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Thermal history of the Carrara Sub-basin: Insights from modelling of the NDI Carrara 1 drill hole

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Insights from modelling of the NDI Carrara 1 drill hole

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Overview

The Carrara Sub-basin is a recently discovered depocentre in the South Nicholson region of the Northern Territory and northwestern Queensland which was revealed following the interpretation of new reflection seismic data (Carr et al., 2019) acquired as part of the Exploring for the Future (EFTF) program (Fig. 1).

This study uses 1D burial and thermal history modelling for the NDI Carrara 1 drill hole, combined with standard kerogen kinetics to estimate the time-temperature maxima that the Carrara Sub-basin has experienced, and understand the timing and nature of hydrocarbon generation.

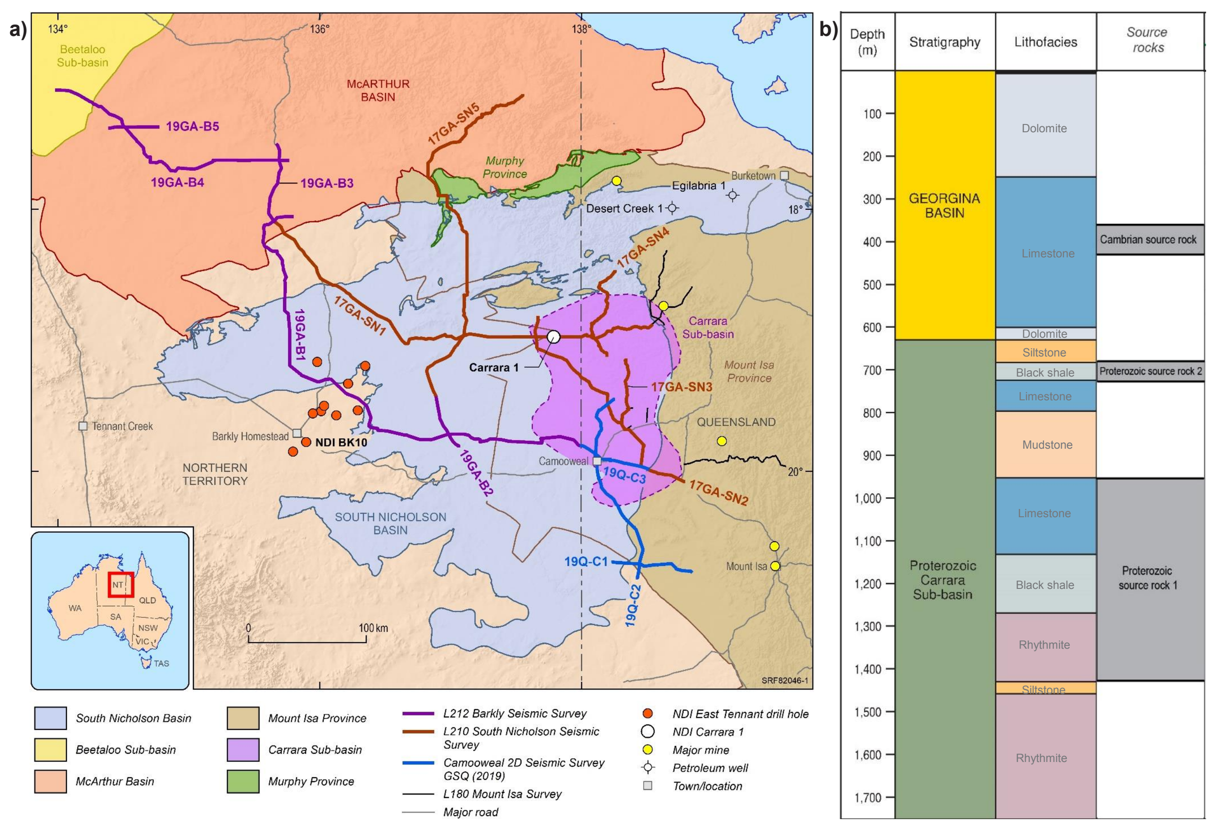

Figure 1: a) Location map of Carrara Sub-basin and NDI Carrara 1, location of new seismic lines and location of northern Lawn Hill Platform modelled wells Desert Creek 1 and Egilabria 1 used as analogues for model inputs for this study (modified from Grosjean et al., 2022); b) stratigraphic chart showing basic lithofacies and modelled source rocks.

Model setup

A 1D burial and thermal history model was constructed for the NDI Carrara 1 drill hole using interpreted data from the drilling campaign (Geoscience Australia, 2021):

- Age information was assigned based on recently acquired SHRIMP zircon U-Pb geochronology.
- Formation picks and lithology information were assigned based on chemostratigraphy and well log analysis.
- Uplift and erosion amounts were estimated through analysis of newly acquired seismic data.
- The model was calibrated using equivalent vitrinite reflectance calculated from bitumen reflectance data.

Source rocks

Rock-Eval pyrolysis and organic maceral analysis on samples are reported in Ranasinghe and Crosdale (2022). These data indicate three potential source rocks and have been modelled using the properties shown in Table 1 as separate units to determine their timing of generation and to assess their generative potential.

Table 1: Source rock attributes used for modelling purposes for NDI Carrara 1.

Source rock	Depth range (m)	TOC (%)	HI (mg HC/g TOC)	Kerogen type
Cambrian	360 – 425 m	3%	400	II (B)
Proterozoic 2	680 – 725 m	2%	600	II (B)
Proterozoic 1	950 – 1415 m	2%	600	II (B)

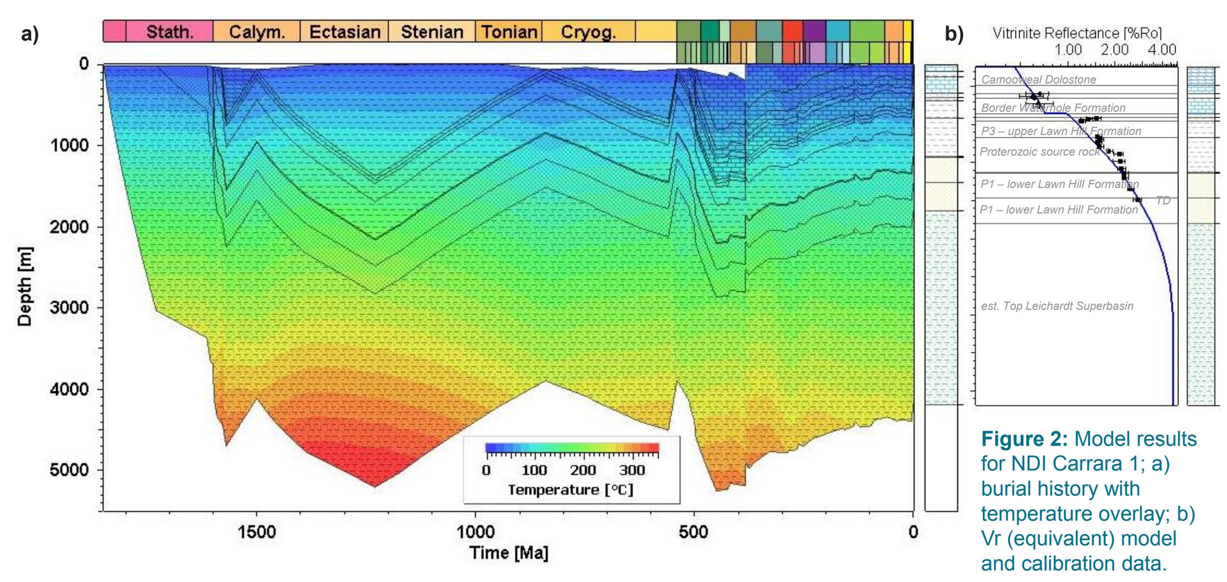

Figure 2: Model results for NDI Carrara 1; a) burial history with temperature overlay; b) Vr (equivalent) model and calibration data.

Results

The modelled time-temperature history with burial is shown in Fig 2, including the Vr (equivalent) calibration with depth. The transformation ratio of each source rock in relation to its burial through time is shown in Fig 3. The timing of generation of hydrocarbons is shown in Fig 4.

Proterozoic source rock 1

Generation of hydrocarbons began ca. 1588 Ma, with a pause in generation from ca. 1570 to ca. 1460 Ma, reaching full generation by about 1220 Ma. Transformation ratios show full transformation of organic matter (Fig 3). This source rock is in the dry gas to late dry gas phase. Any remaining hydrocarbons would be gas if preservation conditions are favourable, (e.g. shale gas) due to the maturity and age of the kerogens and secondary cracking of oil to gas.

Proterozoic source rock 2

Generation of hydrocarbons began ca. 1400 Ma, reaching a maximum at ca. 1200 Ma and reaching a transformation ratio of about 80%. This source rock is in the rich-wet gas to wet gas phase and still has generation potential.

Cambrian source rock

This source rock is in its very early stage of generating oil, which is modelled to have begun at about 450 Ma, and has not yet expelled significant hydrocarbons at present day. The amounts of hydrocarbons generated (Fig.4) are dependent on the makeup of kerogen used for modelling (type II). It is unlikely to have expelled significant amounts of hydrocarbons at present day.

Due to the marginal location of the NDI Carrara 1 drill hole, the Proterozoic 2 and Cambrian source rocks may have experienced more generative potential in the main basin depocentres where the source units have been more deeply buried, potentially enhancing prospectivity across the sub-basin.

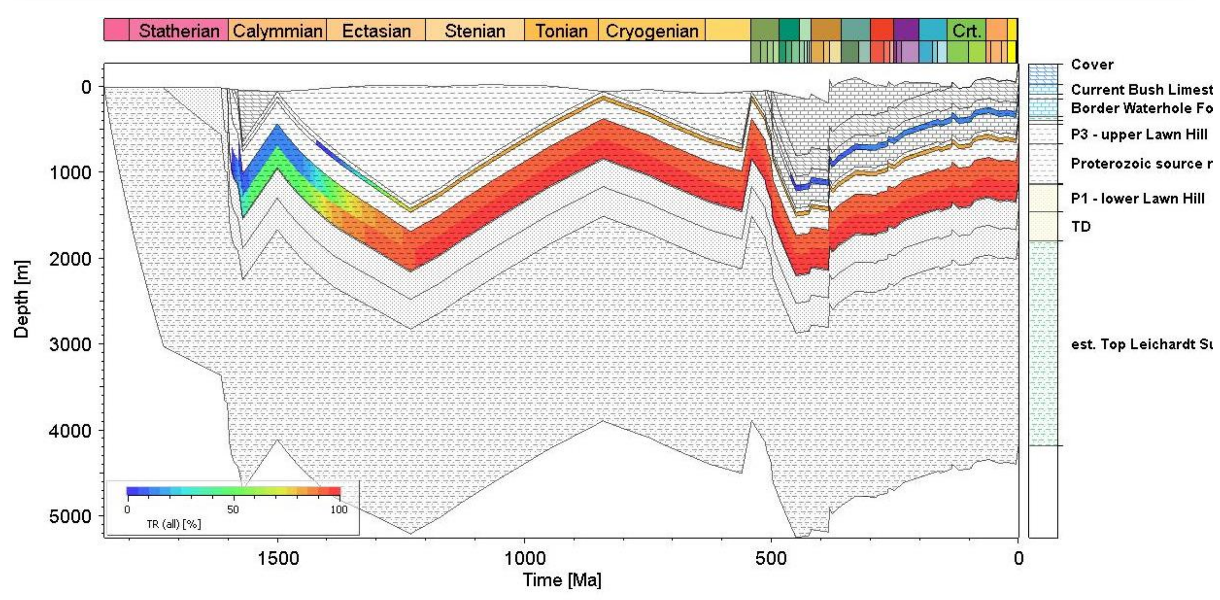

Figure 3: Transformation ratio history with burial depth through time for the three modelled source rocks.

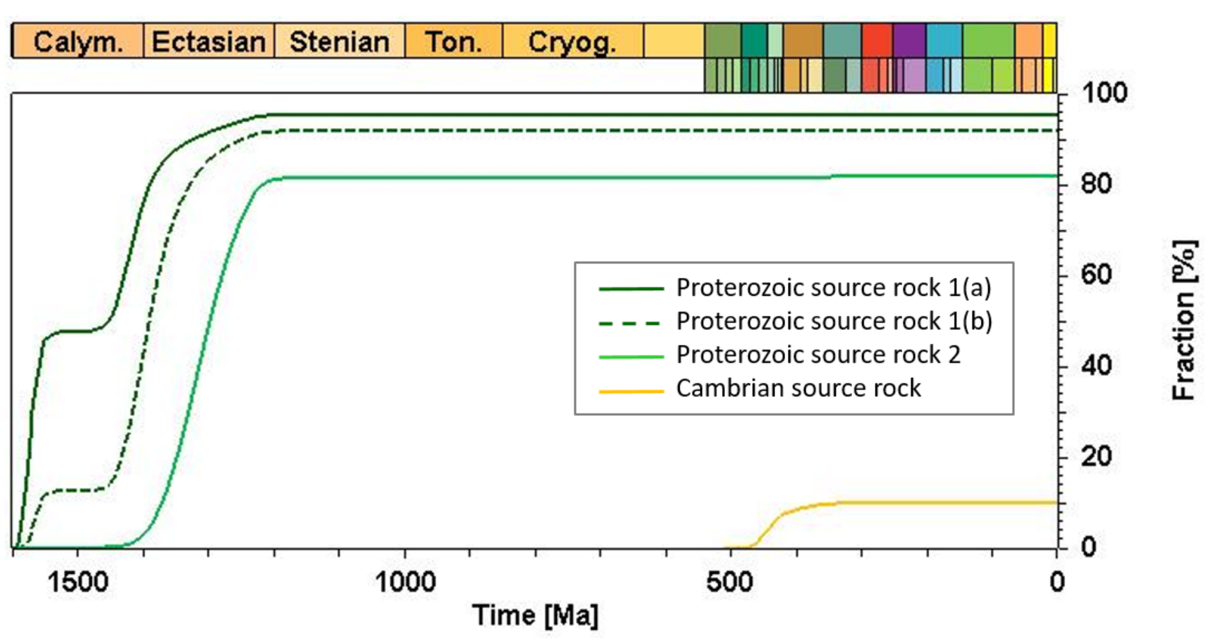

Figure 4: Estimated timing and amount of generation through time for all source rocks. Note that the Proterozoic source rock 1 has been split into two due to its thickness and to show the variability in generation results.

Future work

Future work will focus on developing a 2D model of the sub-basin along the eastern portion of seismic line 17GA-SN1, using pseudo wells to understand where potential source areas could be. This will contribute to an understanding of possible migration pathways for expelled hydrocarbons across this area of the sub-basin.

Acknowledgements and references

Thank you to Chris Carson and Lidena Carr for project support. Note: Well stratigraphy has been inferred from Wang et al. (this volume).
The data that support this study are available in the accompanying online supplementary material accessible via https://www.eftf.ga.gov.au/south-nicholson-national-drilling-initiative

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