

Resource potential of the Carrara Sub-basin from the deep stratigraphic well NDI Carrara 1

Adam H.E. Bailey^A, E. Grosjean^A, L. Wang^A, C. Boreham^A, G. Butcher^A, C. Carson^A, A.J.M. Jarrett^B, L. Carr^A, C. Southby^A, T. Palu^A, P.A Henson^A

^AGeoscience Australia, Canberra, ACT, Australia.

^BNorthern Territory Geological Survey, Darwin, NT, Australia.

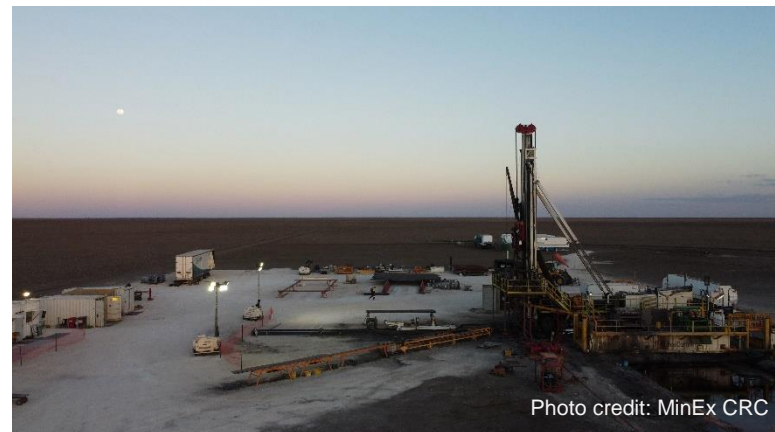
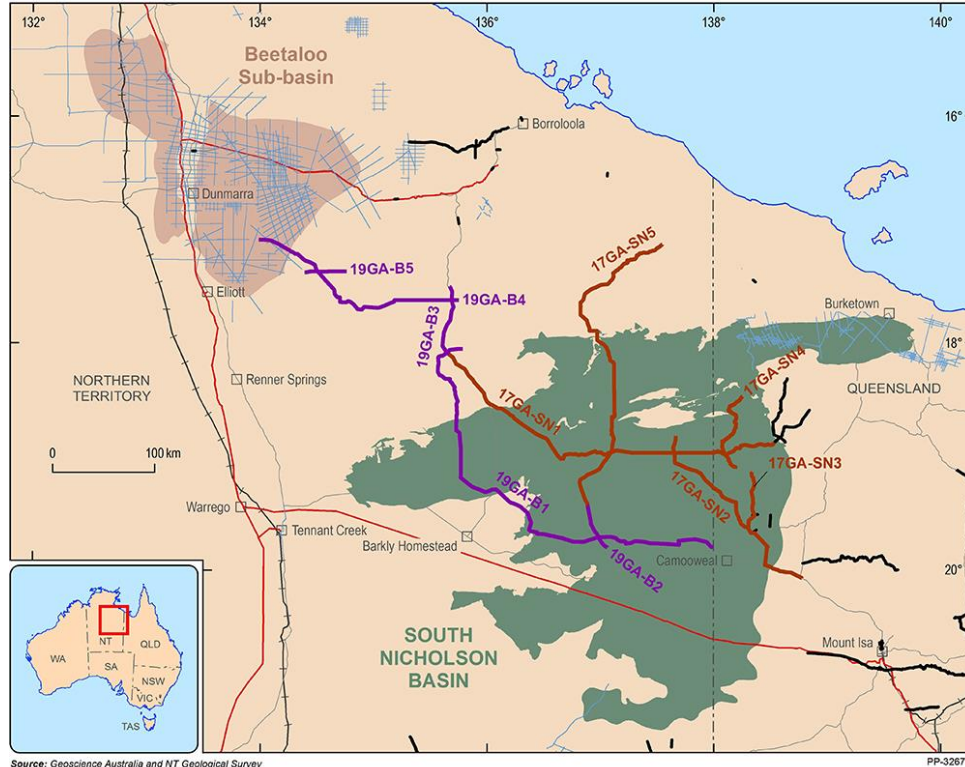


Photo credit: MinEx CRC

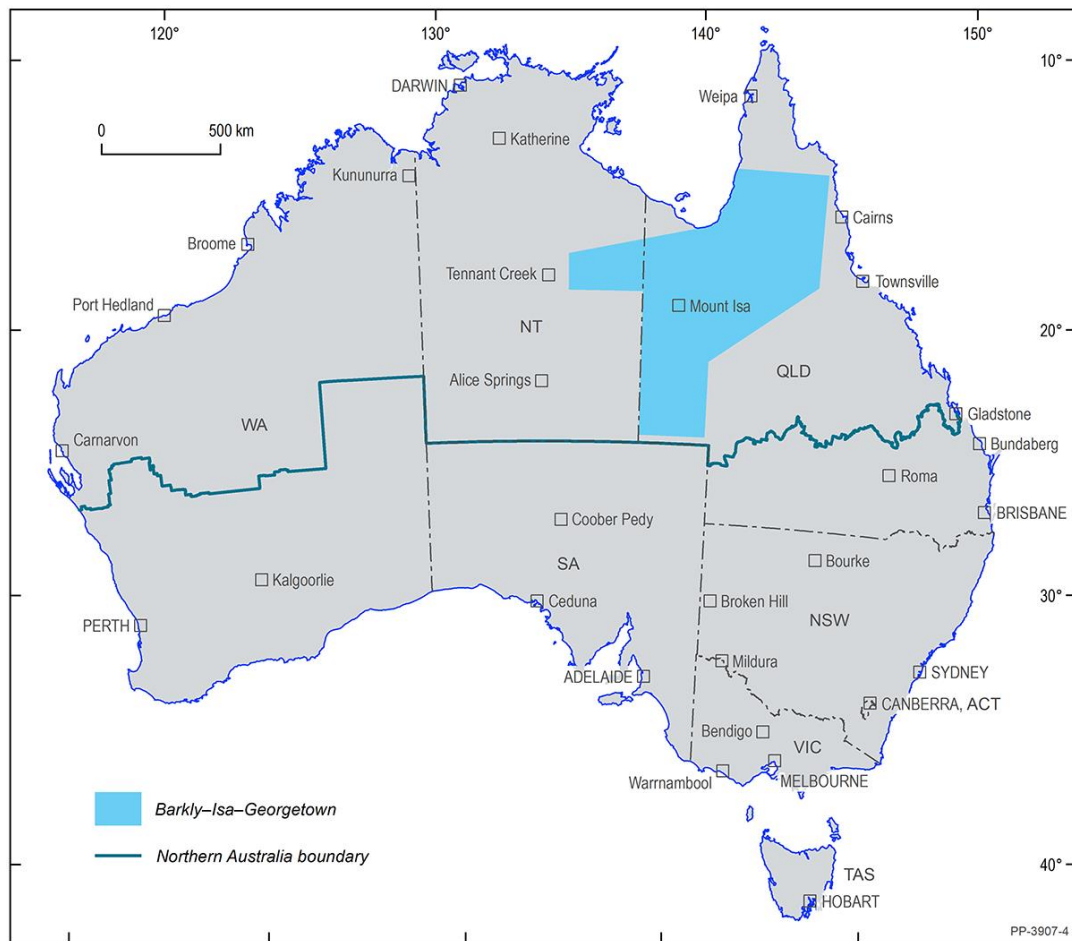
EFTF: 2016-2020



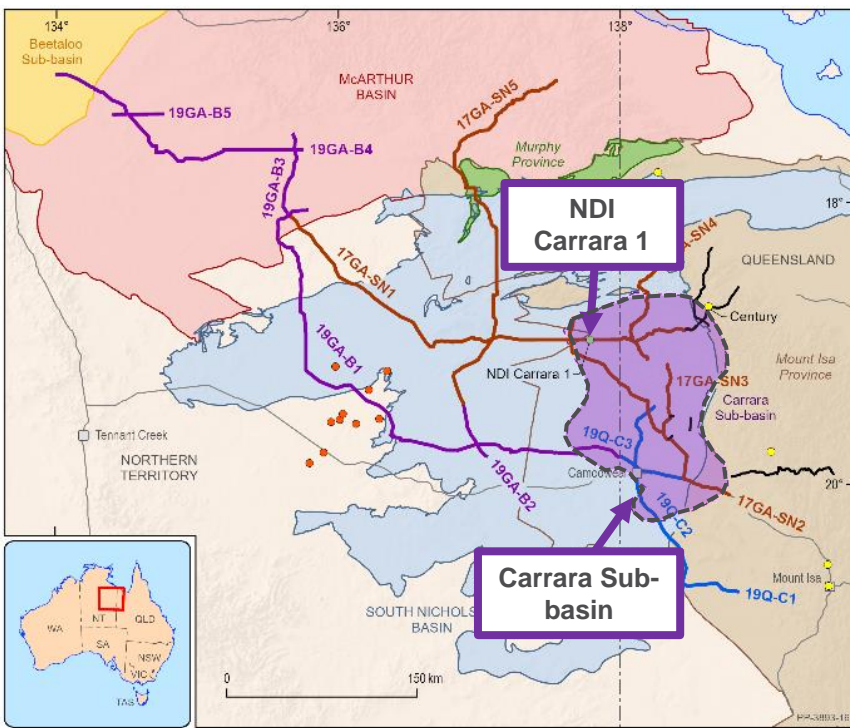
- A comprehensive data acquisition program was conducted under EFTF across the South Nicholson Basin region, NW QLD and NT.
- 2017: Acquired L210 deep crustal seismic survey.
- 2019: Acquired L212 deep crustal seismic survey.
- 2020: Drilled NDI Carrara 1.
- Extensive analysis of legacy and field samples.

EFTF: 2020-2024

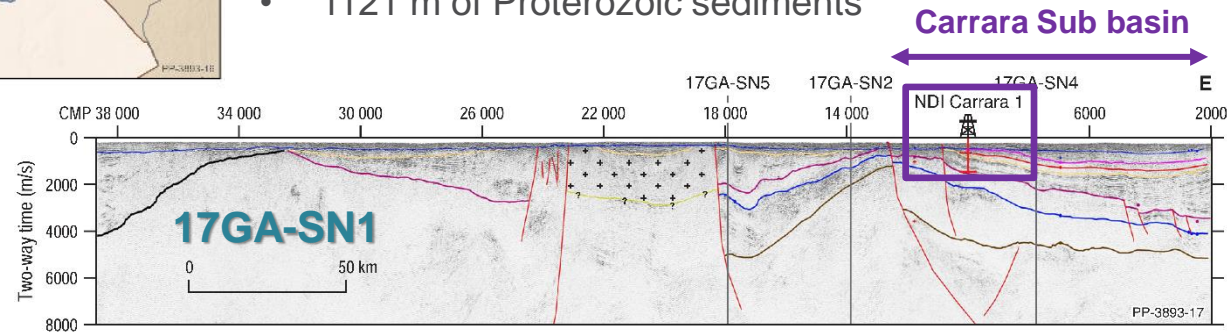
- “South Nicholson National Drilling Initiative”
- Part of the Barkly-Isa-Georgetown Project.
- Builds on work completed in the first four years of EFTF.
- Undertaking analysis of South Nicholson region samples .
- In collaboration with the MinEx CRC and NTGS.



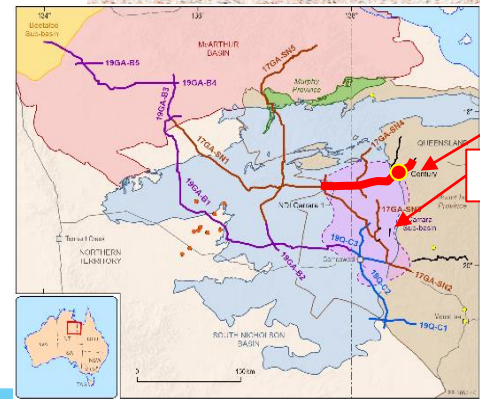
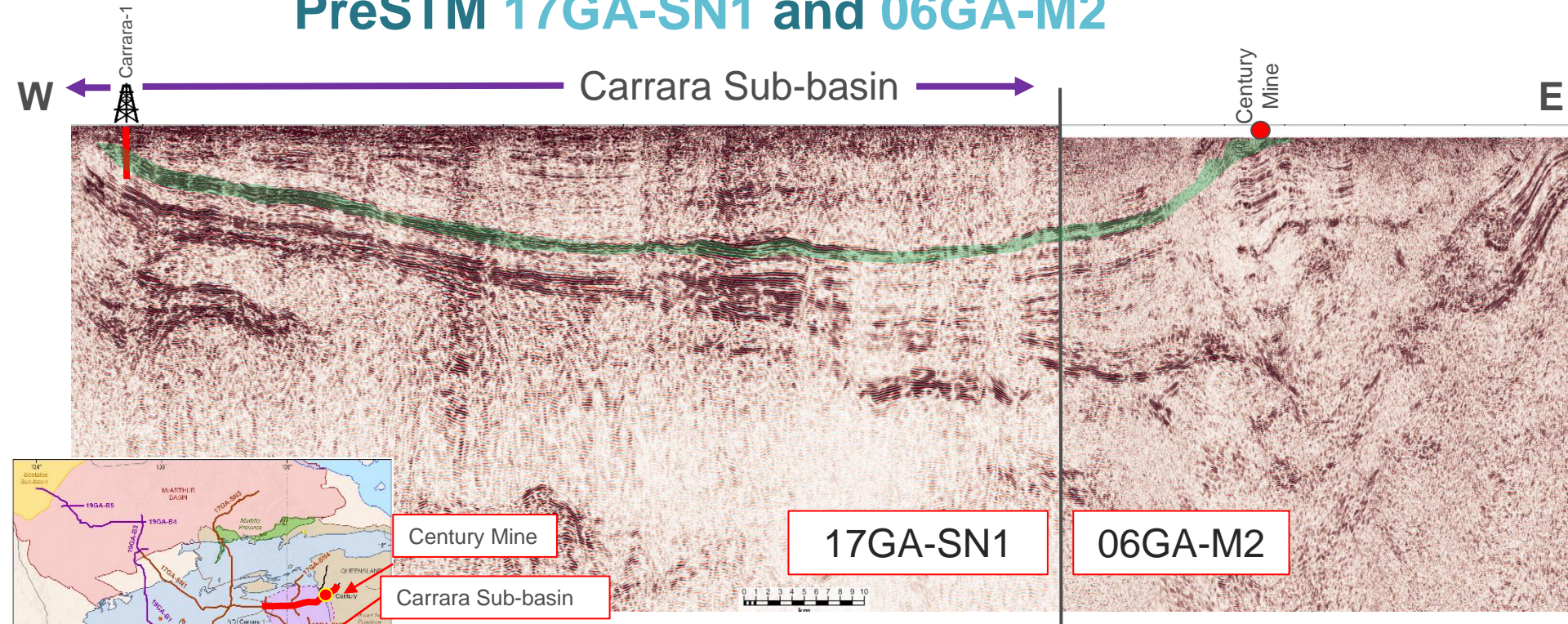
The Carrara Sub-basin and NDI Carrara 1



- Carrara Sub-basin discovered during EFTF 1 South Nicholson Seismic Survey in 2017
- NDI Carrara 1 located on western flank of Carrara Sub-basin
- Drilling of NDI Carrara 1 completed in Dec 2020
- EOH 1751 m
- 630 m of Cambrian Georgina Basin
- 1121 m of Proterozoic sediments



PreSTM 17GA-SN1 and 06GA-M2



- 17GA-SN1 links with legacy line 06GA-M2
- Important for geological control, well-studied outcrop
- Extrapolation into the concealed Carrara Sub-basin

See also:
Frogtech SEEBASE 2017
Gibson et al., 2017, 2016
Carr et al., 2019

NDI Carrara 1 drill hole

Macrofossils study (Laurie, 2022)
Middle Cambrian

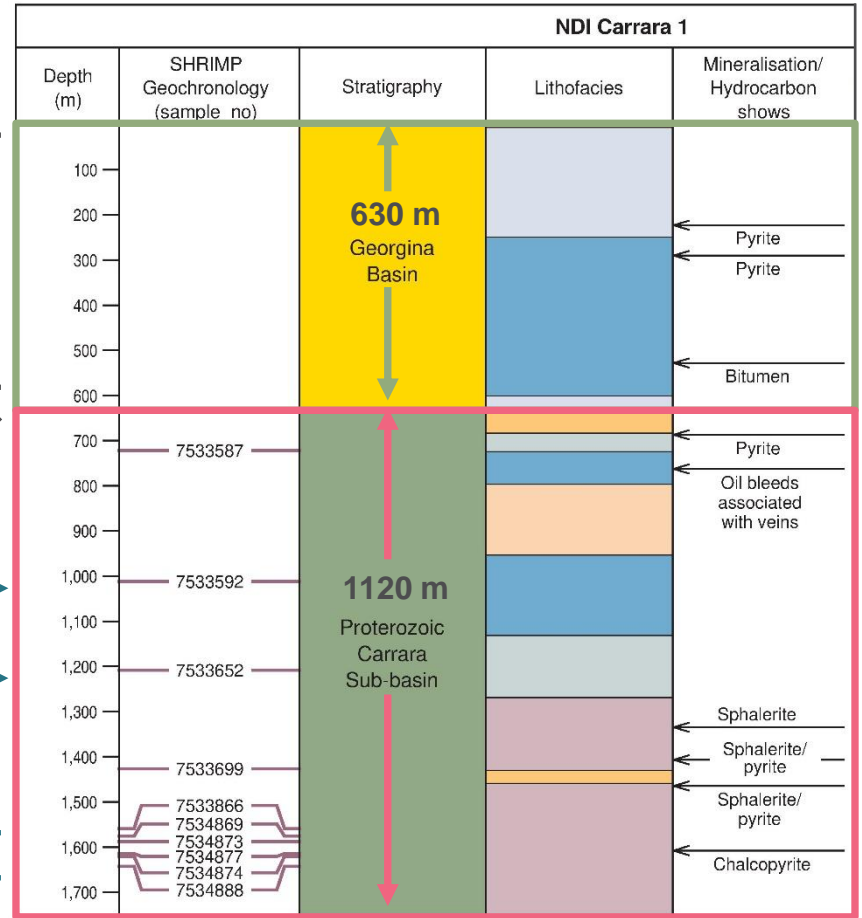
basal unconformity
@ 630 m

Equivalent to the
Paleo- to
Mesoproterozoic
middle to upper
Lawn Hill Fm.

~ 1588 Ma @ 1012 m

~ 1601 Ma @ 1204 m

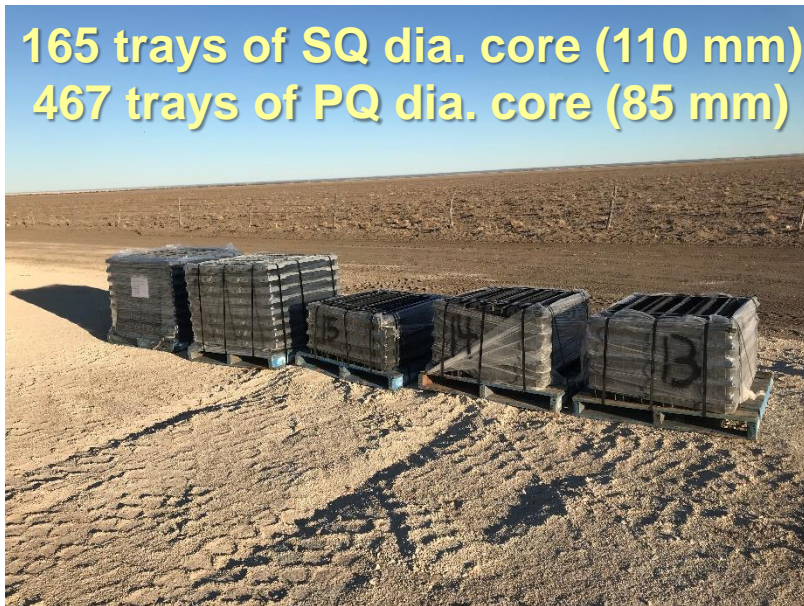
1611 Ma
@ 1580–1650 m



Sampling program

Continuous coring from 284 m to TD (1750.85 m)

165 trays of SQ dia. core (110 mm)
467 trays of PQ dia. core (85 mm)



Credit MinEx CRC

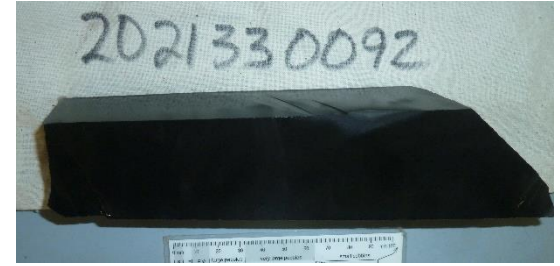
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 NDICARRARA1_6 39.44-641.97_Wj pg	 NDICARRARA1_6 41.97-644.33_Wj pg	 NDICARRARA1_6 44.33-646.63_Wj pg	 NDICARRARA1_6 46.63-649.15_Wj pg	 NDICARRARA1_6 49.15-651.47_Dj pg	 NDICARRARA1_6 49.15-651.47_Wj pg	 NDICARRARA1_6 51.47-653.85_Dj pg	 NDICARRARA1_6 51.47-653.85_Wj pg	 NDICARRARA1_6 53.85-656.27_Dj pg	 NDICARRARA1_6 53.85-656.27_Wj pg
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Borehole Completion Report: <https://portal.ga.gov.au/bhcr/minerals/648482>

One sample every 4m on average for 'routine' analyses: ~500 samples

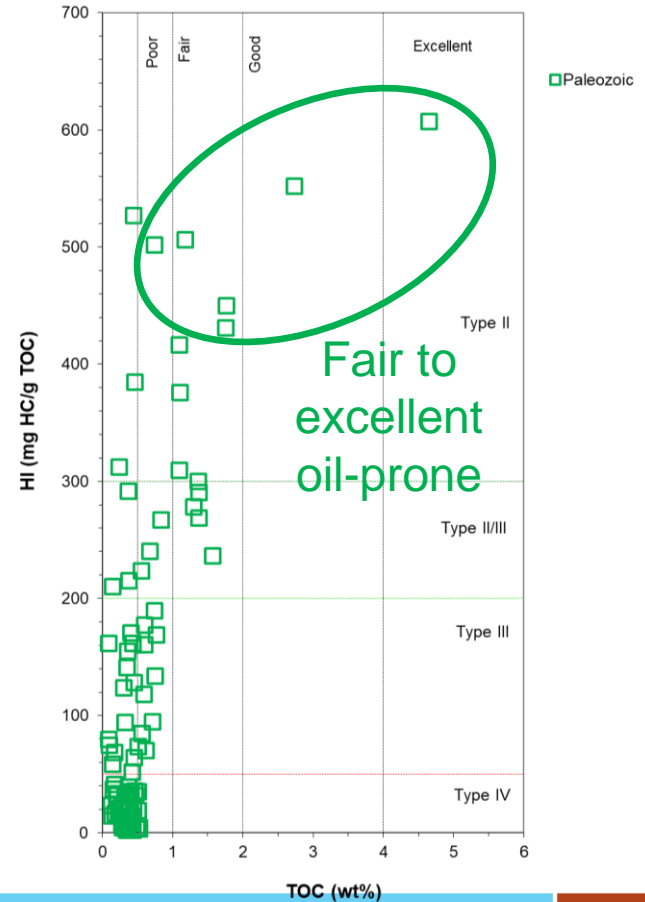
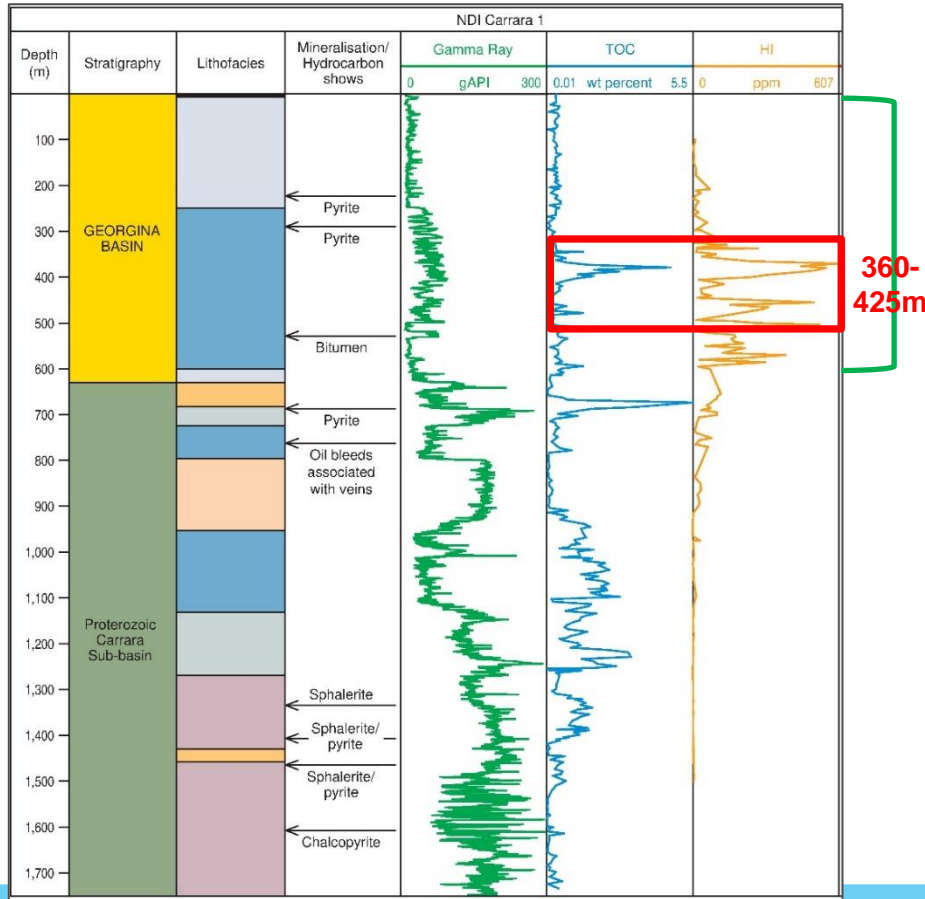
Analyses

- Organic geochemistry: TOC, Rock-Eval, biomarkers
- Organic petrology
- Inorganic geochemistry: qXRD, elemental analyses
- Geochronology
- Fluid inclusion stratigraphy
- Isotopic analyses
- Petrology
- Petrophysics
- Geomechanics
- Sequence stratigraphy

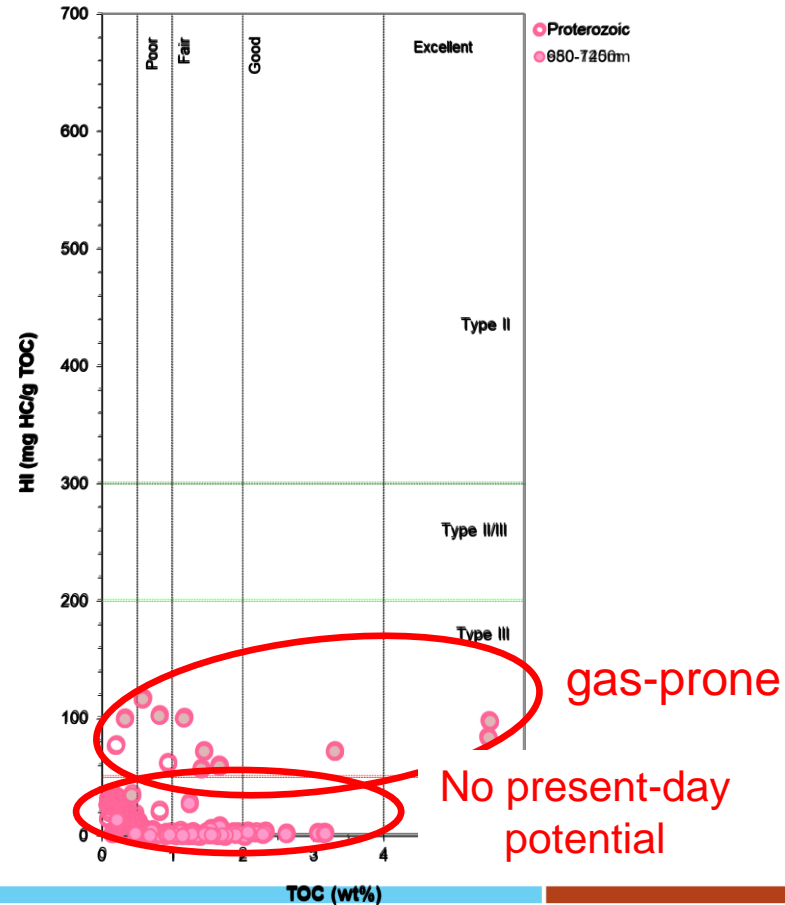
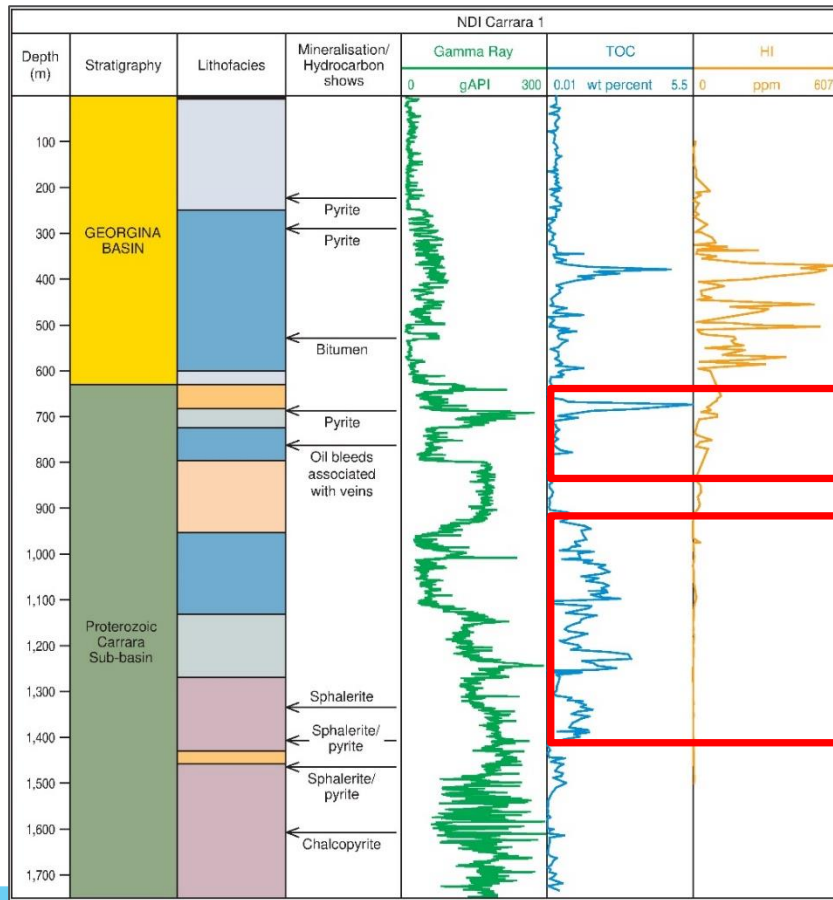


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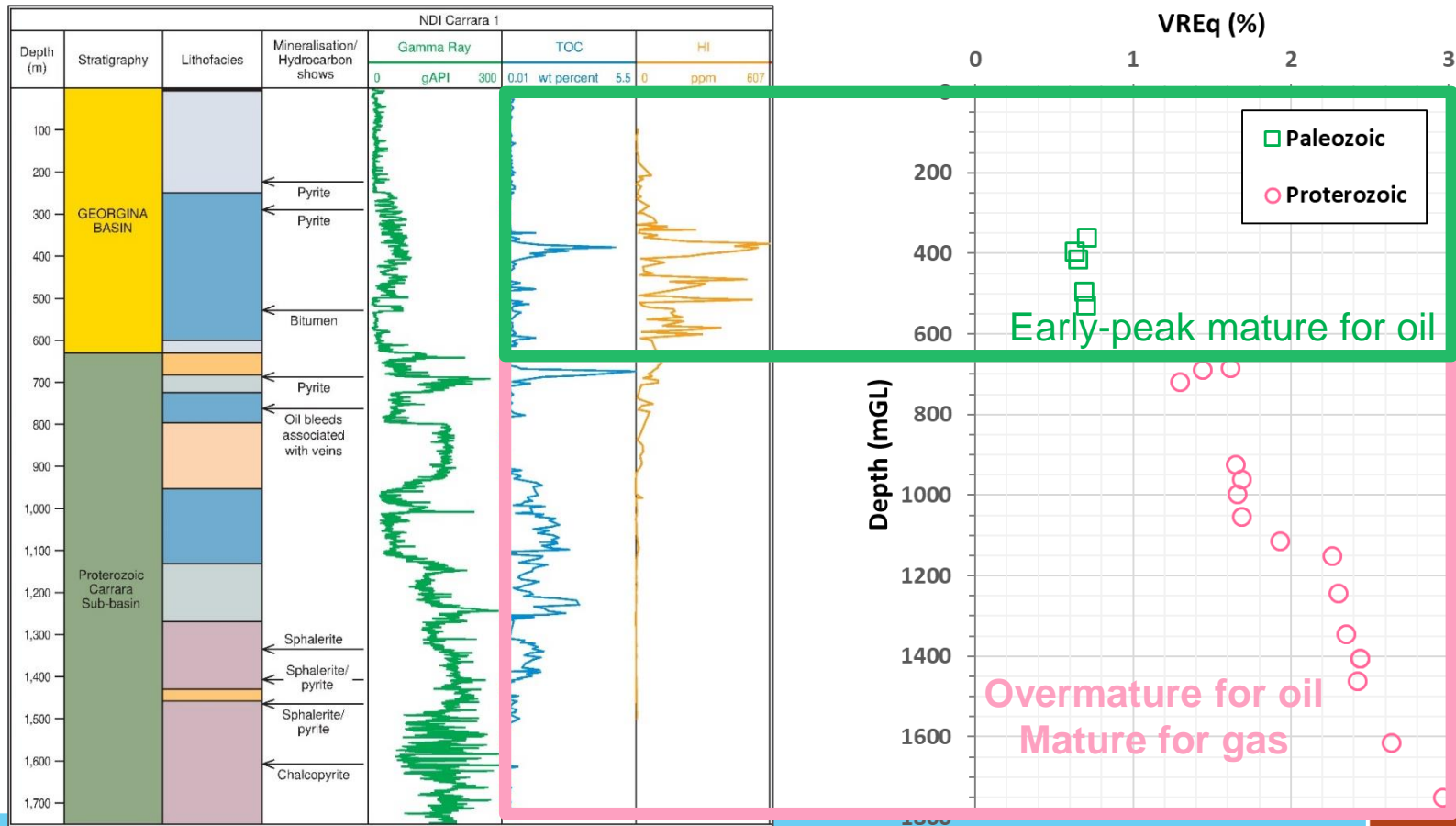
Source rock potential: Georgina Basin rocks



Organic Geochemistry: Source rock potential



Organic Geochemistry: Thermal maturity



Hydrocarbon shows



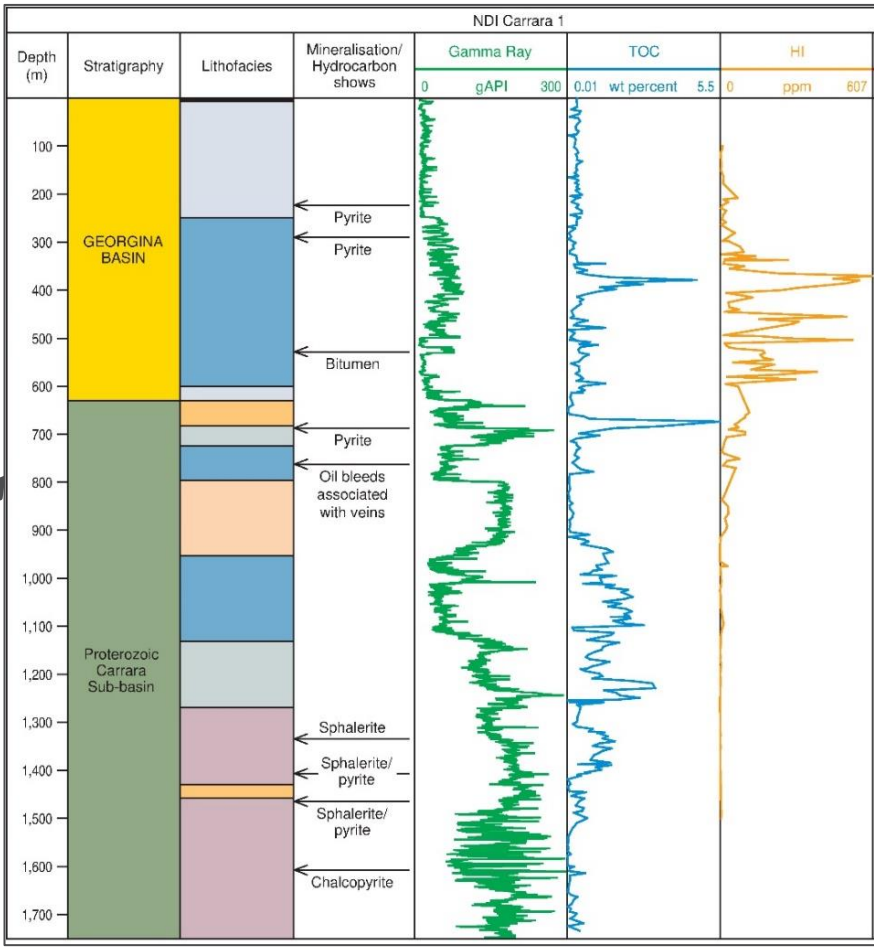
@528 m



@763 m

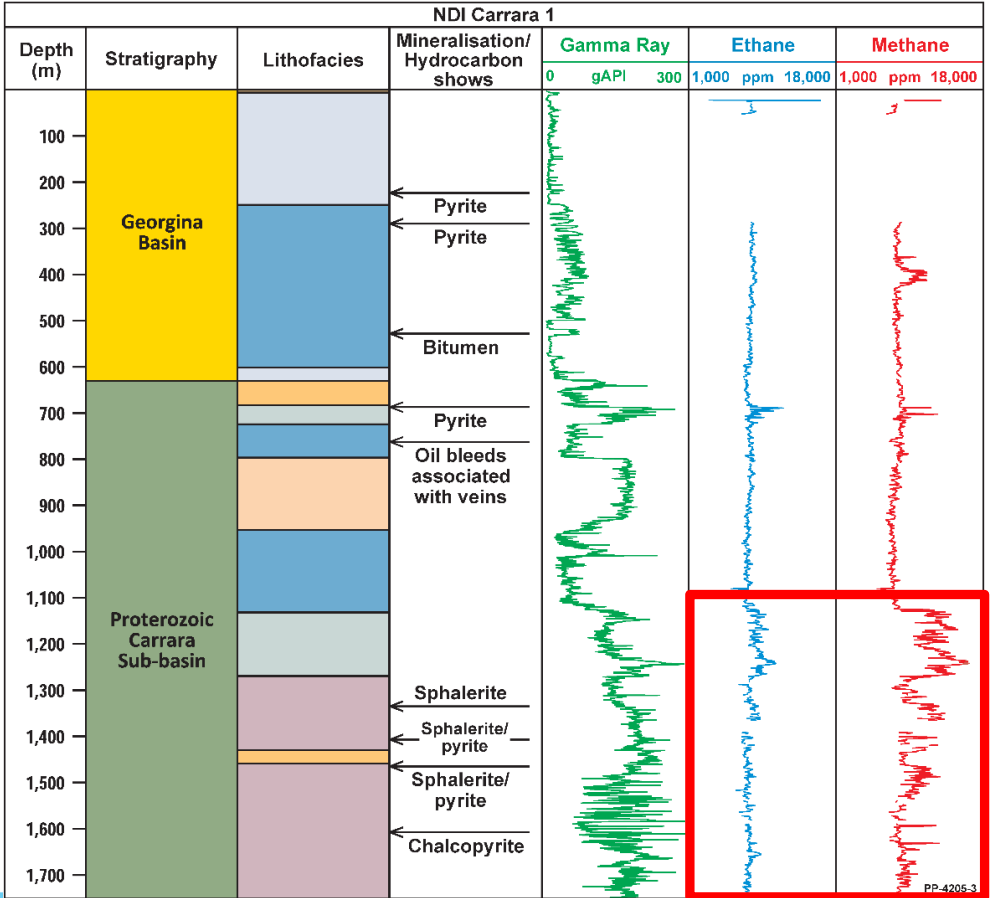


@765 m



Credit MinEx CRC

Hydrocarbon shows



Gas sample



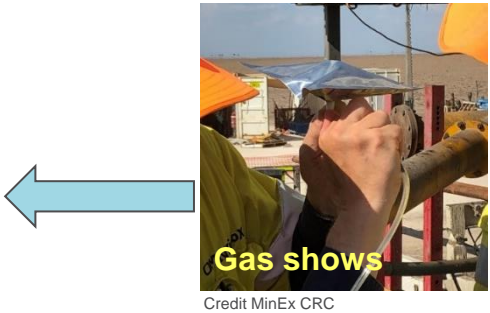
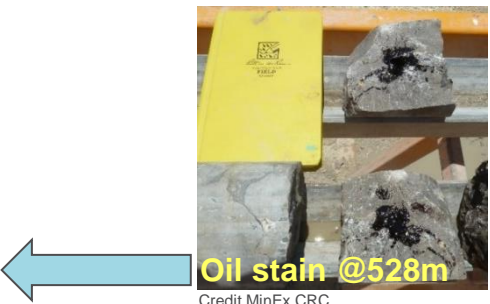
Credit MinEx CRC

Gas sourced from local, thermally mature organic-rich rocks

Boreham et al 2022. Exploring for the Future - NDI Carrara 1 gas geochemistry. GA Record.

Hydrocarbon shows: Petroleum systems summary

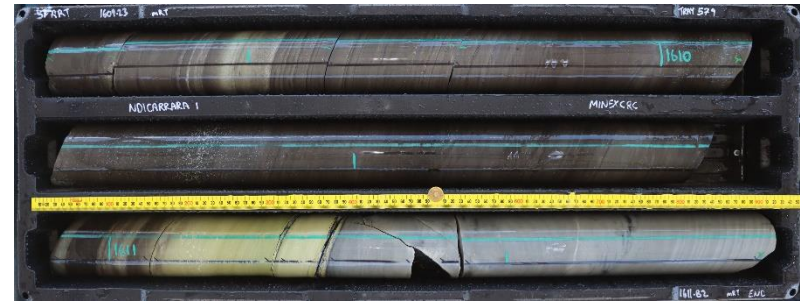
Era/period	Petroleum (Super)system
Cambrian	Larapintine 1
Neoproterozoic	Centralian
Mesoproterozoic	Beetaloo/Urapungan
Paleo- to Mesoproterozoic	Lawn
Paleoproterozoic	McArthur
Paleoproterozoic	Redbank



Bradshaw et al 1994; Jarrett et al 2021

Rock mineralogy

- XRD analyses were undertaken on the routine samples.
- 420 samples analysed via Quantitative XRD (qXRD).
- Provided bulk mineralogy of samples:
 - Identification of 18 mineral groups.
 - One extra group for unknown minerals.
- XRD can be used to calculate rock strength proxies, i.e. Brittleness Index



Rock mineralogy: Brittleness Index



Egilabria 2 DW1 flare. Photo credit, Armour Energy

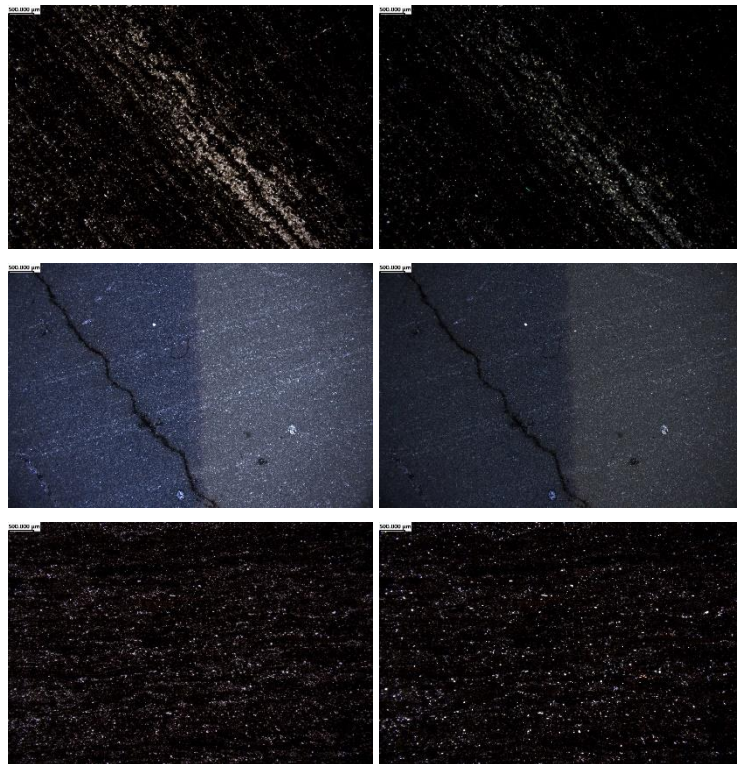
Why bother calculating BI?

- Shale reservoirs can generate and trap vast quantities of hydrocarbons.
- Extremely limited permeability = very limited gas flow... unless the reservoir can be stimulated to generate connected permeability.
- Shale reservoirs mechanical properties (e.g. strength, plasticity, brittleness and elasticity) are often a function of mineralogy.
- A proxy for rock strength, the Brittleness Index (BI) can be calculated from XRD mineralogy.

Rock mineralogy: Brittleness Index

Why bother calculating BI?

- BI *can* provide an insight into stimulation effectiveness.
- However, not always a successful indicator for rock strength.
- An understanding of depositional and diagenetic processes is essential to fully comprehending the relationship between mineralogy and brittleness.
- **In basins with limited data availability BI is a useful and cost effective tool for identifying zones of interest over a large area**



Thin section photomicrographs of high TOC (>2%) shales within NDI Carrara 1 (695 m, 1114 m, and 1245 m (Madden et al., 2022))

Rock mineralogy: Brittleness Index

- Numerous methods for calculating BI exist.
- The most commonly used is the Jarvie *et al.* (2007):

$$BI = \frac{\text{Quartz}}{\text{Quartz} + \text{Carbonate} + \text{Clay}}$$

- Ductile: < 0.16,
Less ductile = 0.16 - 0.32,
Less brittle = 0.32 - 0.48
Brittle: > 0.48

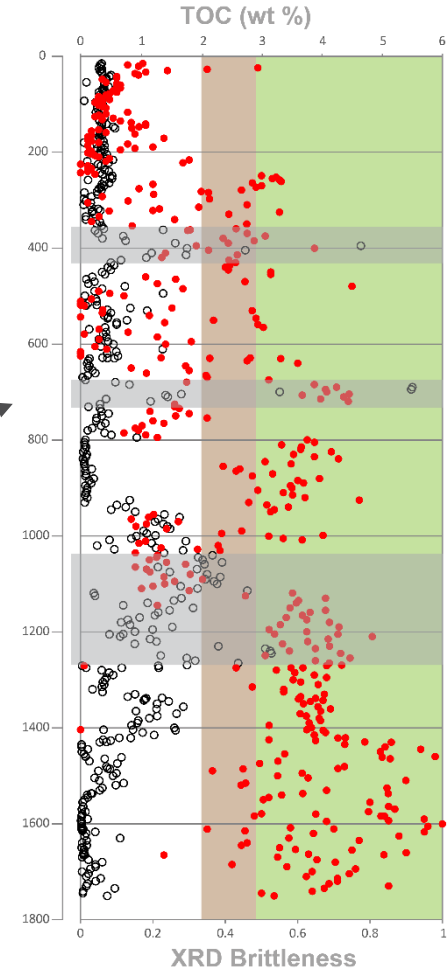


Geomechanics plug from NDI Carrara 1

Rock mineralogy: Brittleness Index

<i>Source Interval (m)</i>	<i>Mean BI</i>	<i>BI range</i>	<i>BI standard deviation</i>	<i>Brittleness</i>
361 - 425	0.39	0.22 – 0.65	0.11	Less Brittle
680 - 725	0.65	0.26 – 0.74	0.13	Brittle
1040 - 1265	0.48	0.15 – 0.81	0.20	Brittle

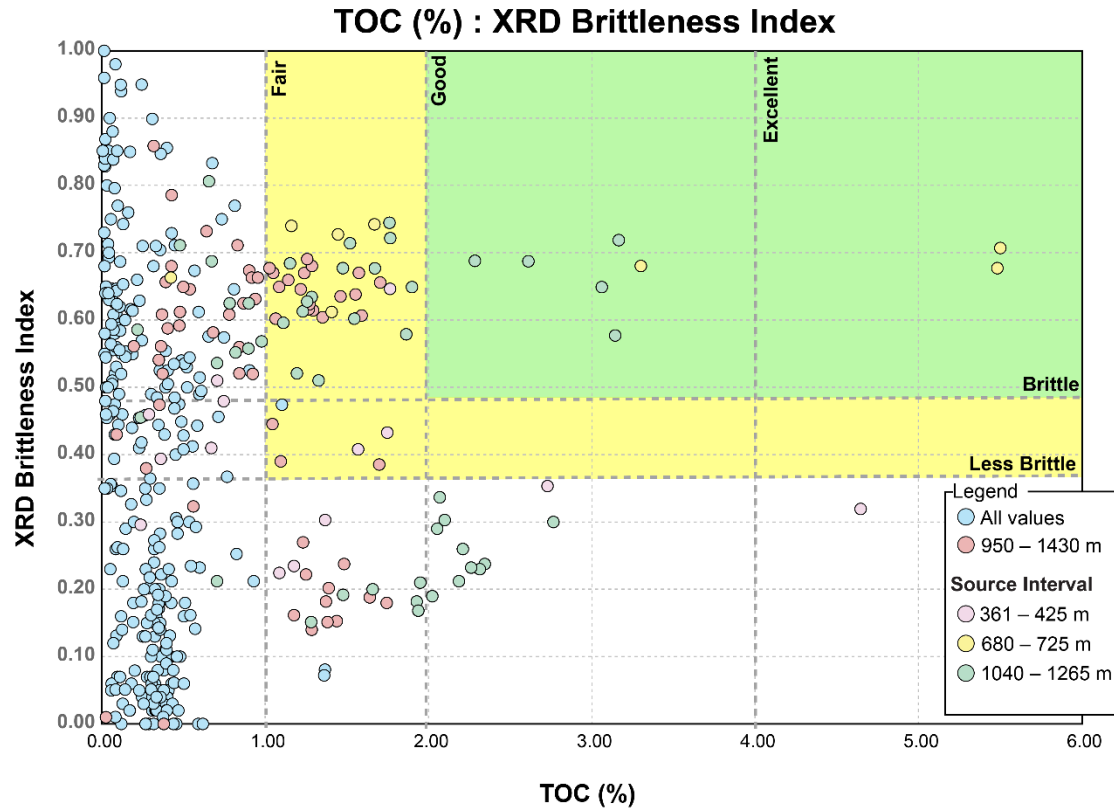
● TOC
● BI



Carrara Sub-basin organic-rich shales have BI that indicate the presence of brittle rocks, likely favourable for stimulation

Carrara Sub-basin: A shale play?

- Crossplot of TOC and BI.
- Highlights area of high TOC, brittle rocks.
- These are in the previously identified source intervals.



Still to come:

- Triaxial and UCS tests to confirm rock elastic and strength properties.
- Detailed petrophysical data (poroperm, MICP, adsorption/desorption etc).

These data can help us further constrain the prospectivity of the Carrara Sub-basin black shales.

<http://www.ga.gov.au/efff/projects/barkly-isa-georgetown/south-nicholson-national-drilling-initiative>

South Nicholson National Drilling Initiative

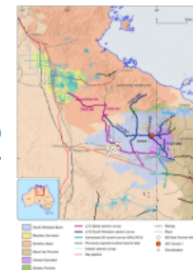
NDI Carrara 1

The South Nicholson National Drilling Initiative (NDI) Carrara 1 stratigraphic drill hole was completed in late 2020, as a collaboration between Geoscience Australia, the Northern Territory Geological Survey (NTGS) and the MinEx CRC. NDI Carrara 1 is the first drill hole to intersect the as yet undifferentiated Proterozoic rocks of the newly discovered Carrara Sub-basin. NDI Carrara 1 is located on the western flanks of the Carrara Sub-basin on the South Nicholson seismic line (17GA-SN1), reaching a total depth of 1751 m, intersecting ca. 630 m of Cambrian Georgina Basin overlying ca. 1100 m of Proterozoic carbonates, black shales and minor siliciclastics.

The NDI Carrara 1 provides unique insights into the energy and mineral resource potential of this frontier region.

Outputs

- As part of the Exploring for the Future program, Geoscience Australia is undertaking a range of investigations into the lithology, stratigraphy and geotechnical properties of NDI Carrara 1 based on wireline data, as well as undertaking a range of analyses on over 400 physical samples distributed through the entire core. These analyses include geochronology, isotope studies, mineralogy, inorganic and organic geochemistry, petrophysics, geomechanics, thermal maturity, and petroleum systems investigations. Routine samples (and planned targeted samples) collected by Geoscience Australia, including planned analyses are available at the [downloadable spreadsheet \[XLSX 96.5 KB\]](#).
- Hylogger data is available at the Northern Territory Geological Survey's [Geoscience Exploration and Mining Information System \(GEMIS\) webpage](#).
- [Sample and core photos](#)



Location of the NDI Carrara 1 stratigraphic drill hole and South Nicholson (L210) and Barkly (L212) seismic survey lines across the South Nicholson region.

Summary

- NDI Carrara 1 is the first intersection of the Carrara Sub-basin.
- Distinct links with the known Proterozoic shale plays of the northern Lawn Hill Platform.
- Organic geochemistry highlights the presence of two organic-rich intervals within the Proterozoic section and one within the overlying Cambrian interval.
- Brittleness indices demonstrate that these two shale intervals are likely to be brittle and, hence, hydraulic stimulation is likely to enhance permeability.
- These data imply that these black shales may form potential shale gas plays within the Carrara Sub-basin.
- **A continuation of the Proterozoic shale play fairway across the Northern Territory and northwest Queensland?**

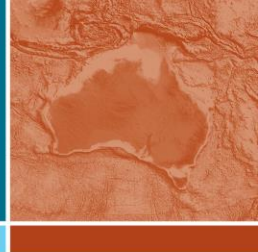


Credit MinEx CRC



Australian Government

Geoscience Australia



Thank you – Questions?

Please keep in mind that the Commonwealth Government is currently in caretaker mode and keep questions *scientific* in nature, as no policy related questions can be addressed at this time.

Phone: +61 2 6249 9111

Web: www.ga.gov.au

Email: clientservices@ga.gov.au

Address: Cnr Jerrabomberra Avenue and Hindmarsh Drive, Symonston ACT 2609

Postal Address: GPO Box 378, Canberra ACT 2601