APPENDIX
ARAURA’S EXPLORATION ACTIVITIES ON EL 24548 (YALYIRIMBI) FOR THE YEAR ENDING 30 NOVEMBER 2013.

By

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<td>Mine/Project Name</td>
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<td>Report Title</td>
<td>Appendix: Arafura’s exploration activities on EL 24548 (Yalyirimbi) for the year ending 30 November 2013.</td>
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<td>Personal author(s)</td>
<td>Kelvin Hussey BSc(Hons) MAIG</td>
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</tr>
</tbody>
</table>
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>TITLE PAGE</td>
<td>1</td>
</tr>
<tr>
<td>COPYRIGHT STATEMENT</td>
<td>2</td>
</tr>
<tr>
<td>REPORTING DETAILS</td>
<td>2</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>3</td>
</tr>
<tr>
<td>List of Figures</td>
<td>4</td>
</tr>
<tr>
<td>Introduction</td>
<td>5</td>
</tr>
<tr>
<td>GEOLOGY</td>
<td>7</td>
</tr>
<tr>
<td>REGIONAL SETTING</td>
<td>7</td>
</tr>
<tr>
<td>ARAFURA RESOURCES LIMITED, YEAR ENDING 30 NOVEMBER 2013.</td>
<td>20</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>22</td>
</tr>
</tbody>
</table>
List of Figures

Figure 1  Location of project area tenements.
Figure 2  Location on Geological Provinces map.
Figure 3  Regional Geology of the project area.
Figure 4  Regional magnetic image of the project area.
Figure 5  Regional radiometric image of the project area.
Figure 6  Chewings Event metamorphic grades and zones in the Reynolds Range region.
Figure 7  Distribution of Chewings Event high grade metamorphism U-Pb ages.
Figure 8  Distribution and constraints on the Alice Springs Event.
Figure 9  Distribution of the Tertiary Basins in the Alleron-Reynolds project area.
Figure 10 North-south section across the Ti Tree Basin.
Figure 11 Stratigraphy of the Tertiary Hale Basin.
Figure 12 Depth to basement, geology and AEM image.
Introduction

A substantial water exploration effort commenced to the south of Nolans Bore in late 2012. This was considered essential as a long-term sustainable water supply is required to support the economic development of Nolans Bore. This has involved an initial phase of water exploration drilling on EL 29503 and EL 29509, and adjacent areas off tenement to the west. These holes are yet to be fully developed and pump-tested but the water quality and airlifted volumes are considered encouraging.

To support this exploration phase, a substantial desktop geological study commenced in early 2013 to define water exploration areas and to constrain the extent and size of the concealed Tertiary basins to the south of Nolans Bore. At this stage, the principal area of interest is largely off-tenement to the west of EL 29509 and south the Napperby access road across to about Day Creek below EL 24548 (Figure 1). However a much larger region needs to be evaluated to better understand the geology and the extents of these concealed basins. This work and all data is detailed in Hussey (2013) and has involved:

1) collating and reviewing all open-file exploration and water bore drill hole data in the general area;
2) depth to basement modelling using Arafura’s detailed airborne magnetic surveys and open-file NTGS regional magnetic data; and
3) reprocessing all available open-file AEM surveys in the region.

Whilst no on ground exploration activities were conducted on EL 24548 by Arafura in the last term, a considerable proportion of the desktop studies and research activities were focussed on historic data collected on the southern parts of EL 24548. This area is covered by recent detailed AEM data and also has the highest density of drilling into the Cainozoic basins south of the Reynolds and Yalyirimbi Ranges. As such the open file AEM data and the drilling results have been reviewed as they provide valuable background information on Arafura’s water exploration target areas to the south and southeast of EL 24548.

The results to date suggest there is potential for a substantial water supply in the Tertiary Basins to the south and southwest of Nolans Bore.
Figure 1: Location of Aileron-Reynolds project area outlining the amalgamated group reporting GR261 tenements in blue and other Arafura tenements in brown. The location of Nolans Bore REE-P-U Deposit, the Amadeus Basin to Darwin gas pipeline, the Alice Springs to Darwin rail way line and other relevant land title boundaries and localities are also shown.
GEOLOGY

REGIONAL SETTING

The Aileron-Reynolds project area is located in the Aileron Province of the Arunta Region in the central-southern Northern Territory (Figure 2). The project area also covers the northeast margin of Neoproterozoic-Palaeozoic Ngalia Basin. A thin veneer of Tertiary to Recent Basin sediments covers parts of the Aileron Province and the Ngalia Basin in the southern and northeastern parts of the project area.

The Proterozoic rocks of the Aileron Province are considered prospective for REE resources and are the principal exploration focus for Arafura Resources. However the younger sedimentary units are also of exploration interest as a long-term sustainable water supply is required to develop the Nolans Bore.

![Figure 2: Geological provinces of the central-southern Northern Territory showing the location of Arafura’s tenements in the in the Aileron-Reynolds area.](image)

The published regional geology for the project area is illustrated in Figure 3. The geology in Figure 3 is based on digital copies of the NAPPERBY (Stewart 1982), ALCOOTA (Shaw and Warren 1975), HERMANNSBURG (Warren and Shaw 1995) and ALICE SPRINGS (Shaw and Wells 1983) 1:250,000 Geological Map Series. Most of Arafura’s tenements in the general project area are located on Napperby and the reader is referred to the various published geological maps, legends and explanatory notes for the map sheets noted above.

The REYNOLDS RANGE Region 1:100,000 Geology Map is also available (Stewart and Pillinger 1981) and provides more detailed geology for the northeastern parts of the project area. Stewart et al (1980) provides detailed geological descriptions and definitions for all mapped units in the project area. Shaw et al (1975, 1979) provides a similar level of detail for all mapped units in the areas surrounding the tenements in Figure 3. Freeman et al (1990) and Young et al (1995a) provides additional details of the Ngalia Basin stratigraphy. The regional magnetic and ternary radiometric images for the same area are shown in Figure 4 and 5, respectively.
Figure 3: Regional geology of Aileron-Reynolds project area outlining the amalgamated group reporting tenements in blue and other Arafura tenements in Aileron Region in brown. The location of Nolans Bore REE-P-U Deposit, the Amadeus Basin to Darwin gas pipeline, the Alice Springs to Darwin rail way line and other relevant land title boundaries and localities are also shown.
Figure 4: Regional magnetic image of Aileron-Reynolds project area outlining the amalgamated group reporting tenements in blue and other Arafura tenements in Aileron Region in brown. The location of Nolans Bore REE-P-U Deposit, the Amadeus Basin to Darwin gas pipeline, the Alice Springs to Darwin rail way line and other relevant land title boundaries and localities are also shown.
Figure 5: Ternary radiometric image of Aileron-Reynolds project area outlining the amalgamated group reporting tenements in blue and other Arafura tenements in Aileron Region in brown. The location of Nolans Bore REE-P-U Deposit, the Amadeus Basin to Darwin gas pipeline, the Alice Springs to Darwin railway line and other relevant land title boundaries and localities are also shown.

The oldest rocks in the Reynolds Range region are the metasedimentary rocks of the Lander Rock Formation. This is a widespread metapelite and metapsammitic unit mapped across large parts of the Aileron Province ranging in metamorphic grade from greenschist- to granulite-facies. The Lander Rock Formation in the central and northwest Reynolds Range displays Bouma sequences implying deposition below storm wave base. This extensive unit is therefore interpreted as an extensive turbidite succession in a deep water marine setting. Donnellan (2008) defined four members in the Lander Rock Formation further to the north and noted the various units reflect a variety of shallow to deep marine settings. Based on extensive sampling as part of the NTGS geochronology project, a number of other localised units on Napperby and elsewhere in the Aileron Province are also correlated as either partial or complete lateral/temporal facies equivalents (eg Aileron Metamorphics). It should be noted that some of these units currently included in the greater Lander package have significant vertical compositional variability and/or are geochemically distinct from typical interbedded metapelite and metapsammitic of the low-grade turbiditic Lander Rock Formation in the northwest Reynolds Range.

Within the project area the Mount Dunkin and Mount Freeling schists and the Nolans Dam and Aileron Metamorphics were all originally correlated with the Lander Rock Formation (Stewart et al 1980). The Wickstead Creek beds were also correlated with the Lander Rock Formation (Stewart et al 1984) but together with the Mount Dunkin and Mount Freeling schists are now considered more likely to belong in the Reynolds Range Group (Dirks 1990). To date, there is no geochronological evidence to support this generally accepted revision.

SHRIMP U-Pb zircon studies indicate that the metasedimentary units attributed to the Lander package have maximum depositional ages in the range 1865-1805 Ma across the Aileron Province (eg Vry et al 1996, Smith 2001, Claué-Long 2003, 2005, Claué-Long et al 2008a, Bodorkos et al 2013). Claué-Long et al (2008a) reports that the Lander Rock Formation is characterised throughout its widespread distribution by a dominant population of 1880-1840 Ma-aged zircons with subordinate older zircon populations scattered back to about 2800 Ma. Claué-Long (2003) reported a maximum age of sedimentation for the Lander Rock Formation of about 1840 Ma, and identified a succession of rocks beneath the Reynolds Range Group which had a maximum age of about 1805±5 Ma. Claué-Long (2005) suggested that these younger zircons (ie 1820-1800 Ma) in addition to the typical Lander Rock Formation provenance spectrum indicate that the Lander Rock Formation can be divided into two stratigraphic units. This younger succession is currently mapped as Lander Rock Formation and its extent is unknown. Similarly young (<1840 Ma) zircon populations have also been recently reported for metasedimentary units on the Alcoota map sheet (Bodorkos et al 2013). Clearly there are unresolved stratigraphic issues within rocks broadly assigned to the greater Lander package, but as pointed out by Donnellan (2008), no tectonic breaks have been identified. Unfortunately metasedimentary rocks are often difficult to accurately date or constrain particularly where there are no distinct stratigraphic markers. Donnellan (2008) suggests that the mafic units are stratiform units and can be used to subdivide the Lander Rock Formation based on geophysical character. Unfortunately it may be not possible to test these geophysical relationships in the Aileron-Reynolds project area as high grade metamorphism has produced significant metamorphic magnetite.

The Lander package is intruded by medium to very coarse grained granitic plutons of the c1810-1790 Ma Harverson Suite (Stewart and Pillinger 1981, Warren 1989, Collins and Williams 1995, Zhao et al 1995, Vry et al 1996, Donnellan 2008, Worden et al 2008). These plutons often contain a variety of...
Igneous phases and form an extensive almost continuous northwest-southeast trending zone that is about 10-25 kilometres-wide and at least 150 kilometres-long, outcropping on Napperby and extending on to Mount Peake. Worden et al (2008) dated two of the prominent granites in the northern parts of the project area, obtaining SHRIMP U-Pb zircon ages of 1806±4 Ma for the Boothby Orthogneiss and 1798±5 Ma for the Yaningidjara Orthogneiss; confirming they are contemporaneous with the Stafford Event and placing a minimum age constraint on the granulite-facies metasedimentary units of the Aileron Metamorphics and Lander Rock Formation in the project area.

Rubatto et al (2006) demonstrated that the localised LP-HT metamorphism at Mount Stafford (Clarke et al 1990; Vernon et al 1990; Greenfield et al 1996, 1998; White et al 2003) is contemporaneous Harverson Suite magmatism. This thermal event has been termed the Stafford Event (Scrimgeour 2003). The LP-HT metamorphism at Mount Stafford and the contact aureole surrounding the Harverson Granite both clearly overprint greenschist facies fabrics and folds indicating regional deformation prior to the intrusive granites and LP-HT Stafford Event metamorphism. The timing of the earlier deformational event at Mount Stafford is currently unknown but it is most probably early Stafford Event deformation as the maximum age of the Mount Stafford beds appears to be about 1823 ± 5 Ma (Rubatto et al 2006). If this reasoning is correct, then the Stafford Event could be a tectonothermal event with early mafic magmatism and deformation prior to extensive felsic dominated bimodal magmatism and LP-HT metamorphism that characterise the Event (Scrimgeour 2003). In this scenario the mafic sills which are overprinted by LP-HT metamorphism in the Stafford Event are high-level intrusions related to early extension in the Stafford Event. Similarly, the folding observed at Mt Stafford is related to the early stages of the Stafford Event. Donnellan (2008) supports this view, stating that the Stafford Event is a substantial tectonothermal event with three phases of folding.

Subordinate mafic gneiss, amphibolite and granulite occur within the Aileron Metamorphics in Aileron-Reynolds project area (Stewart and Pillinger 1981). It is possible that some or all of these units correlate with mafic units elsewhere in the Reynolds Range Region and are older than the main Stafford Event magmatism; for example, they may be correlative of the folded and metamorphosed mafic sills in the Mount Stafford beds and the Tyson Creek mafic granulites, both of which pre-date the 1805-1795 Ma Anmatjira Orthogneiss (Stewart et al 1980, Rubatto et al 2006, Worden et al 2008).

Magma mixing and mingling relationships observed by the author in the Anmatjira Ranges while at the NTGS indicate minor contemporary mafic magmatism is also associated with the Anmatjira Orthogneiss (Harverson Suite). These mafic units form a minor component in this region compared to areas further south and southeast where c 1805 Ma mafic magmatism is more prolific (cf Shaw and Wells 1983, Warren and Shaw 1995, see Claué-Long and Hoatson 2005).

The Lander package and the granitic plutons of the Harverson Suite are unconformably overlain by the shallow marine Reynolds Range Group (Stewart et al 1980, Stewart 1982, Dirks 1990, Dirks and Wilson 1990, Young et al 1995a, 1995b). The deposition of the Reynolds Range Group is followed by voluminous 1770-1785 Ma felsic magmatism (Stewart et al 1980, Stewart and Pillinger 1981, Stewart 1982, Collins and Williams 1995, Smith 2001, Kosticin et al 2103) which intruded units of the Reynolds Range Group and the Lander Rock Formation. This second phase of felsic magmatism, the Napperby Suite, is heterogeneous and dominates the central and western parts of the NAPPERBY 1:250 000 mapsheet. The Napperby Suite is contemporaneous with the Yambah Event mapped across large parts of the Aileron Region (Scrimgeour 2003). Mapped relationships indicate the Napperby Suite is an extensive unit that occurs on the southern side of the Reynolds Range extending from about the Stuart Highway northwest across NAPPERBY and onto MOUNT DOREEN. Warren (1989) indicates the undifferentiated granite outcrops near Patty Hill on EL 24548 are also part of the Napperby Suite. The Napperby Suite may extend further south than this but the isolated outcrops in southern NAPPERBY have not been subjected to geochronological studies. The Napperby Suite was emplaced at relatively high crustal levels with contact metamorphism is locally observed adjacent to these intrusions (Stewart et al 1980, Hand and Buick 2001). The Yambah Event causes minor deformation and local amphibolite facies contact metamorphism in the project area.

Isotope and petrological studies demonstrate that igneous fluids have infiltrated and metasomatized the metasedimentary units close to the igneous contacts during both of the above igneous events (Buick and Cartwright 1994, Buick et al 1994; Vry and Cartwright 1994, 1998; Cartwright et al 2001). Field
work by Arafura also shows that the granites in both of these events have localised hydrothermally altered (chlorite and or muscovite) zones. Exploration by Arafura in 2009 identified localised greisens with weakly anomalous Sn-W and tourmaline alteration within these granites. Tourmaline-rich pods also occur in the Aileron Metamorphics and Lander Rock Formation.

To date, there is no reported geochronological evidence to support the presence of the 1740-1690Ma Strangways Event (Scrimgeour 2003, Claoué-Long et al. 2008b) in the main part of the Aileron-Reynolds project area. Therefore if present it must be low grade.

Based on academic studies in the southeast Reynolds-Anmatjira Ranges over the last 20-25 years, it was generally accepted by most workers that the peak amphibolite-granulite facies metamorphism observed throughout the project area is related to the 1595-1540 Ma Chewings Event (Collins and Williams 1995; Collins et al. 1995; Vry et al. 1996; Williams et al. 1996; Buick and Cartwright 1997; Buick et al. 1998, 1999; Cartwright et al. 1999, 2001; Hand and Buick 2001; Rubatto et al. 2001; Vry and Baker 2006; Anderson et al. 2013; Bodorkos et al. 2013; Morrissey et al. 2013). The distribution of the Chewings Event metamorphic facies and grades for the Reynolds Region is shown in Figure 6 and the location of U-Pb ages used to demonstrate this are shown in Figure 7. Additional ages were also recently reported for rocks to the east of Nolans Bore (Morrissey et al. 2013) and confirm the relationships presented in Figure 6.

Figure 6: (a) Simplified geological map of the Reynolds-Anmatjira Range region showing the metamorphic zones associated with the Chewings Event. (b) Metamorphic zones in the Reynolds Range defined by the assemblages produced during partial melting. Assemblages in the near minimum melting zone include ilmenite-magnetite-bearing leucosomes in migmatised granite. In the granulite zone, leucosomes contain cordierite ± garnet ± orthopyroxene (from Hand & Buick 2001).
However recent dating of the Aileron Metamorphics by the NTGS to east of the project area on the ALCOOTA 1:250 000 map sheet failed to identify any Chewings-aged metamorphic zircon rims in a granulite-facies quartz-rich semi-pelitic migmatite (Bodorkus et al 2013). Instead the results of Bodorkus et al (2013) imply Stafford- and Yambah-aged high-grade metamorphism may also be present in parts of the project area. Additional studies are needed to resolve this.


There are currently no age constraints on the timing of granitic and migmatitic metamorphic rocks in the southern parts of the project area on EL 27337 (Stewart 1982, Warren 1989). At this stage it is assumed that the high grade metamorphism is related to the Chewings Event. This assumption could be completely wrong and needs to be resolved. Warren (1989) reports the presence of hornblende and allanite in the granite on EL 27337. Igneous amphibole and allanite are not observed in the Harverson and Napperby Suites, suggesting this granite might be related to the metaluminous 1620 Ma Ennugan Mountains Granite (Hussey unpublished NTGS data, Smith 2001).
To the south of the Yalyirimbi and Reynolds Ranges, the Arunta Inlier is unconformably overlain by Neoproterozoic and early Palaeozoic sediments of the Ngalia Basin. The Neoproterozoic Vaughan Springs Quartzite, including its Treuer Member, and the Devonian Mount Eclipse Sandstone crop out on EL 24548. Only the Vaughan Springs Quartzite and the Treuer Member crop out on EL 27337. These and other units of the Ngalia Basin are described in Freeman et al (1990), Young et al (1995a) and Haines et al (2001). Most of the Ngalia Basin on the NAPPERBY 1:250 000 mapsheet is covered by a veneer of Tertiary-Recent sediments.

All units the project area are truncated by localised retrogressive high-strain zones. These high-strain zones are part of the mapped east-west or northwest-southeast trending mylonite zones in NAPPERBY (cf Stewart et al 1981) and most are clearly evident in magnetic images (eg Figure 4). These high-strain zones are part of a major fault system in the Arunta usually steeply dipping to the northeast or subvertical and commonly have down-dip lineations with a north over south (reverse) sense of movement (Shaw et al 1982; Dunlap and Teysier 1995; Collins and Teysier 1989). Dating has shown that these structures are coeval with the synorogenic sedimentation developed in the upper parts of the Ngalia Basin and elsewhere in central Australia (eg Haines et al 2001). Micas from mylonitised (retrogressed) granitic gneiss to the northwest of Nolan’s Bore in Sandy Creek have been dated at 334 Ma by Ar-Ar step-heating methods (Cartwright et al 1999). Read (2002) obtained 358-294 Ma Ar-Ar ages from shear zone micas in the region. Micas from the Aileron gold prospect, in a mylonite zone several kilometres to the southeast give a similar Ar-Ar plateau age of 327 ± 3 Ma (Andrew Wygralak NTGS, pers comm. 2005). These ages are consistent with localised high-strain deformation in the Alice Springs Orogeny. Cartwright and Buick (1999), Cartwright et al (1999), Read and Cartwright (2000), Read (2002) and Raimondo et al (2011) provide clear evidence for meteoric fluids within the mid-crustal Alice Springs Orogeny shear zones in the Reynolds Range region.

Figure 8: Metamorphic and temporal constraints on the Alice Springs Orogeny in the Reynolds Range Region (from Raimondo et al 2012).
As can be seen in Figure 2, unconsolidated Quaternary red soils, alluvial sands and gravels and aeolian sand, (Qr, Qa, Qt) along with minor Quaternary calcrite (Qc), blanket much of the lower lying areas along the northern and southern margins of the Reynolds Range including the area of the Kerosene Camp Creek drainage basin immediately surrounding the Nolans Bore prospect. Tertiary saprolite (Tla) and ferricrete (Tlf) is also developed in some parts of the range. The unconsolidated transported cover conceals underlying Tertiary Basins (Figure 9).

Drilling shows there is a distinct stratigraphy within the Ti Tree Basin to the northeast and a significant aquifer occurs at about 500-550m RL (Figure 10). The stratigraphy in the Ti Tree Basin is broadly similar to that of the Hale Basin further to the southeast (Figure 11, Senior et al 1994, 1995) and similar units have been recognised in the Whitcherry Basin on EL 24548 (Higgins and Rafferty 2009).
Figure 9: Distribution of the Tertiary Basins in the Aileron-Reynolds project area after Senior et al. (1994, 1995). The southwest margin of the Ti Tree Basin follows the revision of Higgins and Rafferty (2009). Additional modifications due to the recent regional AEM datasets and drilling have not been made. All boundaries are concealed and interpretive.
Figure 10: North-south (A-B) section across the western part of the Ti Tree Basin (from Read and Tickell 2007).
Figure 11: Stratigraphy of the Tertiary Hale Basin from Senior et al (1994, 1995). Stratigraphic equivalents are recognised in the other Tertiary Basins in the general area. Higgins and Rafferty (2009) used these terms for units in the TiTree, Whitcherry and Burt Basins however strictly speaking these units should only be used within the Hale Basin. Higgins and Rafferty (2009) also identified an informal unit which they named the 'Napperby Formation' above their Waite Formation.
ARAFURA RESOURCES LIMITED, YEAR ENDING 30 NOVEMBER 2013.

Groundwater exploration and evaluation

Arafura has commenced an investigation for groundwater resources in the region as a long-term sustainable water supply is required to support the economic development of Nolans Bore. Mr Graham Ride of Centreprise Resource Group Pty Ltd has been engaged to assist in this process. Mr Ride has advised that an adequate water supply occurs within the Nolans Bore project area. For example, the Ti Tree Basin to the north and northeast of Nolans Bore has large groundwater resources, but it has competing water users and is part of the Ti Tree Water Control District. The Ti Tree Basin contains an estimated at 8,647 GL but this volume was recently revised down to 4,850 GL (Knapton 2006a, 2006b, 2007; NTREAS 2009). Mr Ride advises that these volume estimates are both likely to be conservative estimates as relatively little is known about the deep aquifers and the entire Ti Tree Basin. Given there are competing users, Arafura considers it prudent and more cost effective to investigate alternative water supplies outside of the Ti Tree Water Control District.

With this in mind Arafura is now focussing its water exploration activities to the south and southwest of Nolans Bore in the Burt and Whitcherry Basins (Figures 9 and 12). Arafura engaged Marranji Drillers to drill a number of wildcat exploratory RAB water bores in December 2012. Groundwater was encountered in all holes and some had significant air-lifted volumes. Drilling difficulties were encountered in some holes and only three holes reached basement. Hence rotary mud drilling is proposed for all future groundwater exploration in this area.

To aid geological interpretations, Southern Geoscience Consultants were contracted to model the depths to basement using the magnetic features in the detailed and regional airborne magnetic datasets in the greater project area. Southern Geoscience provided a very large number of modelled solutions using a number of different methods. The entire dataset including these modelled solutions are presented in Hussey (2013). The vast number of modelled solutions need to be thoroughly vetted to be of any use. Arafura filtered the dataset and assessed only the highest confidence modelled depths (>99% confidence). Unfortunately this resulted in little systematic information in the areas where it was needed the most (southeast parts of Figure 12). In general, it appears that a lot the modelled depths in the region of interest are probably within the basement itself and not the depth of cover to the basement itself. The region is complicated by the presence of non-magnetic Ngalia Basin stratigraphy overlying weak to variably magnetic Proterozoic basement rocks. Hence Arafura decided to stop any further studies to refine the magnetic modelling and concentrate on other datasets, such as AEM.

David McInnes of Montana GIS was contracted to reprocess and model all of the available open-file airborne EM data in the greater project area. Fortunately this region was covered by a number of AEM surveys in 2007, 2008 and 2011. All were acquired to assist uranium exploration and are an invaluable resource for Arafura’s water exploration program. All datasets were reprocessed using a 5-layered earth inversion model, McInnes worked on NuPower’s original datasets in 2007/2008 and indicated that he was able to substantially improve on his original processing, largely due to increased computer processing capabilities and newly developed algorithms. The reprocessed AEM data and a series images and GIS files are presented in Hussey (2013). The final merged 300-metres conductance map for the processed AEM surveys is presented in Figure 12. Figure 12 clearly highlights that the deeper cover/basement on EL 24548 corresponds to the warm colours on the conductance image.

McInnes modelled the depth to the top and bottom of the conductor. These are broadly inferred to represent the depth to the saturated zone (ie water table) and the depth to resistive basement. The models suggest there are substantial palaeovalleys and basins to the south and southwest of Nolans Bore. The AEM models therefore highlight substantial areas for water exploration. Arafura has reviewed this data and is planning to drill test a number of exploration targets for groundwater in 2014. Based on very limited drilling information within the project area it appears that the model AEM depths to basement may be underestimated.
Figure 12: Interpreted depth to basement using available drill hole data and modelled depth to regional magnetic features shown on a merged regional geology and AEM conductance image. Areas of shallow resistive units have been masked out of the AEM conductance image. The interpreted basement depths are presented adjacent to their drill hole locations indicated as purple diamonds. There are a number of instances where drill holes did not penetrated into basement. These are shown as greater than the EOH depth. The modelled depth to magnetic features were calculated using the regional NTGS dataset and are all shown thematically using the same colour scheme for each model based on identical depth ranges with 0-50m in red, 50-100m in orange, 100-200 in yellow, 200-300 in green and >300m in blue. The magnetic solution depths are filter to a 99% confidence of depths using S0, S1, S2 and EQ2 modelled solutions. Note the regional NTGS magnetic data was only modelled east of about 276,500E.
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