Zhu Qian received his BSc degree in Geophysical Instruments in 1982 from Changchun College of Geology, PRC. Since 1982 he has been working on micro-processor based geophysical instruments. He is an electronic engineer in the Design Section of the Shanghai Geological Instrument Plant. His professional interests are electronics and geophysical instruments.

Z. Qian, Designing Section, Shanghai Geological Instrument Factory, Anting, Shanghai, People's Republic of China.

Inherent limitations in the determination of basalt flow thickness using magnetic spectral techniques

G. A. Quirk and R. Green

Introduction

The method for the location of deposits of heavy minerals such as gold and tin, which occur in deep leads overlaid with volcanic lava flow, is a problem whose solution is of significant economic importance. For this reason it has been the subject of geophysical research for many years. Of the numerous methods investigated, spectral analysis of magnetic data in particular has been developed over the past quarter of a century, and success has been reported in the determination of the average depth to magnetic interfaces using aeromagnetic data and the spectral slope method.

The spectral slope method uses the slope of a log-amplitude verses frequency plot as a measurement of the depth to a magnetic source. It would appear that the spectral slope method should be applicable to ground magnetic data and locate deep leads by determining the basement topography of a basalt flow. However, when the method is applied to ground magnetic data inherent limitations render the method unusable.

Theory

The spectral slope method was first presented by Spector and Grant (1970). It assumes that the measured magnetic field is the result of a large number of overlapping anomalies. The method results from the postulate that the value of the power density function is equal to the ensemble average of the individual power spectra and can be represented by the formula

$$<E(r)> = 4\pi^2 k^2 <e^{-2hr}> <(1 - e^{-tr})> <s^2(r)>$$

where k is the magnetic moment/unit volume; h is the depth to the top of the body; r is the radial frequency; t is the thickness of the magnetic body, and $s^2(r)$ is a factor that depends on the mean size of the body. $< >$ denotes the ensemble average.

It was found that the factor e^{-2hr} dominates the spectrum to such an extent that if the log of the amplitude is plotted against frequency a straight line results. The slope is a measure of the average depth to the source.

Spector and Grant (1970) stated that for a combined ensemble of two sources, for example the upper and lower contacts of a basalt flow, the log-spectrum consists of two segments, each containing a straight line indicative of the depth. The first, which relates to the deeper source is relatively strong at the small wave numbers and decays rapidly. The second, which arises from the shallower sources dominates the short wavelength end of the spectrum and has a more gradual slope.

Figure 1 is an example of a power spectrum analysis of an aeromagnetic map from an area overlain by thick Tertiary volcanic lava.

The model

The model used to explain the power spectrum characteristics of the magnetic potential field measured over a basalt flow

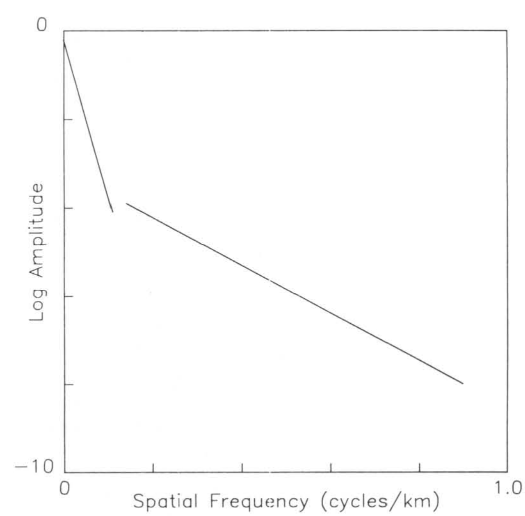


Fig 1 Power spectrum analysis of an aeromagnetic map from an area overlain by thick tertiary volcanic lava.

combines the essential aspects of models used by Spector and Grant (1970), Syberg (1972), and Hahn *et al.* (1976). It incorporates the following points: straight line segment in the log-amplitude spectrum is attributed to a white noise spectrum of the source; the observed magnetic field is the superposition of a large number of individual anomalies; individual anomalies are assumed to be magnetic poles.

Our model provides a white noise source of magnetic poles at the upper and lower contacts of a body. That is, magnetic poles are positioned randomly throughout the basalt flow and are given random intensities. In reality, however, a body is comprised of dipoles aligned in the direction of the earth's magnetic field. The overall result is that within the body there is no net magnetization but towards the contacts the magnetization appears as poles increasing in intensity with increasing proximity to the contact. Therefore, in order to impart more reality, the intensities are made to fall off rapidly and exponentially towards the centre. We also assume the model to be in the southern hemisphere so the magnetic poles are positive if they occur in the upper half of the flow and negative if they occur in the lower half.

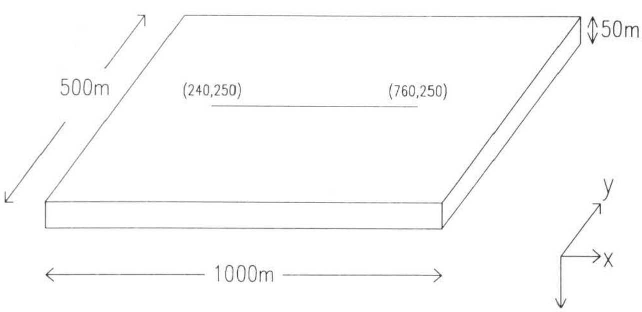


Fig 2 Dimensions of the body used for computer modelling. The co-ordinates show the location of the magnetic profile selected for study.

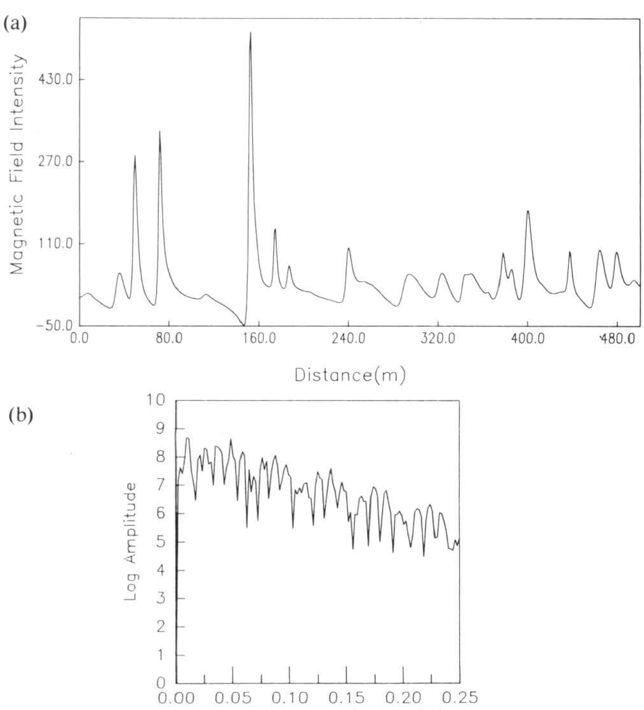


Fig 3 Magnetic profile (a), and log-amplitude spectrum (b) derived for the upper surface of the body.

Applications

A computer programme has been utilized that implements the conditions described above. All of the data presented here has been calculated on a body of dimensions; 1000 m in the x direction, 500 m in the y direction and 50 m in the z direction. Each body contains 60 000 randomly spaced magnetic poles. The profile has been sampled at 1 m intervals and runs from co-ordinates 240 250 to co-ordinates 760 250 (Fig. 2).

Figure 3 shows the magnetic profile and corresponding log-amplitude spectrum for the body when only the upper surface of the body is considered. The magnetic profile and corresponding log-amplitude spectrum when only the lower contact of the body is considered is shown in Fig. 4.

Figures 3 and 4 show clearly the differences in the slope of the log-amplitude spectrum resulting from the different depths to the sources. The depth to the source in Fig. 3 is 1 m whereas the depth to the source in Fig. 4 is 50 m.

When both the upper and lower contacts of the body are considered simultaneously the resulting profile and log-amplitude spectrum are indistinguishable from those in Fig. 3. That is, it is impossible to find any straight line segment in the log-amplitude spectrum that is attributable to the lower contact. The reason for this is that the amplitude of the signal from the upper surface is of the order of 50 times greater than the signal from the lower surface and therefore completely dominates the spectrum, even in the lower frequencies where the signal from the lower contact is relatively stronger. If it were possible to filter the magnetic data in some way as to remove the effects of the upper surface it would be possible to make depth estimates of the lower surface. However, as is evident in the spectra shown in Figs 3 and 4, any form of low pass filtering will still leave the spectrum totally dominated by the signal from the upper source.

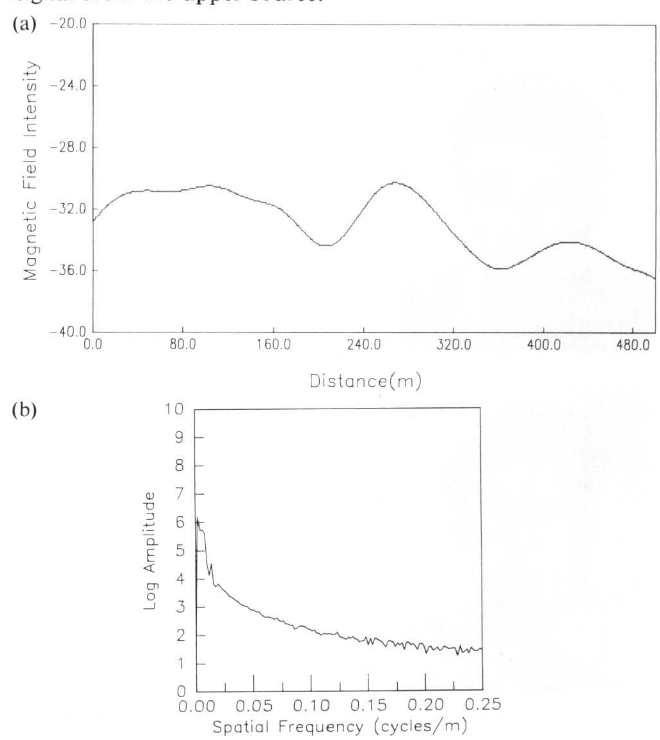


Fig 4 Magnetic profile (a) and log-amplitude spectrum (b) derived for the lower contact of the body.

J

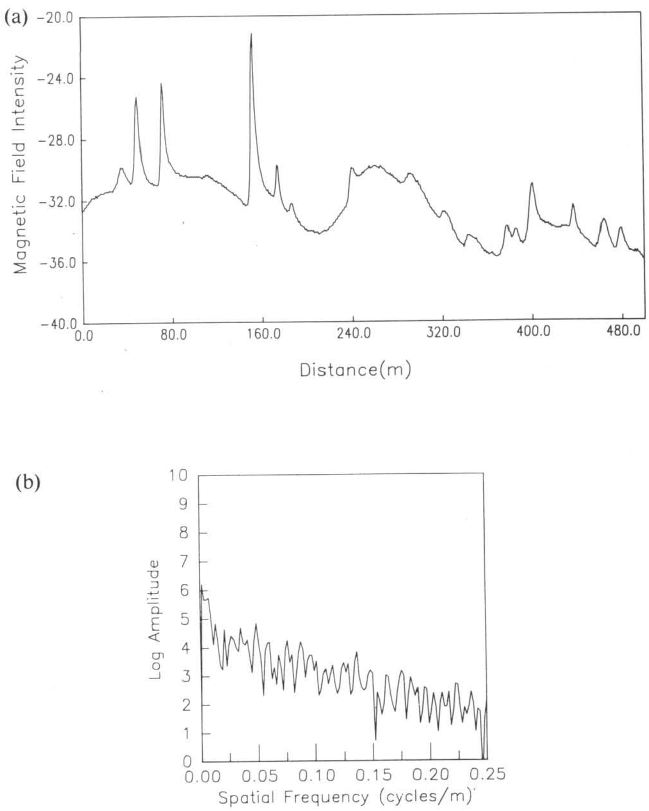


Fig 5 Magnetic profile (a) and log-amplitude spectrum (b) obtained when the amplitude of the magnetic dipoles in the upper half of the body has been reduced to 2% of their original value.

Figure 5 shows a magnetic profile and corresponding log-amplitude spectrum obtained when the amplitude of the magnetic dipoles in the upper half of the body has been attenuated to 2% of their original values. Two straight line segments are now discernible and depth estimates of the lower contact would now be possible.

Conclusion

Theory suggests that the spectral slope method should be applicable to the definition of basalt flow basement topography. However, when the technique is applied to ground magnetic data, it is found that under normal circumstances the signal from the upper contact of the body dominates the spectrum to such an extent that no influence from the lower contact is discernible. If, however, circumstances are such that magnetic contrast of the lower contact is significantly larger than that of the upper contrast the spectral slope method could be expected to yield useful results.

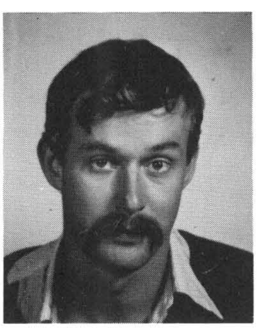
References

Cassano E. & Rocca F. (1975), 'Interpretation of magnetic anomalies using spectral estimation techniques', *Geophys. Prospect.* **23**, 663–681.

Hahn A., Kind E. G. & Mishra D. C. (1976), 'Depth estimation of magnetic sources by means of Fourier amplitude spectra', *Geophys. Prospect.* **24**, 287–308.

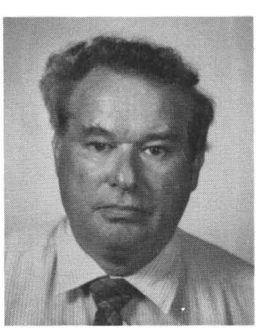
Spector A. & Grant F. S. (1970), 'Statistical models for interpreting aeromagnetic data', *Geophysics* **35**, 293–302.

Syberg F. J. R. (1972), 'A Fourier method for the regional-residual problem of potential fields', *Geophys. Prospect.* **20**, 47–75.



Graeme Quirk received a BSc(Hons) degree majoring in physics and geophysics, and DipEd from the University of New England in 1983. He is presently engaged in a PhD programme investigating the application of geophysical techniques to the determination of basalt flow thickness and hence the location of deep leads.

G. Quirk, Department of Geology and Geophysics, University of New England, Armidale, NSW 2351.



Ronald Green graduated with a BSc(Hons), majoring in maths and physics, from the University of Queensland in 1952 and then worked for the Bureau of Mineral Resources in oil and mineral exploration. In 1960, he was awarded a PhD from the Australian National University for pioneering work in paleomagnetism. For the next six years, Dr Green was Senior Lecturer at the University of Tasmania, which he left to take up an appointment as Head of the Geophysics Department at the University of New England, Armidale. Dr Green has worked in USA, Canada, Finland, Hungary, East Germany, West Germany, Indonesia, China, and Japan. He is presently Director, Geophysical Research Institute, Armidale.

R. Green, Department of Geology and Geophysics, University of New England, Armidale, NSW 2351.