The Liquiñe Ofqui Fault Zone : a major Cenozoic strike slip duplex in the Southern Andes

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RESUMEN

La zona de falla Liquiñe-Ofqui (ZFLO) se extiende por casi 1000 kms en los Andes del sur. Rocas deformadas ocurren a lo largo de la ZFLO, que coincide con el eje Mioceno del Batolito Norpatagónico y con cuencas extensionales terciarias. Un movimiento dextral en el rumbo y luego normal, es consistente con la convergencia entre las placas de Nazca y Sudamérica que ha variado de oblicua a casi ortogonal.

KEY WORDS: Southern Andes, strike-slip duplex, Cenozoic.

INTRODUCTION

The overall deformation resulting from converging plates is partitioned into strain, displacement along discrete faults and block rotation (Lamb and Bibby, 1989; Jackson and Molnar, 1990). Attempts to assess the contribution of these three components of deformation along different mountain belts (Dewey and Lamb, 1992) face the problem that short and long-term slip rates, distributed strain, and the amount and sense of block rotation are generally poorly constrained. This is the case in the Chilean Andes, where hundred-kilometer long crustal lineaments, regarded as major long-lived strike-slip fault systems, have been causally linked to the margin parallel component of oblique subduction of the Nazca (Farallon) plate beneath South America (Hervé, M., 1976; Beck, 1988; Pardo Casas and Molnar, 1988).

The most relevant tectonic feature of the southern Chilean Andes, the 1000 km long Liquiñe-Ofqui fault zone (LOFZ) , has been lately the subject of geologic, geochronologic and paleomagnetic research. An updated synthesis of all available relevant information about the LOFZ is given below.

GEOLOGICAL SETTING

Geometry

The Liquiñe-Ofqui fault zone is represented by a series of NNE-trending crustal lineaments, mainly corresponding to aligned glacial valleys and fjords.

Their spatial arrangement as observed in satellite images, aerial photographs and geologic maps (Fuenzalida & Etchart, 1975; Hervé et al., 1979; Thiele et al., 1986) allows the distinction of three categories of lineaments based on length and shape : straight long segments; *en échelon* features; and curved splays.

The main trace of the LOFZ is represented by two NNE-trending straight segments with a left step in between. These two main segments are linked by a series of NE-trending *en échelon* lineaments resulting in an extensional strike-slip duplex geometry (as described in

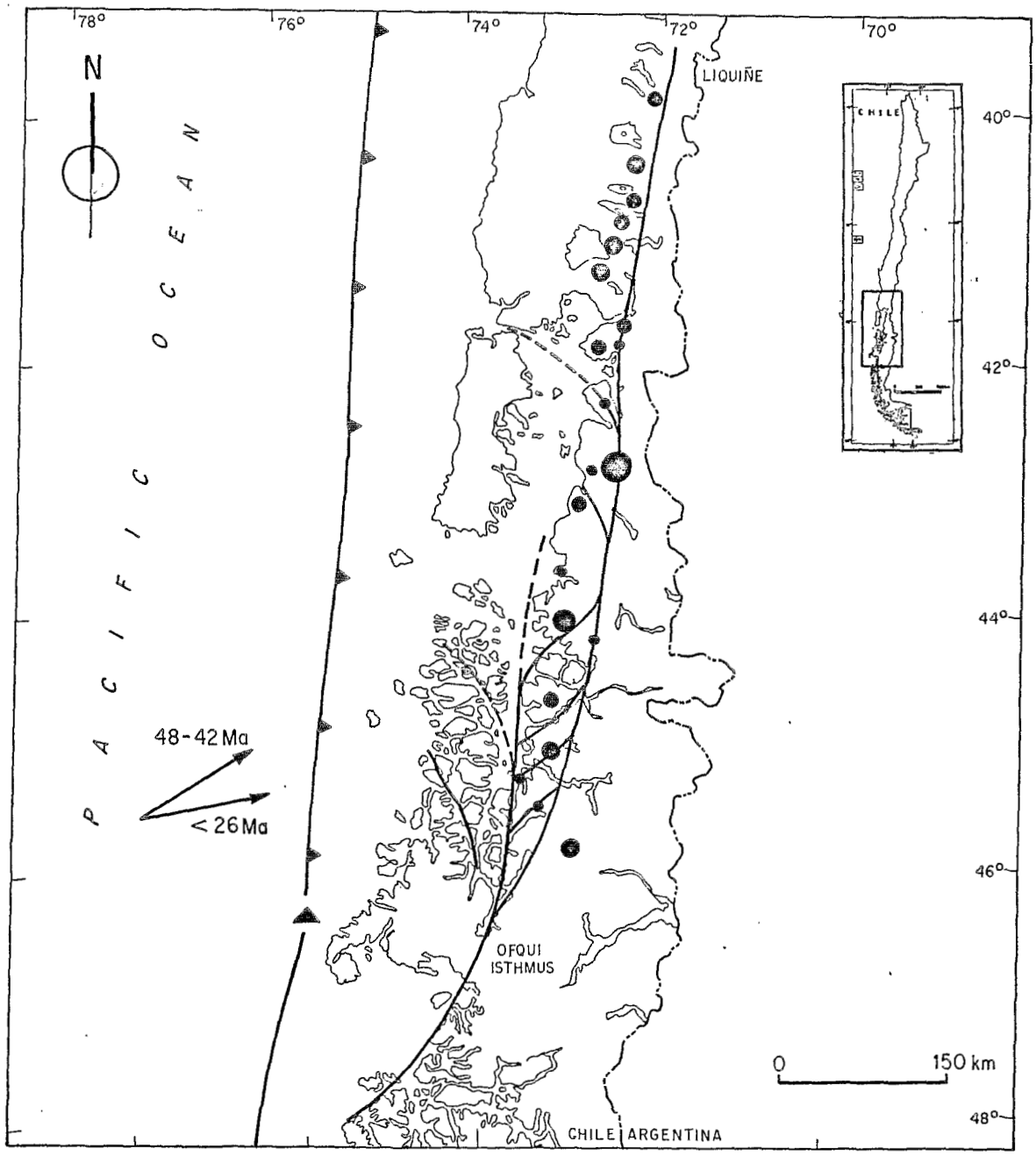

Fig. 1 Sketch map of main lineaments of the LOFZ. Position of the holocene volcanoes (black dots), the trench, the triple point (black triangle) and of the slip directions of the Nazca Plate approximate.

Woodcock and Fisher, 1986). The third important element is a series of NW-trending, concave to the southwest, oceanward splays off the two main segments (Fig. 1).

The LOFZ, along most of its main trace, runs through plutonic rocks of the Meso-Cenozoic North Patagonian batholith, metamorphic rocks of the Paleozoic Accretionary Complex and Cenozoic volcanosedimentary units (Hervé, 1976; Parada et al., 1987; Cembrano, 1992). The Miocene belt of the North Patagonian batholith has a close spatial relationship with the main trace of the LOFZ, as does the holocene southern Andes volcanic chain. It has been suggested that the LOFZ is a deep-seated structure cutting through the lithosphere, favouring magma rising and emplacement. (Parada et al., 1987; Pankhurst et al., 1992).

NS-trending strips of fault rocks, crop out in discrete areas along the LOFZ, between extensive exposures of non-deformed rocks. A steeply-dipping foliation striking NNW characterizes the mylonites. Limited available data on mineral stretching lineations and fault striae are consistent with lateral displacement.

Mid-Tertiary extensional basins (Bartholomew and Tarney, 1986) and holocene volcanoes are spatially compatible with the extensional duplex geometry described.

Paleomagnetism

Paleomagnetic data on rock units adjacent to the LOFZ (García et al., 1988; Cembrano et al., 1992; Rojas et al. in press) have shown a pattern of crustal block rotation consistent with the LOFZ geometry and motion, characterized by small counterclockwise rotations west of the LOFZ and small to moderate clockwise rotations within and to the east of the LOFZ. Beck et al. (in press) propose that the observed pattern is the result of small north-south displacement of blocks along curved splays west of the LOFZ, giving rise to counterclockwise rotation in contrast with distributed dextral shear producing clockwise rotations within and to the east of the LOFZ. Large-scale north-south transport -as found in the US western Cordillera- has not been documented, but available data do not rule out a few hundred km of lateral offset.

Nature and timing of motion

Hervé (1976) proposed that it was a Cenozoic fault zone with both pre-Oligocene dextral and Late Tertiary normal up-on-the-east motions. The main evidence for the early strike-slip component was a steeply-dipping mylonitic foliation along with a conjugate set of NNE-trending dextral and ENE-trending sinistral mesoscopic faults found in a 3km wide NNE - trending belt of fault rocks. The normal, up-on-the-east motion, was interpreted from the fact that deeper crustal levels crop out east of the LOFZ main trace. At 41°S the LOFZ juxtaposes weakly deformed Miocene and Cretaceous plutonic rocks (Drake et al. 1992). At 42°S, NNW striking foliations, subhorizontal mineral lineations and structural asymetries found in both Mio-Pliocene granitoid and their Paleozoic metamorphic wallrocks document a right lateral ductile shear zone of pre-Pliocene age (Cembrano, 1992).

High uplift rates have been calculated for the LOFZ by Thiele et al. (1986) for the last 10 Ma and, up to 9 mm/year, by Hervé and Ota (in press) for the late Holocene, respectively.

CONCLUSIONS

The LOFZ is represented by two major NNE-trending crustal lineaments along which isolated outcrops of ductilely-brittlely deformed rocks occur. Purely geometric considerations of spatially related *en échelon* and curved oceanward features can be assimilated to a strike-slip extensional duplex and associated splays.

Field evidence from within the LOFZ is consistent with a right lateral shear zone with sharp variations in the nature of rock deformation along strike.

The fact that both the Miocene plutonic rock belt and Recent volcanoes spatially coincide with the LOFZ suggests that the structure has exerted control on magma rise and emplacement.

Paleomagnetic data show a pattern of block rotation consistent with the geometry and sense of motion assigned to the LOFZ.

Right lateral followed by normal motion on the LOFZ reflects the Nazca-South America convergence which varied from highly oblique to nearly orthogonal during the Cenozoic.

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REFERENCES

Bartholomew, D.S. and J. Tarney, 1984, Crustal extension in the Southern Andes (45-46°S). In: B.P. Kokelaar and M.F. Howells (Editors), Marginal Basin Geology: Volcanic and Associated Sedimentary and Tectonic Processes in Modern and Ancient Marginal Basins. Geol. Soc. London, Spec. Publ., 16: 195-205.

Beck, M.E. Jr., 1988, Analysis of Late Jurassic-Recent paleomagnetic data for active plate margins of South America. J. of S. Amer. Earth Sci. 1, 39-52.

Beck, M., Cembrano, J., Rojas, C. and F. Hervé, On the significance of curvature in strike-slip fault systems. Geology (in press).

Cembrano, J., 1992, The Liquiñe-Ofqui Fault Zone (LOFZ) in the Province of Palena: field and microstructural evidence of a ductile-brittle dextral shear zone. *Comunicaciones* N° 43, 3-27.

Cembrano, J., Beck., M.E. Jr., Burmester, R.F., Rojas, C., García, A. and F. Hervé, 1992, Paleomagnetism of Lower Cretaceous rocks from east of the Liquiñe-Ofqui fault zone, southern Chile: evidence of small in-situ clockwise rotations. Earth and Planetary Science Letters, 113, 539-551.

Dewey, J.F. and S.H. Lamb, 1992, Active tectonics of the Andes. Tectonophysics, 205, 79-95.

Drake, R., Hervé, F., Munizaga, F. and M. Beck, 1992. Magmatism and the Liquiñe-Ofqui Fault Zone, southern Chile (40°-46° S. Lat.). Comunicaciones N° 42 (Vth International Circumpacific Terrane Conference), 69-74.

Fuenzalida, R. and H. Etchart, 1975, Geología del territorio de Aysén comprendido entre los 43°45' y los 45° latitud Sur. Instituto de Investigaciones Geológicas, Santiago, Chile, 99 pp.

García, A., Beck, Jr. M.E., Burmester, R.F., Hervé, F. and F. Munizaga, 1988, Paleomagnetic reconnaisance of the Región de los Lagos, southern Chile, and its tectonic implications. Revista Geológica de Chile, 15, 13-30.

Hervé, F., Araya, E., Fuenzalida, J.L., et al., 1979, Edades radiométricas y tectónica neógena en el sector costero de Chiloé continental, X Región. In Congr. Geol. Chileno, N°2, Actas vol. 1, p. F1-F18, Arica.

Hervé, F. and Y. Ota. Fast Holocene uplift rates at the Andes of Chiloe, southern Chile. Revista Geológica de Chile (in press).

Hervé, M. 1976, Estudio geológico de la falla Liquiñe-Reloncaví en el área de Liquiñe; antecedentes de un movimiento transcurrente (Provincia de Valdivia). Actas I Congreso Geológico Chileno, B39-B56.

Jackson, J. and P. Molnar, 1990, Active Faulting and Block Rotations in the Western Transverse Ranges, California. Journal of Geophysical Research, vol. 95, N°B13, 22,073-22,087.

Lamb, S.H. and H.M. Bibby, 1989, The last 25 Ma of rotational deformation in part of the New Zealand plate-boundary zone. Journal of Structural Geology, vol. 11, N° 4, 473-492.

Pankhurst, R.J., Hervé, F., Rojas, L. and J. Cembrano, 1992, Magmatism and tectonics in continental Chiloe, Chile (42°-42°30'S). Tectonophysics, 205, 283-294.

Parada, M.A., Godoy, E., Hervé, F. and Thiele, R., 1987, Miocene calc-alkaline plutonism in the chilean southern Andes, Revista Brasileira de Geosciencias 17, 450-455.

Pardo-Casas, F. and P., Molnar, 1988, Relative motion of the Nazca (Farallon) and South American plates since Late Cretaceous times, Tectonics, 6, 233-248.

Rojas, C., Beck, M., Burmester, R., Cembrano, J. and F. Hervé. Paleomagnetism of the Mid-Tertiary Ayacara Formation, southern Chile: counterclockwise rotations in a dextral shear zone. Revista Geológica de Chile (submitted).

Thiele, R., Hervé, F., Parada, M.A. and Godoy, E. 1986, La megafalla Liquiñe-Ofqui en fiordo Reloncaví (41°30'S), Chile, Comunicaciones (Universidad de Chile, Santiago) 37, 31-40.

Woodcock, N.H. and M. Fisher, 1986, Strike-slip duplexes. Journal of Structural Geology, 8, 7, 725-735.