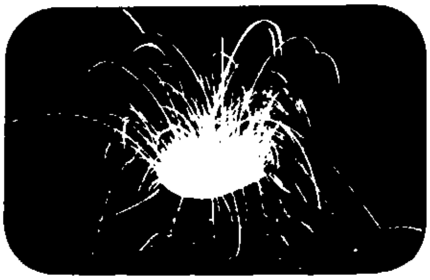
Features



Pyroclasts

The Choice of Satellite-Borne or Air-Borne Remote Sensing for Geology and Mineral Exploration

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The Commonwealth Geographical Bureau organized a workshop entitled "Applications of Remote Sensing Techniques to Tropical Land Management", August 20-27, 1983, at the Gault Estate, Mont St. Hilaire, McGill University. Professor John T. Parry (Department of Geography) invited me to address the workshop participants, but left the contents of my talk to my discretion. What follows is a slightly amended version of the main part of this talk.

The first ERTS satellite, now called Landsat, was launched in 1972. Since then, many papers illustrated with beautiful satellite images have been published, which claimed that computer processing of Satellite Multispectral Scanner (MSS) data would greatly improve the effectiveness of geological work and mineral exploration. It is argued here that these claims were not justified either in theory or by the results achieved so far.

It is possible to avoid wasting money on satellite remote sensing if one ignores the aesthetic attraction of the images and considers what the raw MSS data, acquired under the most favourable conditions, would consist of and possibly be useful for. Enhancement can only make apparent what is already in the raw data. If the raw data do not contain information useful for the solution of a particular problem, no amount of photographic or digital enhancement is going to put it there.

This leads to the problem of how one knows whether the raw data contain the required information. In the case of Landsat, the raw MSS data consist of measurements of reflected solar energy from contingguous pixels each covering about one acre on the ground in four bands, blue-green, red, mixed red and near infrared, and near infrared. If such data, obtained under perfect conditions, could be relevant to the problem, then one is justified in working to find the best enhancement techniques to make use of it. If the data could not be relevant, then one is wasting both time and money proceeding further.

Satellite-borne sensors provide repetitive coverage, but they provide it at a high cost in both money and data quality. Repetitive coverage is essential for studying changing surface phenomena, but it is not essential for the study of geology, which does not change significantly in the time-scale of human activities. The use of satellites as sensor platforms is, therefore, likely to be cost-effective only for the study of changing surface phenomena for which repetitive coverage is essential.

Most data used in the geological interpretation of aerial photographs are derived from the differential relief of the stereo-model which, in turn, is produced by the etching effect of the erosion process on the surface of the ground. This differential relief provides useful data for lithological interpretation even in non-outcrop areas. Thus earth fractures form negative topographic features unless they are dyke-filled, in which case they form either negative or positive features depending on the nature of the dyke and of the country rock. Different beds in a pile of sediments erode at different rates, thus making it possible to recognize sediments as such, and to make an estimate of the direction and amount of their dips. Similarly, different intrusive rocks erode at different rates and this makes it possible for them to be differentiated, even though it may not provide enough information to accurately name them.

Normal stereoscopic aerial photographs at a scale of about 1:30 000 have a vertical resolution of a few metres. Non-stereoscopic satellite images, however, which rely upon shadow to indicate relief, have a vertical resolution greatly inferior to this. Although it is possible to obtain stereoscopic satellite images, the vertical resolution obtainable with them will always be dependent upon their horizontal resolution, which again will necessarily be greatly inferior to that of aerial photography. From this it is deduced that the vertical resolution of both stereoscopic and non-stereoscopic satellite imagery will always be greatly inferior to that of aerial photography. It follows, therefore, that the value of differential relief in the geological interpretation of either stereoscopic or non-stereoscopic satellite MSS data is not, and will not be, comparable to that of stereoscopic aerial photography. The geological interpretation of such satellite MSS data must depend largely on the relative reflected energy in the different bands.

For the purpose of this discussion we can classify all the Earth's land surface into the following categories: (1) areas of no rock outcrops; (2) areas of small outcrops (less than one acre on the ground) surrounded by superficial cover or vegetation; (3) areas of large outcrops (more than one acre on the ground) surrounded by superficial cover or vegetation; and (4) areas of rock outcrop.

Let us consider first the areas in category (4) that are most amenable to lithological interpretation. These are areas that would normally be delineated on a map as representing rock outcrop. How much of such areas actually consists of bare rock? My estimate, based on study of outcrops in many different countries and in many different climatic environments, is that on the average less than 50 percent of the delineated area actually consists of bare rock. The rest consists of weathered-rock debris, vegetation debris, wind-blown sand, major vegetation such as shrubs and occasional trees, and minor vegetation such as ferns, grasses, mosses and lichens. Even in some desert areas the rocks are covered with a black desert varnish. It is therefore clear that even under the ideal conditions of the outcrop of a single rock type, the reflected energy will not depend solely on the rock present and will thus not be a reliable indicator of lithology.

In practice, however, in an outcrop area of about one acre (i.e., the area on the ground represented by one picture element [pixel]) not only is the bare rock area likely to be less than 50 percent of the total, but the bare rock area itself is likely to consist of more than one rock type. Even if the subsidiary rock type can be regarded as being unimportant to the geology, it certainly will affect the reflected energy in the different bands, and thus put further constraints on the precision with which it might be possible to interpret rock types.

For areas of categories (2) and (3) the problems are similar in nature, but increased by the fact that many of the pixels of category (3), and all of the pixels of category (2), will cover non-outcrop as well as outcrop areas. These non-outcrop areas will further reduce the degree to which the reflected energy in the different bands is indicative of the rocks present, and thus put still further constraints on the precision with which it might be possible to interpret rock types.

Most of the world's surface is of the type (1) category; it does not consist of rock outcrop. In non-outcrop areas, an approach to lithological interpretation that depends upon measurements of reflected solar energy in different bands to determine the nature and distribution of the rocks present, is up against obvious and profound difficulties, which will not be discussed further here.

The inevitable conclusion, therefore, appears to be that the lithological interpretation of both stereoscopic and non-stereoscopic satellite MSS data will necessarily be inferior to that obtainable with stereoscopic aerial photography.

It has been suggested that satellite imagery will be particularly valuable in those countries in which aerial photographs are not obtainable. This suggestion seems to be based on the mistaken belief that Landsat images can be regarded as rather poor quality aerial photographs.

When a geologist uses stereoscopic aerial photographs in the field he can, in general, precisely determine his position on the photographs merely by comparing the stereo-model with the surrounding countryside. The sort of precision I mean is that by which he is able to relate a particular isolated tree or bush depicted on the photograph with the living tree or bush on the ground. He can also prick through on the photographs the point corresponding exactly to that part of the outcrop from which he collected his rock specimen.

A geologist attempting to use a Landsat image in the field finds that, in general, it is impossible to determine his position on the image by comparing the image with the surrounding countryside. There is simply insufficient topographic detail on the image.

This is not intended to disparage the value of Landsat images for the purposes for which they were intended. But they were not intended to be an inferior type of aerial photography.

Because of the high cost of putting up satellites, it is likely that commercial satellites will have to carry general-purpose sensors that can be used for many different monitoring and surveillance projects requiring repetitive coverage. The highly specialized sensors now being developed to measure the minerals present in rocks of desert areas, or to measure metal-stress in vegetation, would be out of place on a satellite because they would not be required to produce repetitive coverage. They would be more cost-effective if they were air-borne rather than satellite-borne.

Satelite-borne sensors will be most useful in monitoring changing surface or above-surface phenomena, such as vegetation changes near industrial complexes, agriculture, forests, floods, oceans, fishing activities and weather, for which repetitive coverage is essential.

My general conclusions concerning geological and mineral exploration projects are the following:

(1) The repetitive characteristic of satellite-borne remote sensing has little value for most geological projects. Although it is advantageous for some projects to have imagery obtained during more than one season, (e.g., in the summer to show vegetation and in the early winter when a thin snow-cover emphasizes geological structure), once the desired imagery has been obtained, there is no advantage in having a continuous stream of new imagery.

(2) There appear to be very few cases in which the data obtained by satellite-borne sensors could not have been more cost-effectively obtained by air-borne remote sensors.

(3) For geological purposes, aerial photography is by far the most used and the most useful remote sensing method. Stereoscopic aerial photographs are desirable for virtually all geological and mineral exploration projects. It is highly desirable, therefore, that the remote sensing interpreter involved in geological projects should have considerable practical experience in photogeology.