PS Comparison of Lower Cambrian Carbonate Facies and Halokinetic Sequences in Minibasins Developed on Opposite Sides of Wirrealpa Diapir, Central Flinders Ranges, South Australia*

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Search and Discovery Article #50442 (2011)
Posted July 26, 2011

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*Adapted from poster presentation at AAPG Annual Convention and Exhibition, Houston, Texas, USA, April 10-13, 2011

Abstract

Wirrealpa diapir is flanked by the Woodendinna and Donkey Bore minibasins, which contain different thicknesses and facies of Lower Cambrian carbonate strata, permitting assessment of the role of sediment supply on the formation of composite halokinetic sequences (CHS). Both minibasins contain primarily tapered-CHS, which form when sedimentation rate outpaces diapir rise rate. However, the upper Woodendinna minibasin strata form a thin tabular-CHS, which is not present in the Donkey Bore minibasin. Tabular-CHS form when diapir rise rate outpaces sedimentation rate. In the Donkey Bore minibasin, the Wilkawillina and Mernmerna formations have a combined thickness of 1,200 m, thinning to 250 m near the diapir over a distance of about 700 m, whereas in the Woodendinna minibasin their combined thickness is 3,000 m, thinning to 600 m near the diapir over a distance of about 1,000 m. Sedimentation was twice as fast in the Woodendinna minibasin, causing thinning and halokinetic drape folding within CHS to form over a broader area.

Facies variation between minibasins reflects differential sedimentation rates. The Wilkawillina Fm. in the Donkey Bore minibasin comprises a tapered-CHS composed of windward-side Archaeocyathid bioherm facies with abundant diapir-derived debris flows that accumulated more slowly than the age equivalent tapered-CHS in the Woodendinna minibasin, which comprises leeward-side interbedded ooid shoal and digitate cyanobacterial facies. The overlying Mernmerna Fm. comprises deep-water carbonate turbidites derived from a regional source to the northwest, placing the Donkey Bore minibasin updip of the Woodendinna minibasin. The Mernmerna in the Donkey Bore minibasin forms a tapered-CHS whereas in the Woodendinna it forms a thin tabular-CHS followed by tapered-CHS. The tabular-CHS contains thick diapir-derived debris flows, indicating sediment starvation downdip of the diapir coincident with maximum shelfal transgression. Mernmerna high stand deposition produced tapered-CHS in both minibasins.

Lower Cambrian Carbonate Facies and Halokinetic Sequences in Minibasins Adjacent to Wirrealpa Diapir, Central Flinders Ranges, South Australia

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Abstract

Wirrealpa diapir in the Central Flinders Ranges, South Australia is flanked by the Woodendinna and Donkey Bore minibasins, which contain different thicknesses and facies of Lower Cambrian carbonate strata, permitting assessment of the roll of sediment supply on the formation of composite halokinetic sequences (CHS). The strata of the Donkey Bore minibasin comprise Tapered-CHS, which form when sedimentation rate outpases diapir rise rate. However, Woodendinna minibasin strata form a Tabular-CHS, which forms when diapir rise rate outpaces sediment accumulation rate.

In the Donkey Bore minibasin, the Wilkawillina and Mernmerna formations have a combined thickness of 2500m, thinning to 250m near the diapir over a distance of about 1000m, whereas in the Woodendinna minibasin their combined thickness is about 1000m and maintain a relatively uniform thickness. Sedimentation was over twice as fast in the Donkey Bore minibasin during this time, resulting in different CHS typesin each minibasin.

Facies variation between minibasins reflects differential sedimentation rates. The Wilkawillina Fm. in the Donkey Bore minibasin comprises a Tapered-CHS composed of windward-side Archaeocyathid bioherm facies with abundant diapir-derived debris flows that accumulated more rapidly than the age equivalent Tabular-CHS in the Woodendinna minibasin, which comprises leeward-side interbedded ooid shoal and digitate cyanobacterial facies. The overlying Mernmerna Fm. comprises deep-water carbonate turbidites derived from a regional source to the northwest, placing the Donkey Bore minibasin updip of the Woodendinna minibasin. The Mernmerna in the Donkey bore minibasin forms a Tapered-CHS whereas in the Woodendinna it forms a Tabular-CHS. The Tabular-CHS contains thick diapir-derived debris flows, indicating sediment starvation downdip of the diapir coincident with maximum shelfal transgression. Both Wilkawillina transgression and Mernmerna highstand deposition produced different CHS types in each minibasin, indicating that the Woodendinna minibasin subsided more rapidly than the Donkey Bore minibasin throughout their histories.

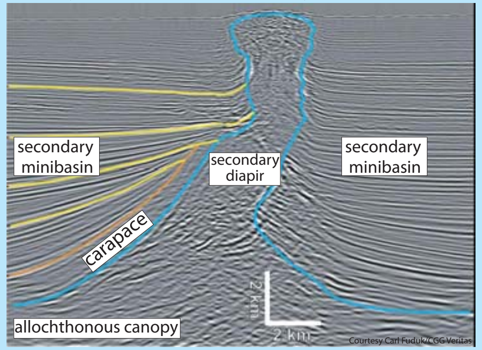
Figure 1: Donkey Bore syncline *Archaeocyathid* reef facies

Study Objectives

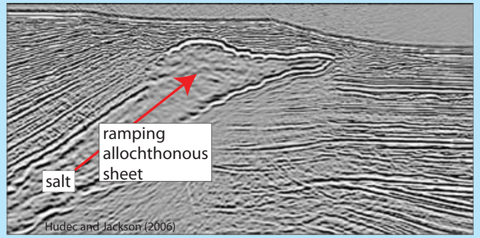
Objective 1: Characterize carbonate facies in suprasalt secondary minibasins adjacent to Wirrealpa Diapir

Wirrealpa diapir is a secondary diapir developed on an amalgamated allochthonous salt sheet.

(c) Secondary salt diapir derived from allochthonous canopy



(b) Ramping allochthonous salt sheet



(a) Primary diapir developed on autochthonous salt layer

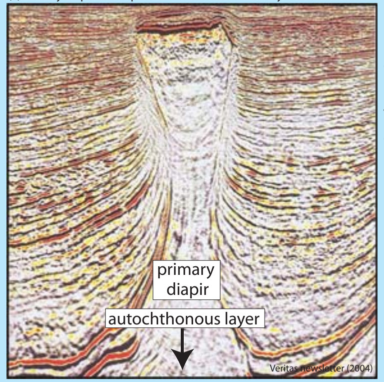


Figure 2: Evolution of a diapiric salt system leading to secondary diapirism

Objective 2: Document facies changes and stratal geometries from diapir-proximal to diapir-distal positions within minibasins

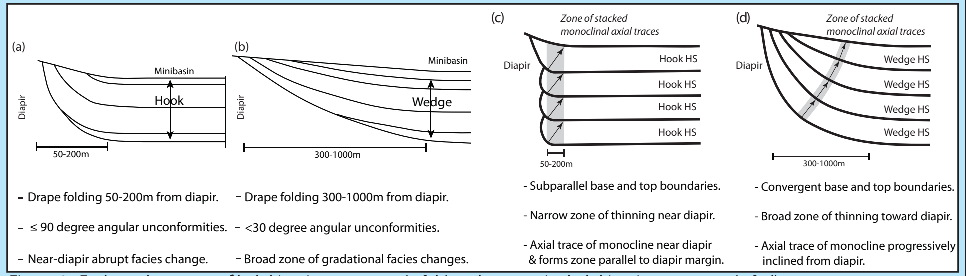


Figure 3: Endmember types of halokinetic sequences (a & b) and composite halokinetic sequences (c & d).

Objective 3: Compare time-correlative stratigraphic packages across Wirrealpa Diapir

- Wirrealpa Diapir is flanked by the Donkey Bore and Woodendinna minibasins.
- Halokinetic sequence development is related to the interplay of diapir rise rate and sediment accumulation rate (Giles and Lawton, 2002; Giles and Rowan, 2011).
- By comparing time correlative stratigraphic packages across a single diapir, salt rise rate can be removed as a variable, allowing for independent evaluation of sediment accumulation rate.
- Composite halokinetic sequences form as a result of third-order shifts in sea level, thus, halokinetic sequence boundaries bound time-correlative stratigraphic packages.

Objective 4: Analyze the effect of salt movement on the development of carbonate systems

- Subaqueously exposed diapirs (and their carapaces and/or caprocks) create zones of bathymetric relief. How does this relief influence the nature and distribution of carbonate sediments?
- Does halokinetic sequence style (hook vs. wedge) influence the nature and distribution of carbonate sediments? If so, how?

(a) (b)

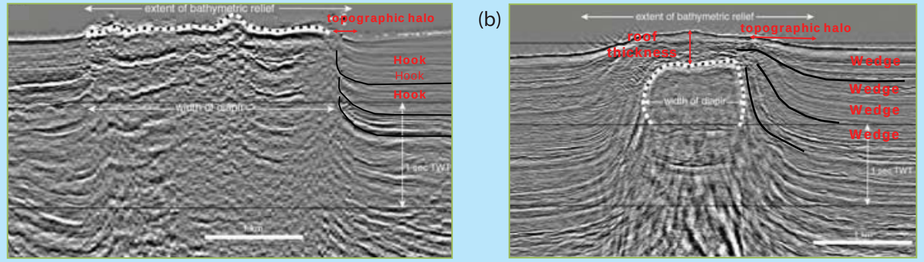


Figure 4: Seismic examples of bathymetric relief created by diapirs displaying Tabular (a) and Tapered (b) CHS. (Modified from Rowan et. al., 2003)

Geologic Setting of Wirrealpa Diapir, South Australia

Figure 5: The Adelaide Fold Belt is a north-south trending orogen resulting from inversion of a Neoproterozoic-Cambrian rift. Over 180 diapirs are exposed in the Adelaide Fold Belt. (Lemon, 2000)

Figure 6: Tectono- stratigraphic representation of Adelaide Fold Belt deposits. The Early Cambrian Hawker Group was deposited during a period of substantial lithospheric stretching. (Jenkins, 1990)

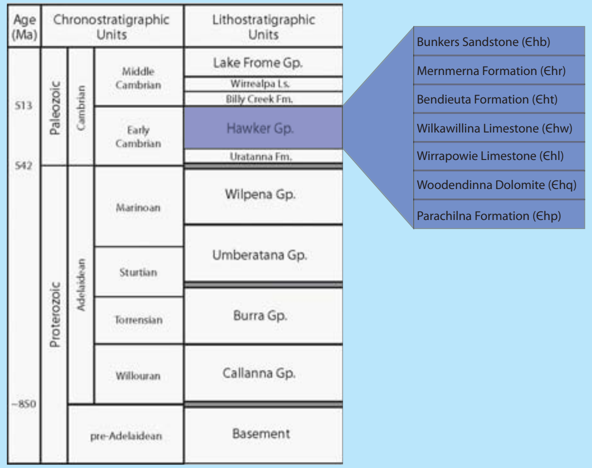


Figure 7: Generalized stratigraphy of the Adelaide Fold Belt.
- The Adelaidean Callana Group represents basal rift sediments, and supplies evaporitic material to the Flinders Ranges diapiric system.
- This study addresses the Early Cambrian Hawker Group, a carbonate-dominated group consisting of lowstand, transgressive, and highstand carbonate shelf deposits and basinal turbidites.
- The Wilkawillina Limestone contains the first appearance of Archaeocyathids in Australia, the first major macrofaunal reef builder.
- Archaeocyathid assemblage (*Dokidocyathus, Ajacicyathus*) in association with trilobites places the Wilkawillina Limestone in the Atdabanian and Botomian period (Rozanov and Debrenne, 1974).

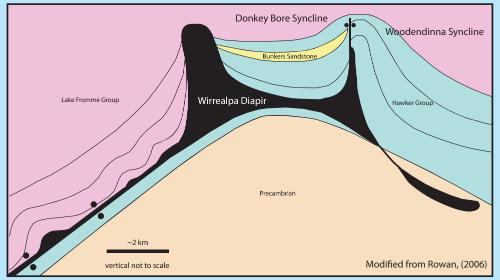


Figure 8: Schematic reconstructed cross-section showing Wirrealpa Diapir as a secondary salt diapir above a welded allochthonous salt sheet.

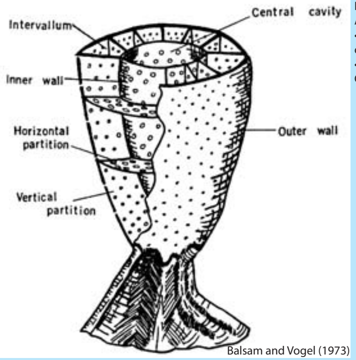


Figure 9: Generalized Archaeocyathid morphology.
- Archaeocyathids are a member of the phylum Porifera.
- Primary index fossil of the Early Cambrian.

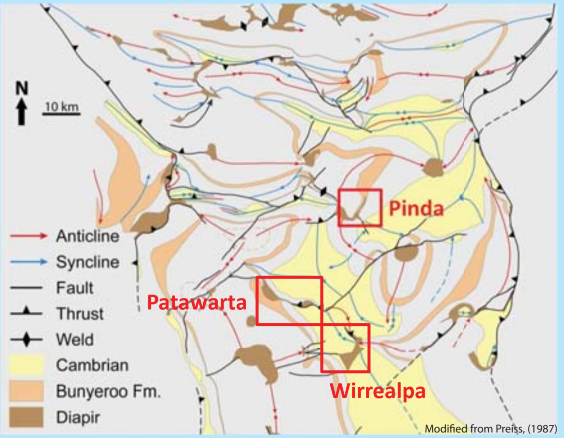


Figure 10: Generalized geology of the Central Flinders Ranges, South Australia. Pinda diapir is a Precambrian autochthonous primary diapir, Patawarta diapir is a Precambrian allochthonous diapir, and Wirrealpa diapir is a Cambrian secondary vertical salt wall.

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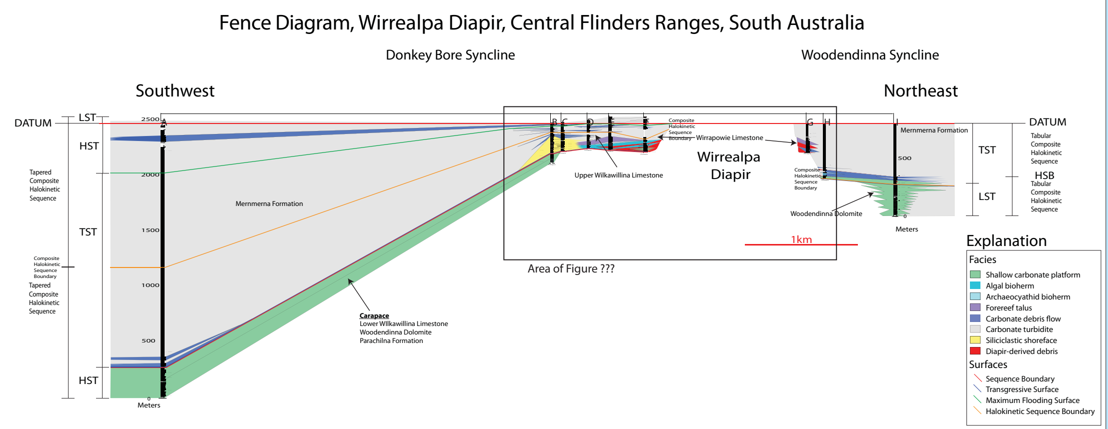


Figure 11: Fence diagram displaying regional facies distributions and geometries in minibasins adjacent to Wirrealpa Diapir.

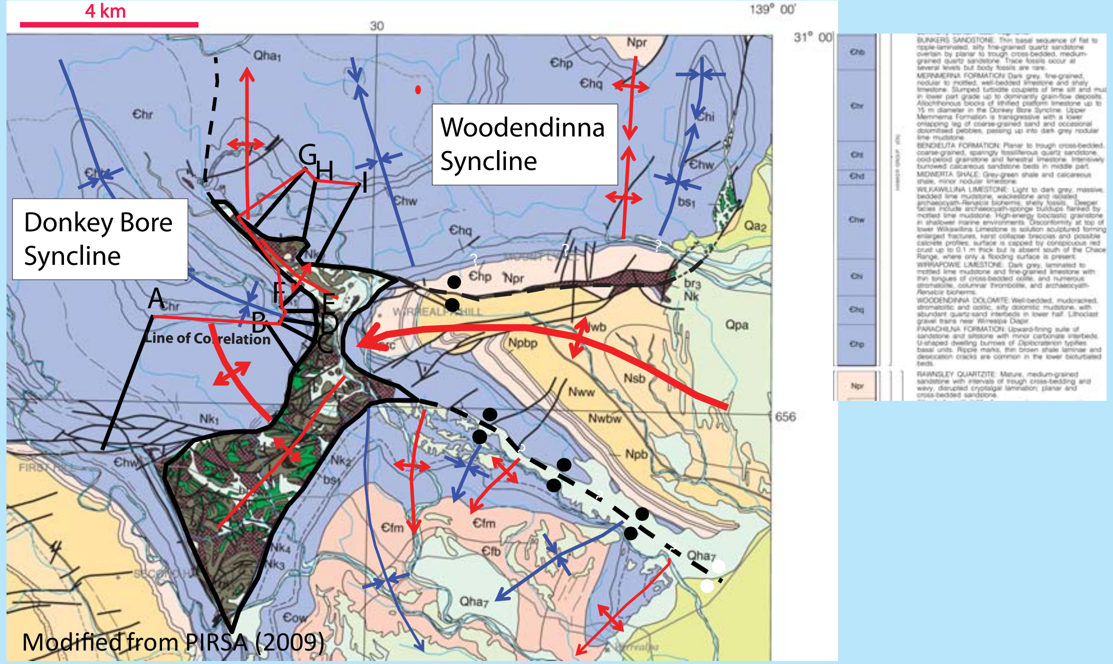


Figure 12: Geologic map of Wirrealpa Diapir displaying stratigraphic section locations, line of correlation, and structure.

Shallow platform carbonates

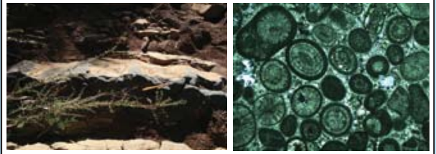
Supratidal Sabkha

- Mud cracks
- Algal lamination
- Flat clast rip-ups
- Dolomitic

Intertidal Flat

- Domal stromatolites
- Peloidal wackestone-packstone

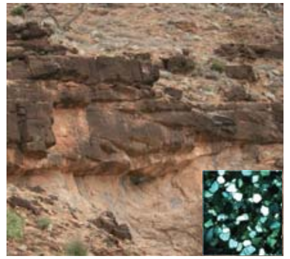
Subtidal



- Symmetrical ripples
- Herringbone cross-bedded
- Peloidal and oolitic grainstones

- Mottled
- Peloidal wacke-packstones
- Silty micrite

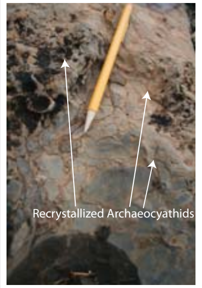
Shoreface sandstone



- Upper shoreface
- Sublitharenite, abundant Qm, carbonate intraclasts
- Common quartzite clasts, likely reworked from Neoproterozoic Rawnsley Quartzite (reworked carapace)

Reef

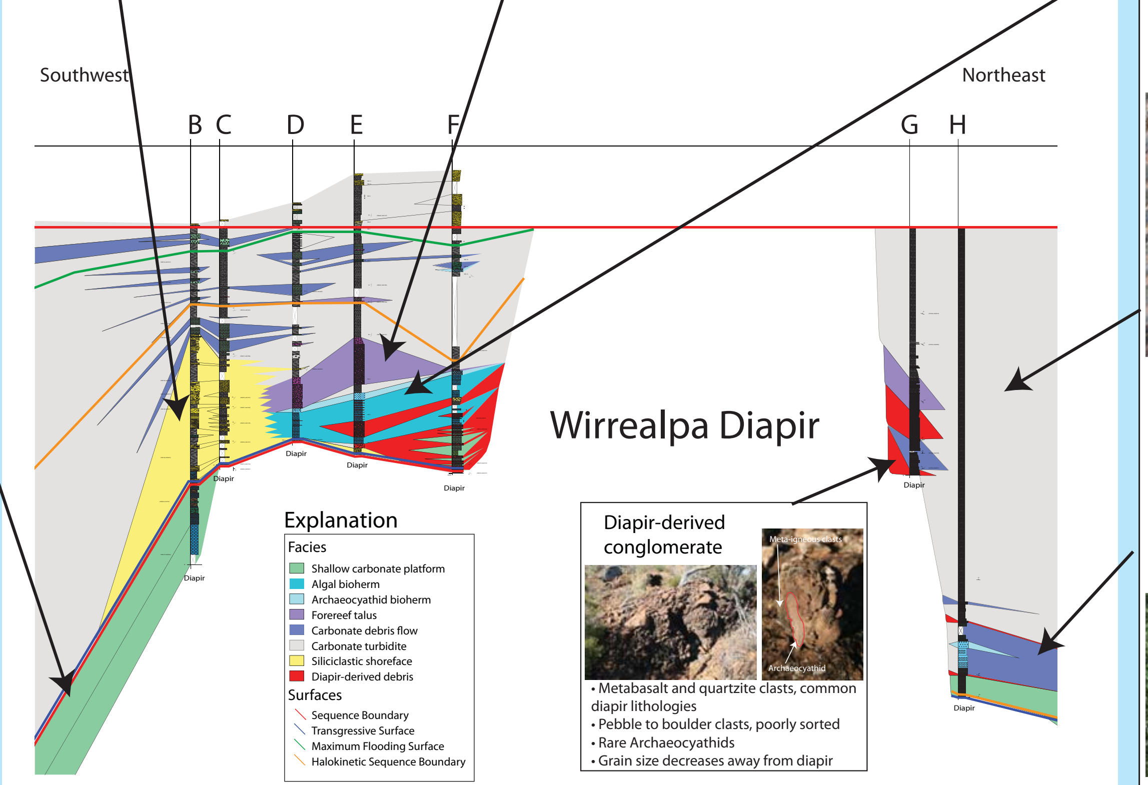
Forereef talus



- Gravel to obble sized reef debris
- Whole and broken Archaeocyathids
- Muddy matrix

Archaeocyathid Bioherm

- Framestone-bindstone
- Archaeocyathids and *Renalcis*
- *Epiphyton* common in lower, primarily algal portions of bioherm
- Within photic zone, but little evidence of wave-resistance



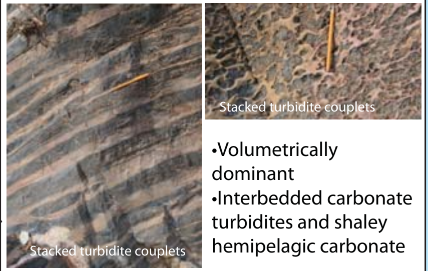
Diapir-derived conglomerate

- Metabasalt and quartzite clasts, common diapir lithologies
- Pebble to boulder clasts, poorly sorted
- Rare Archaeocyathids
- Grain size decreases away from diapir

Figure 13: Descriptions and distributions of facies proximal to Wirrealpa Diapir. Vertical exaggeration: 300%

Midshelf

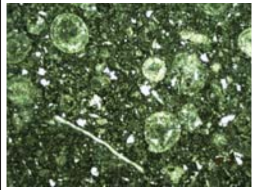
Carbonate turbidites



- Volumetrically dominant
- Interbedded carbonate turbidites and shaley hemipelagic carbonate

Debris flows

Bed-topping carbonate clasts



Skeletal peloid-ooid packstone

- Bed-topping rip-up clasts
- Oolitic, peloidal, skeletal, algal, and micritic intraclasts
- Ooids
- Diverse skeletal fragments
- Basal scour into midshelf turbidite facies
- Laterally discontinuous

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Halokinetic and Sequence Stratigraphic Restoration of Wirrealpa Diapir

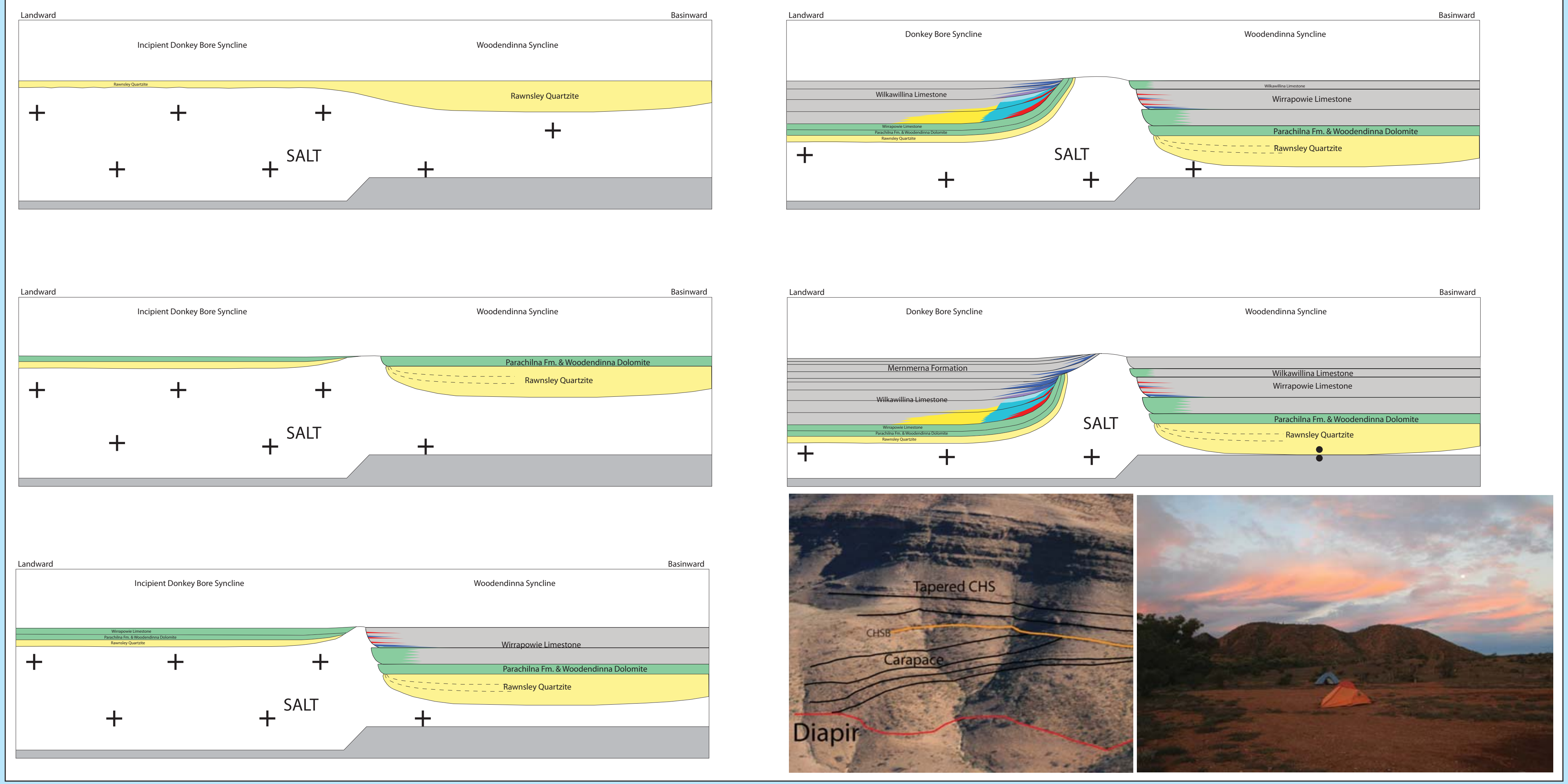

Figure 14: Schematic restoration of the evolution of Wirrealpa Diapir. Facies colors match fence diagram.

Variation between minibasins

Donkey Bore Syncline	Woodendinna Syncline
• Diapir-fringing Archaeocyathid bioherms	• Small, patch-reef style Archaeocyathid bioherms
• Shoreface sandstone unit below Wilkawillina Limestone	• Lacks siliciclastic units
•Tapered-CHS	• Tabular-CHS
•Hawker Group sediments thin toward diapir over about1000m	• Hawker Group sediments thin toward the diapir over 200m or less

Conclusions

- Lower Hawker Group sediments adjacent to Wirrealpa Diapir are composed primarily of slope deposits with subordinate mid- to inner-shelf deposits near the diapir.
- The Parachilna Fm., Woodendinna Dolomite, and Wirrapowie Fm. represent a shallow-water carapace above the allochthonous salt sheet before diapir breakout.
- Biohermal structures were built during the transgressive period
- Sedimentation was, at times, more rapid in the Donkey Bore minibasin than in the Woodendinna minibasin
- The Woodendinna minibasin may have been approaching base salt during deposition of the Wilkawillina and Mernmerna formations, resulting in a decrease in minibasin subsidence and accomodation rates
- Tapered-CHS are present in the Donkey Bore Syncline, while Tabular-CHS are dominant in the Woodendinna Syncline
- Facies vary significantly between minibasins and with proximity to the diapir.
- Wirrealpa diapir provided a bathymetric high upon which shallow-water carbonates were produced.

Figure 15: Four outstanding field assistants. From left to right:
Dr. Carl Fiduk, Rachelle Kernen, Thomas Hearon, and Dr. Kate Giles.

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Acknowledgments

•Rachelle Kernen •Thomas Hearon •Carl Fiduk • Nila Matsler •AAPG Grants-In-Aid
•The 2010 Russell Clemons Field Scholarship •Ian Fargher, land use
•Institute of Tectonic studies and Salt-Sediment Interaction Consortium