Northwest Northern Territory Seismic Survey – resource studies and results

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Introduction

Exploring for the Future (EFTF) is an eight-year, $225 million Australian Government program dedicated to ensuring a sustainable, long-term future for Australia through an improved understanding of the nation's minerals, energy and groundwater resource potential. One objective of EFTF is to encourage industry investment in resource exploration activities in frontier or 'greenfield' regions by acquiring and delivering new precompetitive geoscience data and information. As part of this initiative, Geoscience Australia acquired new 2D seismic reflection data across the northwestern Northern Territory (NT), broadly between Timber Creek (on the Victoria Highway) and the Tanami Region (**Figure 1**). The Northwest Northern Territory Seismic Survey (hereafter referred to as the NW NT Seismic Survey; L214) was acquired between August and September 2023 by Geoscience Australia and co-funded by the Northern Territory Government. The survey was designed to image the underexplored Palaeo- to Mesoproterozoic Birrindudu Basin and adjacent regions, including the highly prospective Tanami Region. This work also improves knowledge of the western greater McArthur

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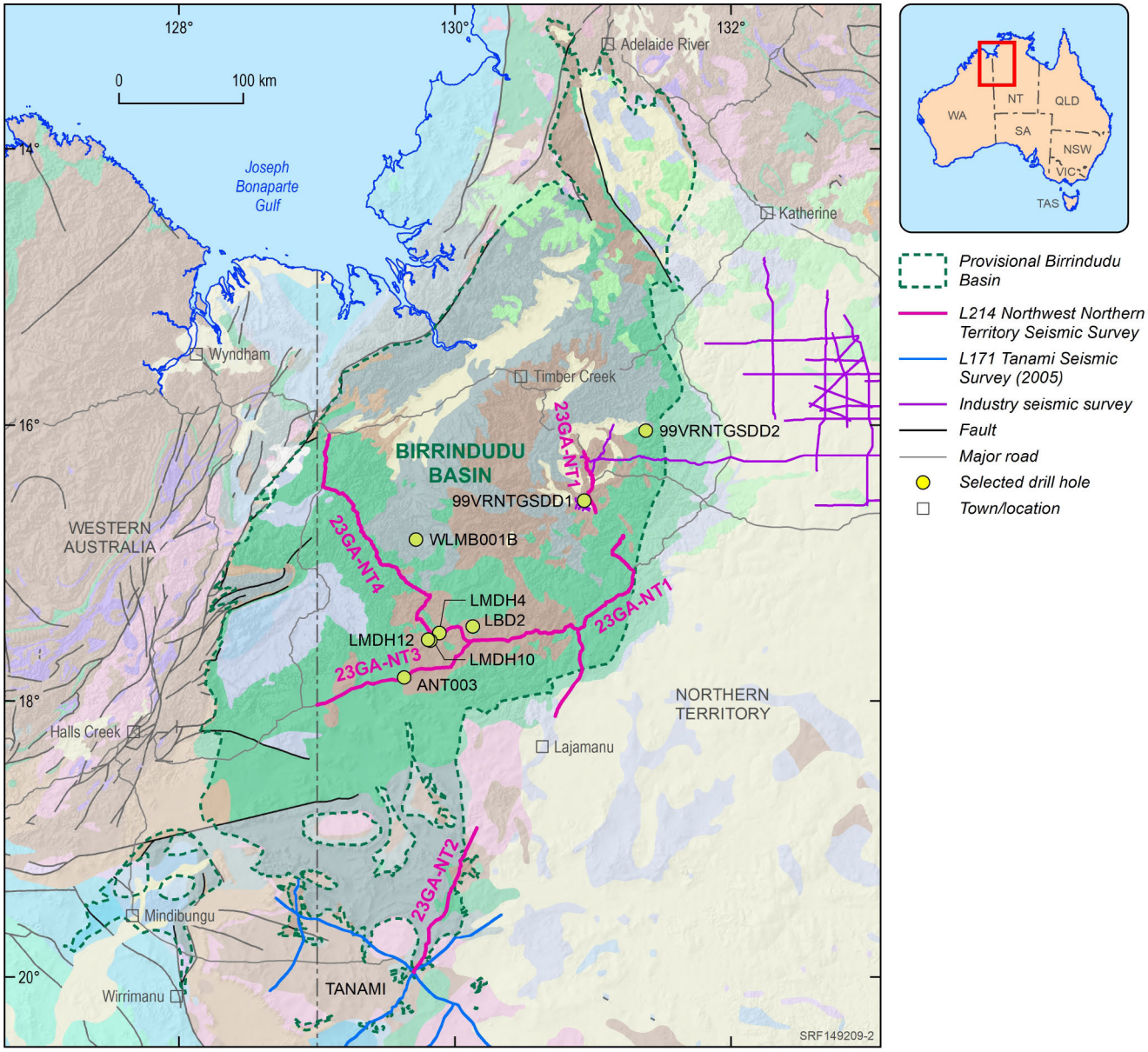

Figure 1. Map showing the location of the Tanami Region and provisional extent of the Birrindudu Basin imposed on a base map of surface geology (surface geology from Raymond *et al* 2012). Provisional Birrindudu Basin boundary is based on the distribution of units on the solid geology map of the North Australia Craton by Stewart (2020). Also shown is the NW NT Seismic Survey (L214), industry seismic lines, and the 2005 Tanami 2D Seismic Survey (L171).

Basin and builds on the success of the South Nicholson and Barkly seismic surveys (Carr *et al* 2019; Southby *et al* 2022).

The Proterozoic rocks of the Birrindudu Basin are thought to be, in part, age equivalent to strata within the McArthur Basin and Mount Isa Province to the east, which contain some of the world's largest sediment-hosted base metal deposits, including the McArthur River, Century and Mount Isa mines (eg Close 2014, Munson *et al* 2020, Jarrett *et al* 2022). Although exploration for hydrocarbons has been limited to date, evidence for an effective petroleum system in the Birrindudu Basin is demonstrated by the occurrence of live oil bleeds in the drillhole 99VRNTGSDD1 (Korsch 2024). Good source rocks have been identified in the Palaeoproterozoic Limbunya Group (Jarrett *et al* 2021), but the dearth of geochemical data means that much of the prospectivity for hydrocarbons in the Birrindudu Basin is inferred from the presence of equivalent-aged rocks in the highly prospective Palaeo- to Mesoproterozoic McArthur Basin. To address these data gaps, the new regional NW NT Seismic Survey 2D seismic data was acquired and, together with a comprehensive sampling and analytical program on newly collected drill core samples, will be used to assess the basin's resource potential.

Seismic survey objectives

The acquisition of the deep crustal NW NT Seismic Survey over the Birrindudu Basin and adjacent regions (**Figure 1**) was connected with the existing the 2D seismic lines: 1) the seismic survey by Pangaea Resources (Hoffman 2014), which extends into the western Beetaloo Sub-basin in the north; and 2) the 2005 Tanami 2D Seismic Survey (L171; Jones *et al* 2005) in the south. Key science objectives of the NW NT Seismic Survey are to:

1. enhance understanding of the stratigraphy of the region and identify any previously undiscovered concealed basins, sub-basins or depocentres
2. evaluate geological and stratigraphic relationships between the Birrindudu Basin, the highly prospective Beetaloo Sub-basin of the McArthur Basin to the east, and the Tanami Region to the south
3. improve understanding of major structures in the region, such as basin geometry, and the timing of tectonic events and their relationship to mineralisation and energy resources
4. determine possible relationships between basin architecture and resource potential.

Background geology

The Palaeoproterozoic to Mesoproterozoic Birrindudu Basin extends across northwestern NT and into northeastern Western Australia (WA). Definition of the basin has evolved with improved knowledge of its geology and stratigraphy (see Dunster and Ahmad 2013, Carson 2014, Korsch 2024). From the base, rocks of the Birrindudu Basin unconformably overlie metamorphosed and deformed rocks of three provinces: the Pine Creek Orogen in the north, the Tanami Region in the south, and possibly the Halls Creek Orogen in the west (Dunster and Ahmad 2013). The basin is unconformably overlain by the Neoproterozoic Victoria and Wolfe basins, the Cambrian Kalkarindji Igneous Province, and the Palaeozoic Daly, Ord and Wiso basins (Korsch 2024). Six lithostratigraphic groups define the basin succession: from oldest to youngest, these are the basal age-equivalent Birrindudu and Tolmer groups, overlain sequentially by the Limbunya, Wattie, Bullita and Tijunna groups (Dunster and Ahmad 2013; **Figure 2**).

Source rocks

The frontier nature of the Birrindudu Basin, together with low data coverage in the region, means little is known about potential petroleum systems in the northwest NT. A review by Jarrett *et al* (2021) suggested the basin has the potential to host conventional and unconventional petroleum resources, based on geochemistry, porosity and permeability data as described by Revie *et al* (2022).

As summarised in Korsch (2024), the first mention of a potential source rock from the Birrindudu Basin was by Crick (1988), who reported organic matter in the form of non-fluorescing lamalginite and rare disseminated bitumen from an outcrop of the Stubb Formation. Evidence of substantial overburden erosion was provided by a mean alginite reflectance value Ro% of 1.0 for the surficial sample, indicating it was once within the oil window. Further studies recognised sedimentary units within the Limbunya Group as the most promising for hydrocarbon-generating potential (Simeone 1991, Ruble *et al* 2016), which was later confirmed from source rocks studies by Jarrett *et al* (2021).

Seismic survey acquisition

Geoscience Australia contracted Terrex Seismic Pty Ltd to collect the L214 NW NT Seismic Survey from the 7th of August to the 20th of September 2023. The survey consisted of four lines, 23GA-NT1 (NT1) to 23GA-NT4 (NT4), located in the northwest of NT. The lines run from the Birrindudu Basin in the northeast to the Tanami region in the south, and west to near the WA border east of Lake Argyle (**Figure 1**). A total of 847 line km of deep crustal seismic data was collected.

The seismic data were recorded using an active spread of 2400 channels, distributed over 24 km. DTCC SmartSolo 10 Hz IGU 16 nodes were used as receivers, spaced every 10 m, one per station. The source array, consisting of three Inova AHV-IV PLS-364 62 000 lb vibrators, was located at the centre of the 24 km spread, giving a nominal maximum source to receiver offset of 12 km for the majority of the survey. The vibrators were spaced with the pads 12 m apart, giving a total source array length of 24 m. Vibe Points (VP) were spaced every 4th station, 40 m apart, with the centre of the vibrator array located midway between receiver stations. A full description of the seismic survey, including acquisition and processing parameters, will be provided in Anderson *et al* (in prep).

The seismic acquisition was subject to a range of land access considerations associated with impassable roads and cultural heritage. These areas were defined, and zones

outlined where no Vibroseis sources or geophones were operated. A full 2400 channels of data were collected for each VP for the entire survey, including over the zones of non-acquisition. This meant that for the non-acquisition zones, some of the data were collected with unusually long offsets in order to retain the full 2400 channels. The maximum offset was increased by about 10 km for VPs in non-acquisition zones. A total of ~900 km of seismic data was collected; however, only ~700 km was occupied by the nodes and Vibroseis trucks. The effect of the non-acquisition zones on the stacked data caused up to seven seconds of shallow data to be missing in those areas. However, the deeper data from the longer offset nodes enabled imaging from the mid crust to the full 20 seconds (to the mantle) for all the lines.

Drill core analytical program

To complement the acquisition of the seismic survey, a sampling program of legacy stratigraphic and mineral exploration drillholes was carried out at the Northern Territory Geological Survey core repository in Darwin.

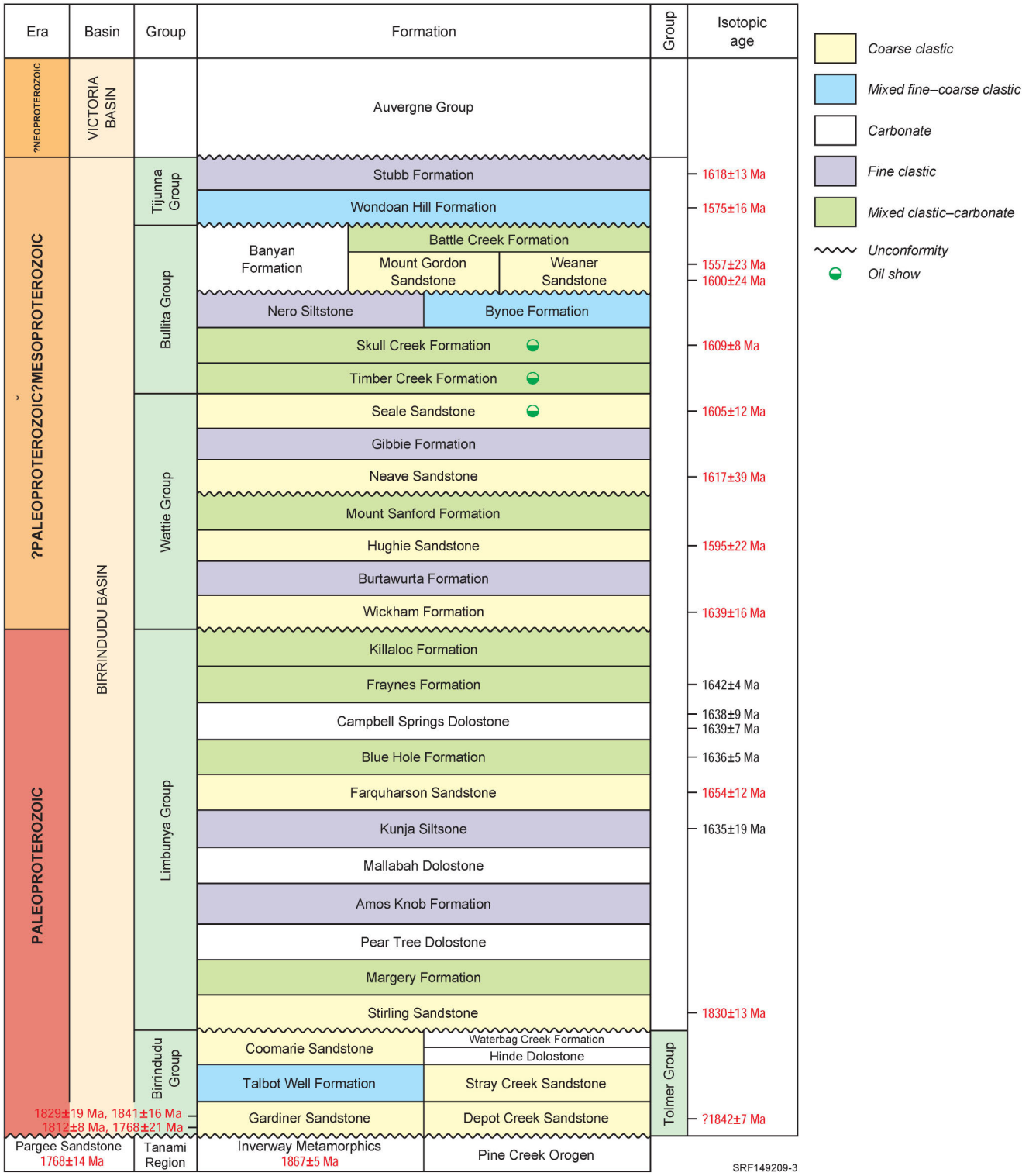

Figure 2. Simplified stratigraphic column of the Birrindudu Basin, after Korsch (2023).

Over 1200 core samples from nine Birrindudu Basin drillholes were collected for analytical work, including new geochemical and rock properties analyses. The resulting datasets are available from the following webpage: https://www.eftf.ga.gov.au/officer-musgrave-birrindudu. Based on these recent organic geochemical analyses, a summary of key insights on the energy resource potential of the basin is presented in Butcher *et al* (in press).

Preliminary results and resource implications

The seismic survey transects unmetamorphosed units of the Palaeoproterozoic to Mesoproterozoic Birrindudu Basin and overlying Neoproterozoic to Phanerozoic provinces. The Birrindudu Basin unconformably overlies low-grade Palaeoproterozoic metasedimentary and metavolcanic rocks of the Inverway Metamorphics (eg Ahmad 2013), and the variably deformed and metamorphosed igneous and sedimentary rocks of the Neoarchean to Palaeoproterozoic Tanami Region to the south (**Figure 1**). To the north of the NW NT Seismic Survey area, the Tolmer Group of the Birrindudu Basin unconformably overlies rocks of the Neoarchean to Palaeoproterozoic Pine Creek Orogen.

Much of the geology transected by the NW NT Seismic Survey has not been thoroughly studied using modern geological techniques or analytical methodologies. The previous seismic data available for the area consists of just one deep crustal seismic reflection survey in the Tanami Region (L171, Jones *et al* 2005), and one petroleum industry seismic survey by Pangaea Resources (Hoffman 2014; **Figure 1**). Only ~280 km of existing seismic data from these surveys extends across the Birrindudu Basin. With the acquisition of the NW NT Seismic Survey, the coverage of seismic data across the Birrindudu Basin has increased by ~900 km—almost tripling the seismic coverage for this basin. The NW NT Seismic Survey provides a link between the survey by Pangaea Resources (targeting the western Beetaloo Sub-basin), and the Tanami seismic survey (targeting the basement architecture of the Tanami Region; Goleby *et al* 2009). These linkages will be used to further develop a wider regional geological interpretation.

The Tanami Region is a Neoarchean to Palaeoproterozoic province that straddles the NT and WA border (**Figure 1**). It is a composite of the Neoarchean Billabong Complex basement, Palaeoproterozoic metasedimentary and volcanic rocks, and Palaeoproterozoic granites (Ahmad *et al* 2013). The Tanami Region hosts significant mineral resources, including numerous Palaeoproterozoic-aged lode-gold deposits, eg the world class Callie deposit (eg Huston *et al* 2007). Other deposits include the heavy rare earth element (HREE) deposits of the Browns Range Dome (eg Nazari-Dehordi *et al* 2018), where Northern Minerals' Browns Range plant produces HREE dysprosium. Interpretation of the NW NT Seismic Survey lines promises a deeper understanding of the major structures in the Tanami Region, unveiling insights into their geometry, timing of events, and relationships to basin evolution and mineralisation. This interpretation may extend the mineral resource potential in the region.

The complementary work from drill core geochemical analyses has enabled an update of the source rock potential in the Birrindudu Basin. In particular, gap analysis identified a critical lack of reliable thermal maturity data in the area. Organic petrological analyses from six drillholes across the basin assessed thermal maturity using alginite and bitumen reflectance (the predominant organoclasts in the rocks). All the drillholes were found to be thermally mature for hydrocarbon generation (Butcher *et al* in press). Programmed pyrolysis confirmed the source potential of sedimentary formations within the Limbunya Group. The detection of oil inclusions indicated past oil generation and migration, reinforcing the occurrence of effective petroleum systems in the Birrindudu Basin. The interpretation of rock properties data is under way and will provide valuable information on the reservoir qualities and seal capacity of some key sedimentary units in the basin.

Conclusions

The NW NT Seismic Survey (L214) was designed to image the underexplored Proterozoic Birrindudu Basin, with links to the highly prospective Tanami Region and Beetaloo Sub-basin. The new survey has tripled seismic coverage over the Birrindudu Basin and adjacent regions, enabling new perspectives to be gained on the basin's geology and relationship to surrounding regions. New interpretation of these deep seismic lines, in combination with newly acquired data from drill cores and legacy 2D seismic lines, is expected to greatly improve the knowledge base of mineral and energy systems in the northwestern Northern Territory. The new dataset will be available as both raw and processed data files from the Geoscience Australia website.

Acknowledgements

The NW NT Seismic Survey L214 is a product of the Australian Government *Exploring for the Future* initiative, conducted in collaboration with, and co-funded by, the Northern Territory Geological Survey. We would like to extend our thanks all the landowners and custodians who facilitated on-ground access. We also wish to thank Silvio Mezzomo for drafting the figures; and Carmine Wainman and Ryan Owens (both Geoscience Australia) for constructive reviews. Geoscience Australia authors publish with the permission of the CEO, Geoscience Australia (eCat 149244).

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