Late Quaternary Intraplate Deformation: The Las Chacras Fault Zone, West-Central Argentina

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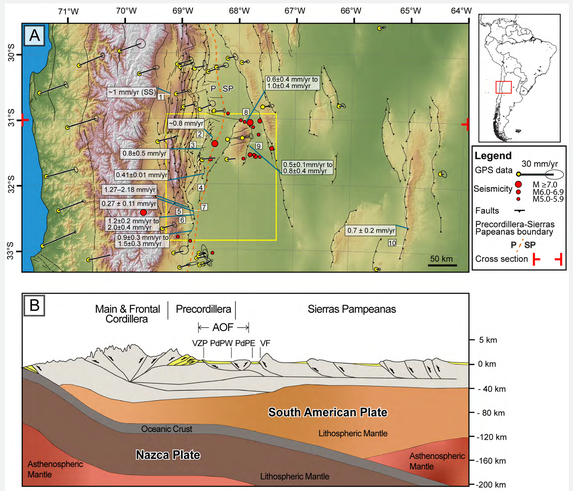
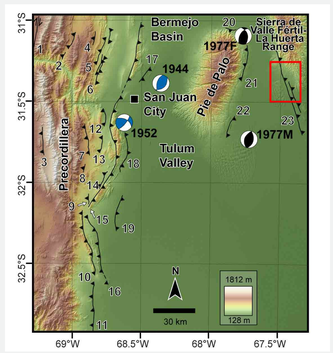
Overview



- Active deformation has been mapped up to 700 km east of the plate boundary, but the existing total shortening estimates are limited to the fold and thrust belts to the west
- There are existing GPS studies using campaign style and continuous measurement surveys that cover the entire region, but towards the east, these are fewer and far apart
- Similarly, geomorphic slip rates on Quaternary deformation in the region are concentrated in the Precordillera region and are largely lacking in the Sierras Pampeanas
- Although there seems to be greater amount of recent shallow crustal seismicity in the west compared to the east, this is not necessarily indicative of the longer-term activity of structures further east

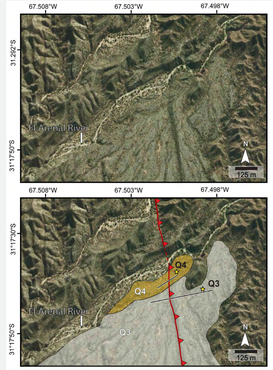
Background



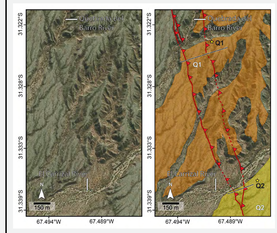
- Quaternary Andean backarc deformation within the Pampean flat-slab segment (27–33.5°S) is widely distributed, extending up to 700 km east from the Peru-Chile trench.
- In the past 10–15 Ma, up to ~75% of the total shortening between the plate boundary and the forearc region at 30°S has been accommodated in the thin-skinned orogenic belts of the Precordillera.
- Activity in the easternmost Precordillera that commenced at ~2.6 Ma and in the westernmost Sierras Pampeanas at ~3 Ma focused deformation between these two sections of the retroarc between 30 and 32°S, forming the Andean Orogenic Front.
- Compared to the thin-skinned structures in the west, little is known about the rates of movement of most of the basement-cored uplifts of the Sierras Pampeanas.
- GPS studies demonstrate an overall west-east gradient of decreasing shortening rates
- It is unclear, however, if this trend holds true on the longer term and if it resembles the trend in level of activity of structures, due to the sparseness of observation points, poor vertical positional accuracy, and limited temporal coverage of GPS studies.

El Arenal Site

- The LCFZ at the El Arenal site exhibits relatively smaller scarps that reach elevations only as high as ~5 m and displace both alluvial fans and strath terraces.
- Surfaces have an average slope of 2°-3° to the west and 3-4° to the south and form an angular unconformity with the Triassic sedimentary
- Surfaces are composed mostly of pebble- to cobble-sized clasts of quartzite, quartz tonalite, quartz diorite, amphibolite, mica-garnet-feldspar gneiss and schist sourced from the Proterozoic Valle Fértil complex on the western flank of the Sierra de Valle Fértil-La Huerta range.

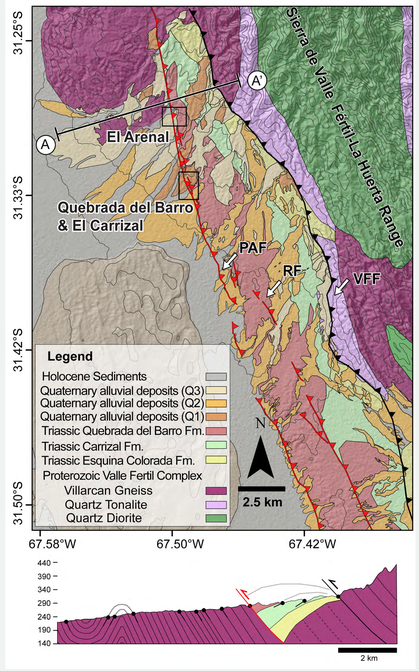


Quebrada del Barro and El Carrizal Sites



- West-facing, downslope-directed scarps of the Pan de Azúcar strand of the LCFZ exhibit their greatest displacement in these sites
- ~20-m-high scarps displace well preserved late Quaternary alluvial fans.
- Trends N15°W and bifurcates towards the north, with the western trace being more continuous than the eastern trace.

Las Chacras Fault Zone



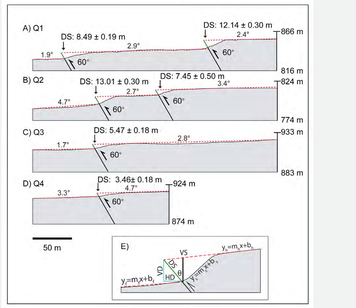
- The LCFZ, is a NW- trending, ~30-km-long, E-dipping zone of reverse faults that are aligned to the southern end of the ~180-km-long Valle Fértil Fault, which bounds the the Sierra de Valle Fértil-La Huerta Range (composed of a Proterozoic igneous and metamorphic basement complex overlain by Triassic sedimentary rocks).
- It is located ~100 km east of the city of San Juan in Argentina. Two main fault strands comprise the LCFZ, the Pan de Azúcar Fault in the west and the Rickard Fault in the east.

Cumulative Scarps

Profile views of the Pan de Azúcar strand of the LCFZ. A. Scarps at the El Carrizal site where Q2 is displaced. B. Scarps at the Quebrada del Barro site where Q1 is displaced.

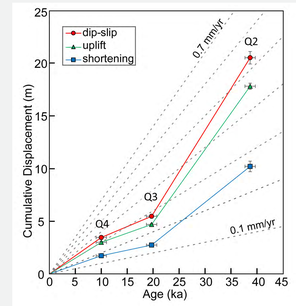
Calculation of Displacement

- DGPS scarp profiles were used as markers to compute displacement (dip-slip, shortening, and uplift) according to the methodology described in Yang et al. (2015).
- Given the orientation of the LCFZ, a left-lateral component is likely. However, it is difficult to quantify this due to the absence of preserved, well-defined piercing points that will allow distinguishing the amounts of separation (a.k.a. apparent slip) from actual lateral-slip on ephemeral streams that cut across the fault scarp diagonally.



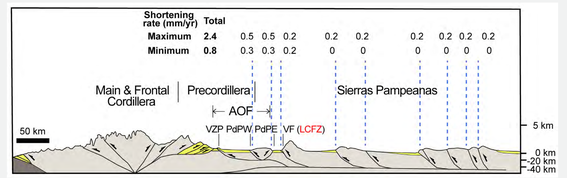
Slip Rates

- Average dip-slip, shortening, and uplift rates measured on surfaces Q2, Q3, and Q4 displaced by the Pan de Azúcar strand of the LCFZ are 0.39 ± 0.03, 0.19 ± 0.02 and 0.33 ± 0.03 mm/yr, respectively.
- Shortening and uplift rates of the Rickard strand of the LCFZ is likely much lower
- The decrease in shortening rate marked by the LCFZ and the abrupt decrease in GPS shortening rates at this longitude coincides spatially with the resumption of normally dipping subduction of the Nazca plate between 67°W and 68°W.



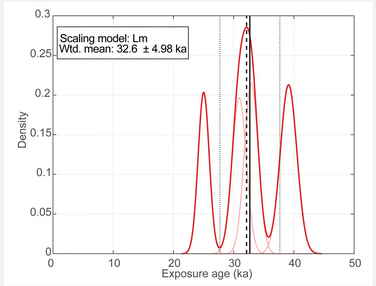
- Slab dip may exert control on this decrease in shortening rate, with lower shortening occurring on faults associated to a more normally (30° to the east) dipping slab due to a lower degree of interplate coupling.
- Therefore, similar to the findings of the relative tectonic activity assessment study by Rimando and Schoenbohm (2019), it appears that W-E shortening gradient shown by the decadal GPS velocity field, reflects the longer-term gradient in slip rates of faults across the Pampean flat-slab segment.

Shortening Across the Sierras Pampeanas



- We estimate the total shortening rate across Pampean structures by using the few measured shortening rates as anchors for the geodetically determined west-east trend of decreasing shortening rates.
- The shortening rate along the LCFZ (adjacent to VF) is 0.19 ± 0.02 mm/yr since ~10 ka according to this study. Assuming lower shortening rates (0 to 0.2 mm/yr) on faults east of the LCFZ, we estimate a minimum and maximum total shortening rate across the Sierras Pampeanas at 31°S of 0.8 mm/yr and 2.4 mm/yr.
- ~2.4 mm/yr is equivalent to 30-40% of the total 5.5-7.7 mm/yr long-term geological (~20 Ma) shortening rate estimated for the entire section from the Principal Cordillera to the Precordillera from latitudes 30–33°S; and ~50% of the 4.5 ± 1.7 mm/yr decadal slip rates across the Andean Orogenic Front .

Cosmogenic dating



- Ages were computed from amalgamated clast samples. Inheritance was accounted for by subtracting the 10Be concentration of adjacent modern channel clasts
- A kernel density estimate (KDE) of individual clast ages (4 clasts: Q2SA, Q2SB, Q2SC, Q2SD) demonstrate good internal consistency.
- Due to the ubiquity of desert varnish on all surfaces, which is an indication of high degree of surface preservation, clast ages were computed assuming zero erosion.
- A sensitivity test was conducted to test effect of erosion rates on age.
- 1 mm/ka of erosion for Q4, Q3, and Q2 underestimates ages by 1, 2 and 3% of the zero-erosion ages, respectively. 5 mm/ka erosion rate underestimates ages by 4, 8, and 20% of the zero-erosion ages, respectively.
- For large clasts, cosmogenic ages are likely to be overestimated due to the inability to fully account for inheritance rather than underestimated due to erosion.
- **Q2**: 38.7 ± 3.7 ka.; Q2SA, Q2SB, Q2SC and Q2SD yield similar ages of 32.9 ± 2.6, 25.0 ± 2.0, 39.1 ± 2.1, and 30.9 ± 2.5 ka, respectively (weighted average age of 32.5 ± 5.0 ka).
- **Q3**: 19.7 ± 4.8 ka.
- **Q4**: 10.0 ± 1.2 ka.

Conclusions

- We determined geomorphically-derived average shortening and uplift rates for the LCFZ of 0.19 ± 0.02 and 0.33 ± 0.03 mm/yr, respectively, from 10.0 ± 1.2 ka to 38.7 ± 3.7 ka.
- Although faults in the Sierras Pampeanas region still widely lack slip rates, the shortening rate we measure on the LCFZ is significantly lower than on most faults to its west both in the Precordillera and in the Sierra Pie de Palo of the western Sierras Pampeanas; this clearly supports a general west-east decreasing trend of shortening rates across the Pampean flat slab.
- The LCFZ, with its abruptly lower shortening rate, also coincides spatially with the resumption to a more steeply-dipping Nazca plate between 67°W and 68°W. Uplift rates, on the other hand, are relatively high and are comparable to those measured on faults in the Precordillera, likely resulting from the steeper dips of structures in the Sierras Pampeanas.
- From slip rate, fault length, and earthquake magnitude scaling relationships, we show that the Las Chacras Fault Zone is capable of generating earthquakes with magnitudes ranging from MW 6.7 to 7.1. These potential earthquakes are large enough to pose hazard of considerable ground-shaking and liquefaction-related damage to nearby cities.
- Further detailed analysis of event horizons from paleoseismic trenching are needed to provide further constraints on timing and recurrence of earthquakes associated with this fault.

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