Advances in Ediacaran biostratigraphy in Australia

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[Récent développement dans la biostratigraphie de l'Édiacarien de l'Australie]

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Introduction

Despite the effort devoted to studying the Archean and Proterozoic fossil record, there has been only limited progress in developing zonal schemes similar to the ones well established for the Phanerozoic. In part, this reflects taxonomic uncertainty, morphological simplicity, slow rates of evolution, and sporadic distribution patterns during the Proterozoic, as well as perceptions that species diversity is restricted. However, the slow advance is also caused by a lack of rigorous biostratigraphic analysis. With the establishment of the Ediacaran System and Period, and recent discussions by the International Stratigraphic Commission to move away from the current chronometric scheme, the need for biostratigraphic subdivision has increased. In Australia, demands for improved Neoproterozoic correlation to assist the exploration industry and the discovery of well-preserved acanthomorphs in drill cores has encouraged biostratigraphic studies of Australian Ediacaran successions (GREY, 2005). This paper presents a review of some of the advances made to date.

Background

Analyses of more than 900 samples from 20 drillcores and 10 field sections in the Centralian Superbasin and Adelaide Rift Complex showed the feasibility of biostratigraphic correlation based on large, morphologically complex, acanthomorph acritarchs. Abundance, complex morphology, wide lithological and geographical distribution, and restricted time ranges make acritarchs ideal biostratigraphic tools.

Preparation techniques are critical to successful results. ZANG & WALTER (1992) demonstrated that samples need gentle treatment (i.e. minimal crushing and no centrifuging) to extract large (>200 µm in diameter), brittle process-bearing acritarchs. Zang obtained good assemblages by processing up to 1 kg of material per sample, but this approach has limitations for biostratigraphy and taphonomic analysis. Refinement of techniques allowed preparation of smaller samples, enhanced specimen recovery, and provided tighter biostratigraphic and palaeo-environmental control (GREY, 1999, 2005).

Results

Well preserved assemblages were obtained from the Officer and Amadeus Basins (Centralian Superbasin); less well preserved samples have been obtained from the Stuart Shelf. Unfortunately, all samples processed so far from the Adelaide Rift Complex, and in particular from the section above the Global Stratotype Section and Point (GSSP) for the Ediacaran showed high levels of thermal maturity and those from the Georgina Basin are badly oxidized. Seventy-one identifiable palynomorph taxa were recorded; 44 were fully identified and 27 were assigned tentatively or placed in open nomenclature. The 64 acritarch taxa consist of 49 acanthomorphs, 12 sphaeromorphs, and 4 coenobia. The 26 existing taxa were substantially emended, and 7 new combinations, 26 new species and 6 new genera were described (*Archaeotunisphaeridium*, *Australiastrum*, *Ceratosphaeridium*, *Labruscasphaeridium*, *Pennatosphaeridium*, and *Taedigerasphaera*. Remaining palynomorphs were filaments and problematica. More recent work by WILLMAN *et alii* (in press) has confirmed identifications and stratigraphic distributions in drill holes not previously studied in detail.

Range plots from several Centralian Superbasin drillholes produce consistent patterns suitable for zonation and 2 palynofloras and 5 assemblage zones were recognized by GREY (2005). The older palynoflora, the Ediacaran Leiosphere-dominated Palynoflora (ELP) consists of a single zone, the *Leiosphaeridia jacutica* – *Leiosphaeridia crassa* Assemblage Zone. A four-fold zonation is recognised in the Ediacaran Complex Acanthomorph-dominated Palynoflora

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(ECAP) consisting of the following (from oldest to youngest): the *Appendisphaera barbata – Alicesphaeridium medusoidum – Gyalosphaeridium pulchrum* Assemblage Zone; the *Tanarium conoideum – Schizofusa risoria – Variomargosphaeridium litoschum* Assemblage Zone; the *Tanarium irregulare – Ceratosphaeridium glaberosum – Multifronsphaeridiumpelorium* Assemblage Zone; and the *Ceratosphaeridium mirabile – Distosphaera australica – Apodastoides verobturatus* Assemblage Zone. Zones are demonstrably independent of lithology, and can be recognised across the Officer and Amadeus Basins and Stuart Shelf despite taphonomic and palaeoenvironmental influences. The acanthomorphs show a marked and rapid increase in abundance, size, morphological complexity, and taxonomic diversity that indicate major diversification and significant evolutionary changes. The acanthomorphs appear to belong to a new, short-lived group of phytoplanktonic green algae that represent resting cyst stages and their first appearance lies about two thirds through the second rise in sea-level after the Marinoan glaciation. The late timing of the diversification suggests it is not an immediate consequence of Snowball Earth.

The possible role of the Acraman impact event

Officer Basin sedimentological studies show at least four, possibly five, basin-slope aprons, each consisting of a succession of fine-grained distal turbidite successions of monotonous mudstone and interbedded siltstone capped by shallow-water carbonate (AROURI *et alii*, 2000). In the second slope apron is an ejecta layer derived from the Acraman impact on the adjacent Gawler Craton (WILLIAMS & WALLACE, 2003). Initially, the ejecta layer was viewed simply as a significant synchronous marker to be used as datum for species distributions in biostratigraphic studies. However, as compilation progressed, a coincidence between the position of the ejecta layer and the first appearance of acanthomorphs became apparent. Lithology before and after the impact is remarkably uniform. An iridium anomaly is associated with the ejecta layer, and there is a marked, short-lived negative excursion in the $\delta^{13}C$ organic carbon curve that indicates a rapid fall in organic productivity. A subsequent positive excursion coincides with the diversification of the biota (GREY *et alii*2003; CALVER & LINDSAY, 1998). The negative excursion is present not only in the Officer Basin, Stuart Shelf and Adelaide Rift Complex, where the ejecta layer is present, but also in the Amadeus Basin, where the layer iself has not been recognised. Furthermore, whole-rock organic geochemical analysis has identified significant changes in sterane patterns and series E and F highly branched alkanes (HBA) at the level of the ejecta layer (MCKIRDY *et alii*2006; WEBSTER *et alii*2006). The HBA appear to be molecular fossils of anaerobic fermenting bacteria, and their variable abundance in the Dey Dey Mudstone apparently records a short-lived collapse of primary productivity in the Ediacaran ocean soon after the Acraman impact. The probable encysting lifestyle of the acanthomorphs may account for their survival and subsequent proliferation, whereas leiospheres and bacterial mats were largely destroyed by the impact. The size of a dust cloud generated by the impact is of particular significance for such a scenario. In the case of the Acraman impact, this may have been exceptionally large because land areas were devoid of vegetation and continental surfaces would be more like those of the Moon or Mars.

Conclusions

Evidence of a relationship between the impact event and palynofloral diversification remains circumstantial, but supporting evidence is accumulating. Diversification of the algae, the base of the food chain, may have triggered other significant biotic changes, and further studies are indicated. A large impact could be a plausible explanation for dramatic biospheric changes that are otherwise difficult to explain.

Some taxa resemble those from probably coeval successions in China, Siberia, and northern Europe, suggesting that the proposed zonation scheme has good potential for global application. This zonation will serve as an important tool for the correlation of successions that at present lack both biostratigraphic and geochronological controls. Although there are still some gaps in the record (mainly resulting from barren samples or samples containing highly corroded organic matter), unequivocal evidence for the biostratigraphic usefulness of Australian Ediacaran acritarchs has emerged, and it should now be possible to apply the results on a broader scale in other parts of the world.

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