The Use of Fractal Dimension for Texture-Based Enhancement of Aeromagnetic Data

Trevor Dhu, B.Sc. (Hons.)

Australian School of Petroleum

The University of Adelaide

This thesis is submitted in fulfilment of the requirements for the degree of Doctor of Philosophy in the Faculty of Science, The University of Adelaide

July 2008

ADELAIDE UNIVERSITY AUSTRALIA

SUB CRUCE LUMEN

Contents

Abstract

This thesis investigates the potential of fractal dimension (FD) as a tool for enhancing airborne magnetic data. More specifically, this thesis investigates the potential of FD-based texture transform images as tools for aiding in the interpretation of airborne magnetic data. A series of different methods of estimating FD are investigated, specifically:

- geometric methods (1D and 2D variation methods and 1D line divider method);
- stochastic methods (1D and 2D Hurst methods and 1D and 2D semi-variogram methods), and;
- spectral methods (1D and 2D wavelet methods and 1D and 2D Gabor methods).

All of these methods are able to differentiate between varying theoretical FD in synthetic profiles. Moreover, these methods are able to differentiate between theoretical FDs when applied to entire profiles or in a moving window along the profile. Generally, the accuracy of the estimated FD improves when window size is increased. Similarly, the standard deviation of estimated FD decreases as window size increases. This result implied that the use of moving window FD estimates will require a trade off between the quality of the FD estimates and the need to use small windows to allow better spatial resolution.

Application of the FD estimation methods to synthetic datasets containing simple ramps, ridges and point anomalies demonstrates that all of the 2D methods and most of the 1D methods are able to detect and enhance these features in the presence of up to 20% Gaussian noise. In contrast, the 1D Hurst and line divider methods can not clearly detect these features in as little as 10% Gaussian noise. Consequently, it is concluded that the 1D Hurst and line divider methods are inappropriate for enhancing airborne magnetic data.

The application of these methods to simple synthetic airborne magnetic datasets highlights the methods' sensitivity to very small variations in the data. All of the methods responded strongly to field lines some distance from the causative magnetic bodies. This effect was eliminated through the use of a variety of tolerances that essentially required a minimum level of difference between data points in order for FD to be calculated. Whilst this use of tolerances was required for synthetic datasets, its use was not required for noise corrupted versions of the synthetic magnetic data.

The results from applying the FD estimation techniques to the synthetic airborne magnetic data suggested that these methods are more effective when applied to data from the pole. Whilst all of the methods were able to enhance the magnetic anomalies both at the pole and in the Southern hemisphere, the responses of the FD estimation techniques were notably simpler for the polar data. With the exception of the 1D Hurst and line divider methods, all of the methods were also able to enhance the synthetic magnetic data in the presence of 10% Gaussian noise.

Application of the FD estimation methods to an airborne magnetic dataset from the Merlinleigh Sub-basin in Western Australia demonstrated their ability to enhance subtle structural features in relatively smooth airborne magnetic data. Moreover, the FD-based enhancements were able to enhance some features of this dataset better than any of the conventional enhancements considered (*i.e.* an analytic signal, vertical and total horizontal derivatives, and automatic gain control). Most of the FD estimation techniques enhanced similar features to each other. However, the 2D methods generally produced clearer results than their associated 1D methods. In contrast to this result, application of the FD-based enhancements to more variable airborne magnetic data from the Tanami region in the Northern Territory demonstrated that these methods are not as well suited to this style of data.

The main conclusion from this work is that FD-based enhancement of relatively smooth airborne magnetic data can provide valuable input into an interpretation process. This suggests that these methods are particularly useful for aiding in the interpretation of airborne magnetic data from regions such as sedimentary basins where the distribution of magnetic sources is relatively smooth and simple.

Statement

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of my thesis, when deposited in the University Library, being available for loan and photocopying.

____________________	____________________
Trevor Dhu	Date

Acknowledgements

I would like to take this opportunity to thank the numerous people who have helped me to complete this thesis. In particular, I owe a great debt of gratitude to my two supervisors, Dr Michael Dentith and Professor Richard Hillis, for their willingness to provide feedback, direction and encouragement above and beyond the call of duty. I am also extremely grateful for the support of my family; my infinitely patient wife Sally, my sister Tania and parents, John and Agnes, and my colleagues at Adelaide University, particularly Drs Jerry Meyer, Scott Reynolds and Scott Mildren. I'm also indebted to Geoscience Australia for providing me time and support to complete my thesis, especially Drs Matt Hayne and John Schneider.

I'd like to thank Drs Duncan Cowan and Gordon Cooper for their valuable comments and suggestions during my time in Perth. I would also like to thank Dr Thomas Ridsdill-Smith for his help with the spectral methods presented in this thesis and Dr Stephen Billings for providing code for calculating 2D power spectra of aeromagnetic data.

I would also like to acknowledge the support of DFA and Earth Resource Mapping for providing access to Intrepid and ERMapper respectively. Additionally, Normandy Exploration, Newcrest Mining, the Northern Territory Geological Survey and the Western Australian Geological Survey have all kindly provided datasets that have been invaluable for testing the various methods discussed herein.

This work has been supported by funding from the Australian Society of Exploration Geophysicists Research Fund as well as an Australian Postgraduate Award.