidence, this interpretation seems unlikely. They are more probably highly deceptive pseudofossils.

CONCLUDING COMMENTS

As mentioned above, there is a strong possibility, based on molecular evidence, that metazoan lineages go back in time beyond the Ghaub glaciation. Soft-bodied micro-invertebrates were therefore presumably present during deposition of the Auros/Ombaatjie Formations and the best chance for their preservation is probably in a phosphatised limestone such as occurs at Halali. The superb preservation potential for embryos and algae has been amply demonstrated by Proterozoic and Early Cambrian phosphorites in China (Bengtson & Zhao 1997; Xiao *et al.* 1998; Zhang *et al.* 1998), so any phosphatic limestone from this time period is well worth investigating.

The possibility, remote as it may seem, of proto-sponge fossils being present in a pre-Ghaub limestone would imply that at least one of the sponge lineages survived the Ghaub or Marinoan 'snowball Earth' episode, to continue on a wider scale once more favourable conditions returned. Remains interpreted as being those of sponges have been well documented in the 'Ediacaran' period, following the glacial (e.g. Brasier *et al.* 1997; Collins 1999; Gehling & Rigby 1996; Li *et al.* 1998; Dong & Knoll 1996). There is even some evidence of Ediacaran-type organisms preserved in intertillite beds of Canada (Hofmann *et al.* 1990). It has been suggested that survival during the snowball Earth glacial would have been possible in locally warmed microhabitats such as close to hydrothermal vents (Erwin 1999, Farmer 2000). But new computer simulations of the snowball Earth scenario suggest that there may, in fact, have been ice-free equatorial oceans, the presence of which would have been critical for the survival of long-standing metazoan lineages (Hyde *et al.* 2000; Runnegar 2000). Studies of the palaeontological potential of the Halali phosphatic limestones will continue in the future, in the hope that they could throw some light on the antiquity of metazoan lineages in the Namibian region.

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