INTEGRATION OF AIRSAR AND AVIRIS DATA FOR TRAIL CANYON ALLUVIAL FAN, DEATH VALLEY, CALIFORNIA

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1. INTRODUCTION

Combining quantitative geophysical information extracted from the optical and microwave wavelengths provides complementary information about both the surface mineralogy and morphology. This study combines inversion results from two remote sensing instruments, a polarimetric synthetic aperture radar, AIRSAR, and an imaging spectrometer, AVIRIS, for Trail Canyon alluvial fan in Death Valley, California. The NASA/JPL Airborne Synthetic Aperture Radar (AIRSAR) is a quad-polarization, three frequency instrument (van Zyl et al., 1992). AIRSAR collects data at C-band=5.66 cm, L-band=23.98 cm, and P-band=68.13 cm. The data are processed to four-looks and have a spatial resolution of 10 m and a swath width of 12 km. The AIRSAR data used in this study were collected as part of the Geologic Remote Sensing Field Experiment (GRSFE) over Death Valley on 9/14/89 (Evans and Arvidson, 1990). The Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) is a NASA/JPL instrument that flies in an ER-2 aircraft at an altitude of 20 km (Vane et al., 1993). AVIRIS uses four spectrometers to collect data in 224 spectral channels from 0.4 μm to 2.45 μm. The width of each spectral band is approximately 10 nm. AVIRIS collects data with a swath width of 11 km and a pixel size of 20 m. The AVIRIS data used in this study were collected over Death Valley on 5/31/92.

2. GEOLOGY

Trail Canyon alluvial fan is located on the west side of Death Valley, California at the base of the Panamint Range. It is a large fan that is 7 km long and 450 m high. The northern part of the fan contains gravels derived from a carbonate dominant source material and the southern part of the fan has gravels derived from a quartzite source material. The quartzite and carbonate gravel mineralogies are not separated on the existing geologic map, which shows three gravel facies (Hunt and Mabey, 1966). The oldest gravel forms a smooth desert pavement of varnished rock fragments which covers approximately 30% of the fan. The younger gravel forms a rough surface of heavily varnished cobbles and covers about 50% of the fan. The youngest gravel is located in the more recent washes, does not have desert varnish, and covers about 20% of the fan. The base of the fan was covered by a lake during the Holocene and is mapped as a carbonate impregnated sand facies.

This study identified seven different surfaces on Trail Canyon alluvial fan based on the AIRSAR and AVIRIS data sets and the geologic map. These surfaces could not all be separated and identified by using only one data source. The surfaces include four facies on the quartzite source part of the fan: desert pavement (q-dp); a middle aged surface (q-m); a younger surface (q-y); and the current washes (q-c). A desert pavement (c-dp) and younger surface (c-y) were identified on the carbonate source part of the fan. The base of the fan (b) where the recent lake reached was also studied.

3. AIRSAR ANALYSIS

The AIRSAR data were calibrated using in-scene trihedral corner reflectors to allow for the extraction of accurate values of backscatter, polarization information, rms surface roughness, dielectric constants, and fractal dimensions. The calibration included an altitude correction, because the aircraft was flying over the mountains and imaging the valley, and a topographic correction using a digital elevation model (Kierein-Young, 1993; van Zyl et al., 1992).

Images of HH, VV, HV, and total power were synthesized for each of the three bands and placed into a "cube" of radar data. Mean frequency-polarization spectra were extracted from this AIRSAR data cube for the seven sites described above. The spectra fall into two main groups. The rougher surfaces include the quartzite middle (q-m), younger (q-y), current washes (q-c), and carbonate younger (c-y) sites. The smoother surfaces include the desert pavements (q-dp and c-dp) and the base of the fan (b).

The first-order small perturbation model (Evans et al., 1992; van Zyl et al., 1991; Barrick and Peake, 1967) was used to estimate the surface power spectral density and the dielectric constant at every pixel by performing an inversion of the AIRSAR data. The fractal dimension and rms surface roughness were calculated using the slope and intercept of the power spectrum obtained from the inversion model (Kierein-Young, 1993; Kierein-Young and Kruse, 1992). Table 1 shows the rms surface roughness, fractal dimension, and dielectric constants obtained from the small perturbation inversion model for the seven sites. These data show that the carbonate derived gravel is smoother than the quartzite derived gravel overall, the carbonate desert pavement (c-dp) is rougher than the quartzite desert pavement (q-dp), and the base of the fan (b) is the smoothest surface. The fractal dimension generally increases as the surface roughness decreases, and the dielectric constant is highest for the desert pavement surfaces.

Table 1. Small perturbation model inversion results for Trail Canyon fan.

Site	rms (cm)	Fractal dimension	Dielectric Constants C	L	P
q-c	15.2	2.13	3.9	3.6	3.0
q-y	14.0	2.14	4.6	3.7	3.0
q-m	15.2	2.105	4.0	3.4	3.0
q-dp	4.4	2.25	6.1	4.3	3.0
c-y	13.5	2.14	4.4	4.6	3.0
c-dp	6.3	2.20	5.1	5.1	3.0
b	2.8	2.405	4.1	3.0	3.0

4. AVIRIS ANALYSIS

The AVIRIS data were converted from radiance to reflectance using an atmospheric correction program, ATREM, to allow for accurate mineralogical determinations (Gao et al., 1992; Gao et al., 1993). The AVIRIS data allow discrimination of the quartzite and carbonate derived parts of the fan based on spectral characteristics. Mean reflectance spectra were extracted from the AVIRIS data and used to identify the surface mineralogy for the seven sites described above. Two dominant mineralogies are seen in the spectra, illite clay and a mixture of dolomite and illite. In addition, the areas that have desert varnish on the surface appear very dark in the images and have a lower reflectance in the shorter wavelengths than those surfaces without desert varnish. Only four general groups of surfaces are distinguishable in the spectra, the current wash, the carbonate part of the fan, the quartzite parts with heavy desert varnish, and the quartzite fan without heavy varnish. The AVIRIS images do not allow for the discrimination of the smooth desert pavement surfaces from the other varnished rough surfaces. This is because the fan albedo is related to the amount of desert varnish on the gravels and not to the roughness of the surfaces. There is no desert varnish on the base of the fan, therefore it is brighter than the surfaces above the upper reaches of the ancient lake.

Automated spectral unmixing was performed on the AVIRIS data for Trail Canyon fan using five endmembers. Every pixel in an image contains a mixture of materials due to its spatial size. Spectral unmixing determines the percentage abundance of each material, or endmember, within a pixel (Boardman and Goetz, 1991). An automated technique was used to determine the mixing endmembers on Trail Canyon fan from only the input data and a geometric model (Boardman, 1993; Boardman, 1994). This method involved first performing a maximum noise fraction (MNF) transform, determining the number of unique endmembers, and using a convex geometric approach to find the endmembers. The first five derived endmembers, corresponding to bright illite, darker illite, illite with desert varnish, dolomite, and shadow were used to generate spatial endmember abundance images. Table 2 shows the results of the automatic unmixing using the AVIRIS data.

Table 2. Unmixing results from the MNF automatic unmixing.

Site	% bright illite	% darker illite	% illite w/ dv	% dolomite	% shadow
q-dp	8.5	13.2	43.4	12.1	21.1
q-m	7.4	21.7	37.6	9.3	24.1
q-y	17.1	33.2	17.5	10.5	18.0
q-c	36.2	19.2	6.7	8.4	11.7
c-dp	8.2	17.3	29.0	34.2	11.3
c-y	7.4	22.5	14.5	32.2	23.4
b	24.6	23.4	10.7	5.8	35.5

5. DATA INTEGRATION

Integration of the data sets was done by performing classification techniques on combined bands of AVIRIS and AIRSAR data. An accurate map of the seven surfaces on Trail Canyon fan was obtained by using a minimum distance classification technique on the co-registered AVIRIS automatic unmixing endmember images and the AIRSAR frequency-polarization cube. This combination of data gives the most accurate results because the unmixing endmembers show the best separation of the mineralogies, and the AIRSAR cube discriminates well between the smooth and rough surfaces. Figure 1 (AVIRIS Workshop Slide 6) shows the map generated from this classification. Classifications based on only one data set did not produce as accurate a map as the combined data.

6. CONCLUSIONS

The results of the data integration show that the morphology of Trail Canyon fan is dependent on the age and mineralogical makeup of the surfaces. The AIRSAR data show the variation in surface roughness, and, in general, the smoother surfaces are older. The roughest area is the current wash which is the youngest part of the fan. The two middle aged surfaces of the fan have about the same surface roughness and cannot be separated in the AIRSAR data alone. The smoothest surfaces on the fan are the desert pavement areas which are the oldest deposits on the fan. The addition of AVIRIS data to the AIRSAR data allows for the separation of the two middle aged surfaces by the amount of desert varnish. The older surface has much more desert varnish than the younger washes. However, the desert pavement and varnished rough surfaces cannot be separated by using the AVIRIS data alone. Therefore, it is necessary to use both the AIRSAR and

AVIRIS data to correctly map and determine the relative ages of the surfaces of Trail Canyon fan.

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