Crisis and Recovery: The Acraman Impact Event and its Biostratigraphic Significance

Gordon Webb

Research School of Earth Sciences,
The Australian National University,
0200 Canberra, Australia
Email: gordon.webb@anu.edu.au

Keywords: impact event

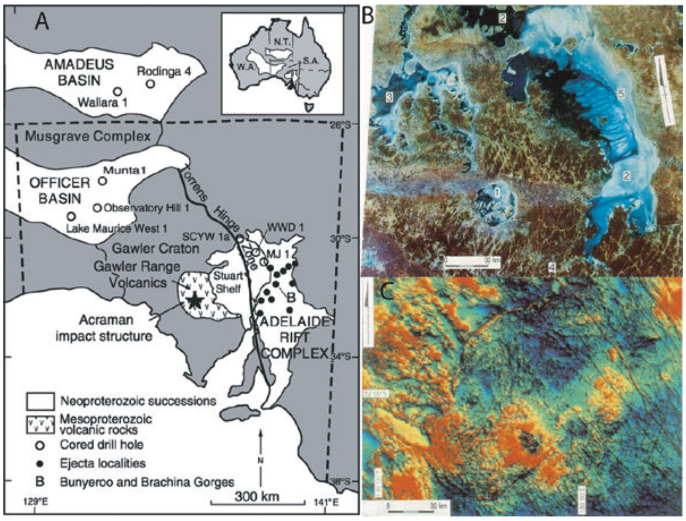
Abstract: Crisis and recovery: The Acraman Impact Event and its biostratigraphic significance

Table of Contents

Extended Abstract

During the late Vendian (ca. 580Ma) a large bolide impacted into the Mesoproterozoic acid volcanic sequences of the central Gawler Craton, South Australia. Lake Acraman, which forms a 30km wide depression in the central Gawler Ranges is believed to be the deeply weathered central zone of the impact crater (Williams, 1986, Figure 1B and C). Estimates of the impact energy of the Acraman collision exceed 106 Mt implying a global catastrophe (Williams and Wallace, 2003). The search for this impact structure was triggered by the discovery of an impact eject layer in Neoproterozoic sediments exposed in the Flinders Ranges (Gostin et al., 1986). The Acraman impact ejecta layer (AEIL) in the Flinders Ranges occurs as a discrete and distinct horizon of course detritus containing angular volcanic clasts and shattered quartz crystals sandwiched between monotonous mudstone and siltstones of the lower Bunyeroo Formation (Figure 1 in Gostin et al., 1989). The ejecta layer was found to have a sharp iridium anomaly compared to the surrounding sediments (Figure 1 in Gostin et al., 1989). This was the first time that an iridium anomaly was observed as a unique chemostratigraphic marker of an impact ejecta layer that was itself linked to an identifiable impact structure (Gostin et al., 1989). The AEIL has now been identified at numerous outcropping localities within the central Adelaide Rift Complex. In addition, fractured crystals and primary and reworked ejecta sediments have been identified in a number of drill holes in other Neoproterozoic basins surrounding the Gawler Craton (Hill et al., 2004, Figure 1).

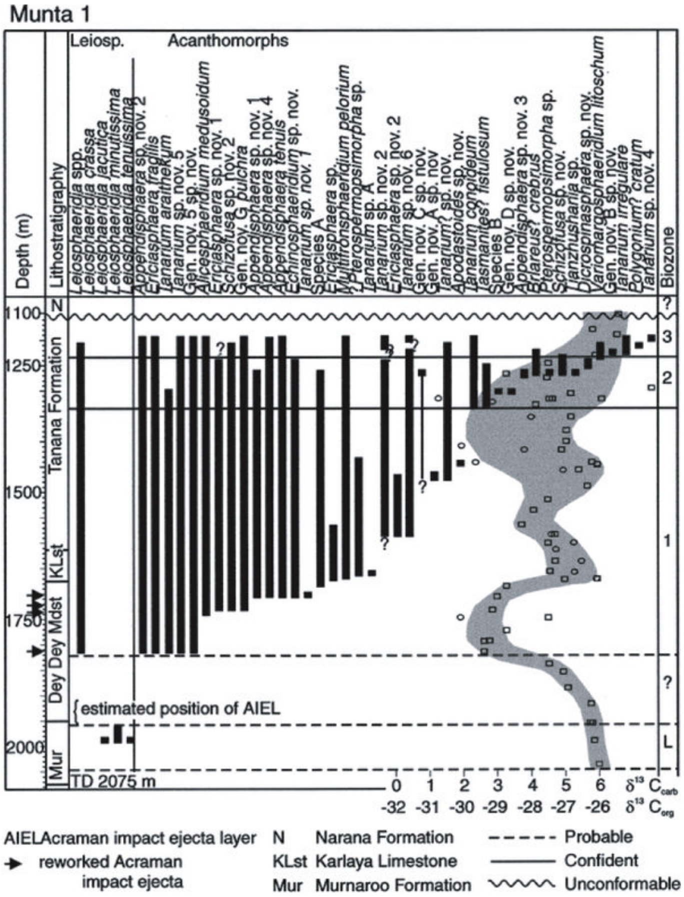
Figure 1. Acraman Impact site.



A) Acraman impact structure, selected drill holes, and impact ejecta localities in Officer and Amadeus Basins and Adelaide Rift Complex. B) Landsat scene covering most of the Acraman impact structure in the Mesoproterozoic Gawler Range Volcanics, showing: 1, Lake Acraman within the Acraman depression; 2, Lake Gairdner; 3, Lake Everard; 4, the Yardea corridor at 85-90 km diameter. Surface water (darker blue) in Lake Gairdner helps define an arcuate trend (5) at ca. 150 km diameter that continues westward to Lake Everard. X marks the location of a central dipolar magnetic anomaly in the southeastern part of Lake Acraman. Landsat scene 15 February 1973, scene center S31-30 E135-51. C) Aeromagnetic image of the Acraman area of the Gawler Craton, covering the Landsat scene (see image below). ER Mapper file: total magnetic intensity, pseudocolor (Gaussian equalisation histogram stretch), sun angle from the northeast. From Williams (1986).

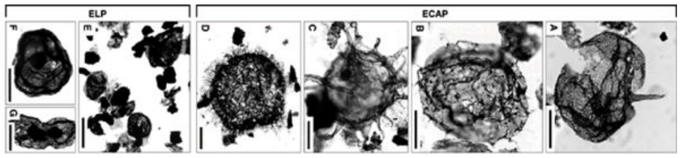
Acritarch records from Neoproterozoic sequences in the Officer and Amadeus Basins and on the Stuart Shelf provide evidence of a biotic crisis that coincides with the Acraman impact. A dramatic palynofloral change occurs immediately after the first occurrence of the AEIL (and reworked equivalents in the Dey Dey Mudstone Grey et al., 2003, Figure 2). Acritarch palynomorphs changed from a narrow assemblage dominated by simple round tests (referred to as the Ediacaran leiosphere playnoflora or ELP) to a more diverse assemblage of short ranging, large, morphologically complex forms with the first appearance of 57 species (Referred to as the Ediacaran complex acritarch palynoflora or ECAP Grey et al., 2003). Complex, process bearing tests (Figure 3) may have provided shelter from harsh environmental conditions following the Acraman impact. Stable isotope analyses of kerogen from sediments throughout this interval indicate a negative carbon excursion immediately after the AEIL (Calver and Lindsay, 1998, Figure 2). The short-lived negative excursion in carbon isotopes is thought to be characteristic of a sudden decrease in biomass and primary productivity. This phenomena has been associated with several mass extinction events (Grey et al., 2003, and references therein).

Figure 2. Ediacrian faunal change and C-isotope stragigraphy.



Munta 1 drill hole, Officer Basin: Sequence-stratigraphic subdivision, carbon isotope stratigraphy (Calver and Lindsay, 1998), and palynological zonation. Start of Ediacarian complex acritarch palynoflora (ECAP) coincides with steep negative then positive carbon isotopeexcursion. Erosional hiatus and lithologic change terminate palynomorph record at 1136m. From Grey et al. (2003) and references therein.

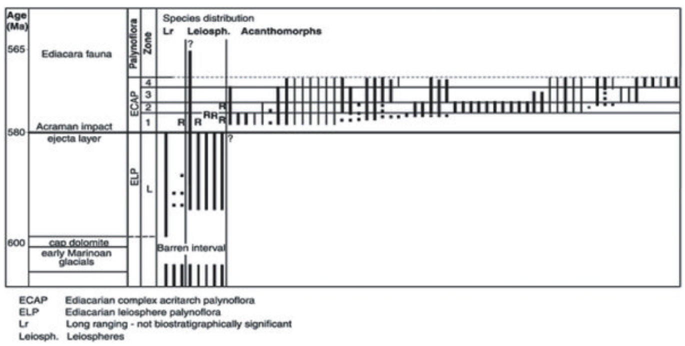
Figure 3. Representative Ediacarian acritarchs.



Representative Ediacarian acritarchs. AD: Key zonal Ediacarian complex acritarch palynoflora (ECAP) acanthomorphs. A: New genus with single process (zone 4). B: Apodastoidessp. nov., with plug at process base (zone 3). C: Tanarium conoideum with large conical processes (zone 2). D: Appendisphaerasp. nov. 2 with ciliate processes (zone 1). EG: Spheroids from Ediacarian leiosphere palynoflora (ELP) (zone L). E: Typical Leiosphaeridia. F: Detail of individual specimen. G: Specimen showing possible cell division. Scale bars 5 25 mm. From Grey et al. (2003).

This period of earth history spans the gap between the Marinoan snowball earth glaciation (ca. 595Ma) and the first appearance of the metazoan Ediacara fauna (ca. 550 Ma) and the subsequent Cambrian explosion. It has been suggested that rise of metazoans occurred as a consequence of change to the earths environment in the aftermath of the snowball earth (e.g. Hoffman et al., 1998c, and others). However, the dramatic acritarch radiation occurred approximately 15 Ma after the end of the Marinoan Glaciation (referred to as a snowball earth period). Furthermore, there is no evidence of significant changes to acritarch biostratigraphy immediately before or after the Marinoan glaciation (Figure 4).

Figure 4. Generalized ranges of Ediacarian palynomorphs.



Generalized ranges of Ediacarian palynomorphs. Distributions plotted by zone (highest degree of refinement currently possible). Note change at ELPECAP boundary and rapid increase in diversity of acanthomorphs above Acraman impact ejecta layer. ARCAdelaide Rift Complex. From Grey et al. (2003).

It has been suggested that the diversification of the ECAP assemblage implies a significant increase in the biomass of the shallow seas of the late Vendian in response to the global crisis caused by the Acraman impact (Grey pers comm.). The Neoproterozoic records of acritarch radiations discussed here fit favorably with models of adaptive radiations following catastrophic events in the Phanerozoic (Grey et al., 2003). It is plausible that this increase in single celled (bottom of the food chain) biomass provided the principal food source for many of the multi-celled grazing organisms of the Ediacaran fauna. The Acraman impact may, therefore, represent a pivotal event in the subsequent evolution of the global biosphere.

References

Calver, C. and Lindsay, J. (1998). Ediacarian sequence and isotope stratigraphy of the officer basin, south australia. Australian Journal of Earth Science, 45:513–532.

Gostin, V., P.W., H., Jenkins, R., Compston, W., and Williams, I. (1986). Impact ejecta horizon within late precambrian shales, adelaide geosyncline, south australia. Science, 233:198–200.

Gostin, V., Keays, R., and Wallace, M. (1989). Impact ejecta horizon within late precambrian shales, adelaide geosyncline, south australia. Nature, 340:542–544.

Grey, K., Walter, M., and Calver, C. (2003). Neoproterozoic biotic diversification: "snowball earth" or aftermath of the acraman impact? Geology, 31:459–462.

Hill, A., Grey, K., Gostin, V., and Webster, L. (2004). New records of acraman ejecta. Australian Journal of Earth Sciences., 51:47–51.

Hoffman, P., Kaufman, A., Halverson, G., and Schrag, D. (1998c). A neoproterozoic snowball earth. Science, 281:1342–1346.

Paul, E., Flottmann, T., and Sandiford, M. (1999b). Structural geometry and controls on basement-involved deformation in the northern flinders ranges, adelaide fold belt, south australia. Australian Journal of Earth Sciences, (46):343–354.

Williams, G. (1986). The acraman impact structures: Source of ejecta in late precambrian shales, south australia. Science, 233:200–203.

Williams, G. and Wallace, M. (2003). The acraman asteroid impact, south australia: magnitude and implications for the late vendian environment. Journal of the Geological Society of London, 160:545–554.

Error: no bibliography entry: d0e101 found in http://docbook.sourceforge.net/release/bibliography/bibliography.xml