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GEOCHEMICAL EXPLORATION FOR OIL AND GAS

UTILITY OF ASTER FOR DETECTING HYDROCARBON

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EXTENDED ABSTRACT

Multispectral instruments, such as Landsat, have demonstrated they can detect subtle geochemical anomalies associated with hydrocarbon seeps. However, these geochemical anomalies are nonspecific, and require field verification. In contrast, hyperspectral instruments (such as AVIRIS) can readily differentiate between ancient hydrocarbon seeps and active hydrocarbon seeps. High cost, small area of coverage, and need for advanced image processing limit the use of hyperspectral data. The Advanced Spaceborne Thermal Emission and Reflection (ASTER) instrument is an excellent compromise between the two approaches. ASTER is a multispectral instrument, but includes more spectral bands in the shortwave infrared region where minerals associated with hydrocarbon seeps have identifiable absorption features. Analysis of ASTER data collected over Trap Springs, Eagle Springs, and Grant Canyon oil fields in Nevada (Figure 1) show that clay minerals more stable within the reducing environment of a seep (e.g., kaolinite) can be differentiated from other more disordered clays (e.g., illite, smectite, montmorillonite). Concentrations of the stable clays are higher inside of spectral anomalies mapped using specially processed ASTER data (Chart 1). At these fields, the re-oxidation of ferrous iron bearing minerals (e.g., pyrite and marcosite, also common within the reducing environment) to hydrous iron oxides (e.g., geothite or 'limonite', characteristic of a hydrocarbon seep), can be differentiated to a higher degree than with Landsat TM data. Concentrations of the ferric iron minerals is lower within the spectral anomalies mapped on the specially processed ASTER imagery (Chart 1).

A comparison of ASTER multispectral data collected over the Dutton Basin Anticline in central Wyoming with the results utilizing AVIRIS hyperspectral imagery reveals the strengths and limitations of the ASTER sensor. Spectral analysis of the hyperspectral data was performed using spectral matching tools such as Spectral Angle Mapper and Spectral Feature Fitting. Reference spectra for minerals from the USGS spectral library were used to map those minerals within the image. The spectral matching tools alternately map the similarity in overall shape of the spectra, or match the wavelength position and depth of diagnostic absorption features. Figures are presented showing results for calcite, hematite, goethite, kaolinite, and montmorillonite. Other minerals diagnostic to hydrocarbon seeps but unlikely to be discernible via multispectral means include siderite, ferrihydrite, copiapite, and jarosite. These are all able to be mapped with a fairly high level of confidence with hyperspectral data.

ASTER spectra are undersampled relative to hyperspectral data, and are not amenable to typical spectral matching algorithms (certainly not absorpion feature mapping). Instead, ratios of bands are used to map minerals. By being selective about which bands to use in complex ratios, results that map the target mineral yet are exclusive of other spectrally similar minerals may be obtained. These results using ASTER data are shown for iron oxide bearing minerals, kaolinite, montmorillonite, and calcite. Note that ASTER does not have enough spectral bands to differentiate most iron bearing minerals, unlike hyperspectral data.

ASTER (Figure 2) does a decent job of mapping calcite relative to AVIRIS (Figure 3), although ASTER is more susceptible to confusion with vegetation. Correcting for this potential confusion in the ratio runs the risk of introducing artifacts. While ASTER is quite capable of mapping ferric iron, it is not able to separate different iron bearing minerals, which can often be important. In the case of Dutton Basin anticline, differentiating goethite, a result of alteration, from hematite, common here as part of the Chugwater Formation, is critical. Mapping of the clays is possible with ASTER, but done to a higher precision with AVIRIS. While large concentrations are easily separable by ASTER, subtle features are often missed. Overall, ASTER data are an inexpensive and effective (although somewhat limited) tool for mapping geochemical anomalies related to hydrocarbon seepage.

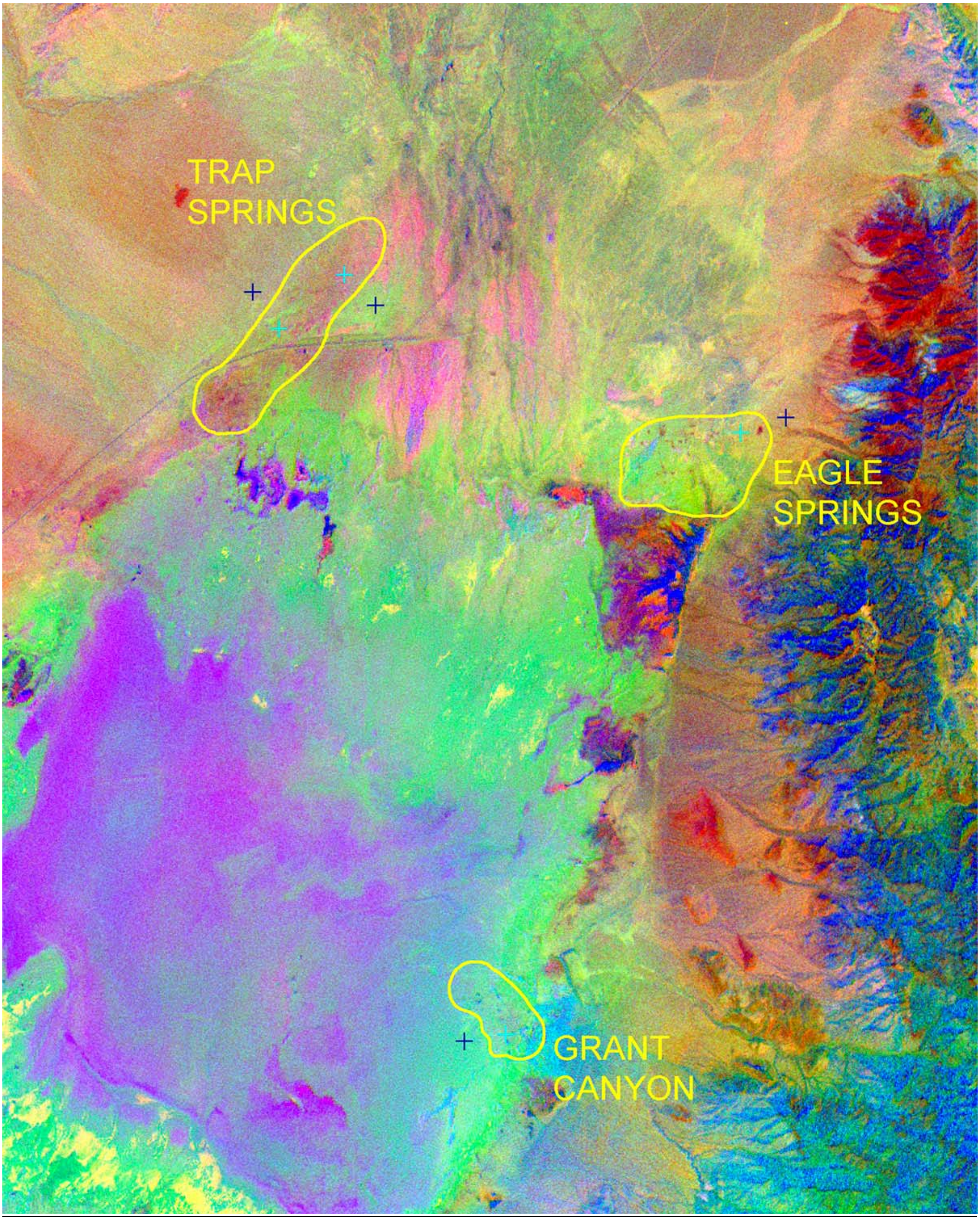

Figure 1: ASTER ratio image of Railroad Valley, Nevada. Dark blue crosshairs are locations of measurements made outside of the spectral anomalies; light blue crosshairs are locations within the anomalies.

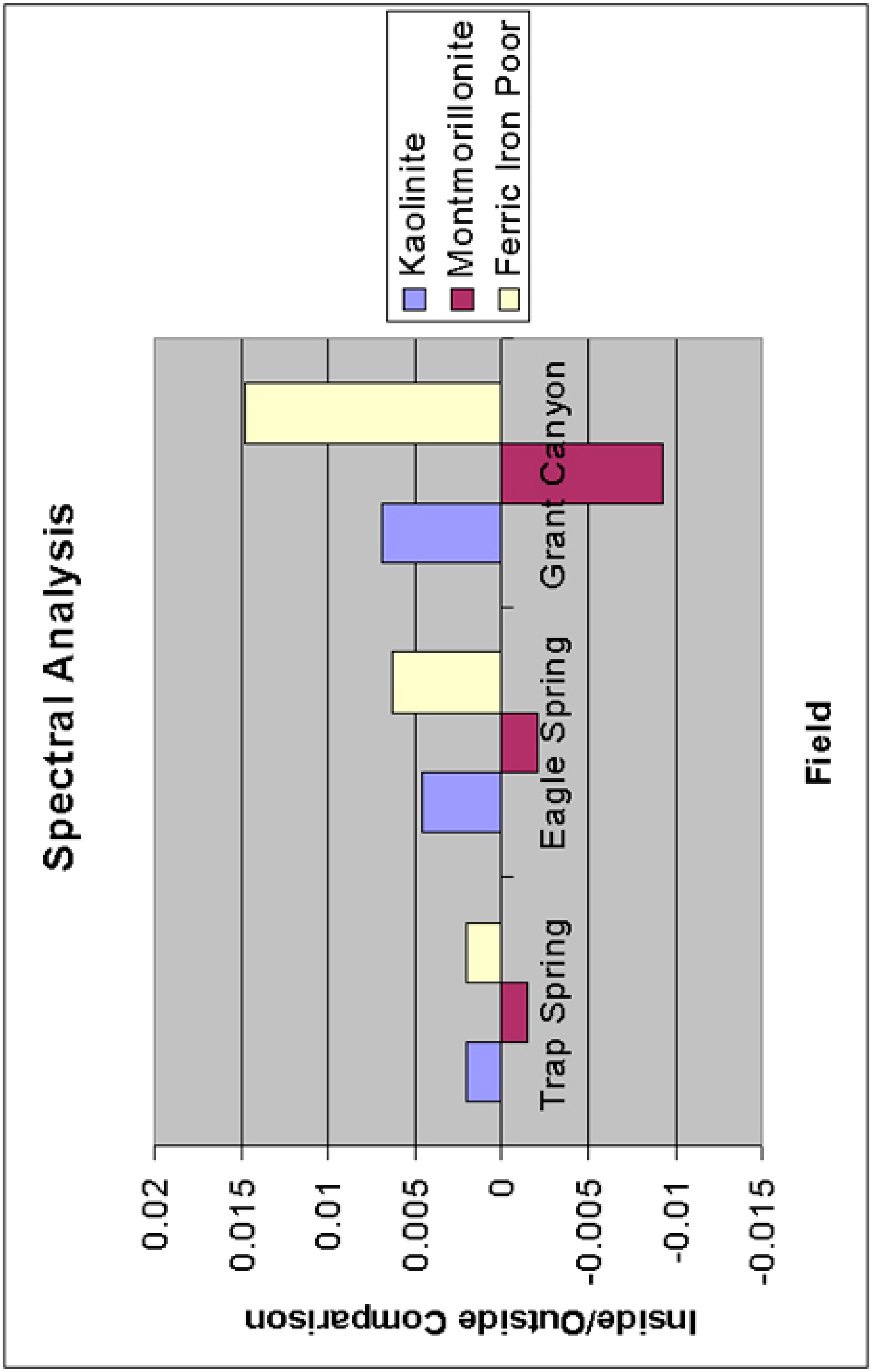

Chart 1: ASTER Spectral Analysis of Trap Springs, Eagle Springs, and Grant Canyon oil fields.

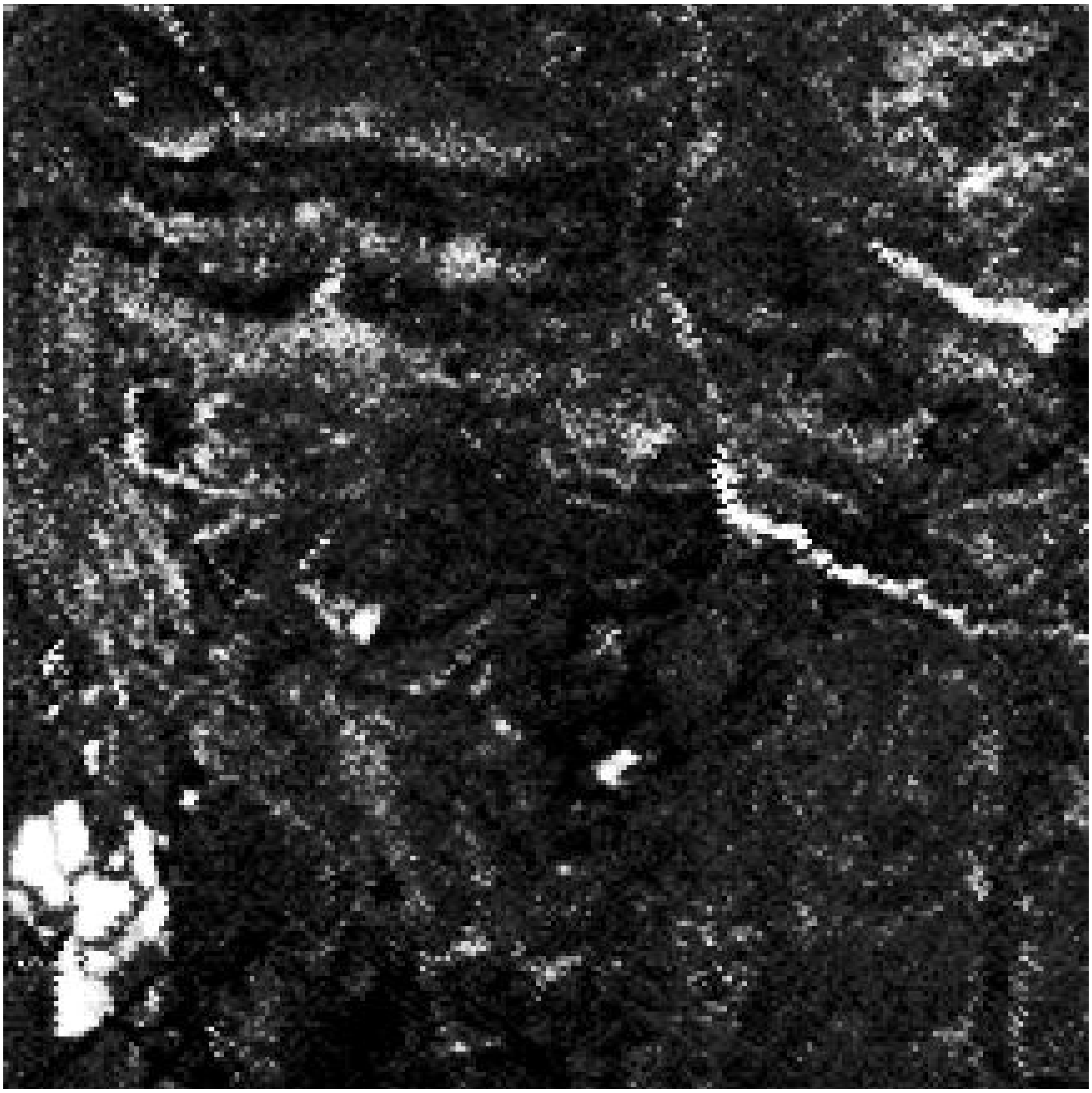

Figure 2: ASTER clay image of Dutton Basin anticline; areas high in clay are white.

Figure 3: AVIRIS clay image of Dutton Basin anticline; areas high in clay are white.