Identification of a Neoproterozoic Shelfal Suprasalt Carapace and Correlation to a Tapered Composite Halokinetic Sequence at Patawarta Diapir, Central Flinders Ranges, South Australia*

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Abstract

Stratigraphic and facies analysis of the Neoproterozoic Wonoka Formation and Patsy Hill Member of the Bonney Sandstone that surround Patawarta allochthonous salt sheet permit identification of an isolated suprasalt carapace section of the Wonoka Fm that is condensed and lithologically distinct from the correlative minibasin section. The two sections are spatially separated by a 3.8 km wide zone of outcropping Callana Group in the Patawarta diapir.

The Wonoka Fm carapace section displays a uniform 14 m thickness of parallel strata over a distance of 2.5 km and lies unconformably above the Patawarta salt sheet. The lower 7 m comprises upper-shoreface to foreshore silty lime mudstone and the upper 7 m comprises debris-flow facies interbedded with peritidal sandstone and shale capped by lagoonal stromatolitic mudstone. Debris-flow clasts were derived from older Wonoka Fm units and the Callana Grp. Equivalent strata in the adjacent minibasin comprise outer-shelf to upper-shoreface lime mudstone, siltstone and shale with minor sandstone. These strata form the bulk of a tapered composite halokinetic sequence (CHS) that thins (975 m to 117 m) and turns upward (<86 degrees) toward the diapir over a distance of 457 m. The uppermost shale unit in the minibasin contains 12 thin, sandy, pebble conglomerate beds, also sourced from older Wonoka Fm units and the Callana Grp, that display a progressive unroofing sequence.
The carapace and correlative minibasin section record the highstand systems tract (HST) of a 3rd-order depositional sequence. The transgressive systems tract (TST) and early HST formed by the lower Wonoka Fm units in the minibasin are not preserved in the carapace section. The top of the Wonoka Fm carapace is a sequence boundary (SB) that correlates to a SB in the minibasin formed at the contact between the Wonoka Fm and overlying Patsy Hill Member of the Bonney Sandstone.

The debris flow facies in the Wonoka Fm carapace and the correlative conglomerate beds in the minibasin are interpreted to be locally derived from strata that were originally deposited atop the ramping Patawarta salt sheet between the carapace and the minibasin. We infer that during the process of salt sheet breakout, the tip of the Patawarta sheet became a zone of diapiric inflation forming a local topographic high in the margin area, which was eroded during the later part of the HST and shed clasts onto both the carapace and the minibasin.

**Selected References**


Objectives of Study

- Document facies distribution, stratigraphic geometry and structure of suprasalt and subsalt Wonoka Formation adjacent to Patawarta salt sheet
- Correlate shelfal suprasalt and subsalt stratigraphy within a depositional sequence stratigraphic and halokinetic sequence stratigraphic framework
- Evaluate models for salt sheet advancement of emplacement
- Hypothesize differences in Proterozoic shelfal carapace vs. Phanerozoic shelfal carapace

Geologic Setting of the Flinders Ranges, South Australia

General Stratigraphy and Snowball Earth

A lagoonal depositional system of shallow-water sandstone, siltstone, and mudstone (Rowan et al., 2010)

Previous Maps of Patawarta Area Including Interpreted Carapace

Figure 10: Patawarta Diapir is one of more than 120 exposed diapirs in South Australia (Preiss, 1987). The diapir is a large structure that extends for hundreds of kilometers. The diapir is characterized by a central core of crystalline rock, surrounded by a halo of sedimentary rock. The diapir is thought to have formed as a result of diapiric activity, which is driven by the movement of salt. The diapir is one of the largest diapirs in South Australia and is one of the most prominent features of the Patawarta area. The diapir is located in the western part of the Flinders Ranges, South Australia. The diapir is thought to be one of the largest and most prominent features of the Patawarta area. The diapir is characterized by a central core of crystalline rock, surrounded by a halo of sedimentary rock. The diapir is thought to have formed as a result of diapiric activity, which is driven by the movement of salt. The diapir is one of the largest diapirs in South Australia and is one of the most prominent features of the Patawarta area. The diapir is located in the western part of the Flinders Ranges, South Australia. The diapir is thought to be one of the largest and most prominent features of the Patawarta area. The diapir is characterized by a central core of crystalline rock, surrounded by a halo of sedimentary rock. The diapir is thought to have formed as a result of diapiric activity, which is driven by the movement of salt.
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Figure 13: The Wonoka Formation and Patsy Hill Member of the Bonney Sandstone deposited locally as a composite sequence and coastal setting. The Wonoka Formation and Patsy Hill Member form an unoored composite halokinetic sequence.

Figure 14: The Wonoka Formation forms the highstand systems tract of a third order depositional sequence. The Patsy Hill Member was deposited during the lowstand systems tract.

Figure 15: The Wonoka Formation forms the highstand systems tract of a third order depositional sequence. The Patsy Hill Member was deposited during the lowstand systems tract.

Figure 16: Flute casts; wave-dominated lower to upper shoreface.

Figure 17: Mud drapes, horizontal bedding.

Figure 18: Tape stripes, upper shoreface.

Figure 19: Litharenite; wave-dominated lower to upper shoreface.

Figure 20: Flute casts; wave-dominated lower to upper shoreface.

Figure 21: Mud drapes, horizontal bedding.

Figure 22: Tape stripes, upper shoreface.

Figure 23: Litharenite; wave-dominated lower to upper shoreface.

Figure 24: Flute casts; wave-dominated lower to upper shoreface.

Figure 25: Mud drapes, horizontal bedding.

Figure 26: Tape stripes, upper shoreface.

Figure 27: Quartz arenite; wave-dominated lower to upper shoreface.

Figure 28: Mud drapes, horizontal bedding.

Figure 29: Litharenite; wave-dominated lower to upper shoreface.

Figure 30: The Wonoka Formation forms the highstand systems tract of a third order depositional sequence. The Patsy Hill Member was deposited during the lowstand systems tract.

Figure 31: The Patsy Hill Member (lower limestone, sandstone, and upper limestone beds) form on a tidally-dominated shelf. The Patsy Hill Member was deposited during the Lowstand Systems Tract.
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Correlating Suprasalt Carapace to Subsalt Stratigraphy

- Correlating Suprasalt Carapace to Subsalt Stratigraphy
- Proterozoic vs. Phanerozoic Carapace
- Correlating Subsalt Sequence Stratigraphy to Carapace Section

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**Unroofing of Suprasalt Carapace Recorded in HST Green Mudstone Member in Subsalt Stratigraphy**

- Figure 40: Progressive pinning of salt
- Figure 41: Depositional model for Proterozoic carapace
- Figure 39c: Transgressive systems tract buries carapace

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**Figure 39c**: Transgressive systems tract buries carapace

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**Figure 40**: Progressive pinning of salt

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**Pinned Inflation and Unroofing: Mechanism for Allochthonous Salt Advancement**

- High sedimentation rates during the HST begins to 'pin' down the toe/tip of ramping salt sheet
- Only during the HST is carapace deposited on the shelf because rising sea level
- Correlation of suprasalt and subsalt sections (14 m carapace vs. 975 m subsalt)

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**Proterozoic vs. Phanerozoic Carapace**

- Carapace barriers
- Salt advances
- Carapace progradation
- Salt advance
- Correlation of carapace (Section M) to subsalt stratigraphy and depositional sequence stratigraphy
- Unroofing of Suprasalt Carapace Recorded in HST Green Mudstone Member in Subsalt Stratigraphy

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**Conclusions**

- Correlation of suprasalt and subsalt sections (14 m carapace vs. 975 m subsalt)
- Proterozoic carapace primarily formed during late highstand systems tract and was exposed and eroded during lowstand systems tract, and forms during transgressive systems tract
- Allochthonous break-out by pinned inflation at the tip of the salt sheet associated late highstand erosional thinning of carapace permitted by break out
- Proterozoic carapace great analog for Gulf of Mexico because lacks carbonate producers and reef builders

**Comparison of Intra-slope and Shelfal Carapace**

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**References Cited**

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**Acknowledgments**

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**Image Descriptions**

- a) Depositional model for Proterozoic carapace
- b) Depositional model for Phanerozoic carapace
- c) Chart comparing Proterozoic vs. Phanerozoic shelfal carapace

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**Correlation Chart**

- Correlation of carapace (Section M) to subsalt stratigraphy and depositional sequence stratigraphy
- Unroofing takes place when sea level begins to drop at the end of the HST
- Patsy Hill Member was not deposited on carapace because it was subaerially exposed during the LST

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**Exploration Significance**

- High sedimentation rates during the HST begins to 'pin' down the toe/tip of ramping salt sheet
- Only during the HST is carapace deposited on the shelf because rising sea level
- Correlation of suprasalt and subsalt sections (14 m carapace vs. 975 m subsalt)

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**Carapace Facies**

- Sandy carbonate and reef, back reef
- Different source, reservoir, or seal composition

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**Subsalt Section**

- Undifferentiated Subsalt Section:
  - Patsy Hill Member
  - Wonoka Fm middle limestone
  - Wonoka Fm upper limestone
  - Wonoka Fm conglomerate mudstone
  - Wonoka Fm lower limestone
  - Wonoka Fm lower limestone

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**References Cited**