PACE Copper Coompana Drilling Project

Drillhole CDP004
preliminary field-data report

Rian Dutch, Mark Pawley, Tom Wise, Liz Jagodzinski, Luke Tylkowski, Amy Lockheed, Sarlae McAlpine and Philip Heath

Report Book 2017/00040

PACE Copper

Australian Government
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SOUTH AUSTRALIA

Government of South Australia
Department of the Premier and Cabinet

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Geological Survey of South Australia
Resources and Energy Group
Department of the Premier and Cabinet

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ABSTRACT

The Geological Survey of South Australia, in partnership with Geoscience Australia, is undertaking a regional pre-competitive geoscience research drilling program in the far west of South Australia called the Coompana Drilling Project. The Coompana Province, located between the western Gawler Craton to the east, the Musgrave Province to the north and the Madura Province to the west, is one of the least understood and explored geological provinces remaining on the Australian Continent. The region is completely covered by Neoproterozoic to Cenozoic sediments and there are no known basement exposures. Up to 18 new drillholes were planned as part of this project to intersect as many of the different geophysical domains as possible, as delineated from the recently acquired Coompana Magnetic survey and Coompana Gravity survey.

The primary objective of the Coompana Drilling Project is to obtain high quality drill core samples from the untested basement units beneath the Nullarbor Plain. The outcome of the Coompana Drilling Project will be to provide our stakeholders with new pre-competitive data and a geological framework that more clearly defines the geology and prospectivity in this region. This report provides the first release of the preliminary data collected on-site during the drilling of drillhole CDP004. This compilation includes well completion information, location and site access data, results of pre-drilling cover geophysics and depth estimates as well as the field geological logs and acquired down-hole geophysical data.

INTRODUCTION

PROJECT BACKGROUND

The Geological Survey of South Australia (GSSA), part of the Department of the Premier and Cabinet, in partnership with Geoscience Australia (GA) is undertaking a regional pre-competitive geoscience research drilling program in the far west of South Australia: The Coompana Drilling Project.

The GSSA and GA are committed to driving scientific understanding and discovery beneath post-mineralisation cover in South Australia through pre-competitive data capture and knowledge value-add. These goals are aligned with the objectives set out in the National Mineral Exploration Strategy and the UNCOVER Initiative.

The Coompana Drilling project forms a major part of, and is funded through, the Far West Discovery Program component of the South Australian Governments $20M *PACE* Copper initiative. Additional funding for the project comes from Geoscience Australia and the Australian Federal Governments Exploring for the Future initiative.

The Coompana Drilling Project is the next phase in a staged pre-competitive geoscience data acquisition program for the far west of South Australia which includes:

- The deep crustal seismic profile 13GA-EG1 (Eucla-Gawler seismic line). A collaborative project between the GSSA, GA, The Geological Survey of Western Australia and AuSCOPE.
- The Coompana airborne magnetic and radiometric survey. Currently the largest single survey in South Australia acquired by GA on behalf of the GSSA and funded through the *PACE* Frontiers initiative.
- The Coompana Gravity Survey. A regional 2, 1 and 0.5 km gravity survey to be acquired as part of the Far West Discovery Program component of the South Australian Governments *PACE* Copper initiative.

All data and reports associated with the Coompana Drilling Project and associated geophysical acquisitions is available from the GSSA Coompana Project website (http://minerals.dpc.sa.gov.au/geoscience/geological_survey/gssa_projects/far_west) and the South Australian Resources Information Gateway (https://map.sarig.sa.gov.au/).

PROJECT OVERVIEW

The Coompana Province is one of the least understood geological provinces remaining on the Australian Continent. The region is completely covered by Neoproterozoic to Cenozoic sediments and there are no known basement exposures. Limited previous exploration in the province resulted in 16 existing drillholes that intersect basement, only 8 of which are diamond holes (Fig. 1; Table 1). Because of these factors the geology and mineral prospectivity of the region is largely unknown.

Geographically, the Coompana Province is located under the Nullarbor Plain, across the SA/WA border. Geologically, the Coompana Province is situated at the nexus between the West, South and Northern Australian Cratons(Fig. 2), and may record the final amalgamation of the proto-Australian Continent during the Mesoproterozoic.

Due to the absence of basement outcrop, the newly acquired Coompana airborne magnetic survey (Fig. 3a) and Coompana gravity survey (Fig. 3b) have been used to sub-divide the Coompana Province into a series of domains with distinct geophysical characteristics (Fig. 4; See Wise, et al. (2015) for preliminary domain definitions based on the Coompana magnetic survey). These are interpreted to represent regions with distinct lithologies and geological histories. The aeromagnetic domains are consistent with the crustal blocks recognised in the 13GA-EG1 deep crustal seismic profile (Dutch, et al., 2016b). The SA Coompana Province also hosts a number of intriguing geophysical anomalies including the enigmatic Coompana Magnetic Anomaly (Fig. 3a; Wise, et al., 2015). This ~50 km wide deep seated remanently magnetised anomaly is associated with a low density signature (Fig. 3b). The cause and significance of this anomaly is currently unknown.

Drillhole locations (Fig. 4) have been planned to intercept as many of the different geophysical domains as possible. These domains include the moderate magnetic intensity, low density domains with a defined NNE trending fabric (Domain 1; Fig. 4) which likely represent the oldest protoliths in the region. Domain 2 is characterised by a variable, mottled magnetic signature with both high and low densities which may represent reworked basement by subsequent granitic intrusions (Fig. 4). Domain 3 includes the prominent NE trending line of magnetic intrusions that bisects the province (Fig. 4). Finally, there is the main remanently magnetised Coompana Magnetic Anomaly itself and a number of possibly associated smaller satellite intrusions located coincident and adjacent to the main magnetic anomaly, but which are associated with density highs.

Approximately 18 new drillholes were planned as part of this project to intersect the above domains and other structures seen in the geophysical data (Fig. 4). The drillholes are located in the far south-west of South Australia: south of the Trans-Australia Railway, east of the SA/WA border, west of a line ~130.00°E and north of the Eyre Highway (Fig. 5).

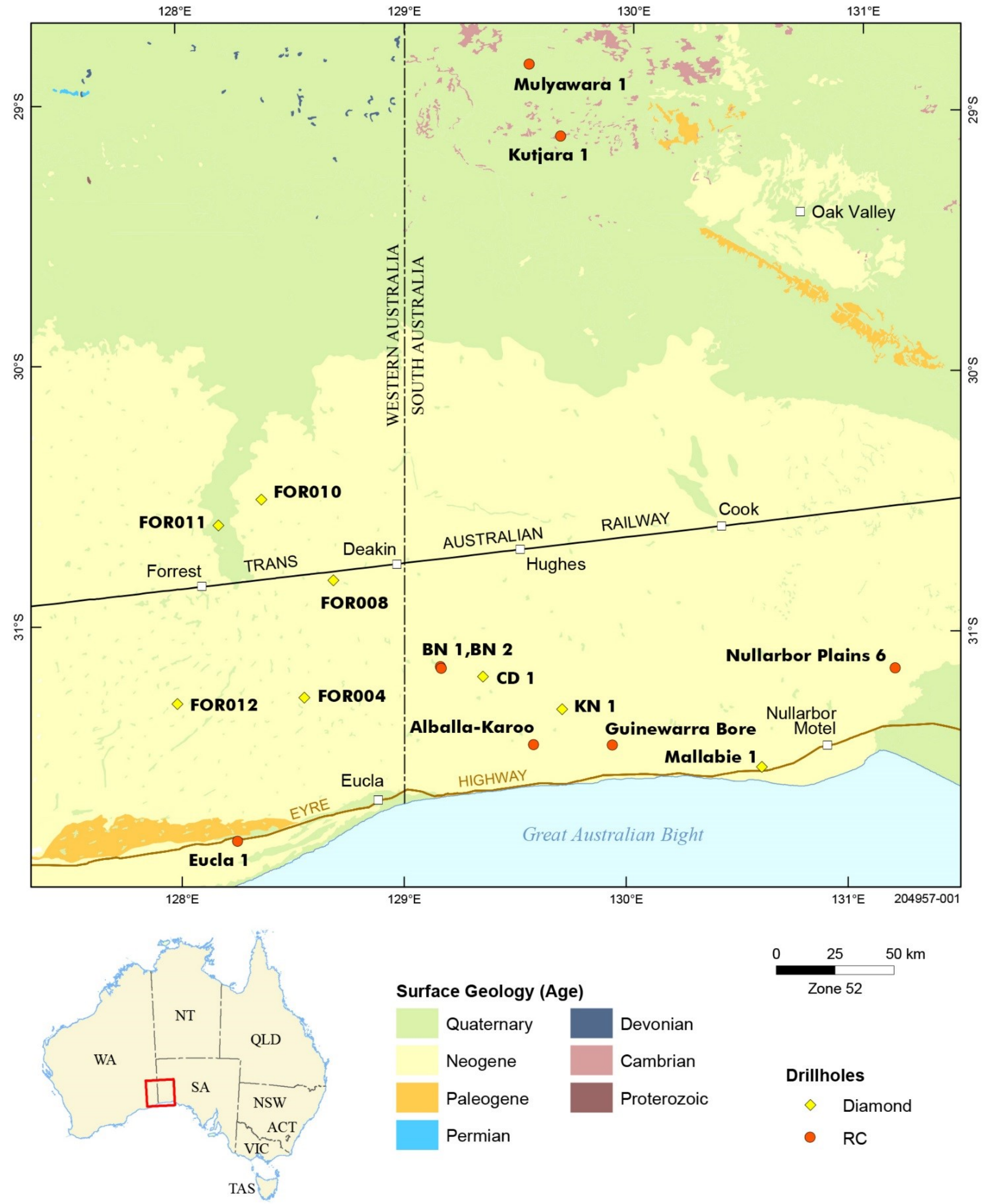

Figure 1. Location of the Coompana Province with existing drillhole locations on 2 million scale surface geology.

Table 1. Summary of basement-intersecting drillholes in the Coompana Province

Drillhole	Geology	Unit	Magmatic age (Ma)	Metamorphic age (Ma)	Geochron reference	Drillhole reference
Guinewarra Bore	Granitic basement					
Alballa-Karoo	Granitic basement					
Nullarbor Plains 6	Granitic basement					
FOR004	Granitic basement	Toolgana Supersuite	1613 ± 4; 1611 ± 7	1179 ± 10	1	2
FOR008	Granitic basement	Toolgana Supersuite	1613 ± 13; 1604 ± 6	1150 ± 10	1	2
Kutjara 1	Granitic basement	Toolgana Supersuite	1591 ± 11	1167 ± 7	3	4
Mallabie 1	Granitic basement	Undawidgi Supersuite	1505 ± 7		5	6
FOR012	Granitic basement	Undawidgi Supersuite	1499 ± 9		1	2
FOR011	Granitic basement	Undawidgi Supersuite	1488 ± 4	1174 ± 12	1	2
FOR010	Granitic basement	Undawidgi Supersuite	1487 ± 9		1	2
Mulyawara 1	Granitic basement	Moodini Supersuite	1168 ± 6		3	7
Eucla 1	Granitic basement	Moodini Supersuite	1140 ± 8		1	2
CD 1	Mafic volcanics and intrusives	Neoproterozoic volcanics	859 ± 66		8	9
BN 2	Mafic volcanics and intrusives	Neoproterozoic volcanics				10
BN 1	Mafic volcanics and intrusives	Neoproterozoic volcanics				10
KN 1	Mafic volcanics and intrusives	Neoproterozoic volcanics				11

References: 1. Wingate, et al. (2015); 2. Spaggiari and Smithies (2015); 3. Neumann and Korsch (2014); 4. Baily, et al. (2012a); 5. Wade et al. (2007); 6. Outback Oil Company NL (1969); 7. Baily, et al. (2012b); 8. Travers (2015); 9. The Shell Co. of Australia Ltd (1983); 10. Carpentaria Exploration Co. Pty Ltd (1982a); 11. Carpentaria Exploration Co. Pty Ltd (1982b).

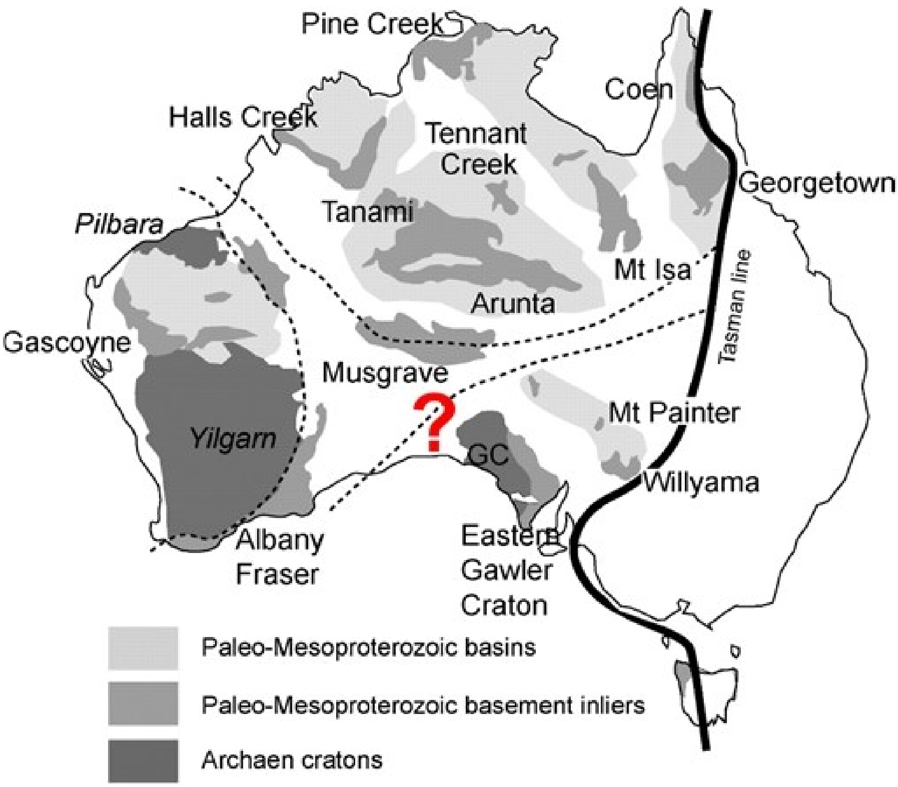

Figure 2. Map of Australia showing the old cratonic blocks that make up the continent (After Myers, et al., 1996)**.** The highlighted Coompana Province area beneath the Nullarbor Plain sits at the contact between the Yilgarn and Gawler (GC) cratons.

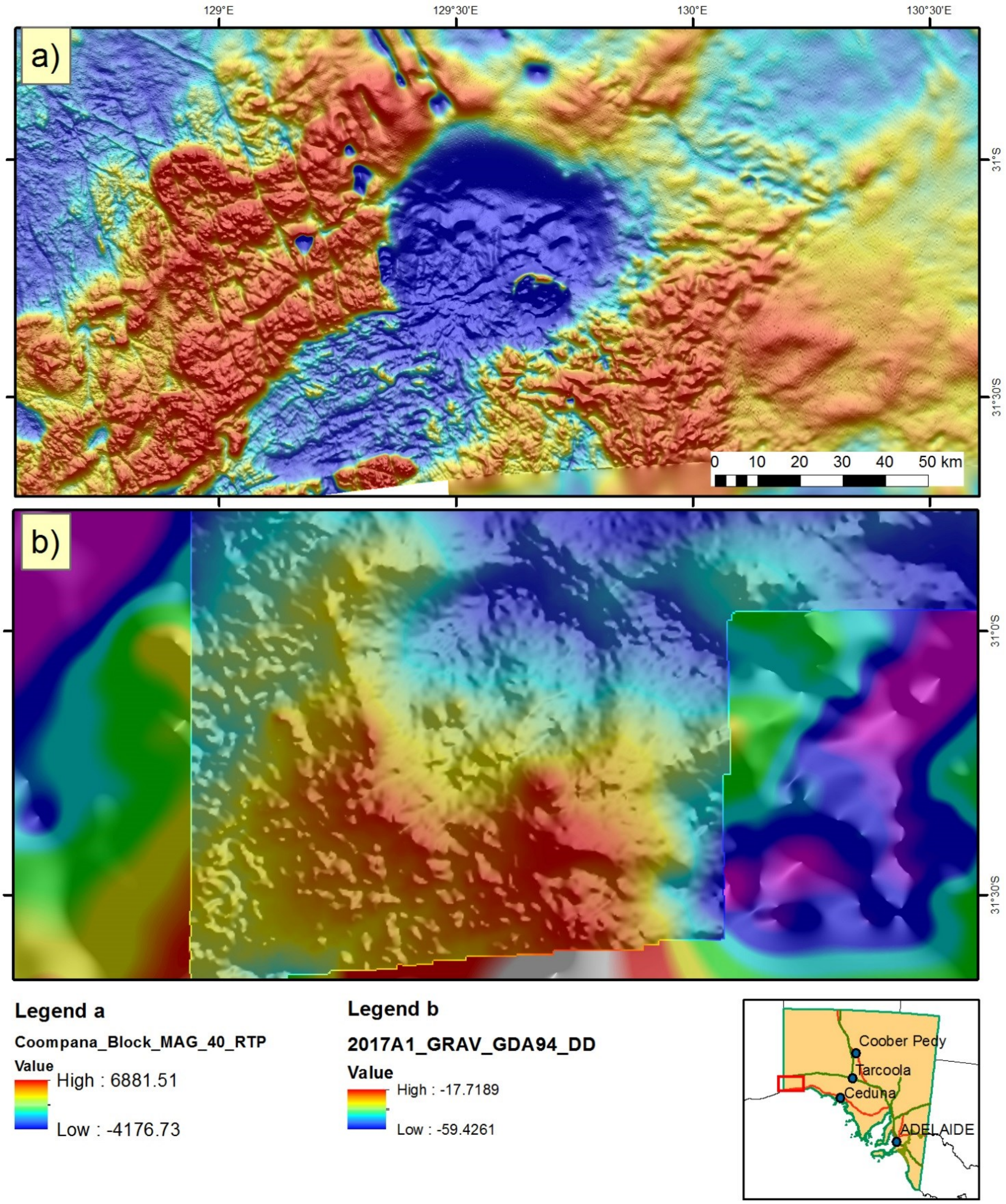

Figure 3. Newly acquired Coompana magnetic and gravity data. a) 200 m and 400 m line spaced Coompana RTP magnetic grid. **b)** 1 km and 0.5 km spaced Coompana gravity grid over regional onshore gravity data.

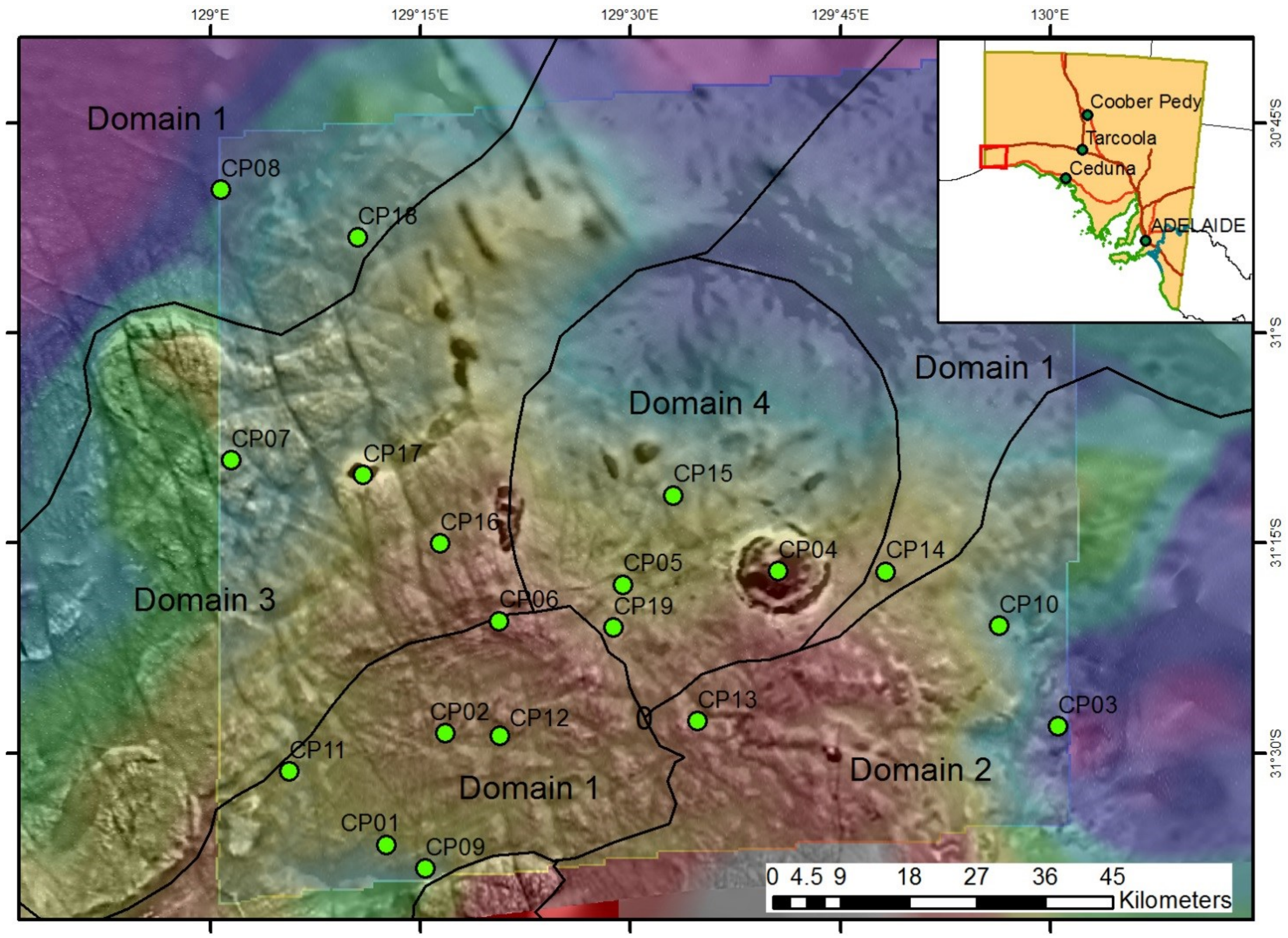

Figure 4. Coompana Province interpreted basement domains with planned drillhole locations. The image is a composite with Bouger gravity (colour) beneath grayscale 1VD total magnetic intensity (TMI). The interpreted domains are preliminary and based on both the TMI and gravity response and extend the preliminary domains proposed by Wise et al. (2015).

PROJECT OBJECTIVES

The primary objective of the Coompana Drilling Project is to address this lack of knowledge and test geophysically derived geological models by collecting high quality drill core samples from the untested basement units beneath the Nullarbor Plain. The outcome of the Coompana Drilling Project will be to provide our stakeholders with new pre-competitive data and a geological framework that more clearly defines the geology and prospectivity in this region.

The Project aims to:

- Undertake rigorous scientific analysis of the retrieved samples to improve our understanding of the stratigraphy and tectono-thermal history of the region, to generate a knowledge-framework to understand the geological significance and potential for different mineral systems in the buried basement rocks beneath the Nullarbor Plain.
- Provide new pre-competitive geological, geophysical and geochemical data in an under-explored greenfields area. This new data will be used to map cover thickness and character, identity possible distal footprints of buried mineralisation or mineralised terranes and estimate the depth to target source rocks which may have economic potential for various commodities.
- Be an exemplar for reducing exploration risk in challenging greenfields regions and provide generic work flows and understanding that will be applicable for exploration and discovery in the far west of South Australia, utilising a best practice approach to environmental protection and safety in this sensitive and logistically challenging area.

- Enhance each Project Parties organisational capabilities in drilling as a pre-competitive data product for research and industry through exposure to standard drilling technologies as well as innovative technologies where deemed appropriate.
- Allow use of the data by a broad range of State and Federal government agencies, researchers and private companies engaged in natural resources and water management.

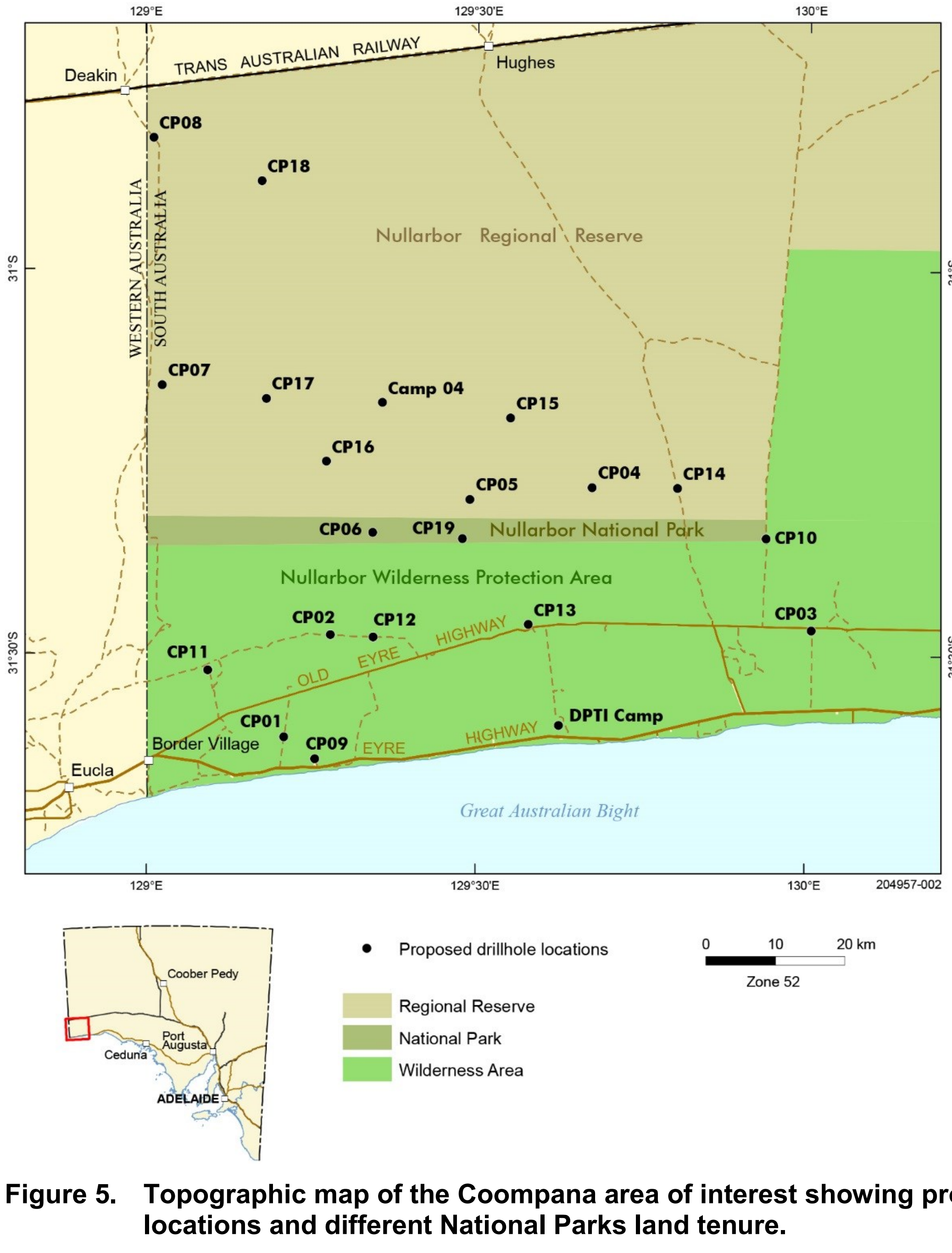

Figure 5. Topographic map of the Coompana area of interest showing proposed drillhole locations and different National Parks land tenure.

LAND TENURE, GEOGRAPHY AND ACCESS

The area of the planned Coompana Drilling project occupies three different land tenures (Fig. 5). Drill sites located south of a line -31.3°S fall within the recently proclaimed Nullarbor Wilderness Area, a single proclamation wilderness protection area. Drill sites located north of this line fall within the Nullarbor National Park and the Nullarbor Regional Reserve, both dual proclamation conservation reserves. The entire area is within the determined Native Title claim of the Far West Coast Aboriginal Corporation.

Access to the Coompana Drilling Project area is either via the Eyre Highway or the Trans-Australia railway access road. Access to the proposed drill sites is via established park roads (including the old Eyre Highway and Koonalda Station tracks), previous exploration tracks and some new tracks within the Regional Reserve. No new tracks will be created within the Nullarbor Wilderness Area.

The nearest populated centers are Eucla and Border Village located at the SA/WA border, the Nullarbor Roadhouse and Cook railway siding. The nearest major center is Ceduna, ~500 km east along the Eyre Highway

PURPOSE OF THIS REPORT

This report represents a progressive update and data release during the operational phase of the Coompana Drilling Project. The results presented here are preliminary in nature and are intended for reference purposes only. All care has been taken to ensure accuracy but this represents field data acquired at site and is subject to revision, updating and subsequent QA/QC processes.

GEOLOGICAL OVERVIEW

COVER SEQUENCES

The cover overlying the Coompana Province in the study area is interpreted to comprise three main packages; the Carboniferous-Permian Denman Basin, Jurassic-Cretaceous rocks of the Bight Basin and the Tertiary Eucla Basin.

Carboniferous-Permian Denman Basin

The Denman Basin is an intracratonic, north-northwest-trending, fault-bounded trough ~200 km long and between 20–70 km wide (Hibburt, 1995). The sedimentary package in the trough varies from 300 m thick in the north, to 1000 m thick in the south.

The basin is filled with Permian sediments that unconformably overly the basement, and are unconformably overlain by Cretaceous and Tertiary rocks. The rocks are glacial at the base, and up sequence are interpreted to represent progressive de-glaciation and glacio-eustatic marine transgression.

Jurassic-Cretaceous Bight Basin

The Jurassic-Cretaceous Bight Basin is a large, mainly offshore basin that extends along the southern Australian margin (Hill, 1995). The basin contains a Middle Jurassic to Late Cretaceous sedimentary succession that is unconformably overlain by the Eucla Basin.

LOONGANA FORMATION

The Early Cretaceous Loongana Formation is a sandy to shaly succession with a maximum thickness of 324 m (Hill, 1991; 1995). The unit has been formally described as “Cross-bedded feldspathic sandstone, locally conglomeratic, carbonaceous sandstone; glauconitic sandstone, siltstone, claystone and shale; commonly pyritic” (Geoscience Australia and Australian Stratigraphy Commission, 2017). The rocks are interpreted to represent an initial rift phase in a terrestrial low-sinuosity fluvial environment within isolated grabens of the developing rift valley (Hill, 1995).

MADURA FORMATION

The Early Cretaceous Madura Formation conformably overlies the Loongana Formation. The Madura Formation has a maximum thickness of 474 m, and has been formally described as “Carbonaceous or glauconitic sandstone, siltstone, and claystone and shale; commonly pyritic” (Geoscience Australia and Australian Stratigraphy Commission, 2017). The sediments were interpreted to have been deposited in a marine environment with limited circulation suggested by low-energy lacustrine conditions (Hill, 1995).

Tertiary Eucla Basin

The Tertiary Eucla Basin comprises a widespread, thin package of marine and terrestrial sediments that were deposited on the passive margin along southern Australia.

PIDINGA FORMATION

The lower unit is the Pidinga Formation. This is a 30–60 m thick package of carbonaceous, terrigenous clastic sedimentary rocks that were deposited in topographically low settings, such as palaeochannels and broader depressions (Benbow, et al., 1995). The Pidinga Formation has been formally described as "Interbedded, well-sorted, fine to coarse-grained carbonaceous sand and silt with minor lignite. Flood zone clays and lignite, fluvial/estuarine channel sands, gravelly (carboneous) coarse sands" (Geoscience Australia and Australian Stratigraphy Commission, 2017).

HAMPTON SANDSTONE

The Pidinga Formation is overlain by the Hampton Sandstone. This unit comprises quartz-rich sands that were deposited as lenses and sheets in marine, estuarine and fluvial environments (Benbow, et al., 1995). The Hampton Sandstone has been formally described as "Poorly sorted limonite-stained sandstone, typically quartz rich; includes subordinate gravel, conglomerate and siltstone" (Geoscience Australia and Australian Stratigraphy Commission, 2017).

WILSON BLUFF LIMESTONE

The Wilson Bluff Limestone overlies the Hampton Sandstone. The Wilson Bluff Limestone is <150 m thick east of the Coompana Block, increasing westwards to ~300 m thick in Western Australia (Benbow, et al., 1995). The unit has been formally described as "Wackestone, white to grey; skeletal mudstone; rudstone and minor packstone. Locally laminations and scour channels, infilled with coarser material" (Geoscience Australia and Australian Stratigraphy Commission, 2017). The limestone is interpreted to have been deposited during marine transgression on a drowned carbonate platform (Benbow, et al., 1995). This is the rock that forms the whitish cross-bedded and parallel-bedded unit in the lower parts of the Bunda Cliffs.

ABRAKURRIE LIMESTONE

The Abrakurrie Limestone is thin (generally <10 m thick) unit that overlies the Wilson Bluff Limestone, and forms a distinct yellow-brown band in the Bunda Cliffs (Benbow, et al., 1995). The Abrakurrie Limestone has been formally described as "Yellowish coarse-grained bryozoan calcarenite and calcirudite, distinctly cyclic, and contains numerous hardgrounds; locally dolomitized" (Geoscience Australia and Australian Stratigraphy Commission, 2017). The limestone is interpreted to have been deposited on partly to completely drowned platform (James and Bone, 1991).

NULLARBOR LIMESTONE

The Nullarbor Limestone is a 20–35 m thick unit that overlies the Abrakurrie Limestone, and forms the 'lumpy' brown, parallel-bedded unit at the top of the Bunda Cliffs (Benbow, et al., 1995). The unit has been formally described as "Limestone, bioclastic, micritic. Subtidal, platformal, above fair weather wave-base. Includes large benthic foraminifera and aragonitic material; well-cemented" (Geoscience Australia and Australian Stratigraphy Commission, 2017). The limestone is interpreted to have been deposited in a shallow platform setting, with the paucity of terrigenous material suggesting river systems carried little debris to the coast (James and Bone, 1991).

BASEMENT

Recent drilling by the Geological Survey of Western Australia (Spaggiari and Smithies, 2015) has begun to shed light on the evolution of the region, indicating a complex multi-phase history beginning with interpreted Paleoproterozoic oceanic crust formation. This was followed by magmatic events, associated with subduction and crustal reworking, throughout the Mesoproterozoic (Spaggiari and Smithies, 2015; Dutch, et al., 2016a; Kirkland, et al., 2017).

Isotopic constraints indicate the development of oceanic crust at c. 2000–1900 Ma. There is no direct geological evidence for this event (Kirkland, et al., 2017).

This was followed by widespread arc magmatism and recycling of the oceanic crust at c. 1610 Ma, which resulted in the Toolgana Supersuite (Spaggiari and Smithies, 2015). The Toolgana Supersuite comprises granitic to monzodioritic rocks with compositions that suggests a subduction-modified mantle source. In particular, the rocks appear to be derived from a mantle wedge or subduction-modified lithosphere (Wingate, et al., 2015; Kirkland, et al., 2017). In drill core, GSWA found the Toolgana Supersuite to include locally migmatitic monzodioritic to granodioritic to monzogranitic gneisses and metadolerites that have been metamorphosed to amphibolite facies (Spaggiari and Smithies, 2015). The Toolgana Supersuite is the same age as, and is geochemically and isotopically similar to, the St Peter Suite in the western Gawler Craton (Wingate, et al., 2015; Dutch, et al., 2016a).

The Toolgana Supersuite was followed by c. 1500 Ma extension and rift-related c. 1490 Ma Undawidgi Supersuite magmatism in the west. This supersuite includes metagranitic and possible bimodal metavolcanic rocks that are derived by melting of lower mafic crust and the introduction of a mantle component. They are also interpreted to include recycled Toolgana Supersuite material (Wingate, et al., 2015). In drill core, GSWA found the Undawidgi Supersuite to include: variably foliated metatonalites and metamonzogranites, which are locally gneissic and migmatitic; metamonzodiorites; and variably sheared/mylonitic felsic and mafic schists. The felsic schists are interpreted to have a monzogranitic or volcanic protolith (Spaggiari and Smithies, 2015). The Undawidgi Supersuite is similar in age to the granodiorite gneiss from Mallabie 1 to the east of the current project (Fig. 1; Wade, et al., 2007).

Major extension at c. 1200–1120 Ma resulted in crustal thinning and widespread reworking of the crust. Reworking included generation and intrusion of the widespread intraplate c. 1190–1140 Ma Moodini Supersuite (Spaggiari and Smithies, 2015). In the western Coompana Province, this supersuite comprises high-KMg shoshonitic magmas that are bimodal with mafic and felsic compositions. The compositions are interpreted to reflect deep melting of wet, oxidised modified mantle lithosphere, indicating that the western Coompana Province retained a thick lithosphere into the c. 1200–1120 Ma event. This contrasts with the Madura Province to the west, where compositions suggest highly extended, dry and reduced crust with little or no remaining lithosphere (Wingate, et al., 2015). In drill core, GSWA found the Moodini Supersuite to include: equigranular to porphyritic, massive syenogranites, shoshonites and monzogranites that form thin sheets that cut the earlier foliations at variable angles (Spaggiari and Smithies, 2015). The magnetotelluric data suggests that some of the crustal-scale structures and crustal blocks are conductive, representing significant fluid flow and magmatic processes, such as MASH zones (Thiel, et al., 2016). This extensional event in the Coompana Province (and Madura Province to the west) coincides with Stage II of the Albany–Fraser Orogeny to the west, and the Musgravian Orogeny to the north. This widespread event, which affected the crust between the Yilgarn, Gawler and North Australian cratons has been called the Maralinga Event.

BOREHOLE DATA

Site ID: CP08	
Hole ID: CDP004	
Easting (MGA z52J)	501181
Northing (MGA z52J)	6589229
Latitude (WGS84)	-30°49’48”
Longitude (WGS84)	129°00’45”
Elevation (m)	~120
Bore Spud Date	2/06/2017
Bore Completion Date	5/07/2017
Total Depth (m)	681.4
Drilling Contractor	Boart Longyear Australia Pty Ltd
Drilling Supervisor Name	B Vandekamp, N Hodgetts
GSSA Drilling Coordinator Name	L Tylkowski/A Lockheed
On-site Geologist Name (Pre-collar)	L Tylkowski/A Lockheed
On-site Geologist Name (Diamond Coring)	S McAlpine/M Pawley

SITE ACCESS

CDP004 is located approximately 95km north of Border Village. The site is located on the Deakin Track approximately 6km south of the Great Southern Railway. It is accessed from the Eyre Highway from Eucla along well-maintained access tracks to the Nullarbor Links Golf Course, and the Deakin Track. CDP004 is located within the Nullarbor Regional Reserve.

Land Tenure	Wilderness Area ☐	National Park ☐	Regional Reserve ☒
	DPTI ☐		
Associated PEPR	Coompana Stage 1 ☐	Coompana Stage 2 ☒	
Heritage Survey Undertaken	Yes ☒	No ☐	
DEWNR Permit Number	Q26618-1		

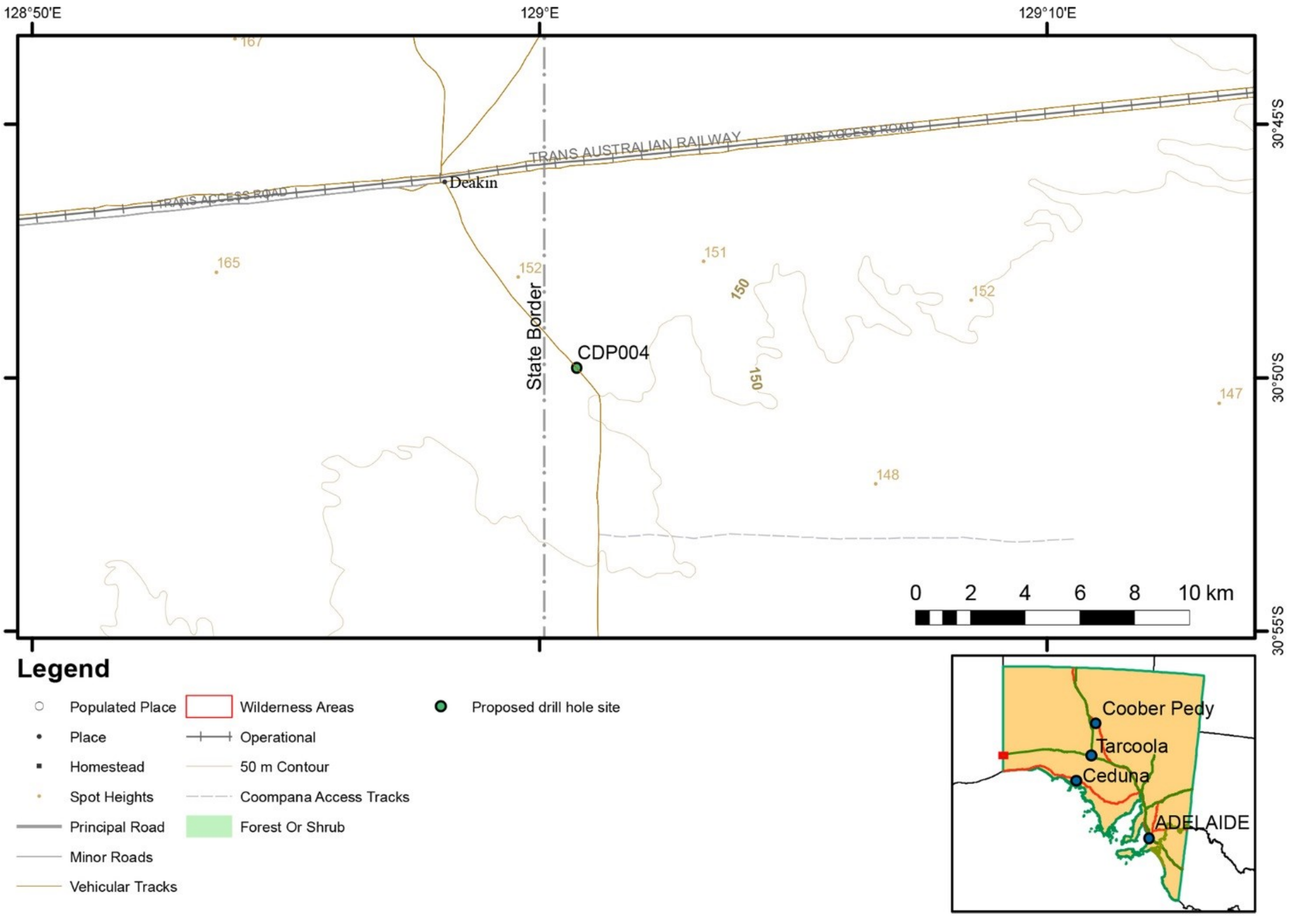

Figure 6. Site access map for site CDP0014 on 1:250 000 scale topographic map.

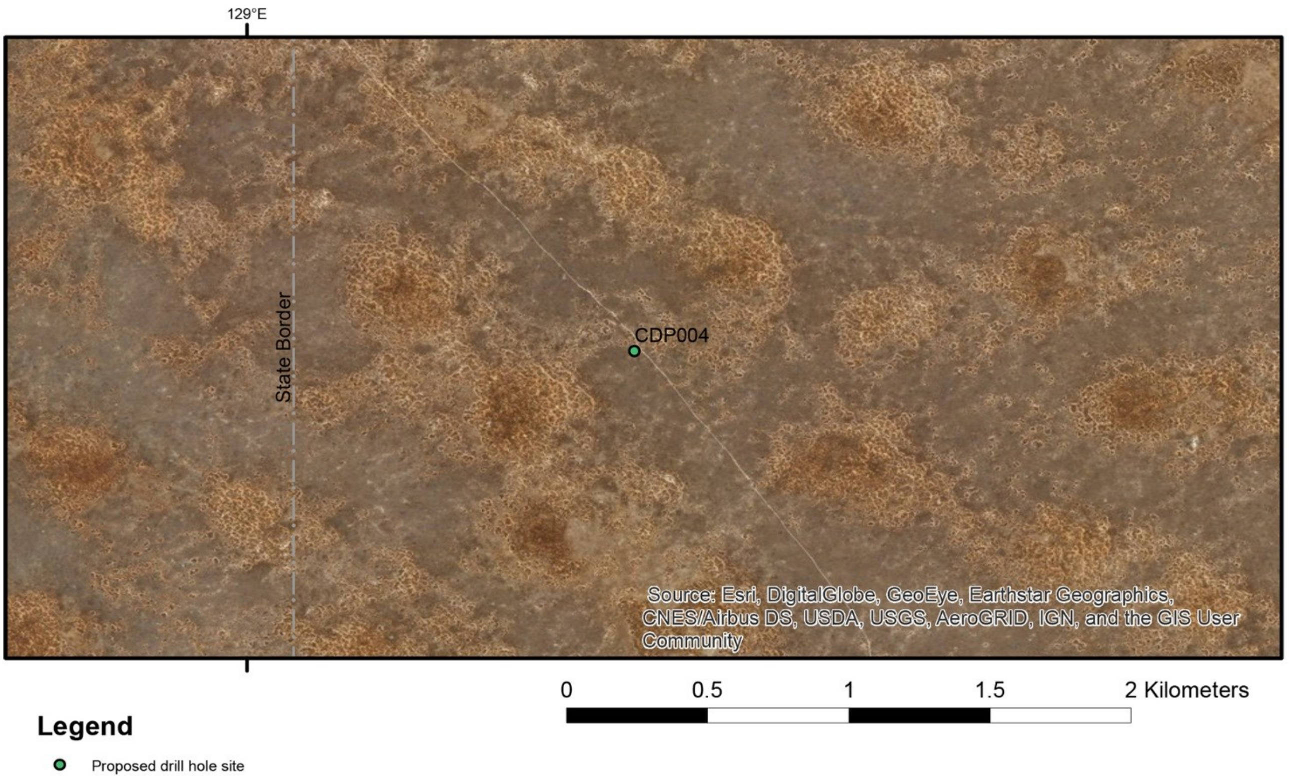

Figure 7. Orthoimage of site CDP004.

DRILLHOLE TARGET

CDP004 targets a zone that is characterised by relatively low magnetic response comprising concentric patterns and areas with a variably developed northeast-striking grain (CP08 Fig. 4). It is unclear if the concentric areas represent folded layered rocks or if they're zoned plutons, although both may be present. The layered rocks would represent the basement in this area, and form part of the Deakin Domain.
Based on work from further north (i.e. Kutjara 1 and Mulyawara 1) and across the border in WA (Wingate et al., 2015) the layered rocks are likely be the c. 1610 Ma Toolgana Supersuite, which is a package of metamorphosed mafic to felsic igneous rocks. These rocks will likely have a c. 1200-1120 Ma metamorphic overprint.

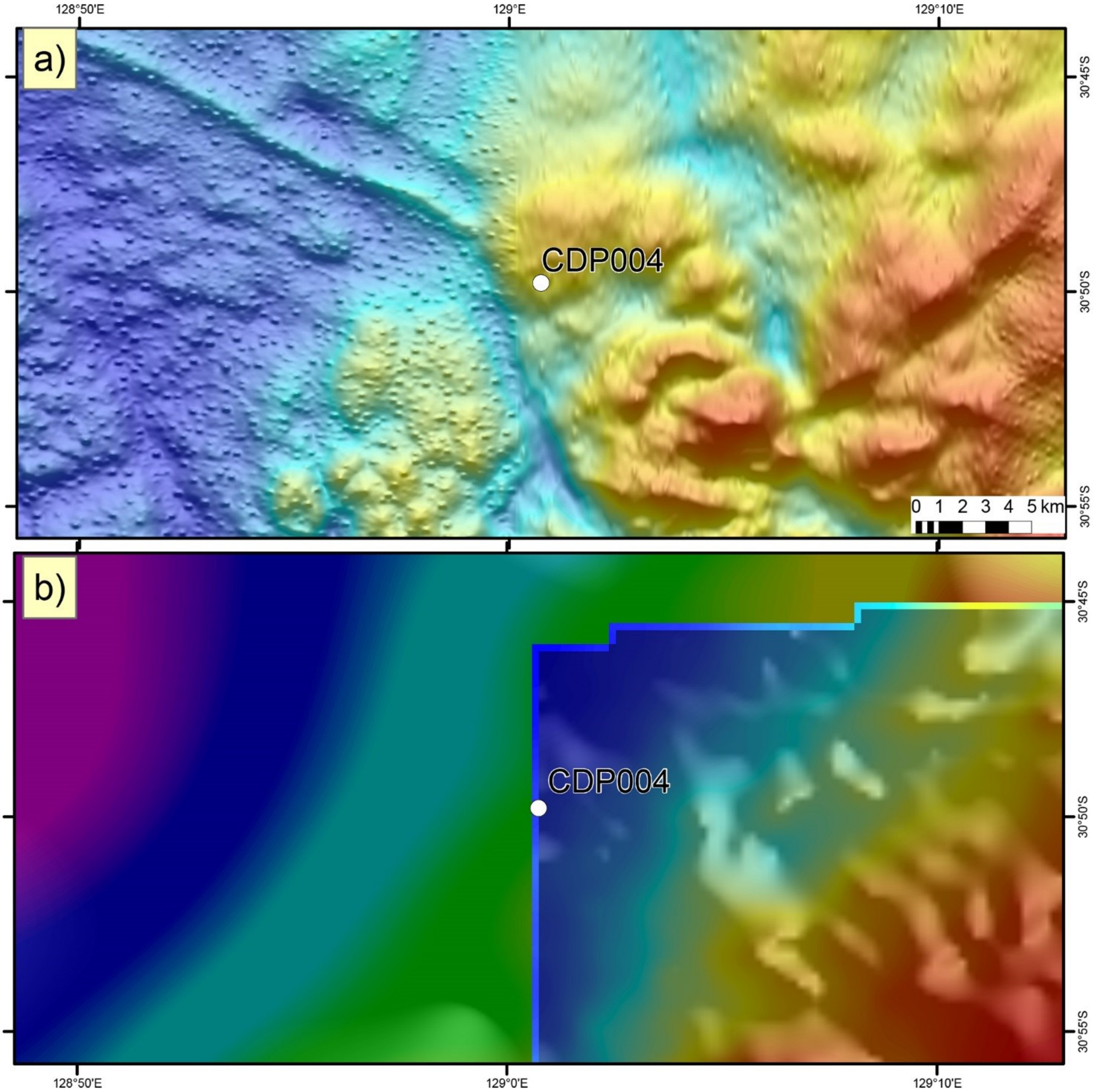

Figure 8. Site of drillhole CDP004 on a) RTP TMI and b) Bouger gravity.

DRILLING SPECIFICATIONS

Bore inclination (deg):	-85°			
Bore Azimuth (deg):	000°			
Pre-collar 1 Limestone	From (m): 0		To (m): 136.60	
	RC ☒	Mud rotary ☐	Diamond ☐	DTFR ☐
	Rig Type	Schramm T130 RC Air rotary with water injection		
Pre-collar 2 Soft seds	From (m): 136.60		To (m): 444.6	
	RC ☐	Mud rotary ☒	Diamond ☐	DTFR ☐
	Rig Type	Schramm T130 Mud rotary		
Diamond Tail	Length (m): 236.80			
	Rig Type	UDR1200		
Diamond Core size	PQ (85 mm) ☐	HQ3 (61.1 mm) ☒	NQ2 (45 mm) ☐	
Casing Specifications	1st casing to isolate limestone. Cased to basement			
Casing Notes	1st casing is 6 5/8” to 136.60m, 2nd casing HWT to 444.60m.			
Casing Retrieved	Pre-collar 1 Yes ☐ No ☒	Pre-collar 2 Yes ☒ No ☒	Stratigraphic Hole ☐	
Casing Retrieval Notes	1st level of casing (6 5/8”) could not be retrieved. 2nd level HWT casing was cut at 198m, with that length retrieved.			
Water Source	Eucla ☐	Border Village ☒	KN1 ☐ KN2 ☐	Other ☐
Borehole Abandonment	Abandoned according to regulatory requirements: Yes ☒ No ☐			
Borehole Abandonment Notes	Borehole abandoned by placing a Van Ruth plug and grouting with cement from 150m to surface to isolate the unconfined aquifer in the Wilson’s Bluff Limestone.			
Additional Notes				

PRE-DRILLING GEOPHYSICS AND DEPTH ESTIMATES

Prior to the commencement of drilling, a number of geophysical techniques were trialled to ascertain their effectiveness at determining the thickness and nature of the cover units overlying the Nullarbor basement rocks. This work was done in conjunction with GA and the CSIRO. A combination of Audio Magnetotellurics (AMT) passive seismic and active seismic (reflection and refraction) were undertaken at selected proposed drill sites prior to drilling. For details of the methodologies and full results the reader is referred to Gorbatov, et al. (in prep.), Holzschuh, et al. (in prep.), and Jiang, et al. (in prep.). In addition to acquiring new data, depth to magnetic basement estimates were calculated using the newly acquired Coompana airborne magnetic data. The reader is referred to Foss, et al. (2017) for the full methodology and results.

Depth estimate results

Thickness of Nullarbor/Wilsons Bluff limestone	
Method	**Depth (m)**
Nearby bores	170 (BN1 ~40 km E-SE) 172 (BN2 ~40 km E-SE)
AMT	
Passive Seismic	
Active Seismic	
Depth to Basement interface	
Method	**Depth (m)**
Nearby bores	~380-385 (FOR008 ~30 km W) ~300 (BN1 ~40 km E-SE) ~280 (BN2 ~ 40 km E-SE)
Magnetic basement	~586 (2.66 km N) ~579-591 (5-6 km E)
AMT	290 ± 10%
Passive Seismic	
Active Seismic	
Depth Recorded from Drilling	
Base limestone cover	130
Basement interface	444
Pre-drilling micro-gravity undertaken	Yes ☒ No ☐
Recommendations	Hole location OK

Micro-gravity

The Nullarbor Plain is known for its large and numerous cave systems. Because of this aspect, prior to drilling a series of micro-gravity surveys were undertaken at each site in an attempt to locate the presence of large, blind, cavities that may be in the vicinity of the drill collar. The survey was undertaken using two Scintrex CG5 gravity meters on a regular grid pattern with stations spaced at 10 m intervals. The total gravity field was measured and then the regional trend has been removed in post-processing to highlight the near surface density variation. The results indicate areas of lower density in the near surface that may indicate the location of sub-surface cavities and allow the drill collar to be moved to avoid intersecting these. For a full account of the methodologies and results the reader is referred to Heath, et al. (2017).

The results for the survey around the CDP004 collar (Fig. 9) indicate a total variation in the gravity field of 0.40 mGal. The location of the collar (central point on Fig. 9) was determined to be clear of large cavities and clear to drill.

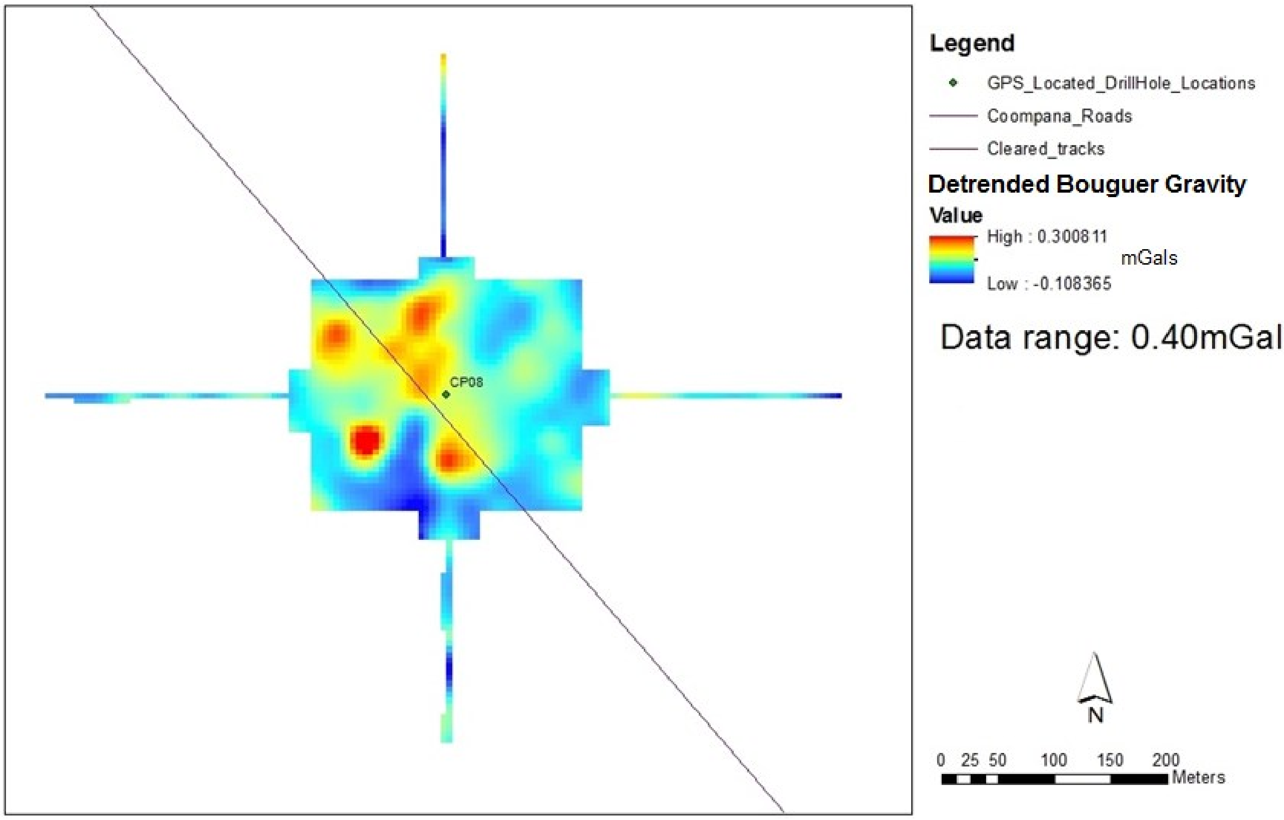

Figure 9. Microgravity survey of site CP08 (CDP004) showing a grid of the regionally de-trended isostatic gravity.

DOWN HOLE SURVEYS AND ANALYSIS

Directional survey required every 30m and EOH ☒	Multi-shot survey ☐ Single-shot survey ☒	Gyro ☐	
Core orientation required		Yes ☒Every Run No ☐	
Core Orientation Tool Used		Boart Longyear TruCore	
Downhole geophysical surveys planned		Yes ☒ No ☐	
Downhole geophysical surveys run		Yes ☒ No ☐	
Tru-scan XRF scanning run on core		Yes ☒ No ☐	
Survey Tool	**Method**	**Date**	**Run By**
Globaltech TruProbe	Wireline and In-rod	7/07/2017	T Hamon/P Clegg
Temperature Probe	Wireline in rods	6/07/2017	L Tylkowski
Temperature Probe	Wireline in open hole	7/07/2017	L Tylkowski

FIELD SUMMARY LOGS

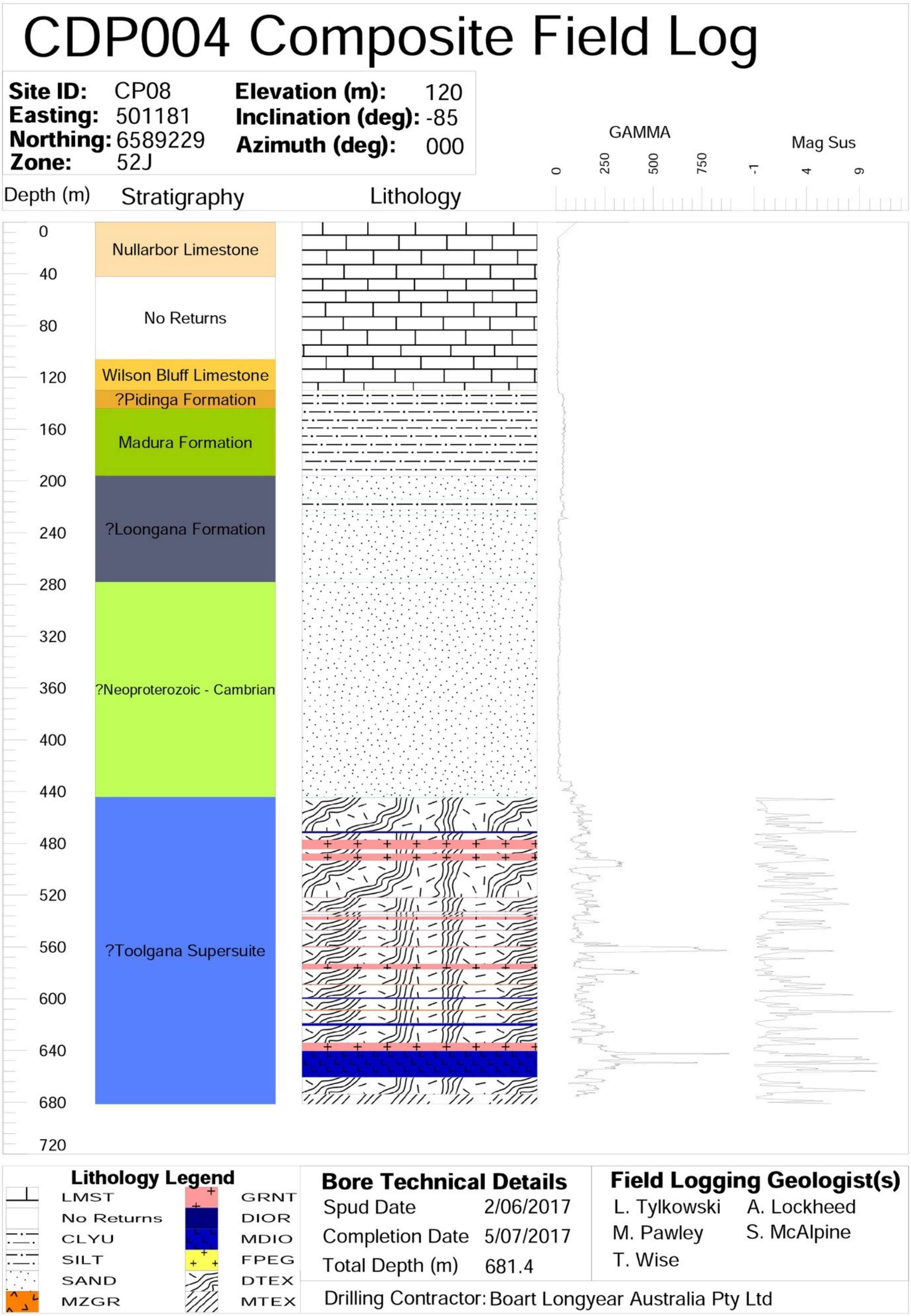

Figure 10. Summary graphic log of drillhole CDP004. Abbreviations: LMST limestone, CLYU Undifferentiated clay unit, SILT silt, SAND sand, SLST silt stone, MZGR monzogranite, GRNT granite, DIOR diorite, MDIO monzodiorite, FPEG felsic pegmatite, DTEX diatexite, MTEX metatexite.

BASEMENT LITHOLOGY DESCRIPTIONS

Schlieren diatexite (MTEX)

Fine- to very coarse-grained grey to black and white speckled, schlieric diatexite composed of feldspar, quartz and biotite (e.g. 538.88–541.05 m). The feldspar is often subhedral and up to 2 cm-across, but is also anhedral and irregular (xenocrysts). The biotite is fine- to medium-grained, generally occurs along grain boundaries, and forms schlieren. Quartz ranges from interstitial to intergrown with the feldspars. The diatexite is locally brown, medium-grained, relatively homogenous and inequigranular with irregular feldspar phenocrysts up to 1 cm across (e.g. 583.1 m). The groundmass appears to be relatively massive with igneous textures. There are scattered pegmatitic patches (e.g. 545.55) and medium-grained, mesocratic schollen (e.g. 544.20 m).

The mafic schlieren is generally at a low angle to the core and appears to meander, suggesting open recumbent folds (Fig. 11; e.g. 547.37–559.28 m and 541.05–546.8 m). The schlieren are often internally truncated, suggesting magmatic-state flow (e.g. 547.37–559.28 m and 577.22–588.76 m).

Figure 11. Representative core from CDP004 showing the schlieren diatexite (MTEX). Photograph of tray 30, showing the well-developed banding defined by darker mafic schlieren in the leucocratic groundmass (well-developed at 548.50 and 549.25 m). Folded layering can be seen at 548.50 m. A pegmatitic patch can be seen at 549.60 m.

Schollen diatexite (DTEX)

Black and white speckled, coarse-grained layered rock with local leucosomes, up to 10 cm-wide that are at a moderate angle to the core. The rock contains areas of medium- to fine-grained mesocratic foliated rock or gneiss, which are up to 30 cm-wide (e.g. 459.5 m). In places, the groundmass appears to be relatively massive with igneous textures, suggesting it is a migmatitic rock with the mesocratic blocks possibly representing schollen- i.e. schollen diatexite. The melanoocratic schollen are often back-veined by the leucosomes (Fig. 12; e.g. 501.50 m).

There are minor pegmatite patches and layers that are sub-parallel to the gneissosity. There are minor irregular patches of green, massive, medium-grained, quartz-poor dioritic material (e.g. at 469.5 m).

The layering is folded into open structures with axial planes that are at a high angle to the core, suggesting recumbent folding (e.g. 465.85 m and 505.85 m).

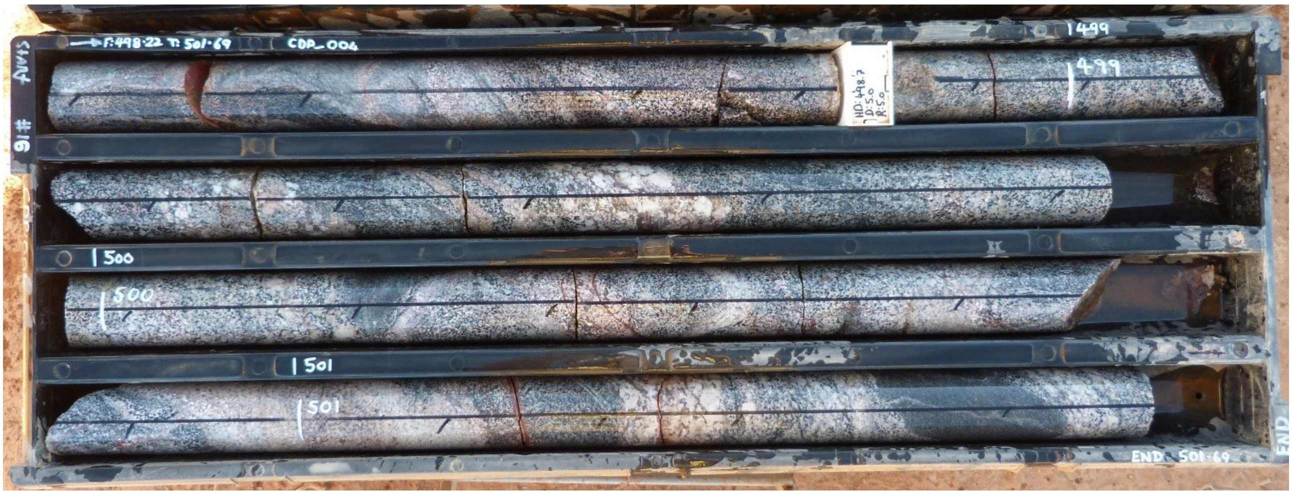

Figure 12. Representative core from CDP004 showing the schollen diatexite (DTEX). Photograph of tray 16, showing the finer grained, darker mafic schollen in the coarse-grained leucocratic groundmass (at 500.20 and 501.50 m). The schollen at 501.50 m is back-veined by the leucocratic material. Schlieric layering can be seen at 498.50 m. Pegmatitic patches can be seen at 499.60 and 501.25 m.

Diorite

Unit of relatively homogenous, grey-green, massive, medium-grained quartz-poor diorite. The rock is similar to the mafic-rich, green patches observed in the diatexite.

At 510 m, a ~1.5 m-wide zone of relatively homogenous diorite has a local foliation, which is defined by the alignment of the mafic minerals (Fig. 13). This zone has a gradational contact with the adjacent gneisses, defined by the increasing proportion of leucosomes.

Figure 13. Representative core from CDP004 showing the diorite. Photograph of tray 19, showing the medium-grained, speckled diorite at 509.40 to 511.10 m. The lower part of the diorite is intruded by thin granite sheets (e.g. 510.9 m).

Granite

The granite is a heterogenous unit that represents a transition from diatexite to granite. This is likely to have occurred as the melt-rich diatexite started to flow and homogenise to form a granite.

An example of the diatexite end-member occurs between 477.25–483.72 m (Fig. 14). In this interval, the rock comprises ~70% grey, coarse- to medium-grained gneiss with common igneous textures and mafic schlieren, and ~30% of leucocratic, very coarse-grained to pegmatitic material that forms patches.

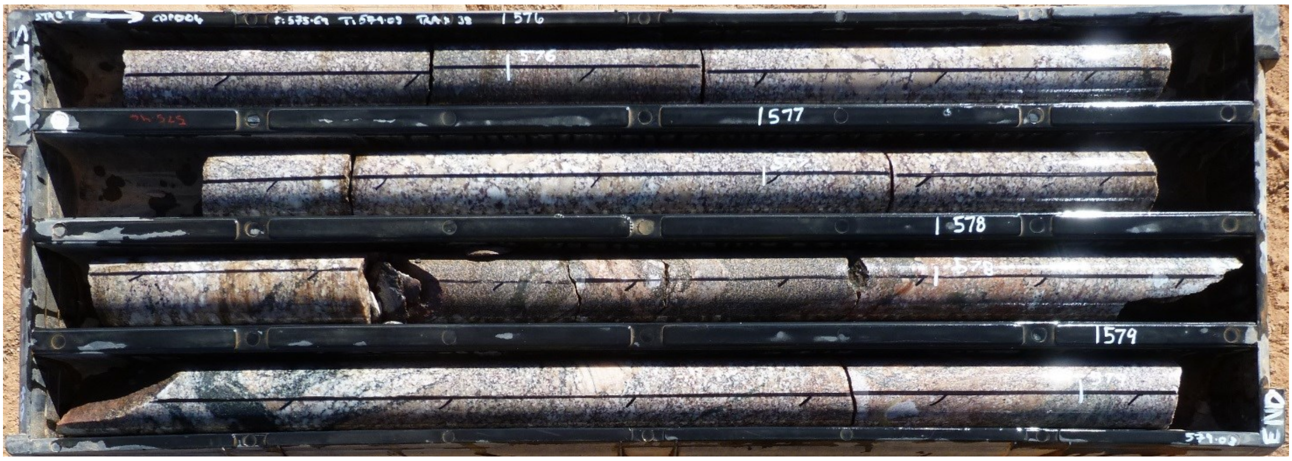

Figure 14. Representative core from CDP004 showing the granite. Photograph of tray 38, showing the very coarse- to coarse-grained granite (at 577.00 to 577.40 m) within the schlieric diatexite. The mafic schlieren at 578.25 m is truncated at a high-angle by compositional layering suggesting magmatic-state flow.

An example of a more transitional component occurs between 483.72–484.47 m. This interval comprises brown, fine- to medium-grained, massive, inequigranular granite with scattered irregular feldspar phenocrysts that are up to 1 cm long. Based on the irregular shapes, the feldspar phenocrysts are interpreted as xenocrysts that would have crystallised in melt-rich parts of the diatexite prior to mobilisation and dispersal. At 491.8 m is a very large (10 cm-long) irregular feldspar xenocryst with graphic intergrowth, which is likely to have been derived from a pegmatite, similar to those in the diatexite. The base of the granite layer cuts the gneissosity at an angle with an irregular, gradational to stepped contact.

Another example occurs between 573.67–577.22 m. This interval mostly comprises coarse- to medium-grained, cream-grey, massive, inequigranular feldspar, quartz and biotite granite with common irregular feldspar xenocrysts, up to 1.5 cm across. There is minor grey to black and white speckled, medium- to coarse-grained schlieren diatexite, with common leucosomes and mafic schlieren in a relatively massive groundmass with igneous textures.

An example of the more granitic end-member is seen between 546.8–547.37 m. In this interval, the granite is brown, fine- to medium-grained, massive, seriate-textured granite, containing feldspar, quartz and biotite. The feldspars are often euhedral and equant to tabular. The quartz is interstitial with rare phenocrysts. The biotite is fine and occurs along grain boundaries with local interstitial aggregates.

The granites between 521.64–522.05 m and 532.45–532.92 m are generally massive, but locally have a foliation defined by aligned biotite flakes in a massive groundmass, suggesting magmatic state mineral alignment. The contacts of this unit is sheeted sub-parallel to the layering in the host over about 10 cm. the granite contains a cm-scale raft of coarse-grained migmatitic material that is similar to that seen in the surrounding rocks.

An unusual granite can be seen between 559.28–560.26 m and 573.08–573.67 m. These intervals contain chunky to very coarse-grained leucocratic rock predominantly composed of feldspar, with interstitial quartz and minor biotite. The feldspars are up to 1.5 cm-wide, generally white, relatively equant, and subhedral to anhedral. The interstitial quartz indicates a magmatic origin, and the rock is possibly a feldspar cumulate zone, or a filter-pressed layer.

Monzogranite

Blue-grey, fine to medium-grained, relatively equigranular monzogranite (Fig. 15; e.g. 588.76–589.24 m). The unit has gradational boundaries with the surrounding rocks.

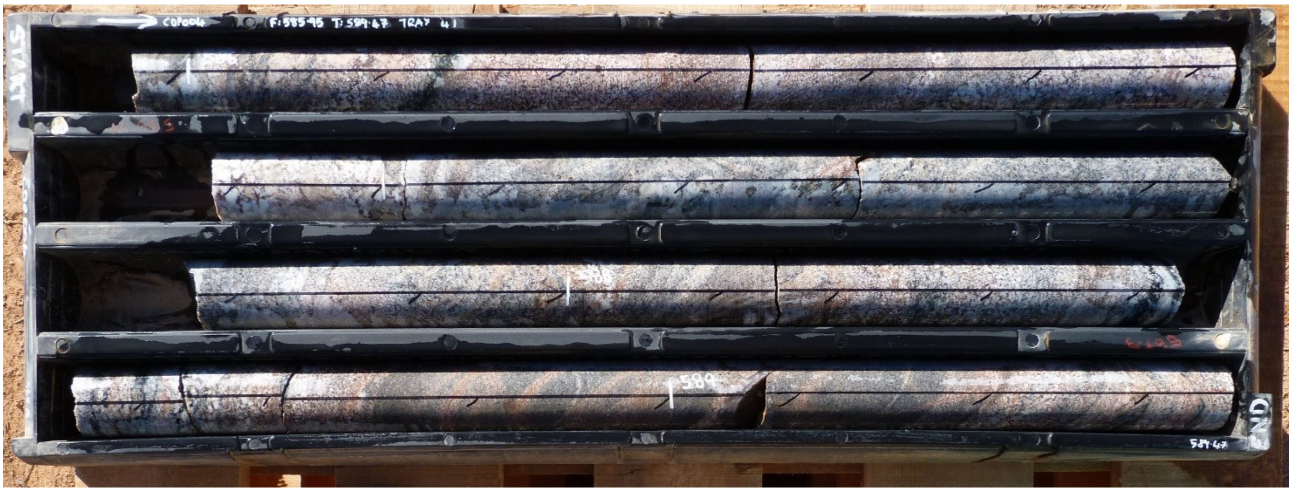

Figure 15. Representative core from CDP004 showing the monzogranite. Photograph of tray 41, showing a sheet of the medium-grained, grey to blue monzogranite granite (at 588.70 to 589.20 m) within the schlieric diatexite.

STRUCTURES

The gneissosity is folded into an open structure with axial planar that is at a high angle to the core, suggesting recumbent folding (e.g. 465.85 and 505.85 m).

At 466.4 there is a zone, about 7 cm-wide, of finer-grained rock with relatively rounded mm-scale feldspars that cuts the gneissosity at a moderate angle. The zone may represent a solid-state shear zone/mylonite.

ALTERATION

Fe-alteration was observed in several places in CDP004. Pervasive red-brown alteration was observed at 444.6–449.25m (Fe-altered), and patchy Fe-alteration was observed between 560.26–573.08 m (Fig. 16).

Figure 16. Representative core from CDP004 showing the Fe-altered schollen diatexite. Photograph of tray 16, showing the strong, pervasive Fe-alteration overprinting the schollen diatexite. Primary textures, such as mafic schollen (at 444.95 m), mafic schlieren (at 444.80 m), and pegmatitic patches (at 446.00 m) can be seen despite the alteration.

The rocks have local pervasive silicification, which often results in polished, glassy core (e.g. 449.25–450.10 m, 495.76–497.05, 549.5–557.39, 580.08–580.52, 581.18–581.84 m). Some of these intervals are also brecciated.

VEINING

Several sets of veins were observed in CDP004. A closer examination will be required to determine the order of formation.

There are mm-scale chlorite veins at a moderate angle to the core. The veins at 449.70 m overprint the pervasive silicification between 449.25–450.10 m.

There are thin mm-scale red veins (hematite) at a moderate angle to the core (Fig. 17; e.g. 461.3–464, 493.07, 501.1–502.1, 518.1–518.35, 523.25–531.9, 541.25–557.39, 563.80–568.35, 571.2–574.43, 579.25–583.4 m). One vein at 537.82 is at a low angle to the core and locally branches to form a fine network. Some of the hematite veins have bleached alteration haloes about 5 mm-wide (e.g. 494.25, 494.7, and 495.34 m).

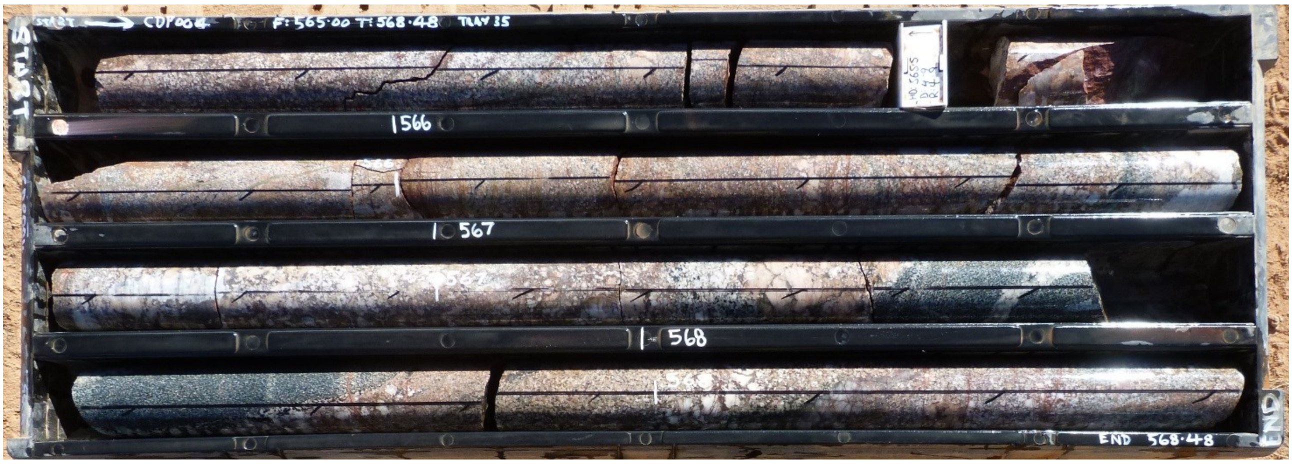

Figure 17. Representative core from CDP004 showing hematite veins in the diatexite. Photograph of tray 35, showing the common, thin (mm-scale) hematite veins cutting the diatexite at a high to moderate angle (at 566.05 to 566.30 m and 568.10 to 568.30 m). Primary textures, such as mafic schollen (at 567.60 m), and pegmatitic patches (at 568.20 m) are well-developed in the host rock.

There are mm-wide quartz veins cutting the core at a low angle at 471.78 m. Epidote(?) veins are up to 5 mm-wide and at high angle to the core (e.g. 507.6, 530.30–531.2, 578.8–581.61 m). The epidote veins at 530.30–531.2 have a 5 mm-wide alteration halo.

PRELIMINARY INTERPRETATION OF CDP004

The core has common igneous textures and the layering is often defined by variations in grain size and proportions of the minerals. There are considerable compositional and textural ranges, i.e. from dioritic to granite. The rock contains common schollen, which are back-veined by the leucosomes.

Overall, the rock looks like migmatite, but appears to be dominated by igneous textures and consequently magmatic-state processes, and may be more diatexitic than metatexitic. In places, the rock looks like a dirty granite, suggesting that the network of the migmatite is breaking down, and the magma is flowing and starting to homogenise to form the granite and monzogranite. In particular, the granite preserves a range of textures that support the interpretation that it is transitional to the diatexite. Furthermore, there are no, or few, augen-like or solid-state recrystallisation textures, as were seen in CDP001, which would indicate a metamorphosed granite dominated by plastic deformation.

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