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Departamento de Geología – Universidad de Chile – Santiago

APLICACION DE SENSORES REMOTOS A LA INVESTIGACION DEL VOLCANISMO EN LOS ANDES CENTRALES: PASADO Y FUTURO

APPLICATIONS OF REMOTE SENSING TECHNIQUES TO THE INVESTIGATION OF VOLCANISM IN THE CENTRAL ANDES: PAST AND FUTURE

P.W. FRANCIS

Lunar and Planetary Institute, 3303 NASA Road 1, Houston, Texas, 77058, USA.

The vast extent, altitude, clear atmosphere and arid climate of the Central Andean volcanic province make it ideal for the application of modern satellite remote sensing techniques to volcanological and petrological problems. The first synoptic map of volcanic features in the Central Andes was made using the simplest techniques: 70 mm color photographs obtained by astronauts on the Skylab 4 mission in 1974 (Freidman and Hieken, 1977). Spacecraft of the Landsat series began to obtain systematic multispectral data in four spectral bands in 1972, and complete coverage for the region exists with a ground resolution of approximately 80 m.

Existing technology

Primarily designed for agricultural surveys, the first generation of Landsat spacecraft (1-3) were not ideal for discrimination or identification of lithological units, but the synoptic coverage provided the basis for several lines of research, using single band black and white products:

(i) Feature recognition. Knowledge of the morphology and structure of volcanic features in other regions enables similar features to be identified in unknown areas. Examples include the identification of major resurgent calderas in Argentina and Bolivia (Francis and Baker, 1978, Baker 1981). Associated with calderas are large ignimbrite sheets which may extend up to 150 km from their source and outcrop in 3 countries. Landsat MSS imagery enabled mapping of these flows for the first time. The May 1980 eruption of Mt. St. Helens focussed attention on the importance of large scale collapse of volcanic edifices, associated with the emplacement of large debris avalanche deposits and lateral blast. Since 1980 about 10 large volcanic debris avalanche deposits have been identified in the Central Andes from remote sensed data alone (Deruelle, 1978; Francis et al. 1985; Francis and Ramirez, in press; Francis et al., in press;).

(ii) Regional volcanological and stratigraphic surveys. Given limited surface geochronological control, geomorphological characteristics of volcanic structures can be used to investigate age variations, volcano spacing and relation to structure and crustal thickness; to estimate relative volumes of different volcanic products, and overall rates of eruption. (Baker, 1977;, Baker and Francis; 1978). Kussmaul et al. (1977) used Landsat MSS imagery as the basis of the first study of the volcanism and structure of the SW Bolivia province. MSS imagery has also been used extensively in the preparation of the geological map of Chile e. g. Ramirez and Gardeweg, (1982).

(iii) Structural control of volcanic activity and related phenomena. Even at relatively low resolution the relationships between volcanic and tectonic features is clear. Examples include relationships between faulting and location of basaltic andesite scoriacones, and structural control of mineralisation in large calderas (Francis et al. 1981).

Although not optimal for geological applications, the multispectral capability of the Landsat MSS (0.5-0.6; 0.6-0.7; 0.7-0.8 and 0.8-1.1 micron bands) has useful applications when combined with digital image processing techniques. Field observations show that volcanic units of different compositions vary more in albedo (brightness) than color, (Rothery and Francis, 1984), but some units are spectrally distinct, e. g. lavas with Fe-oxidisation crusts and fumarolically altered materials. Classification techniques can be used to create thematic maps of volcanic rock units in favorable conditions. 70 mm Hasselblad photography from the Space Shuttle has the potential to provide 20 m ground resolution with stereoscopic overlap. Whereas automated spacecraft sensors routinely provide nadir-looking views with consistent lighting, the flexible nature of the Shuttle photography enables coverage with variable viewing and lighting geometries, important in structural and textural interpretation.

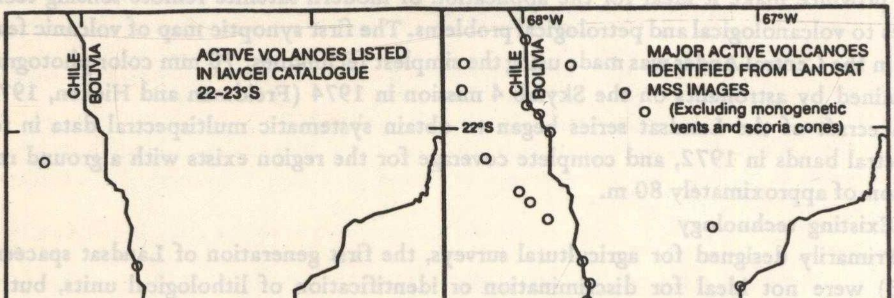

Fig.1. Comparison of numbers of active volcanoes identified in Catalogue of Active Volcanoes with those identified from Landsat MSS imagery.

Fig.1. Comparación de número de volcanes activos identificados en el Catálogo de Volcanes Activos con aquéllos identificados en imágenes Landsat MSS.

Short term future technologies and plans

Remote sensing studies of the Central Andean volcanic province are in process of rapid development with the advent of the new generation of Landsat spacecraft (4 and 5) equipped with Thematic Mapper (TM) sensors. These offer 30 m ground resolution; 6 spectral bands in the visible and near IR (0.45-052; 0.52-0.6; 0.63-0.69; 0.76-0.90; 1.55-1.75; and 2.08-2.35 microns) and 1 thermal IR band (10.4-12.5 micron) with 120 m resolution. The existing Catalogue of Active Volcanoes of the World (IAVCEI, 1966) lists only 17 active volcanoes in Peru and north Chile; none at all in Bolivia and Argentina. Preliminary studies suggest that of the order of 150 volcanoes should be regarded as active on geological grounds. A major part of remote sensing research over the next three years will be to use Thematic Mapper data to prepare and publish a new catalogue of Central Andean volcanoes, and a data base of volcanological parameters (volcano type, summit height, edifice height, crater/caldera diameter, basal diameter, spacing etc.).

When night thermal IR data become available they will enable identification of volcanoes with active fumaroles and of hot springs feeding lakes. Complementary day and night time thermal IR views will also be used on a pilot basis to determine if lava compositions can be discriminated from their contrasted thermal inertias. Kahle et al. (1976) demonstrated the viability of this technique for the Pisgah volcanic field using HCMM data, but the Landsat TM overflight times are less favorable.

Longer term future technologies

Many other remote sensing systems will become operational over the next decade. Simplest in concept is the Shuttle Large Format Camera, which can provide 43x20 cm panchromatic or color IR film negatives with up to 80°/o stereo overlap, at 7 m resolution. These images offer enormous potential for geological and volcanological photointerpretation and mapping. More sophisticated systems include the French SPOT system, offering 20 m resolution plus TM style multispectral capability; Landsat 6 with TM resolution improved to better than 20 m; the Shuttle Modular Optoelectronic Multispectral scanner, and Shuttle Imaging radars (SIR-C etc.). The latter use active rather than passive techniques and offer the possibility of investigating new parameters such as surface roughness, radar reflectivity and dielectric properties.

Future Shuttle missions will also carry variants of existing (airborne) TIMS (Thermal Infrared Mapping Scanner), which has 6 narrow spectral bands in the 6-12 micron range. This offers for the first time the possibility of mapping mineral distributions directly, and by implication, lithologies. These techniques have the potential to transform techniques for mapping volcanic rocks in arid areas such as the Central Andes.

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