Increasing prospectivity in a covered terrain – the southern Thomson Orogen, northwestern NSW

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SUMMARY

The Southern Thomson Project aims to advance understanding of tectonic history and mineral prospectivity of basement rocks of the southern Thomson Orogen beneath extensive Mesozoic and Cenozoic cover. The project area in northwestern New South Wales (NSW) and western Queensland is considered underexplored, with poor definition of structural corridors and mineral systems in the Palaeozoic rocks. This collaborative project between Geoscience Australia, the Geological Survey of New South Wales (GSNSW) and the Geological Survey of Queensland is acquiring and interpreting new geoscience data, including geophysical, geochemical, and isotopic investigations. Geophysical data interpretations and models have been tested through a program of stratigraphic drilling to provide basement cores for studies of petrology, geochronology, geochemistry, petrophysics and mineral systems. Downhole geophysical logging of the drillholes also aims to characterise the cover sequences and define depth to basement.

Interpretation of regional aeromagnetic and gravity data and synthesis of existing mineral, water-bore and petroleum drillholes created a geological map of basement lithologies and structures. Stratigraphic drilling has targeted areas with no data to constrain lithologies or their ages, with four key areas selected for drilling in far northwestern NSW. Information on the thickness of cover sequences over resistive basement interpreted from AEM inversion models has proven useful during the selection of drilling locations.

Seven stratigraphic drillholes were completed within NSW using a combination of mud rotary and diamond drilling. All holes penetrated surface regolith, as well as sedimentary rocks of the Eromanga Basin, to achieve approximately 50 metres of basement core for analyses. Resulting improvements to geological understanding and development of exploration techniques will be a keystone to progress future investigations in the southern Thomson Orogen.

Key words: Thomson Orogen, stratigraphic drilling, mineral exploration under cover

INTRODUCTION

Prospective structural corridors and mineral systems are likely to exist in the southern Thomson Orogen in northwestern NSW and southwestern Queensland, but discovery of deposits is impeded by the challenge of exploring through younger sedimentary rock units that form almost complete cover across the region (Figure 1). The Thomson Orogen sits within a group of orogenic belts in eastern Australia known collectively as the Tasmanides. Basement rocks within the Thomson Orogen may hold similar mineral potential to adjoining belts, including the base metal and gold endowment of the Lachlan Orogen to the south and the Koonenberry Belt in the

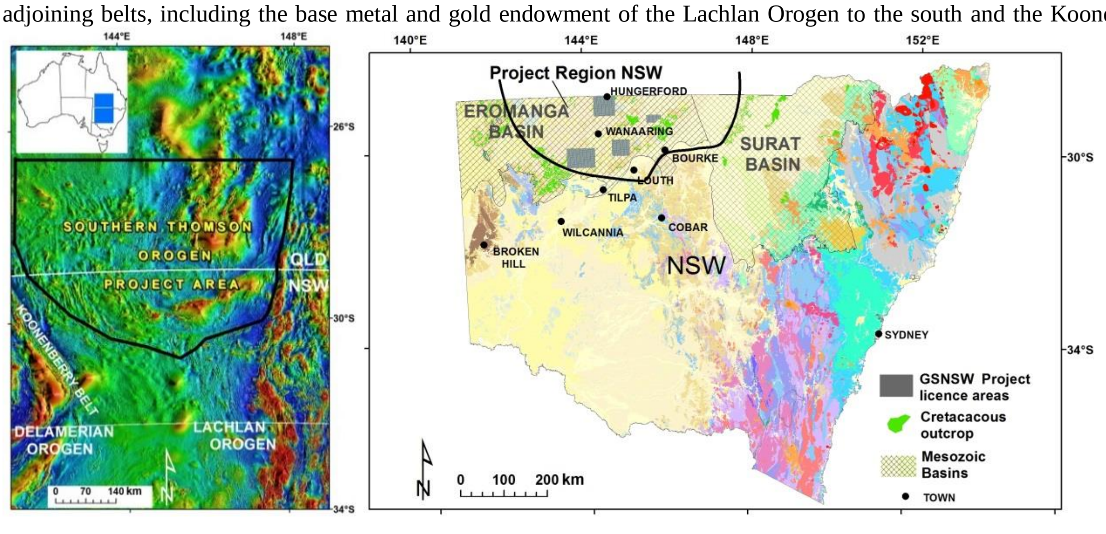

Figure 1: Location of the Southern Thomson Project area in eastern Australia (left) on regional Total Magnetic Intensity (TMI) image. Project activity locations in NSW (right) on the statewide 1:1 000 000 geological map. Post Permian sedimentary rock units are shown in yellow and green.

Delamerian Orogen to the southwest. Details of cover sequences, variations in the depth to the basement surface, and basement lithologies in the Thomson Orogen are mainly known from very sparse water bores and petroleum exploration drillholes. Several mineral exploration programs in the past decade have penetrated basement units in the southern Thomson Orogen and some indications of metallic mineralisation have been identified. However, overall the terrane offers significant potential for metallic mineral deposits within Palaeozoic basement rocks.

The collaborative Southern Thomson Project commenced between GSNSW, the Geological Survey of Queensland and Geoscience Australia in 2013, aiming to improve the understanding of basement geology and mineral potential across the western NSW/Queensland border area. The project sits within the national Uncover initiative, which aims to reverse the decline in Australia's known mineral reserves by providing new information to explorers about undercover regions. The first stage of the project integrated existing geoscience datasets such as regional mapping and potential field geophysical datasets, and acquired pre-competitive geoscience data and information that could reduce exploration risk in the region. The new data apply to a range of depths of investigation – from surface and near-surface surveys such as landscape geochemistry and airborne electromagnetics (AEM), extending through to deep-crustal scale magnetotelluric (MT: Wang et al. 2017) and gravity traverses (Figure 2).

The second stage of the Southern Thomson Project commenced in 2015, aiming to test the geophysical interpretations through a program of stratigraphic drilling. The drilling planned to generate new geochronological, petrophysical, petrological and geochemical data and resulting inferences. Drill sites were selected to evaluate significant basement-sourced features identified in a regional aeromagnetic and gravity interpretation (Hegarty, 2010; updated in Purdy et al., in prep.), and in AEM inversion models of conductivity/resistivity for depths of up to 300 m below surface (Roach ed., 2015; Roach, 2018). Ground geophysical surveys including AMT, passive seismic and seismic refraction provided pre-drilling interpretations of the depth to basement within some site areas (Goodwin, 2018).

This presentation provides the geological and geophysical rationale for seven stratigraphic drillholes completed in NSW for the Southern Thomson Orogen Project, along with preliminary outcomes. It refers to previous and current mineral exploration efforts in this part of NSW and the indications of mineral systems identified by private industry to date.

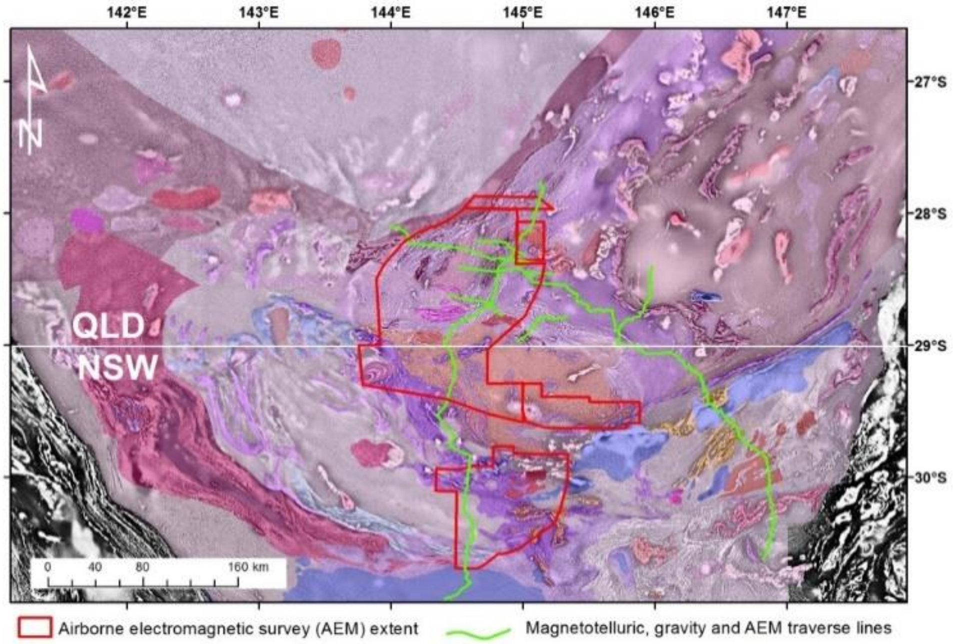

Figure 2: Regional geophysical surveys competed in the Southern Thomson Project area. Background image is a transparent solid geology interpretation layer over 1VD RTP TMI.

TESTING GEOPHYSICAL INTERPRETATIONS

The Southern Thomson drilling program is supplying framework geoscience data, as well as testing and refining exploration techniques through cover. The project scope does not include direct testing for mineralisation – the project aims to fill the stratigraphic and tectonic knowledge gaps identified for the southern Thomson Orogen. This augments the sparse mineral exploration drillholes and petroleum/stratigraphic wells that provide valuable basement information.

Planning of the drilling program commenced with each participating organisation compiling site selection lists, followed by a workshop to evaluate their likely outcomes and geological merit. A shortlist of 20 sites was further reduced to 14 sites in four key areas after prioritising for:

- Significant interpreted units where no information and or/samples are available
- Areas where basement depth is indicated to be shallow (for cost efficiency), and adjusting locations using AEM results
- Testing AEM inversion model results and obtaining downhole conductivity data and validate AEM data inversions
- Avoiding known artesian aquifers and areas of high environmental significance

For each feature being tested, 2 or 3 sites were prepared to allow flexibility during the processes of environmental and cultural clearances, and land access negotiation. Being regional reconnaissance, precise collar locations were not required and sites were selected to utilise existing access tracks and previously disturbed ground where possible.

The drilling program completed 7 stratigraphic holes in NSW (and a further 5 holes in Queensland) following consideration of various factors including access, environmental sensitivities, community and culture, depth of cover, and aquifer protection. Field operations took place within 4 Exploration Licences for Group 1 (metallic) minerals held by NSW Department of Planning and Environment (Figure 3) to provide suitable guidelines/processes and to protect project interests until the public release of information. Previous drilling for mineral exploration in the region has proven challenging as programs have typically encountered difficult drilling conditions, such as swelling smectite clays, hard boulder beds on unconformities, and "running sands" (i.e. poorly consolidated sandstones with matrix that dissolves in water). The conditions were reviewed in preparation for the Southern Thomson program. A drilling methodology was developed and specifically used a combination of:

- rotary mud drilling to chip through cover sequences,
- diamond drilling of underlying basement rocks to provide around 50 m of representative core samples from each site, and
- supervision of operations by a licenced water bore driller.

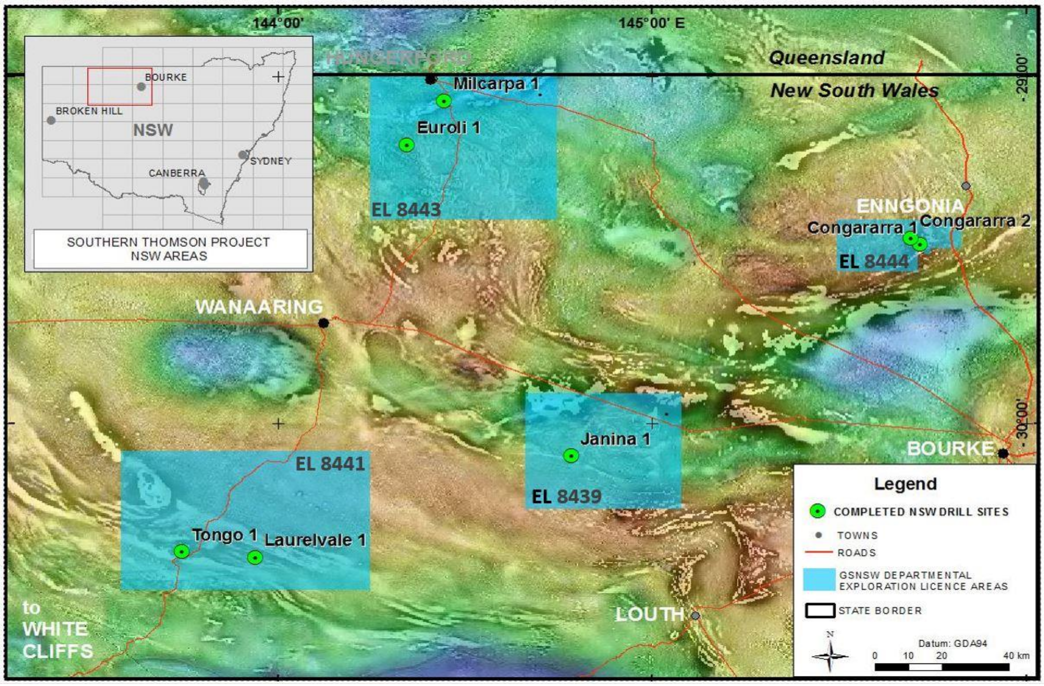

Figure 3: Locations of project drillholes within GSNSW licence areas. Composite background image of greyscale 1VD RTP TMI over a pseudocolour Bouguer gravity image.

The program successfully obtained about 50 m of basement cores from every site, with no redrills or significant delays (results in Table 1). All NSW holes were drilled at an angle, with the exceptions of Milcarpa 1 and Euroli 1. Wireline geophysical logs were run in each hole prior to casing. The geological and geophysical rationale for each of the stratigraphic holes is summarised in Table

Table 1: Drill holes completed in NSW for the Southern Thomson Orogen Project (depths represent drilled length, including approximately 50 metres of core).

Drill hole	Total Depth (m)	Basement lithology
Milcarpa 1	290.9 m	Rhyodacite
Euroli 1	153.7 m	Metasedimentary schist
Tongo 1	312.8 m	Granodiorite
Laurelvale 1	386.8 m	Siliciclastic turbidite
Janina 1	222.2 m	Granite
Congararra 1	119.6 m	Quartz-biotite gneiss
Congararra2	317.9 m	Biotite–muscovite granite

Hungerford–Wanaaring area

Granite outcrops occur at Hungerford and several other Queensland locations (e.g. Granite Springs, Eulo) on the Eulo Ridge – an extensive platform of shallow basement rocks that trends northeasterly in Queensland and southeasterly in NSW (see Roach, 2015). Short-wavelength aeromagnetic anomalies characterise a broad area (Figure 4), indicating that basement rocks are present at drillable depth (<500 m). Some anomalies are complex and have high magnetic intensity (e.g. an interpreted zoned intrusion) but there has been no previous mineral exploration drilling in this area.

Two distinctive magnetic features were selected for stratigraphic drill testing. Both are close to Hungerford, where cover thickness was expected to be <300 m. The Swamp Bore feature, about 15 km south of Hungerford, is a series of elongate high-amplitude anomalies which form a curvilinear band that is closely coincident with a zone of low gravity values. The feature trends east-northeast. This is also the orientation of the Culgoa aeromagnetic lineament and other narrow zones of high-amplitude magnetic anomalies in the southern Thomson Orogen, so age-dating could add to the geodynamic understanding of the wider region. The Swamp Bore feature had been interpreted as a probable Devonian I-type granitoid prior to drilling. Stratigraphic drillhole Milcarpa 1 intersected weakly altered, veined rhyodacite which indicates a narrow volcanic unit and/or high-level intrusion, but did not intersect strongly magnetic rocks. Geochemical data and petrographical study will help classify the lithology and geological setting, and geochronology will provide an emplacement/cooling age.

The second drillhole tested subtle, banded patterns of curvilinear, low-amplitude magnetic anomalies that characterise a broad area to the south of the Swamp Bore magnetic feature. Several water-bore logs record either schist or granite through this area, but their discrimination in magnetic imagery is difficult to interpret and it is possible some effects relate to weakly-magnetic cover sequence rocks on the unconformity surface. Gravity values are quite variable in this area – it is likely that lower values may indicate granitic basement, and higher values indicate metamorphic rocks. Stratigraphic drillhole Euroli 1 was drilled on shallow resistive basement seen in the AEM inversion model. It intersected metasedimentary schist, confirming that the magnetic anomalies have valid basement sources and interpretations can be extrapolated over the broader area. Analysis of the core will determine the nature of the metamorphism, the protolith's detrital spectrum and the lithology of a magnetic interval.

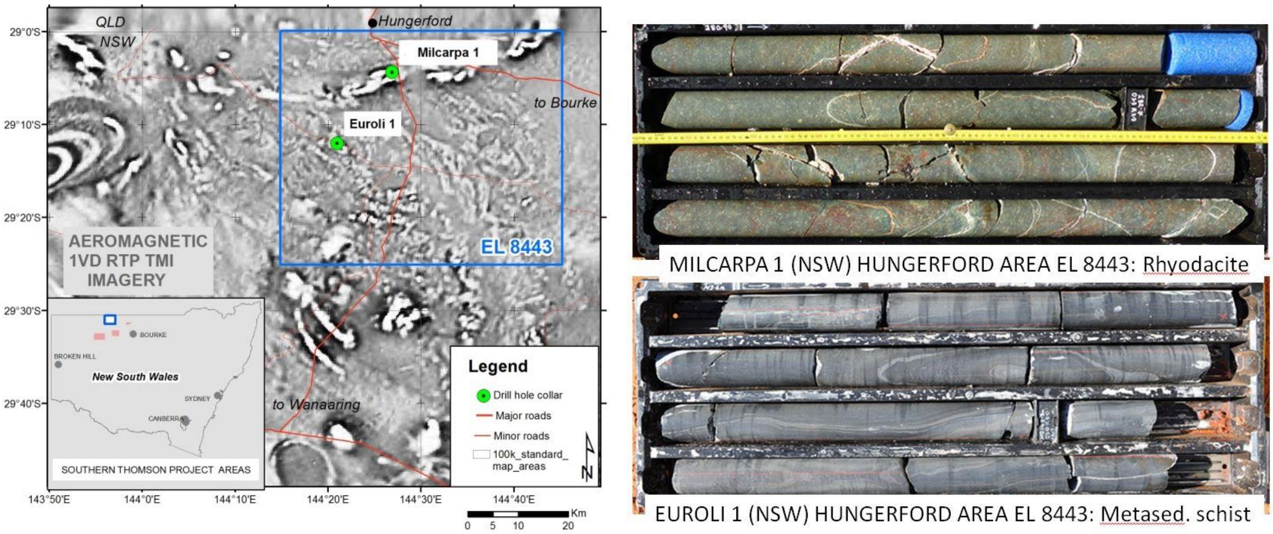

Figure 4: Location of drillholes Milcarpa 1 and Euroli 1 in EL 8443, south of Hungerford, on a greyscale 1VD RTP TMI image (left), and example core from each hole (right).

Tilpa–Tongo area

During the past decade, mineral explorers have drilled several discrete high-amplitude aeromagnetic anomalies in the region between Tilpa and White Cliffs, targeting metallic deposits within the curved northwest-trending belt interpreted as the Yancannia Formation of the Warratta Group. No exploration drilling has occurred within a parallel, west-northwest belt of linear aeromagnetic anomalies along its eastern flank, interpreted as the Tongo Fault and adjoining Tongo Zone. Core-tail drilling by GSNSW tested a magnetic horizon in the eastern part of the Tongo Zone, intersecting laminated silty mudstone with quartz veins (DDH Eugene; Dick and Simpson, 2010). This zone has no known age constraints, and so far no zircons have been extracted from the core samples that could provide a maximum detrital age (MDA). The magnetic anomalies are interpreted to represent ductile deformation against a competent Warratta Group fault contact, but correlation of the rock units with Cobar Supergroup or other units requires samples for age-dating.

Age-dating the emplacement of any intrusions or dykes is also useful to constrain the age of host metasedimentary rocks. The Nantilla intrusions are interpreted from discrete elongate to oval-shaped magnetic anomalies on a northwest trend (Figure 5) and these appear to intrude (thus, post-date) the Tongo Zone metasedimentary rocks. Ground geophysical surveying of the main pluton (Nantilla 1 feature) and also over a smaller circular magnetic feature to the south (Nantilla 2 feature) produced estimates of depth to the basement surface (Goodwin et al., 2018). Those results confirmed basement was shallower to the south and, also considering stronger aquifer flows were known near Nantilla 1, it was decided to drill the Nantilla 2 feature as a proxy for the main pluton. Stratigraphic drillhole Tongo 1 intersected magnetic, medium-grained granodiorite, which confirmed the intrusive nature of the anomaly source. Comparison of the geochemistry, age and petrology will be made with mineralised magnetised granite of the F1 prospect (20 km southeast; tenement holder, Thomson Resources Pty Ltd), which has previously been investigated in a mineral systems study for the Southern Thomson Project (Armistead et al. 2017).

Magnetic trends within the Tongo Zone include linear anomalies of moderate to high magnetic intensity, which enclose a central area of dominantly low magnetic intensity. The central area includes some narrow anomalies with an indication of low-plunge isoclinal folding. The location of any drill sites is restricted to suitable topography due to the Paroo River overflow. The objective of the drill site was primarily to obtain a lithology that contains zircons (or fossils) for dating the Tongo Zone, and secondly to identify magnetic source rocks (Eugene 1 already tested magnetic anomalies further southeast). Stratigraphic hole Laurelvale 1 intersected thin- to medium-bedded turbidites, with strongly graded bedding. Fine- to medium-grained sandstone intervals will be tested for zircons, and any provenance spectrum compared with defined formations through the region and adjoining orogens to identify correlations.

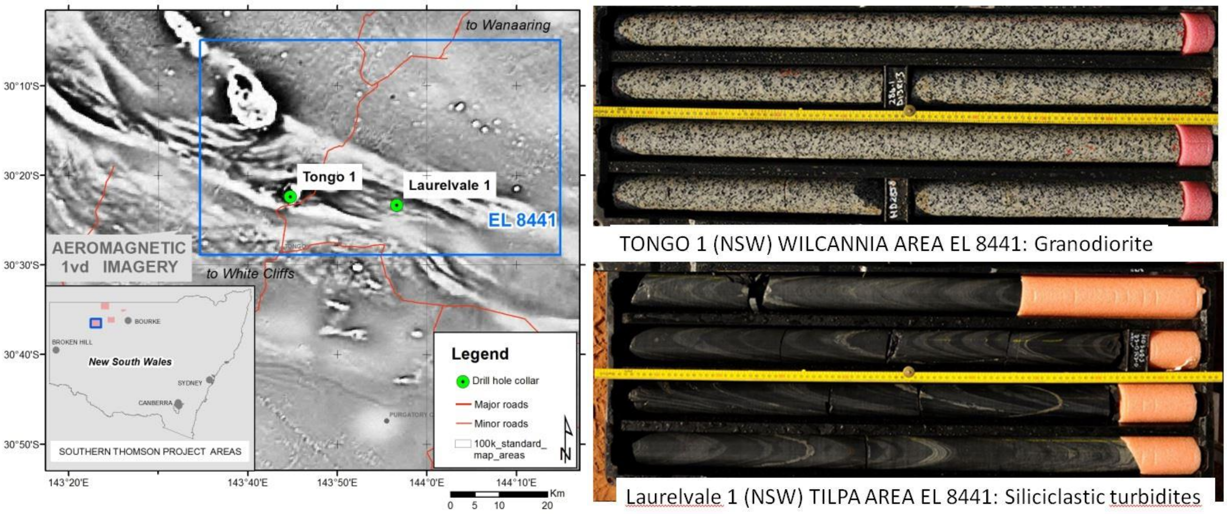

Figure 5: Location of drillholes Tongo 1 and Laurelvale 1 in EL 8441, north of Tilpa, on a greyscale 1VD RTP TMI image (left), and example core from each hole (right).

Louth–Wanaaring area

Previous mineral exploration undertaken between Louth and Wanaaring has only targeted strongly magnetic features, and these have provided five basement intercepts of quartz–feldspar porphyry, quartz diorite and diorite, collectively known as the Devonian Tinchelooka Suite (Figure 6). The surrounding lithologies are inferred from water-bore logs to be slate, biotite hornfels and granite in the Utah Lake area. Interpretive basement mapping of these rock types based on their subtle magnetic patterns is difficult, but suggests that S-type granites and their intrusive roof zones cold be present in the area. Variations in gravity data may indicate the extent of granite at, or below, the basement surface. Shallow basement (<150 m) recorded in water-bore logs was tested by AEM survey lines, and inversion models of resistive basement depth were used to select the drilling location.

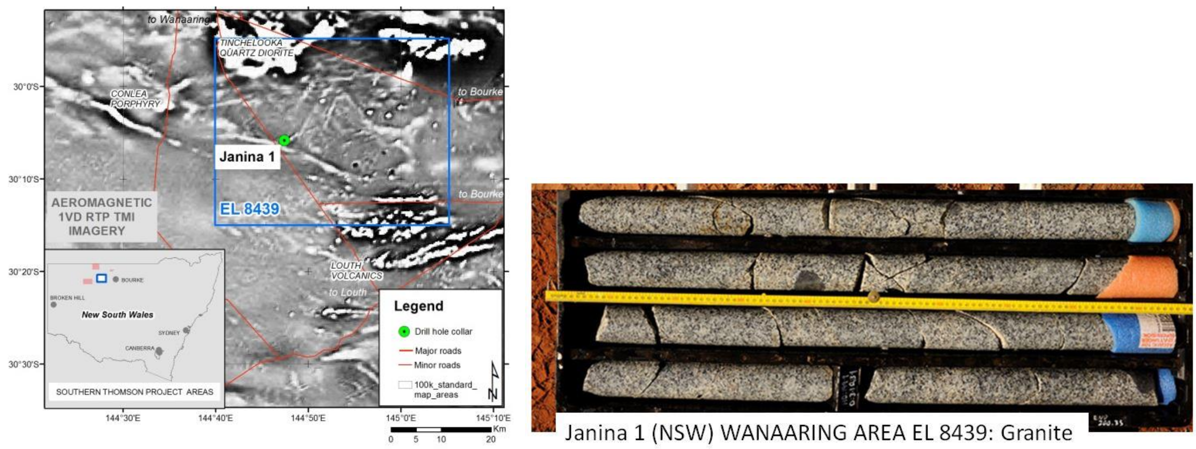

Figure 6: Location of drillhole Janina 1 in EL 8439, northwest of Louth, on a greyscale 1VD RTP TMI image (left), and example core from the hole (right).

Stratigraphic hole Janina 1 intercepted coarsely porphyritic granite. Geochronology will test proposed correlations with other non-magnetic granite plutons in the region, in particular those located north of the Mount Oxley Fault such as the Late Silurian Brewarrina Granite. Geochemistry and petrology results may suggest likely intrusion-related mineral systems.

Enngonia–Bourke area

The Culgoa aeromagnetic lineament lies within a structural shear zone that extends for over 150 km along the northern flank of the Devonian–Carboniferous Paka Tank Trough, north of Bourke. The feature is defined by a single continuous magnetic anomaly. A similar elongate magnetic trend with a curved bulbous end occurs in an area characterised by varied magnetic patterns southwest of Enngonia. In this area, basement chips of sillimanite-bearing granite at a depth of around 80 m in a water bore were reported by Byrnes (1979). About 20 km south, mineral exploration has been conducted on the northern flank of the Paka Tank Trough during the past decade (by Nimrod Resources Pty Ltd).

On the basis of AEM survey results, two stratigraphic drilling sites were selected on the western side of the Warrego River. One site tested the magnetic horizon in a site of very thin cover (Congararra 1) and the other targeted the non-magnetic area 3 km to the northwest, where cover thickness was expected to exceed 250 m (Congararra 2). Geochemistry, geochronology, structural fabrics and petrography will be used to investigate magnetic quartz–biotite schist from Congararra 1 and granodiorite from Congararra 2.

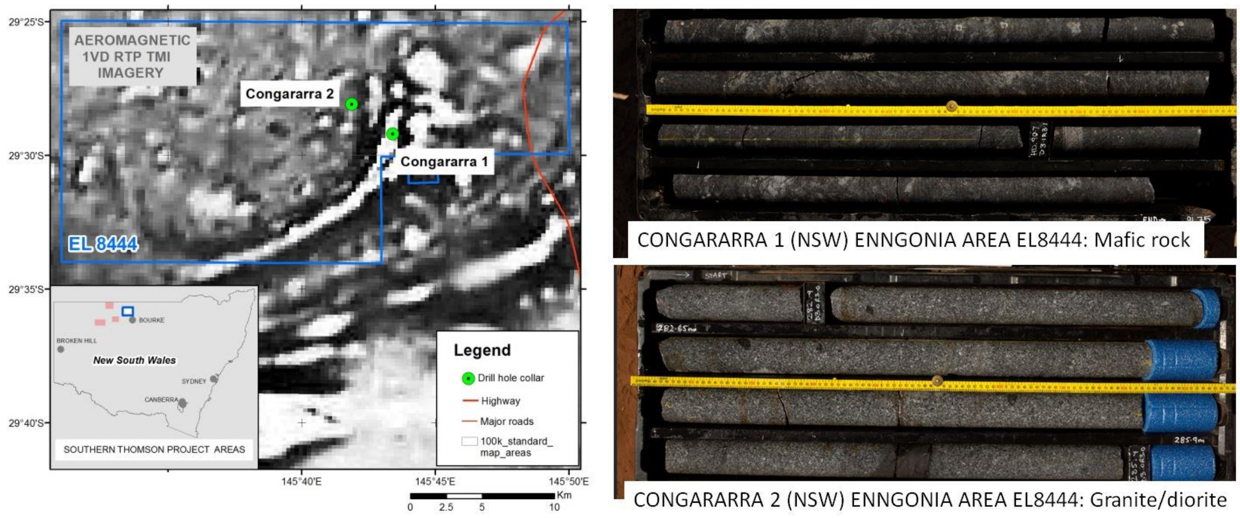

Figure 7: Location of drillholes Congararra 1 and Congararra 2 in EL 8444, north of Bourke, on a greyscale 1VD RTP TMI image (left), and example core from each hole (right).

CONCLUSIONS

Stratigraphic drilling of basement rocks has tested geophysical interpretations based on regional aeromagnetic, gravity and AEM data within four separate areas in the southern Thomson Orogen Project area in northwest NSW. All areas are completely covered by sedimentary rock sequences of the Eromanga Basin and regolith, but drilling issues were successfully overcome and core samples were obtained for multi-disciplinary geoscience studies. Methodical drill site selection has produced samples and geoscience data in key geological settings where no information was previously available. AEM surveying in 2014 and 2016 revealed areas of shallow cover, where basement rocks are present at drillable depths for mineral exploration. The NSW stratigraphic drilling sites are all located in areas where basement lies <300 m below surface, and at one site near Enngonia (Congararra 1) schist and gneiss were intersected at <60 m depth.

The program tested a wide range of geophysical features and sampled a variety of lithologies including volcanic, granitic, sedimentary and metamorphic rocks. The drilling results are consistent overall with the anticipated basement depths and lithologies. Each drill core is being investigated through geochemistry, petrophysics, petrography and isotopic analyses to establish and document its geological and deformational history. The results will add to the limited exploration and stratigraphic drilling across the wider project area, providing fresh basement information, demonstrating exploration techniques and improving understanding of the cover that masks exploration potential.

ACKNOWLEDGMENTS

The authors wish to acknowledge the many inspiring geoscientists and staff involved in the collaboration that generated the information presented, in particular; Michael Doublier, Tim Barton and Angela O'Rourke and many others from Geoscience Australia David Purdy and Dominic Brown from the Geological Survey of Queensland, and John Greenfield and other participating staff at GSNSW.

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