British Geological Survey

Minerals from space

The use of remote sensing to identify mineral deposits

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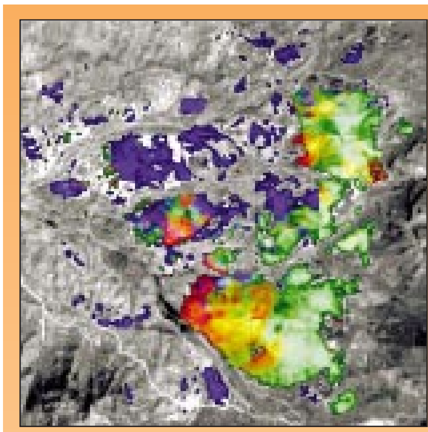
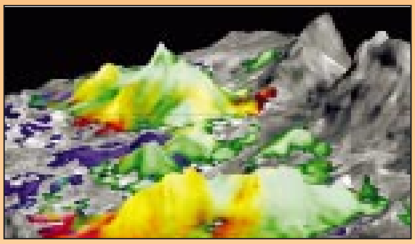
It is now more than a quarter of a century since the launch of the first earth-observation satellite. Although there have been several advances in sensor design and sensitivity in this period, the suite of current satellites (e.g. Landsat, SPOT, IRS, JERS-1) is still rather inadequate to meet the needs of the exploration geologist. Despite this, remote sensing from space, especially in arid regions, has provided some spectacular successes in mapping structure, discriminating lithologies and, significantly, detecting rock alteration associated with hydrothermal mineral deposits.

The latter possibility derives from the reflectance properties of minerals such as clays, carbonates and sulphates, common in alteration assemblages, which typically have absorptions in the 2.1–2.3 µm wavelength region (shortwave infrared) and of iron oxides which absorb in the 0.4 – 0.6 µm region (visible to nearest infrared). Using Landsat Thematic Mapper data, an image incorporating ratios of bands 5 & 7 and bands 1 & 3 will highlight areas where concentrations of these minerals occur, thereby discriminating altered from unaltered ground. These





Simulated ARIES data from Oatman, Arizona, showing abundances of alunite (red), kaolinite (green) and muscovite (blue) on a panchromatic image base (courtesy of CSIRO and the ARIES Consortium).

techniques have been successfully used by mining companies to target areas of potential mineralisation for subsequent ground follow-up.

Now at long last a new generation of high-spectral-resolution (‘hyperspectral’) sensors is set to advance these techniques from mere discrimination to the remote identification of individual mineral species. Aircraft sensors are already being used operationally by exploration companies, and the first space sensors will soon be deployed. Hyperspectral sensors have tens to hundreds of spectral channels in the 0.4 to 2.5 µm region, which allow a nearly complete reflectance spectrum to be produced for each ground element in the image. For many minerals, laboratory spectra show features that are unique and therefore diagnostic. These minerals include aluminium and magnesium hydroxides, amphiboles, micas, clays (smectites and kandites), carbonates, sulphates, arsenates, iron oxides, ammonia-bearing minerals and chlorites. The spectra collected remotely show some differences from laboratory spectra, caused by atmospheric effects and by the fact that the ground surface is typically a mixture of minerals, rocks, soils and vegetation. However, software (and experience) allows the unmixing of the signal and the identification of individual minerals and their relative abundances.

One satellite of particular relevance to geologists is ARIES (Australian Resource Information and Environment Satellite) scheduled for launch in the year 2000. This is designed for the minerals industry and will provide users with a range of high-level image products including quantitative mineral abundance maps. Simulation studies have already shown that it will be possible to map the chemistry of a range of important minerals even in areas of moderate vegetation. The image displays an example of simulated ARIES data showing abundances of alunite, kaolinite and muscovite on a panchromatic image base.

Other developments in spectral geology involve the use of hand-held portable spectrometers, such as the PIMA (Portable Infrared Mineral Analyser), which can be used for the rapid field identification of both alteration and industrial minerals. This method has fewer complications than the spaceborne systems, and it also has the advantages that the samples can include outcrop and drill core, and no preparation is required. The BGS is actively engaged in developing new applications in this area.

PIMA being used to measure a reflectance spectrum at an outcrop.