

throughout the year with periods of stronger intensity. Earlier year-to-year observations show that seasonal and interannual variations in this area are very strong. Variations are reflected in organic walled dinoflagellate assemblages showing relationship between cyst production and conditions in the upper water column. Cyst production is compared with periods of stronger upwelling, SST and the Saharan dust input. Results of the trap investigations are compared with the geographic distribution of cysts in the surface sediments from the studied region.

## Session g2

### PRE-CAMBRIAN PALYNOLOGY/CIMP SYMPOSIUM

#### Australian Neoproterozoic biozones and Ediacaran acritarch diversification

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Conventional wisdom asserts that Precambrian biozonation is implausible because of low species diversity, taxonomic uncertainty, morphological simplicity, sporadic distribution, and conservative evolution rates. A more probable cause is a failure to apply standard biostratigraphic techniques, e.g. the systematic logging of samples and the production of range charts. Stratigraphic data have seldom been adequately recorded, and relative stratigraphic positions are usually ignored, so it is often impossible to determine species ranges. In Australia, hydrocarbon and mineral exploration in the Officer, Amadeus, and Georgina Basins, and the Adelaide Rift Complex has resulted in the development of palynological (mainly acritarch) correlations using range charts based on >2000 samples from >30 drillholes (ZANG & WALTER 1992, ZANG 1995, GRAVESTOCK *et al.* 1997, GREY 1998 & in press, HILL & *al.* 2000). These studies demonstrate that biostratigraphic subdivision of the Neoproterozoic is feasible.

Palynomorphs from c.850-700 Ma are well represented in Western Australian drillholes, and consist of conservative species of coccooid and filamentous cyanobacteria, fragments of benthic microbial mats, and a leiosphere-dominated shelfal plankton. Many species have a global record extending backwards to about c.1200 Ma. Rare, short-ranging, ornamented taxa (e.g. *Cerebrosphaera*) are important marker fossils. Palynological correlations match correlations based on stromatolites and isotope chemostratigraphy (HILL & *al.* 2000). Assemblages are sparse during and between the Sturtian and Marinoan glaciations (c.700-600 Ma). Samples immediately above the Marinoan glaciation are barren, but benthic mats and leiospheres quickly re-established and proliferated as sea level rose. However, most post-glacial species are present in pre-glacial successions, and the only difference is a further depletion of an already impoverished biota. Consequently, Australian assemblages contradict Snowball Earth predictions. There is no post-glacial recolonisation by rapidly diversifying species, and taxa did not evolve from extremophiles from hot-spring refugia.

There is a striking change in the palynoflora some 20m.y later, when >50 species of large, acanthomorph acritarchs first appear. They differ significantly from older taxa and many resemble dinocysts. Acanthomorph diversification was rapid, and four assemblage zones have been erected. Global extension of the scheme is not yet possible because ranges of key species have not been determined outside Australia. Nevertheless, these are complex in common with Svalbard, Norway, Siberia, and China, indicating a potential for global correlation. These complex acanthomorphs were short-lived, and they are not recorded above the Ediacara fauna in Australia (<c.565 Ma).

Acanthomorph radiation did not occur until the second post-glacial marine excursion and appears unrelated to sedimentology or sequence stratigraphy (AROURI & *al.* 2000). However, there is a remarkable coincidence between the first appearance of the acanthomorph palynoflora, a  $\delta^{13}\text{C}$  organic carbon excursion, and the Acraman impact ejecta layer. More detailed studies are in progress to determine whether the Acraman impact significantly influenced biotic evolution.

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#### Remarkable development of eukaryotic protists known from Mesoproterozoic Ruyang group of Shanxi, China

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Most known Mesoproterozoic biological fossils were obtained from silicified carbonates. They are characterized by coccooid, clubbed microfossils and mat-building filamentous fossils and most of them could be correlated with living bacteria and cyanobacteria in morphology. However, organic-walled microfossils obtained from shale of the Mesoproterozoic Ruyang Group are shown more diversified forms, including acanthomorph acritarchs, netromorphic acritarchs, multicellular filaments and membranous fragments as well.

Following features of organic-walled microfossils from the Ruyang Group could be summarized: 1) Sphaeromorph acritarchs, such as *Leiosphaeridia* (Eisenack)Turner, 1984, *Valeria lophostriata* Jankauskas, 1982, *Dictyosphaera* Sin and Liu, 1973, etc. are normally large (40 to 120µm), and some specimens of *Leiosphaeridia* display a circular opening; 2) occurrence of *Navifusa segmentatus* Prasad and Asher, 2001, characterized with transverse veins on vesicle wall; 3) acanthomorph acritarchs named as *Shuiyousphaeridium* (Yan)emend. Yin, 1997 and *Tappania* Yin, 1997 are characterized with vesicle wall of small polygonal 'plates' and neck-like extension, respectively; 4) branched tubular algae shown longitudinal strings on the surface; 5) multicellular filamentous algae displayed as Arctacellularia Hermann, 1976; 6) membranous fragments with annular-helical thickening and lateral 'parenchyma' of netlike structures; and 7) other uncertain multicellular organic remains.

Similar palynomorphic fossils have been found from Mesoproterozoic shale in Australia and India (Javaux *et al.*, 2001; Prasad and Asher, 2001). Previously, the age of the Ruyang Group was dated by glaucocyanite K - Ar as 1100 - 1200Ma (Ma *et al.*, 1980; Guan *et al.*, 1988). Which is more confirmed by one zircon U-Pb dating of 1492±3Ma for the Roper Group of Australia (Javaux *et al.*). It is remarkable that eukaryotic protists had a significant radiation in the late Mesoproterozoic and some acritarch forms, i.g. *Valeria lophostriata*, *Tappania plana* and *Navifusa segmentatus*, already had intercontinental distribution.

### A new approach in deciphering early protist paleobiology and evolution: Combined microscopy and microchemistry of single acritarchs.

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Between the late Archean biomarker record of Eucarya (2.77 Ga) and the ca. 1.2 Ga bangiophyte red algae from Arctic Canada lies a rich assortment of acritarchs. Determining the biological affinities of these potentially protistan microfossils requires a combination of microscopy (light microscopy, scanning electron microscopy, and transmission electron microscopy) and microchemical analyses of individual microfossils (Micro-FTIR spectroscopy, Laser micro-Raman spectroscopy, Energy Dispersive X-ray Spectroscopy (EDEX) in the SEM, laser micro-pyrolysis-GC/MS, and in situ ion microprobe analysis (IMF/SIMS)). These techniques have been applied successfully to superbly preserved microfossils extracted from shales in the Roper Group, Australia (1.5–1.4 Ga), the Ruyang Group, China (~1.4–1.3 Ga) and the McArthur Group, Australia (1.65 Ga) (Javaux et al., 2001, 2003, 2004). Similar fossil assemblages have been reported in the Sanda Formation, Ganga Basin, India (poorly dated but broadly correlative) and the Totta Formation, Siberia, 1.3 Ga and thus have a worldwide distribution in the late Paleoproterozoic-early Mesoproterozoic. Analyses of Cambrian acritarchs from the Observatory Hills Formation, Australia (0.5 Ga) have also been performed for comparison. Earlier work by Moczydlowska, Moldovan and Talyzina integrated morphological, ultrastructural and geochemical studies of acritarchs and suggested the presence of prasinophytes, green algae and dinoflagellates in the early Cambrian.

We have outlined several criteria to differentiate eukaryotic from prokaryotic fossil cells and to evaluate their degree of complexity. Our samples contain eight different populations identified as eukaryotic. At least two (*Tappania plana* and *Shuiyousphaerium macroreticulatum*) can be recognized as eukaryotic based on morphological characters observable by light microscopy. SEM imaging of cell wall microstructure marks two additional forms (*Sarka favosa* and *Valeria lophostriata*) as protists. But for the four remaining taxa (three species of *Leiosphaeridia* and unnamed tubular microfossils), TEM imaging is necessary to reveal eukaryotic characters. Preserved wall ultrastructures of spheroidal acritarchs range from single, homogeneous, electron-dense layers (*Tappania plana*, *Valeria lophostriata*, and *Sarka favosa*) of variable thickness, variably ornamented, to multilayered walls differentiated by electron density and texture. Micro-chemical analyses reveal the presence of resistant biopolymers specific to each taxon and suggests that FTIR spectroscopy permits the characterization of unique chemical compositions of microfossil walls, which could be associated with specific biological affinities when combined with biomarker analysis. Raman spectroscopy elucidates the carbon structure and thermal alteration of constituent organic matter.

The discovery of complex eukaryotic ultrastructures in the walls of morphologically simple mid-Proterozoic microfossils indicates that TEM can provide an important tool to probe the biological relationships of simple microfossils in ancient rocks. Different wall ultrastructures characterize different taxa, implying divergent biological affinities (and/or stages of life cycle) and a level of diversity undetected via light microscopy. Moreover, the morphological complexity shown by taxa with processes and/or with walls made of polygonal plates imply cytological complexity by 1.5 Ga: the evolution of a eukaryotic cell with nucleus, cytoskeleton, and internal membranes involved in secretion and self-assembly of wall components. Our ongoing research includes the determination and characterization of resistant biopolymers in a range of living prokaryotes, protists and fungi by combined microscopy and microchemistry, the determination of the modifications of chemical composition due to thermal alteration, and the comparison with combined microscopy and microchemical analyses of Precambrian and Paleozoic microfossils. Such a multidisciplinary approach offers new possibilities to investigate the biological affinities of acritarchs, and the record of early life on Earth and beyond.

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### Neoproterozoic microbiota—adaptations and survival of severe environmental disturbances

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Fossil Prokaryotes and Protoctists are the most abundant organisms preserved in the fossil records and they record life on Earth for ca. 3.8–3.5 Ga. During this time, single-celled organisms have evolved into many different biochemical, morphological and ecological types. Their greatest diversity is observed in the Neoproterozoic (ca. 1.0 Ga – 544 Ma), and is best known from the shallow marine environments, despite the fact that during this period the Earth experienced severe global climatic and environmental changes such as fragmentation of the Rodinia and final assembly of Gondwana Supercontinents, the Snowball Earth glaciations, and marine anoxic event. Despite the morphological simplicity and microscopic dimensions, prokaryotes and protoctists dominate over other eukaryotes in their diversity of metabolic processes, reproduction cycles and modes of life. Sexual reproduction evolved among early eukaryotic protoctists and it has substantial advantages with regard to the exchange of genes and genetic recombination. The evolution of eukaryotic sexuality resulted in a great variety of organisms and it is evidenced by increased rate of evolution seen in the fossil records. The variety of modes of life (a result of environmental adaptation) and success in reproduction (expressed by sexually increased genetic recombination in eukaryotes and mass occurrence of vegetative populations in prokaryotes) must have been an advantage and opportunity to survive the extreme environmental stress at least in a few reduced refuge sites.

The record of filamentous cyanobacteria from shallow shelf and tidally influenced depositional settings is fragmentary and stratigraphically discontinuous in the Neoproterozoic. However, the occurrence of certain tubular species with morphologically diagnostic trichomes, and presumably of a close biological affinities, pre- and post-dates the global Varangerian/Marinoan glaciations. Similarly, several taxa of acritarchs survived this long-lasting ecological disaster, providing evidence that both more opportunistic prokaryotes and advanced eukaryotes persisted throughout the major extinction caused by the Snowball Earth conditions. Acritarchs are considered, in gross, to be preservable cysts of unicellular algae. Some morphotypes may, however, represent vegetative envelopes, having an internal cyst and/or the excystment opening, and it shows that some taxa indeed represent the dormant/reproductive cysts whereas other are vegetative cells in their complex life cycle. Formation of the cyst, the excystment structure (pylome) and alternation of the generations (sexual and asexual) in the life cycle of unicellular microbiota may shed light on the development of the early strategies to survive ecological crises events and as a competitive advantage in increasingly complex marine ecosystems. However, to maintain the alternation of sexual/vegetative generations and to produce a cyst, acritarchous microbiota must have had access to the bottom sediments to rest periodically before popping-up into the photic zone of the water column as Modern algae do. This condition and the evidence of persisting taxa speak against the radical version of the Snowball hypothesis assuming that oceanic photosynthesis and bioproductivity in the surface ocean collapsed for millions of years because of the ice cover blocking out sunlight. This would have been caused by the global glaciation into low latitudes, continental and shelf ground ice sheets, disruption of oceanic circulation and anoxia (totally frozen ocean). In this radical scenario (Hoffman et al., 1998), the only refuges for bacteria and simple eukaryotes could be in meltwater pools and bare ground, ice cracks, open leads or hydrothermal veins. A more plausible explanation, following the micropalaeontological records, is that although limited in extent the marine shelf environments, including bottom sediments, were free from the permanent ice cover (at least seasonally?) in the low latitudes. This is also supported by the simulation of the conditions and the model of Earth (Hyde et al., 2000) with the ice free islands or continental shelves in the equatorial zone.

The case studies of prokaryotic cyanobacteria and eukaryotic algae (acritarchs) from diverse palaeogeographic settings and of various ages will be discussed in this presentation to get insight into the evolutionary development of microbiota in the context of environmental and global climate change, and interactions with evolving metazoans during Neoproterozoic.

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### Advances in the study on genus *Tianzhushania* of Neoproterozoic Doushantuo formation in Weng'an, Guizhou province, South China

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The genus *Tianzhushania* Yin and Li, 1978, was first found at Tianzhushan Mountain near Changyang County and was considered one of the most distinctive acanthomorphic acritarchs in the Doushantuo Stage of Sinian or any other Neoproterozoic formation. It is characterized by large diameter (350–1000 µm) and processes that penetrate a multilamellate wall layer to support an external multilamellate membrane. Previous palaeontological research on the genus has been based mainly on petrographic thin sections made from chert nodules or bandings in the Doushantuo Formation at the Yangtze Gorges, Hubei Province, and Weng'an, Guizhou province. So far, two morphospecies of *Tianzhushania* have been reported, both from cherty intercalations in the Doushantuo Formation. The type species, *T. spinosa* (Yin and Li, 1978) was first found in the Yangtze Gorges area and later in the Weng'an area. The other species is *T. tuberifera* Yin, Gao and Xing, 2001, found in the same horizon in the Doushantuo phosphorites of the Weng'an area. This species differs from the ones described as *T. spinosa* in having a distinct dense and robust middle wall with clearly demarcated tubercles or arches.

Comparative study of microfossils from two kinds of sediments: chert intercalations (studied in thin section) and phosphorite/phosphatic carbonate (in thin section and maceration), from the upper Neoproterozoic Doushantuo phosphorites in the Weng'an area, Guizhou Province, South China, shows that the phosphatized *Megasphaera ornata* Xiao and Knoll, 2000, and the chert-preserved *Tianzhushania tuberifera* Yin, Gao and Xing, 2001, should be regarded as representing the same taxon preserved by different mineralization processes. In phosphatized specimens the outer wall is often peeled off, exposing the ornamented middle wall. Some phosphatized specimens isolated from the rock matrix and specimens seen in thin sections of phosphorites show a partly preserved outer wall with spines, which can be compared to the thin-sectioned specimens from the chert beds. The small pits usually seen on the surface of the ornamented middle wall of phosphatized specimens correspond to the attachment spots of the spines in the outer wall. The presence of a spiny outer wall is a characteristic of *Tianzhushania* Yin and Li, 1978. So, *Tianzhushania ornata* (Xiao and Knoll) Yin, Bengtson and Yue should be a valid name for the species (Yin, Bengtson and Yue, 2004). The proposed resting-egg nature of *T. ornata*, mainly based on the ornament type of the middle wall, cannot be excluded. The presence of a spiny outer wall, however, suggests that it is a pelagic rather than a benthic form.

Morphological and taphonomic studies of permineralized fossils in cherts and phosphorites of the Doushantuo phosphorites in the Weng'an area, South China indicate that specimens assigned to *Megasphaera ornata* Xiao and Knoll, 2000, are preservational variants of *Tianzhushania tuberifera* Yin, Gao and Xing, 2001. The discovery of *Tianzhushania* both in the Weng'an area and in the Yangtze Gorges provides not only new data for studying spheroidal microfossils in phosphorite but also a way to correlate the silicified assemblages with phosphatized ones. The fossiliferous horizons at Weng'an and in the Yangtze Gorges are coeval.

**Acknowledgements.** The research was jointly sponsored by the National Natural Science Foundation of China (Grants Nos. 49872002 and 40272015) and the Chinese Geological Survey (Grant No. 200213000042).

### Session g3

### LOWER PALAEOZOIC PALYNOLOGY/CIMP SYMPOSIUM

#### On the biological affinities of galeate acritarchs: morphological and biogeochemical data

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Per definition, the Acritarcha are organic-walled microfossils for which the biological affinities are unknown (Evlitt, 1963). The list of possible biological groups to which the acritarchs could belong to is long and includes the dinoflagellates, prasinophyceae, chlorophyceae and zygneophyceae algae, arthropod (coepod) egg cases, exoskeletal elements of other invertebrates and of vertebrates and remains of higher plants (e.g. spores).

Up to know, mostly morphological criteria are used to elucidate the biological assignment of acritarchs. However, over the last years the analysis of biomarkers, and more recently palynomorph wall-polymers have emerged as additional tools to characterise algae and they have also been applied to elucidate the biological affinities, though with different success. Nevertheless, clear differences are found in polymer structure amongst recent algal groups like Dinophyta and Chlorophyta and also within these groups polymer structure appears to vary significantly. As such, there remains considerable potential for these chemical techniques to elucidate acritarch biological affinities.

The Late Cambrian-Ordovician galeate acritarchs strongly resemble the cysts of dinoflagellates from a morphological point of view: the large "apical" opening may correspond to the archeopyle of the dinoflagellates, while the polygonal fields observed on some galeate vesicles may correspond to a paratabulation. In addition, the morphology of the processes and their variability strongly resembles those of some dinoflagellate cysts. The palaeoecological and palaeogeographical distribution of the galeate acritarchs also corresponds to that of modern and fossil dinoflagellates.

In this lecture, we present the results of the first study on the chemical structure of galeate wall polymers. The results will be discussed in relation to our current understanding of the composition of recent and fossil palynomorph polymers.

#### Late Cambrian acritarchs from the "Túnel Ordovícico del Fabar", Cantabrian Zone, N Spain

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The excavation of the El Fabar Tunnel of the Cantabrian superhighway provided the opportunity for detailed investigation of the Cambrian-Ordovician successions of the Laviana and Rioseco nappes, eastern Cantabrian Zone of the Iberian Massif (GUTIÉRREZ-MARCO *et al.* 2003).

The Middle? to Upper Cambrian La Matosa Member of the Barrios Formation consists mainly of quartz sandstones and comprises a thick fossiliferous intercalation of dark shales ("El Fabar beds"). These shales yielded olenid trilobites and filocarid crustaceans and one sample provided an acritarch association of Late Cambrian age.

The palynoflora is well preserved and quite rich but not highly diverse. The most common genera are *Cristallinum*, *Retisphaeridium*, *Timofeevia*, *Cymatogalea*, *Acanthodiacrodiun* and *Stelliferidium*.

*Lusatia dendroidea* BURMANN 1970, reported for the first time from Spain, is a very characteristic element of this association. In the material at hand, *Lusatia dendroidea* exhibits a great morphological variability and occurs in high number, mostly as completely preserved specimens.

Some taxa, represented by numerous specimens, are of problematic generic assignment and their taxonomical interpretation requires further investigations and comparisons with other areas where similar associations occur.

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