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Magnetic Anomaly Modeling of Volcanic Structure and Stratigraphy - Socorro Island, Eastern Pacific Ocean

Jaime Urrutia-Fucugauchi, Marisol Escorza-Reyes, Julio Pavon-Moreno, Ligia Perez-Cruz, and Osvaldo Sanchez-Zamora

Universidad Nacional Autonoma de Mexico, Instituto de Geofisica, Mexico, Mexico (juf@geofisica.unam.mx)

Results of a magnetic survey of the volcanic structure of Socorro Island in the Revillagigedo Archipielago are presented. Socorro is part of a group of seamounts and oceanic islands built by volcanic activity at the northern end of the Mathematician ridge and intersection with the Clarion and Rivera fracture zones. Subaerial volcanic activity is characterized by alkaline and peralkaline compositions, marked by pre-, syn- and post-caldera phases of the Evermann volcano, and the Holocene mafic activity of the Lomas Coloradas. The magnetic survey conducted in the central-southern sector of the island permits to investigate the volcanic structure and subsurface stratigraphy. Regional fields for second- and third-degree polynomials show a magnetic low over the caldera, positive anomalies above the pre-caldera deposits and intermediate amplitude anomalies over Lomas Coloradas. Residual fields delineate the structural rim of the caldera, anomaly trends for the pre- and post-caldera deposits and a broad anomaly over Lomas Coloradas. Regional-residual anomalies, first vertical derivative, analytical upward and downward continuations, and forward four-layer modeling are used to construct the geophysical models.

Rock magnetic properties were analyzed on samples collected at 24 different sites. Magnetic susceptibility showed wide range of variation from $\sim$10 to $\sim$500 10-3 SI, corresponding to the different lithologies from trachytes and glass-rich tuffs to alkali basalts. Data have been divided into groups with low, intermediate and high values. Rock magnetic analyses indicate that magnetite and titanomagnetites are the main magnetization carriers. Magnetic hysteresis loops indicate low coercivity minerals, with high saturation and remanent magnetizations and PSD domain states. Magnetic susceptibility versus temperature curves show irreversible behavior with Curie temperatures around 560-575 C, suggesting magnetite and Ti-poor titanomagnetites. Paleomagnetic directions determined on samples from one site in the pre-caldera flows and three sites in the post-caldera and Lomas Coloradas units, indicate normal polarity directions with mean declination of 350 and inclination of 37, close to the dipolar direction. Additional data on remanent magnetizations reported in Sbarbori et al. (2009) support dominant normal polarities for pre- and post-caldera units, with mean directions close to the dipolar and the present-day field directions. Implications for the magnetization contrasts used in modeling are to increase the intensities assigned for model units. The effective magnetizations assumed for the model units have dipolar inclinations and northward declinations.

The magnetic anomaly shows a broad minimum over the caldera zone, a maximum over the caldera rim and a second maximum closely spaced, followed by a larger wavelength anomaly over the volcano slope and the pre-caldera deposits. The maximum is associated with the caldera rim and the minimum on the outer rim edge is associated with a fracture zone or a deep pre-caldera feature. Preferred models incorporate a topographic relief for the basaltic pre-caldera unit and post-caldera deposits. Top of the pre-caldera basaltic unit lies at depths of about 300 m and up to 600 and 800 m below sea level. The Lomas Coloradas Formation is modeled with thickness of about 200-350 m.

Models allow evaluation of stratigraphic distribution and thickness of pre-, syn and post-caldera units and the Lomas Coloradas Formation. Preferred models for the southern flank incorporate a pre-caldera basaltic unit with abrupt relief and syn- and post-caldera silicic deposits with Lomas Coloradas alkaline basalts covering the volcano flanks. Relief for pre-caldera basaltic unit may be associated with the volcanic conduit system for Lomas Coloradas. The structure shown at the southern end of the profile is present in the reduction to the pole, residual field and analytical continuation fields. Models for Evermann volcano show structural features associated caldera collapse, the caldera rim and the pre-caldera morphology. Possible occurrence of fracture zones on the buried caldera rim, marked by lower susceptibilities related to alteration and down-faulted sequence are shown in the modeling. Depth of caldera collapse region filled by the syn- and post-caldera units depends on magnetic contrasts. Incorporation of a weakly magnetized alluvium-fill layer results in shallower depths for collapse depression. The caldera structure and amount of collapse are important parameters to constrain erupted volumes and explosion dynamics. Complex caldera structures with large collapse depressions may form as a result of multiple episodes

forming nested structures, documented in silicic peralkaline centers. In Socorro, evidence for nested calderas has not been documented; Bohrson et al. (1996) suggested that caldera formation was associated with the eruption occurring between 370 and 182 kyr, and that other explosive episodes did not result in caldera formation. Caldera size has been estimated from extrapolation of exposed caldera wall and topography. Reconstructed caldera appears elongated in a NW-SE direction with a size of about 4.5 x 3.8 km, which is in the range for other peralkaline calderas. Constraints on the volcanic stratigraphy and thickness of volcanic units are important to estimate eruption rates and volumes and for understanding the long-lived volcanic activity and the tectonic evolution.