TERTIARY ANDEAN VOLCANISM IN A CALDERA-GRABEN SETTING

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Resumen

En Chile central aflora una secuencia volcánica miocena (Fm. Farellones), que se depositó en un ambiente volcano-tectónico del tipo caldera-graben. Esto se infiere de sus límites laterales coincidentes con fallas longitudinales normales contra las cuales los estratos se levantan y adelgazan, del gran volumen de magma ácido extruido y de un paleogradiente térmico alto. Se asume que procesos similares fueron comunes en los Andes Centrales durante el Terciario.

Key Words: Andes, central Chile, Tertiary, volcanism, graben, caldera.

Introduction

Tertiary volcanic sequences, up to 3000 m thick, predominantly consisting of ash flows in their lower part, and intermediate to basic lavas and rhyolitic domes in their upper part, with intercalations of lacustrine sediments, outcrop in the High Andes of central and northern Chile and central Peru. The Miocene Farellones Formation in central Chile (32°-35°S) is an example of such sequences (Fig. 1). It is *ca.* 2000 m thick, 250 km long and 20-30 km wide, and intruded by Miocene to Pliocene granitoids and Pliocene subvolcanic bodies, including two major porphyry copper deposits (Los Bronces-Río Blanco and El Teniente). Hydrothermal breccias (diatremes) occur in some places. The following description and discussion refer largely to the central segment (33°-34°S) of the sequence.

The Farellones Formation

Stratigraphy and lithology

The Farellones Formation consists of three members; intraformational disconformities are common and the volcanic rocks occur as interfingering 'packs' of beds of restricted distribution. The lower member (*ca.* 600 m thick; thicknesses refer to the type locality, Farellones, Fig. 1), is dominated by 20-50 m thick dacitic to rhyolitic pyroclastic flows and lahars. The flows have a vitroclastic matrix and are rich in fragments larger than 5 cm, attaining sizes up to 2 m. The most frequent rock types among the fragments are basic and intermediate lavas followed by pumice. Bedded tuffaceous sandstones and ash-rich lacustrine siltstones are intercalated between the pyroclastic flows. Magma mixing features are displayed at the top of the member: 'blebs' of andesite hosted by rhyolitic ash flow.

The middle member (*ca.* 1000 m thick) is mainly composed of intermediate to basic lavas, with a predominance of basaltic andesites. The flows are 10-30 m thick and many of them are amygdaloidal and/or autobrecciated in their upper part.

The upper member (up to 400 m thick), which is cut by the present level of erosion, comprises rhyolitic to dacitic subvolcanic rocks with spherulitic/perlitic texture and andesitic lavas and ashes, forming domes, lacoliths, sills and remnants of stratovolcanoes. A caldera morphology somewhat modified by glacial erosion is apparent in several areas (e.g. Lagunillas and Euscadi, 20 and 35 km south of Farellones, respectively). A slight disconformity characterizes the contact between the upper and middle member.

Structure

The rocks of the Farellones Formation are generally subhorizontal (Fig. 2), with gentle N-NW striking symmetrical folds of 5-8 km wavelength and shallow-dipping limbs (dips commonly less than 15°). Flexures with subvertical strata occur locally near the lower contact of the formation. The style of folding in the underlying, lithologically similar Abanico Formation of Early Tertiary age is different. The latter is characterized by asymmetric open concentric folding with axes striking N-NE and limbs usually dipping 45° or more. The Abanico rocks, like those of the Farellones Formation, occur as interfingering subunits separated by disconformities.

No generalization can be made about the contact relationship between the two formations. It has been described as interfingering, pseudoconformable, unconformable and/or tectonic by different authors. In fact, the two formations are locally separated by a distinct unconformity, in other places by a pseudoconformity, and in others by N-striking normal faults or fault systems with an up to 500 m thick zone of megabreccia towards which the strata tend to pinch out and become upraised (Fig. 2).

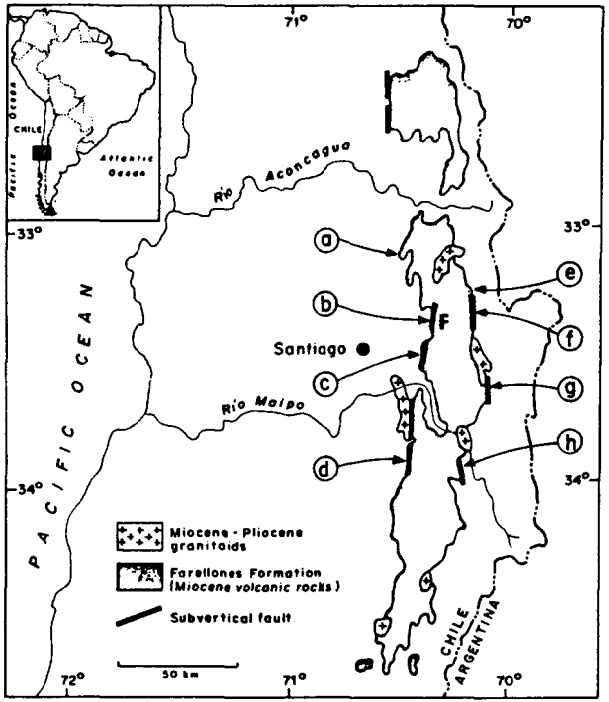

Fig. 1. Distribution of the Farellones Formation and related granitoids in central Chile, excluding isolated occurrences to the north. Locality b includes the type section of the Farellones Formation (F = Farellones village). Schematic cross sections (a-h) are shown in Fig 2.

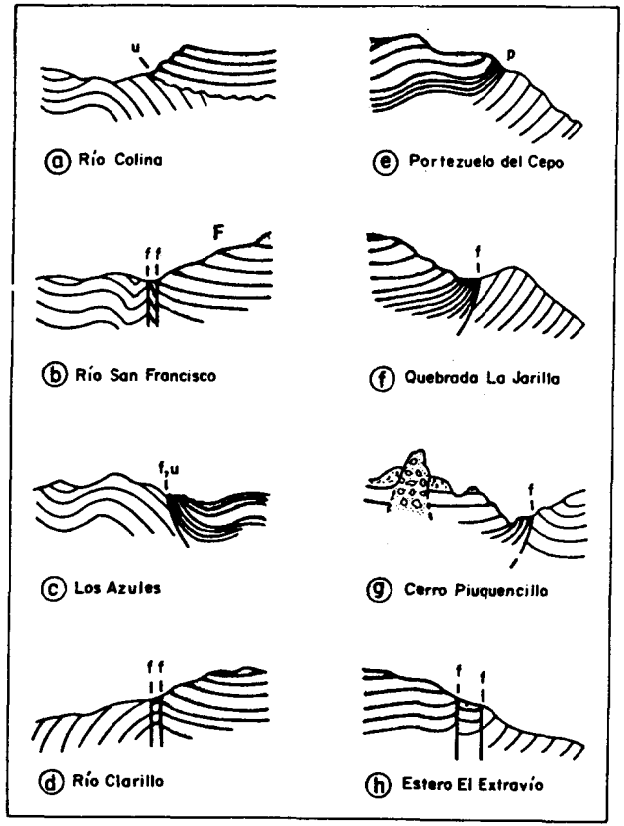

Fig. 2. Structural relationship at representative contacts between the Farellones (shaded) and Abanico Formations (u = unconformity, p = pseudoconformity, f = subvertical fault or fault system; a volcanic breccia intrudes Farellones volcanics and lacustrine sedimentary rocks at g. Locations are given in Fig. 1.

Geothermal field type of alteration

An X-ray diffraction study of 66 samples from the Farellones Formation at its type locality shows that assemblages with mordenite, cristobalite and smectite (mordenite subfacies of the zeolite facies) are present in the upper member, with laumontite, swelling chlorite and quartz (laumontite subfacies) in the intermediate member, and with wairakite, chlorite, quartz ±epidote (wairakite subfacies) in the lower member. The inferred fossil thermal gradient was *ca.* 150°C/km, i.e. of a magnitude typical for geothermal fields. Zones with pervasive hydrothermal alteration (e.g. silicification and kaolinization) occur locally near the boundaries of the formation.

Conclusions

The Farellones Formation was deposited in a volcano-tectonic graben formed through a series of caldera collapses. This interpretation is based on (a) the presence of longitudinal normal boundary faults towards which the strata pinch out and become upraised, indicating deposition during subsidence, (b) the huge volume of erupted acid magma, and (c) a high paleothermal gradient of geothermal field type. Similar Tertiary volcanic sequences in northern Chile and central Peru probably also formed by eruptions in a caldera-graben setting. The setting and the geothermal field type of alteration make these volcanic sequences good prospecting targets for epithermal gold deposits.