N94-16675

# FIRST RESULTS FROM ANALYSIS OF COORDINATED AVIRIS, TIMS, AND ISM (FRENCH) DATA FOR THE RONDA (SPAIN) AND BENI BOUSERA (MOROCCO) PERIDOTITES

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## Introduction

Ultramafic rocks are relatively rare at the Earth's surface but constitute the vast majority of the Earth by volume. Exposures of ultramafic bodies are therefore crucial for deducing many important processes that occur in the Earth's mantle. An important science question regarding the spatial distribution, abundance, and composition of mafic minerals in ultramafic bodies that can be examined with advanced sensor data is the melting process. When a lherzolite melts, clinopyroxene (cpx) melts first and therefore variations in the modal amount of cpx remaining in the mantle are a reflection of the amount of fractional melting that has occurred. Fe goes preferentially into the melt during melting but a 20% batch melting (i.e. closed system) acquires less Fe relative to 20% fractional melting (i.e. open system). Since the strength and wavelength of diagnostic absorptions is a strong function of Fe content, it is possible to make maps of the variation in Fe:Mg ratios which can be related to the general melting process. Accurate ground-truth information about local mineralogy provides internal calibration and consistency checks. Investigations using imaging spectrometer are very complementary to field studies because advanced sensor data can provide a synoptic view of modal mineralogy and chemical composition whereas field studies focus on detailed characterization of local areas.

Two excellent exposures of ultramafic lithologies are being investigated with visible to mid-infrared imaging spectrometer data: the Ronda peridotite near Ronda, Spain and the Beni Bousera ophiolitic fragment in northern Morocco (Figure 1a). Although separated by the Alboran Sea, these bodies are thought to be related (Bonini et al, 1973, Frey et al, 1985) and represent fertile sub-continental mantle. The Ronda peridotite, shown in Figure 1b, is predominantly spinel lherzolite but grades into harzburgite and shows considerable variation in major and trace element compositions (Frey et al., 1985). Mafic layering and dykes (i.e. olivine gabbro) are also observed. This indicates some sections of the peridotite have experienced greater degrees of partial melting. The Beni Bousera peridotite, shown in Figure 1c, also contains mafic layers and dykes and grades into harzburgite representing similar fundamental shifts in the bulk chemistry of this ultramafic body probably related to an episode of partial melting (Lorand, 1985). The specific mode of emplacement of these bodies is controversial (allocthonous thrust related bodies, Frizon de Lamotte et al, 1990: mantle core complexes, Doblas and Oyazun, 1989; 1990) and important for understanding the tectonic evolution of this region. Our investigations are not necessarily designed to help resolve this controversy. Rather, these exposures provide excellent and unusual examples of fertile mantle which have undergone variable degrees of partial melting.

## ISM-AVIRIS Cross Calibration

A significant aspect of the European deployment of the NASA aircraft is the unique opportunity for cross calibration of the ISM and AVIRIS sensors. ISM data were obtained over the Ronda peridotite in July 1991, two weeks before the AVIRIS flight, and were also obtained over the Beni Bousera peridotite. However NASA chose not to fly over any targets in Africa during this deployment. The ISM instrument contains two arrays of 64 PbS detectors each for the 0.76 to 1.51 µm and 1.63 to 3.16 µm wavelength regions which have spectral resolutions of 12.5 and 24 nm respectively. The instrument has an IFOV of 10' cross track and 40' along track. From a typical flight altitude of 6000 meters this translates to a pixel size of 18 x 75 meters. The scanning mirror has a displacement of ±20° which corresponds to a 4.5 km swath from 6000 meters. Although the instrument is not directly comparable to AVIRIS in spectral and spatial resolution, the predicted signal to noise of ISM is ~500:1 with a 50% reflective target and the ISM wavelength range extends to longer wavelengths. Therefore these instruments have important complementary characteristics.

## Data Reduction and Analysis

The calibration and reduction of the AVIRIS, TIMS, and ISM data is just beginning but will proceed in a series of well defined steps. Upon acquisition of AVIRIS data tapes from JPL all bands will be inspected for data quality and channels with unacceptably low signal to noise levels (less than 40:1 for spectrometers A, B, C, and less than 20:1 for spectrometer D) will be identified and removed from the analysis. The precise ground coverage will be determined and a library of field and laboratory spectra for these areas will be assembled for reference. Additional spectra from the extensive RELAB library established in previous investigations (i.e. Moses Rock Dike, Kings-Kaweah ophiolite melange) which are pertinent to this investigation will be included. A sub area from each field site containing several homogeneous targets will be selected for initial calibration and a linear mixing analysis of the raw data will be performed to determine the dimensionality of the raw data. The image endmembers determined from this analysis will be passed through the spectral library to determine a set of gains and offsets to calibrate the raw data to reflectance (e.g. Smith et al, 1990). Estimates of atmospheric scattering determined with the field spectrometer will be compared to the offsets determined by this method. The calibrated AVIRIS data will then be inspected to validate the calibration procedure and compared to field and laboratory spectra. Once we are satisfied with the calibration we will expand the analysis to the entire field site at both locations.

TIMS data are a measure of the surface temperature in the 8-12 µm region. Preliminary analysis of the standard decorrelation stretched images clearly distinguishes the mafic, ultramafic, and felsic rock types exposed in the Ronda peridotite. However, emittance is the parameter that is desired. This will be estimated by assuming an emittance of 0.93 for channel 6 of TIMS (approximately 11.5 µm) for silica rich targets or channel 1 for silica poor targets. Using these assumptions, an estimate of the surface temperature at the other wavelengths can be calculated and the emittance is the difference between the estimated temperature and the TIMS data. This calibration process reduces the number of TIMS channels from 6 to 5. The calibrations will be checked to establish that topography, slope, and other local surface temperature effects are completely removed. These data will then be co-registered with the AVIRIS data.

Cross-calibration of the NASA acquired AVIRIS data with the ISM data acquired by CNES is an important part of this investigation. The ISM data are complementary to the AVIRIS data. Although AVIRIS has a higher spectral resolution (approx. 9.75 nm between 0.4 and 2.45 µm) than ISM (approx. 12.5 between 0.76 and 1.51 µm: 24 nm between 1.63 and 3.16 µm), the signal to noise anticipated from ISM is very high (>500:1). Also, since the spectral range of ISM extends to 3.16 µm, the spectral range of AVIRIS can be extended to the saturated atmospheric water band near 2.7 µm. The ISM instrument is configured with a comparable spatial resolution to AVIRIS from a 6000 meter altitude and data were collected over the Ronda and Beni Bousera peridotites in July of 1991. These data are currently being calibrated in France using internal calibration sources. The AVIRIS and ISM data will then be co-registered and the two calibrations evaluated. Drawing on the strengths of each instrument (higher spectral resolution, greater visible coverage of AVIRIS: higher signal to noise and extended wavelength range of ISM) we will converge on a consistent set of calibration parameters and a greater understanding of the two instruments.

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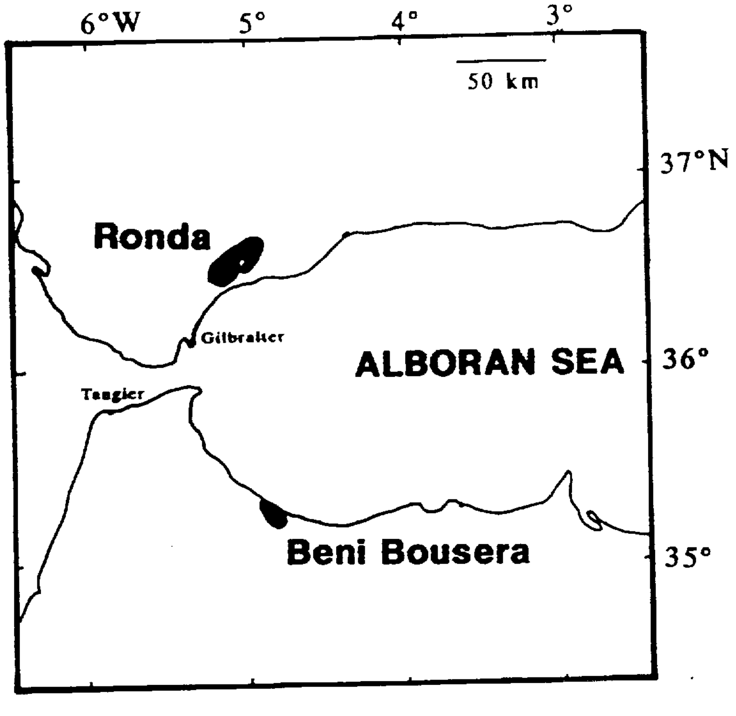

Figure 1. Generalized location map for the Ronda and Beni Bousera peridotite bodies.