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LITHOLOGIC DISCRIMINATION AND ALTERATION MAPPING FROM AVIRIS DATA, SOCORRO, NEW MEXICO

K. K. Beratan and N. DeLillo, Dept. of Geology and Planetary Science,
University of Pittsburgh, Pittsburgh, PA, 15260
A. Jacobson and R. Blom, Jet Propulsion Laboratory, California Institute of
Technology, Pasadena, CA, 91109
C. E. Chapin, New Mexico Bureau of Mines, Socorro, NM, 87801

1. INTRODUCTION

Geologic maps are, by their very nature, interpretive documents. In contrast, images prepared from AVIRIS data can be used as uninterpreted, and thus unbiased, geologic maps. We are having significant success applying AVIRIS data in this non-quantitative manner to geologic problems. Much of our success has come from the power of the Linked Windows Interactive Data System. LinkWinds is a visual data analysis and exploration system under development at JPL which is designed to rapidly and interactively investigate large multivariate data sets. In this paper, we present information on the analysis technique, and preliminary results from research on potassium metasomatism, a distinctive and structurally significant type of alteration associated with crustal extension.

2. LINKWINDS AND MULTISPECTRAL DATA

The AVIRIS instrument collects 224 contiguous spectral channels within the visible and near-infrared. The large number of channels makes analysis difficult; only a few channels can be displayed in image format at one time, and individual rock spectra are hard to distinguish from one another. One approach is to take advantage of the digital nature of the data by comparing spectra from different image elements to laboratory spectra of minerals. However, this approach is hindered when individual minerals are combined into rocks and more than one rock type is averaged into a single image element (pixel). Spatial information, as important as spectral information for geologic interpretation, is not readily included in this type of analysis. Geologists are used to analyzing data in 2-dimensional map format, and the human eye is well-adapted for pattern recognition. However, it is not possible to create an image that simultaneously presents the information from 224 channels.

Spectral information that is important for mapping a specific area or answering a specific geologic question commonly is contained within only a few wavelength channels. However, which channels may not be apparent from theoretical considerations. LinkWinds allows the user to interactively scan through all channels and all combinations of band ratios, with the data presented both graphically (e.g., spectra and statistics) and in image form. Links between the two forms preserve spatial relationships. Visual evaluation allows identification of significant geological information. The advantage of this approach is that a priori selection of spectral regions believed significant is avoided.

LinkWinds is a UNIX-based integrated multi-application execution environment which has a full graphical user interface and presently runs on Silicon Graphics workstations. Data sets and individual tools in the form of data displays and controls for manipulating those displays are coded as objects, each occupying a window on the LinkWinds screen. Messages are passed between objects along one-way paths set up (or broken) by linking (or unlinking) the objects or windows at the discretion of the user. This data-linking paradigm makes the system perform much like a graphics spreadsheet, and is a powerful way of organizing the data for analysis while providing an intuitive and easy-to-learn interface.

3. POTASSIUM METASOMATISM

Potassium-metasomatism (K-metasomatism) is a form of alteration in which large amounts of potassium are added to rocks. In this process, rocks of diverse composition tend to be homogenized to a mixture of potassium feldspar (adularia) + hematite \pm quartz \pm illite-montmorillonite. Rock textures are preserved. Potassium-bearing phenocrysts, such as sanidine and biotite, are generally not affected and give the illusion that the rocks are unaltered (Chapin and Lindley, 1986). K-metasomatism is commonly associated with crustal extension. Examples of K-metasomatism are found associated with detachment faulting (extension along large-scale, low-angle normal faults) in California and in the Rio Grande Rift of New Mexico.

Two models have been proposed for the origin of metasomatizing fluids. In one, the fluids travel from depth along faults and play an important role in the mechanically difficult process of initiation of low-angle normal faults (Bartley and Glazner, 1985). In the second model, the fluids are surficial alkaline, saline brines, and metasomatism results from long-duration brine circulation through basins formed by extension-related subsidence (Chapin and Lindley, 1986). The two models have very different tectonic and structural implications. It should be possible to test the models by comparing an alteration map with a fault map; the most intense K-metasomatism should be associated with fault zones if the first model is correct, whereas distribution should be more diffuse and widespread if the second model is correct. This problem is ideally suited for analysis using AVIRIS data.

4. THE SOCORRO POTASSIUM ANOMALY

The Datil-Mogollon volcanic field, southwestern New Mexico (Fig. 1) was part of a huge Oligo-Miocene volcanic province related to the Rio Grande Rift. Here, huge calderas were sources for sheets of silicic ignimbrites erupted prior to development of Basin and Range topography (Elston, 1978). Socorro, New Mexico, lies on a boundary between two domains of imbricate normal fault blocks that are tilted in opposite directions (Chapin, 1989).

The Socorro potassium anomaly is an L-shaped zone in which one arm trends northward along the axis of the early rift Popotosa basin (Fig. 1). The other arm extends southwest from Socorro across an overlapping series of late Oligocene calderas. Using only the volume of altered tuffs (900 km^3) and an average enrichment of 2.9% K_2O , a minimum of 6.4×10^{10} tons of potassium has been added within the anomaly (Chapin and Lindley, 1986). The Socorro area is ideal for the study of K-metasomatism because five regional ash-flow tuff

sheets extend across the potassium anomaly and well beyond it, allowing traverses from fresh rock into progressively more metasomatized rocks within the same stratigraphic unit. In addition, interbedding of basaltic andesite lavas between the ash-flow tuff sheets permits comparison of alteration effects on both mafic and silicic rocks (Chapin and Lindley, 1986).

5. ANALYSIS OF AVIRIS DATA

This study was initiated as a result of the observation that syn-extensional sedimentary and volcanic rocks within the Whipple detachment terrane, southeastern California-western Arizona, display a distinctive spectral signature in LANDSAT Thematic Mapper data (Beratan et al., 1990). We hypothesized that this signature is related to compositional changes resulting from syn-extensional K-metasomatism. Although the added potassium would not be apparent in the visible and near-IR spectral range, associated hematite should be. Therefore, AVIRIS data was acquired for the Whipple Mountains area and for Socorro, New Mexico. We focus on the Socorro data in this paper.

A 3-component RGB image was made with a channel within the Fe^{+3} absorption feature assigned to blue, a channel within the Fe^{+2} absorption feature assigned to green, and a channel containing a calcite absorption feature assigned to red (Fig. 2). These three channels produced an image that displays a remarkable degree of lithologic discriminability. Not only can basaltic andesites be distinguished from silicic tuffs, but different basaltic andesite and tuff units can be delineated (Fig. 2). Also identifiable are Precambrian crystalline units and younger metasedimentary units, most notably the Pennsylvanian Madera Limestone. In fact, comparison of detailed field mapping (Chamberlin, 1982) and Chapin's field work in the area suggests that the lithologic discrimination possible with the image is approximately equal to that observable in the field.

Intense K-metasomatism is indicated by a deep orange color in the 3-component RGB image. The alteration spectral signature is independent of initial rock type, occurring both in metasomatized silicic tuffs and basaltic andesite lavas, which is consistent with the tendency for K-metasomatism to homogenize rock compositions. The origin of this distinctive spectral signature is apparent in an image which displays the ratio of a channel within the Fe^{+3} absorption feature vs. a pure-reflectance channel. The energy return displayed by the pure-reflectance channel is a measure of the albedo of the rocks; in general, light-colored rocks are more silicic than dark-colored rocks, and so this channel provides a crude indication of rock type. The ratio image highlights areas in which the energy return displayed by the Fe^{+3} channel is significantly lower than expected, based on that from the pure-reflectance channel. The ratio image thus highlights rocks which contain significant amounts of Fe^{+3} -bearing minerals, probably hematite. These areas correspond to the deep orange areas on the 3-component RGB image.

6. CONCLUSIONS

Our preliminary results show that K-metasomatism can be mapped from AVIRIS data. This represents a significant advance since, due to the visual subtlety of the alteration, large numbers of chemical analyses have been

required previously to construct even a crude alteration map. We have begun systematic sample collection based on the image analysis. Chemical analysis of these samples will allow us to calibrate the AVIRIS spectral data in order to determine the corresponding degree of alteration. The alteration map produced from this data should allow testing of the two metasomatism models.

7. REFERENCES CITED

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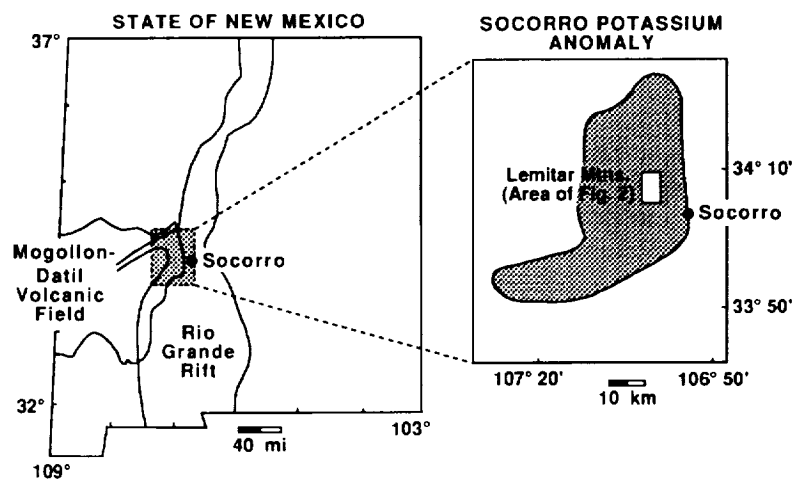


Figure 1. Map showing the location and approximate extent of the Socorro potassium anomaly. (Modified from Chapin and Lindley, 1986.)

Figure 2. (See Slide 1.) 3-component RGB image of the study area; AVIRIS data collected in August, 1990. Blue = AVIRIS band 12; green = band 48; red = band 213.