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Glacial sediments and cap carbonate sequences in the Umberatana Group: Evidence for a snowball Earth?

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Abstract: The Umberatana Group brackets two of the largest glaciations in Earth's history - the Sturtian and Marinoan glaciations. In the central Flinders Ranges, several interesting aspects of the Umberatana Group are exposed, particularly in the vicinity of the Enorama Diapir. Here continued movement of the diapir after the group was deposited has resulted in exposure of the complete group within a relatively small area (see Figure 1).

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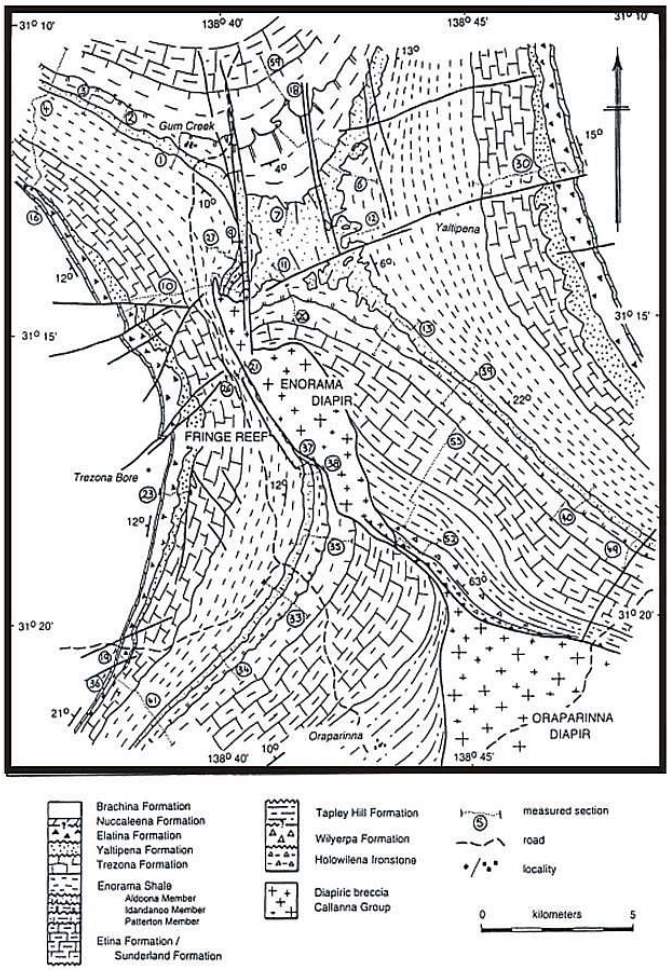
Introduction

Between these major glaciations, interglacial sediments were deposited, and in the central Flinders zone these are commonly shallow water facies such as stromatolitic limestones and localized biogenic reef mounds, as a shallow shelf persisted here for much of this interval.

Figure 1. Enorama Diapir



Geological map of the area surrounding the Enorama Diapir, illustrating a near complete section of the Umberatana Group, and locations of the biogenic mounds and fringing reefs blanketed by the Enorama Shale on the western side of the diapir (from Lemon, 2000).

Glacial sediment characteristics

Sedimentological characteristics indicative of a glacial origin when observed in South Australian diamictites (from Coats and Preiss, 1987):

- Presence of dropstones in associated laminites, indicating ice rafting
- Presence of polished, facetted, striated and grooved clasts
- Variable clast lithology, with certain lithologies persisting over large areas
- Distinctive facies that recur in variable successions
- Wide range of grainsize, including boulders
- Very poor sorting

Cap carbonates

In the snowball Earth hypothesis, the position of the continents near the equator in the Neoproterozoic pre-glacial episodes, resulted in an increase in Earth's albedo, and in combination with the increase in silicate weathering in the tropics due to the location of the continents, caused cooling of the Earth and expansion of the polar ice caps. Positive feedback resulting from further increase in planetary albedo resulted in ice reaching the equator, glaciated continents, and a shutdown of the global hydrological cycle: the 'snowball earth'. Volcanic outgassing of CO_2 gradually warmed the atmosphere, and eventually resulted in catastrophic meltdown of the global ice cover. Mixing of cold biocarbonate-rich deep waters with warm shallow waters, in addition to increased silicate weathering producing more HCO_3^-, resulted in global deposition of a 'cap carbonate'.

Whatever the formation mechanism, ie: Snowball Earth or not, the 'cap carbonate' sequences are depositional sequences associated with post glacial sea level rise. The transgressive systems tracts of these depositional sequences is often a thin 'cap dolostone', which grades into a deeper water limestone or shale, which in turn gradually shoals upward through carbonate and siliciclastic lutites and arenites. Because cap dolostones are transgressive, they typically extend far beyond their antecedent glacial deposits, and unconformably overlie preglacial rocks.

Glacial sediment/cap carbonate sequences in the Umberatana Group

Sturtian Glacial sequence (central Flinders Zone): Holowilena Ironstone, Wilyerpa Formation, Tindelpina Shale Member.

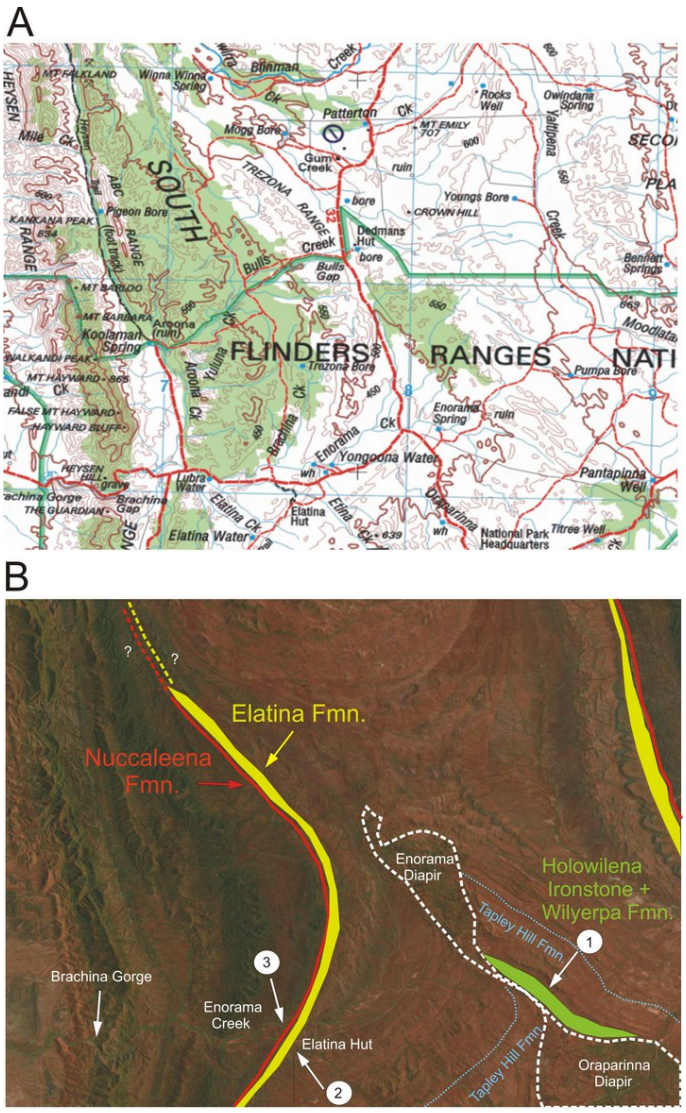
The Holowilena Ironstone and the overlying Wilyerpa Formation are believed to represent the Sturtian glaciations - the Holowilena Ironstone was probably deposited towards the end of the first Sturtian glaciation by chemical

precipitation, and the Wilyerpa Formation during the second Sturtian glaciation (Coats and Preiss, 1987).

The Holowilena Ironstone and Wilyerpa Formation are exposed between the Oraparinna and Enorama Diapirs in the central Flinders zone (Figure 2B - site 1 on satellite image). The Wilyerpa Formation is 90% mudstone, shale, siltstone, arenites and only 10% tillite and pebbly mudstone.

The base of the Tindelpina Shale Member at the base of the Tapley Hill Formation is considered to be a 'cap dolomite', which is often sharply defined by thin, continuous dolomite bands that conformably overlie the diamictites, siltstones and sandstones of the Sturtian glacial deposits. Total thickness of this unit reaches ~60m, comprising dark grey, pyritic, carbonaceous, or dolomitic silty shale.

Figure 2. Locality map



(A) Geography of the area surrounding the Enorama Diapir.

(B) Satellite image of this area with key field localities in the Umberatana Group marked, in addition to geologic units discussed in the text.

Marinoan Glacial sequence (central Flinders Zone) : Elatina Formation, Nuccaleena Formation.

The glacigenic Elatina Formation consists of a lower unit of massive, pink, fine - medium grained arkosic sandstone, overlain by a red-brown, massive, pebbly to bouldery sandy siltstone interpreted as a tillite. The Elatina Formation is exposed along Enorama Creek, south-west of the Enorama Diapir. Close to Elatina Hut, it is exposed as

a pebbly siltstone with a fine reddish matrix containing scattered clasts of basic igneous origin, and according to Coats and Preiss (1987), some of these clasts are polished and striated indicating their glacial origin (site 2 on satellite image).

Directly overlying this is the thin (less than 5-10m thick), commonly discontinuously lensed 'cap carbonate' at the base of the Nuccaleena Formation. At Enorama Creek (site 3), the Nuccaleena Formation is a pale reddish dolomite, ~5m thick grading down abruptly into a 0.15m thick, well banded reddish fine sandstone at the top of the Elatina Formation (Forbes and Preiss, 1987). In the Flinders Ranges, the Nuccaleena Formation is widespread marker bed being readily recognizable over a large area.

References

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