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Enigmatic chambered structures in Cryogenian reefs: The oldest sponge-grade organisms?

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ABSTRACT

Previously undescribed chambered structures are common and widespread in the Cryogenian (post-Sturtian glacial) carbonates of the Oodnaminta Reef Complex (Adelaide Geosyncline, South Australia), the Rasthof-Berg Aukas Formation (Namibia) and the Gauss Formation (Namibia). These carbonate structures have millimetre to centimetre-scale chambers separated by well-defined and generally thin micritic walls. Chamber walls now consist of dolomite, but were probably originally aragonitic. The chambers may have a lobate, polygonal or dendritic morphology and are often further divided into smaller chambers. Chambered structures occur as reefal growth frameworks; as cavity-fillings in neptunean dykes and growth cavities; and as intercolumnar material within stromatolite frameworks. In the Oodnaminta Reef Complex, these structures are only present in the sub-photic deep water framework.

These structures probably represent the calcified remains of an organism or community of organisms that was globally distributed and widespread for a significant time period following the Sturtian glaciation. No precisely analogous structures have been previously described from modern or ancient settings, but the complexity and degree of organization suggests a significant evolutionary advance over older Proterozoic fossils. The closest morphological analogues for the structures are: (a) some types of reef-dwelling sponges; and (b) some complex microbialites from Archaean and Paleoproterozoic carbonates. The structures lack spicules and ostia found in sponges, ruling out a true Poriferan origin. However, it is plausible that they are proto-sponges, sponge-grade organisms, or complex microbial precursors to sponge-grade organisms. Whatever their affinity, we suggest these structures record a significant evolutionary event on the path towards organic complexity.

1. Introduction

The sudden and widespread appearance of soft-bodied metazoan organisms during the Ediacaran and the later development of organisms with hard mineralized skeletons in the latest Ediacaran – Early Cambrian are events which challenge our understanding of early life (Conway Morris, 1993; Grotzinger et al., 2000, Maloof et al., 2010a; Kouchinsky et al., 2012). The relatively sudden appearance of these advanced organisms in the geological record and the lack of ancestral precursors has focussed attention on the preceeding early Ediacaran and Cryogenian periods. The discovery of biomarkers and spicules derived from demosponges (Du and Wang, 2012; Love et al., 2009), possible foraminiferans (Bosak et al., 2012), and possible sponge-grade calcified fossils from the Cryogenian (Maloof et al., 2010b) suggests that the Cryogenian is highly prospective for the discovery of complex fossils.

However, there has been considerable debate about the origin of many Precambrian structures that are purported to be fossils and the literature abounds with such controversies (e.g. Neuweiler et al., 2009; Planavsky, 2009; Brain et al., 2012). Even if a biological origin is confirmed, the affinity of many fossils from the Precambrian has also proven to be problematic, this being the case even with the well documented Ediacaran fossils themselves (e.g. Seilacher et al., 2003; Narbonne, 2005).

Here, we describe chambered structures consisting of carbonate from Cryogenian interglacial successions in Australia and Namibia.

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The structures are widely distributed and common, but have not previously been described. We compare these to previously described organic and inorganic structures and can find no precisely analogous structures documented from any time period. We attempt to deduce the possible affinity of these chambered structures by an analysis of similarities and differences from previously described structures.

2. Geological setting

The chambered structures described here occur within Cryogenian interglacial successions of South Australia (Northern Adelaide Geosyncline) and Northern Namibia (Otavi Mountainland and the Kaokoveld) (Figs. 1 and 2). Cryogenian successions from the Adelaide Geosyncline (Australia) and Northern Namibia are closely comparable, with the Sturtian and Marinoan glacials being recognized in both successions, interglacial successions being dominantly carbonates, and similar age constraints (Fig. 3). The main difference between the two successions is the greater abundance of carbonates in the Namibian succession.

Chambered structures from Australia occur within Cryogenian reef complexes of the Umberatana Group in the northern Adelaide Geosyncline of South Australia (Giddings et al., 2009) (Fig. 4). These reefs are of late Cryogenian age, overlying Sturtian diamictites and underlying Marinoan glacigenic strata (Giddings et al., 2009). The reef-rimmed platforms consist of dolomite of the Balcanoona Formation that is laterally equivalent to the basinal Tapley Hill Formation calcareous and dolomitic shales (and also laterally equivalent to the peritidal Angepena Formation, Fromhold and Wallace, 2011). Fanning and Link (2008) reported a U–Pb zircon age of 659 ± 6 My BP from a tuffaceous horizon within the uppermost Sturtian diamictites of the Northern Adelaide Geosyncline. This would suggest (by linear extrapolation) that the overlying Balcanoona Formation is approximately 650 My BP. The recently discovered possible sponge-grade fossils from the central Adelaide Geosyncline (Maloof et al., 2010a,b) were found in the Trezona Formation, which is significantly younger than the Balcanoona Reef complex (probably around 10–15 million years younger).

The reefs of the Balcanoona Formation consist of a high-energy platform facies, underlain by a massive reef margin facies (Giddings et al., 2009). The uppermost portion of reef margin facies consists of stromatolitic frameworks (i.e., a growth framework), while the lower, deeper water portion of the reef margin consists of a non-stromatolitic organic framework (Fig. 5). Underlying this non-stromatolitic framework facies are allochthonous breccias of the lower slope. The breccia facies directly overlies and interdigitates with the basinal calcareous shales of the Tapley Hill Formation (and the basal Yankaninna Formation). Basinal shales contain large allochthonous blocks and megabreccias shed from the reef margin. The regional and internal geometry of the platform indicates a strongly progradational reef history, with the platform margin

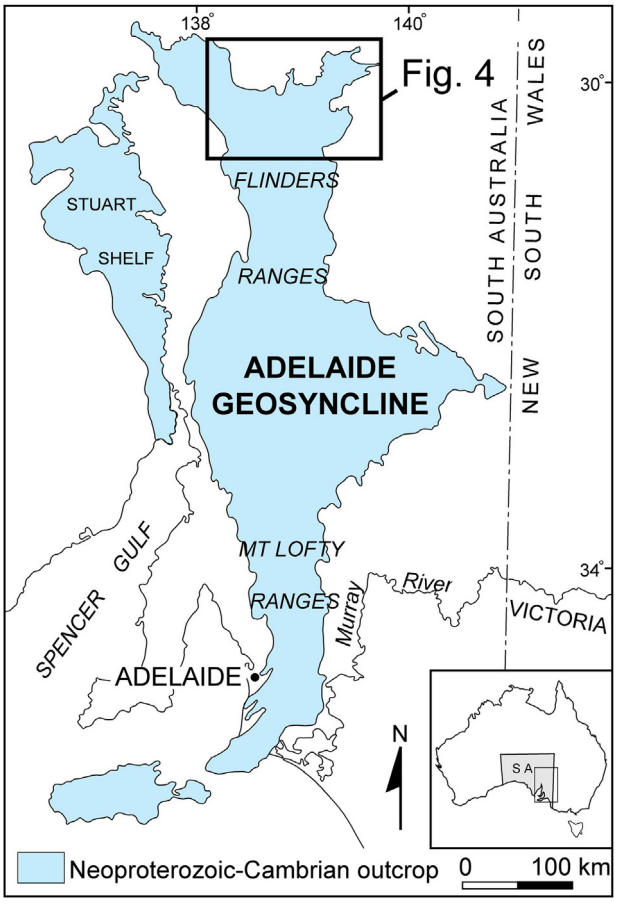

Fig. 1. Adelaide Geosyncline of South Australia showing location of study area in Northern Flinders Ranges.
Modified from Giddings et al. (2009).

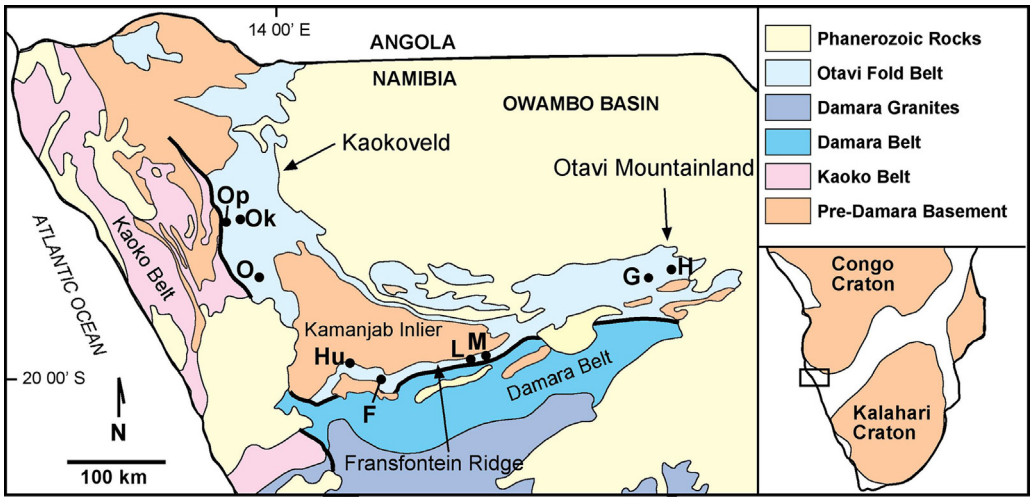

Fig. 2. Geology of Northern Namibia with studied localities (modified from Hoffmann and Prave, 1996). G = Ghaub Farm, H = Hurisib Farm, M = Matunda Farm, L = Luisental Farm, F = Fransfontein, Hu = Huab Area, O = Ongongo Gorge, Op = Ombepera, Ok = Okaaru.