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**APPLICATION OF MAC-EUROPE AVIRIS DATA TO THE ANALYSIS OF  
VARIOUS ALTERATION STAGES IN THE LANDDMANNALAUGAR  
HYDROTHERMAL AREA (SOUTH ICELAND)**

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**1. INTRODUCTION**

In June 1991 extensive airborne remote sensing data-sets have been acquired over Iceland in the framework of the joint NASA/ESA Multisensor Airborne Campaign Europe (MAC-Europe).

The study area is located within the Torfajökull central volcanic complex in South Iceland. This complex is composed by anomalously abundant rhyolitic acid volcanics, which underwent intensive hydrothermal alteration. Detailed studies of surface alteration of rhyolitic rocks in the area showed that all the major elements are leached as the rock is affected by complex mineralogical changes. Montmorillonite appears during the earliest stages of alteration. In the ultimate alteration product montmorillonite is absent and the rock consists mostly of amorphous silica, anatase, up to a volume of 50% kaolinite and variable amounts of native sulphur and pyrite (ARNORSON et al., 1987).

The case study presented shall contribute to assess the potential of MAC-Europe AVIRIS and TMS data to determine a possible zonation of hydrothermal alteration in relationship to the active geo-thermal fields and structural features. To this end, the airborne data is analysed in comparison with laboratory spectral measurements of characteristic rock, soil and vegetation samples collected in the study area in summer 1992. Various spectral mapping algorithms as well as unmixing approaches are tested and evaluated. Detailed geological and structural mapping as well as geochemical analysis of the main rock and soil types were performed to underpin the analysis of the airborne data.

## **2. TEST SITE DESCRIPTION AND AVAILABLE DATA SETS**

The test site is part of the Torfajökull rhyolitic complex (S. Iceland) and covers an area of approximately 100 km<sup>2</sup> around the center coordinate 64°N 19°W. The geology is characterized by a caldera structure built up by tertiary to recent acidic volcanics (mainly rhyolites) in the interior. At the margins of the caldera pleistocene hyaloclastites and postglacial basic and intermediate lavas are predominant. Hot springs are the recent expression of the hydrothermal activity, which intensively altered the rhyolites.

The hilly to mountainous area is covered by sparse mossy vegetation. Dense algae and moss canopies are concentrated around the wells of hot water.

The following data sets have been included in the investigations:

- Remote Sensing Data: AVIRIS, TMS; Acquisition date 17 June 1991
- Atmospheric Measurements: In-flight P, T, HV, radiosonde profile Keflavik airport
- Ground Truth: Geological maps 1 : 20 000, 1 : 250 000; laboratory spectral measurements and geochemical analysis of field samples
- Structural Data: Structural maps derived from Landsat-TM and aerophotographs

## **3. ANALYSIS OF FIELD SAMPLES**

Field samples of all rock units and relevant vegetation types were collected in summer 1991 and 1992. Furthermore, a 500 m cross section through a thermal field was taken with sampling every 25 m.

Field and laboratory spectral measurements were performed with a GER S-FOV IRIS spectroradiometer.

Fluorescence X-ray analysis was used for element geochemistry.

X-ray diffractometry (XRD) was applied to the determination of various clay minerals, respectively phyllosilicates, in the alteration facies.

Spectroradiometer measurements clearly exhibit that spectral reflectance is an excellent parameter to distinguish altered rhyolite from unchanged volcanic rocks. In all spectral regions from 400 to 2500 nm alteration leads to an increase of reflectance and more prominent absorption features can be observed, due to recrystallisation and formation of oxides, sulphates and OH-bearing minerals. However, the differentiation of various clay fractions, potentially characterizing different stages of alteration, definitely requires spectral information from the 2000 to 2500 nm part of the spectrum. XRD analysis revealed abundances of typical alteration minerals like alunite, chlorite, kaolinite and nontronite in the samples from the thermal field transect. In fact, these

minerals show characteristic absorption features around 2200 nm, at 2270 nm and around 2300 nm. Consequently, the fourth AVIRIS spectrometer is of utmost importance for mineral mapping inside the alteration zone.

#### **4. ANALYSIS OF AVIRIS DATA**

According to the findings of field sample analysis the investigations concentrated on the SWIR II module (channels 172-224) of AVIRIS. Unfortunately, this spectrometer was damaged in early June and therefore strongly affected by throughput reduction (GREEN et. al., 1992).

##### **4.1. Data Quality**

Data quality assessment was based on visual inspection of all channels and a simple scene dependent approach to determine SNR. Assuming that for a homogeneous target sample

$$\text{SNR} = \text{Average Signal/Standard Deviation}$$

the following average SNR values were estimated:

VIS (Channels 1-32)	50 - 100
NIR (Channels 36-96)	50 - 100
SWIR I (Channels 102-160)	60 - 100
SWIR II (Channels 172-224)	<1 - 12

The data of the first three modules could be used without any constraints. In the SWIR II region only channels 185 to 215 (2060 nm - 2360 nm) were considered usable, although with limitations.

##### **4.2. Data Processing and Analysis**

Data processing and analysis were performed using LOWTRAN7, the SIPS software package (CSES/CIRES 1992) and the AGF SPEX spectral analysis tool, both developed under IDL.

For calibration to apparent reflectance, the LOWTRAN7 code as well as the empirical line method were used. Due to the lack of reliable in-flight field spectral measurements and the availability of consistent atmospheric/weather information of the flight day, better results were achieved applying the atmospheric model.

The usable SWIR II channels (185-215) were spatially and spectrally filtered. In a first step spikes were set to the average value of the surrounding pixels. Spatial noise was smoothed applying a low pass filter, in the spectral domain fft filtering was applied.

From this data set reference spectra for known sample points were extracted and interactively compared to the field sample spectra using SPEX. Two AVIRIS and four field sample spectra were selected as "endmembers" representing abundances of "altered material", "phyllosilicates" and "amorphous silica". The Spectral Angle Mapper provided with SIPS was used to determine pixels with high spectral similarity to these "endmembers". The quality of fit is currently being analysed by merging the SAM images with detailed geological/petrographical maps (1 : 25000) in a GIS.

## 5. CONCLUSIONS

- Even though affected by severe radiometric defects, the 1991 AVIRIS SWIR II channels seem to bear information about absorption features of alteration minerals.
- Mixture modelling including SWIR II channels will probably be hindered due to noise constraints.
- Full use of spectral information will be taken by merging it with other spatial data sets such as geological and structural maps in a GIS system.

## 6. REFERENCES

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