Geothermal Site Characterization Using Multi- and Hyperspectral Imagery

Wendy Calvin, Mark Coolbaugh and R. Greg Vaughan

Great Basin Center for Geothermal Energy, University of Nevada, Reno

Keywords

Remote sensing, thermal anomalies, mineral mapping

ABSTRACT

Remote sensing imagery has been widely used as an exploration and site characterization tool for both mineral and petroleum economic development as well as environmental assessment. Well-established techniques in multispectral and hyperspectral analysis, coupled with new, state-of-the-art imagery from spaceborne and airborne sensor systems, allows their direct and immediate application to problems in geothermal energy development and assessment. Surface mapping of mineralogy and rock type, vegetation stress, and thermal anomalies can be used in conjunction with structural and subsurface context to provide a more comprehensive picture of known geothermal source regions and can help identify new sources or expand existing fields. We have been working with both airborne and spaceborne multi- and hyperspectral data over two known geothermal fields in Nevada: the Steamboat Springs region just south of Reno and the Brady Hot Springs region, near Desert Peak. We are able to map surface mineralogy related to geothermal activity and we are exploring the potential of day/night thermal imagery in identifying thermal anomalies.

Introduction

Thermal infrared imagery has been used previously to locate hot-springs above geothermal resources (Lee, 1978; Allis, *et. al.*, 1999), but its usefulness in exploration has been limited because the thermal anomalies were detected only in the immediate vicinity of known hot springs or fumaroles. Hyperspectral imagery in the visible and near-infrared has long been used to map surface mineralogy and hydrothermal alteration (e.g. Kruse, 1999; King, *et. al.*, 2000). Recent significant advances in the availability and quality of both short-wave and thermal infrared imagery demand a reassessment of their role in geothermal exploration. Work by the remote sensing group of University of Nevada's Arthur Brant Laboratory (ABLE) and supported by the Great Basin Center for Geothermal Energy, focusses on developing techniques of analysis for two new sensors, ASTER and SEBASS.

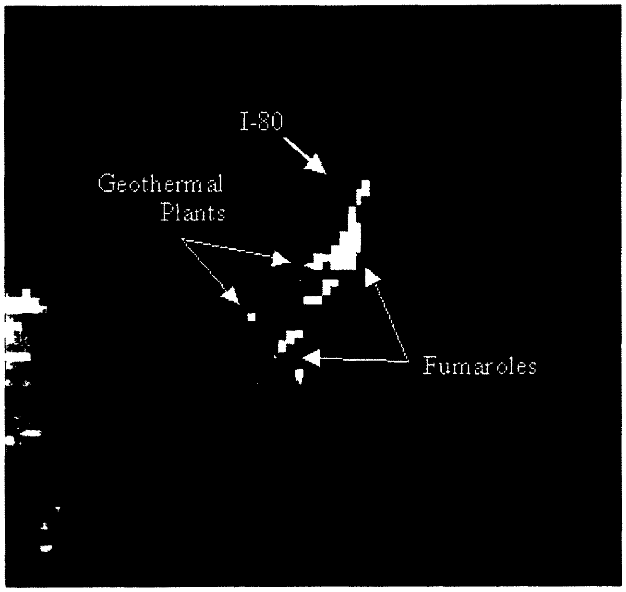
ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) is a multi-spectral imager recently launched on NASA's earth observation platform Terra. ASTER has 9 visible and near-infrared channels, and 5 thermal infrared channels with spatial resolutions ranging from 15m to 90m. All wavelength ranges are co-registered and day/night pairs can be acquired in the thermal, facilitating surface temperature and thermal inertia separation. The co-registered visible channels can be used to constrain albedo while the numerous thermal channels allow for temperature-emissivity separation. ASTER data is currently available at no cost via download through the world wide web. We are currently using ASTER for day/night analysis of thermal anomalies.

SEBASS (Spectrally Enhanced Broadband Array Spectrograph System) is a hyperspectral thermal imaging spectrometer system owned and operated by the Aerospace Corporation. SEBASS covers the wavelength range from 7 to 14 µm with 128 spectral channels. In a group shoot in September of 1999, UNR acquired several flights near Reno, including one strip over Steamboat Springs. The resulting ground resolution was 2m/pixel and swath of 128 pixels so the images cover a narrow portion of the Steamboat main terrace and associated geothermal field. We have been using SEBASS to provide detailed mineral maps of hydrothermal alteration products including sulfates and multiple ages of sinter at the main terrace.

Initial Results

ASTER Day/Night Thermal Analysis

Because of the large areas covered by its 60-kilometer-wide swath, ASTER TIR imagery can be used as a regional exploration tool to systematically search large areas for thermal anomalies, including regions previously considered unpromising. This holds special significance in the desert Basin and Range province, where low water tables may limit the surface discharge of hot water and/or steam. In remote desert areas, these thermal zones may be detected most easily with remote TIR sensing methods. A preliminary study using 5-channel TIMS data has shown that appropriate correction for topographic slope orientation, albedo, and thermal inertia can increase the number of remotely detected thermal anomalies by an order of magnitude (Coolbaugh et al. 2000). This initial study was performed in the Steamboat Springs region. Similar work with ASTER data is being conducted over the Brady Hot Springs region (Figure 1), where a thermal anomaly associated with the Brady's fault (white area near the center of the image) shows up clearly on raw imagery. At 90m/pixel this spaceborne data can easily identify a thermal feature ~2km in length. We will present the methodology of the approach and final analysis of the ASTER scenes at the meeting. In the summer of 2002, we hope to acquire day/night pairs at much higher spatial resolution than ASTER; preliminary analysis of these data will be included.



Hyperspectral Mineral Mapping

Mineral mapping using the SEBASS data has been the subject of several years of work in calibration and field validation of the data set (Vaughan, *et. al.*, submitted). The advantage of hyperspectral thermal imagery is that individual minerals can clearly be identified and mapped at the 2m spatial scale. The thermal wavelengths can also distinguish a number of primary silicates (feldspars, quartz, opaline silica) that are spectrally bland or have features that are non-unique at shorter wavelengths. We have worked with SEBASS data over an older pit and vent structure where elemental sulfur is exposed in the field, as well as the main Steamboat terrace. Clearly distinguished are a number of silicate deposits with varying compositions. Over the main sinter terrace SEBASS has distinguished younger from older sinter based on the strength of the absorption features. Our analysis shows the hyperspectral SEBASS data have the ability to map lithologies based on subtle spectral variations in mineralogy. Even a simple method such as a decorrelation stretch (Gillespie, *et. al.*, 1986) can clearly separate quartz, clay and feldspar regions with intermediate colors suggesting sulfates such as jarosite or alunite. Detailed spectral mapping discriminates pure quartz from quartz/alunite, clays including kaolinite, montmorillonite and illite, varying ages of sinter deposits, and a variety of sulfates such as gypsum, alunite and jarosite. We will present initial mineral maps for the Steamboat region as well as a site characterization using a multi-spectral instrument with a broader swath than SEBASS. We should acquire short wavelength hyperspectral data this summer for synthesis with the SEBASS data.

Summary

It is expected that this work will help identify new methods of remote characterization of geothermal site potential. It is hoped that unique mineral indicators of springs or seeps (salts, borates), levels of vegetation stress and/or thermal anomalies can be used to target new sites or assist in identifying expansion in existing areas.

Acknowledgments

This material is based upon work supported by the U.S. Department of Energy under instrument number DE-FG07-02ID14311.

References

Allis, R. G., Nash, G., and Johnson, S. D., Conversion of thermal infrared surveys to heat flow: comparisons from Dixie Valley, Nevada, and Wairakei, New Zealand; *Geothermal Resources Council Trans*, 23, p. 499-504, 1999.

Coolbaugh, M. F., Taranik, J. V., and Kruse, F. A., Mapping of surface geothermal anomalies at Steamboat Springs, NV. using NASA Thermal Infrared Multispectral Scanner (TIMS) and Advanced Visible and Infrared Imaging Spectrometer (AVIRIS) data; *In:* Proceedings, 14th Thematic Conference, Applied Geologic Remote Sensing, Environmental Research Institute of Michigan (ERIM), Ann Arbor, MI., p. 623-630, 2000.

Gillespie, A.R., A.B. Kahle, and R.E. Walker, Color enhancement of highly correlated images. I. Decorrelation and HIS contrast stretches, *Remote Sensing of Environment*, 44, p. 165-178, 1986.

King. T.V.V., R.N. Clark, and G.A. Swayze, Applications of imaging spectroscopy data: A case study at Summitville, Colorado, in *Remote Sensing for Site Characterization*, F. Kuehn et al. Eds., Springer-Verlag, pp.164-185, 2000.

Kruse, F.A. Visible-Infrared sensors and case studies, in *Remote Sensing for the Earth Sciences: Manual of Remote Sensing, 3rd Ed., Vol. 3*, A. N. Rencz, Ed., pp. 567-611, 1999.

Lee, K., Analysis of thermal infrared imagery of the Black Rock Desert geothermal area; *Colo. Sch. Mines Quarterly*, n. 3, part 1, p. 31-43, 1978.

Vaughan, R.G., W.M. Calvin and J.V. Taranik, SEBASS hyperspectral thermal infrared data: Calibrated surface emissivity and mineral mapping, *Remote Sensing of Environment*, submitted, April 2002.