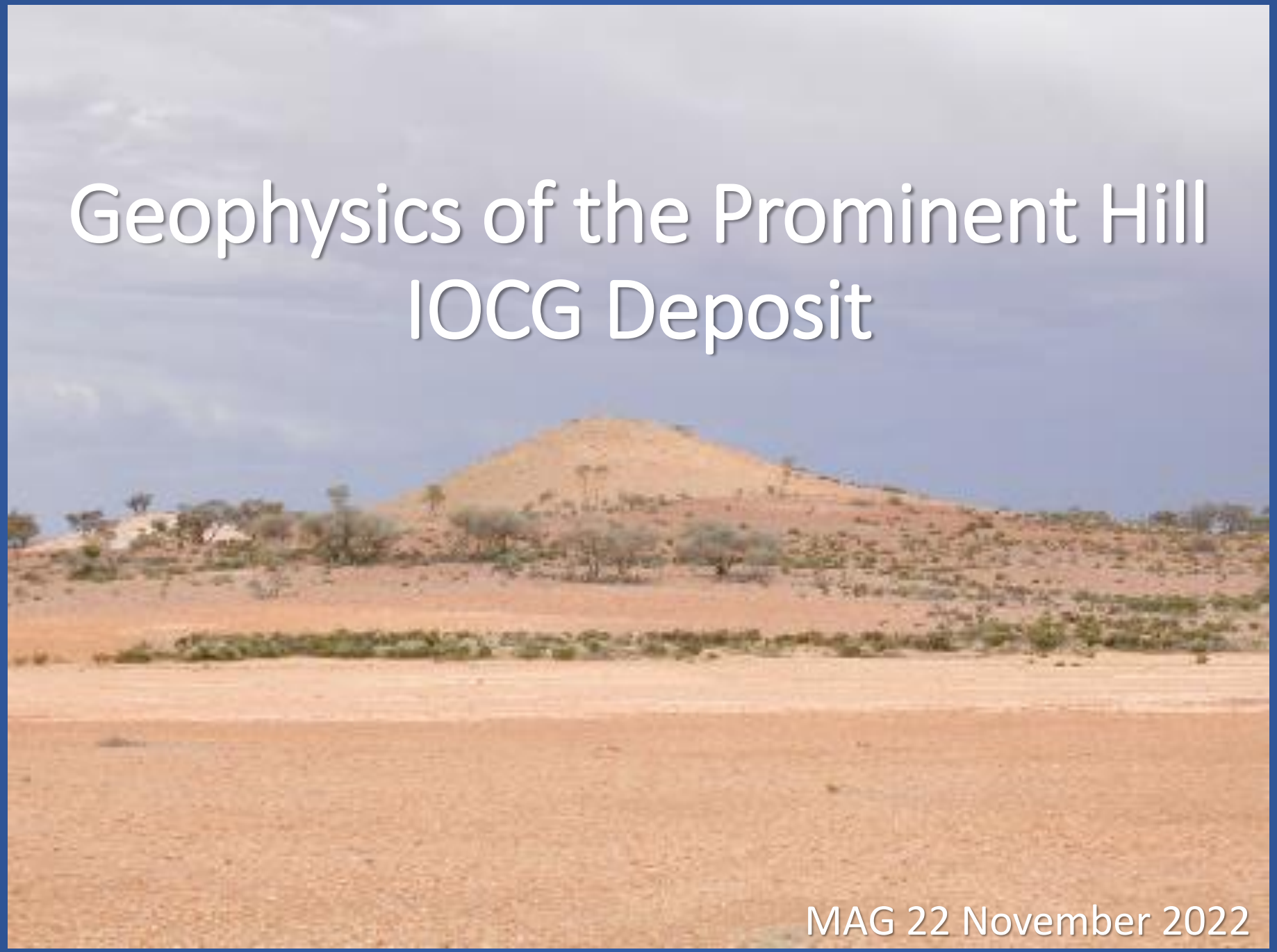
Geophysics of the Prominent Hill IOCG Deposit



MAG 22 November 2022

Outline of Presentation

- Introduction.
- Deposit Summary and Regional Setting.
- Summary Discovery History.
- Pre-discovery Drilling and Geophysical Data.
- Review of the Pre and Post Discovery Gravity Data.
- Conclusions.

Introduction

- In February 2002 (>20 yeays ago), I gave a talk at the Adelaide ASEG covering geophysical responses of the then newly discovered Prominent Hill Deposit. I am not presenting that talk.
- Instead highlight more of the pre-discovery geophysics, how the deposit lay undiscovered for over 12 years and in the process highlight the wealth of geoscientific data that is available via the openfile data collections held by the various Geological Surveys across Australia.
- Most of data in this presentation comes from Envelope 06960 via the South Australian Resources Industry Gateway (SARIG).

Envelope 06960

https://map.sarig.sa.gov.au/

Data release [made at SA Director of Mines' discretion] : Painted Hill, Birthday Hill, White Hill, Mount Hawker and The Twins (the Mount Woods Project). Progress and combined annual reports for the period 27/11/1987 to 31/12/2007. [Index Part 1 of 4].

Finch, I.D.; Carthew, S.; Elliott, P.J.; Purvis, A.C.; Carter, D.N.; Robinson, P.

May 2008

Juka Mine Management Pty Ltd; Aerodata Holdings Ltd; Search Exploration Services Pty Ltd; Pontifex and Associates Pty Ltd; Elliott Geophysics Pty Ltd

Metals Exploration Ltd; Burmine Ltd

EL01448; EL01465; EL01816; EL01819; EL01868; EL02483; EL02492; EL02563; EL02597; EL03056; EL03079; EL03162; EL03229; EL03795

Metals Exploration Ltd; Burmine Ltd; Poseidon Exploration Ltd / Normandy Exploration Ltd; Minotaur Resources Ltd; Oxiana Ltd

Metals Exploration Ltd; Burmine Ltd

A multi-licence area located between 65 km and 170 km south-east of Coober Pedy was taken up to explore for possible economic precious and base metal deposits that might lie concealed within shallow Proterozoic basement.

Exploration activity during the first two years of tenure consisted of semi-detailed airborne geophysical surveying with ground follow-up of significant anomalies, leading to reconnaissance drilling at selected priority targets.
During May 1988, Aerodata Holdings flew an 8000 line km aeromagnetic and radiometric survey for grant licensee Metals Exploration, which comprised north-south flight lines spaced 300 m apart, using a nominal 70 m sensor height above the ground surface. Metals Exploration defined 50 magnetic anomalies of interest amongst the survey's processed data, and 30 of these were given priority for gridding and ground magnetic delineation once a Landsat imagery lineament study had been completed. A programme of RC drilling commenced in November 1988, and by late February 1989, when unseasonally wet weather stopped progress, 5 drillholes had been completed for a total penetration of 712 m, comprising 231 m of blade percussion, 385 m of RC hammer and 96.1 m of NQ diamond coring (the last being necessary to reach basement in holes where sands flowing from within the cover interval halted the open hole RC technique). The drilling was not able to recommence at all in the following year, due to the saturated ground conditions which persisted on the local pastoral properties, precluding access by heavy vehicles.
The drilling which was carried out first, at the most favoured 'Venus' magnetic anomaly of a circular pipe-like nature, located about 9 km south-southwest of Birthday Hill, produced the most encouraging result of the programme when it encountered intervals of massive magnetite metasomatism containing skarn type chlorite-feldspar alteration and carbonate veining, forming a replacement mineral assemblage within granodiorite-diorite and granite. Assaying of a 6 m wide sulphidic intercept cored below 110.39 m depth in this hole, where pyrite-pyrrhotite-chalcopyrite in the ratio of 5:4:1 appears to replace up to 10% of the magnetite, gave maximum values of 0.2% Cu, 0.07% Pb, 0.07% Zn, 0.08% Ba, 64 ppm U and 0.12 g/t Au. This precious metal and base metal mineralisation was regarded by Mines Exploration as anomalous, but did not point towards anything economic, particularly in the light of the poor results next obtained from the other four drillholes sited some distance away to the west, since they encountered only unaltered or moderately magnetite-rich granite, granodiorite and diorite.

A farm-out agreement to allow earning a 50% interest in the subject licences was effected late in 1989, and was approved on 22/5/1990, whereupon new partner Burmine Exploration assumed the technical management of ELs 1448 and 1465 and resumed field work after confirming that thirteen magnetic anomalies were drill-ready. Burmine considered that the Mount Woods joint venture area had high prospectivity for:
1) Roxby Downs style Cu-Au-U mineralisation hosted in a haematitic granite breccia, and in granitoid rocks
2) Au-Cu mineralisation in a felsic to intermediate volcanic pile, e.g. like WMC's Acropolis deposit
3) stratabound banded iron formation/related gold mineralisation
4) Cu-Au mineralisation in magnetite-rich calc-silicate skarn rocks, e.g. like Red Dome in Qld
and
5) diamondiferous kimberlite pipes.
During August 1990, 1:5000 scale geological mapping and rock chip sampling of the region's scarce examples of outcropping metasedimentary basement were undertaken in the vicinity of Mount Woods near the southern boundary of EL 1465, hoping to find evidence of possible stratabound, Menninnie Dam style lead-zinc mineralisation within the complexly folded carbonate horizons recorded there. However, a close inspection revealed that the thin dolomite beds are sheared and appear to occupy fault planes that are parallel to the bedding and foliation of banded quartzo-feldspathic gneisses and schists. When the dolomite and surrounding strata were geochemically sampled across strike near the nose of the principal fold closure, no anomalous base metal values were detected, although elevated gold values to 0.32 g/t Au were returned from magnetitic bands in the gneiss.
During September-November 1990, Burmine completed the drilling of 12 inclined RC holes for an aggregate 1965 m at 10 widely spaced magnetic targets, 9 of which were on EL 1448. One anomaly, Neptune, yielded minor but persistent magnetite-pyrite-chalcopyrite mineralisation of interest (best assay result 12 m @ 0.21% Cu and 0.12 g/t Au below 79 m depth) that was developed on the surface of late stage microfractures within a silicified hornblende syenite continuing over a drilled interval of 96 m to the hole TD, the tenor of copper content appearing to increase with depth in the drillhole, accompanying an increase in visible sulphides to around 2% by volume. Minor intercepts of magnetite- chalcopyrite (including 4 m @ 0.2% Cu and 0.09 g/t Au from 153 m depth) were also intersected in a phlogopite skarn at the Uranus prospect located ~4.2 km to the west-northwest of Neptune. Drilling at Earth prospect located slightly further away to the north-east failed to reach the basement due to collapsed hole bogging the drill rods at 174 m depth, whilst at the other eight prospects, where no mineralisation was found, the magnetite content that is present either in sheared granite, amphibolite or ultramafic intrusive rocks or in gneisses and metasediments adequately explained the target magnetic anomalies.
Petrographical studies were performed on a suite of 18 basement rock samples recovered as drill cuttings and drill core from the project area by the joint venture's drilling. These studies suggested that two mineralised geological settings exist there:
1) a metasomatic replacement skarn type of environ, where younger granitoid rocks and their solutions (i.e. either or both the Engenina Adamellite and Balta Granite) have remobilised magnetite and associated sulphides from calc-silicates, calcareous metasediments, BIF and impure banded ironstone facies. This particular setting was invoked for Mars, Armstrong, Uranus and especially Venus. It was interpreted that Venus had undergone multiphase metasomatic alteration stemming from both intrusive phases, whereas the other localities had only been affected by the post-orogenic Balta Granite intrusion.
2) a fluorine-rich hydrothermal event associated with silica flooding and introduced magnetite-pyrite-chalcopyrite mineralisation crystallising on late stage fractures in trachyte. This setting was found at Neptune.
Subsequent whole rock analysis performed during March 1991 on 9 selected drillhole samples from Mars, Armstrong, Uranus and Neptune prospects revealed unusually high contents of barium (to 1600 ppm Ba), lanthanum (to 240 ppm La) and cerium (to 350 ppm Ce) at Neptune, prompting comparison with similar element enrichments observed by Western Mining Corp. in the mineralised haematite-rich breccias at the giant Olympic Dam deposit.

Also during March 1991, 18 line km of gridding, 12 line km of ground magnetics, 10 line km of dipole-dipole IP surveying, 3 line km of gradient array IP surveying and one resistivity sounding were completed at Neptune to look for indications of additional breccia-related Cu-Au mineralisation. The IP work defined several low-order responses on 5 of 11 surveyed lines, so 3 inclined RC percussion holes for 578 m were drilled to test them. This drilling failed to identify the source of the IP anomalies, but gave indications that two subsidiary circular magnetic anomalies near Neptune (Alpha and Neptune South) are probably caused by the same feature of magnetite-bearing fractures within trachytes.
Three lines of gradient array IP were acquired at Uranus prospect, 8 km west of Neptune, as part of the March 1991 survey programme. A poorly defined, weak IP anomaly was detected just 100 m north of the centre of the magnetic high, but was not drill tested.

During the remainder of 1991 the joint venturers conducted a review of the exploration results so far obtained, and tried to fit them within the known regional geological and tectonic framework.
After June 1991, Burmine decided to seek another joint venture partner to help expedite the way forward.

[abstract continues in Part 2 index record]

This release to the public of the subject mineral exploration data, namely, company data which was acquired more than 5 years ago, is being done by DMITRE in accord with the provisions of Section 77D of the Mining Act 1971 and Regulation 88 of the Mining Regulations 2011.

The index has been separated into four logical parts to accomodate the extent of subject matter summary description required to allow concise reference retrieval.

Includes:

- Elliott, P.J., December 1988. Report on ground magnetic surveys and modelling for the Birthday Hill and Painted Hill licences, near Coober Pedy, South Australia (Search Exploration Services Pty Ltd consultant's report for Metals Exploration). Appendix 1 of ELs 1448 and 1465 combined annual report to 27/2/1989. 134 pages, 1 appx.

- Elliott, P.J., January 1990. Brief report on (geophysical) interpretation of drilling results from the Birthday Hill and Painted Hill licences near Coober Pedy, SA (Elliott Geophysics consultant's report for Burmine Exploration). Appendix 3 of ELs 1448 and 1465 combined annual report to 27/2/1991. 27 pages, 2 appx.

- Elliott, P.J., April 1991. (Interpretation of an) Induced polarisation and ground magnetic survey, Painted Hills EL 1448, SA (Elliott Geophysics consultant's report for Burmine Exploration). Appendix 2 of ELs 1448 and 1465 combined annual report to 27/5/1991. 13 pages, figures.

https://sarigbasis.pir.sa.gov.au/WebtopEw/ws/samref/sarig1/wci/Record?r=0&m=1&w=catno=2035489

Download Document (871MB)

https://mer-env.s3.amazonaws.com/ENV06960.pdf

871MB

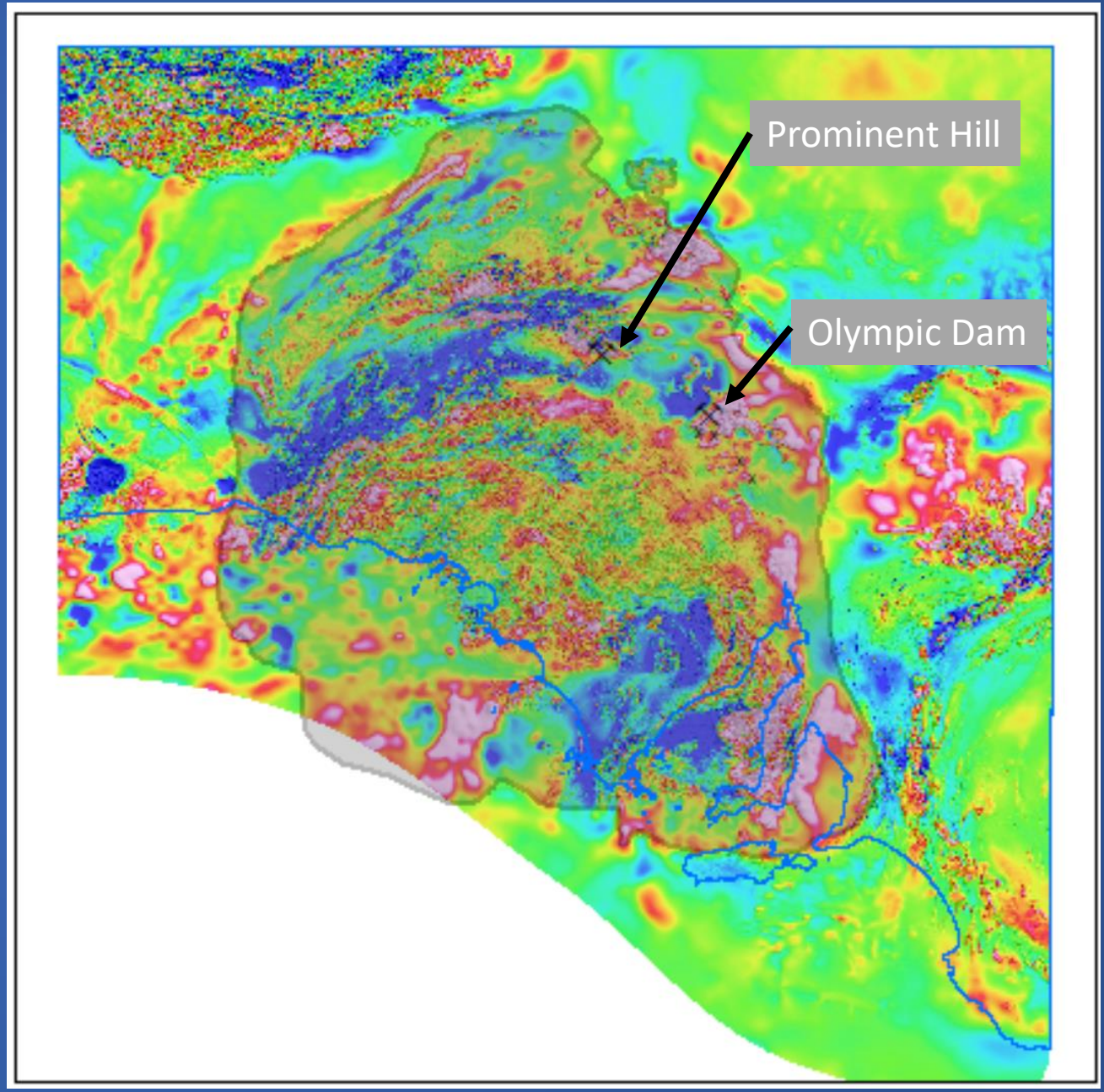
Prominent Hill Deposit Summary.

- The Prominent Hill Iron Oxide Copper Gold Deposit is located in the Mt Woods Inlier, at the northern end of the Gawler Craton.
- Mineralisation consists primarily of copper sulphides, ie chalcocite, chalcopyrite and bornite +/- Au, hosted in hematite-rich breccias. A separate Au rich breccia is also present in the deposit.
- The declared Ore Reserves and Mineral Resources at Prominent Hill in mid 2008, prior to the commencement of production in 2009, were:

283.4 Mt @ 0.89% Cu, 0.81 g/t Au, 2.48 g/t Ag.

Regional Setting.

- Deposit is located in the Palaeo-Meso Proterozoic Mt Woods Inlier, which is located on the eastern margin of the Gawler Craton (shown in grey).
- This eastern margin hosts the majority of known IOCG Deposts and Prospects in the craton.
- This margin is very magnetically active.



Variable Reduced to Pole Aeromagnetic Data over South Australia

Data provided by the Geological Survey of South Australia.

Prominent Hill Discovery History.

- Uranus Prospect (which was later christened Prominent Hill) was one of six targets identified for followup in the Mt Woods Joint Venture Area by Minotaur Resources.
- Gravity and Ground Magnetic Data had already been collected over the Prospect Area by one of the Joint Venture Partners (Normandy). and *two drillholes had already targeted the magnetic anomaly, intersecting a magnetite skarn assemblage with anomalous copper.*
- Discovery hole URAN001 was sited following inversion of the existing gravity data by Billiton geophysicists.

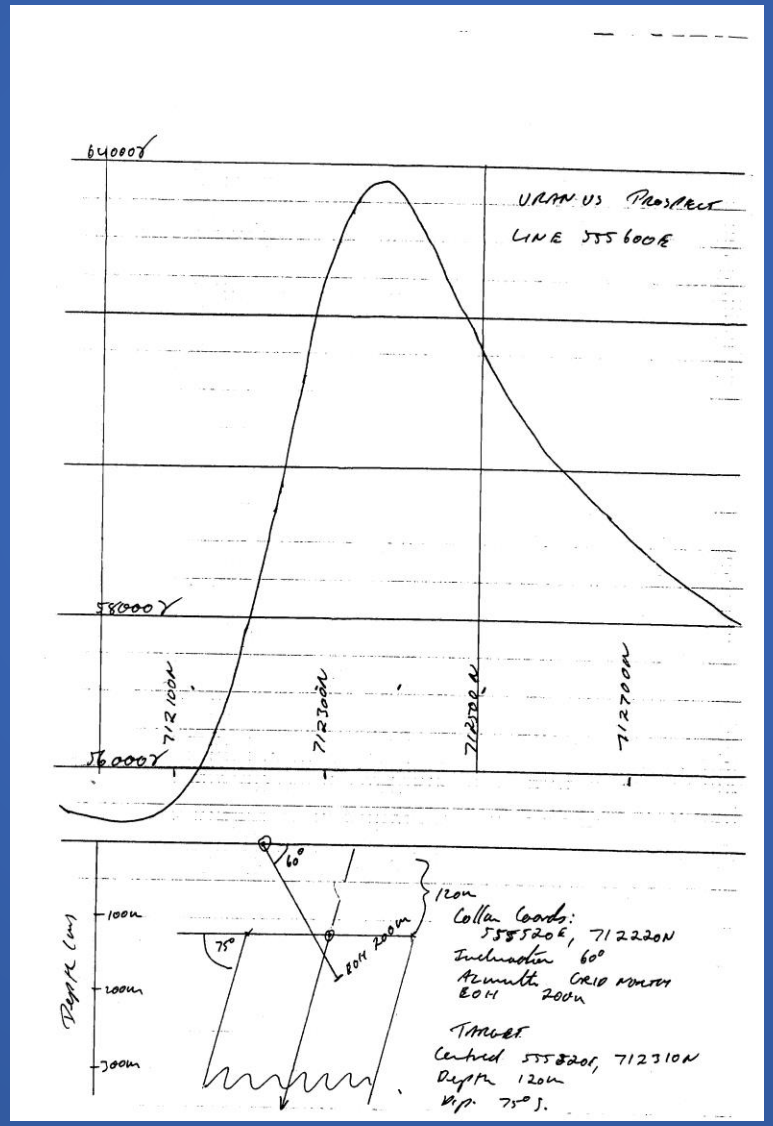
Prominent Hill Discovery History (cont'd)

- Drillhole URAN001 commenced in October 2001. The vertical hole passed through 108 metres of younger cover before intersecting a massive haematite-supported breccia.
- The haematite breccia averaged 1.94% copper and 0.66 g/t Au from 200 -307m depth.
- Mineralisation consisted of predominantly chalcocite occurring as disseminations and thin veins within the matrix supported haematite-silica breccia. The breccia contained highly altered clasts of sandstones and volcanics.
- Deepening of URAN001 intersected a further 152m averaging 1.20% Copper and 0.61 g/t Au from 429m, also hosted in a haematite breccia.

Early Exploration Work

- In May 1988, Metals Exploration Limited undertook an 8000 line km Aeromagnetic Survey. Interpretation of the Survey highlighted the Uranus Anomaly as a high priority target.
- Ground Magnetic data was collected in October and November 1988. The amplitude of the magnetic anomaly was > 8000nT. The data was modelled and a single hole drill test was designed.
- In November 1990, Burmine Exploration (new JV partner) undertook a drilling program at Uranus. Drillhole 90URAN-RC-1 was completed and intersected a highly magnetic skarn assemblage that was anomalous in base metals.

Magnetic Modelling – Uranus Prospect.



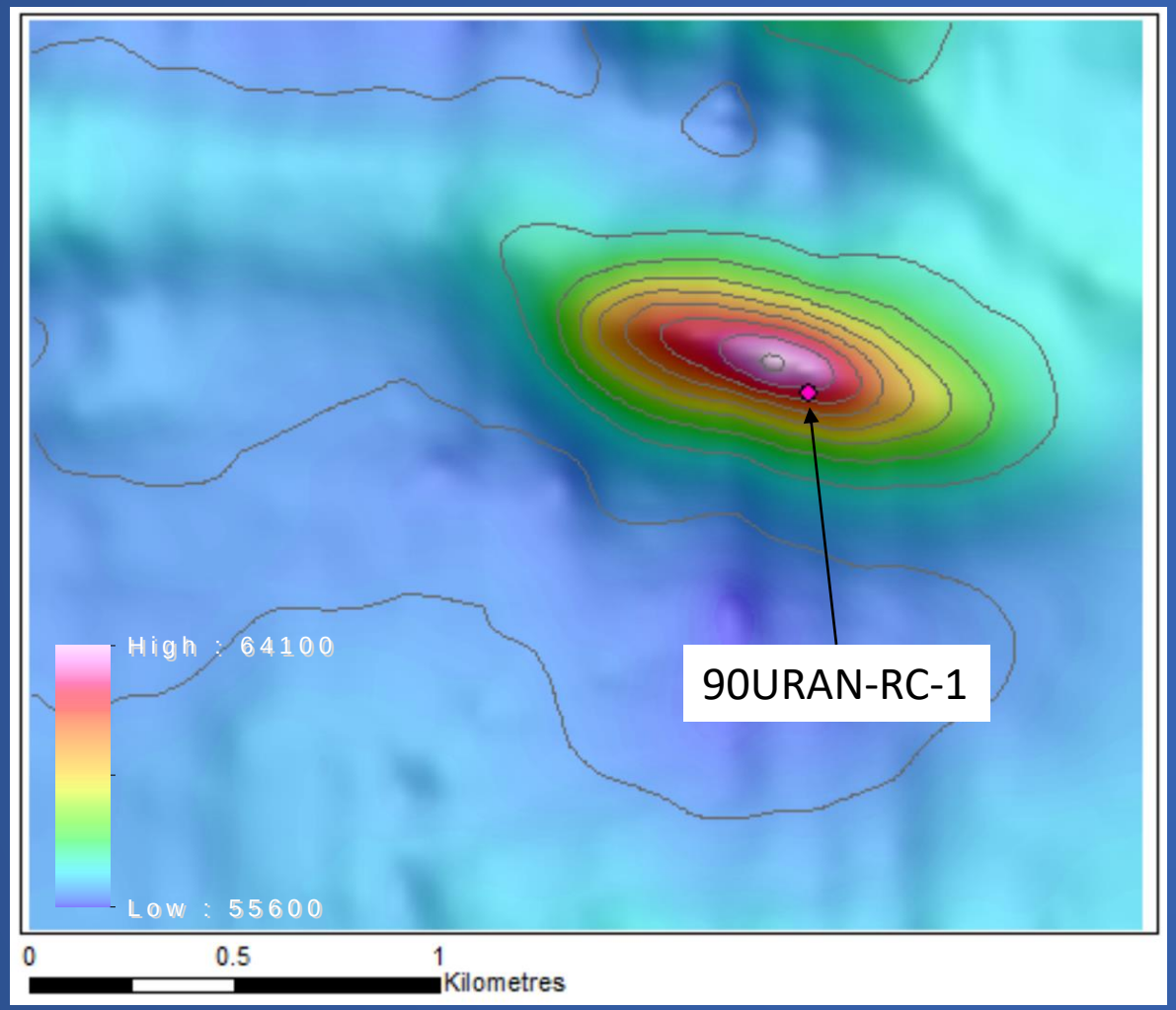
90URAN-RC-1 Drilling Summary

- Summary Log

0 – 132m	Cover Sequence
132 – 134m	Amphibolite granulite
134 – 144m	Magnetite breccia +/- ultramafic and granulite
144 – 149m	Ultramafic
149 – 153m	Amphibolite
153 – 159m	Fault zone with pyrite
159 – 162m	Magnetite breccia
162 – 200m	Amphibolite with pyrite, granite intrudes.

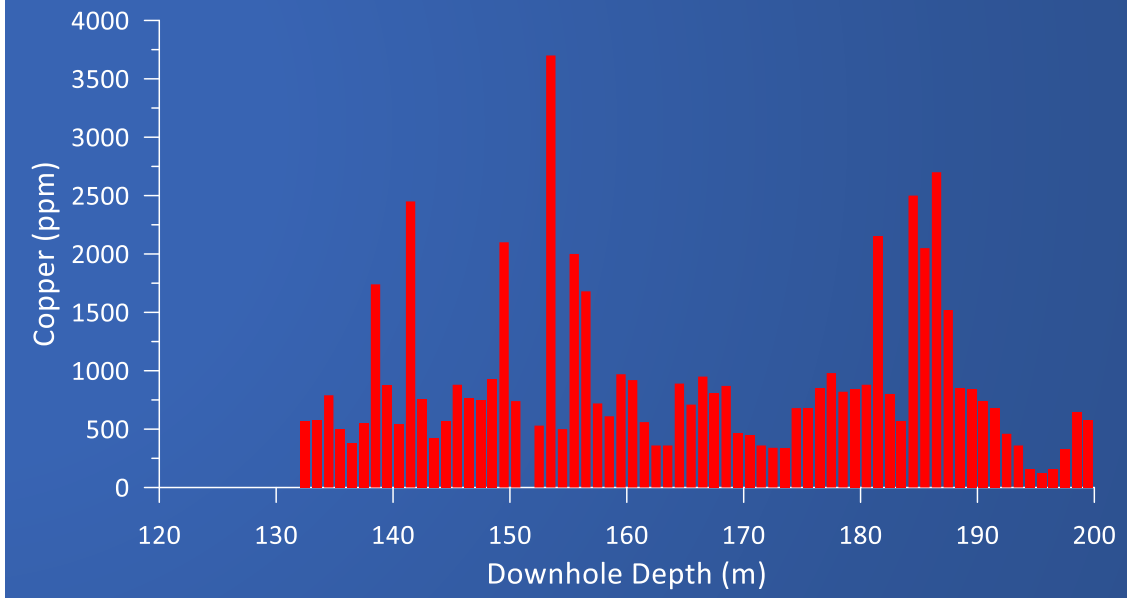
- Consistently high mag sus readings with a peak of 100000 x10-5 SI between 160-162m.

Initial Drilling at the Uranus Prospect.



Reduced to Pole Ground Magnetic Data (Contour Int = 1000nT)

Basement Interval Averaged 894ppm Copper.
Max. Cu 0.37% from 153m-154m

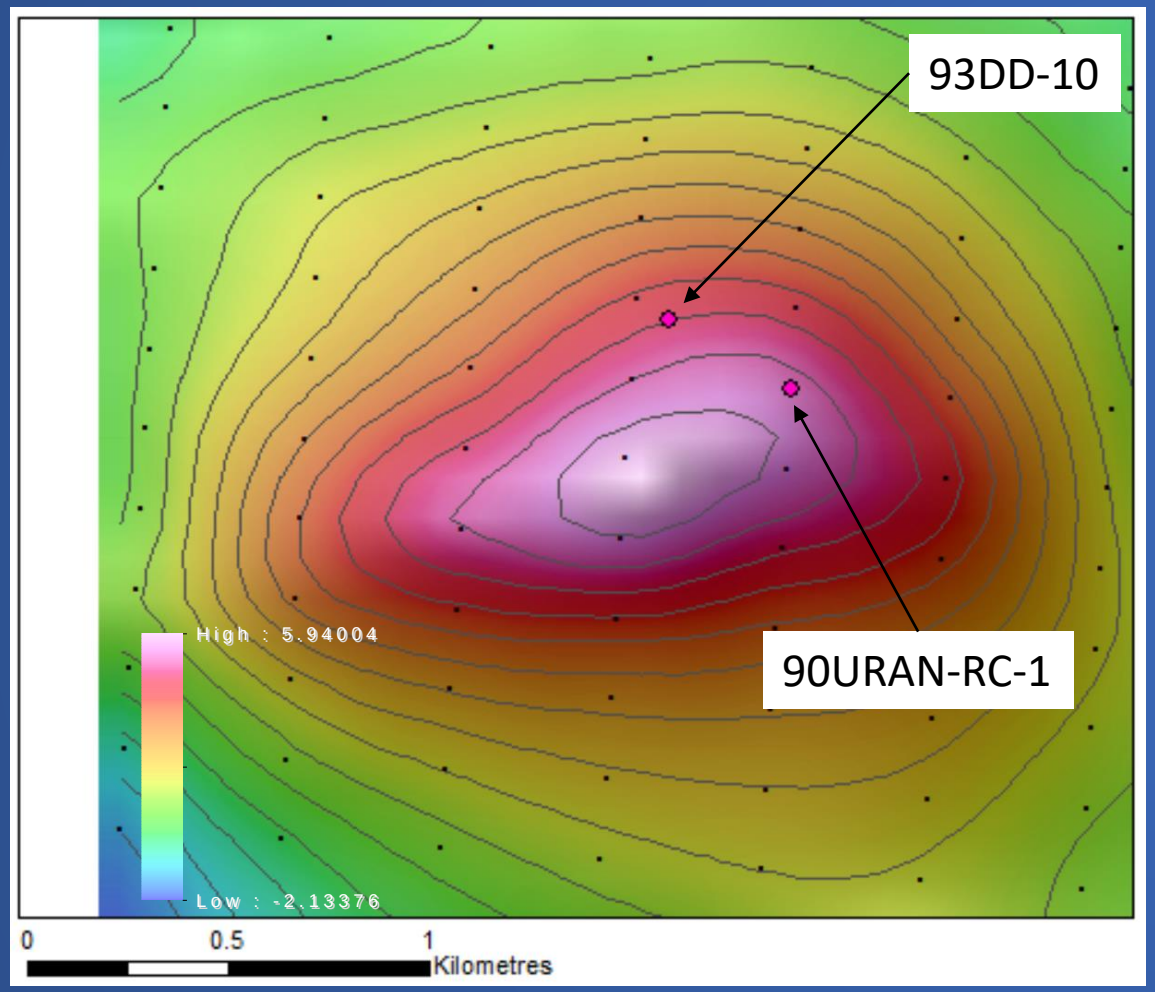


Downhole Geochemical Assays

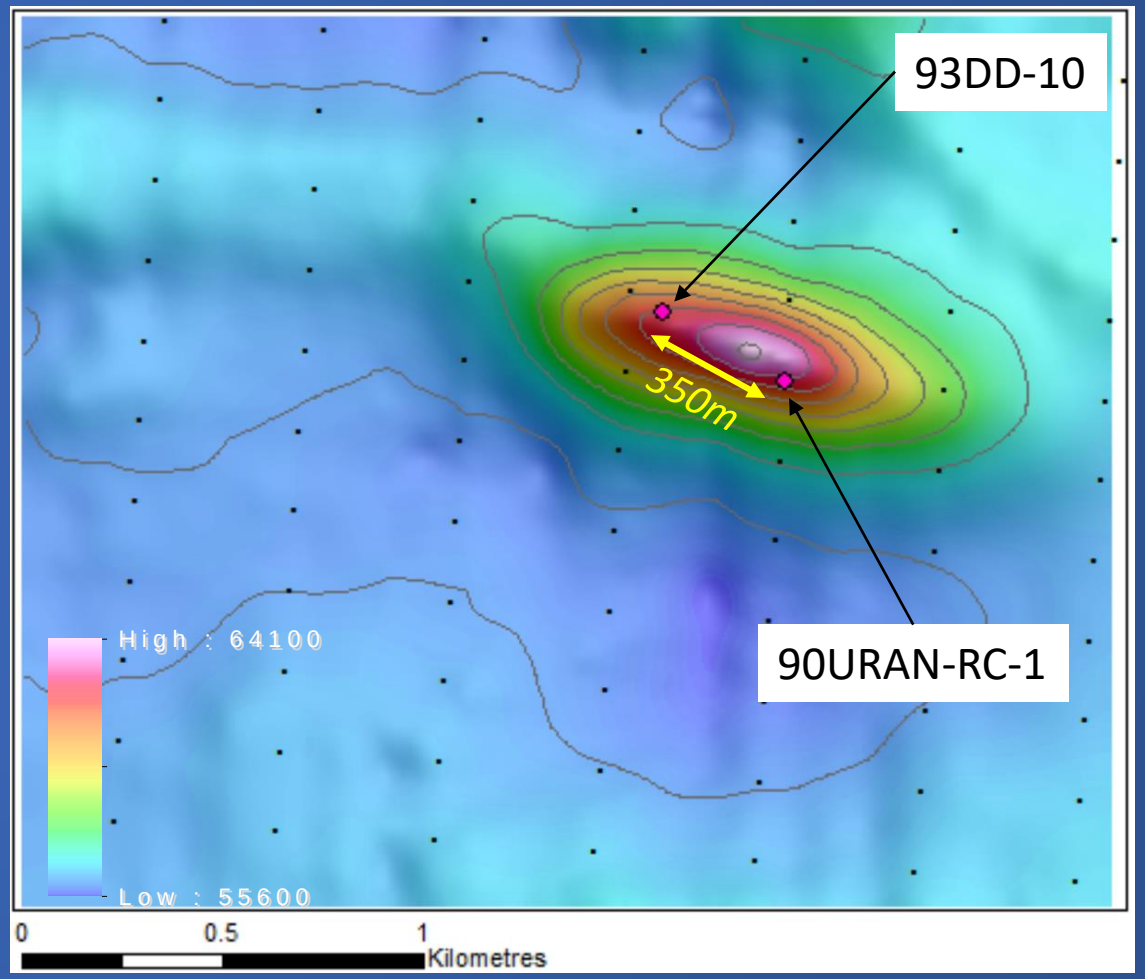
Normandy Exploration Program.

- In November 1991 Normandy Exploration farmed into the Project.
- During 1993 Normandy Exploration established a grid at Uranus comprising 8 x 400m spaced lines centred on the Burmine drill collar and completed gravity and ground magnetic surveys over all lines.
- Results are described as indicating a discrete high amplitude 5-6000nT magnetic anomaly ***coincident*** with a +3.0 mGal gravity feature.
- Normandy initially planned to re-enter drillhole 90URAN-RC-1, but with the hole blocked drilled an additional vertical hole 93DD-10 350m WNW (along strike) of the original drillhole.

Drilling at Uranus Prospect Part II.



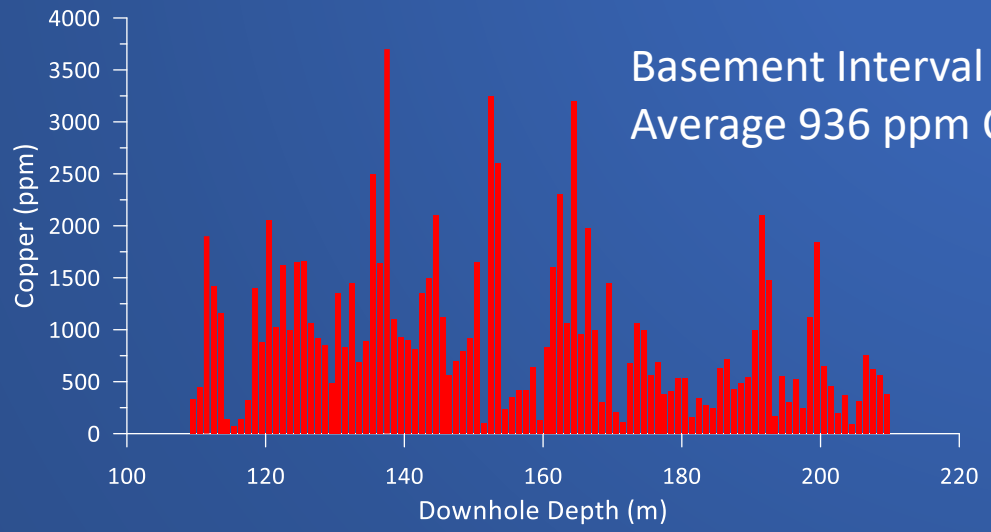
Residual Bouguer Corrected Gravity Data
(Contour Int = 0.5 mGals)

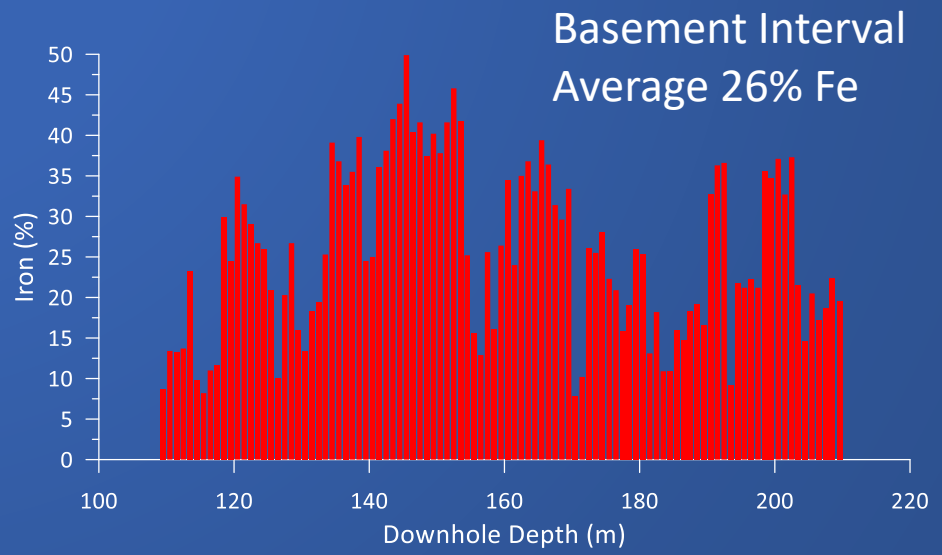


Reduced to Pole Ground Magnetic Data

Results from Drillhole 93DD-10

- The hole intersected a sequence of very fine grained, very altered albite-actinolite-quartz-chlorite rock and magnetite-phlogopite-carbonate-tremolite +/- hematite +/- pyrite +/- chalcopyrite rock, with intervals of moderate to intense carbonate-quartz +/- fluorite-pyrite-chalcopyrite veining and fracture fill with a max mag. susc. of 159,000 x 10^{-5} SI.





Results from Drillhole 93DD-10 cont'd.

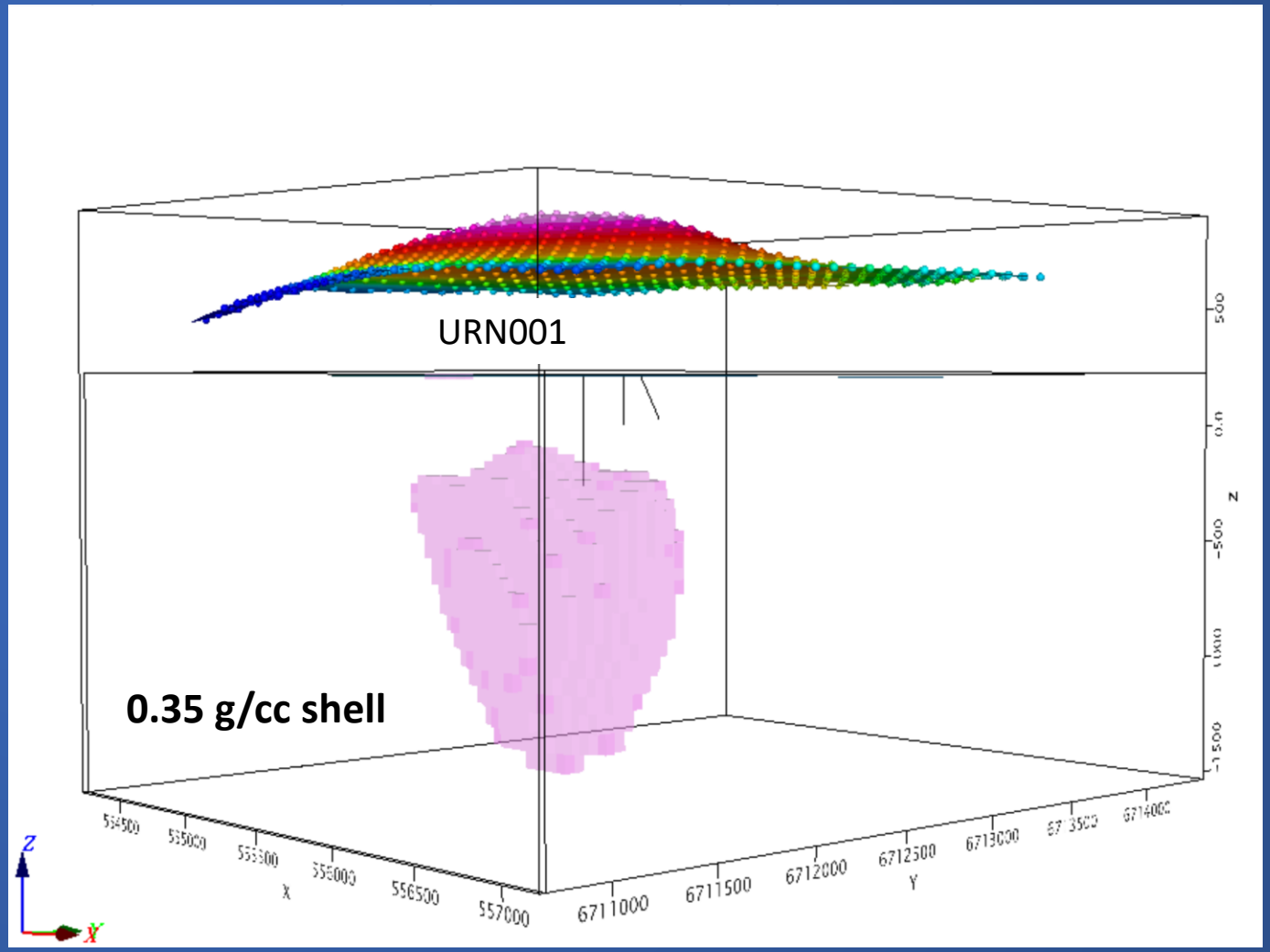
- The geological and geochemical results from 93DD-10 were identical to that seen in the original drillhole 90URANRC-1.
- Given that the second drillhole was essentially along strike from the first hole.
- Although more work was recommended to be undertaken at Uranus, no further work was completed by Normandy.
- The description of Uranus as a coincident gravity/magnetic anomaly appears to have hindered any thoughts of followup.

Minotaur Resources Exploration Program

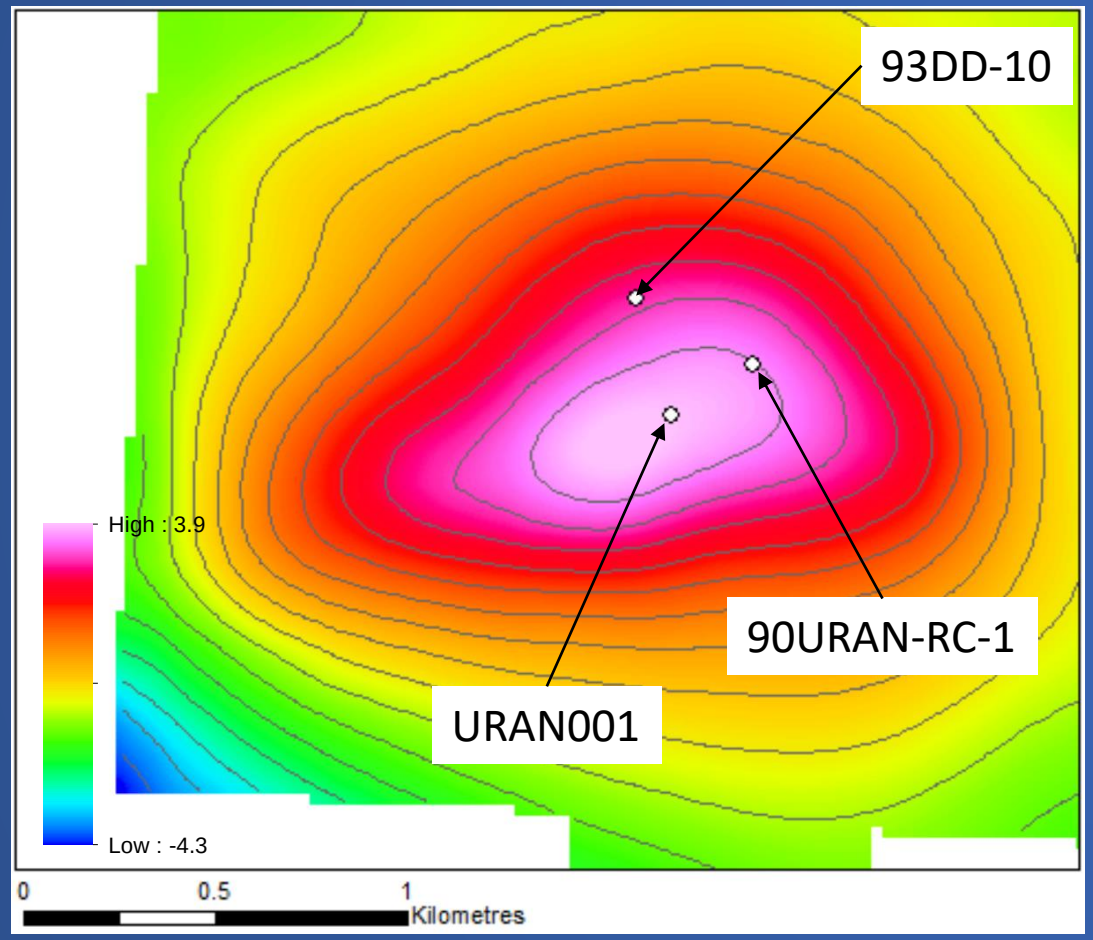
- In 2000, Minotaur Resources and Billiton Exploration farmed into the Mt Woods Joint Venture.
- A review of the potential of the Mt Woods inlier to host higher level, haematite dominated iron oxide alteration systems by consultant geologist Barbara Anderson (ex-Normandy), with input from Minotaur and Billiton geologists, resulted in the selection of six regional targets for initial focus. These targets were, Peculiar Knob North, Manxman , B, *Uranus*, Neptune, Blaze and Armstrong North.
- Geophysical re-processing of the six priority targets was undertaken by Billiton geophysicist Wayne Petit using 3-D inversion modelling software. No new data was acquired.

Geophysical Inversion – Uranus Prospect.

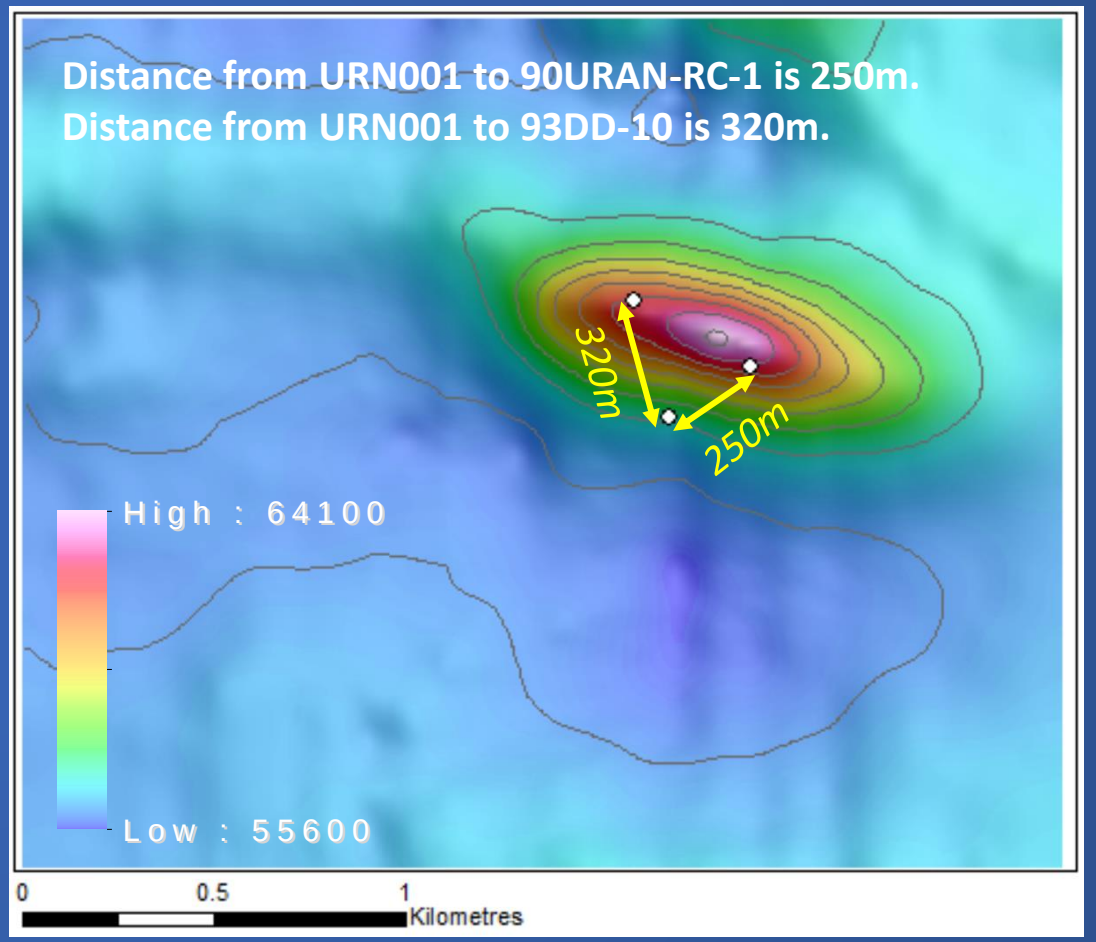
- Discovery drillhole URAN001 was sited on the density model produced using the GRAV3D code. This has been replicated using the VOXI Code.
- The location of the two previous drillholes is also shown.



Drilling at Uranus Prospect Part III.



Residual Bouguer Corrected Gravity Data



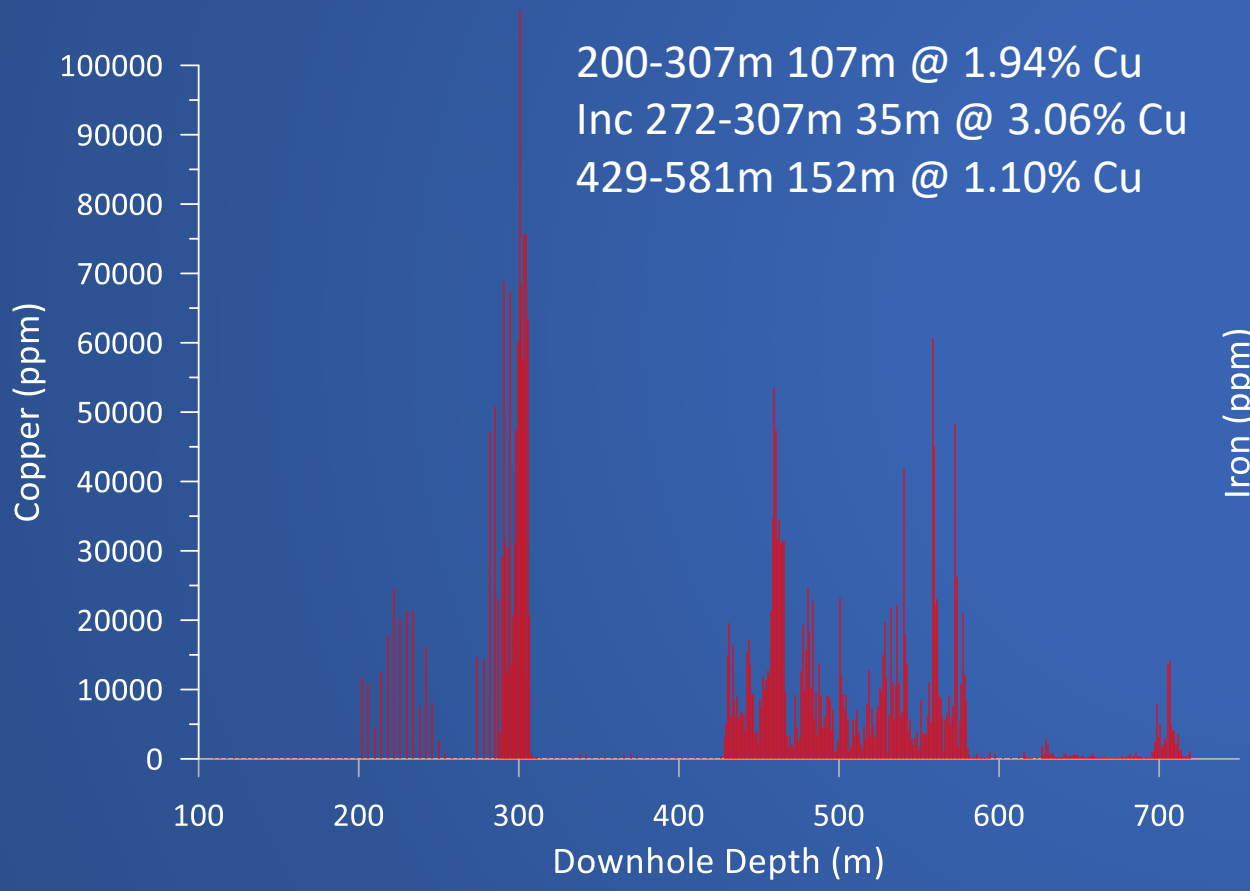
Reduced to Pole Ground Magnetic Data

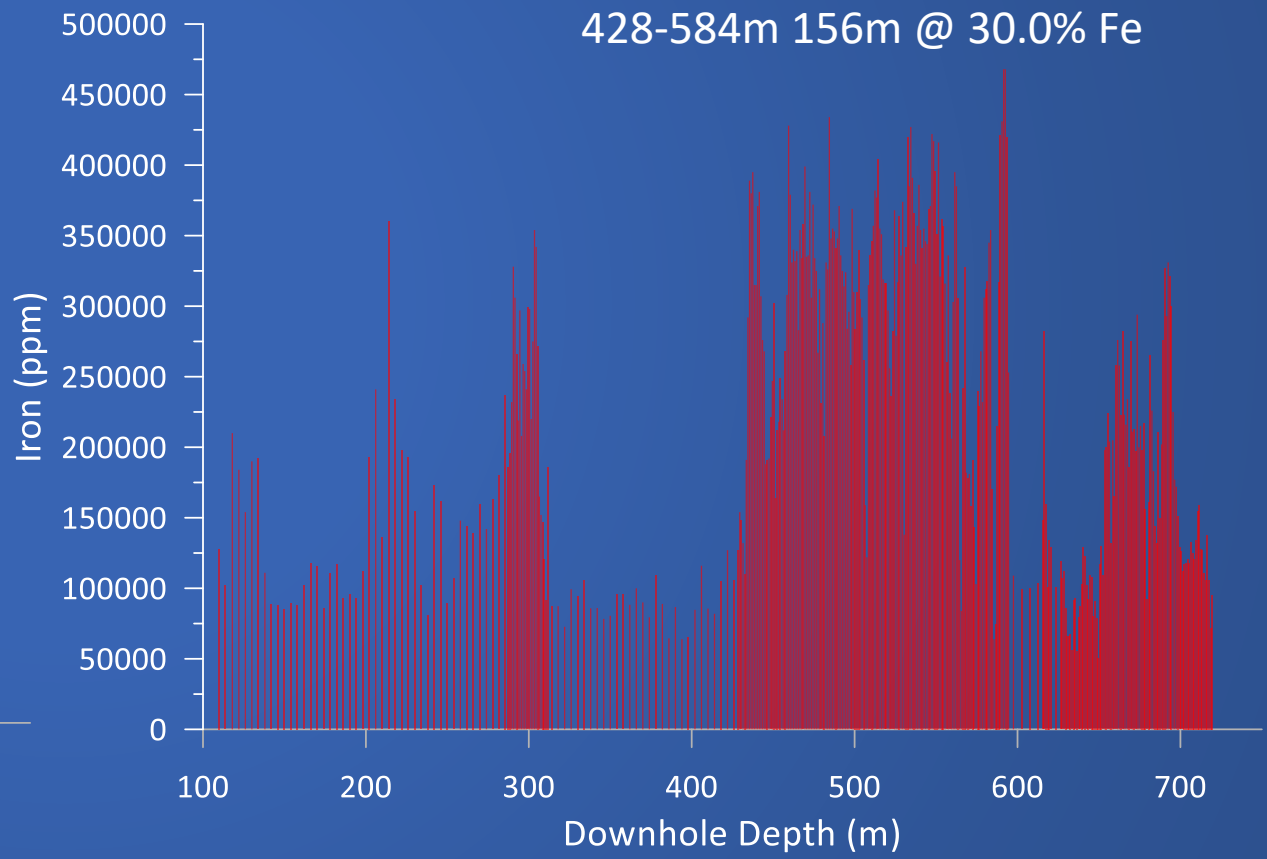
Drillcollar location URAN001.

URAN001 Drill Summary.

0-108m	Cover sequence (shale, sand)
108-200m	Fractured, brecciated and haematite-veined metasediments
200-307m	Matrix-supported, grey haematits-silica breccia with highly altered (haematite-sericite-silica) clasts.
202-307m	Chalcocite mineralised, matrix supported haematite-silica breccia, with highly altered (haematite-sericite-silica) clasts.
307-429m	Weaky brecciated metasediment and late-stage dolerite dyke.
429-581m	Red-grey milled haematite breccia with variably developed and dispersed chalcopyrite and bornite and haematite-sericite-silica altered clasts.
581-720m	Interbedded amygdoloidal felsic volcanics, agglomerate, minor dolerite dykes and silica-haematite breccia. Minor chalcopyrite.

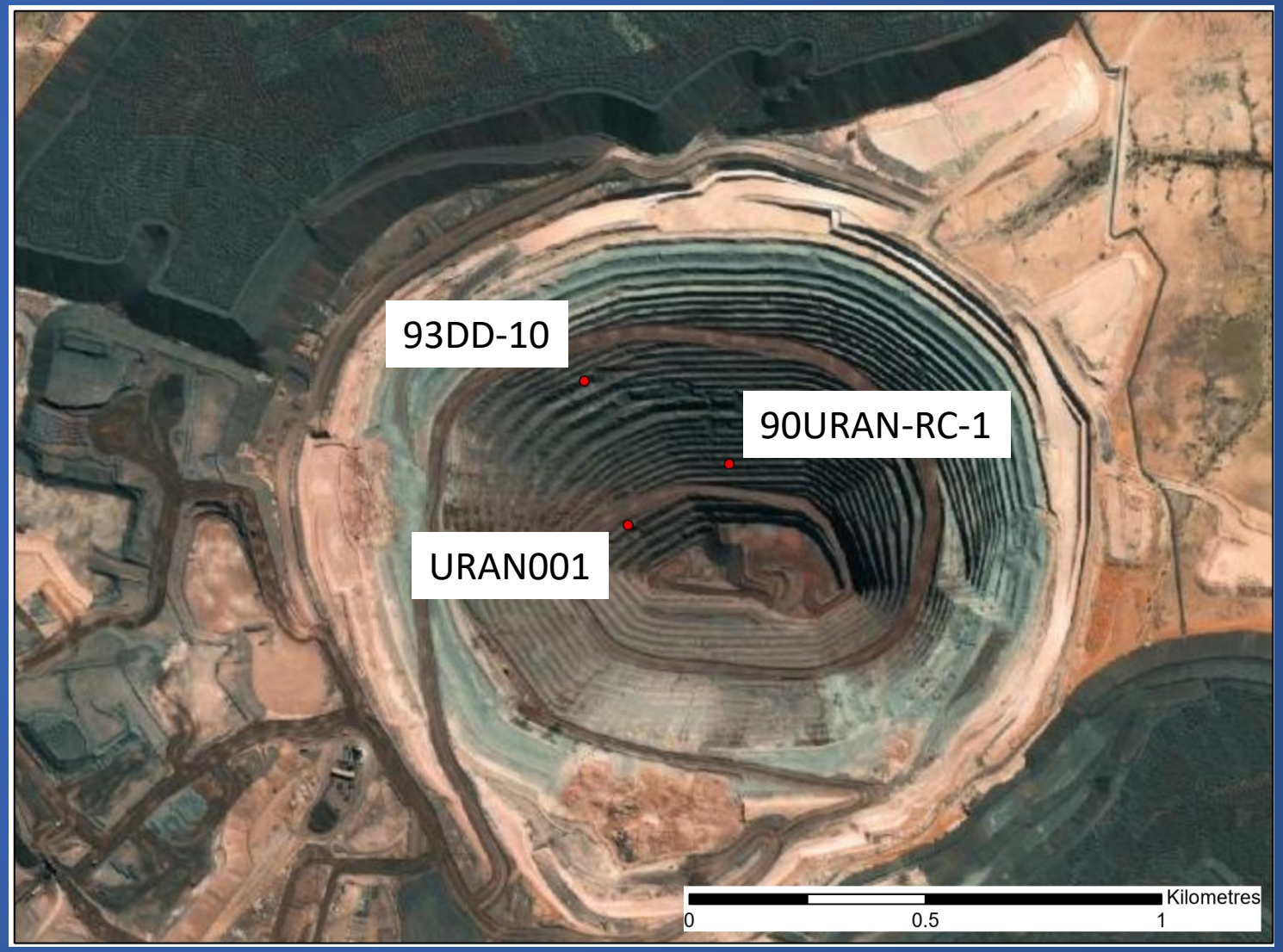
URAN001 Assay Results.





Location of drilling on current infrastructure.

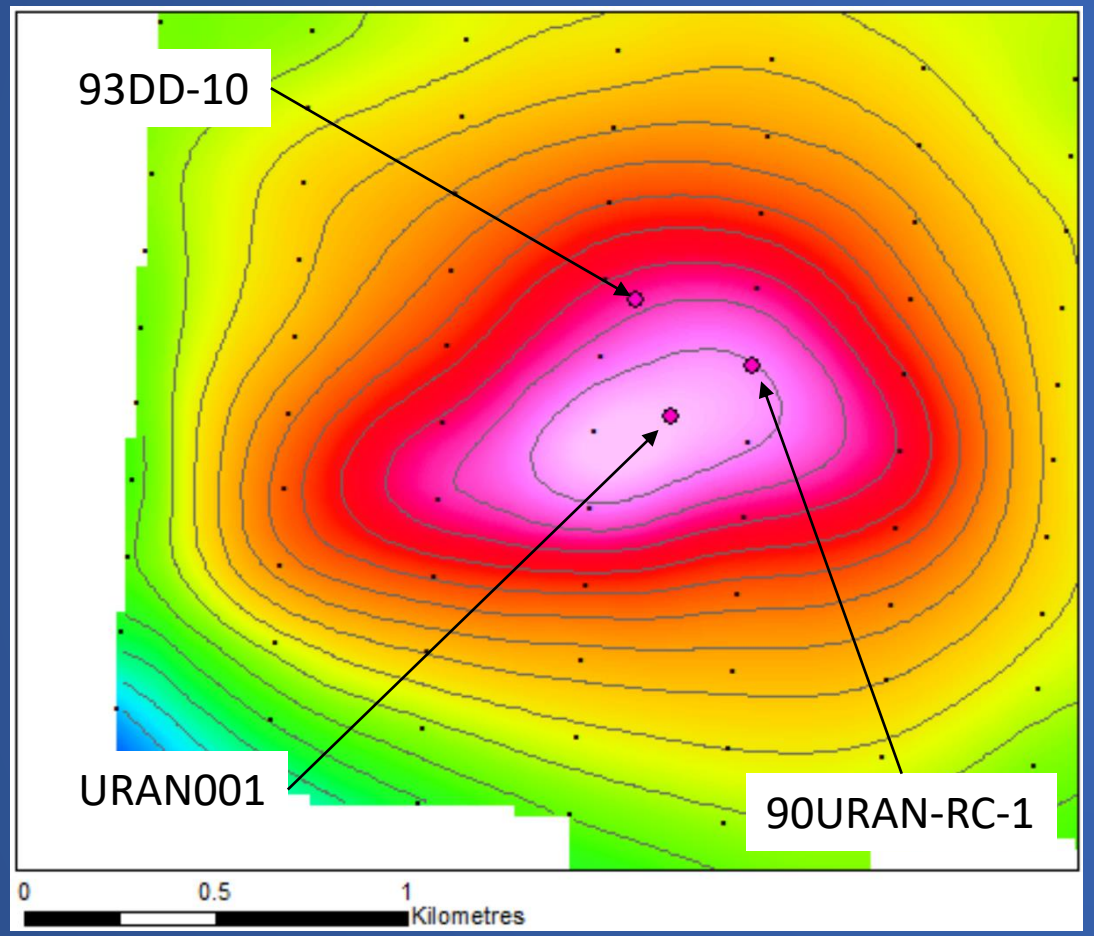
- Plotting the drillhole collars on the openpit highlights just how close the first two drilholes were to the orebody.



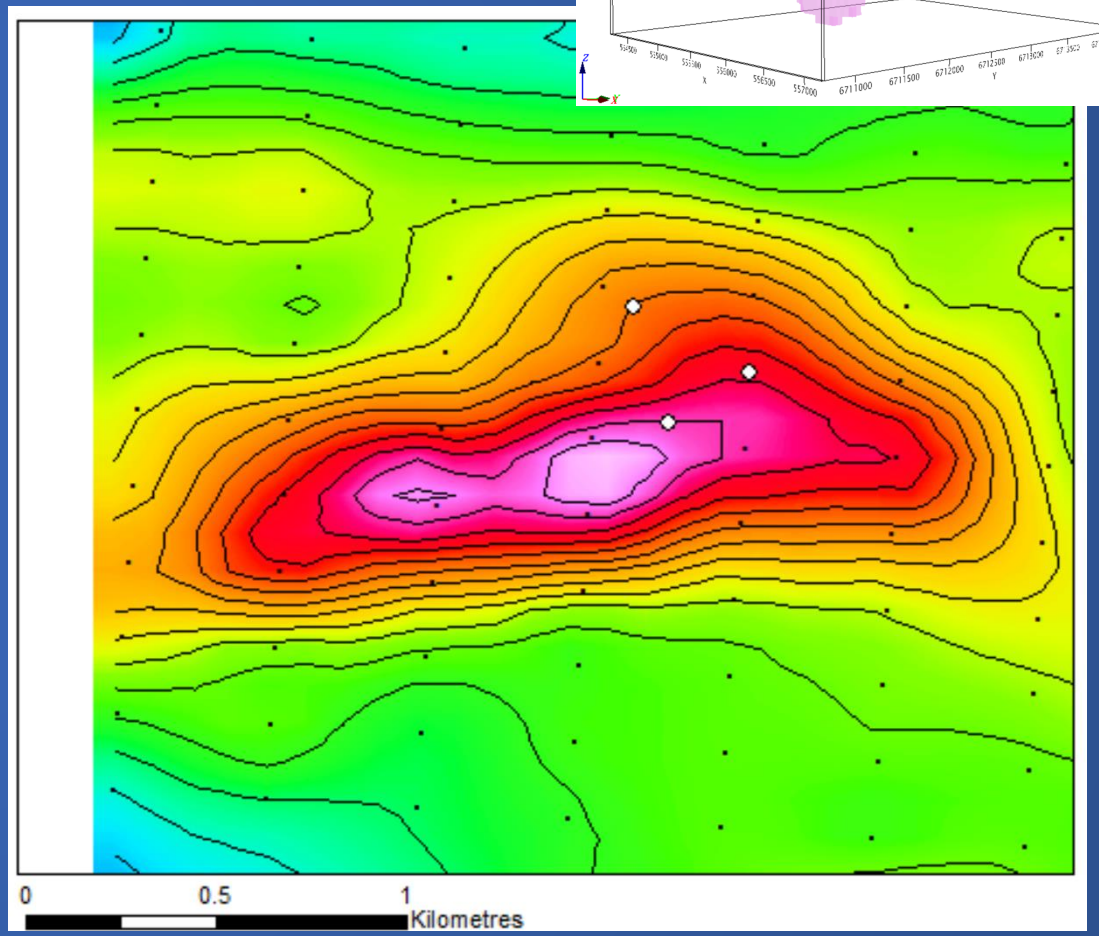
Review of Ground Gravity Data.

- Although the inversion of the gravity data has led to the discovery of Prominent Hill, and encouraged the team to commit to a deep drillhole, the density structure from the model was not very a good representation of the sub-surface.
- URAN001 was targeted on the main part of the density volume from the inversion, but this is essentially beneath the peak of the gravity response.
- In reality there are three main dense bodies mostly contributing the gravity anomaly, and URN001 was drilled between them.
- This became more apparent with the collection of more detailed data but was also apparent in the original data.

Review of Ground Gravity Data.



Residual Bouguer Corrected Gravity Data

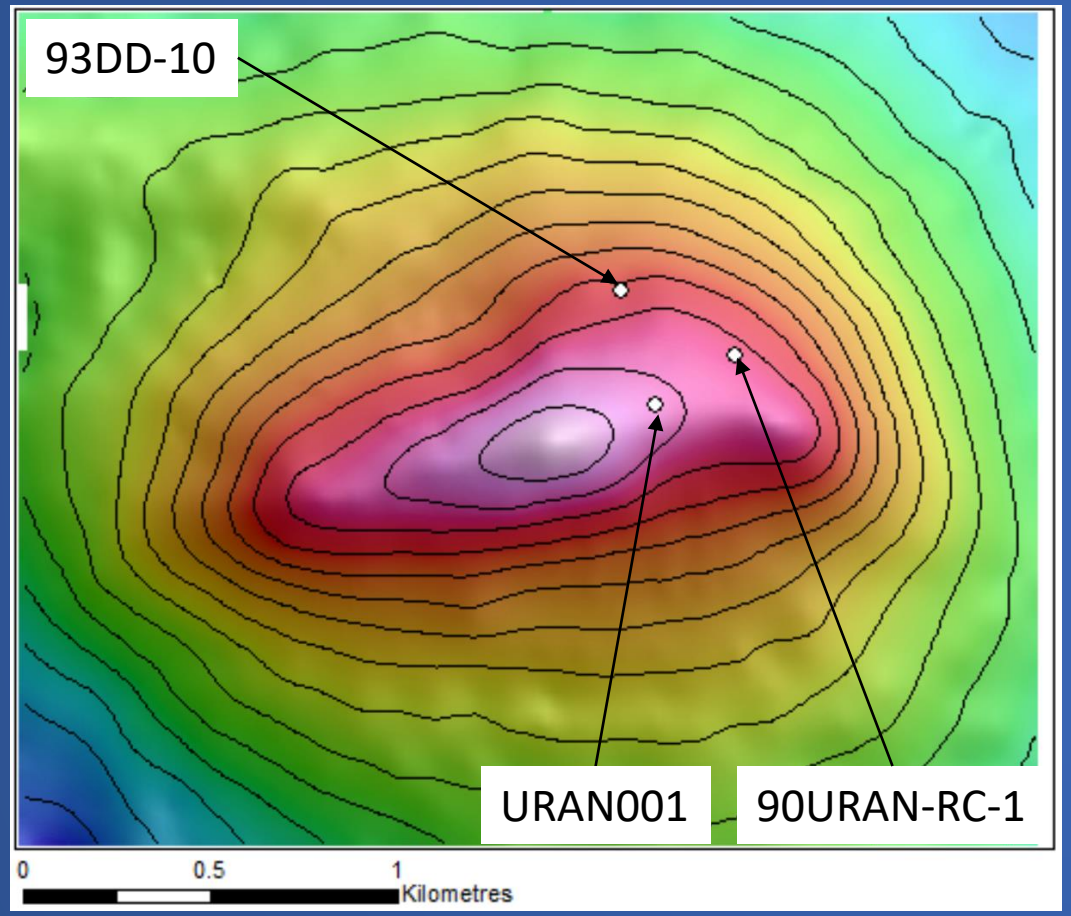


First Vertical Derivative Bouguer Corrected Data

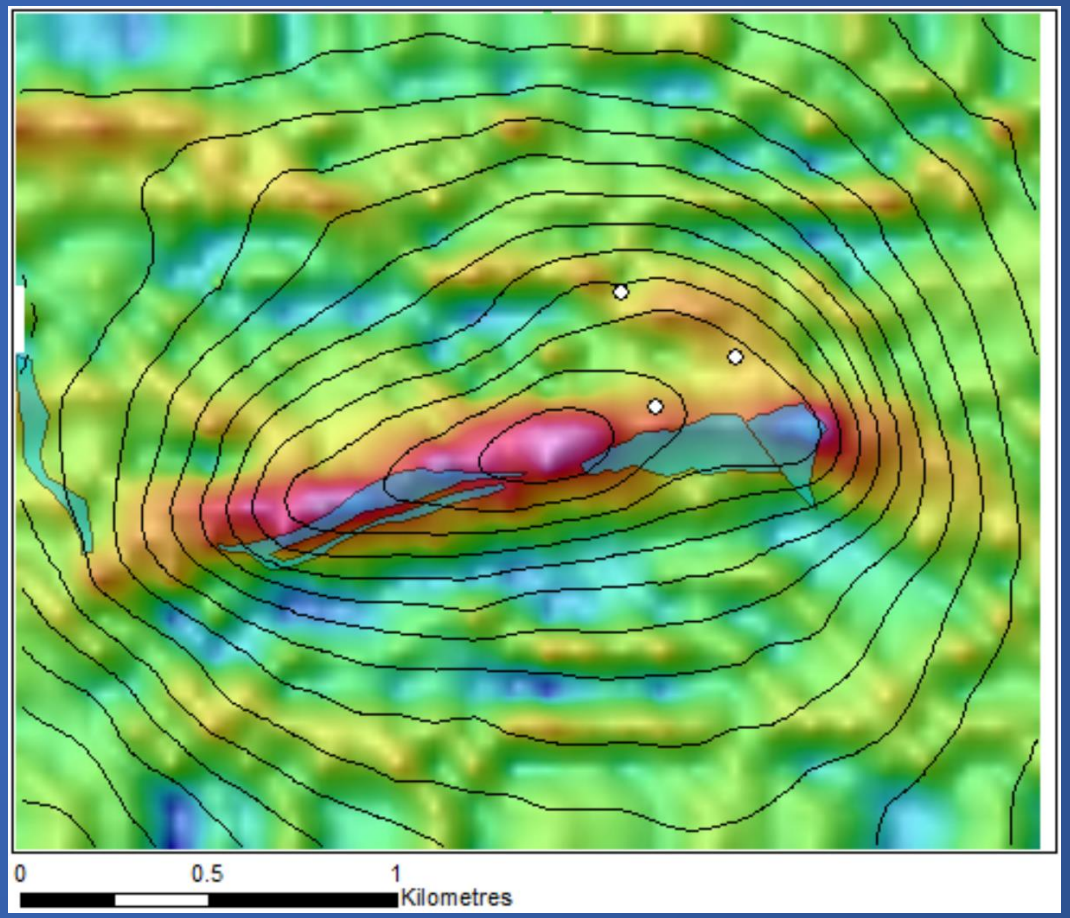
Post Discovery Gravity Data.

- Following the drilling of URN001, gravity data was collected on a 100m x 100m grid over the Prominent Hill Prospect Area.
- This higher resolution data (c.f 200m x 400m collected by Normandy) was important in highlighting the source bodies.
- The following slide shows images of this data along with the location of the three drillholes discussed previously.

Post Discovery Gravity Data.



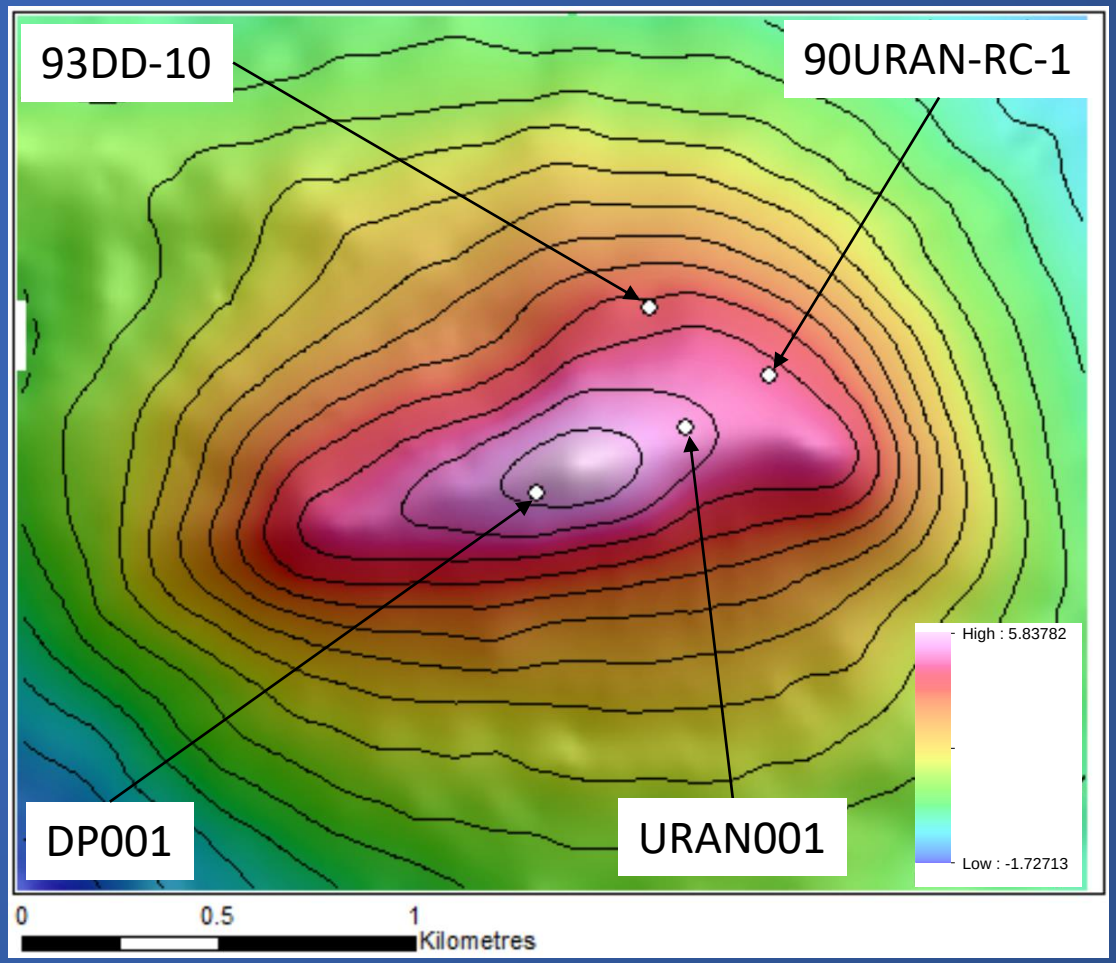
Residual Bouguer Corrected Gravity Data
Contour Interval 0.5 mGals



Second Horizontal Derivative Bouguer Corrected Data
Location of mineralised breccias below the cover shown in blue (from Freeman and Tomkinson, 2010)

Post Discovery Gravity Data.

- The more detailed data shows the peak of the gravity anomaly located to the west of URN001.
- Drillhole DP001 was drilled adjacent to the peak of the residual gravity data (first order surface removed).

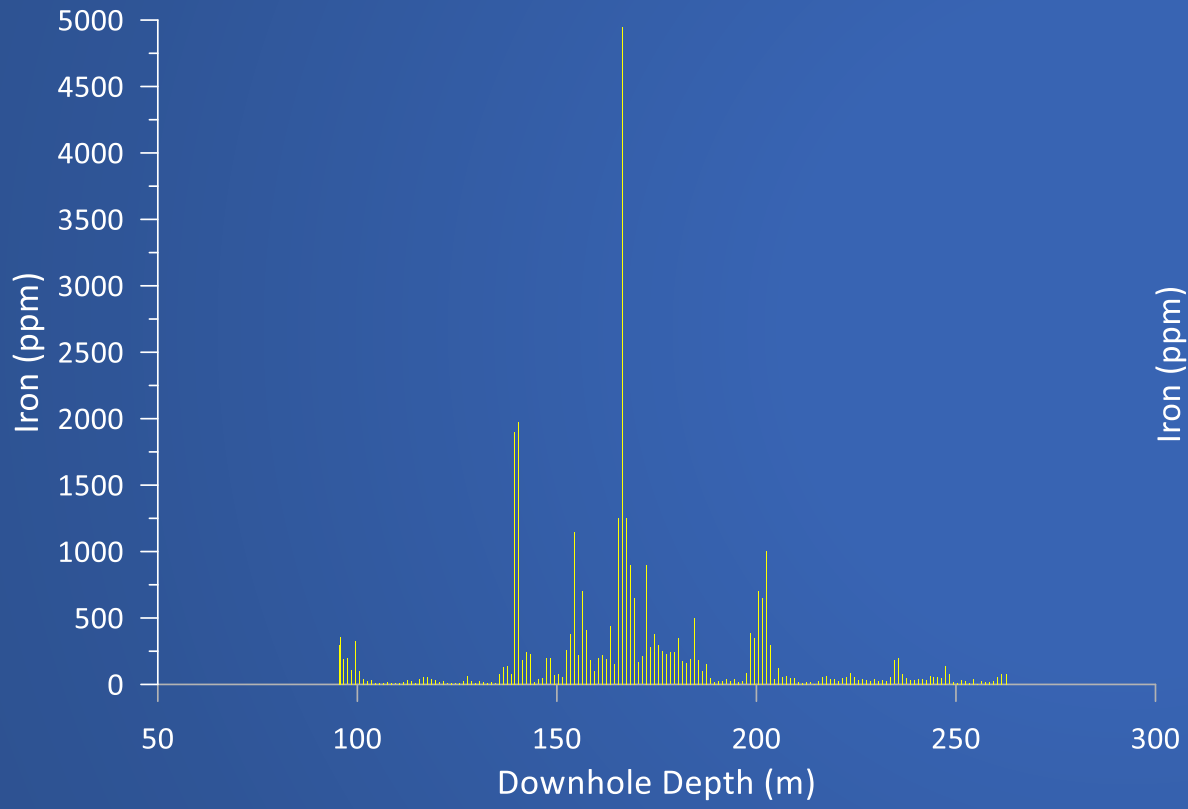


Residual Bouguer Gravity Data
Contour Interval = 0.5 mGals

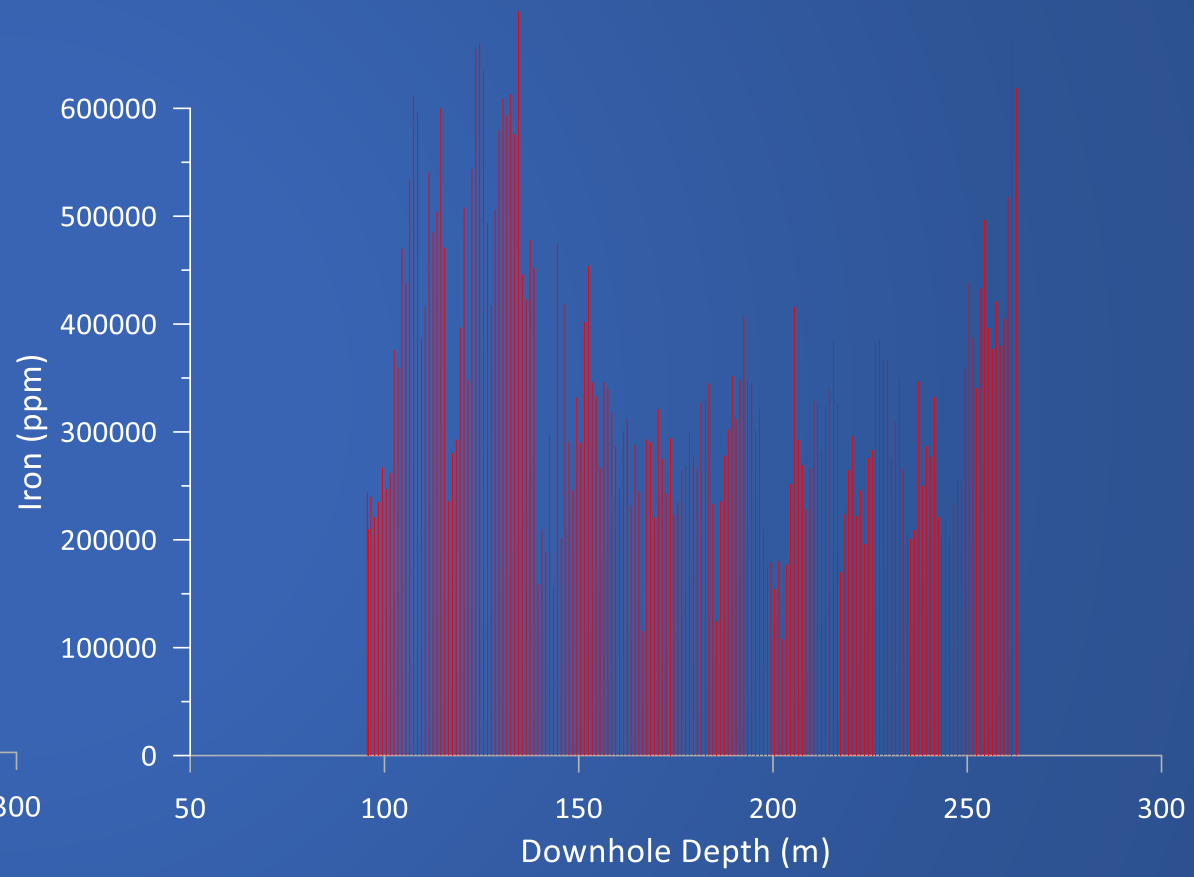
DP001 Drill Summary.

- DP001 intersected basement at depth of 95.4m. The primary rock type encountered was pervasively hematite-quartz +/- sericite altered brecciated volcanic rocks containing possible sedimentary fragments, and overprinting steely-grey massive hematite veins (to a few metres thickness), post-dated again by specular hematite and barite veinlets (generally <30mm thickness).
- Extensive silicification completely obliterated primary textures through much of the core. Only minor sulphide was noted (pyrite and chalcopyrite) usually within fine (<1mm) late-stage veinlets.

DP001 Assay Results



Basement Interval Averaged 196ppm Copper.
Max. Cu 0.5% from 166m-167m.



Basement Interval Averaged 26% Fe.
Inc 50% Fe from 104m-134m

DP001 Drill Summary.

- If more detailed gravity data had been available at the time the location of URN001 may have shifted. The drillhole would have intersected significant Iron alteration, but only minor base metal anomalism.
- It is interesting to conjecture what would have happened next, maybe another 10 years may have passed before the discovery of Prominent Hill.
- If DP001 had been the third hole drilled, how do you find the mineralisation?

Conclusions.

- The Prominent Hill IOCG Deposit was discovered 12 years after initially being highlighted in an aeromagnetic survey.
- Discovery hole URAN001 was the third hole drilled at the Prospect, after targeting an untested gravity anomaly, using data that had been collected 9 years previously.
- A significant proportion of the data collected at Prominent Hill is available via the South Australian openfile system, and I was able to use this data to construct this case study.
- High quality data is available over many deposits across Australia and these datasets can be used to produce case studies, which are an invaluable aid in designing exploration programs.