JURIJ ALEXANDROVICH ORLOV MEMORIAL NUMBER
JOURNAL OF THE PALAEONTOLOGICAL SOCIETY OF INDIA
VOL. 20, 1977 pp. 170—177 (*For* 1975).

CHUARIA CIRCULARIS WALCOTT AND OTHER PRECAMBRIAN FOSSILS FROM THE GRAND CANYON

TREVOR D. FORD AND WILLIAM J. BREED

DEPARTMENT OF GEOLOGY, UNIVERSITY OF LEICESTER, LEICESTER LE1 7RH
MUSEUM OF NORTHERN ARIZONA FLAGSTAFF, ARIZONA, U.S.A.

ABSTRACT

The carbonaceous disc-like fossil *Chuaria circularis* is shown to be algal in nature, probably a megasphaeromorphid acritarch. Occurrences in the Grand Canyon, Sweden, France, Siberia, Canada, Iran and India are all in very late Precambrian rocks; together they suggest an episode of giantism among planktonic algae and they may have provided the food for the evolving metazoa. The Indian fossil *Fermoria* is demonstrably conspecific with *Chuaria circularis* and the name can no longer be regarded as valid.

The associated stromatolites and nannoplankton from the Grand Canyon are briefly described, as well as the dubiofossil and pseudofossil "medusoids" and "burrows", none of which can be proved to be of organic origin.

INTRODUCTION

During the past century a number of fossils or possible fossils have been described from the Precambrian rocks of the Grand Canyon but in recent years most of these have either been reassigned to biological groups other than those in which they were first placed, or they have been questioned as to whether they were fossils at all. With the increasing interest in the early stages of life on our planet several reviews of Precambrian life in general have been published (e.g. Glaessner 1961, 1962, 1966, 1969, Cloud 1968) and these have presented conflicting interpretations of some of the fossils from the Grand Canyon. Recently, one of these fossils, *Chuaria circularis*, has been shown to be conspecific with the well-known Precambrian fossils from India *Fermoria*. (Ford and Breed 1973). This paper presents a review of the state of knowledge concerning the Precambrian fossils from the Grand Canyon, together with a re-assessment of *Fermoria*.

STRATIGRAPHY

All the fossils herein described were found in the sediments of the Grand Canyon Supergroup. These total some 4000 m of unmetamorphosed sediments, dominantly argillaceous, with some limestones, mostly dolomitic, and sandstones. They rest unconformably on a highly metamorphosed crystalline "basement" of schists, gneisses, and intrusive granites, the Vishnu Group, mostly yielding dates of around 1700 m.y. Following folding and faulting towards the end of the Precambrian, both the Vishnu Group and the Grand Canyon Supergroup were covered with great unconformity by the almost horizontal Cambrian. Deep incision of the River Colorado has revealed the outcrops of the Precambrian in the floor of the Grand Canyon. The stratigraphic succession is tabulated below.

STRATIGRAPHIC SUCCESSION IN THE GRAND CANYON
CAMBRIAN

......................"Great Unconformity"..................

Precambrian	Formation	Member	lithology	thickness
Chuar Group	Sixtymile	..	Breccias	36 m
	Kwagunt..	Walcott	Shale & Dolomite	255 m
		Awatubi ..	Shales	344 m
		Carbon Butte	Sandstones Shales	76 m
	Galeros ..	Duppa ..	Shales	174 m
		Carbon Canyon ..	Limestones Shales	471 m
		Jupiter ..	Shales and some limestones	462 m
		Tanner ..	Dolomite Shales	195 m
	Nankoweap		Sandstones	100 m
	Cardenas Lavas			297 m
Unkar Group ..	Dox		Sandstones	952 m
	Shinumo		Quartzites	410 m
	Hakatai		Shales	289 m
	Bass		Dolomites etc.	100 m
	Unconformity			
Vishnu Group	Gneisses, schists and granites.			

CHUARIA CIRCULARIS

This small disc-like carbonaceous fossil was first found by Walcott during his pioneer work in the Grand Canyon Series (Precambrian) in 1882-3. It was formally named in 1899 and described as a primitive brachiopod allied to *Obolella* or *Discina*. As such it was the first Precambrian brachiopod to be described, and it is somewhat surprising that it was largely overlooked by subsequent writers. The exceptions include Wenz (1938) who assigned *Chuaria* to the Gastropoda, without giving very clear reasons for so doing, Häntzschel (1962) who regarded *Chuaria* as inorganic and both Glaessner (1966) and Cloud (1968) who tentatively regarded it as algal in nature, without going into details. Rowell's review of supposed Precambrian brachiopods (1971) did not mention *Chuaria*.

Ford and Breed (1969) relocated Walcott's type locality and obtained many more specimens from a horizon high in the Awatubi Member in the Kwagunt Formation, Chuar Group. This is some 10 m stratigraphically below a prominent ledge of pisolitic chert in the saddle on the east side of Nankoweap Butte in the eastern Grand Canyon. The stratigraphic details are in Ford and Breed (1972 a and 1973 a) while the fossil itself has been discussed by the same authors (1972 b, 1973 b, 1974).

Chuaria circularis has the form of crushed spheroid, composed of organic matter, largely carbonized. Generally 2-3 mm diameter, specimens lie either alone or side by side in small clusters; none have been seen to lie on top of another, indicating their globular shape at the time of deposition. Specimens extracted from the shale with acids, are hollow with an apparent narrow margin caused by crushing, which has wrinkled the central area. No apertures have been seen and no ornament recognized. It is quite clearly not a brachiopod shell, nor is it a gastropod. Other tentative suggestions have included the possibilities that *Chuaria* might be a trilobite egg or a non-calcareous foraminiferan but no evidence to support such suggestions can be found.

The limited chemical evidence which can be obtained from the highly carbonised remains of *Chuaria* support the morphological arguments that it is of algal origin (Eisenack 1966; Ford and Breed 1973 b; Niklas and Chaloner 1975).

Fossils from the Precambrian of southern Sweden help to answer the question—what is *Chuaria?* First described by Wiman (1894) they were named *Chuaria wimani* by Brotzen in 1941, and have been the subject of investigation by Eisenack (1951; 1966) and by Timofeev (1960; 1969; 1970). Martinsson (in litt.) has informed us that he regarded what Timofeev had called *Laminarites* pellicles as really *Chuaria* apparently altered by the method of preparation. Since Vidal (1974) has investigated many hundreds of specimens of *C. wimani* and has come to the same conclusion as the present authors, that there is no distinction between *C. wimani* and *C. circularis*, and that the latter name has priority. Vidal has also supported the present authors in referring Timofeev's *Kildinella magna* (Timofeev 1969 & 1970) to *Chuaria circularis* and has added *Trachysphaeridium vetterni* Timofeev (1969) to the synonymy. Vidal has noted the occurrence of a variety of other microplankton fossils with *Chuaria* in the Visingsö Series, just as Downie (in Ford and Breed 1969) noted their presence in the Grand Canyon. Specimens referable to *Chuaria* range from a few microns in diameter up to several millimetres.

In describing medusoids from the Central Mt. Stuart Beds of the Central Australian Late Precambrian, Wade (1969, p. 356, pl. 69, fig. 5-7) noted 'numerous minute unidentifiable organisms' in maroon sandstones with minor shales. Latex casts have been examined by the present authors and the impressions clearly show the concentric wrinkles characteristic of *Chuaria*, though they are somewhat larger, ranging between 5 and 8 mm. Hofmann (1971) compared them with the Canadian specimens of *Chuaria*.

A fossil comparable to *Chuaria* is *Fermoria*, first described from the late Precambrian of India and more recently from Iran.

Small carbonaceous disc-like fossils were found in the Suket Shales of the Vindhyan System of India by Jones (in Holland 1909, p. 66) ,who commented that they might be compared with either *Obolella* or *C. circularis*. Other suggestions (see Pascoe, 1959, p. 498) were that they belonged to *Acrothele*, known to occur in the Cambrian of the Salt Ranges. However, Chapman (1935) assigned the specimens to two genera and four new species, *Protobolella jonesi*, *Fermoria minima*, *F. granulosa*, and *F. capsella*.

Sahni (1936) thought that there was insufficient evidence for the separation of these and placed them all in the synonymy of *F. minima*, though at the same time erecting a new generic name *Vindhyanella* for one of those specimens figures as *Protobolella jonesi* by Chapman (1935, pl. 2, fig. 1), though he admitted that the specimen was lost!

In 1954 Sahni and Shrivastava briefly described and named a single, larger, new fossil found with *Fermoria* as *Krishnania acuminata*. Their illustration (1954, fig. 4) is entirely unconvincing regarding the filaments they claim to be attached, and the writers support Glaessner (1962) in regarding it simply as a large *Fermoria*.

Misra and Dube (1952) recorded new material with *Fermoria* which they regarded as mostly inorganic pellets. Misra (1957) restated this, noting that some alleged *Fermoria* were chlorite aggregates in schists, and others were haematite spots in sandstones. Misra's plate 7, however, shows forms which could easily be badly preserved algal bodies like *Chuaria*.

Pascoe (1959, facing p. 498) figured specimens up to 4 mm diameter. He also commented that *Fermoria* left a white ash when incinerated and was therefore a plant, but at the same time he felt it possible that *Fermoria* could be an archaic form of brachiopod though with 'no reliable features definitely attributable to this class'.

A few specimens of *Fermoria* from the Geological Survey of India collections have been examined. They are from Neemuch, Madhya Pradesh (24 °24′ north, 74° 54′ east), in the Vindhyan System. They occur either isolated or as small clusters of smooth carbonaceous discs on fissile olive-coloured shale. Taking these in conjunction with the various descriptions of other specimens, the writers have no doubt that *Fermoria* should be regarded as synonymous with *Chuaria*. In this they support Rowell (1971) who, in his review of supposed Precambrian brachiopods, discussed *Fermoria* at length saying that he could not regard it as a brachiopod and that it was probably algal. Rowell also noted that the generic name *Fermoria* was of doubtful validity according to the International Code of Zoological Nomenclature, owing to Chapman's failure to designate a type species.

Fermoria has also been found in Iran, apparently in large numbers at several localities. Assereto (1963, pp. 507-508, fig. 2) and Stocklin *et al.* (1964 p. 14. pl. 1, figs. 3-5) have recorded *Fermoria* in the Chapoghlu Shales (late Precambrian) of Northern Iran. They figure specimens up to 3 mm diameter crowded together.

A few specimens of *Fermoria* from Iran have been examined, and a number of unpublished photographs by R. Assereto of other specimens have been available for comparison. Though mostly lacking in carbonaceous matter, the impressions on fine-grained olive-grey shale are so close to *Chuaria* as to leave no doubt that here again, organisms identical to *Chuaria* were present. Whole surfaces of chips of shale are covered with impressions, and clusters of at least fifty are indicated. They are commonly 2-3 mm in diameter. There is little indication of overlap, but concentric wrinkles are frequent particularly near the margins.

Recent interpretations of *Fermoria* have either been non-committal or that it is algal. In the Treatise volume on Brachiopods (Williams *et al.* 1965, p. H864) *Fermoria* is noted only as a synonym of *Protobolella*, which in turn is listed among the generic names erroneously ascribed to Brachiopoda. Häntzschel (1962, p. W 240) listed *Fermoria* amongst unrecognizable genera.

Glaessner (1966, p. 41) was non-commital and noted both *Fermoria* and *Chuaria* under the heading of 'other algae', thus supporting (Howell (1956, p. 110), while Cloud (1968 also listed *Fermoria* as 'possibly algal but needs restudy'.

A further occurrence of what are probably *Chuaria* has been found in silty and argillaceous members of the Hazara Slate Formation near Bargali in Pakistan (Davies 1973). In his paper he quotes Rowell as saying they were similar to *Fermoria* but he doubted whether they were brachiopods and suggested they could be algae.

Small fossils were found many years ago in the late Precambrian Hector Formation of Banff National Park in Canada (Allan 1913) though they were not named until Hofmann (1971) referred them to *Chuaria*. Both the present authors (Ford and Breed 1973 b) and Gussow (1973) have studied these independently and have come to the same conclusion that they were identical to *Chuaria circularis* from the Grand Canyon. Gussow also commented that he regarded *Fermoria* as identical to *Chuaria*.

Chuaria has also been found in the Vendian of Siberia though named *Beltanelloides sorichevae* by Sokolov (1973) and regarded by him as small medusoids. Subsequently in correspondence he has agreed that this was a mistaken identification and that the Siberian fossils are in fact *Chuaria*. Commonly 5 mm in diameter they range up to an exceptional 44 mm.

In the Brioverian of Northern France Roblot (1964) described "sporomorphs" up to 00.25 mm in diameter and it seems very likely that these are small *Chuaria*.

All the more recent writers have agreed that *Chuaria circularis* and hence *Fermoria* is algal—Ford and Breed (1973b) and Vidal (1974) are agreed that it is best regarded as a giant acritarch of the "Group Megasphaeromorphida" of Timofeev (1969).

All occurrences of *Chuaria*, in the Grand Canyon, in Canada, Siberia, France, Iran, India and Australia are in late Precambrian rocks generally in the 700-800 million year range, though accurate radiometric dating has proved difficult owing to the lack of suitable rocks. It seems likely that this was a period in the Earth's history when life in the seas was characterized, at least for a time, by giant planktonic algae, possibly going through an encysted stage. It is possible to speculate that they provided the metabolic stimulant food for the metazoan animals which were evolving then.

In association with *Chuaria*, Walcott also noted the presence of a hyolithid shell, a fragment of a tribolite and Lingulid shell. Subsequently (1899) he dismissed the first two as inorganic (his drawings allow no conviction that the objects were of organic origin), and the Lingulid shell was not mentioned again, so it may also be dismissed. He also (1899) noted an enigmatic object showing similarity to the brachiopod *Acrothele* in a limestone 45 m above the shale with *Chuaria*. This has been seen in the U. S. National Museum (no. 33801) and it provides no conviction that it is organic in any way.

White (1928) reported a form closely similar to *Chuaria*, which he regarded as of plant nature, in the Bass limestone, but as he did not specify a locality and none of his specimens can be located so this record must remain unconfirmed.

MEDUSOIDS

A structure found in a sandstone of the Nankoweap Formation in Basalt Canyon, eastern Grand Canyon, was claimed to be the impression of a stranded jellyfish by Van Gundy (1937, 1951). Comprising a series of lobes rounded at the extremities, some with a median groove, radiating from a small irregular hollow, the whole some 12 cm in diameter, this was further described as a jellyfish impression by Hinds (1938) and Bassler (1941). It was named *Brooksella canyonensis* by Bassler as a new species of a genus well-known in the Paleozoic. However the interpretation of the genus as a jellyfish is still in some doubt. Cloud (1960, 1968) obtained a partial second specimen, but claimed that the structures were of inorganic origin, formed by "compaction of find sands deposited over a compressible but otherwise unidentifiable structure, possibly a small gas blister". Glaessner (1969) was unconvinced by Cloud's explanation and drew comparison with stellate trace fossils in the Mesozoic, deducing that it was of organic origin and that its "possible originator was a sediment feeder able to burrow into the sediment ... worm-like in shape ... probably an annelid". Glaessner accordingly re-named the structure *Asterosoma? canyonensis*. In view of the probable age of the Nankoweap Group being about 1000 million years, this would make this fossil one of the earliest records of a burrowing sediment feeder on earth. In view of the profusion of burrows in Cambrian rocks, the sparsity of such fossils, if they are such, in the Nankoweap Formation arouses suspicion. One of the writers has been able to see both specimens and the similarity to small "sand-volcanoes" formed by the expulsion of gas or fluid from sands deposited in shallow-water turbidite conditions is striking. In view of this the writers find it difficult to support Glaessner's interpretation. A more intensive search of Nankoweap sandstone outcrops for comparable structures is obviously needed.

Two further types of "jellyfish-like" impression were described by Alf (1959) from bedding surfaces of a red siltstone at about the boundary of the Hakatai and Bass Formations of the Unkar Group, a few metres below the Kaibab trail into the Grand Canyon. These show concentric wrinkles round an irregular depression (preserved as a boss on the cast). Pairs or triplets with straight mutual boundaries are not uncommon. Associated bedding surfaces show abundant ripple-marks, mud-cracks and occasional salt-pseudomorphs, indicating very shallow water sedimentation with intermittent desiccation. Alf (1959) regarded the structures as the impressions left by jellyfish, but Seilacher (1956) interpreted them as diagenetic haloes around crystal pseudomorphs of inorganic origin, while Cloud (1960; 1968) noted them as non-vital structures, expressing the opinion that they were due to a scatter of raindrops falling on to wet sediment. Some of Alf's specimens bear a close resemblance to the gas-pit shown in Maxson's (1940) figure 1. However, Glaessner (1966; 1969) disagreed, saying that the structures could not be formed by a falling drops. Instead he drew a comparison with the gelatinous sheaths formed by certain living diatomaceous algae in Australia. This comparison warrants further investigation but the present authors are sceptical, and feel that the disturbance of the laminae beneath the centres of the structures idicates escaping gas bubbles, in some cases with subsequent diagenetic crystal growth. Germs (1972) has noted similar structures to Alf's in the Nama System of South West Africa and he supports Glaessner's interpretation by regarding them as being of algal origin.

None of the so-called medusoid impressions from the Grand Canyon bears any resemblance to those described from Ediacara, South Australia, described by Glaessner and Wade (1966); and the existence of fossil jellyfish in the Grand Canyon must be regarded as unproven.

TRACKS AND BURROWS

At Alf's ',medusoid" locality near the Kaibab trail, Seilacher (1956) also noted rare tiny bilobate marks comparable to the tracks of bilateral animals, but Cloud (1968) regarded these as non-vital. Alf (1959) described some "vermiform markings", and both Cloud and present writers have seen numerous elongate lobate structures superficially similar to tracks or burrows in the Grand Canyon Precambrian where close examination has shown them to be the lower terminations of mud-crack structures due to desiccation, as was suggested by McKee (1932) for markings on bedding planes in the Dox Formation.

Together with Glaessner's interpretation of *Brooksella canyonensis* discussed above, records of tracks, trails and burrows in the Precambrian of the Grand Canyon must be regarded as unproven as yet.

SPONGES

Alf (1959) also described a silicified sponge from the Hakatai, but Cloud (1968) dismissed it as a nodule, and all other writers appear to agree. Nitecki (1971) found closely similar siliceous concretions to be common in the Bass Formation near Bass Rapids, and argued that they were of inorganic diagenetic origin, though on dissolving one in hydrofluoric acid small "pollen-like" bodies were released. These may be nannoplankton and warrant further investigation.

OTHER MACROFOSSILS

Smith (1968) described what he claimed to be small bivalves of unknown affinity in the Bass Formation. Taking the form of ellipsoids one-tenth to one-fourth of an inch in length, they occur in a bed 10-20 cm thick over a considerable length near Bass Canyon. However, close examination of material from the original locality shows what appears to be rounded mud-flakes or pellets with a micrite envelope, possibly oncolites of algal origin. While a bivalve origin in rocks of this age is most unlikely the possibility that they may be partly algal growths requires further investigation.

STROMATOLITES

The structures in Precambrian, and later, limestones known as stromatolites have been and still are the subject of much controversy. While most workers accept now that they were built by the activities of mats of Cyanophyte algae, differences of opinion exist concerning whether Precambrian forms are analogues of modern forms in their shape and environment. Most modern stromatolites are found in inter-tidal or supra-tidal environments, though a few occur in deeper water. In the Precambrian the sediments associated with stomatolites generally indicate quiet shallow waters if not actually inter-tidal, but a few occur in sediments indicative of much more turbulent water. The geometrical forms built by the laminae either as biochemical byproducts of the algal metabolism or by adhesion to the mucous filaments vary from undulations through connected domes, to discrete domes and columns with numerous tuberous excrescences sometimes present. In modern cases the geometrical form appears to be controlled by the position with respect to tide levels on a shore line and some workers have claimed this to be the case in the Precambrian also. On the other hand the species which make up the assemblage in a stromatolite can also exert some control over its shape, and many workers have thus named distinctive forms as though they were biological entities with reasonably constant form. Many years of research in the Precambrian of Russia have allowed a detailed biostratography to be built up, with assemblage zones of stromatolites, each bearing a biological name, used to delimit divisions of Precambrian time. The same technique has been applied successfully in Australia, but in North America only preliminary work has been done as yet.

Stromatolites are common in the Precambrian of the Grand Canyon, where they were first noted as "concretionary limestones" by Walcott (1894) and given the now obsolete name *Cryptozoon occidentale* by Dawson (1897), though their nature was not then understood. Ford and Breed (1969, 1973 a) have recorded three conspicuous stromatolite horizons in the Chuar Group, as well as a number of less important occurrences. They generally have shapes such as gentle undulations or low domes with confluent laminae and only occasionally show the more distinctive columnar forms which Russian workers regard as the diagnostic fossils. Forms have been recognized by comparing the external form with those illustrated by Cloud and Semikhatov (1969) though diagenetic alteration has obscured internal detail and made more specific determination impossible. The recognition of these genera allows correlation of the Chuar Group with the Russian Upper Riphean, i.e. late Precambrian.

The three beds of stromatolites in the Chuar Group are well-exposed; the highest forms a bed of stromatolite bioherms at the base of the Awatubi Member and the columnar structure suggests the form *Boxonia* Koroljuk. The middle horizon is a single bed of dolomitic limestone within the many of the Carbon Canyon Member which contains abundant forms resembling *Baicalia off rara* Semikhatov. The lowest horizon is in a rubbly limestone with gypsum pseudomorphs at the base of the Jupiter Member; it includes the forms *Inzeria* and *Stratifera*.

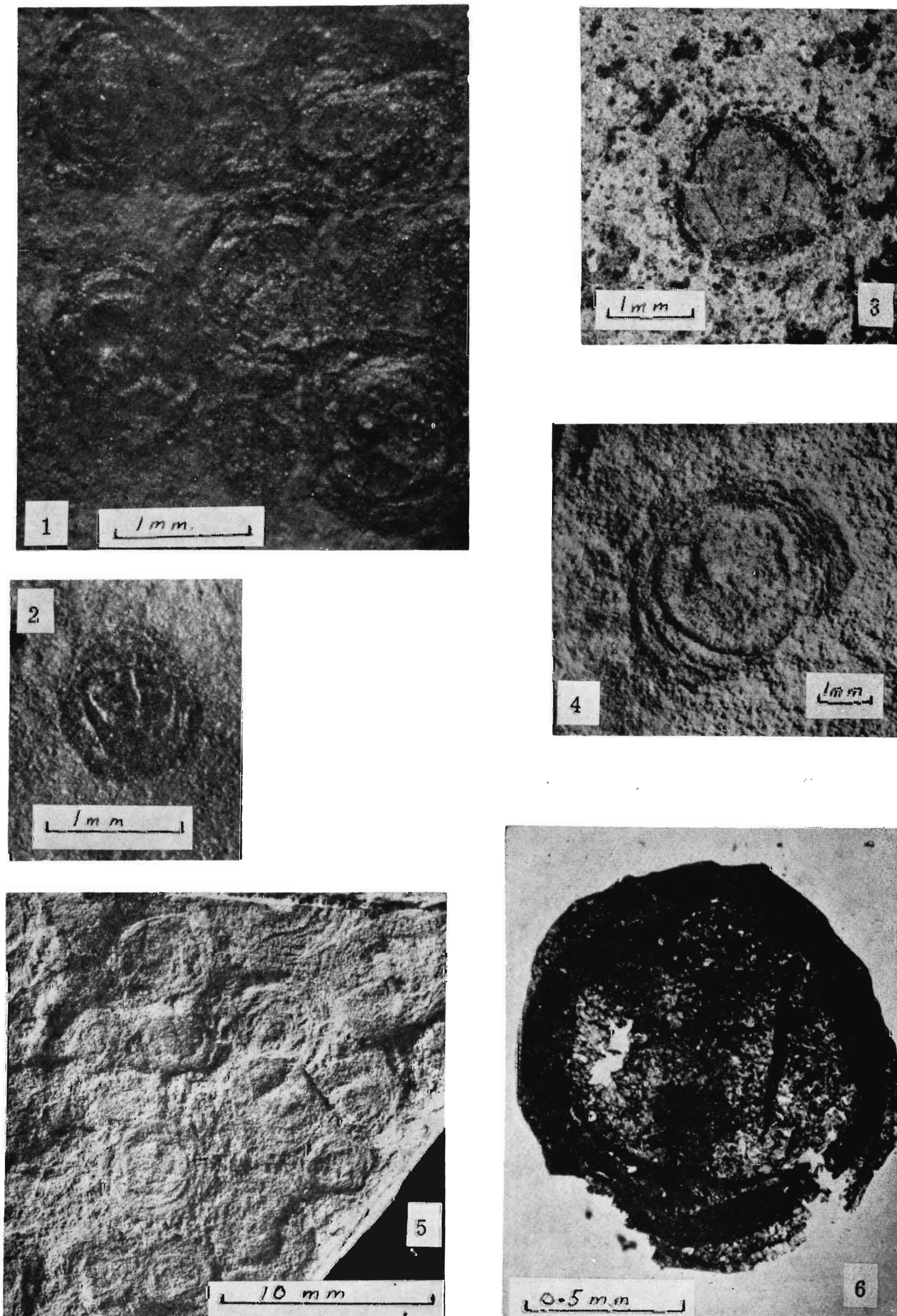
Stromatolites have also been found in the Bass Formation, though the stratigraphically diagnostic columnar forms are uncommon, and only the forms *Collenia undosa* Walcott, *C. symmetrica* Fenton & Fenton and *C. frequens* Walcott have been recorded so far (Beus *et al.* 1974). A further stromatolite horizon, as yet undescribed, has been found in the Dox Formation.

The environment of stromatolites in the Grand Canyon is, judged by the associated sediments, one of quiet shallow waters. Ripple-marks and mud-cracks are common suggesting intermittent desiccation. Thin layers of flake-breccia indicate occasional turbulence of brief duration, but no evidence directly indicating an inter-tidal environment close to a shore-line has been seen.

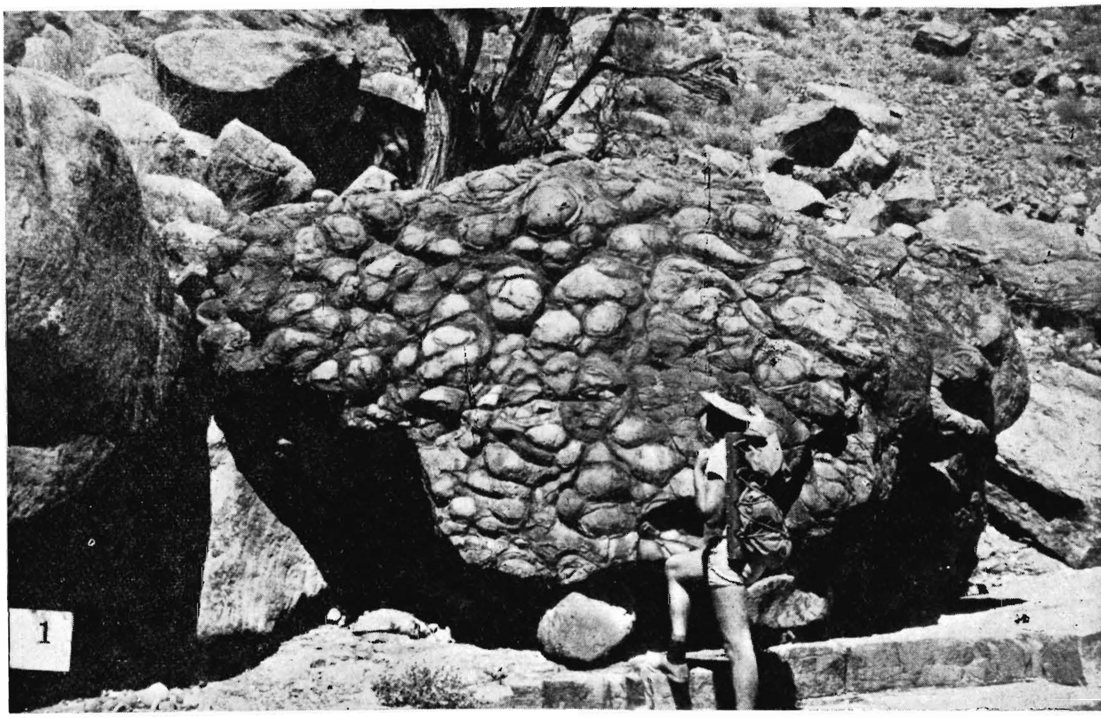
MICROFOSSILS

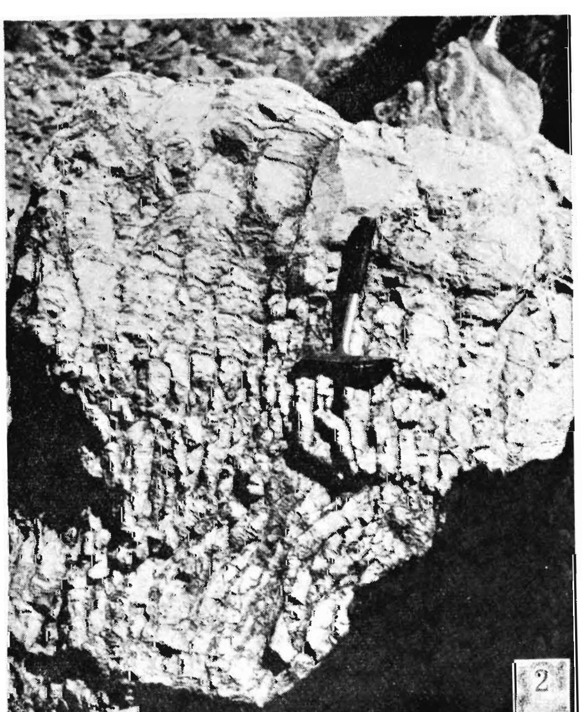
The study of micro-organisms, usually regarded as nanno-planktonic algae, has been developed widely in Russia, and a few other places around the World. In the Grand Canyon the only record are of the pollen-like bodies released from siliceous nodules in the Bass limestone (Nitecki 1971), and of the variety of round or oval bodies ranging from 12 to 62 mm in diameter found by Downie (in Ford and Breed 1969) in the *Chuaria* shales. Downie compared these with forms named from the Visingso Series of Sweden by Timofeev (1960, 1969) but also pointed out the considerable nomenclatorial problems surrounding these. Clearly more micro-paleontological work is needed in the Precambrian of the Grand Canyon.

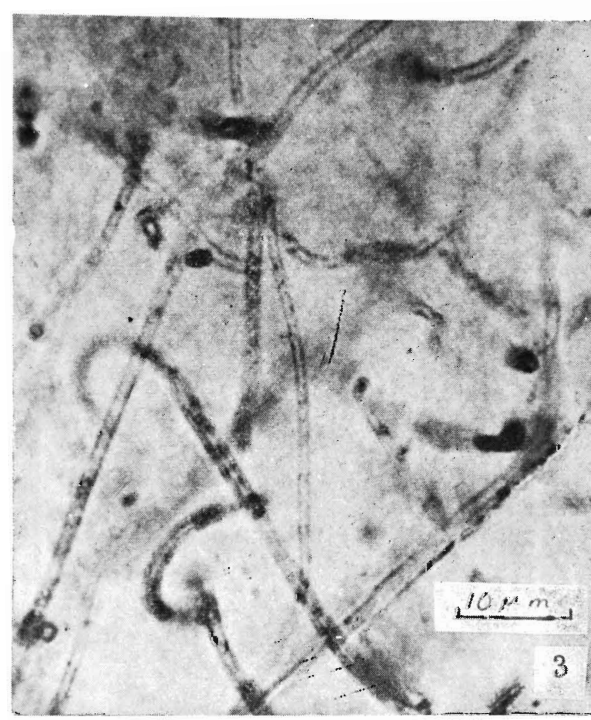
A further assemblage of microfossils has been found in the cherty pisolite at the base of the Walcott Member of the Kwagunt Formation on Nankoweap Butte, (Schopf, Ford and Breed 1973). These consist of well-preserved spheroidal and filamentous nannofossils and they are



FORD AND BREED



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most abundant in the outer layers of the silicified pisoliths. The spheroidal forms are probably related to coccoid blue-green algae, while the filaments bear a striking resemblance to *Eomycetopsis*, a thallophyte previously recognized in the bedded cherts of the Bitter Springs Formation of Central Australia.

A similar, but more abundant, assemblage, has subsequently been found in black chert nodules in limestones of the Carbon Canyon Member of the Galeros Formation (Schopf, verbal communication 1975).

Larger filaments, less certainly of algal origin, have also been reported in thin sections of the Bass Limestone, where associated with stromatolites (Dalton, 1972; Beus *et al.* 1974). Ranging up to 2 mm in length, these are associated with apparent calcispheres about 0.4 mm in diameter and with ovoid pellets from 0.1 mm to 3 mm in diameter. The latter are suggestive of the faecal pellets of a burrowing organism though no burrows were recognised. Further study of these possible fossils from the Bass Formation is still needed.

CONCLUSIONS

Of the variety of Precambrian fossils reported from the Grand Canyon only the large acritarch *Chuaria* probably a giant algal cyst, stromatolites and the nannoplankton in the cherty pisolite are undisputed. The identification of medusoid impressions, bivalves, burrows and sponges can only be regarded with scepticism. *Chuaria* and the nannoplankton have only been found in the Chuar Group, but some of the stomatolites and possible plankton have been found in the Unkar Group. The former probably date from about 700—800 million years ago, but the Unkar Group appears to have been deposited between 1400 and 1000 million years ago (Elston and Gromme 1974).

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CHUARIA

EXPLANATION OF PLATES

Plate I.

Chuaria circularis

Fig. 1. Cluster of *Chuaria circularis* Walcott from the Chuar Group, Grand Canyon, Arizona.

Fig. 2. Typical specimen of *Chuaria circularis* Walcott from the Grand Canyon.

Fig. 3. *Chuaria circularis* from the Grand Canyon prepared by the peel teehnique.

Fig. 4. One of Wallott's "type specimens" of *Chuaria circularis* from the Grand Canyon in the U. S. National Museum collection No. 33800.

Fig. 5. *Chuaria circularis* cluster on Chapoghlu Shale, Iran, previously noted as "*Fermoria*".

Fig. 6. *Chuaria circularis* from the Visingso Series of Sweden, previously noted as *Chuaria wimani.*

Plate II.

Grand Canyon Precambrian fossils.

Fig. 1. Stromatolite bioherm of form *Boxonia* from the Kwagunt Formation, Chuar Group, Grand Canyon, Arizona.

Fig. 2. Part of Stromatolite bioherm of form *Boxonia* from the Grand Canyon.

Fig. 3. Algal filaments from cherty pisolite, Kwagunt Formation, Chuar Group, Grand Canyon(photo courtesy J. W. Schopf).

ADDENDUM

Since the above was written in early 1975 there have been three important publications relating to Precambrian fossils in the Grand Canyon.

Bloeser *et al.* (1977) have noted the distribution of *Chuaria* and of algal unicells and filaments at further horizons in the Chuar Group, notably the Carbon Canyon Member of the Galeros Formation. Much more important, however, is the discovery of abundany Chitinozoans in the Walcott Member at the top of the Chuar Group. These protozoan cysts are well known in the Palaeozoic but had not previously been reported earlier than the lower Ordovician (Tremadocian) so that the discovery considerably extends their chrolonogical range.

Vidal (1976) has added considerably to detailed knowledge of *Chuaria* in a study of acritarchs from the Visingso Series of Sweden. He has found that *Chuaria* ranges down in size to 100 m. Some specimens showed a psilate or chagrinate surface.

In an electron microscope study of Tasmanitids and later unicellular algae, Jux (1977) has found that the walls of *Chuaria* was sufficiently permeable to permit germination without pores, and that there is a progressive replacement of this permeability by pores in later acritarchs.

Chuaria has recently been found in the Uinta Mountains of Utah, USA in younger Precambrian strata (Hoffman, verbal communication).

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