MT. BULGA REVISITED

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Mt Bulga is located near Orange, New South Wales some 260 km west of Sydney. The first payable gold discovery in Australia was made in this region in 1851. In the immediate Mt Bulga area discoveries of silver and gold were first reported in 1886 and copper was mined and smeltered there until 1913.

Modern geophysical exploration commenced in 1964 and was directed at gossan outcrops, pits and shallow workings extending north from the old copper mine to the Mt Bulga ore body. The results obtained with magnetics, SP and IP were encouraging and an extensive drilling program followed in the 1970' s. This intersected significant sulphide mineralisation represented by the relatively small Mt Bulga ore body and defined the subsurface geology, however, no economic ore body was discovered.

The main feature features of the Mt Bulga ore body are summarised in Table 1.

Table 1: Main features of the Mt Bulga Ore Body

Ore Reserves	Total	0.46mT
	Tonnage/grade	0.34mT: 0.75% Cu, 1.54% Pb, 5.5% Zn 0.12mT: 0.97% Cu, 0.64% Pb, 3.92% Zn
DISCOVERY		Soil geochemistry, SP, IP
Mineralisation	Massive (main lens)	Syngenetic fine grained banded massive pyrite-galena-sphalerite-chalcopyrite
	Veins	Pyrite-chalcopyrite-pyrrhotite in mineralised volcanics
Geometry	Form	Steeply dipping unfolded sheet displaced by three cross-faults
	Depth to massive ore	20 – 60 m
	Depth extent	260 m
	Width	1.5 – 6.5 m
	Strike length	150 m
	Dip	$70 - 90^0$
Geology	Age	Middle – Upper Silurian
	Hanging wall	Altered meta siltstones
	Footwall	Chloritic quartz porphyry, fine sediments
SURFACE EXPRESSION		Gossan and old workings at the southern end of a prominent ridge
GOSSAN		Cavernous haematite-goethite gossan containing weathered host rock breccia

Considerable geophysical research followed this exploration phase until the 1990' s and included a number of seismic refraction surveys across the ore zone. Whiteley et al. (1984) and Palmer (2000) have presented some of the refraction data and interpretations. However, these interpretations were obtained with the relatively simple Reciprocal or GRM methods and the geology is quite complex.

Without the benefit of detailed geological information, Siegfried Rohdewald (www.rayfract.com/tutorials/mtbulga.pdf) recently produced an interpretation of Palmer' s data using a smooth 2D inversion and 100 WET inversions. This interested us as we had access to considerable geological information from the Mt Bulga area and other refraction data from a number of lines over the ore body.

Following completion of the geophysical research, the Mt Bulga area has undergone extensive rehabilitation and re-forestation. Many of the old mine shafts and pits have been filled and the exploration grid and borehole markers have been buried or destroyed. Consequently, the location of Palmer' s seismic line is only approximately known. This line was completed just beyond the southern end of the main shallow Mt Bulga ore body. Its approximate location is shown in Figure 1 superimposed on the geological level plan at 60m depth that was derived from the extensive drilling.

Mt. Bulga Deposit geology showing approximate location of Palmer's Seismic Line

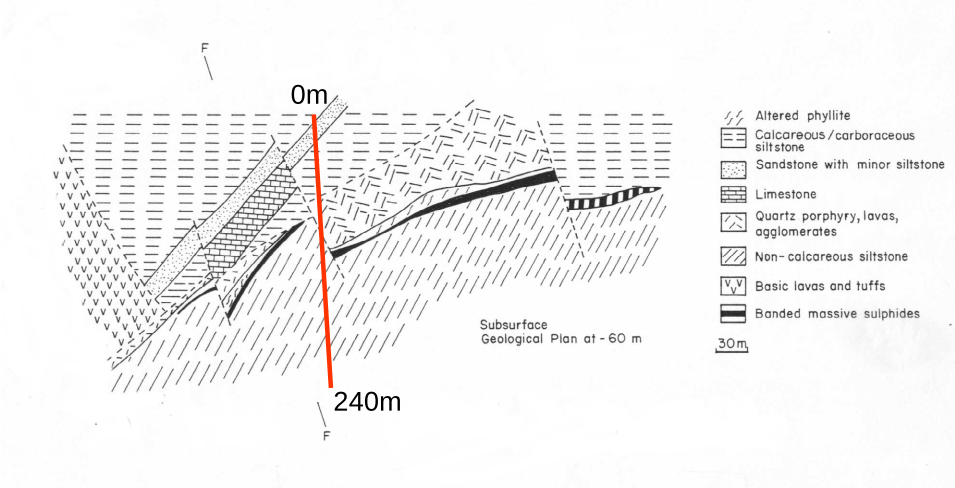


Figure 1

A geological cross-section (FF, Figure 1) obtained from the drilling just south of this line together with Palmer' s line projected onto it is shown in Figure 2.

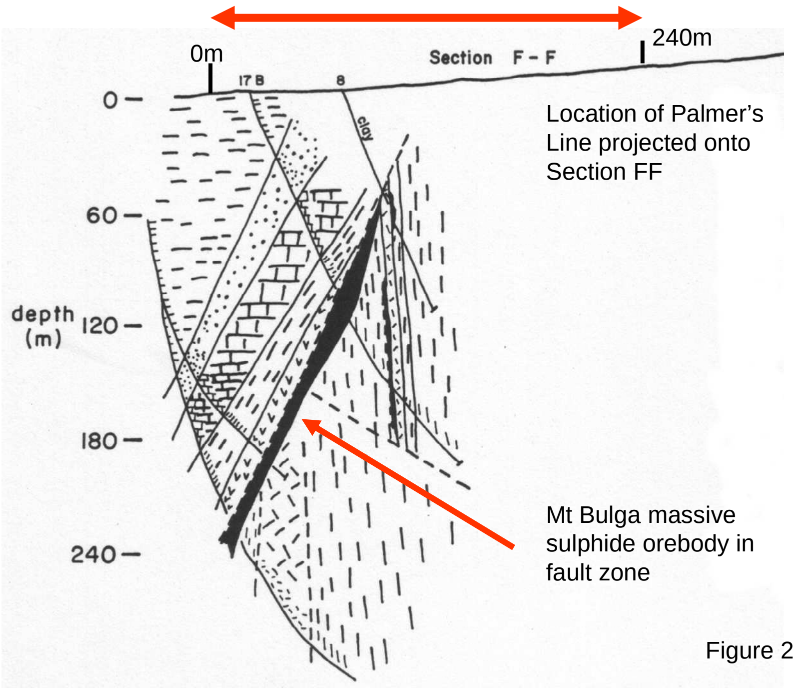
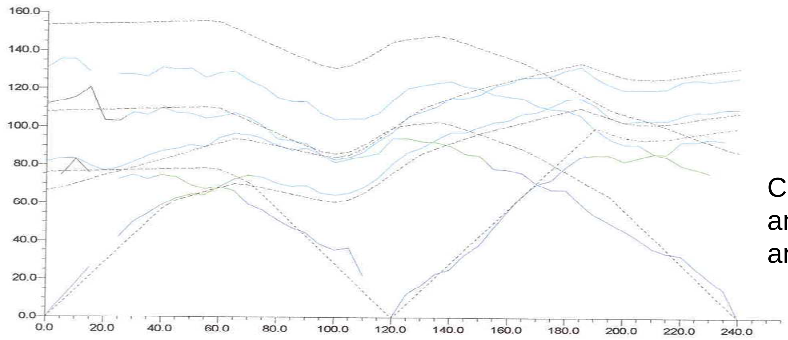
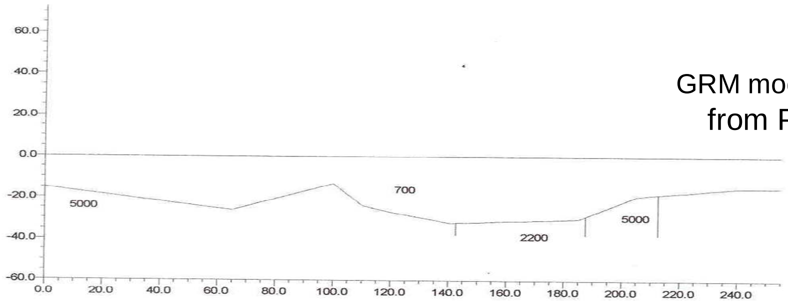


Figure 2

Figure 3 shows the first arrival travel-time data and GRM interpretation (from Palmer, 2000, Figs. 4 and 7) where a low velocity zone was interpreted over the Mt Bulga ore body with an abrupt peak in the refractor on the western side. We took this model at face-value and used modified ray tracing algorithms (from Ackermann et al. 1982) to generate synthetic travel-time data for comparison with Palmer' s field data. These are also shown on Figure 3 and differ considerably from the field data. Consequently, the GRM interpretation cannot be considered an accurate representation of the subsurface over the Mt Bulga ore body and this interpretation does not even fall within the domain of possible equivalent solutions.



Comparison of field and raytrace first arrivals



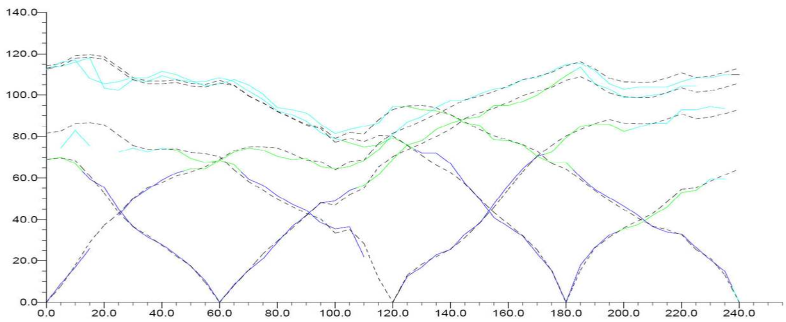
GRM model from Mt Bulga from Palmer (2000)

Figure 3

As noted earlier by Siegfried Rohdewald (www.rayfract.com/tutorials/mtbulga.pdf) there is simply not a sufficiently continuous “main refractor” or uniform enough overburden for the GRM work to effectively in this situation.

We also re-interpreted Palmer’ s data using Visual Interactive Ray Tracing (VIRT, Whiteley, 2004). The resulting interpretation that closely agrees with the reliable field data is shown in Figure 4. Considerable effort was required to obtain this ray trace model because of its complexity.

This interpretation is very different from Palmer’ s original GRM interpretation in Figure 3.



Visual Interactive
Raytrace Interpretation

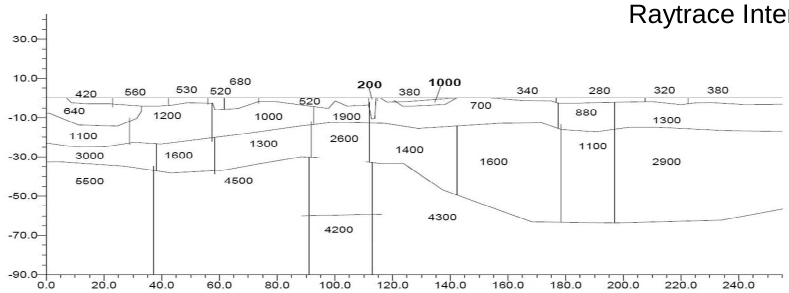


Figure 4

Siegfried Rohdewald also independently carried out WET inversions with 100 and 500 iterations. These interpretations are shown together in Figure 5 and are compared with the VIRT interpretation in Figures 6 and 7.

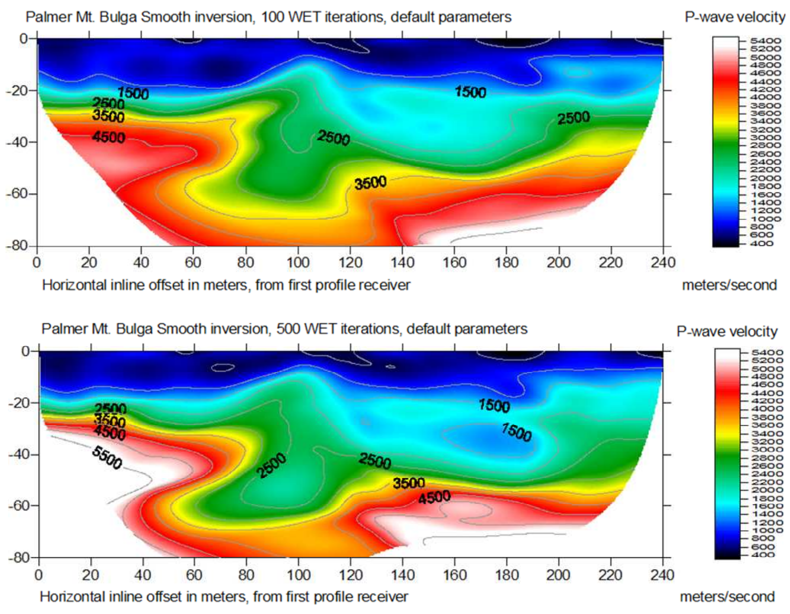


Figure 5

After seeing the geology and the VIRT interpretation, Siegfried Rohdewald offered following comments (in italics) i.e.

The reason why WET output after 100 iterations shows a more steeply dipping fault (in agreement with the dip of 70^o to 90^o from the drilling) than after 500 iterations may be the cross fault which the line traverses (Figure 1). So 3D refraction/diffraction effects occur, and the imaging effect increases with increasing imaged depth. This explains why the imaged fault gets wider at depth, after 500 iterations.

The apparently more gradual weathering on the eastern side of the ore body may be caused by vertical blurring/smoothing of velocity contrast, as inherent in our "Smooth inversion" and WET processing.

(see Sheehan et al. http://rayfract.com/pub/srt_evaluation.pdf.)

As can be seen on Figures 6 and 7, the WET models clearly show the essential subsurface features observed on the VIRT model and were obtained much more rapidly and easily than with our interactive ray tracing.

Comparison of WET and VIRT Models

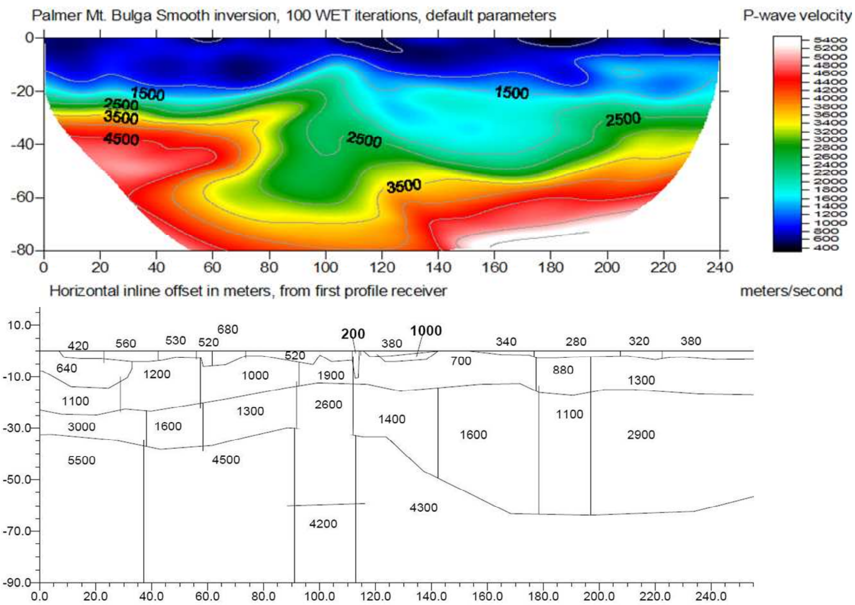


Figure 6

Comparison of WET and VIRT Models

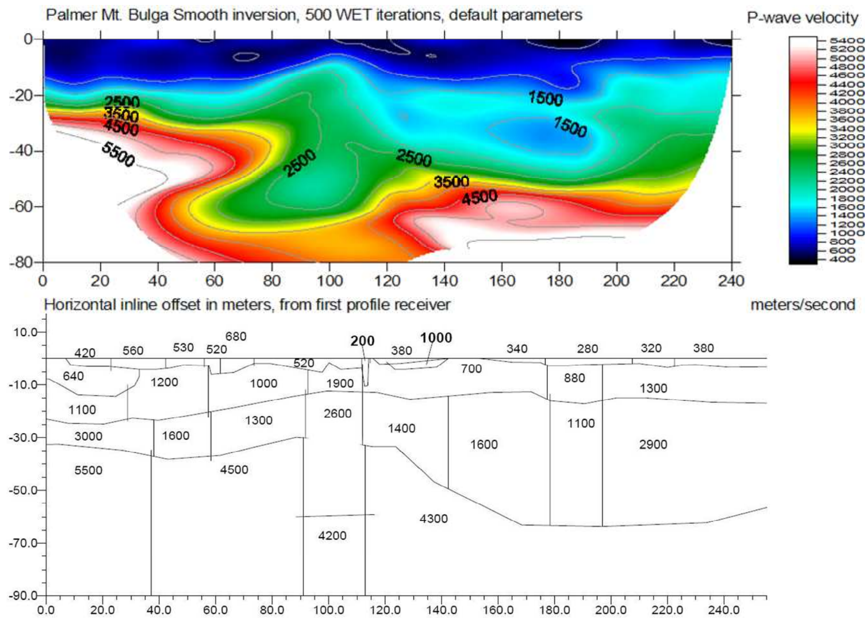


Figure 7

In summary, the key features of the WET models in relation to the known geology at Mt Bulga are:

- A low velocity zone is clearly observed over the upper part of the massive sulphide ore zone that extends to about 60 depth, to near the top of the fresh massive sulphides.
- This low velocity zone is marked by a fault on its western side and the location of the fault is accurately mapped, dipping to the west from about Stn. 100m.
- The low velocity zone in the shallower part of the image from Stn. 120m to 200m corresponds to a clay-filled paleochannel extending to about 40 m depth that has incised the altered siltstone host rock on the eastern side of the ore body (this feature has also been identified on other seismic refraction lines to the south of this line).
- There are significant variations in the depth to the higher velocity bedrock on either side of the ore body that reflect the responses of the different host rocks to weathering. On the western side of the ore body, bedrock depths range from about 25 to 30m. The higher velocity shallow "pinnacle" near Ch. 100m, on the edge of the major fault zone, is due to the seismic line crossing the quartz porphyry that is more resistant to weathering and has a higher seismic velocity. On the eastern side of the ore body, weathering is much deeper to about 50m depth and more gradual due to the finer grained siltstones and alteration caused by faulting and mineralisation.

Our general conclusion is that the GRM is clearly inadequate in this situation. Further, the interpretation obtained with interactive ray tracing agrees well with both the WET models obtained using RAYFRACT but it took considerable effort by very experienced interpreters to produce it.

Even in this complex 3D geological environment with over a shallow massive sulphide ore body, the smoothed 2D inversion using the WET algorithms in the RAYFRACT software has produced a detailed subsurface model that agrees very well with the extensive geological information. In our view, this result has the potential to extend the application of refraction methods, supported by this improved interpretation approach, to the search for deeper massive sulphide ore bodies that have entered the weathered layer.

REFERENCES

Ackermann, H.D., Pankratz, L.W. and Dansereau D., 1982, A comprehensive system for interpreting seismic refraction arrival-time data using interactive computer methods: USGE Open File Report 82-1065.

Palmer, D. 2000, Can amplitudes resolve ambiguities in refraction inversion? Exploration Geophysics, 31, 304-309.

Whiteley, R.J., Hawkins, L.V. and Govett, G.J.S., 1984, The seismic electrical and electrogeochemical character of the Mount Bulga massive sulphide orebody. Expanded Abstracts 54th SEG meeting, Atlanta, Dec 2-6, 1984, MIN5, 310-314.

Whiteley, R.J. 2004, Shallow seismic refraction interpretation with visual interactive ray trace (VIRT) modelling. Exploration Geophysics, 35, 116-123.