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Analyses of TIMS and AVIRIS Data, Integrated with Field and Laboratory Spectra, for Lithological and Mineralogical Interpretation of Vulcano Island, Italy

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1. Introduction

Vulcano Island is part of the Eolian archipelago, located about 25 km from the north-east coast of Sicily. The archipelago comprises seven major volcanic islands, two of which are active volcanoes (Vulcano and Stromboli). Vulcano covers an area of about 50 km^2, and is about 10 km long.

The volcanic history of the island is spanned by its four main structural units: (I) the South Volcano complex (stratovolcano) and the Piano Caldera, (II) the Lentia Group, (III) the Fossa Caldera and Fossa Volcano complex, and (IV) Vulcanello, which is connected to the main Vulcano Island by a half-kilometer-wide isthmus; see Figure 1. The oldest structure, the South Volcano, probably originated in the upper Pleistocene. The youngest structure, Vulcanello, originated in an eruption that occurred about 183 B.C. The volcanic rock types found on Vulcano range from mafic to intermediate-acidic in composition.

Explosive volcanic activity has predominated in the geological evolution of Vulcano Island, and there is no evidence that this pattern has ceased. Rather, the current situation is one of unrest, so a strict regimen of continuous geophysical and geochemical monitoring has been undertaken over the last decade. Though the year-round population of Vulcano is small (under 1000), during the summer the island becomes a very popular resort, and has thousands of additional tourists at any time throughout the high season, thus substantially increasing the number of people potentially at risk from an explosive eruption or other hazards such as noxious gas emissions (e.g., CO_2, H_2S, SO_2).

During the past ten years, remote sensing data have been repetitively acquired with optical and microwave airborne sensors (see Table 1). The present work shows the preliminary results of a study based on the integration of various remote sensing data sets with field spectroscopy, and other laboratory analyses, for the geological and geomorphological mapping of the island. It is hoped that such work will also usefully contribute to the evaluation of the volcanic hazard potential of the island, as well as to the evaluation of the status of its current activity.

2. Image Data

The remote sensing imagery available for Vulcano is tabulated here in Table 1. Our study utilized data from airborne optical sensors operating in the very-near (VNIR), short-wave (SWIR) and thermal (TIR) parts of the infrared spectrum. The TIR data used here were acquired in 1986 during C-130 aircraft overflights with the Thermal Infrared Multispectral Scanner (TIMS: 8-12 μm, 6 channels) as part of a JPL/NASA-CNR airborne campaign over volcanoes in southern Italy (Bianchi *et al.*, 1990). Although Thematic Mapper Simulator (NS001) data were also acquired during that campaign, we preferred to use the more comprehensive VNIR-SWIR data set acquired with the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS: 0.4-2.5 μm, 224 channels) taken during the subsequent NASA-CNR MAC-EUROPE '91 ER-2 deployment. Aircraft for these campaigns were deployed by the Medium and High Altitude Missions groups of NASA Ames Research Center in Palo Alto, California.

3. Other Data Sets

Ground truth information in the VNIR-SWIR was collected by performing field measurements with a portable spectro-radiometer (GER Mark IV) at different times, but in the same season as the image data acquisition. Rock samples were collected for spectral analyses in the TIR wavelengths, since a portable spectrometer was not available for this spectral range.

Table 1.
Multispectral Airborne Sensor Data Acquired Over Vulcano Island

Sensor	*Flight Date*	*Sensor*	*Flight Date*
TIMS	29 July 1986	AIRSAR	28 June 1991
NS001	29 July 1986	MIVIS	21 July 1994
AVIRIS	19 July 1991	TMS	19 July 1991

A digital elevation model (DEM) was created by digitizing a topographic map at the 1:10,000 scale (courtesy AGIP Oil Corporation, 1980), with vector interpolation of the contour lines. The DEM was used for both geometric rectification of the remotely sensed images (e.g., TIMS, AVIRIS) and for morphological and structural interpretations.

Rock samples were collected on the most representative volcanic formations and were spectrally and chemically analyzed for information regarding mineralogical composition.

4. Atmospheric Correction of TIMS and AVIRIS Data

Calibrated AVIRIS radiance data were corrected for atmospheric effects by using LOWTRAN-7 and MODTRAN radiative transfer models (Berk *et al.*, 1989). As input for the models, we used atmospheric profiles and ground reflectance measurements performed over a flat field reference. TIMS data were also corrected for atmospheric effects by using radiative transfer models (LOWTRAN-7). Spectral emissivity was then calculated by using a normalization technique (Realmuto, 1990).

5. Analysis Approach

Reflectance and emissivity image data were analyzed--first separately and then combined in color composites--for geological and lithological interpretation by means of photo-interpretation techniques. A comparison of the retrieved emissivity and reflectance values was performed by extracting image spectra relative to the surface materials for which we had also made field and laboratory measurements. The AVIRIS reflectance images were analyzed by means of principal component techniques (Gillespie *et al.*, 1986) in order to compress the data dimension but retain the spectral information of the selected channels. The most significant color composites of the principal component analyses were then co-registered with the DEM for the combined analysis with TIMS images. TIMS emissivity images were analyzed using decorrelation stretching techniques.

6. Preliminary Results

The preliminary results showed that it is possible to compare the TIMS-retrieved emissivity spectra (Figure 2) with the laboratory ones for the well-exposed volcanic materials (Figure 3). The analysis of mixed AVIRIS reflectance and TIMS emissivity image color composites showed color variations that are in good agreement with changes in the surficial lithologic composition of the various volcanic products. Observed variations of the surface roughness of the exposed volcanics at the 1-100 cm scale also play a role in increasing the variance of the spectral response.

7. Future Work

The next step is to complete the comparison between laboratory spectra in the

VNIR-SWIR range with AVIRIS-retrieved reflectance spectra. Additionally, microwave image data acquired by the JPL-AIRSAR during the MAC-EUROPE '91 campaign will be integrated with the optical data to add necessary textural information.

During the summer of 1994, the new Multispectral Infrared and Visible Imaging Spectrometer (MIVIS) of the Italian National Research Council (CNR), under the auspices of the Project for Environmental Studies of Southern Italy (LARA), was also flown over the Eolian Islands. Multi-temporal images were acquired in both the VNIR-SWIR and TIR bandpasses, and a detailed ground measurement campaign was carried out during the overflights. The future analyses and interpretation of these data will hopefully increase the accuracy of the lithologic mapping and hazard assessment not only on Vulcano Island, but on other more complex areas, such as Mt. Etna, where some of us are also attempting to apply these techniques to address geological and hazard-related problems.

8. Acknowledgements

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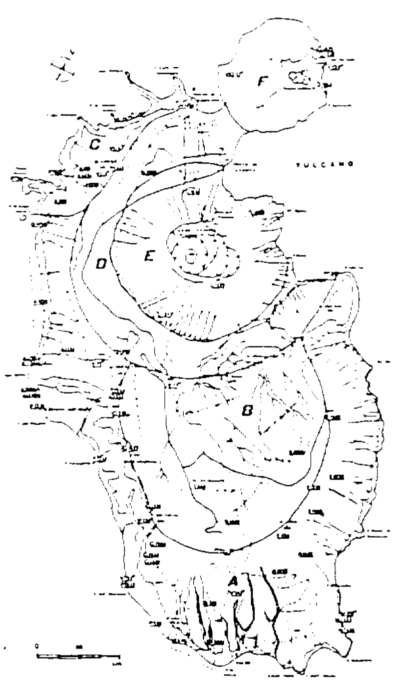

Figure 1.

The main geological and structural units of Vulcano Island:

(A) and **(B)**--South Volcano and Piano Caldera

(C)--the Lentia Group (latite, trachyte, and rhyolite lava dome complex);

(D) and **(E)**--Fossa Caldera and Fossa Volcano;

(F)--Vulcanello

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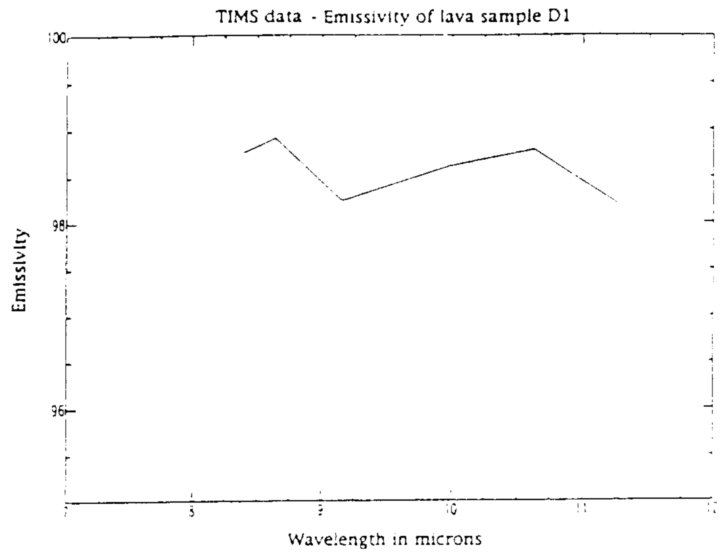

Figure 2.
Emissivity of a Lentia lava flow retrieved from TIMS data versus wavelength.

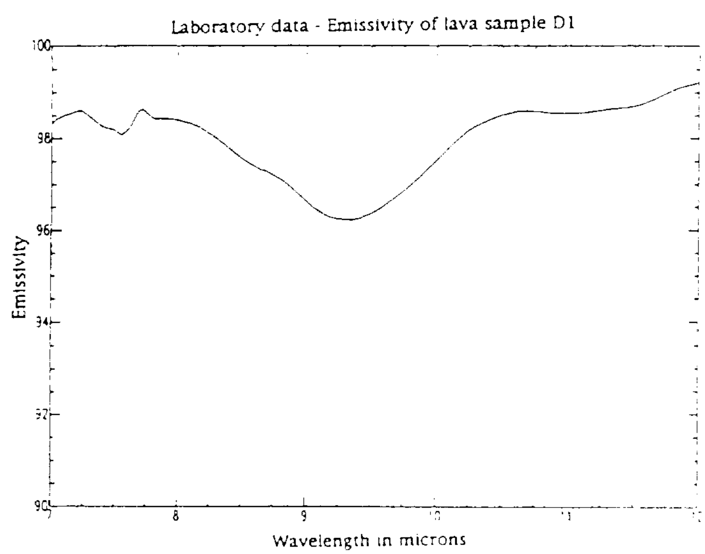

Figure 3.
Emissivity of a sample of a Lentia lava flow measured in the laboratory versus wavelength.