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# Active tectonics and kinematics of the Chomache fault (Salar Grande, Northern Chile)

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North of the Loa river, the northern end of the N-S dextral Atacama fault shows a splay towards the West (Salar Grande and Chomache faults). During the Neogene, these faults together with normal N-S trending faults gave rise to the Salar Grande basin in the Coastal Cordillera (Santanach et al., 1996, Reijs and MacClay, 1998, González et al., 2002). Most of the N-S normal faults of the Salar Grande area dip to the East and define a half-graben system clearly visible on the morphology thanks to well-developed east-facing mountain fronts. The E-W fault scarps that are also present in this area have been interpreted as normal faults, coeval to the former (Santanach et al., 1996, Reijs and Macclay, 1998), while Allmendiger et al. (2005) have shown that they correspond to reverse faults developed during late Miocene-early Pliocene times. The aim of this paper is the analysis of the faults that show very fresh ruptures and of the system of open cracks that affects recent sediments and country rocks, particularly to the West of the Atacama fault

## Morphological evidence of fault activity

Different levels of freshness along faults and heterogeneous distribution of extensive open crack fields (they were usually found near the active faults) were observed in the studied area. This was used to classify the relative age of the activity of the faults. The study was based on the aerial photograph analysis (1:70000 scale) together with field work. Differential GPS was punctually used to level some morphological features to quantify and better describe their nature. Owing to these morphological criteria we distinguished two groups of faults: those very recently reactivated and those without evidence of very recent reactivation (Figure 1).

## Faults having been recently reactivated

These are mainly the Chomache fault system, some ENE-WSW faults near the Loa River and some NE-SW faults to the W of the Salar Grande. The criteria used to attribute very recent activity to these relief along the Chomache fault and the large amount of cracks associated. In figure 2b the free face of this very recent fault scarp is revealed from the topographic map with a very steep scarp. The faults were: 1) free faces along the fault scarps and 2) a significative number of cracks or open cracks clearly linked to the fault.

Figure 2 shows an example of the morphology of a very recent fault scarp. Figure 2a represents a scarp trend of the open cracks was systematically measured and mapped together with the faults (Figure 1). In the SE tip of the Chomache fault,

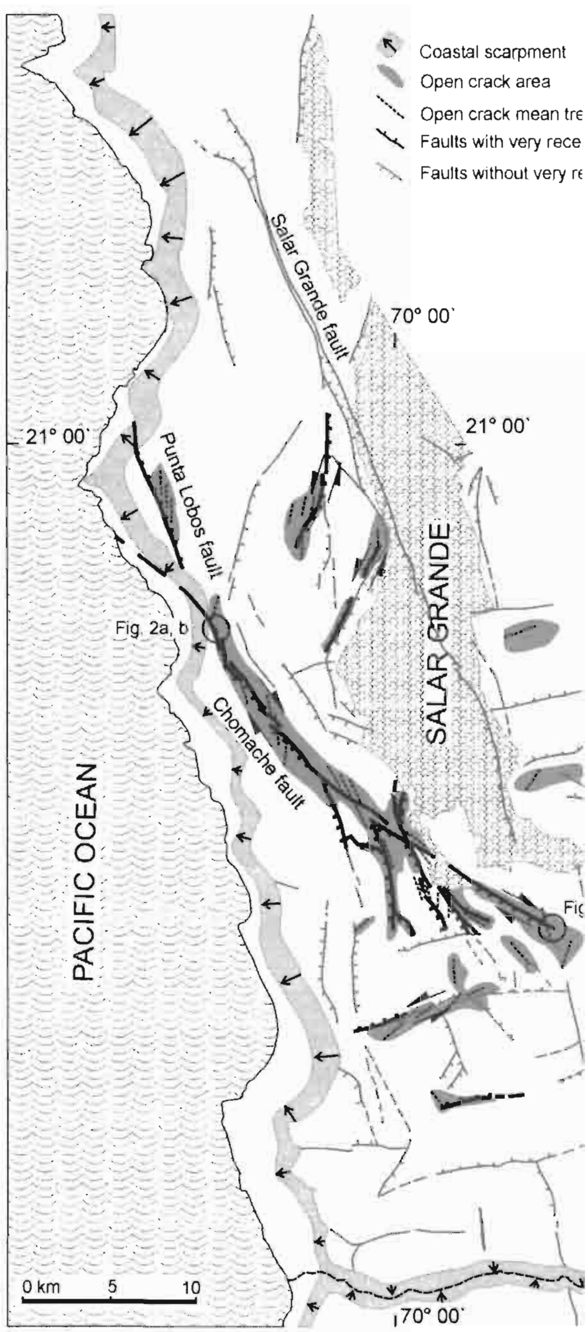


*Figure 1. Tectonic sketch of the analysed area with indication of the very recently activated faults. Note that "normal fault" sign is used only to indicate the downthrown wall, not the normal nature of the fault.*

push-ups, normally not taller than 1m, were usually linked between them by open cracks. Morphological evidence of individual offset events separated by quiescence periods was also detected along the Chomache fault. This was attributed to paleoearthquakes and thus the Chomache fault is suggested as seismogenic.

Some parts of these faults showed also cumulative scarps (more than a few offset events) revealing a long period of activity along them. Locally large push-ups (up to 15 m high) and a 15 m deep pull apart basin were mapped along the Chomache fault suggesting that the recent history of this fault is longer than the few earthquakes recorded along the very fresh scarps. Both, the pull apart and the high push-ups are normally cut by oblique open cracks evidencing their very recent reactivation.

**Faults without evidence of very recent reactivation**

Fault scarps without evidence of very recent reactivation were also mapped (Figure 1). Among these, the northern termination of the Atacama fault which links with the Salar Grande fault. Any of these faults show free face or open cracks associated although both show a fault scarp (the Salar Grande fault produces a remarkable fault scarp in the salt surface, but without a free face along its trend). A number of east facing mountain fronts were observed and interpreted as not recently active normal faults (including some of the faults bounding the Salar Grande). E-W faults east and south of the Salar were also considered in this category. Although these EW faults are also deforming in some extent the Salar surface, the intensity of this deformation is much lower than that of the Atacama system. They may probably have stopped their activity before the Atacama fault did.

**Kinematics**

Since very few outcrops show slikensides along the fault planes the kinematic information was obtained mainly from the surface: the orientation of open cracks and push-ups, the geometry of pull-apart basins, the obliquity of

open cracks respect to the fault scarps and the en echelon distribution of fault traces. The deviation of gullies across the fault scarps was also considered in some cases. The resulting kinematics was coherent between the sites recording few paleoearthquakes and the sites recording a larger amount of cumulative deformation.
According to these results the Chomache fault is a dextral fault with a vertical component while the ENE-WSW fault south of it is senestral and vertical. The N-S faults located in between these two faults show normal slip. The NE-SW faults to the West of the Salar Grande provided evidence of a senestral component of slip as well.

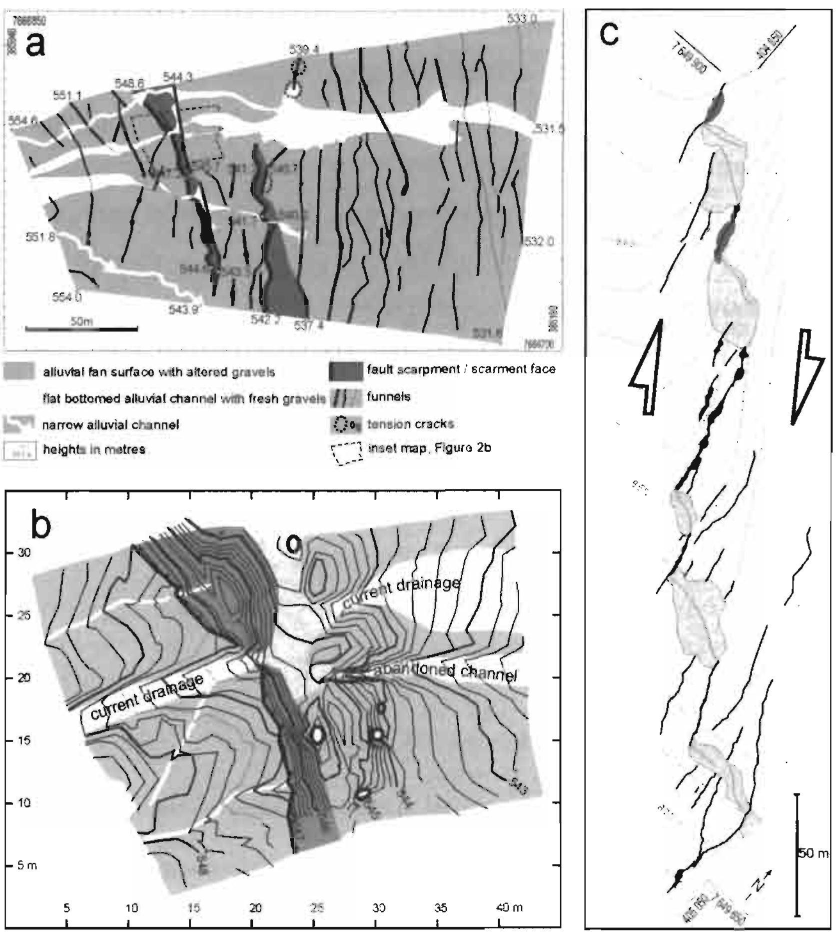


*Figure 2. a: Topographic map of the area of step over between two fault scarp segments obtained with differential GPS measurements. Note the obliquity of the open cracks respect to the general trend of the scarps. B: detail of an offset gully across the fault. Location in figure 2a. C: example of the orthogonal distribution of the open cracks and the push ups at the southern tip of the Chomache fault. Locations in figure 1.*

The obliquity of the open cracks with respect to the fault scarps (figure 2a) was coherent with geomorphological data at a more detailed scale (lateral offset of a channel in figure 2b for example). Push-up and open crack were usually alternating and almost ortohogonal between them as illustrated in figure 2c, and constituted a good kinematic indicator. The arrangement of gullies, push-ups, open cracks, and fault scarps provided coherent kinematic results in fault scarps with free face recording a small number of events and in scarps recording a large number of events.

**Concluding remarks**

Morphological analysis evidences that only few of the faults of the analysed area have been recently reactivated. These are the Chomache fault, an ENE-WSW fault south of it and some NE-SW faults to the west of the Salar Grande. The rest of the faults, including the Atacama fault (north of Loa River, including the Salar Grande fault), show a fault scarp without evidence of very recent reactivation although they have been active in some cases after the formation of the Salar Grande as they deform its surface.

The recurrent movements along the very recently activated faults were observed to be episodic suggesting the seismogenic nature of this fault system.

The dextral slip along the Chomache fault, the senestral slip along the southern ENE-WSW fault, the N-S normal faults and the N-S open cracks denote a very recent E-W extension of the triangular zone located between the two faults. Since this area is located next to the coastal escarpment, the E-W extension may be gravity driven. However, other very recent NE-SW faults were described as senestral to the north of this area without a clear physical link with the coast. Furthermore, the cumulative mountain front along the Punta Lobos normal fault faces east and shows evidence of very recent reactivation at its base. This suggests that, additionally to the extensional effect of the coastal scarp, a very recent regional E-W extension and N-S compression is taking place in this area. The E-W extension has also been described along the Coastal Cordillera to the south (Armijo & Thiele, 1990, Delouis et al, 1998, Plafker & Savage, 1970; Ruegg et al., 1996). The observed E-W extension results from the coseismic cumulative deformation (Delouis et al, 1998). The interseismic deformation measured by the GPS, shows current E-W compression (Khazaradze & Klotz, 2003).

The activation of this fault system is episodic and with quiescent periods separating the deformation episodes. This activation can be directly related with the E-W extension generated by the subduction earthquakes as proosed by Delouis et al. (1998) but can also be gravity driven and triggered by these earthquakes.

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