Visualizing the geological "edges" of US Gulf of Mexico structures

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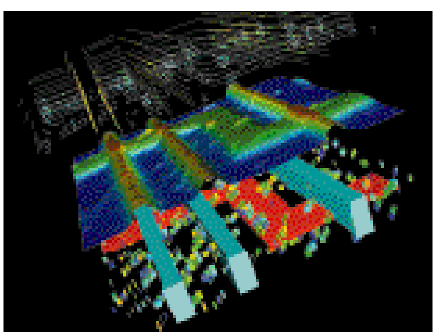
Creating "worms" for quick interpretation

A three-dimensional potential field interpreter with application to both gravity and magnetic data sets has been developed in Australia under a collaborative project between the CSIRO Division of Exploration and Mining and Fractal Graphics Pty Ltd, an integrated geosciences services group. The interpretation technique uses a multiscale edge detection technique to highlight geological features.

The applications to date have been confined to the minerals domain with a single interpretation of an onshore petroleum acreage. We feel, however, the technique used has a large range of applications in the oil and gas industry, particularly when combined with other data (e.g. seismic).

In looking at new ways to treat potential field data, CSIRO researchers (Hornby et al. 1999) adapted wavelet techniques used in image processing (Mallat and Zhong, 1992). The underlying feature of this work, that allows us to map to geological structures, is that the location and characteristics of irregularities often carry most of the information found in signals.

In an image, these irregularities normally group themselves into sets of linear features. In the visual inspection of potential field data, irregularities correspond to geological contacts, faults, and lineaments that are the main target of the analysis and indeed are very close to the lines that geologists draw over a potential field map when they attempt a 2D geological interpretation.



Potential field anomaly in the traditional form, (middle), 3D corresponding sheets (top). Demonstrative estimation of the shape and depth of the causative source (bottom). A potential field anomaly is represented in the traditional form, and, on top of it, the set of 3D corresponding sheets. Analysis of each anomaly can be performed individually by clicking on the corresponding sheet.

Wavelet domain

This can be formalized rigorously in multiscale wavelet domain. Such linear features correspond to local maxima of the wavelet transform and, at the change of scale of the analysis, form 3D sheets of various shapes around the different anomalies in the map. We call these linear features "worms."

With the use of a specialized wavelet, designed purposely for the potential field applications, the shape of such sheets can be related to the shape and depth of the causative underground anomalous sources. This property can be used for both enhanced visual interpretation of the original map and for mathematical inversion.

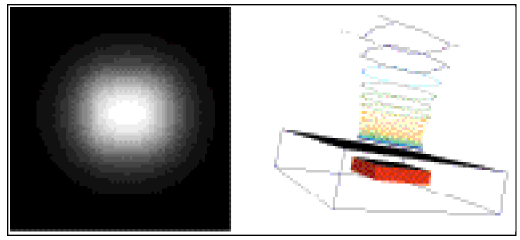
The shape of the anomalous source is easier to recognize visually from the "worms." Mathematically, the change of intensity in the "worms" (mapped as change of color on the sheet) contains information to reconstruct accurately the shape and depth of the source. Such reconstruction is particularly robust to noise.

Mathematical transform

These 3D sheets should be seen as a mathematical transform, in the lines of a Fourier transform, in which the information is conserved, while converted into a form suitable for specific purposes. By manipulating such sheets and reconstructing the image, feature enhancement, sharpening, removal and de-noising can be achieved.

The great advantage compared to Fourier processing lies on the local property of such sheets. Each sheet corresponds approximately to a single anomaly, and accordingly specific anomalies can be enhanced or removed individually, with minimum perturbation to adjacent ones. This can not be achieved with traditional processing methods.

We thus have a framework, with robust mathematical basis, and a number of modular applications: enhanced visualisation, inversion, 'feature-based' image processing and, freshly out of our research group, stable downward continuation.



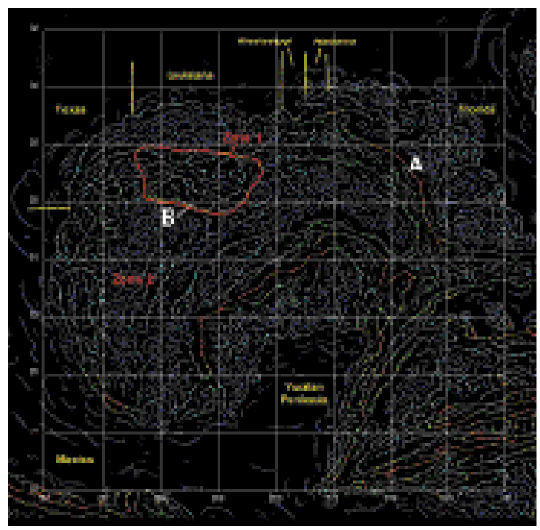
(a) Synthetic gravity anomaly due to a prismatic body in the traditional 2D representation as gray scale image. (b) "Worms" representation as 3D sheets.

"Worming" a dataset

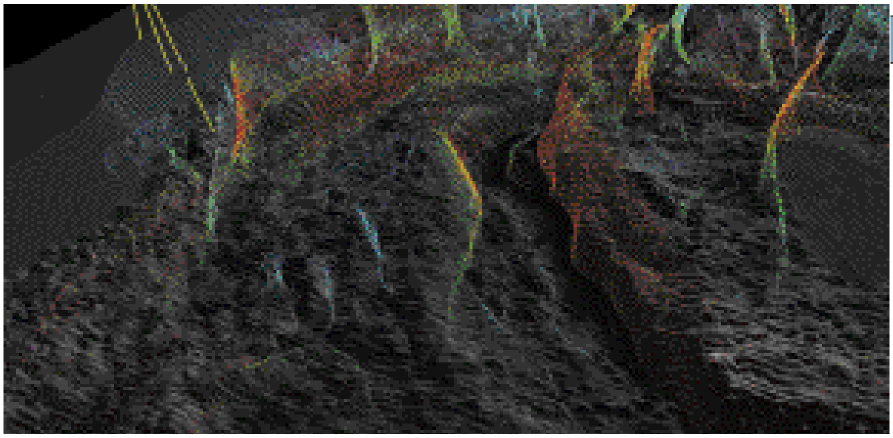
Good visualisation is part of the key to interpreting the "worms." Using computer graphics environments, the "worms" at different scales can be overlain on the color or gray scale images of the potential field.

The ability, in these graphics environments, to define multiple windows of clipped volumes (3D sectioning) allows the interpreter to focus on a particular response of interest. In addition we are constructing an interpreter's atlas of various responses by "worming" forward models of synthetic geological features (folds, intrusions, dykes etc.) created in Noddy, a forward modeling package written by Mark Jessell of Monash University.

We have "wormed" (as we call it) a gravity dataset from the Gulf of Mexico to illustrate the results as displayed in a modern computer graphics environment.



"Worms" at fine scale: A = edge of carbonate province, B = edge of Sigbee Escarpment, and Zone 1 = Self Deformation Province with different "worm" texture to Zone 2 (Hemipelagic deposits).



Oblique view of Gulf of Mexico gravity map, with multiscale edges on top.

The varying colors of blue (low) to red (high) represent increasing wavelet amplitude and hence intensity of the edge. A comparison between the worms and the USGS Gloria interpretation referenced at http://kai.er.usgs.gov/images/gloria/gom/intro.html has been carried out.

The edge of the western carbonate province is clear. The southern margin of the Salt Deformation Province (SDP) and the Sigsbee escarpment is also clearly featured in the fine scale edges. The "worms" density and texture can also be used to assess facies and structures and to discriminate between different areas.

For example, in the area identified as the SDP, the "worms" show different patterns [mid range intensity (green) and a lower density than the hemi-pelagic deposits immediately to the south]. Therefore the "worms" can identify internal structures that collectively distinguish geological styles.

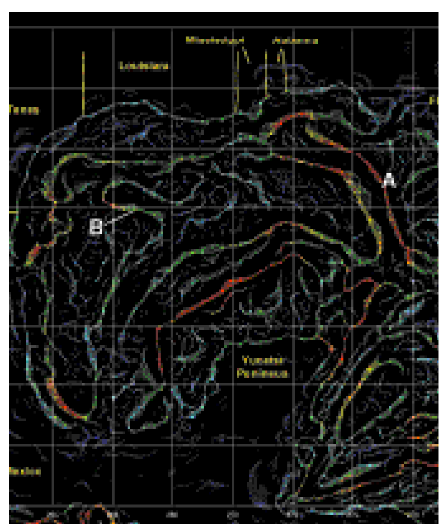
The "worms" at larger scales identify the major structures in the data. The carbonate province is still a major feature whereas location of the Sigsbee Escarpment is less well defined at this scale. An interesting embayment trending NNE-SSW through the SDP has no geological equivalent in the USGS GLORIA Interpretation.

Further information on this technique can be obtained from the authors at nja@fractalgraphics.com.au or fabio@ned.dem. csiro.au. See also http://www.ned.dem.csiro. au/BoschettiFabio and http://www.fractalgraphics. com.au.

References

Hornby, F.Boschetti, F. H. Horowitz, 1999, "Analysis of potential field data in the wavelet domain", in print, Geophysical Journal Intenational.

Mallat, S. and Zhong, S., 1992. Characterisation of signals from multiscale edges, IEEE Transaction on Pattern Recognition and Machine Intelligence, 14, 710-32.



"Worms" at coarse scale: A = edge of Carbonate province, B = embayment through Salt Deformation Province; possibly relative to a deeper structure.