The truth about geophysical exploration and discovery in central NSW

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To this

From this
”When you see a real ore deposit in your geophysical data – you will know it.”

True?
The Discovery of the Larsen's East and Tritton Ore Deposits.

Girilambone NSW
Looking for more of this

Chalcocite
Don't mistake it for this

Unmineralised host rock
Or this will do
So we can make more of this --- 99.99999% pure copper
Prior to the mine commencing, test moving loop EM surveys had been run. These detected sulphides beneath the mine.

This was NOT the target which was the oxide copper near surface but detection of sulphides was seen as a possible indirect tool to find the supergene zones.
Girilambone Mine
Murrawombie Open Pit

100m Moving Loop Sirotom II
Amplitude at 4.9mS
1989 survey
Downhole EM surveys beneath the mine confirmed that the sulphide veins were good conductors.
So a program of surface 200m moving loop Sirotem was commenced.

This started with a 2km square trial zone north of the mine at a prospect known as Northeast where there was a known small occurrence of oxide copper.
The very first survey line detected a strong EM response.

But this was about a kilometre from the known oxide copper occurrence just east of an old working known as Larsen’s Pit.
Completion of the 2km square trial revealed a discrete strong conductor at Larsen' East.

Negligible response was obtained over the known copper occurrence at Northeast.

A large moderate conductor further north subsequently named 'Ben Hur'
Larsen's East

200m Moving Loop Sirotom II

Decay constant at 1uV/A

True North

Ben Hur

Larsen's East
More detailed 100m moving loop EM confirmed these and also shows a small response at the original target – Northeast Prospect.

Subsequent drilling proved that the Larsen's East conductor was associated with oxidised copper mineralisation which was drilled out and added to the ore inventory.

The Ben Hur conductor was graphite.
Larsen's East

100m Moving Loop Sirotetem II

Decay constant at 1uV/A

Ben Hur

Larsen's East Open Pit
IP surveying could not be run at Larsen's East at that time due to all the drilling activity.

Ben Hur and Northeast both have an IP response

Later surveys show that Larsen's East has a distinct IP response
Gravity surveying over the area gave a complicated pattern with local highs adjacent to the deposits.

But no direct indication of the ore zones.
Larsen's East

Detailed Gravity

200m High Pass Filtered

Ben Hur

Larsen's East Open Pit

True North

- 0.2
0.2 milligal

500 m
Downhole EM through the ore zone consistently showed offhole responses that suggested the conductors were steeply dipping with at least two en-echelon lenses.

This was not consistent with drilling results at 25m centres which suggested a 45 degree dipping ore zone. The mine was planned on the basis that the drilling interpretation was correct.
When the zone was mined, the downhole EM was proven correct. Lesson learned – always drill some scissor holes.

Attempts to recover the high grade zones (conductors) eventually resulted in the collapse of the pit wall.
An exploration licence to the southwest covering the historic Great Hermidale, Budgerygar and Budgery mines was relinquished by other explorers.

This licence was acquired and the airborne magnetic data added to the Girilambone data base.
Because of the success of the exploration strategy of using ground EM at Larsen's East it was decided to use this in the new areas.

The surveying started in the area surrounding the old Budgerygar Mine. Known sulphides there showed a strong response so the survey was extended.
Tritton - 200m Moving Loop Sirotom - Channel 10 (5.78mS)

Budgerygar

Tritton

True North

0 5 µV/A

500 m
The discovery of the Tritton EM response offered encouragement that this technique could be effective and the EM surveying continued for several years.

Eventually a huge area was covered with 200m moving loop Sirotem. Unfortunately no further deposits were detected with this technique.
The Budgerygar and Tritton conductors were very apparent in these data.

They were highlighted by the presentation of the data as a time constant. All further data was examined closely as both response amplitude and time constant.
Decay (time) constant presentation was also of use on a local scale
Detailing with smaller moving transmitter loops highlighted the conductors further. And gave higher resolution details for further interpretation.

With the smaller transmitter loops and reduction to time constant form, it became obvious that Tritton was the stronger of the two conductors.
Tritton - 100m Moving Loop Sirotex - Decay Constant

Budgerygar

Tritton

True North

0 7 mS

500 m
Fixed loop Sirotexm surveys confirmed the moving loop data and sharpened up the interpretation in terms of depth and location.

With this survey geometry a conducting response is a broad negative. The adjacent high indicated dip to the east. The Tritton conductor is deeper and hence the response is broader.
Tritton - Fixed Loop Sirotom - Channel 16 (15.58 mS)  
Horizontal X (East) Component

Budgerygar

Tritton

True North

-1 0.5 uV/A

500 m
Seven RC holes were drilled updip from the interpreted conductor searching for oxide copper resources. None were found.

For the eighth hole (of ten proposed) it was decided to test the actual conductor to check that it was a sulphide body.
Hole 10 (downdip from the discovery hole 8) was logged with downhole EM to beyond the mineralised horizon.

The EM contractor, Peter McSkimming, recognised that the mid time channels were still rising past the mineralisation and recommended the hole be extended.
Upper Sulphide Lens @ 410 m

Downhole Sirotent II μV/A

End of Hole

Ch. 10
5.8 mS

Ch. 16
15.6 mS

Ch. 22
39.1 mS

Tritton - Downhole Sirotent Hole 10
Tritton - Geological Cross Section - Line 29300N (Local grid)
After several years of ground EM surveying (and two discoveries) it was decided that the expense was too great. Airborne EM tests were carried out over the known Tritton/Budgerygar sulphides.

A Geotem Deep survey was flown at 100m line spacings in both directions to determine if it was possible to detect Tritton.
The Geotem system was unable to detect the Tritton conductor due to its depth of burial. The fact that the shallower sulphides at Budgerygar were detectable was sufficient to allow the use of the airborne system over broader areas.

The areas to be covered with Geotem were most of the prospective areas within the exploration licences that had not been covered with ground EM.
Girilambone Project
200m Moving Loop
Sirotlem II

Channel 4 = 1.66 mS
Girilambone Project
Geotem Deep

Principal Component 1
Mid Times Ch's 7-11
High Pass Filtered
Only one clearly anomalous response was detected. This was confirmed using ground EM surveys and drill tested. Unfortunately it was due to graphite, similar to the Ben Hur Prospect.

Test surveys were also flown using the then experimental Hoistem system but no responses were detected over the Tritton deposit.
"Look! Up in the sky!"

"Is it a bird?"

"Is it a plane?"
A single line of MIMDAS pole-dipole IP and MT was run over the deposit.

IP values are elevated in the footwall rocks but there is no distinct response directly associated with the deposit.

This is consistent with an exhalative genesis for the deposit.
The magnetotelluric (MT) data failed to detect the deposit despite the fact that it is a strong EM conductor.

The intrinsically plane wave nature of the MT signal makes this technique inappropriate for detecting compact, short strike length targets.
Tritton - MIMDAS - 2D Inversion of Magnetotellurics
At the time that the mine was starting construction, there were no funds available to further test IP or gravity surveys prior to construction.

Contractor Hugh Patterson volunteered to run a detailed gravity survey over the area of the mine site free of charge so that the data would be available for subsequent exploration evaluation.
Tritton - Detailed Bouger Gravity

Budgerygar

Tritton

True North

0 1 milligal

500 m
Subsequently, the gravity survey was expanded considerably. The data shows that the deposits do not have a coincident gravity high but have an association with adjacent elevated gravity.

This is similar to the observations from North Girilambone.

The gravity high may be due to silicification associated with the deposits.
”When you see a real ore deposit in your geophysical data – you will know it.”

Probably – if the right technique is used but only to a limited depth (possibly 300m for this style of deposit).
Tritton - 200m Moving Loop Sirotém - Decay Constant

Budgerygar

Tritton

True North

0 3.5 mS

500 m
Fast forward a decade or so

And move 120km southwest
The Discovery of the Mallee Bull Ore Deposit.

Gilgunningia NSW
Exploration was concentrated around the abandoned May Day Mine which lies immediately southwest of the Gilgunnia gold fields.

Considerable magnetic, IP and drilling work had been carried out by previous explorers.
Other explorers were using VTEM heli-borne EM surveying on the adjacent exploration licences.

Despite very tight budgets it was decided to fly two postage stamp sized VTEM surveys over the May Day Mine and the nearby Four Mile goldfields.
May Day - Mallee Bull Magnetic Data (from VTEM survey)

8.9 sq. km. + 12.5 sq. km. = 21.4 sq. km.

Butcher's Dog
Mallee Bull
May Day
This was against the advice of the consultant geophysicist (yours truly) who thought (based on previous experience at Girilambone) that the money would be better spent on a comprehensive ground EM survey over May Day.

Had this advice been followed, there would be excellent ground EM data at May Day but Mallee Bull would probably remain undiscovered.
May Day - Mallee Bull  Late time VTEM data

- May Day
- Butcher's Dog
- Mallee Bull

10km
BINGO!

Lady Luck smiled down.
May Day - Mallee Bull  VTEM Time Constant
With the budget now extremely thin the question of how to follow up the VTEM response was addressed.

An EM contract crew was nearby so a single line of fixed loop ground EM was planned.

In the event of no response, another line at right angles to this would have been run to check for west-east strike. This turned out to be unnecessary.
A clear deep response occurs at late times.
Figure 4

Mallee Bull Prospect
VTEM follow up
Crone PEM Fixed Loop

Line 6413350N
[MGA55 GDA94]

X (East) component
Eureka!

Let's drill

(But we don't have any money!)
Somehow funds for a drill hole were found.

The hole intersected minor sulphides but no massive conductor.

Downhole EM was run to check that the EM target had been tested.
OOOPS  Missed it!

Drill again!

(But we now have less money!)
OOOPS  Missed again!

Drill yet again!

(Surely you are joking!)
As happens, the initial holes had both deviated very badly and had tested almost the same patch of ground, well away from the interpreted EM target.

Lesson learned – survey your drill holes – even if it costs money you don't have.
A third hole was drilled hesitantly based on the downhole EM results (but with the memory of Larsen's East and Tritton still vividly clear).

“Trust the Force (aka downhole EM) Luke!”
At last!
Once the deposit had been confirmed by drilling a single line of 100m dipole-dipole IP was run.

2D inversion modelling of these data appeared to indicate that the deposit was associated with a moderate IP anomaly and a minor resistivity low.
But later 3D offset pole-dipole surveys and 3D inversion modelling shows that the IP response (and a strong resistivity low) lie in the footwall rocks below the deposit.

As with the Girilambone deposits, this is strongly suggestive of a syngenetic exhalative genesis for the deposit.
With the deposit discovered and definition drilling underway, attention turned to the search for extensions or additional deposits.

In particular the large deeply buried magnetic target to the north was of considerable interest due to the presence of pyrrhotite in the Mallee Bull deposit.
This prospect was named Butcher's Dog to conform to the theme “as fit as a mallee bull” and now “as fit as a butcher's dog”

For fear of upsetting the ASX this naming theme was never extended to “as fit as a fiddle”
May Day - Mallee Bull Regional Airborne Magnetic Data

- Butcher's Dog
- Mallee Bull
- May Day

10km
3D inversion modelling of the surrounding magnetic data seems to suggest a strong link between the Mallee Bull and Butcher's Dog prospects.

The implication is that Butcher's Dog is a much deeper and very much larger extension of the Mallee Bull system.
Mallee Bull / Butcher's Dog  3D Magnetic model
A deep drill hole based on the magnetic models intersected disseminated pyrrhotite at the Butcher's Dog prospect.

Due to the great depth of the magnetic source (approximately 1km), further investigation was undertaken with a so-called “deep penetration” technique standard and audio frequency magnetotellurics MT and AMT.
Survey Lines on Geology
A 3D inversion model of the combined MT and AMT data was generated. This model indicated that a deep conductor was coincident with the interpreted deep magnetic source.
3D MT model at 600m below the surface
Examination of the 3D MT model closer to the surface shows that the MT conductor continues up-plunge almost to the surface.

However, the MT / AMT surveys did not detect the ore deposit. This is similar to MT results for Tritton. This technique is inappropriate for small highly conducting targets.
3D MT model at 300m below the surface
Comparison of the 3D MT model with the 3D IP model shows that the MT conductor is directly coincident with footwall IP source.

This response in IP and MT is assumed to be a pyrrhotitic feeder zone for the mineralisation at Mallee Bull.
3D IP model at 300m below the surface
This zone is visible as a distinct resistivity low in the 3D IP / resistivity inversion model.

The resistivity low / IP high / MT conductor can be traced to greater depths in the IP model than it can in the MT model.
3D resistivity model at 300m below the surface
The IP / resistivity / MT source is semi-coincident with the magnetic trend in the 3D magnetic model.

The likely source of these effects is a large, north plunging zone of disseminated pyrrhotite.
3D magnetic model at 300m below the surface
Gravity data shows a high directly coincident with the anomalies. This is assumed to be due to sulphide alteration and silicification. Like other deposits in the Cobar region, the gravity high is associated with the ore body but not directly coincident.
Mallee Bull / Butcher's Dog Gravity data
In a more regional context, the gravity high cannot be considered a true “anomaly”.

However, similar gravity highs are worth further investigation.
”When you see a real ore deposit in your geophysical data – you will know it.”

True?
Based on the data from Girilambone and Gilgunnia, the right sort of EM survey will produce an “obvious” response over an ore deposit. Not so for other methods.

However, for deeper deposits this may not be true.

Personally I hope that one day a really subtle geophysical response will turn out to be an ore deposit. I am still waiting....