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'Ground-Truth' in Aeromagnetism

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Abstract

One of the unkowns in the interpretation of magnetic anomalies is often the magnetic properties of the source rocks. These properties can, however, be measured independently and at a cost that is small compared with the cost of carrying out an airborne survey. A systematic programme of rock-property measurements, linked to geological mapping in new aeromagnetic survey sheet areas, could develop into a valuable resource for all those using geophysical map data of Australia. Some examples from Africa are used to illustrate these points.

Key words: aeromagnetic surveys, rock magnetism.

Introduction

One of the most fruitful approaches to the interpretation of potential field anomalies is to generate the model of a source body which could, in theory, replicate very closely a given anomaly observed in the field. The fundamental problem of non-uniqueness is usually reduced to manageable proportions by independent *a priori* information, geological reasonableness or even plain common sense. In the best tradition of scientific investigation, the method then leads to a hypothesis which (a) serves to explain all existing data and (b) may be tested by future experiment. The result consists of a set of parameters which define the position and geometry of the source body in three dimensions plus a value for the physical property contrast which sets the body apart from its host environment. Unless there is good reason to the contrary, economy of hypothesis dictates that the causative body is assumed to be physically uniform and of simple — but geologically plausible — geometry.

The above paragraph encapsulates the process by which we attempt to acquire knowledge and understanding of three-dimensional geology by way of carrying out and interpreting potential field surveys over a two-dimensional (x,y) surface at — or above — the earth's surface. Producing a geophysical anomaly map — of which an aeromagnetic map is perhaps typical — involves carrying out a series of observations from which a contour presentation or image may be produced more-or-less unequivocally; an independent group of observers should arrive at a map which is essentially identical.

The **interpretation** of that map or image is equivocal because the solution to the three-dimensional geological problem is under-determined by the two-dimensional observation set in the x,y plane. One approach to reducing the uncertainty is obvious — the magnetic properties of rocks **can** be determined from measurements made at outcrop sites and on hand specimens returned to the laboratory. For some reason this approach is sadly neglected almost universally, even though useful data may be collected at a fraction of the cost of carrying out an airborne survey.

Rock magnetism and the magnetic interpreter

Rocks exhibit magnetisation either because it is induced by the present-day geomagnetic field (**induced** magnetisation) or because they have inherited a permanent magnetisation from some event in their geological past (**remanent** magnetisation). Induced magnetisation is, by definition, in the direction of the present-day earth's field which can be known to the interpreter simply by looking at world charts of total magnetic field, inclination and declination. Only the magnetic susceptibility remains to be determined. Remanent magnetisation, on the other hand, can be in **any** direction, given the apparent polar wandering for the site, the frequent reversals of the geomagnetic field during the geological time-spans over which remanent magnetisation can be preserved and the thermo-tectonic history of the site. The interpreter encountering remanent magnetisation needs to discover a magnitude **and** direction of magnetisation for which, in general, he has no reasonable control.

For a typical dipping body with (near-)infinite strike-length there is additional ambiguity in that present-day magnetic inclination, body-dip and remanent magnetisation all contribute to the position of the anomaly curve shape within the family of curves which covers all possible anomalies for a given body-geometry (see, for example, Reeves, 1989). In other words, remanent magnetisation may be confused with body-dip for a given inclination of the inducing field. When there is no good reason to the contrary, interpreters are forced to assume only induced magnetisation. Counter-indications are usually limited to severe cases where no reasonable body-dip can account for the shape of the observed anomaly. Even this situation can be solved by the expediency of assuming 'reversed magnetisation'.

Some support for the predominance of induced magnetisation in magnetic anomalies comes from a systematic study of some 30,000 specimens collected in northern Scandinavia and analysed in a joint project of the geological surveys of Norway, Sweden and Finland (Henkel,1991). The average Koenigsberger ratio for all these samples was about 0.2.

Usually, aeromagnetic surveys are carried out at the forefront of an exploration programme, before significant 'ground-truth' studies have started. Furthermore, they find particular application in those areas where the bedrock geology is obscured from direct examination by cover-rocks or weathering. The aeromagnetic interpreter therefore seldom has a great deal of ground truth of any sort to fall back on, let alone laboratory measurements of oriented specimens. The interpreter needs to preserve a broad perspective and, as with most types of geophysics, be opportunistic where a more holistic approach to his subject can be taken.

In the case of Australia, where reconnaissance aeromagnetic survey coverage nears completion and a new generation of more detailed surveys is under way, the opportunity for initiating a systematic sampling programme in sheet areas selected for detailed survey should not be missed. If sampling follows compilation of the aeromagnetic data, the main rock units which generate magnetic anomalies can be identified from the anomaly maps and then visited for field sampling. The essential parameters to measure would be magnetic susceptibility and total NRM (magnitude and direction). Selected anomalies which betray remanent magnetisation could be treated in more detail. It is conceivable, for example, that intrusions could be dated from their palaeo-pole position or that other facts which might assist in the interpretation of the geological history of a sheet area could be revealed. Together with density measurements, such an exercise would build into a solid physical-property data-base for all interpreters of Australian geophysical map data. The advantages of linking this with any on-going age-dating programme are fairly clear (BMR, 1992).

Some examples from Africa may serve to demonstrate some of these points.

Botswana

An impressive swarm of basic dykes, seen only very locally in outcrop due to the cover of Kalahari Sand, was revealed by the aeromagnetic survey of Botswana (Reeves, 1978). While the bulk of anomalies suggested normal induced magnetisation, others could only be modelled by assuming 'reversed' magnetisation. The shape of both 'normal' and 'reversed' anomalies was later found to be consistent with remanent magnetisation acquired at the time of emplacement (dated as mid-Jurassic), implying at least one magnetic reversal during the period when emplacement was taking place (Reeves, 1989).

Ivory Coast

About 70 small, circular anomalies were revealed by the aeromagnetic survey of Ivory Coast (Grant *et al.*, 1980). Some of these anomalies coincided with known vertical plug-like metabasic intrusions. Anomaly shapes were consistent with a vertically-oriented remanent magnetisation; some of the bodies showed the direction to be oriented vertically upward, others vertically downward. The age of the intrusions is known to be about 1900 Ma when African apparent polar wander paths show west Africa to be close to the magnetic pole. Again, remanent magnetisation, with at least one magnetic reversal occurring during the period of emplacement, is consistent with the observations.

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References

BMR, (1992), 'Evaluation of the Geophysical Observatories Program', 93pp.

Grant, F.S., Misener, D.J., Reeves, C.V., and Angoran, Y., (1980), 'An airborne magnetometer and gamma-ray spectrometer survey of Ivory Coast'. *EOS (Transactions American Geophysical Union),* **61**, 416.

Henkel, H., (1991), 'Petrophysical properties (density and magnetisation) of rocks from the northern part of the Baltic Shield'. *Tectonophysics,* **192**, 1-19.

Reeves, C.V., (1978), 'A failed Gondwana spreading axis in southern Africa'. *Nature,* **273**, 222-223.

Reeves, C.V., (1989), 'Aeromagnetic interpretation and rock magnetism'. *First Break,* **7**, 275-286.