Lecture A2

Geophysical methods and advanced inversion methods

Worms:

(from: Murphy 2008 and Holden 2001)

There is a high degree of uncertainty or ambiguity in the interpretation of potential field data (gravity, magnetics), due to the fact that an infinitive number of 3D distributions of susceptibility or density can derive from the same measurements in the magnetic or gravity fields respectively. Gradients in the potential field contain most of the information, as they reflect density or magnetic susceptibility contrast due to changes in rock composition and map the boundaries of subsurface rocks. In terms of 3D geology (i.e. architecture), knowing the positions and nature of these gradients are key elements and the detection and visualization of the gradients at different scales (multiscale edges) can greatly enhance the interpretation of the data.

Multiscale edge mapping is an automatic process of edge detection in potential field data, using wavelet-based algorithms, to detect the positions of maximum gradients across multiple heights of upward continuation. These points of maximum gradient are ‘worms’. The ‘worm’-technology was developed by CSIRO through the Australian Geodynamics Cooperative Research Centre (AGCRC) in collaboration with Fractal Graphics.

‘Worms’ record the position (xyz) and the amplitude (w) of gradients and, when derived in 3D and visualized across multiple levels of upward continuation, form surfaces (‘worm’ sheets), whose shape and associated parameters are a function of the 3D subsurface geometry of rocks with contrasting properties. Hornby et al. (1999) have shown that, with the choice of an appropriate wavelet, derived from

Green's function of gravitational acceleration, the measured potential field or its spatial derivatives can be treated as a wavelet transform of the source distribution. In other words, a complete or observed wavelet is broken down into a series of components or wavelets. Importantly, there is a equivalence between the potential field upward continuation and the change in scale in scale in wavelet analysis. Through selection of appropriate scaling and gridding functions, this relationship is optimized for the production of worms. Worms at low levels of upward continuation are called ‘fine-scale’ worms (high frequency, short wavelength edges in the near surface environment); worms at high levels of upward continuation are termed ‘coarse-scaled’ worms (low frequency, long wavelength edge, generally relating to deeper levels and more persistent crustal sources).

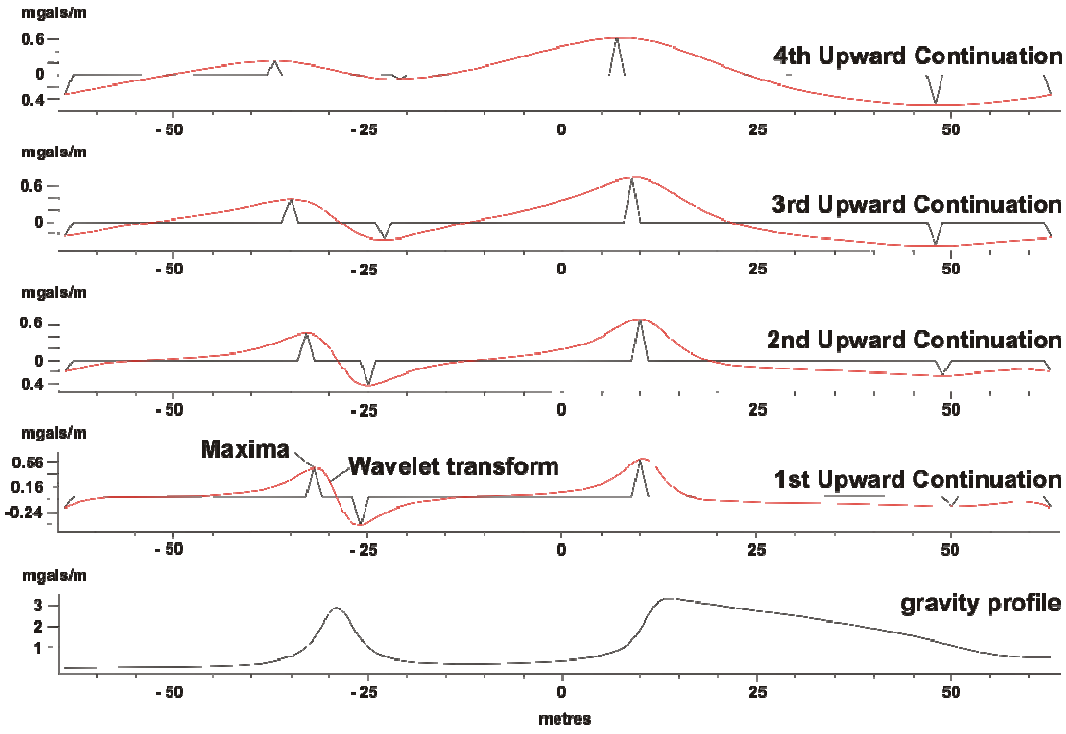

Figure 1: Concept of multiscale edges

Figure 1 illustrates the concept of multiscale edges, with the gravity profile and its horizontal derivatives (upward continuation). The spikes mark the locations of

four edges (local extrema) in each of the four horizontal derivative profiles. Analysis of these edges in the profiles at different scales (i.e. at different levels of upward continuation, as mentioned above) is multiscale edge analysis. The collection of the multiscale edges is defined as edge tree and is shown, for the same gravity profile, in Figure 2.

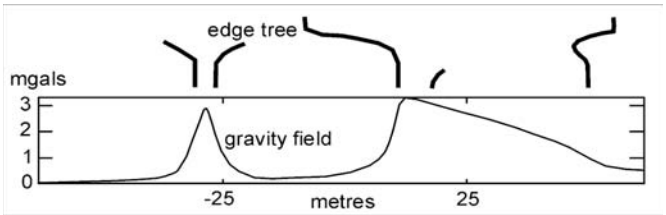

Figure 2: Edge trees from same gravity profile as Figure 1.

Multiscale edge analysis indicates that the location and amplitude of edges contain the same information as the original profile, which is why information about causative sources (geological contacts) can be obtained by analysing the multiscale edge. Holden et al (2001) produced synthetic models, which indicate that the dip direction of a worm sheet can be the mirror image of the dip direction of the geological contact. Information about the depth of a geological contact can be obtained using the height and length persistence of worms.

Worm data provides information about the location, dip direction and depth extent of the causative source and can significantly reduce ambiguity in interpretation. For the construction of 3D models, the upward continued levels in profile view help to constrain the nature of geological contrast, but worms should be used in combination with other geophysical and geological data as ambiguity remains an issue.

The pmd*CRC applied worms in several regions to constrain the regional architecture and their relationship to metal distribution (i.a. Yilgarn Craton, Mt. Isa Inlier, Tasmania) and for the construction of 3D models (Tasmania). For regional scale construction of 3D models, the large dimension faults are modeled in the first instance and, in the absence of other supporting data, strike length can be a proxy for depth of penetration. An analysis of gravity and aeromagnetic gradients provides a basis for generating interpreted fault length images of regions. This

has relevance to fault-related hydrothermal deposits, particularly when exploring in under-cover regions where there is a heavy reliance on potential field data. Long wavelength, strike extensive gradients commonly correlate with major faults discontinuities. Many hydrothermal mineral deposit types display a spatial relationship with faults and crustal discontinuities and such large dimension structures are intrinsically weaker, wider damage zones that can be conduits for hydrothermal fluids.

References:

Murphy, F. C. (2008). Architecture: Worms and what they can show. New Perspectives: The foundations and future of Australian exploration. Abstracts for the June 2008 pmd*CRC Conference., Perth, Geoscience Australia Record 2008/09.

Holden, D., Archibald, N., Boschetti, F. , and Jessell, M. (2001). "Inferring Geological Structures Using Wavelet-Based Multiscale Edge Analysis and Forward Models." Exploration Geophysics **31**(4): 000-000.

For further reading:

Hornby, P., Horowitz, F., Boschetti, F., and Archibald, N. (1997). "Inferring Geology from Geophysics." AGCRC Geodynamics & Ore Deposits Conference: 120-122.

Hornby, P., Boschetti, F., and Horowitz, F.G. (1999). "Analysis of Potential Field Data in the Wavelet Domain." Geophysical Journal International **137**: 175-196.

Boschetti, F., Hornby, P., and Horowitz, F.G. (2001). "Wavelet based inversion of gravity data." Exploration Geophysics **32**: 48-55.

Bierlein, F. (2006). "Distribution of orogenic gold deposits in relation to fault zones and gravity gradients: targeting tools applied to the Eastern Goldfields, Yilgarn Craton, Western Australia." Mineralium deposita **41**(2): 107-126.

Or:

https://newer.horow.net/old_csiro_site/franks_old_site/oldsite/index.html

http://www.per.marine.csiro.au/staff/Fabio.Boschetti/full_pap_list.html