

## Insights from the Jessica Regional VTEM Survey and updated geochronology from 17GA-SN1: Implications for Proterozoic basins

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Encounter Resources (Encounter) controls a large portfolio of Australian exploration projects, which are prospective for copper, zinc, rare earth elements, and lithium, including the Jessica Project in the Northern Territory (NT). A subsidiary of South32 Ltd (South32), in partnership with Encounter, have been exploring the Jessica Project since 2023, including undertaking deep diamond drilling, multielement geochemistry, and more recently geochronology and a regional VTEM geophysical survey. Drilling results and new and highly valuable geochronology data both provide constraints on stratigraphy and seismic interpretations; the newly acquired VTEM data builds on existing regional and pre-competitive datasets in the area while assisting with direct and indirect exploration targeting in the NT's Barkly region.

### Jessica Regional VTEM Survey

#### Jessica Copper Project

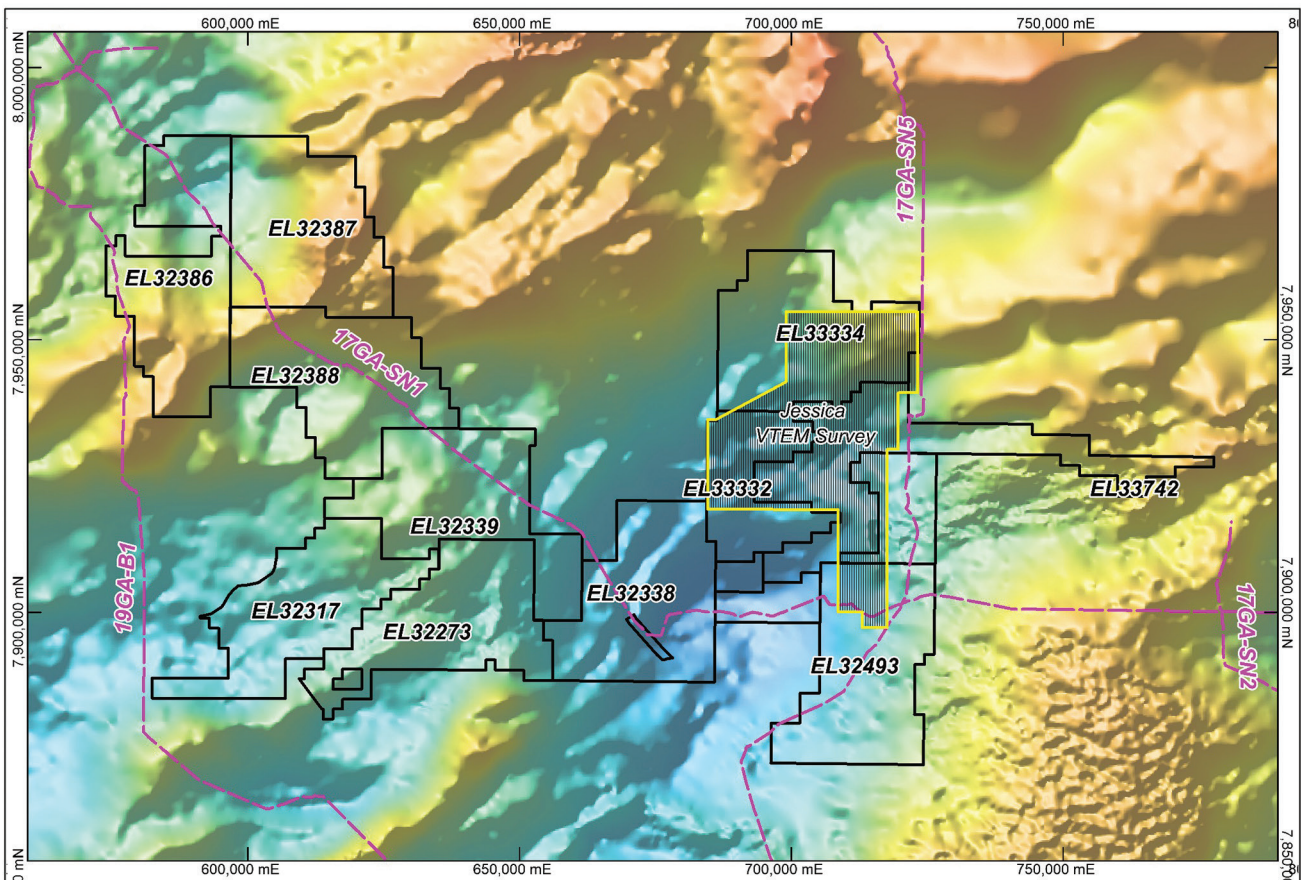
The Jessica Project extends over 9600 km<sup>2</sup> within key structural corridors east of Tennant Creek, a region

prospective for both sediment-hosted copper and iron oxide copper-gold (IOCG) deposits (**Figure 1**). The project area includes compelling structural targets along the Brunette Downs Rift Corridor (identified by Geoscience Australia; Southby *et al* 2021) and prospective magnetic/gravity geophysical anomalies (identified in regional datasets). In addition, previous assessment of drill chips from water bores in the region – completed by Encounter and previous explorers using handheld x-ray fluorescence (XRF) spectrometers – has identified areas of copper anomalism including one sample containing up to 1.5% Cu recovered from a depth of 0–3 m in water bore RN28419 (James 2024). In June 2022, Encounter and South32 entered into a farm-in agreement covering the Jessica Project (and now exited Carrara Project; Encounter 2022). Since that time 11 drillholes have been completed to test previous and new interpretations. This drillhole data has revealed new information about the Barkly region and greenfields exploration frontier.

#### Survey background

South32, in joint venture with Encounter Resources, was awarded co-funding as part of the NT Government's *Resourcing the Territory* initiative Geophysics and Drilling

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**Figure 1.** Jessica project. Location plan and extent of co-funded VTEM Survey overlain on Northern Territory regional Bouguer anomaly gravity map.

Collaborations (GDC) program (Round 18). This funding supported a regional scale airborne electromagnetic VTEM survey over the northeastern portion of the Jessica project (**Figure 1**), an area considered prospective for sediment-hosted zinc and copper mineralisation. The survey was designed to help identify and interpret geological structures and to map lithologies and conductive units up to 300 m below the surface, aiding the prioritisation of drill targets in this covered terrane. The survey successfully delineated high-resolution conductive features concealed beneath younger, often more resistive, sediments. These new data were able to be integrated with existing seismic data, regional geophysical datasets and existing drillholes to generate refined interpretations of the subsurface geology and mineral potential.

### ***Preliminary results and interpretation***

The northeast trending Mitchebo and Wild Cow Faults commonly juxtapose Cambrian flood basalts of the Helen Springs Volcanics (ca 510 Ma) against Proterozoic sediments, with late thrusting (and possibly inversion) thought to have occurred episodically until at least the Alice Springs Orogeny (Rawlings *et al* 2008). The VTEM survey provides supporting geophysical information which supplements the recently updated and released Mount Drummond Explanatory Notes (Munson *et al* 2025) and provides new constraints on lateral displacements and basement architecture through mapping of conductive and resistive features across fault zones. Recent reinterpretations of the South Nicholson Basin (Carr *et al* 2019; Carson *et al* 2022), precompetitive seismic data by Geoscience Australia (Carr *et al* 2019), and mapping by the NTGS (Munson *et al* 2025) suggest westward extensions of the Maloney Creek Inlier (Proterozoic Lawn Hill Platform) in the hanging wall of the Mitchebo Fault. The VTEM conductive/resistive patterns now enable more accurate delineation of inlier boundaries, fault offsets, potential onlap relationships and the potential thickness of cover sequences, enhancing models of basin evolution and prospectivity for sediment-hosted mineral systems (**Figure 2**).

Additionally, the survey enhances geological interpretation and exploration targeting for sediment-hosted copper mineralisation by integrating with the existing regional AusAEM survey, particularly around the Alexandria Gravity Low which shows zones of conductive and resistive symmetry. The presence of highly conductive units (mapped as Crow Formation) within the Alexandria Gravity Low (AGL), in the presence of oxidized sandstones, is favourable for traditional sediment-hosted copper exploration models. The outcomes of the survey enable delineation of near surface conductive anomalies as outlined above to help target with shales and other key reductants in sediment-hosted copper systems. Furthermore, when combined with regional magnetic and gravity datasets our new data will allow for refined interpretation of fault architecture, stratigraphy, depocentres and structural targets within the Jessica Project.

### **Updated geochronology**

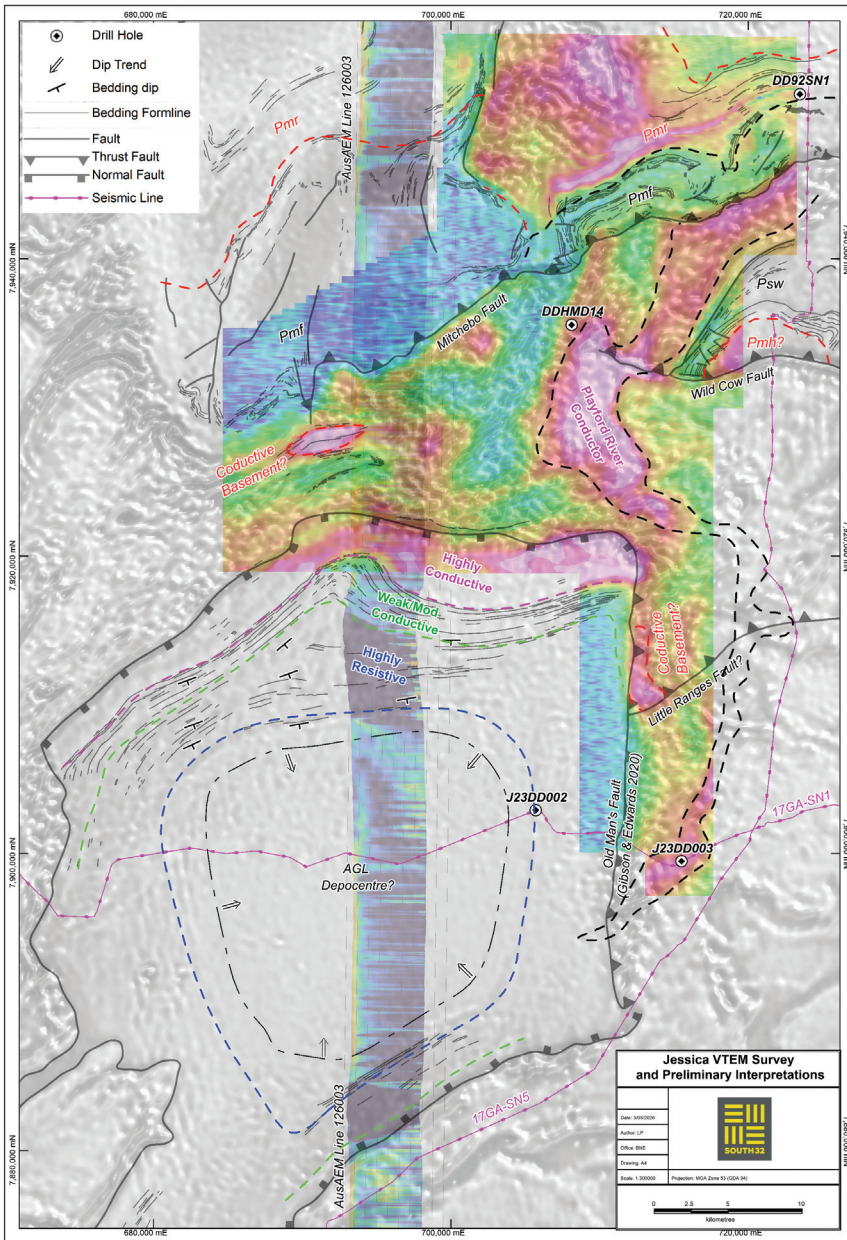
First pass exploration drilling from 2023 over seismic line 17GA-SN1 included holes targeting key interpreted stratigraphic horizons located west of the NDI Carrara 1 deep stratigraphic drillhole (which helped define the Carrara sub-basin). The 2023 drilling program represents the first wave of industry-led exploration following the *Exploring for the Future* program undertaken by Geoscience Australia in partnership with the Northern Territory Geological Survey (NTGS).

### ***Zeta Prospect***

The Zeta Prospect is a coincident gravity and magnetic anomaly associated with a discrete seismic reflector. Encouragingly, the Zeta drilling encountered several key IOCG indicators (Encounter 2023; Pickering 2024): (1) chalcopyrite/bornite in thin quartz-chlorite-carbonate veins; (2) intense and pervasive red rock hematite alteration; and (3) interpreted bimodal felsic and mafic volcanic sequences (**Figure 3**). Samples of felsic to intermediate volcanics from drillholes Z23DD001 and Z23DD002 were submitted for U–Pb zircon dating to constrain the crystallisation age of the host unit and to interpret the basement terrains. The weighted mean age  $1867 \pm 4$  Ma (62 grains) is tentatively interpreted as the volcano-sedimentary Junalki Formation (pending supporting lithochemical evidence). The Junalki Formation is widely regarded as a stratigraphic correlative and age equivalent to the Warramunga Formation. The Warramunga Formation hosts the well-known Tennant Creek mineral field that is a major IOCG (iron oxide copper-gold) province characterized by Au-Cu-Bi deposits hosted within hematitic shales and ironstones, and temporally associated with the Tennant Creek Supersuite granites (ca 1850 Ma).

### ***Jessica and Carrara projects***

Initial results from drilling in the Jessica and Carrara projects (South32 has since exited the Carrara Project; Encounter 2024) were encouraging. The drillholes intersected thick (>200 m) sequences of deep-water sediments in the form of pyritic black shales in drillholes C23DD001 and C23DD003 (**Figure 4**); these lithologies are possibly comparable to shales intersected approximately 20 km east in NDI Carrara 1 and which were recently established to be equivalent to the Lawn Hill Formation ca 1595–1610 Ma (Carson *et al* 2022). Selected tuff layers interbedded with the shales were identified in drillholes C23DD001 and C23DD003 and submitted for U–Pb zircon geochronology. Zircon U–Pb analysis on the tuffaceous samples from drillholes C23DD001 and C23DD003 returned weighted mean ages for the youngest coherent populations in the range  $1654 \pm 11$  Ma to  $1663 \pm 13$  Ma, after excluding older inherited zircon grains. These ages were unexpectedly older (**Table 1**) than previously published data from NDI Carrara 1 and suggest the shales intersected in the Carrara Project drilling are stratigraphically older than those in NDI Carrara 1 (Lawn Hill Formation equivalent) and are instead possible stratigraphic



**Figure 2.** Map of the Jessica VTEM Survey, showing dB/dt Z-component response (Channel 48) histogram equalised. The image illustrates variations in conductivity and resistivity, domains and possible basement structures. Note drillhole DD92SN1 intersected organic rich sediments originally interpreted as Mullera Formation (Lanigan 1993) but later remapped as Racecourse Formation (Munson *et al* 2025); Pmr (Racecourse Formation), Pmf (Fish Hole Formation), Psw (Wild Cow subgroup), Pmh (Lawn Hill Formation).



Z23DD002 464m-468.7m Pervasive red-rock altered felsic volcanics

**1867±4 Ma** Sample Z2302A (468.1m) Junalki Fm?



**Figure 3.** Example of volcanic unit intersected at the Zeta Prospect and geochronology summary for the Jessica Project.



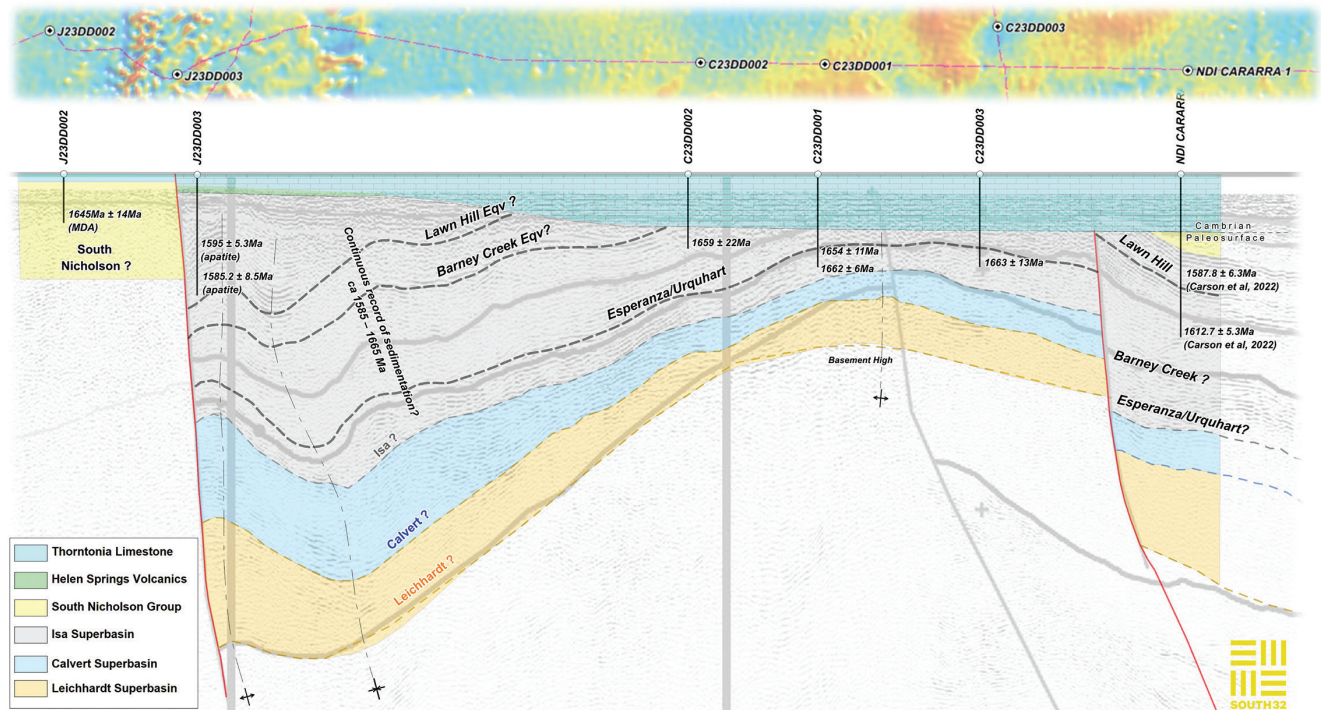
**Figure 4.** Shales intersected in drillholes C23DD001 and C23DD001 of the Carrara Project and compared with those from drillhole NDI Carrara 1 (Carr *et al* 2019).

equivalents of the Esperanza Formation or Urquhart Shale of the lower Isa Superbasin. Apatite dating was performed on two samples, from tuff layers at 862.4 m and 1206.25 m, from Jessica Project drillhole J23DD003; both samples were also dated using zircon (U–Pb) for comparison (Table 1). For sample J3-862.4m, a limited number of zircon grains were recovered. These grains yielded a discordia lower intercept age of ca 1595 Ma, interpreted as a reasonable estimate of the depositional age, albeit with caution due to reliance on the discordia intercept and limited single-grain data. For sample J3-1206.25m, abundant zircon grains provided a well-constrained age of ca 1600 Ma, with apatite data from this sample yielding a discordia lower intercept age of ca 1585 Ma, consistent with the zircon result. Overall, the apatite ages from both samples provide reliable estimates of the depositional

age of the sediments, in the range ca 1585–1600 Ma for the sampled interval, and which therefore correlate with the youngest sequences of the Isa Superbasin. These results support westward thickening into the Old Man’s Fault and eastward thinning wedge-like geometry as proposed by Gibson and Edwards (2020). Considering the age data from the Carrara Project drilling and the 17GA-SN1 seismic survey, it likely that the Isa Superbasin sediments extend much deeper than originally interpreted, possibly preserving a near continuous record sedimentation from ca 1585–1665 Ma with equivalents of the Esperanza/Urquhart, Barney Creek, and Lawn Hill units (Figure 5). Drill core from drillholes C23DD001, C23DD002 and C23DD003 has been donated to the core facility in Darwin and is available for independent analysis and research.

**Table 1.** Samples and summary of U–Pb and apatite geochronology from the Jessica and Carrara project drilling.

Hole ID	Sample ID	Depth (m)	Lithology	Interpreted age	Comment
C23DD001	C2301A	610.7	Sandstone	no yield	Insufficient zircon recovered
	C2301B	635.2	Tuff	no yield	Insufficient zircon recovered
	C2301C	676	Tuff	1636±22 Ma	Oldest concordant grains - 1747±29 Ma (2 grains, detrital?). Youngest concordant grains - 1636±22 Ma (2 grains).
	C2301D	746.5	Tuff	1654±11 Ma	The main population has a weighted mean age of 1654±11 Ma (14 grains).
	C2301E	858.6	Tuff	1662±6 Ma	Most concordant grains define a single population with a weighted mean age of 1662±6 Ma (31 grains).
	C2301F	985.15	Tuff	1657±43 Ma	The youngest concordant grain has an age of 1657±43 Ma.
C23DD002	C2302A	657	Sandstone	no yield	Insufficient zircon recovered
	C2302B	675.5	Tuff	1659±22 Ma	There are 6 concordant zircon grains that return a weighted mean age of 1659±22 Ma.
C23DD003	C2303A	900.4	Tuff	no yield	Insufficient zircon recovered
	C2303B	910.6	Tuff	1657±25 Ma	There are 15 concordant grains in this sample that spread between ~1770 Ma ~1640 Ma. Using the radial plot function in IsoplotR the youngest population has an age of 1657±25 Ma.
	C2303C	919.5	Tuff	1645±23 Ma	The youngest 2 grains have a weighted mean age of 1645±23 Ma. The next oldest 2 grains have a weighted mean age of 1703±22 Ma (detrital?).
	C2303D	925	Mudstone	1663±13 Ma (MDA)	There are 39 concordant grains in this sample between ~1870 Ma and ~1640 Ma. The youngest population using the radial plot function in IsoplotR is 1663±13 Ma.
Z23DD002	Z2302A	468.1	Felsic volcanic	1867±4 Ma	The weighted mean age for 62 concordant grains is 1867±4 Ma.
J23DD001	J2301B	629	Sandstone	1633±23 Ma (MDA)	Most concordant grains define a population at 1830±7 Ma. The youngest concordant grain has an age of 1633±23 Ma.
	J2301C	650.5	Tuff	1574±7 Ma	The weighted mean age of 1574±7 Ma is considered the true age of this sample.
	J2301E	911.2	Sandstone	1847±14 Ma (MDA)	Sample has four concordant grains, 2 grains older than 2000 Ma and 2 younger grains that have a weighted mean age of 1847±14 Ma. Weighted mean age likely reflects the true age of this sample although due to the small number of zircon grains analysed it should be treated with care.
	J2301F	1037.8	Lithic volcanic unit	1684±16 Ma (MDA)	Using the radial plot function in IsoplotR the youngest identified population consisting of 2 grains has an age of 1684±16 Ma.
J23DD002	J2302A	511.7	Sandstone	1662±20 Ma (MDA)	Youngest population 1662 Ma (only three grains), major peaks at 1796 Ma, 1833 Ma and 1887 Ma. Youngest Population 1662±20 Ma.
	J2302B	523.6	Sandstone	1645±14 (MDA)	Youngest population 1645 Ma (only 4 grains), major peaks at 1814 Ma and 1893 Ma. Youngest Population 1645±14 Ma.
J23DD003	J2303A	311	Tuff	no yield	Insufficient zircon recovered
	J2303B	862.4	Tuff	no yield	Insufficient zircon recovered
	J2303B	862.4	Tuff	1595±31.1 Ma	Apatite - the discordia plot gives a lower intercept age of ~1595 Ma. Good approximation for the MDA for this sample. Note reliance on the discordia intercept and the difficulty to treat grains individually. Lower intercept 1595.0±31.1 Ma.
	J2303C	1206.3	Tuff	ca 1600 Ma	Abundant of zircon grains. The youngest population is at ~1600 Ma with a few older grains at 1654 Ma and 1877 Ma.
J2303C	1206.3	Tuff	1585.2±8.5 Ma	Apatite - sample yielded a MDA at ~1600 Ma from the zircon grains. The apatite data indicates a lower discordia intercept age of ~1585 Ma which is not that different from the zircon age data. Lower intercept 1585.2±8.5 Ma.	

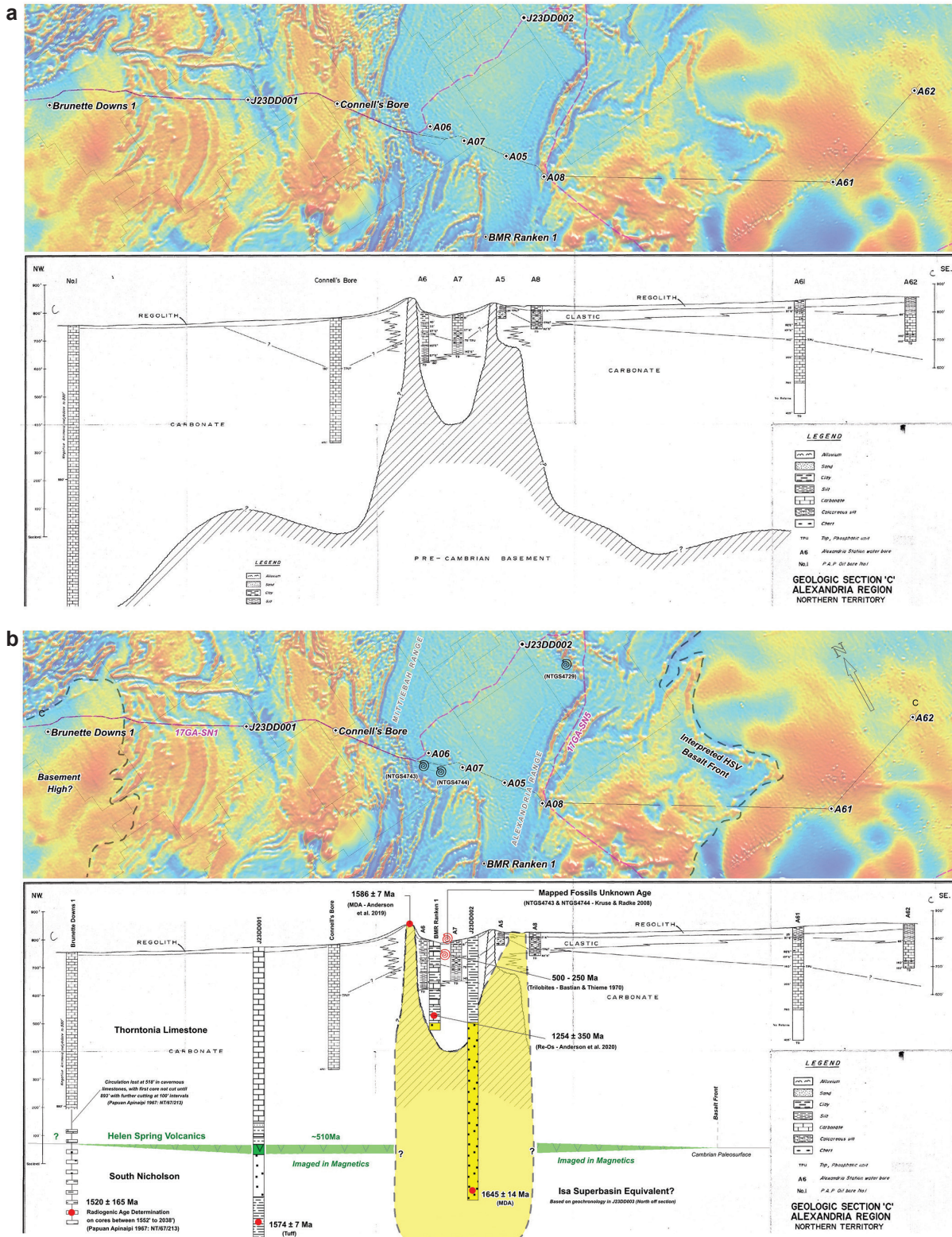


**Figure 5.** Updated U–Pb zircon and apatite geochronology and interpreted superbasins for the eastern portion of seismic line 17GA-SN1. Original seismic images and interpretation from Carr *et al* (2019).

*Alexandria Gravity Low*

Previous results from drillhole J23DD002 (Pickering 2024), within the Alexandria gravity low (AGL), intersected a thick sequence of ferruginous (red-brown) sandstones, interspersed with sporadic thin siltstone interbeds, from 100.9 to 524.9 m (EOH) depth. These units exhibit an average specific gravity of 2.55, potentially explaining the observed

gravity anomaly, but questions remain regarding the basin evolution and timing of sediment deposition. Previous exploration efforts by IMC Development Corporation (IMC), while targeting phosphate in the Alexandria region, encountered similar challenges in reconciling initial cross sections honouring mapped and interpreted Precambrian basement as evident in their schematic section showing highly variable basement architecture (Figure 6a). These



**Figure 6.** Alexandria Gravity Low: (a) Original schematic cross section of IMC’s Alexandria Phosphate Project (IMC Development Corporation 1968). (b) Modified schematic cross section of IMC’s Alexandria Phosphate Project showing available geochronology data, updated drilling and interpreted geological boundaries.

geochronological and structural inconsistencies persist today, complicating interpretations of the AGL. Sample GA 2676116 from the Mittiebah Formation in the Mittiebah Range has a published detrital zircon U–Pb maximum depositional age of  $1586 \pm 7$  Ma (Anderson *et al* 2019). Possible Mittiebah Formation intersected in drillhole J23DD002 yielded a maximum depositional age of  $1645 \pm 14$  Ma (at 520 m depth); in drillhole J23DD001 a tuff (possible Favenc Package) at ~650 m depth yielded a zircon U–Pb age of  $1574 \pm 7$  Ma.

Additional conflicts about the age of the Mittiebah Formation arise from the BMR Ranken 1 stratigraphic hole. In that drillhole trilobite fossils (ca 520–250 Ma) identified by Bastian and Thieme (1970) occur in carbonates that overlie a whole-rock Re–Os age (although imprecise) of  $1254 \pm 350$  Ma (Anderson *et al* 2020), recorded by organic-rich sediments that overlie interpreted sandstones of the Mittiebah Formation. These discrepancies, juxtaposed against and above the Cambrian erosional paleo-surface constraining the  $510.7 \pm 0.6$  Ma (Jourdan *et al* 2014) Helen Springs Volcanics and associated Kalkarindji event, may reflect: (1) detrital inheritance; (2) unrecognised depositional phases within the region; or (3) effects related to the Alice Springs Orogeny. The IMC schematic section has been updated to incorporate available geochronological data and drilling constraints (**Figure 6b**).

The Mittiebah Formation (previously Mittiebah Sandstone) makes up almost all the outcropping stratigraphy of the AGL and was recently moved from the Accident Subgroup to the Wild Cow Subgroup (Munson *et al* 2025) suggesting opportunity for reinterpretation. This transfer into the Wild Cow Subgroup was because no clear unconformity has been identified that could correlate to the base of the Accident Group, however Munson *et al* (2025) note the significant thickness of the Mittiebah Formation (>2000 m) and compatibility with the nearby Mitchiebo belt with this updated correlation. Alternatively, the Mittiebah Formation may represent an unrecognised Paleozoic sedimentary sequence (Pickering 2024) which could preserve missing Cambrian stratigraphy at depth. Note that the original SEEBASE study and interpretation by Frogtech Geoscience (2018) interpreted deeper basement associated with the AGL (semi-circular to elongate zones of lower density) beneath possible granitic intrusions that are concealed by the Mittiebah Formation. Regardless of the exact age of the Mittiebah Formation, it needs to be consistent with: (1) the linear magnetic margins and emplacement of the (interpreted) Helen Springs Volcanics coincident with the gravity low (indicating linear and steep flanks impeding the HSV); (2) the sag geometry of the upper (youngest) sedimentary layers; (3) the structural history and geodynamics of the region; and (4) subsequent erosion and integration with the present-day topography.

## Conclusions

The key findings and implications from the recent VTEM survey and geochronology from drillhole 17GA-SN1 are:

- Based on reflectors in seismic line 17GA-SN1, geochronology and recent drilling, the depth extent of

Isa Superbasin sediments in the eastern portion of the Jessica Project is likely to be greater than previously interpreted. These sediments may preserve a near continuous record sedimentation from ca 1585–1665 Ma.

- Carbonaceous shales intersected in drillholes C23DD001 and C23DD003 are possible age equivalents of the Esperanza Formation/Urquhart Shale.
- Although not directly intersected, the geochronology results predict the presence of additional prospective shale units, such as the Barney Creek and Lawn Hill Formation, may exist within the project area.
- The Alexandria Gravity Low shows conductive/resistive symmetry around interpreted basin (?) margins and possible depocentre.
- Conflicting age constraints and geometry of Cambrian stratigraphy bounding the Alexandria Gravity Low may support the presence of an unrecognised younger, possibly ?Devonian-aged basin.
- Basement intersections from the Carrara Project drilling (drillholes C23DD001, C23DD002 and C23DD003) have been donated to the Core Facility in Darwin and available for independent research and analysis.
- Regional magnetotelluric survey is planned for seismic line 17GA-SN1 and will help constrain current drillhole data and constrain further interpretations.

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