

Ramps, Flats, and Rubble Zones: Case Studies of Deformation beneath Allochthonous Salt in the Flinders Ranges, South Australia

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Motivation and Significance

Salt bodies are significant traps for hydrocarbons throughout the world. The viability of these traps most often depends on near-salt pinchouts and deformation, many of which occur less than 300 m from the salt-sediment interface, a scale below the resolution of most seismic data. Deformation beneath allochthonous salt is especially challenging to predict because it can originate by carapace slumping or halokinetic processes. Numerical models aim to predict the nature and extent of deformation beneath allochthonous salt, but offer contrasting results. Nikolinakou et al. (2018a) predicts substantial subsalt deformation, whereas Li and Fischer (2018) show little strain in the subsalt strata (Figure 1).

This project uses field work to characterize the deformation beneath allochthonous salt and tests the hypothesis (Figure 2; Williams et al, 2019) that the deformation near allochthonous salt will vary with structural position (i.e. ramps v flats, Figure 3). We provide new data on deformation adjacent to an allochthonous salt sheet in the Flinders Ranges of South Australia, with special emphasis on the contrasting subsalt deformation between ramps and flats. See presentation EGU2020-21148 by Wegmann et al. in this same session for additional case studies of subsalt deformation elsewhere in the Flinders.

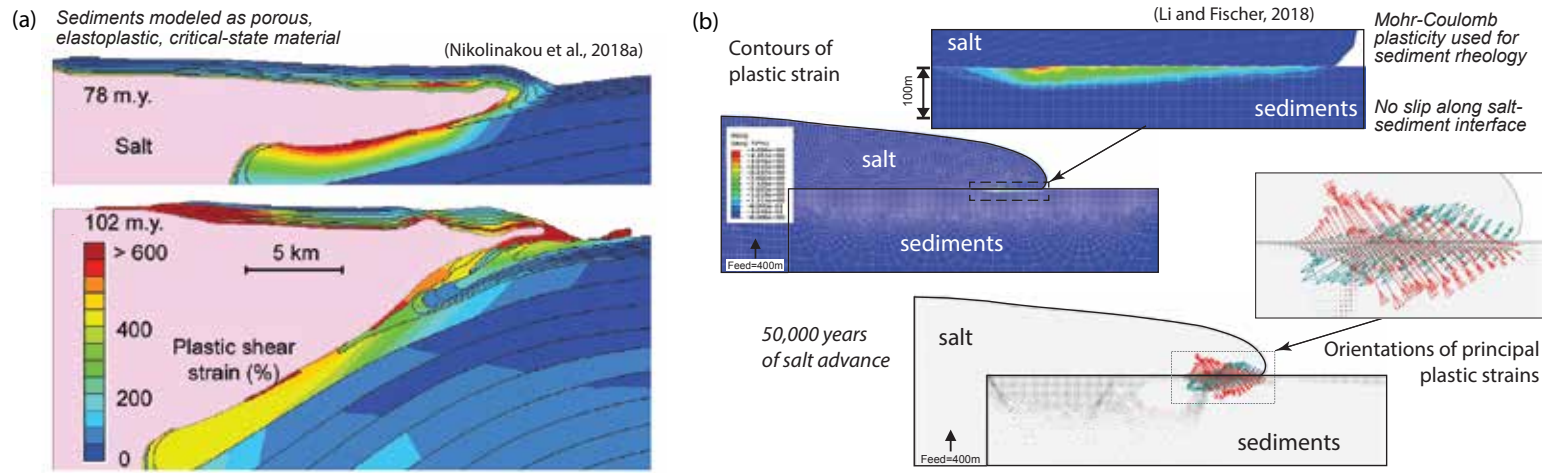


Figure 1. (a) Left; Contours of plastic shear strain in the sediments surrounding an advancing salt sheet after 78 m.y. and 102 m.y. The model predicts high shear strain at distances up to ~2km beneath and advancing salt sheet. (b) Right; Magnitude and orientation of principle plastic strains beneath a salt sheet that has advanced over a planar surface. This model predicts subsalt shearing will be concentrated in a <50m wide zone beneath the salt. Strain orientations imply structures with unique orientations will be concentrated in this zone.

Conceptual Model of Deformation Patterns During Submarine Advance of Allochthonous Salt

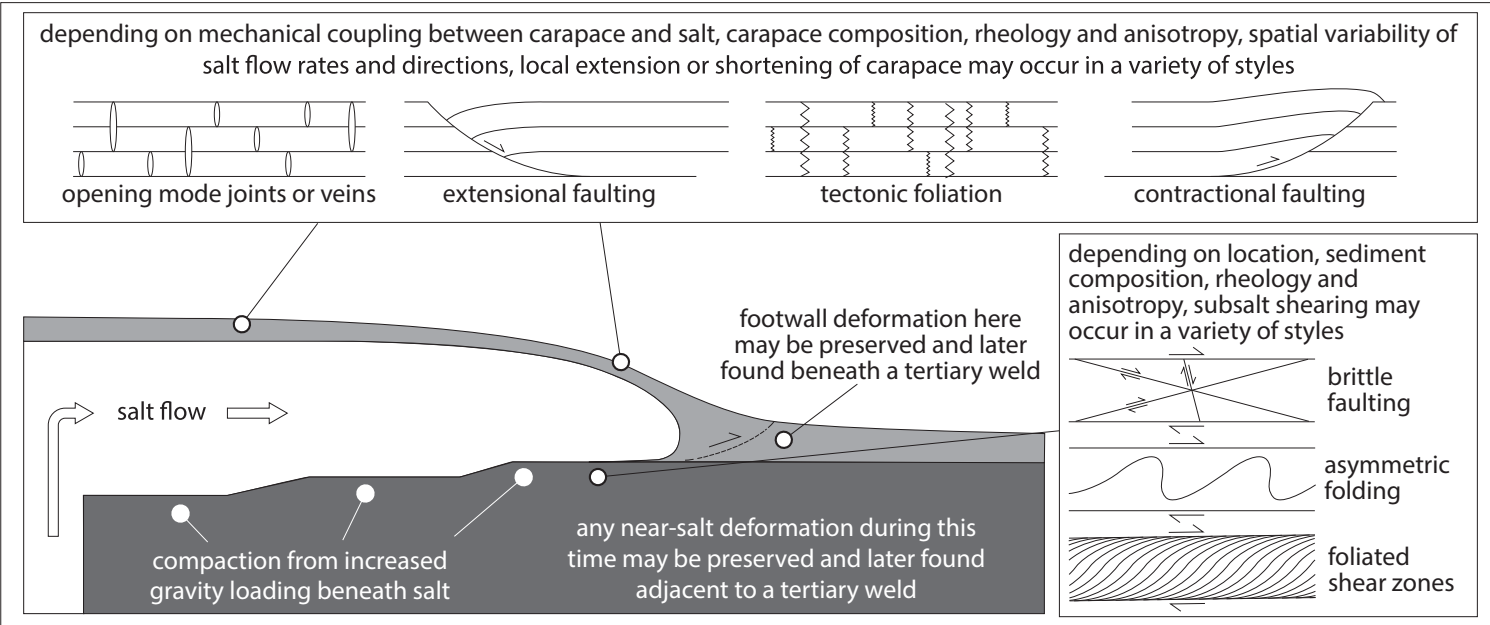


Figure 2. Deformation patterns associated with allochthonous salt advance hypothesized by Williams et al. (2019).

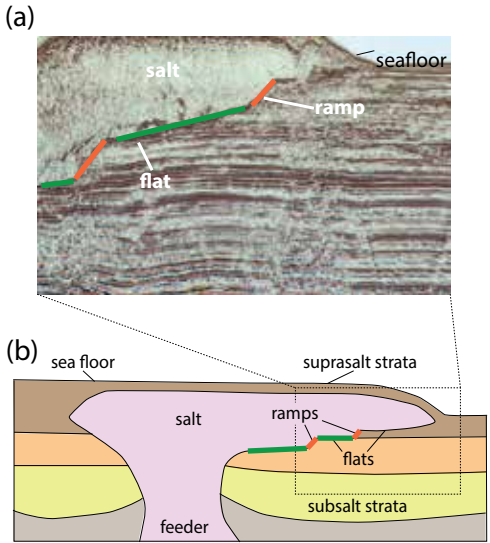


Figure 3. (a) Seismic data of allochthonous salt sheet underlying the Sigsbee Escarpment in the Gulf of Mexico. Subsalt flats (green) and ramps (orange) are highlighted for comparison with the schematic drawing in (b). (b) Schematic cross-section of an allochthonous salt sheet showing suprasalt and subsalt strata. Figure adapted from Hudec and Jackson (2006). Flats (green) and ramps (orange) are highlighted in the subsalt strata.

Tourmaline Hill Field Area Map

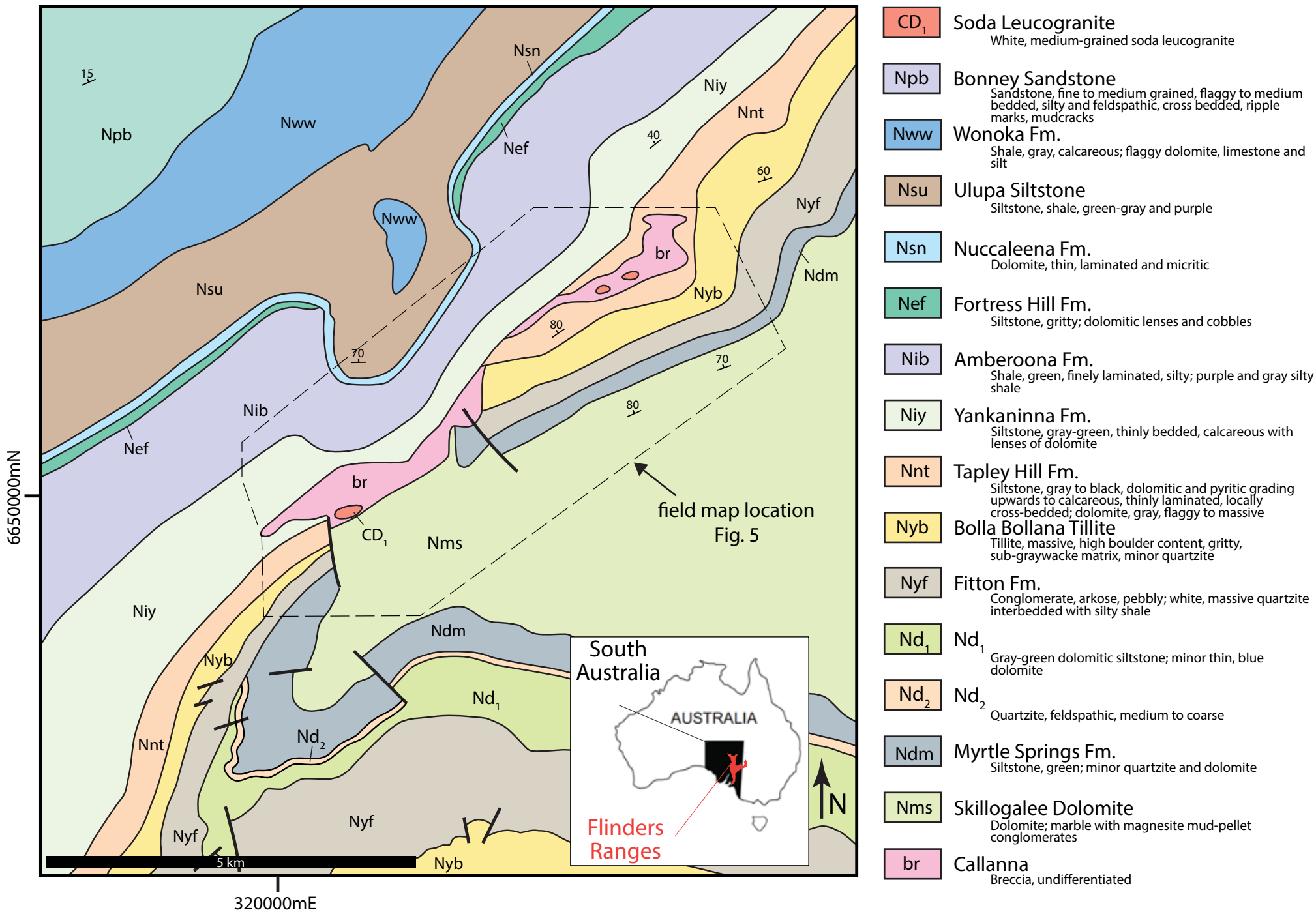
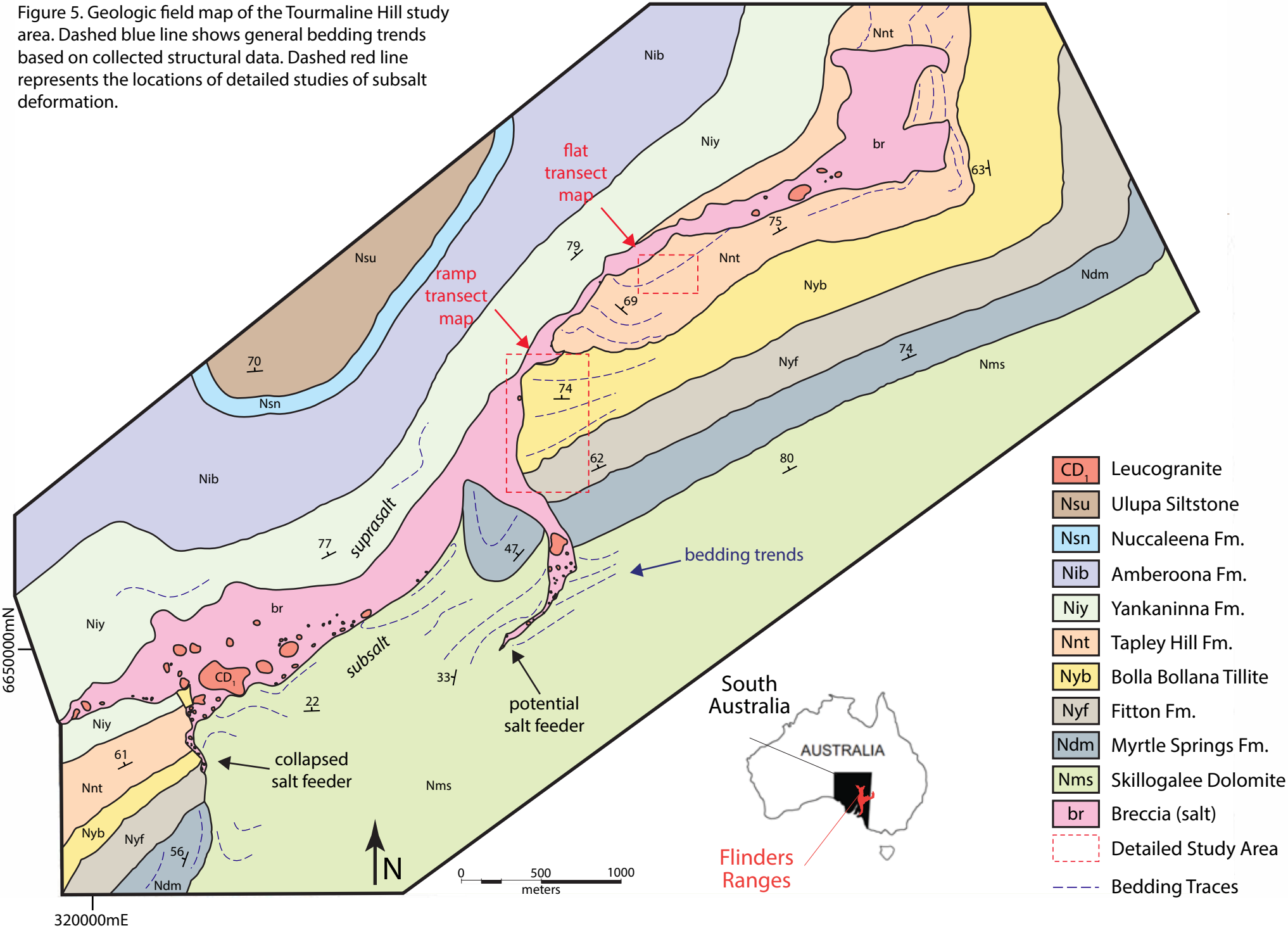


Figure 4. Regional geologic map and stratigraphic column of the Tourmaline Hill area based on the Umberatana Quadrangle. The black outline represents the detailed field area in Figure 5.

Tourmaline Hill Field Map

Figure 5. Geologic field map of the Tourmaline Hill study area. Dashed blue line shows general bedding trends based on collected structural data. Dashed red line represents the locations of detailed studies of subsalt deformation.



Subsalt Flat Transect

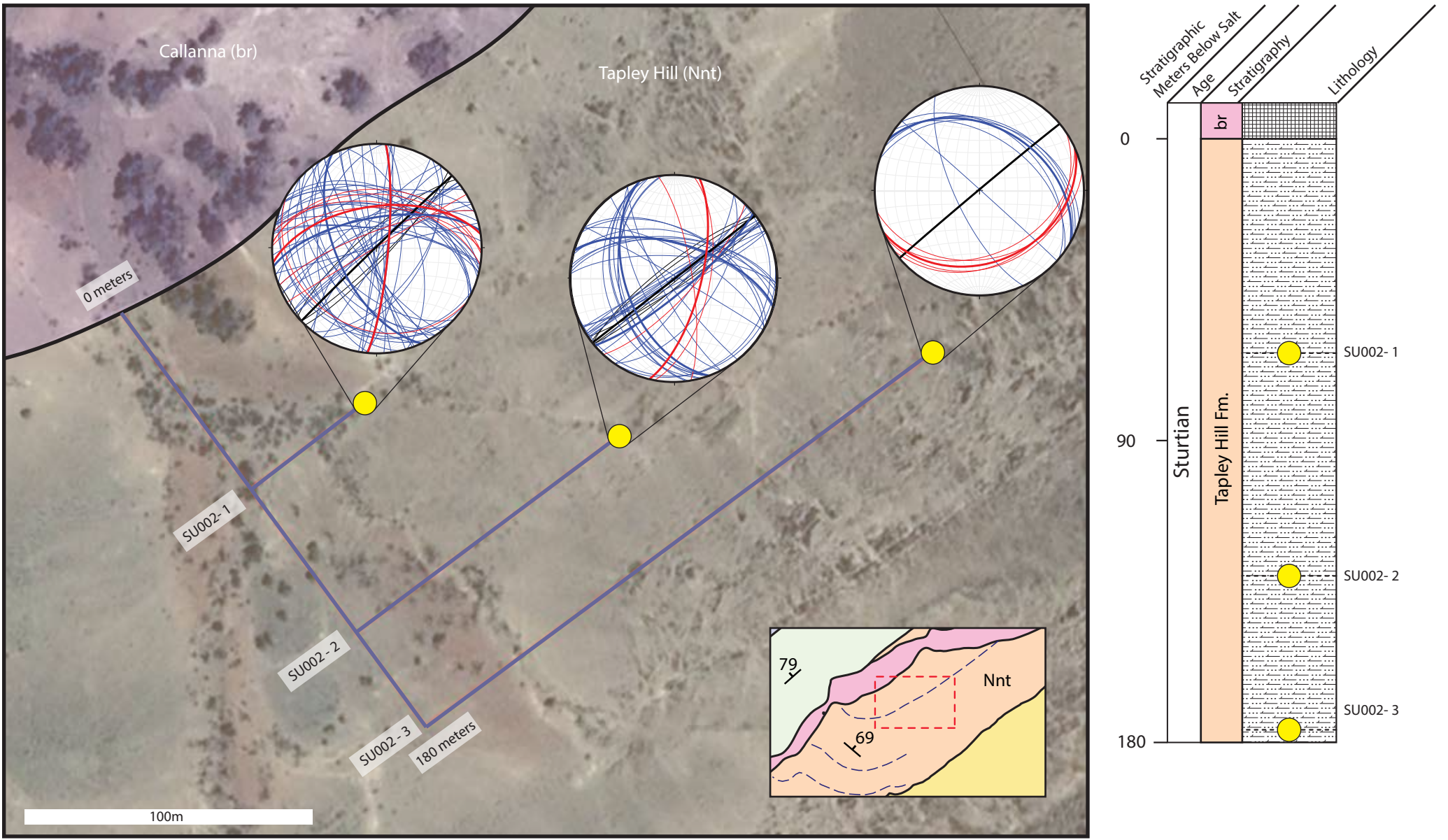
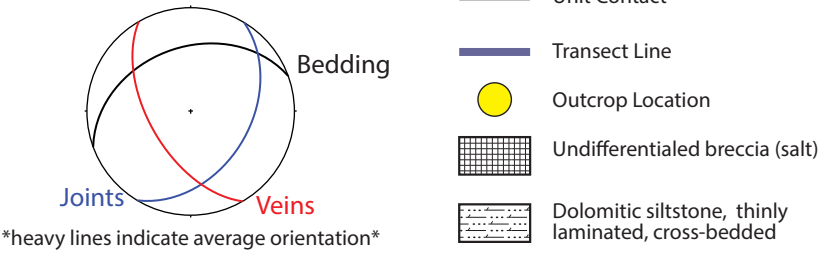


Figure 6. Close-up aerial photo and lithostratigraphic column of the transect location in the subsalt flat showing the station locations (yellow dots) where data were collected. The transect line (purple) is oriented perpendicular to bedding. The transect starts at the salt-sediment interface, and spans 180 meters of stratigraphic section through the Tapley Hill Formation.



Tourmaline Hill Ramp Detail

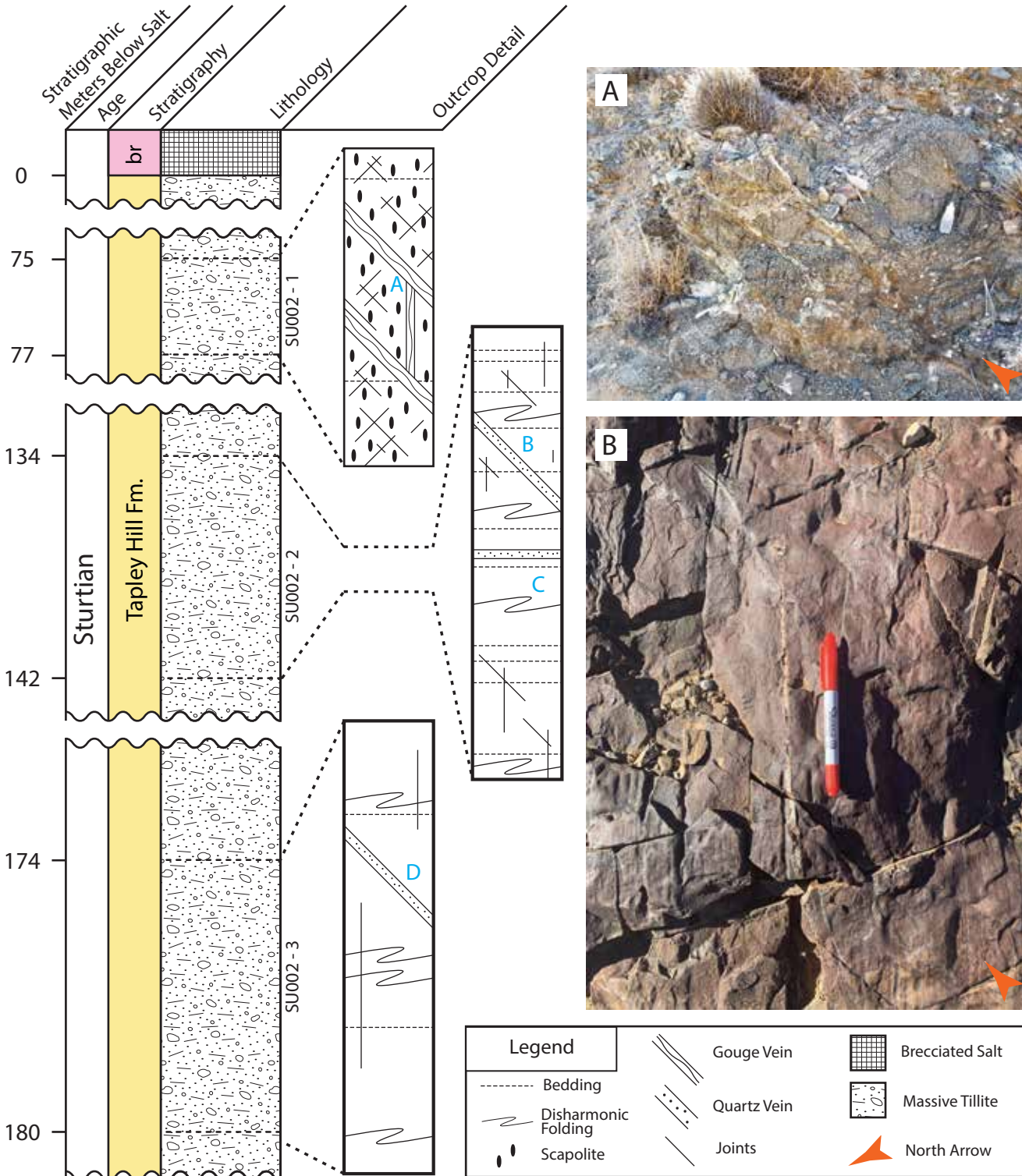
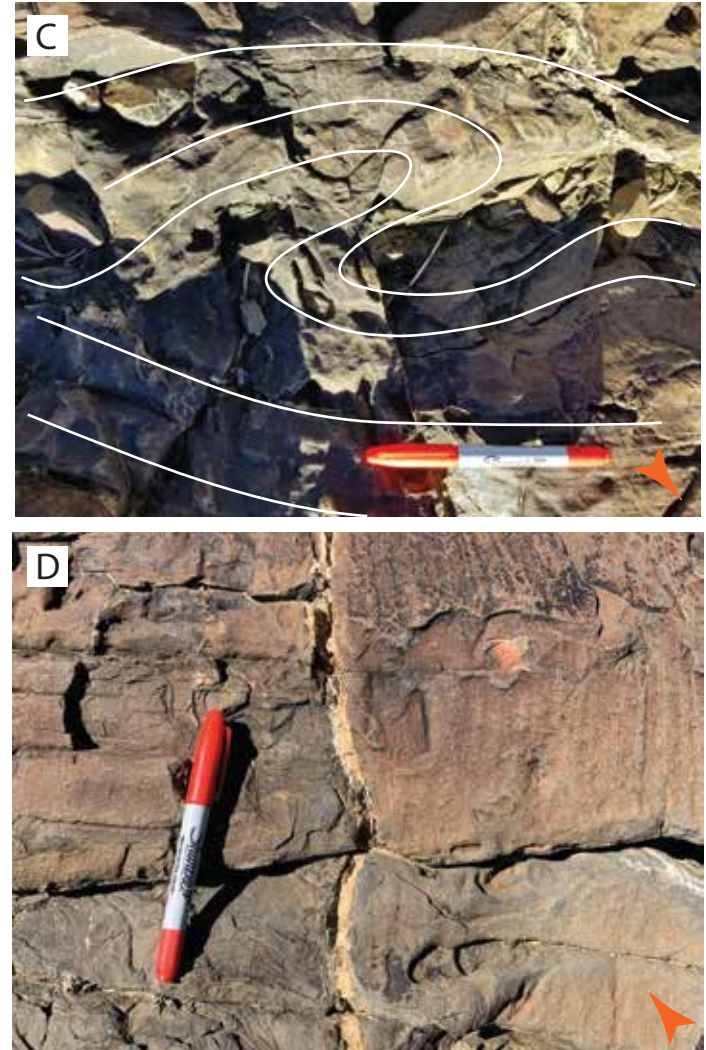


Figure 7. Lithostratigraphic column and deformation details of stations located along the subsalt flat transect. A) Outcrop example showing the abundance of scapolite mineralization and the cross-cutting relationship of gouge veins at station SU002-1. B) Well indurated massive siltstone with quartz vein at SU002-2. Note that scapolite is not present. C) Detail of disharmonic folding (slumping?) within the bedding of SU002-2. D) Detail of quartz vein oblique to bedding orientation at Station SU002-3.



Subsalt Ramp Transect

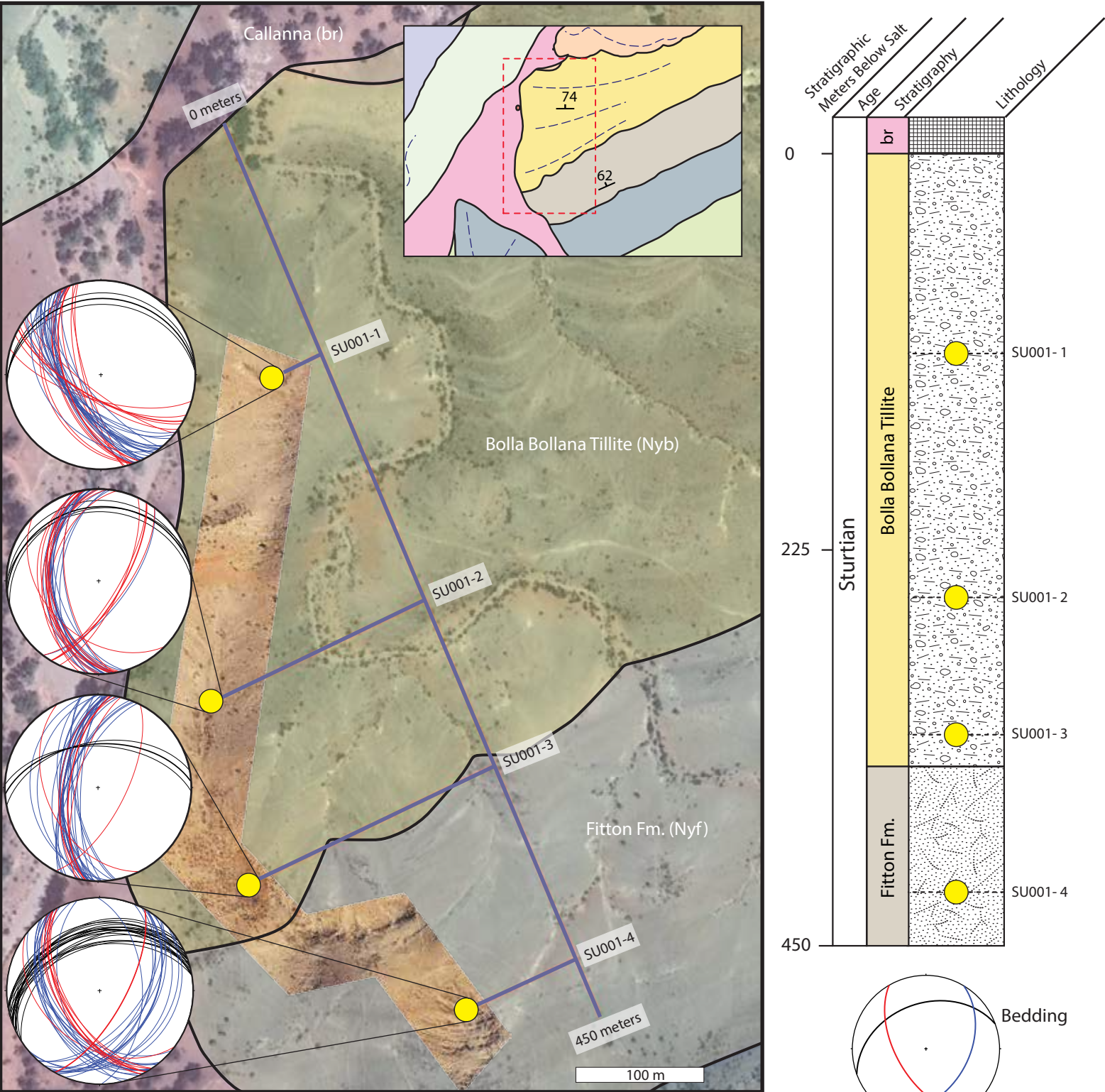


Figure 8. Close-up aerial photo and lithostratigraphic column of the transect location in the subsalt showing the high resolution drone image and station locations (yellow dots) where data were collected. The transect line (purple) is oriented perpendicular to bedding. The transect starts at the salt-sediment interface, and spans 750 meters across the Bolla Bollana Tillite, ending in the Fitton Fm.

Tourmaline Hill Ramp Detail

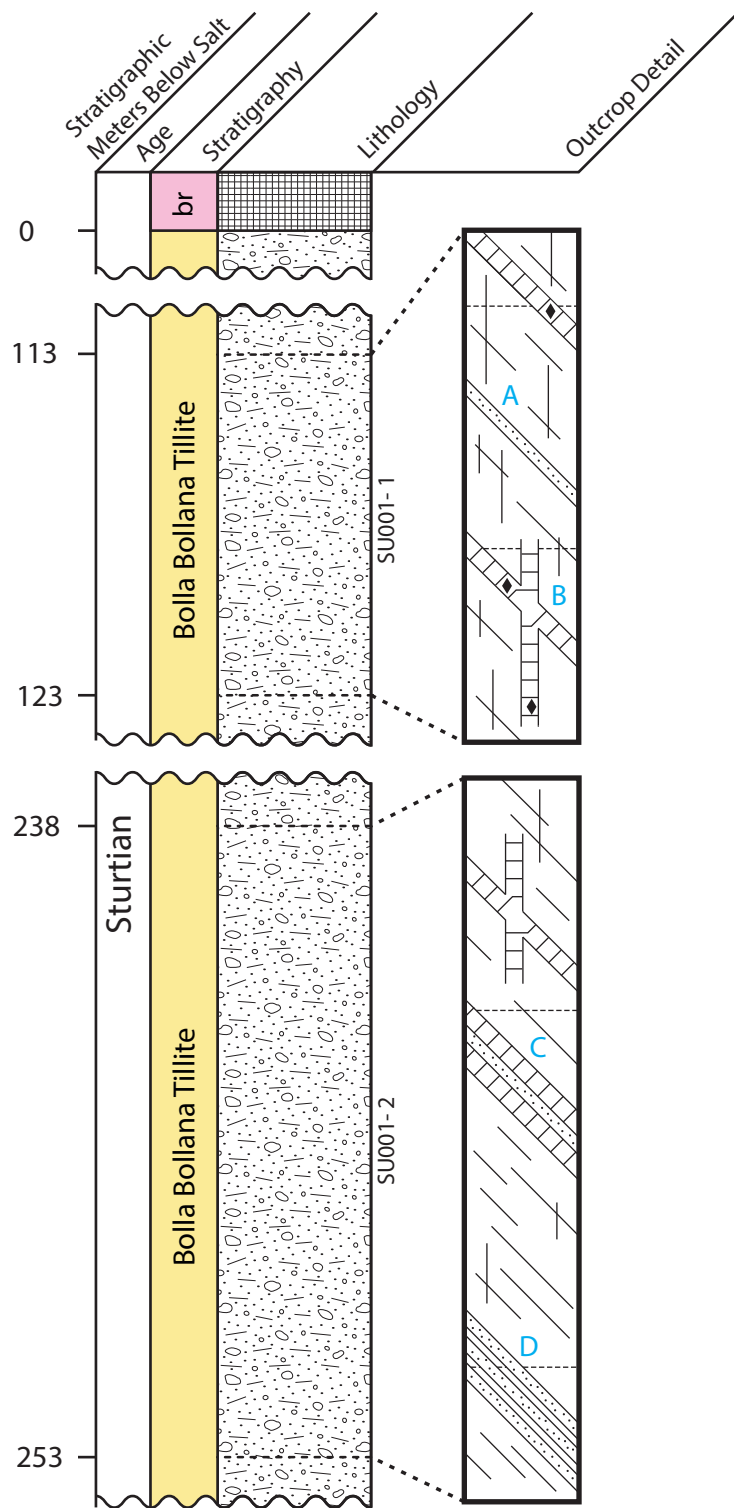
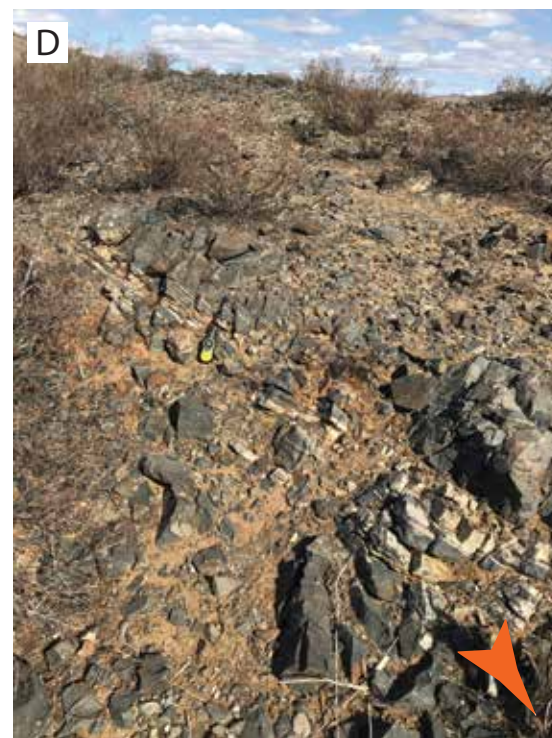
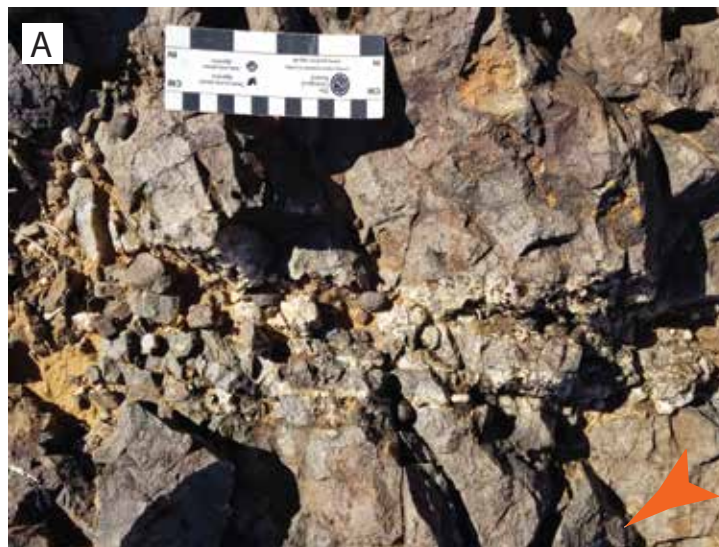


Figure 9. Lithostratigraphic and deformation details of stations located along the subsalt ramp transect. A) Quartz veins at station SU001-1 oriented oblique to bedding. B) Siderite veins at station SU001-1 oriented perpendicular and oblique to bedding. C) Quartz in a siderite vein at station SU001-2. D) Quartz veins at station SU001-2 oriented oblique to bedding.



Tourmaline Hill Ramp Detail

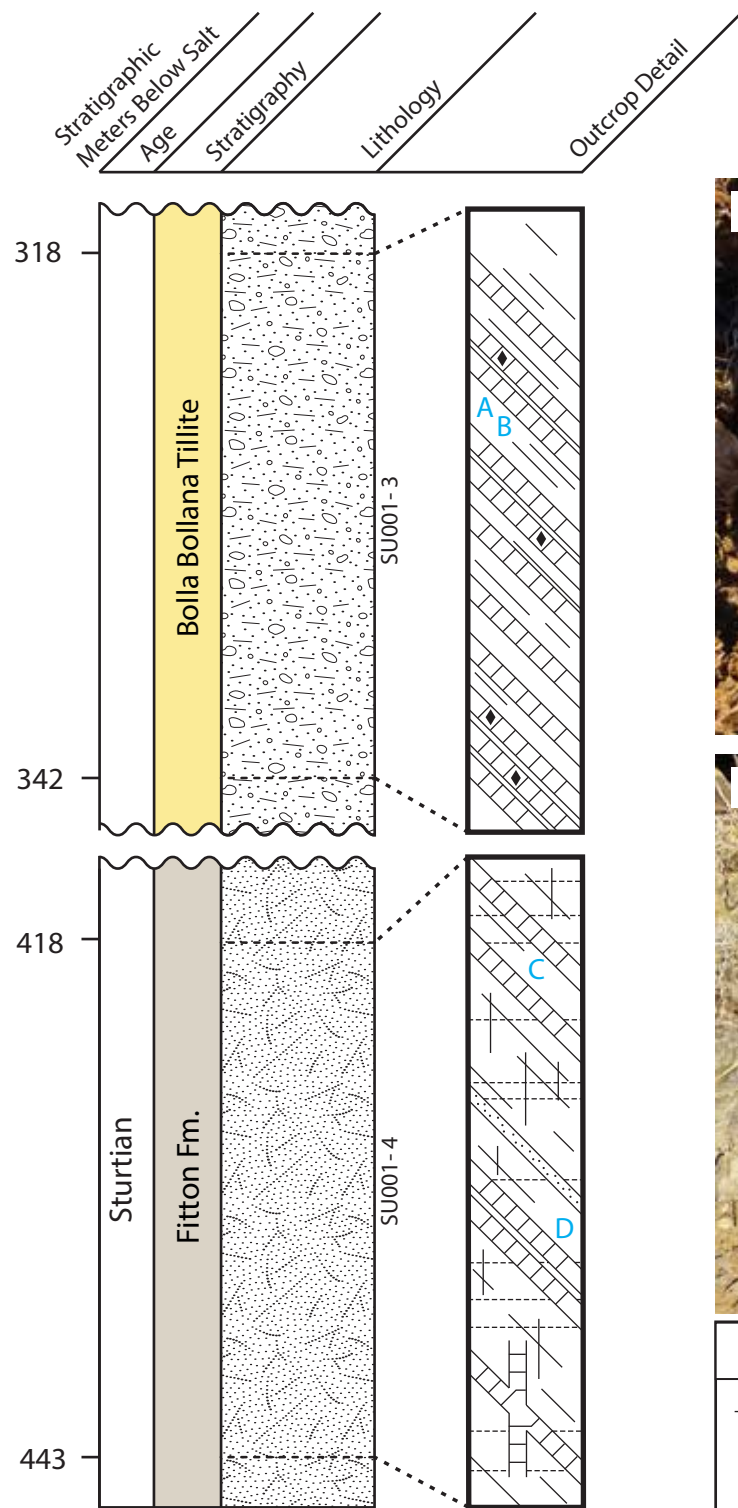
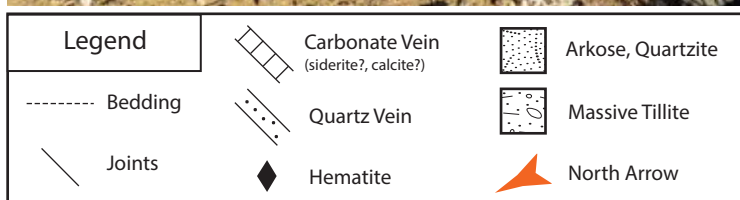


Figure 10. Lithostratigraphic column and deformation details of stations located along the subsalt ramp transect. A) Siderite mass comprising station SU001- 3. B) Detail of large siderite crystals and calcite? in mass at SU001- 3. C) Vein of siderite and calcite? at station SU001- 4 oriented oblique to bedding. D) Siderite and calcite vein at SU001- 4 oriented oblique to bedding.



Summary

Fractures are generally nonsystematic and abundant near the salt contact and become systematic and less abundant with distance away from salt. Scapolite is abundant near the salt-sediment interface, and rare or absent in rocks more than 100m away from the salt-sediment interface.

Subsalt Ramps

- decameter scale folding
- abundant mineralized fractures
- fluid migration (accumulation?)

Subsalt Flats

- strata-bound, decimeter scale folding
- soft-sediment deformation of slumped carapace?
- few mineralized fractures

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Prompts for Discussion

Numerical models have predicted a phenomenon some call “stem push” near where allochthonous salt emerges from a feeder or where salt diapirs are near the surface of the seafloor.

What are some of your thoughts about this concept?

Have you seen evidence of it? How would you test for its existence?

What is the rheology/strength of sediments/rocks when allochthonous salt is advancing over them?

Do subsalt deformation patterns correlate to the distribution of ramps and flats beneath an advancing allochthonous salt sheet? Should we expect more or less intense deformation at ramps?



References

Li, Z. and Fischer, M. P. (2018) Stress and deformation during the emplacement of allochthonous salt: results of numerical models. [Thesis] Northern Illinois University

Nikolinakou, M.A., Heidari, M., Hudec, M.R., Flemings, P.B., 2018a, Geomechanical modeling of stress and deformation associated with salt-sheet advance. In: Proceedings of the 52nd US Rock Mechanics/Geomechanics Symposium. American Rock Mechanics Association Paper ARMA 18-637.

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