Investigation of Pastos Grandes (Bolivia) Volcanic Features with RADARSAT

Jose Luis Lizeca [1,2], Wooil M. Moon [2,4], Christine Hutton [3], Liyuan Wu [3], and C.W. Lee[4]
1. SERGEOMIN, La Paz, Bolivia ("Jose Luis Lizeca" abtema@coord.rds.org.bo (Eamil))
2. Geophysics, The University of Manitoba, Winnipeg, Canada R3T 2N2
(((204)-474-9833(O); (204)-474-7623 (FAX); wmoon@cc.umanitoba.ca (Email))
3. Application Division, Canada Center for Remote Sensing, Ottawa, Canada K1A 0Y7
("Christine Hutton" christine.hutton@ccrs.nrcan.gc.ca ; liyuan.wu@ccrs.nrcan.gc.ca (Email))
4. Earth System Science, Seoul National University, Seoul 151-742 Korea
((02)-880-8898 (O); (02)-871-3269 (FAX); wmoon@eos1.snu.ac.kr ; bosscq@eos1.snu.ac.kr (Email))

ABSTRACT

The volcanic terrain in and around Villa Alota and Cerro Caquella is unique in several aspects: very dry desert like surface features with almost no vegetation, well preserved volcanic flows and tuff deposits, and extensive evaporite lakes between volcanoes. In many aspects, it is an ideal place for investigating backscattering effects of various types of volcanic flows and eruptives. Several scenes of RADARSAT standard mode image data were acquired over the study area as a part of GlobeSAR 2 program. As the first step of detailed investigation, field wrok was carried out and also digital elevation model (DEM) was generated using RADARSAT data. Preliminary investigation indicate that the DEM generated using RADARSAT was very useful for collapsed caldera and associated small active volcanoes. Detailed calculation of σ^0 and scattering model study is in progress.

INTRODUCTION

The study area chosen for this collaborative investigation is located near the Bolivia and Chile border, along the western flank of the Andean Mountain chain. It is one of the driest places on Earth and situated between Sala de Uyuni (Bolivia) and Sala de Atacama (Chile) and the average altitude of the study area is over 5000 m above seal level.

Geologically the study area is located in the central part of the Western Cordillera, and belongs to the Central Colvanic zone of the Andes. There are also outcrops of Paleozoic and Paleogene sedimentary rocks mostly overlain by Middle Miocene to Pleistocene volcanic deposits. Earlier studies indicate that volcanism in the study area is related with NW-SE oriented transpressive megastructures, like that of Pastos Grandes [2]. The eruptions deposited extensive ignimbrites on which stratovolcanoes and domes of andesitic, dacitic and rhyolitic compositions are built [3].

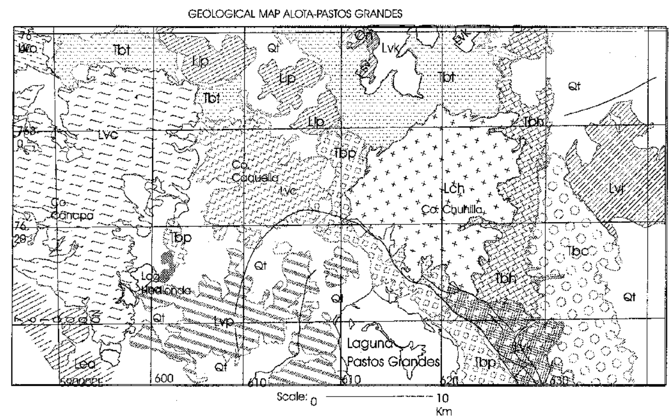

Figure 1. Geology map of the Villa Alota - Pastos Grandes study area. (The lower central portion of the map area is the Laugna Pastos Grandes).

Most lakes in the study area are evaporated and covered with white or light colored powdery evaporites [4]. To study minerlalogical and chemical composition of these evaporites, a number of wet and dry samples are taken for laboratory analyses such as chemical and x-ray analysis.

Tectonically, continental terrigeneous deposition was resulted from tectonic shortening during the late Oligocene [2]. During the transpressive tectonic events of the Andean Cycle, NE-SW megafractures, such as the Pastos Grandes - Cojina Faults allowed for the development of the nested calderas of Capina, Pastos Grandes, and magmatic episodes such as the efussive eruption of lavas from fissures. It is believed that the eastern flanks of the Pastos Grandes Caldera, which is related with the Pastos Grandes Fault, was repeatedly reactivated during its evolution, resulting in small normal faults.

Auxiliary data sets, in addition to the RADARSAT data, include partial coverage of geology, regional coverage of aeromagnetic data, and geochemical samples taken during the recent field work.

DATA PROCESSING

Geological maps and geochemical data are digitized using flat bed digitizer and AUTOCAD software. Most preprocessing of theses data sets were carried using ERMapper and PCI's EASI/PACE software.

RADARSAT (standard mode 3 and 6) data were filtered for speckle noise and geocoded. The rugged topographic terrain in the study area required careful topographic corrections. However, there was no detail digital elevation model (DEM) available and it was decided to generate DEM using available RADARSAT data over the study area. There are generally two approaches of generating DEM suing RADARSAT data. One approach is first computing interferogram from the RADARSAT SLC data and then apply phase unwrapping algorithm to generate DEM. The second and more popular approach is the digital photogrammetric approach of using two or more of stereo image pairs.

Mathematical model which underlies and forms the basis for the analytical photogrammetric DEM solutions is implemented in the PCI's EASI/PACE software. The detailed description of the methodology can be found in Toutin, (1985) [5].

RADARSAT Data	Residue in m		
	X (longitude)	Y (latitude)	RMS
Standard _3	27.17	22.16	35.06
Standard_6	27.54	20.42	34.28
Note 1 - *Earth Ellipsoid used : E004*			
Note 2 - *GCPs used range from 15 to 30*			

Table 1. RADARSAT DEM model calculation.

The procedure employed for image matching in EASI/PACE is to proceed to the image matching stage using the rectified and re-sampled data [1]. The minimum number of ground control points (GCPs) needed to effect a photogrammetric solution for each image is four (Toutin and Carboneau, 1989) [6]. In this study, we selected 15 readily recognizable ground points as GCPs and carried out DEM generation. Some of the statistical parameters are listed in Table 1.

Geochemical and x-ray mineralogical data are basically point data and they were first plotted and interpolated to generate gridded data. The most common minerals in the evaporite samples are gypsum and halite with smaller amounts of thenardite (Na sulfate), eugsterite (hydrous Na+Ca sulfate). However, interpretation and correlation of these geochemical data will be made later when other spatial data processing and interpretation are completed.

STRUCTURAL INTERPRETATION

As the first step of interpretation, a visual geological structural interpretation is attempted. The welded tuff formations from Villa Alota to the Cerro Caquella region is well represented on the RADARSAT data with the consistent backscattering signature, which is caused extremely rugged surface topography. The radial lineaments which form right angles with the Pastos Grandes Fault system is clearly visible on the RADARSAT image. The nested caldera structure is also characteristic of the area and well imaged on the RADARSAT data.

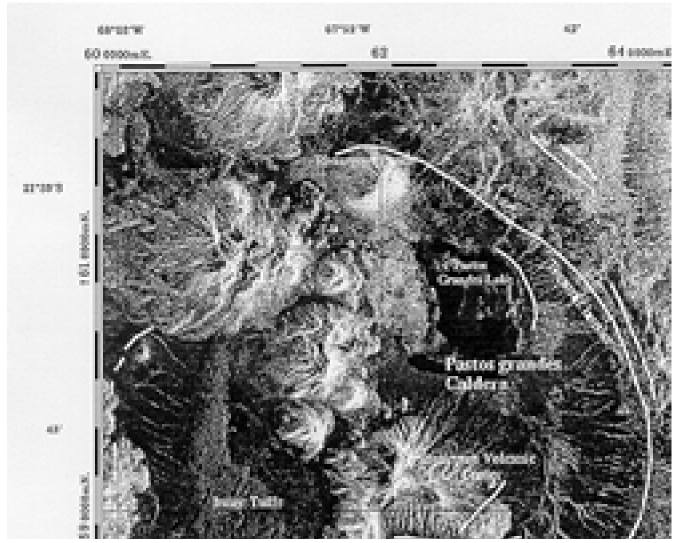

Figure 2. Structural interpretation of the Laguan Pastos Grandes Caldera area.

The dark (relatively low sigma nought) regions inside the Pastos Grandes Fault system appear to represent high heat flow areas, which may in turn represent areas of active subsurface hydrothermal circulation. The numerous small lava domes also indicate considerable thermal activities in the area. This anomalous feature may require further field investigation.

PRELIMINARY CONCLUSIONS

Although this study is still in progress, the following preliminary conclusions may be drawn:

1. RADARSAT is an excellent tool for investigating arid remote volcanic areas where vegetation covers is minimum.
2. The DEM obtained from RADARSAT image pairs is accurate enough for preliminary interpretation of the geological surface features and subsequent structural interpretation. (Fig. 4)
3. For more quantitative application of RADARSAT data for volcanic hazard study, we need further backscattering models appropriate for specific geological features.

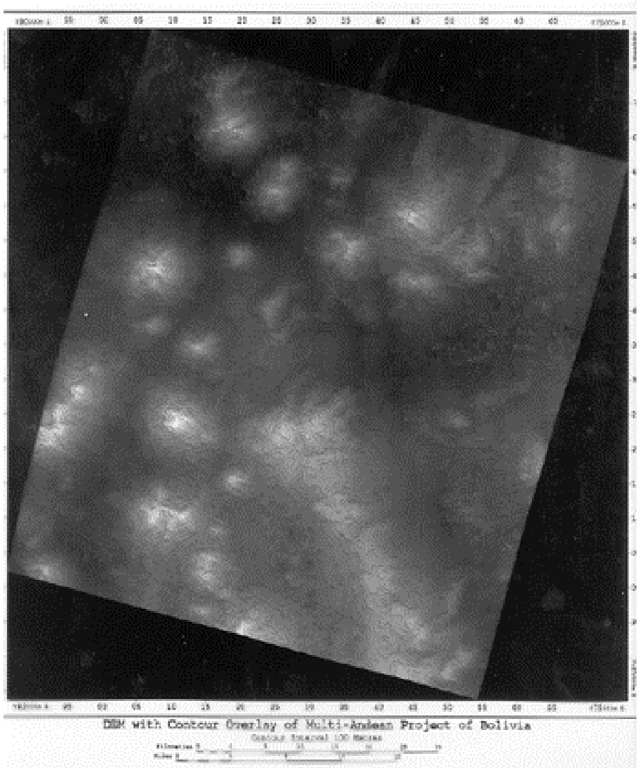

Figure 4. DEM generated from the RADARSAT standard mode (3 & 6) image pairs. (See Table 1 above).

ACKNOWLEDGEMENTS

This is a part of the GlobeSAR 2 programme and the authors gratefully acknowledge the opportunity to work on this collaborative project. This research is funded by the NSERC of Canada Operating Grant #7100 to Wooil M. Moon. Professor Bill Last kindly carried out the X-ray and chemical analyses of the geochemical samples.

REFERENCES

[1] N. Al-Rousan, P. Cheng, G. Petrie, Th. Toutin, and M.J. Valadan Zoej, 1997. Automated DEM Extraction and Orthoimage Generation from SPOT Level 1B Imagery. Photogrammetric Engineering and Remote Sensing, Vol. 63, No. 8, pp. 965-974.

[2] M.C.W. Baker, and P.W. Francis, 1978. Upper Cenozoic Volcanism in the Central Andes-Ages and Volumes. Earth and Planetary Sciences Letters.

[3] E.A. Du Bray, S. Ludington, and et. al., 1995. Compositional Characteristics of Middle to Upper Tertiary Volcanic Rocks of the Bolivian Altiplano. U.S. Geological Survey Bulletin 2119., P. 6.

[4] F. Risacher, and O. Ballivian, 1981. Les Bassins A Evaporites de L'Altiplano Bolivien (Les Salars). Publicacion UMSA-ORSTOM, La Paz-Bolivia

[5] Th. Toutin, 1985. Analyse Mathematique des Possibilites Cartographiques du Systeme SPOT. Doctoral Thesis, Ecole National des Sciences Geographiques, Paris. P.

[6] Th. Toutin, and Y. Carbonneau, 1992, Generating Ortho-Images Using DEM: Description of a New system, Canadian Journal of Remote Sensing, 18(3), 136-142.