NEOGENE TO QUATERNARY DEFORMATION OF THE SALAR GRANDE AREA, COSTAL CORDILLERA OF NORTHERN CHILE: IMPLICATIONS FOR FOREARC TECTONICS

Gabriel GONZÁLEZ L (1)., Alejandro MACCI; Daniel CARRIZO (3) and José CEMBRANO (4)

(1) Departamento de Ciencias Geológica, Universidad Católica del Norte, Chile; ggonzale@ucn.cl
(3) dcarrizos@yahoo.com
(4)jcembrano@ucn.cl

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Introduction

The continental margin of northern Chile is an excellent place to study the interaction between near-surface forearc deformation and deep-seated tectonics related to plate convergence. Well-exposed structures formed during the Neogene to Recent deformation history of the forearc, provide important information of the long-term and short-term tectonic processes that have dominated at the margin surface. Several contributions regarding the local Neogene tectonics of Antofagasta area and the Mejillones Peninsula have been published over the last years (Armijo and Thiele 1990; Niemeyer et al., 1996; Delouis et al., 1998). In this contribution, we present new field structural data of the Salar Grande (20º45', Fig. 1) and provide a first integrated model of the Neogene to Quaternary deformation of this part of the Coastal Cordillera. This area is very important to improve the current understanding of long-term and large-scale processes operating in Andean-type margins.

Fault arrangement and timing of deformation

The fault architecture of the Salar Grande area consists of three north-west-striking strike-slip faults and several north-south to north-northeast striking normal faults. The most important northwest-striking faults are the Salar Grande Fault and the Chomache Fault; both structures splay towards the west from north-south trending faults (Fig. 1). The Chomache Fault shows dextral-slip displacement, which is evidenced by the lateral offset of alluvial fans and streams, small-scale pull-apart structures formed along releasing bends, and push-up swells occur along restraining bends. The Salar Grande Fault trends parallel to the Chomache Fault along the inner part of the Coastal Cordillera, cutting the Salar Grande Basin which is filled with 100-150 m thick pure halite (Chong et al. 1999). Along this fault, morphological kinematic indicators, such as displaced streams, evidence consistently a dextral-strike slip character for this fault. Dextral kinematics is also documented by a drag fold in the northern part of the Salar Grande Fault, which affects Late Jurassic-Early Cretaceous red beds. Both the Chomache and the Salar Grande Faults have subhorizontal striae and dextral strike-slip outcrop-scale kinematic indicators. They are consistent with the kinematics arising from morphological analysis.

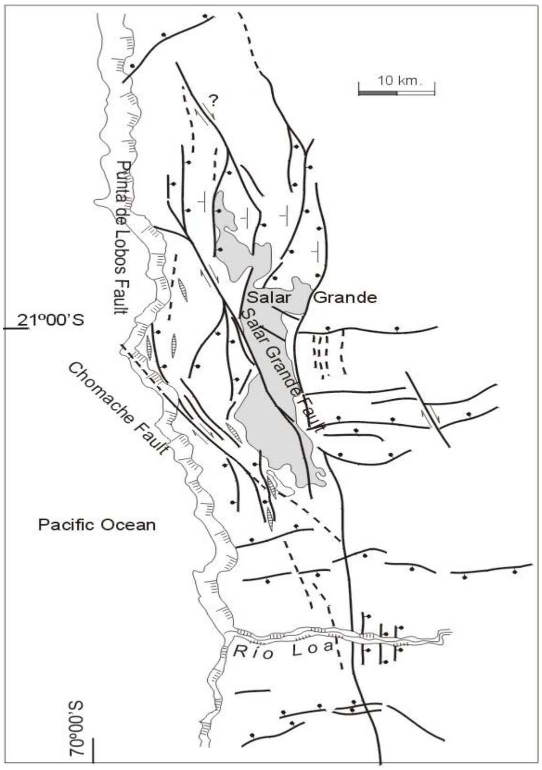

Figure 1. Structural map of the Salar Grande Area

The north-south-striking normal faults of the Salar Grande area, exert an important control on the morphology of the Coastal Cordillera at this latitude. They define asymmetric horst and graben morphology; the grabens are located on the eastern side of the faults and are limited by 50-100 m east-facing scarps. In the vast majority of cases, fault surfaces are not exposed and thus they do not provide any direct evidence of their kinematic character. Dip-slip component of motion on these faults is indirectly deduced from the displacement of both stratigraphic markers and pediplain surfaces of the top of the Coastal Cordillera. The Punta the Lobos Fault is the best exposed north-south striking fault. It dips 82º east and forms the boundary between a 1000 m in high, north-south oriented range and a fault-parallel alluvial basin, located at the west of the fault. The exposures of this fault show down-the-dip striae and have outcrop-scale kinematic indicators that evidence a normal dip-slip character of the displacement.

A complex system of open cracks that affect both sediments and country rocks are present in the Salar Grande area. The cracks are hectometric in length, 0.3-5 m in width and 1-7 m in depth. They strike mainly north-south, north-northwest and less commonly northeast and east-west. The north-south open cracks occur locally in the footwall of north-south striking normal faults, such is the case of Punta de Lobos Fault and the Geoglifo Fault. The north-northwest cracks are developed in low-land topographic zones affecting the alluvial graben-infill of north-south striking normal faults. The northeast and east-west cracks occur in clusters mainly in the highest parts around the Salar Grande. Some of these cracks are localized in the uplifted part of old east-west oriented fault scarps, whereas others are not spatially related to faults. Because open cracks affect both highlands and lowlands, an origin exclusively by topographically-controlled gravitational movement can be discarded.

Because both the Chomache Fault and the Salar Grande Fault show well-defined fault traces, displace streams and have well preserved fault scarps, it is likely that the dextral displacements along these faults occurred in the Pliocene or Quaternary. In fact, the observation that the Chomache Fault cuts the youngest alluvial fan deposits and displaces the Plio-Pleistocene Coastal Cliff (Niemeyer et al., 1996) suggests that the dextral slip along this fault has a Pleistocene or younger age. The Salar Grande Fault has a more strongly eroded morphological scarp and does not show fresh ruptures, it can then be interpreted that the dextral displacement along this fault has an older age than the Chomache Fault. The Punta de

Lobos Fault, deforms alluvial fan deposits with interbedded tuffs that in other parts of the Coastal Cordillera yielded 3-5 Ma-K-Ar ages. Thus, a Late Pliocene or younger age for this fault is likely.

Kinematic Analysis

Using the attitude of the fault plane, the orientation of the slip direction and the sense of slip, we applied the kinematic graphical reconstruction of Marrett and Allmendinger (1991) to obtain the P and T-axes, the principal incremental shortening axis (P) and the principal extensional axis respectively (T). The Salar Grande Fault, the Chomache Fault and the Punta de Lobos Fault show well-developed striae and very well exposed kinematic indicators. The T-axes obtained from the two dextral strike-slip faults have a subhorizontal, east-west orientation. The attitude of the P-axes is nearly subhorizontal and trends north-south. The linked Bingham distribution of the tensor axes for the right lateral faults yielded a N89ºE-trending, subhorizontal T axis and N01W-trending, subhorizontal P axis. For the Punta de Lobos Fault, the P-T analysis shows that the T axes are subhorizontal and trend east-west. In contrast with the Salar Grande Fault, the P-axis derived from the Punta the Lobos Fault is subvertical, which is determined by the normal character of the fault. In other normal faults, we found a similar orientation of the T and P axes. Applying the same Bingham analysis to the whole normal fault population, we obtained a N78ºE-trending, horizontal T axis. This attitude is similar to that yielded by the dextral faults.

Using crack orientation we tried to obtain the T axes related to their formation. We assume that for each crack the fracture-plane pole correspond with the orientation of the T axes. In the Salar Grande area the fracture orientation define a maximum pole located between N60-70E, a secondary maximum is oriented N80-90E.

The comparison between the T axes obtained from the fault slip data and those derived from crack orientation show that there is some correlation. However, a detailed analysis of the cracks-data shows that there is a group of cracks having T axes oriented N60-70E, which departs from the T axes orientation related to the faults.

Concluding remarks

The fault-slip data of Salar Grande evidence a kinematic compatibility within an overall east-west extensional regime. The northwest striking dextral strike-slip faults act as high-oblique transfer structures on the nearly east-west extensional deformation. We base this idea on the following field observations: (1) the Salar Grande Fault and the Chomache Fault do not crosscut the Salar del Carmen Fault at the southern tip of the Salar Grande and (2) the Chomache and Salar Grande Faults connect two north-south striking normal faults with opposite dip senses; and (3) the obtained T axes for the strike-slip and normal faults have similar attitude and orientation. Thus, we propose that the normal and the strike-slip faults of this area form a linked fault system related to the bulk east-west directed extension. The extensional direction is nearly parallel to the trench normal at this latitude. Trench perpendicular extension is also documented by north-south trending tensional cracks, which are exposed along the Coastal Cordillera. However, oblique extension relative to the normal component of the trench orientation also has been recorded, this is the case the north-northwest striking open cracks of the Salar Grande area, whose T axes are oriented N60-70E.

Our field data indicate that the part of the forearc structures exposed at the Coastal Cordillera has experienced near-surface extensional deformation which is trench normal orientated. The mechanism that controls this extension is probably related to plate-convergence. Several marines terraces exposed at this Coastal Cliff of this area attest to currently active uplift of the Coastal Cordillera. By the uplift process, the forearc surface between the trench and the Coastal Cordillera forms an upward flexure. The west flank of this flexure is subjected to gravitationally-driven movement towards the trench that promotes extensional deformation. Thus, extensional deformation results from a sort of large-scale buckle folding, where normal faulting is concentrated in a thin sheet, above a neutral surface that separates it from an underlying sheet undergoing contraction. This hypothetical configuration may explain why most faults of the Coastal Cordillera and Mejillones Peninsula are listric in section. The depth at which the faults become flat may represent the neutral surface, above which the crust is detached and moved towards the trench.

According to the fracture data processing, the cracks formation mechanism is related to the same extensional deformation. This is the case of the nearly north-south trending cracks, which are closely related to the normal faults. However, considering that the extensional direction, derived from the N20-30W trending open cracks, deviates from the north-south direction, it is plausible to suppose that other mechanism are intervening in the formation of open cracks. Because this type of cracks are nearly normal to the convergence vector, we propose that they are related to coseismic extension arising from elastic rebound during great earthquakes in the subduction zones.

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