INFLUENCE OF REGIONAL TECTONICS ON MIOCENE VOLCANIC CALDERA FORMATION IN THE PUNA ALTIPLANO, NW OF ARGENTINA: THE AGUAS CALIENTES CALDERA COMPLEX

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INTRODUCTION

Large volcanic caldera complexes, up to 30 km in diameter, of Miocene age are located in a region with active strike-slip tectonics and reverse faulting, the Puna Altiplano of northwestern Argentina. Strike-slip tectonics is produced by the oblique subduction of the Nazca plate beneath the South American plate (Fig. 1) (de Silva, 1989). The Puna Altiplano is placed east of the present magmatic arc and west of the active foreland fold and thrust belt, the Santa Barbara System (Fig. 1). N-S reverse faults as well as WNW-ESE sinistral strike slip faults are being active in the Puna during all the Cenozoic times (Allmendinger et al. 1983). Superimposed on the former tectonic setting caldera collapse events developed starting in Middle Miocene and ending in Upper Miocene.

Miocene volcanic complexes are located between 3500 and 5000 meters above sea level and are thought to represent part of an ancient magmatic arc (Viramonte & Petrinovic, 1990). Volcanism is typically orogenic, i.e. calc-alkaline type (Harmon & Barreiro, 1984), and is closely related to the strike-slip tectonics and reverse faulting developed in the Puna. After caldera formation strike-slip and reverse faulting masked some of the geomorphologic features produced by caldera collapsing. In order to evaluate the effects of pervasive strike-slip and reverse faulting on short-lived caldera collapse dynamics a detailed study of the Aguas Calientes caldera complex has been carried out (Fig. 2 and 3).

The Aguas Calientes caldera complex

The Aguas Calientes complex is a 10 Ma old caldera located between two major WNW-ESE strike-slip faults (Fig.2), the Calama-Olacapato-El Toro fault and the Pastos Grandes fault. Both faults can be traced throughout the Puna following major satellite lineaments and also volcanoes and sag ponds alignments (Fig. 2). The eastern part of the Aguas Calientes caldera wall can be seen as a fault scarp that trends N-S and bends to E-W in the southern part of the caldera (Fig. 2 and 3). The fault scarp is located in the south block of the Calama-Olacapato-El Toro fault in a zone where the trend of this fault slightly bends to the ENE yielding a transtensive fault bending (Fig. 2). Adjacent to the caldera fault scarp the caldera floor is depressed, but further east it is elevated up to 1000 m above the fault scarp. This elevation is thought to be caused by a thermal resurgence of caldera floor after caldera collapse (Petrinovic, 1995).

The stratigraphy in the Aguas Calientes area is composed of pre-caldera Ordovician granites, welded syn-caldera ignbimbrites with a strong columnar jointing and quaternary post-caldera deposits represented by lava flows of shoshonitic composition and alluvial fan deposits (Fig. 3). Pre-caldera rock exposures are located outside the caldera depression, whereas syn-caldera and post-caldera deposits crop out either inside and outside the caldera depression (Fig. 3) (Petrinovic, 1995).

The Calama-Olacapato-El Toro fault extends from Calama in northern Chile to El Toro in northwestern Argentina and is expressed as a major lineament in satellite images. Segments of this fault link two shoshonitic volcanic cones of 200 ka to 400 ka near San Antonio de los Cobres and are the northern end of the Aguas Calientes caldera (Fig. 2 and 3). In this zone the sinistral movement on the Calama-Olacapato-El Toro fault has displaced about 10 km a post-Cretaceous thrust that places Precambrian rocks over alluvial fan Cretaceous deposits (Fig.2), whereas east of San Antonio de los Cobres the displacement observed on the syn-caldera ignimbrite is 2 Km. A broad, spaced (cm to dm) and steep cleavage has developed adjacent to the Calama-Olacapato-El Toro fault plane on the syn-caldera deposits (Fig. 3a) in the northern part of the Aguas Calients caldera.

The Pastos Grandes fault links three WNW-ESE aligned volcanoes of Lower Pliocene age south of the Salar del Rincón and can be traced from the former volcanoes to Santa Rosa de Pastos Grandes (Fig. 2). South of this fault another WNW-ESE fault can be traced along several step over fault segments that produce small Quaternary sag ponds. Some of the fault segments are transpressive step over segments which indicate a sinistral shear movement (Fig. 2). A weak, spaced and steep cleavage can be observed adjacent to the fault plane on the Aguas Calientes syn-caldera ignimbrite near Santa Rosa (Fig. 2).

Structures with a N-S trend that bound uplifted zones of Ordovician and Precambrian rocks and depressed zones filled up with Quaternary alluvial fan deposits and N-S elongated Quaternary salars are commonly observed in the Aguas Calientes area (Fig. 2). Most of these structures are interpreted as N-S trended reverse faults being the fault plane either dipping to the E or to W (Allmendinger et al. 1983). Northeast of the Aguas Calientes caldera N-S reverse faults bend to the SW as a result of sinistral movement on the Calama-Olacapato-El Toro fault (Fig. 2).

In the northern boundary of the Aguas Calientes caldera one of the former N-S reverse faults is trending NNE-SSW, dipping 45° to the WNW, and is displacing two fault blocks of syn-caldera ignimbrite (Fig.3b). The fault plane is characterized by a 10 m thick hydrothermally altered zone in the footwall and by a closely spaced cleavage in the hangingwall as well as in the footwall (Fig. 3). Cleavage displays a sigmoid geometry that indicates a reverse movement on the fault plane. This fault is buried by a shoshonitic lava flow extruded from a vent located on the Calama-Olacapato-El Toro fault plane (Fig. 3).

The Aguas Calientes caldera fault scarp and caldera depression have been extensively studied in order to find evidences on the influence of regional tectonics in caldera dynamics. Hydrothermal alteration postdates caldera formation since it has been observed in the syn-caldera ignimbrite along the fault scarp and along E-W and NW-SE fault planes located inside the caldera depression (Fig. 3). The Aguas Calientes caldera wall is interrupted to the north by a segment of the Calama-Olacapato-El Toro fault (Fig.2, 3). North of this strike-slip fault no geomorphological signature of the caldera wall can be observed and minor exposures of syn-caldera ignimbrite occur (Fig. 3). Striated surfaces on fault planes inside the caldera depression and on the caldera wall indicates a poliphase kinematic history that postdates caldera collapse. Therefore most fault planes have at least two sets of striae, one of them indicating a strike-slip and other a dip slip movement (Fig. 3c and 3d). Strike-slip may be either dextral or sinistral, whereas dip slip striae clearly postdates strike-slip ones but no sense of movement has been possible to deduce from them.

CONCLUSIONS

The location of the Aguas Calientes caldera in the context of the regional tectonics in the Puna Altiplano suggest that caldera collapse dynamics is closely controlled by a network of previous fault planes. This caldera is located south of a transtensive bend of the Calama-Olacapato-El Toro fault and only minor erupted volcanics crop out north of this fault. Thus, we suggest that the former strike-slip fault was reactivated as a normal fault during caldera collapse allowing the extrusion of volcanic material. After the volcanic event strike-slip movement continued as demonstrated by fault cleavage and fault displacement observed in the syn-caldera deposits either on the Calama-Olacapato-El Toro fault and on other faults located inside the caldera. Dip slip sets of striae on the former faults postdates collapse events are likely to be related to the thermal resurgence. Movement on reverse faults outside the caldera also continued after caldera collapse as demonstrated by cleavage and fault displacement observed in syn-caldera deposits. Thus, after the short-lived caldera collapse events the regional strike-slip and reverse faulting that dominate the Aguas Calientes area continued.

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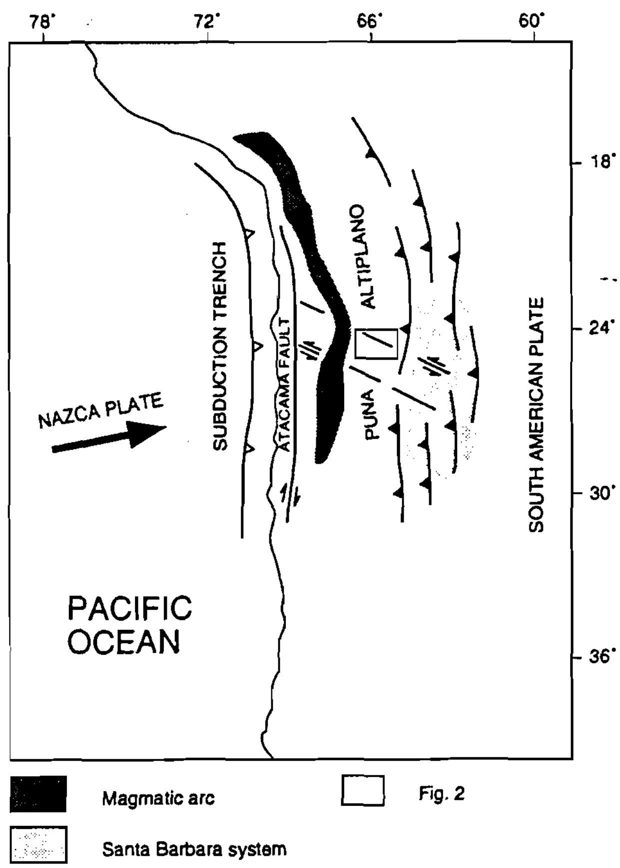
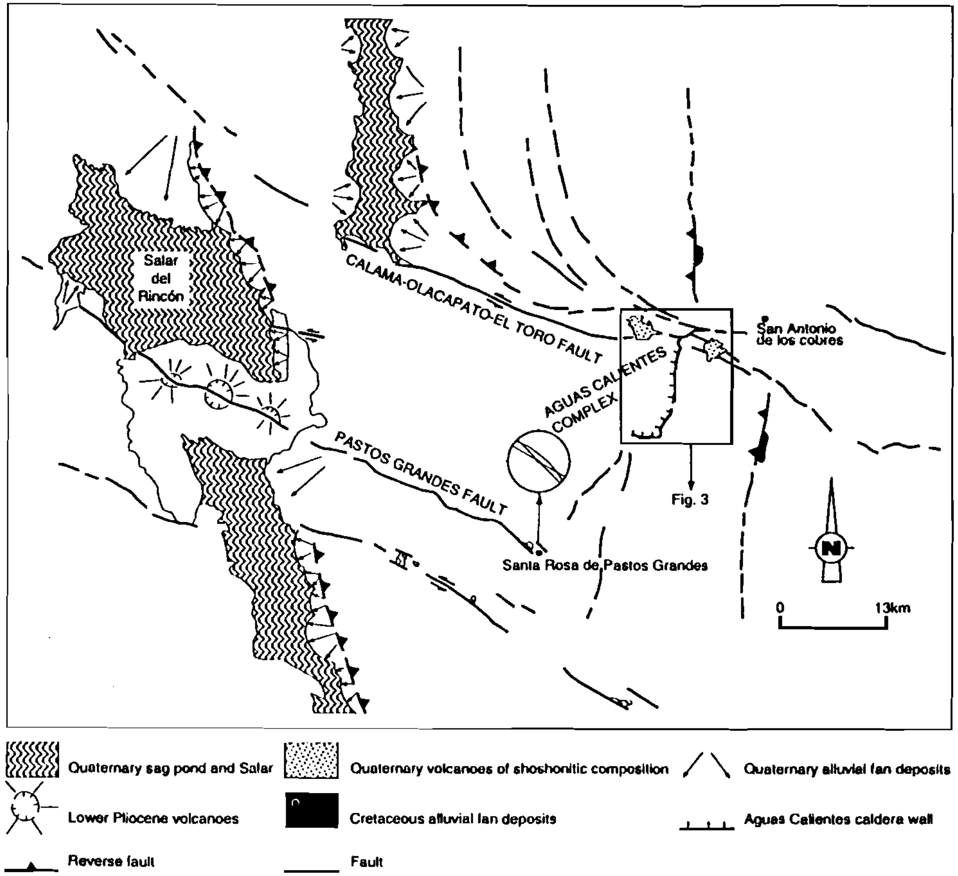


Fig. 1. Simplified tectonic map of the central Andes in northwestern Argentina showing oblique subduction of the Nazca plate beneath the South American plate and location of the studied area.



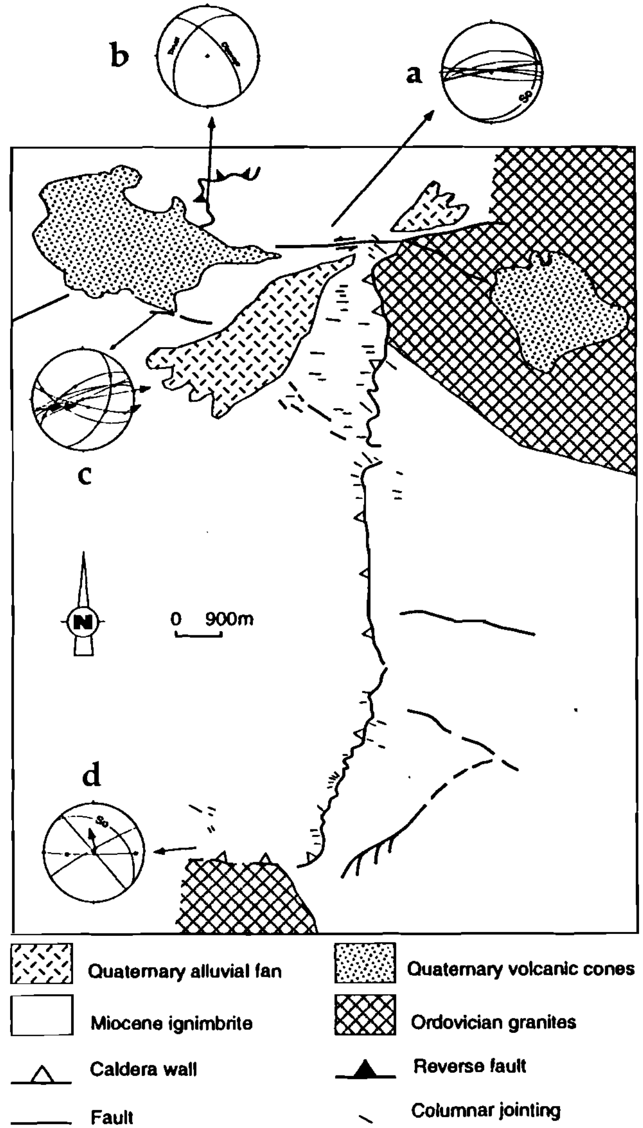


Fig. 2. Geological map of the Puna Altiplano in the Aguas Calientes area. Major tectonic and geomorphologic features have been drawn from unpublished Landsat satellite images and from field data. Lower hemisphere equal area plots of cleavage planes on the Pastos Grandes fault are also shown.

Fig. 3. Geological map of the Aguas Calientes caldera fault scarp showing lower hemisphere equal area plots of several structural elements and sense of movement on fault planes (see text for explanation).