



Geological remote sensing in aerospace and time. Introduction

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Received 4 January 1997; accepted in revised form 17 December 1998

Key words: airborne geophysics, geoinformation

Abstract

The more one considers the earth sciences these days, the more one realises that any view that falls short of global runs the risk of being short-sighted. This article sketches the position of remote sensing in geology following several points of observation: 1) Earth scientists are not blind but when it comes to geology are we not all blind? 2) We all come to whatever particular earth science problem we have to tackle with a background of scientific knowledge. 3) Interpretations are ephemeral. Our specialist windows each bring us a partial view of the hidden subsurface. If we are wise we share our fields of expertise so that the earth sciences can best deliver their potential benefits to global society.

The more one considers the earth sciences these days, the more one realises that any view that falls short of global runs the risk of being short-sighted. In executing the mission of ITC, this is a point that can never be emphasised often enough. For example, when one works with global tectonics, originally tectonics on a spherical surface, a postulated adjustment or reconstruction of any one plate or fragment affects all the others, and all must sum to the total coverage of the globe. With our world-wide student population, we should be uniquely positioned to 'think globally'. How do we achieve the global view?

Let me start my first point with an inspirational poem from a book I borrowed from one of my children (Saxe 1988):

It was six men of Hindostan,
To learning much inclined,
Who went to see the elephant,
(Though all of them were blind):
That each by observation
Might satisfy his mind.

The *first* approached the Elephant,
And happening to fall
Against his broad and sturdy side,
At once began to bawl:

'Bless me, it seems the Elephant
Is very like a wall'

And so they go on in turn, each feeling a different part of the elephant and jumping to a hasty and ill-considered conclusion based on the particular part of the beast they happened to touch. Surely a pitfall of remote sensing!

Now these blind men are not earth scientists. But when it comes to geology, are we not *all* blind? We would like to watch the movie of earth history, but we can only see the single frame of the present day. We seek to look below the ground surface but most often we can see no more than the surface itself. So, because we cannot in general see or touch underground space the way we do with objects in everyday life, we are, like the blind men, reduced to 'sensing' the underground remotely by whatever methods our intelligence is able to develop. In fact we are 'remote sensing' in both space *and* time.

My second point is that, like the blind men, we each come to whatever particular earth science problem we have to tackle with a background of scientific knowledge. In earth science, we can consider this knowledge divided into two parts. First there are the principles of geological processes such as global tec-

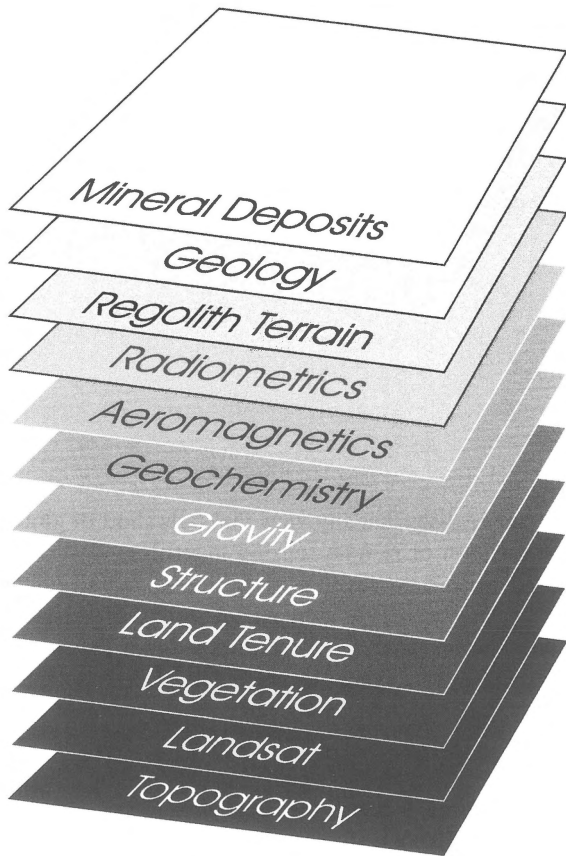


Figure 1. Some of the many possible 'layers' of geo-information that may be available for any given survey area (from BMR 1992).

tonics, sedimentology, mineralogy, structural geology, etc. These are principles which describe and quantify the processes of geology worldwide. This part I like to refer to as '*text-book knowledge*'. Then there is the vast body of information in map format, x,y -referenced data, unique to each given location on earth, to some extent summarised in the local geological map. This part I call '*atlas knowledge*'.

Text-book knowledge is a part of the equipment of even the most recently-qualified earth scientist. When he or she applies that knowledge to a specific area or locality, examination of 'previous work' in that particular area is always high on the list of priorities. In other words, the pre-existing '*atlas knowledge*' for the area is called upon. With experience, the value of familiarity with a variety of atlas knowledge from different locations in many parts of the world becomes an important part of the earth scientist's equipment. And, even if some x,y -referenced data cannot be immediately understood, it must still be kept available because

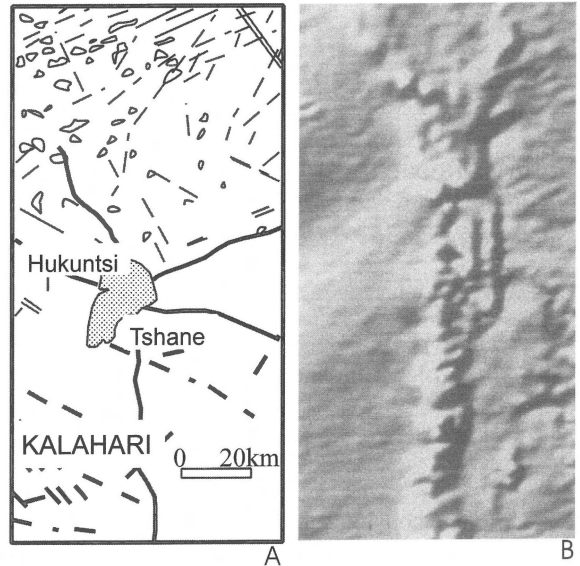


Figure 2. Remote sensing, *sensu lato*, over the Kalahari Line, south-west Botswana. A) Geological interpretation of Landsat imagery, supported by interpretation of aerial photography and field checking (from Mallick et al. 1981), reveals only surface features of the Kalahari sand. B) Total magnetic anomaly image of the same area as A) in shaded-relief presentation, illuminated from the west, reveals a major tectonic feature with a strike length of more than 600 km (redrawn from Reeves & Zeil 1990).

it is part of the knowledge-base (a priori knowledge) against which new models of our understanding of the geology and resources of any area can be tested in the future. Management of all x,y -referenced data is therefore an important and growing aspect of applied geoscience that we underestimate at our peril!

Thirdly, interpretations are ephemeral, but the assemblage of hard data is a timeless asset. (And we should remember that even the familiar geological map is only a type of interpretation of a limited number of factual field or aerospace observations.) In any given area, there are many different types of data available. Each data-set is often referred to as a 'layer' and each layer may be thought of as a potential window on the unseen subsurface. If the objective is mineral exploration, then the layers shown in Figure 1 may be among the most useful.

These layers are the raw materials for any attempt we, as mere human beings, make to appreciate the three-dimensional reality that exists below the ground surface – and its evolution in the time dimension. Furthermore, easy-to-find resources are in most cases already known and/or consumed. Future resources will require deeper-looking investigation methods and

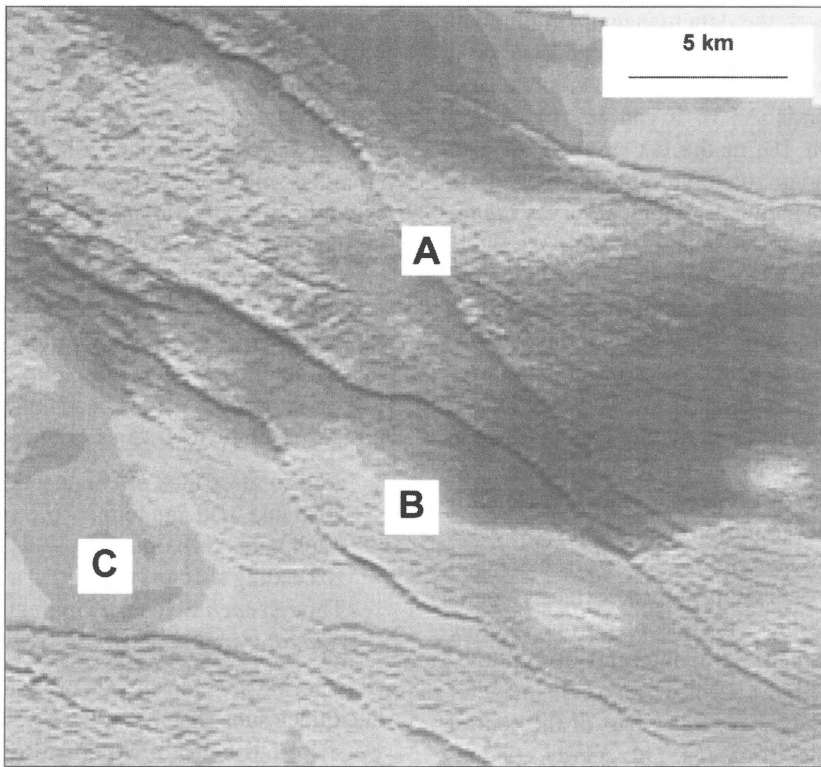


Figure 3. High-resolution, low-altitude aeromagnetic survey coverage of part of the Palla Road survey area in eastern Botswana. Interpretation of faults and fractures (such as A) cutting a thick (several hundred metres) basalt sheet underlying Kalahari sand cover – in conjunction with satellite imagery – is invaluable to ground-water exploration. A porous sandstone, stratigraphically below the basalt, is a productive aquifer where overlain by basalt (revealed by the speckle it imparts to the magnetic image, e.g. at B) but much less so where the basalt is absent (such as at C); (Barritt et al. 1995). (For full colour reproduction of this figure, see Appendix at the end of this issue.)

better insight into the processes by which resources came into existence in the first place.

In recent decades, the term ‘remote sensing’, the theme of the symposium underlying this special issue, has come to mean the acquisition and presentation of images of the ground surface using various wavelengths of the visible (or near-visible) electromagnetic spectrum received by an earth-orbiting satellite. In a broader sense, geophysical (and, indeed, geochemical and other) techniques may also be seen as a type of remote sensing which has its origins, not in the optical reflectivity or emission of the ground surface, but in the physical (or chemical) properties of the subsurface rocks themselves. The ‘remoteness’ of the sensing then includes the thickness of whatever is uninteresting between the ground surface and whatever lies below. This broader definition might serve our profession better, particularly if we choose to become problem-oriented rather than technology-driven.

While a given survey produces a unique set of results, perhaps acquired originally for a specific pur-

pose, these results may later be interpreted repeatedly by many different users, each with a different set of objectives in mind. In this sense, the survey results become part of the *data-base* for a given area, region or country. In view of the value we have now ascribed to this hard data, there is clearly a need for custodianship of the archive of earth-science data that persists for decades beyond data collection rather than the months or years of a given project. In most countries this is the task of the national geological survey. Countries wishing to take best advantage of all existing geoscientific data in solving (for example) groundwater or environmental problems, as well as giving a solid scientific base to resource development and sustainability, should publish these data routinely and punctually and have well-organised (preferably digital) data-bases readily available to supply to users and investors on demand. In a democratic society, this function is often described as being in the ‘public good’.

At a national level, the data management function is a cost. But, properly managed, it can also be a most worthwhile investment. For example, in the case of Australia (Richards 1993), it can be shown that no more than about 1% of the tax revenue realised from the mineral and petroleum production industry is required to support a national geological survey organisation that manages the geoscientific *data-base* and is the envy of geoscientists in many other parts of the world. In terms of area and general geology, Australia does not differ much from Africa south of the equator, for example, where the state of geological data-bases causes much concern.

Finally, to wave my own particular flag a little, one of the most sought-after data-types provided by national geological surveys is geophysical data which, I feel, deserves more recognition amongst the advocates of remote sensing *sensu stricto*. My work has taken me almost without exception to those extensive parts of the world where there is little or no outcropping geology to map in the field or interpret from photographs or imagery. Figure 2B is a grey-scale image of aeromagnetic anomaly data over a part of the central Kalahari in southwest Botswana. This survey, conducted in 1975–6, first revealed a large tectonic feature which has become known as the Kalahari Line and more recently interpreted as a Proterozoic suture with important implications for the tectonic evolution of the region. Within Botswana it has a strike length of some 600 km. Drilling has revealed mafic rocks at depths of almost 1000 m. Interpretation of satellite imagery and conventional aerial photographs of this region revealed little more than the geomorphic features of the overlying Kalahari sand (Figure 2A).

Elsewhere in Botswana, the 1990s have seen success in the application of high-sensitivity, low-altitude aeromagnetic surveys in mapping faults and fractures (such as A, Figure 3) in areas where productive sub-Kalahari aquifers can be delineated by this means, supported by satellite image interpretation (Barritt et al. 1995). A porous sandstone, stratigraphically below the basalt, is a productive aquifer where overlain by basalt (revealed by the speckle it imparts to the magnetic image, e.g. at B, Figure 3) but drilling is found to be relatively unproductive where the basalt is absent (such as at C, Figure 3).

Aeromagnetic surveys can, then, very often provide what might be considered the X-ray image of the elephant!

It is not my intention to state that any one data layer is more important than any other. Each window has its strengths and weaknesses. To approach any problem scientifically, all available layers of geo-data should be interpreted synergetically. In the best spirit of scientific pursuit, the resulting model (or perception) then a) satisfies all available data and b) may be tested by future experiment. In the world of exploration this means detailed ground follow-up, drilling, etc. This is a more productive approach than that shown by the blind men in the final verse of the poem:

And so these men of Hindostan
Disputed loud and long,
Each in his own opinion
Exceeding stiff and strong,
Though *each* was *partly* in the right
And *all* were in the wrong.

Our specialist windows each bring us a partial view on the hidden subsurface. If we are wise men (or women) we share our fields of expertise so that the earth sciences can best deliver their potential benefits to global society.

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