

PROCEEDINGS OF THE 19TH EARSeL SYMPOSIUM ON REMOTE SENSING IN THE 21ST
CENTURY/VALLADOLID/SPAIN/31 MAY – 2 JUNE 1999

Remote Sensing in the 21st Century

Economic and Environmental Applications

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Discrimination of active alluvial sedimentary surfaces in TM images based on laboratory reflectance spectroscopy

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ABSTRACT: The purpose of this work is to discriminate the areas that most probably will be affected by future alluvial sedimentation and erosion in a semiarid quaternary basin located in the southeast of Spain, based on spectral differences shown by Thematic Mapper images. X-ray diffraction analysis shows very similar mineralogical contents, due to the uniformity of the source areas. Carbonate develops during consolidation processes after sedimentation, being the only relevant mineralogical difference. Carbonate contents are responsible for the spectral differences detected both in the laboratory and imagery. Recent areas of sedimentation show flatter spectra and an overall lower reflectance confirmed by the imagery. Different ages of alluvial fans and degrees of sediment consolidation can be mapped using images. Different rock consolidation and geomorphological features help to define the areas most likely suffering future erosion and sedimentation processes in a natural hazard prone area.

1 INTRODUCTION

The study of the actual pattern and characteristics of landforms informs about the natural processes which are active in the present and have been active in the recent past. Observation of the Earth's surface from space is essential to map the terrain in terms of natural hazards. Detailed surveys of the terrain using satellite images, aerial photographs and field-work help the recognition, inventory and outline of mapping units showing differences in terms of terrain characteristics and active geomorphological and geological processes. This approach using visual interpretation of satellite images has been applied in the same study area (García-Meléndez & Ríaza 1997; García-Meléndez et al. 1998).

The purpose of this work is to explain the differences observable by visual interpretation in terms of the spectral response of the Earth's surface, related to variations in mineralogical composition. Laboratory reflectance spectroscopy analysis has been applied and the spectral response is explained in terms of the mineralogical composition analyzed by X ray diffraction, with reference to absorption features gathered by spectral libraries.

1.1 Geologic and Geographic setting.

The study area is located in the northeastern part of the Huércal-Overa basin, which is filled by a variety of Neogene continental and marine sedimentary en-

vironments overlaid by Quaternary alluvial sedimentary facies. This basin is located in the Eastern Betic Cordilleras (Southeast Spain) and is affected by faulting along two regional seismic lineations oriented E-W and NE-SW, conditioning the geomorphological pattern. The basin studied is located at the foot of the southern part of the Sierra de Las Estancias. This zone is suffering active denudation in a dry, semiarid climate in an area with active tectonics. The eroded material from the ridges, sediments on alluvial fans in the low areas, with irrigated crops and human settlements. The Almanzora river hydrographic basin hosting the study area is featured by dry water courses only active after infrequent heavy rainstorms causing considerable damage. Non consolidated lithologies and a sparse vegetation cover favour erosion processes.

2 METHOD

Laboratory reflectance spectroscopy involves the measurement and interpretation of the variation with wavelength of the ratio of reflected/incident electromagnetic radiation. This method is based on the physical principles involved in the interaction of electromagnetic radiation and matter.

The morphosedimentary levels under study present a mixture of rock fragments and minerals such as quartzite, shale, micaschists, quartz, among others whose composition is closely associated with the

source area. Chemical weathering after sedimentation produces different response depending on the mineralogical composition, climate and local soil drainage. The geomorphology and mineralogy of the surfaces is controlled by the alluvial sedimentation parameters, the source area composition and mineralogical changes related to postsedimentary processes. Representative samples from a total number of 105 were selected for mineralogical analysis.

After sample preparation, X ray diffraction was performed with a Siemens D-500 diffractometer in order to obtain the mineralogical composition through the comparison of results with the ASTM tables. A semiquantification analysis was performed estimating the area of the peaks of the main minerals depicted in the diffractograms.

Spectral measurements were made with a Perkin-Elmer Lambda-9 spectrophotometer provided with an integrating sphere registering reflectance with reference to a standard of Barium sulphate (SO_4Ba); measurements were taken within 1 μm interval in the visible and near infrared range of the electromagnetic spectrum (0.4 – 2.5 μm). Electronic charge transfer, crystal field effects and vibrational effects are the primary physical processes that control scattering, absorption and/or re-emission of electromagnetic radiation on these wavelengths for sedimentary rock-forming minerals (Lang et al. 1990). Electronic processes involving transition metal ions such as Fe^{+3} and Fe^{+2} and vibrational processes such as those involving H_2O , OH , CO_3^{-2} , among others, give specific features in reflectance spectra (Hunt 1980), referred as absorption features.

The laboratory spectral analysis helped to identify series of fans mappable through image processing in terms of their different mineralogical contents.

3 RESULTS

All spectral measurements show similar shapes, nevertheless minor but significant variations occur. They can be grouped in two classes: I) spectra with a relative low overall reflectance with weak absorption features, and II) spectra with higher overall reflectance and sharper absorption features.

The mineralogical composition determined by X ray diffraction for the selected representative samples (Table 1) is very similar. Quartz and phyllosilicates (illite and chlorite) with small amounts of feldspars are the main minerals present, being the carbonate content the principal difference.

According to spectral libraries (Grove et al. 1992, Clark et al. 1993), pure quartz is almost devoid of spectral features, milky white or gray quartz show absorption features at 1.4, 1.9 and 2.6 μm due to fluid inclusions (Hunt et al. 1970). Pure feldspars are also spectrally featureless, being the only present

Table 1. Mineral Composition through X-diffraction analysis (%).

Sample	Quartz	Feldspar	Phyllosilicates	Carbonates
S40	70	5	25	-
S54	62	3	20	15
S60	72	4	21	2
S61	52	10	18	20
S62	58	6	26	7
S63	51	6	21	26
S64	65	3	19	13
S65	62	5	33	-

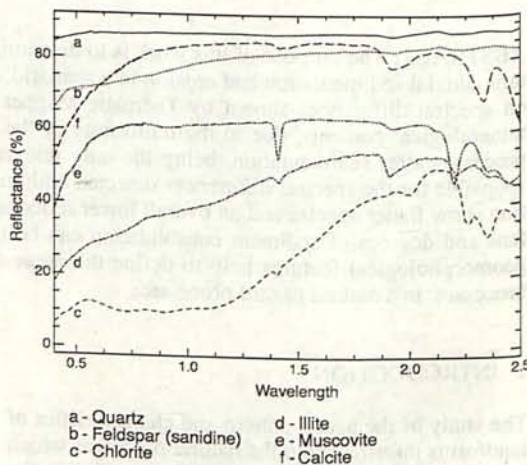


Figure 1. Representative spectra for minerals listed on Table 1. Wavelength in μm . Spectra a, c, e and f, from Clark et al. 1993. Spectra b and d from Grove et al. 1992.

spectral features due to small amounts of impurities such as iron and water because of the incipient alteration (Hunt et al. 1973). From X ray diffraction, the main phyllosilicates found are chlorite and illite. Chlorite presents spectral features due to the ferric ion at 0.7 and 0.9 μm , and also hydroxyl absorption features near 2.2, 2.35 and 2.45 μm . The presence of molecular water trapped in the lattice is indicated at 1.9 μm . Illite presents absorption features at 1.4 μm due to OH , at 1.9 μm due to molecular water and at 2.2, 2.35 and 2.45 μm due to the OH stretch and to the Al-O-H bending mode at 2.2 μm (Hunt & Salisbury 1970; Hunt et al. 1973; Clark et al. 1990). The observed absorptions in carbonates are due to the CO_3^{-2} ion, being the strongest at 2.5-2.55 and at 2.3-2.35 μm (Clark et al. 1990). (Figure 1).

The morphosedimentary units show two distinctive spectral responses according to subtle differences on their mineralogical contents:

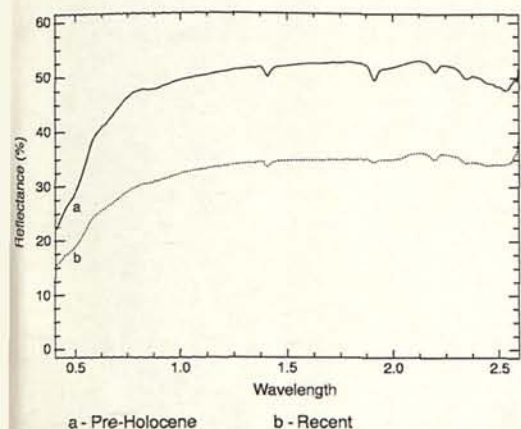


Figure 2. Spectral measurements for a) Recent alluvial sedimentary units; b) old alluvial sedimentary units. Wavelength in μm .

3.1 Recent alluvial fan spectra (Holocene)

Spectral measurements from Holocene alluvial fans show an almost flat shape in the wavelength range 1–2.5 μm (Figure 2a). The absorption feature at 1.4 μm is due to the OH^- group present in the minerals, and the almost absent absorption feature at 1.9 μm represents a small amount of molecular water in the mineral structure. The absorption feature at 2.2 μm in the recent alluvial fan spectrum is related to the presence of phyllosilicates with a dioctahedral structure, which together with the feature at 2.33 μm represents a combination of processes associated to the OH^- stretch and with the angle between the cation (Al^{3+} , Mg^{2+} , among others) and the OH^- group. All samples display the 2.2 μm absorption feature, therefore can not be used as a discriminating element through image processing.

3.2 Old alluvial sedimentary spectra (pre-Holocene alluvial fans)

The main spectral differences on the older alluvial fans (Figure 2b) compared to the previous sedimentary units (Figure 2a) are displayed on the wavelength range between 1 μm and 2.5 μm . The absorption feature at 1.9 μm is better defined, and there is a new absorption feature located at 2.54 μm which together with the one at 2.3 μm account for the presence of carbonate. The 2.3 μm absorption feature is related in this case, both to the CO_3 ion and the OH^- stretch in phyllosilicates.

The overall reflectance is higher for the old alluvial sedimentary surfaces through all the wavelength range. This is evident in the Thematic Mapper bands, showing lighter gray tones. The X-ray diffraction mineralogical analysis demonstrate that car-

bonate is responsible for the higher overall reflectance (Table 1, Figure 2).

All spectra show between 0.4 μm and 1 μm a strong decrease of reflectance that may be caused by strong iron absorption features at short wavelengths outside the considered spectral range (Van der Meer 1995).

4 CONCLUSIONS

Landforms created in the study area by alluvial fan sedimentation with similar lithological source areas show mineralogical differences related to their relative ages and consolidation processes. These differences are observed in the TM satellite images in terms of different spectral response which can be mineralogically explained by means of laboratory reflectance spectroscopy and X-ray diffraction analysis, demonstrating the usefulness of such techniques to map natural hazards prone areas. The presence of small carbonate content increases remarkably the overall reflectance of the areas. The precipitation of carbonates is a consolidating post-sedimentary process. Therefore, the areas lacking carbonates indicate a younger sedimentation and a higher possibility of future sedimentary accumulation. Mapping areas where preferred erosion and sedimentation are likely to occur could help the outline of terrain units qualifying future damage.

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