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# The Liquiñe Ofqui fault zone: a long-lived intra-arc fault system in southern Chile

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**Abstract**

Plate reconstructions for the Cenozoic document relatively steady right-oblique subduction of the Farallon (Nazca) plate beneath the Chilean continental margin. The kinematic signature recorded along the intra-arc Liquiñe–Ofqui fault zone (LOFZ), a major feature of the southern Andes, may help to understand the way in which the Nazca–South America slip vector has been partitioned into strain and displacement along and across the continental margin.

The LOFZ consists of two NNE-trending right-stepping straight lineaments, a strike-slip duplex at the right step, and curved features which splay off the straight lineaments toward the northwest. The LOFZ runs mostly through heterogeneously deformed Cenozoic plutonic rock of the North Patagonian Batholith and patchy metamorphic wall rock. Early Cenozoic volcano-sedimentary rocks and dyke swarms, found in close spatial association with the strike-slip duplex, are believed to have developed in strike-slip-related basins. Quaternary volcanoes are aligned parallel to the LOFZ.

Both ductile and brittle kinematic indicators within centimeter-to-meter-wide high-strain zones, document late Cenozoic dextral shear deformation. Contrasting left-lateral deformation recorded on older and wider mylonitic zones, suggests that the LOFZ may be a long-lived shear zone that accommodated continental-scale deformation arising from the Farallon (Nazca)–South America plate convergence.

A block rotation pattern, as indicated by paleomagnetic data, is consistent with the geometry and Cenozoic kinematics of the LOFZ.

## 1. Introduction

The southern Chilean Andes constitute a suitable tectonic setting to investigate how deformation arising from obliquely converging plates is partitioned (Fitch, 1972; Beck, 1983, 1991; McKenzie and Jackson, 1983; Jarrard, 1986; Dewey and Lamb, 1992). Plate-kinematic reconstructions for the southeast Pacific are well constrained for the time since 49 Ma and show a relatively simple history of dextral oblique subduction of the Farallon (Nazca) plate beneath the Chilean continental margin. The sole exception is the 26–20 Ma time span when convergence was nearly orthogonal, following the breakup of the Farallon plate (Fig. 1; Pilger, 1983; Pardo-Casas and Molnar, 1987).

By investigating the geometry, geology, paleomagnetism and kinematics of ancient or active intra-arc strike-slip fault systems (Fitch, 1972; Dewey, 1980; Beck, 1983, 1991; Jarrard, 1986; McCaffrey, 1992) it is possible to better understand deformation partitioning along obliquely converging plates.

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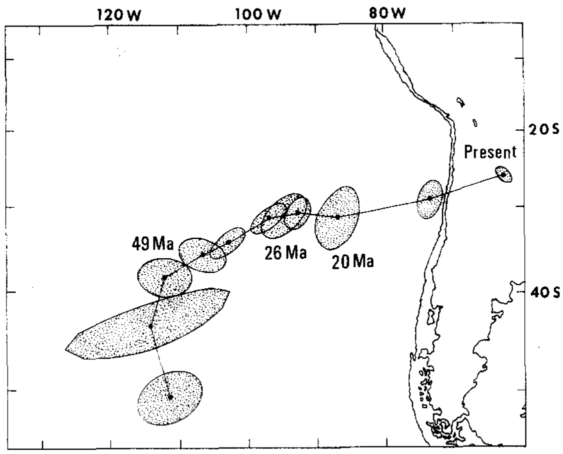


Fig. 1. Nazca–South America plate convergence for the Cenozoic, as illustrated by the trajectory of a point lying on the Nazca plate with respect to fixed South America (simplified from Pardo-Casas and Molnar, 1987).

Transtensional or transpressional tectonics are likely to be found along the magmatic arc, characterized by syntectonic pluton emplacement (Hutton, 1988; Paterson et al., 1989; Busby-Spera and Saleeby, 1990; Glazner, 1991) and by intra-arc oblique extension or shortening resulting in basin formation and uplift, respectively (Scheuber and Reutter, 1992).

Evidence of both transpressional and transtensional tectonics have been documented along the Liquiñe–Ofqui fault zone (LOFZ) of the southern Chilean Andes. The LOFZ is a 1000-km-long complex set of intra-arc lineaments (Fig. 2; Hervé, 1976, 1994; Hervé et al., 1979; Hervé and Thiele, 1987; Cembrano and Hervé, 1993). In this paper, the geometry, geology, paleomagnetism and kinematics of the LOFZ are discussed by integrating all available information and recently obtained data. A speculative tectonic model is proposed as a basis of further research.

## 2. Geometry

During the last two decades work on experimental and theoretical shear zone kinematics (Tchalenko, 1970; Sanderson and Marchini, 1984; Hempton and Neher, 1986; Naylor et al., 1986) and field tectonics (Crowell, 1974; Freund, 1974; Aydin and Nur, 1982; Woodcock and Fisher, 1986; White et al., 1986) stressed the importance of overall geometry and geologic setting in understanding the kinematics of fault systems. The LOFZ has received little attention in this regard; although descriptions are available for discrete segments of the LOFZ (Fuenzalida and Etchart, 1975; Hervé, 1976; Thiele et al., 1986; Cembrano, 1990), only two integrated schemes has been proposed to date (Hervé and Thiele, 1987; Hervé, 1994).

Therefore, a new attempt is made here to address the overall geometry of the LOFZ from the analysis of morphologic features and lineaments seen in areal photographs and satellite images, which might or might not correspond to unexplored faults in the field. Based on trend, length and shape, three types of well-defined lineaments have been identified (Fig. 2): (1) two NNE-trending, largely straight lineaments, which are hundreds of kilometers long; (2) at least four NE-trending, straight, en échelon lineaments whose lengths are of the order of tens of kilometers; and (3) three NNW-trending, curved lineaments which are hundreds of kilometers long and concave to the southwest.

The two straight lineaments run from 39 to 44°S and 44 to 47°S. They are offset by a right step located at 44°S and are connected by a series of en échelon lineaments along the right step. In contrast, the NNW-trending curved lineaments are located west of the straight lineaments from which they splay oceanward. This simple spatial arrangement is very similar to the idealized strike-slip geometry shown in Woodcock and Fisher (1986). The arrangement defined by the straight lineaments and the en échelon lineaments is identical to a strike-slip duplex (Fig. 2). Whether the duplex is extensional or contractional depends on the overall shear sense.

The spatial association of Quaternary volcanoes and main lineaments of the LOFZ is remarkable. While in the northern part most volcanoes are aligned parallel to the N–S-trending fault zone, the location of volcanic centers within the duplex is restricted to the NE-trending en échelon lineaments. A possible genetic relationship will be addressed below.

## 3. Geology

To fully describe the geology of the LOFZ is beyond the scope of this paper and can be found elsewhere (Hervé, 1976; Hervé et al., 1979, 1993; Parada et al., 1987; Cembrano, 1990). The synthesis presented here includes the most relevant characteristics of the LOFZ, particularly those having tectonic implications.

Perhaps the most conspicuous feature of the LOFZ

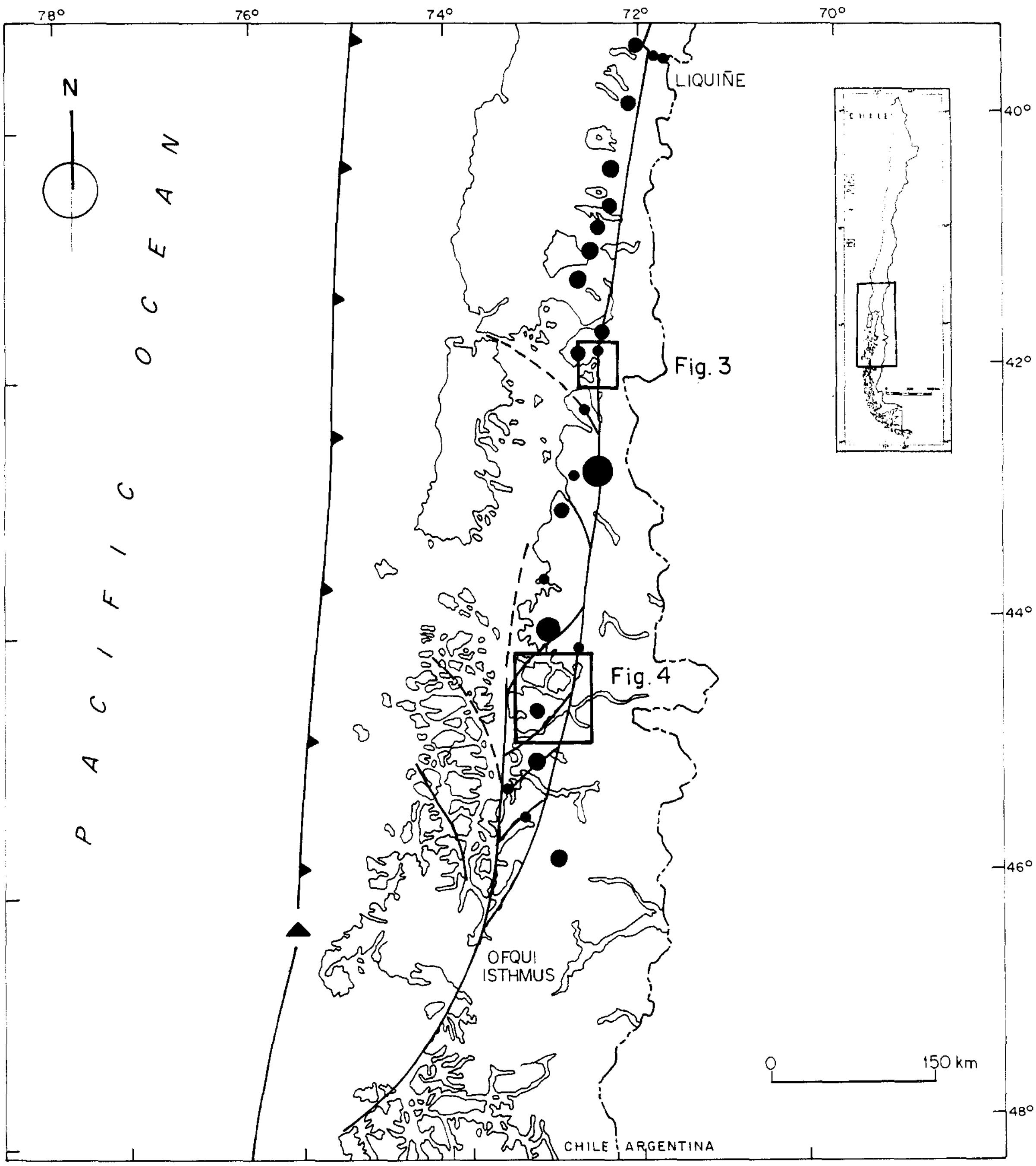


Fig. 2. Regional-scale geometry of the Liquiñe–Ofqui fault zone. Dots = Quaternary volcanoes, the size of the dot is roughly proportional to the volume of lava erupted; filled triangles = Nazca–South America–Antarctica triple junction.

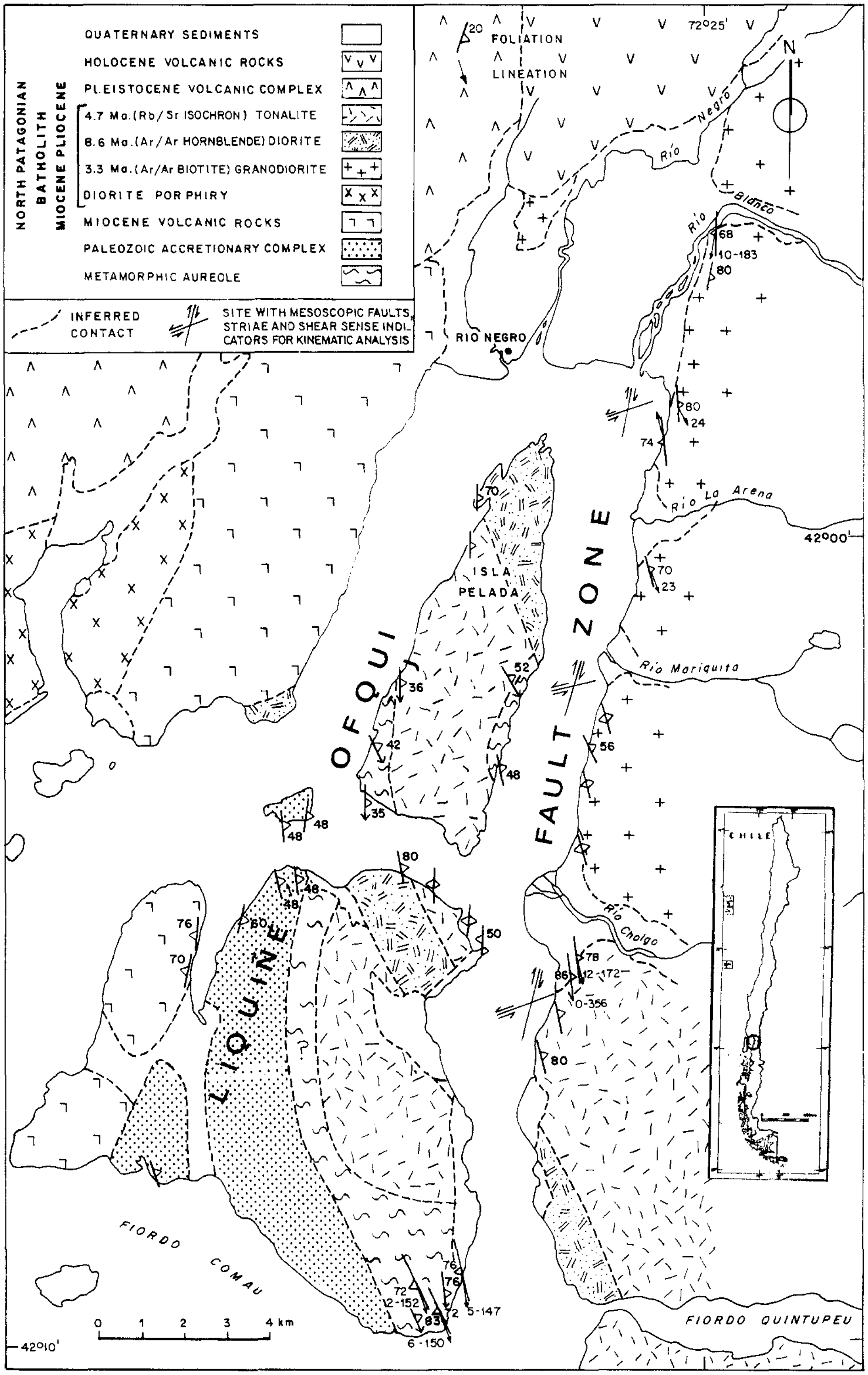


Fig. 3. Geology of the LOFZ at 42°S. Steep schistosity and subhorizontal mineral lineation shared by plutons and wall rock are oblique to the LOFZ trend. Modified from Hervé et al. (1979) and Cembrano (1992).

is the great heterogeneity regarding distribution, nature and intensity of rock deformation within the fault zone, although most rocks involved are tonalitic to granodioritic plutonic rocks, with minor metamorphic and volcano-sedimentary wall rock.

The intrusive rocks are part of the North Patagonian Batholith (NPB), a huge Meso-Cenozoic plutonic belt hundreds of kilometers long and tens of kilometers wide, between 39 and 47°S (Munizaga et al., 1988; Pankhurst et al., 1992). Rock fabric of the

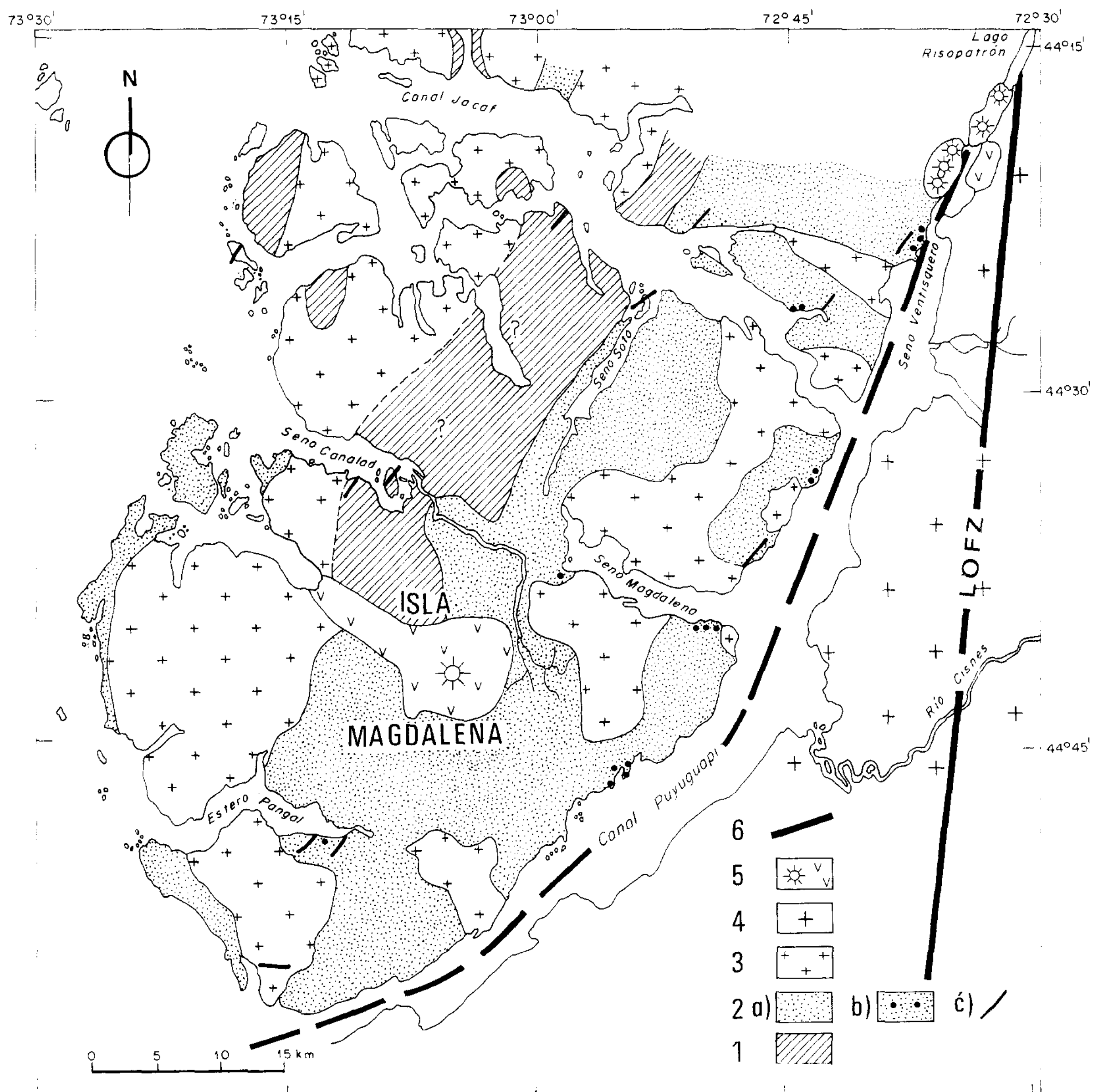


Fig. 4. Geologic sketch map of part of the LOFZ strike-slip duplex at Isla Magdalena (Hervé et al., 1993). *1* = metamorphic basement; *2* = Eocene–Miocene Traiguén Formation, (*a*) = volcano-sedimentary sequence, (*b*) = pillow basalts, (*c*) = dyke swarm locality; *3* = Miocene granitoid plutons; *4* = undifferentiated North Patagonian Batholith; *5* = Quaternary volcanic rocks and volcanoes; *6* = en échelon lineaments constraining the duplex.

NPB generally is isotropic, but isolated high strain zones are found along the LOFZ. These zones are as much as 2 km wide at the northern end of the LOFZ (Hervé, 1976). Generally they are centimeter-to-meter-scale highly deformed rocks within otherwise weakly to non-deformed rocks. The wall rock, when present, may be highly strained as at 42°S, where NNW-striking, steeply dipping foliations and subhorizontal mineral lineations extend into syntectonic Neogene plutons (Fig. 3; Cembrano, 1992). Post-Pliocene mesoscopic fractures and faults are superposed on the early ductile fabric with conspicuous subhorizontal striae on N–S-trending meter-scale faults.

Early Cenozoic volcaniclastic rocks and spatially associated dyke swarms, which have been grouped into the Traiguén Formation (Fuenzalida and Etchart, 1975; Hervé et al., 1993, 1995), crop out in close proximity to the strike-slip duplex described above (Fig. 4). Rocks of the Traiguén Formation are highly deformed along the southern straight lineament, where both steeply and shallowly dipping foliations have been described (Bartholomew, 1984).

## 4. Paleomagnetism

The LOFZ has been the subject of paleomagnetic investigations for the last decade (García et al., 1988; Cembrano et al., 1992; Rojas et al., 1994). Original search for evidence of large-scale (several hundred kilometers) N–S-directed transport analogous with

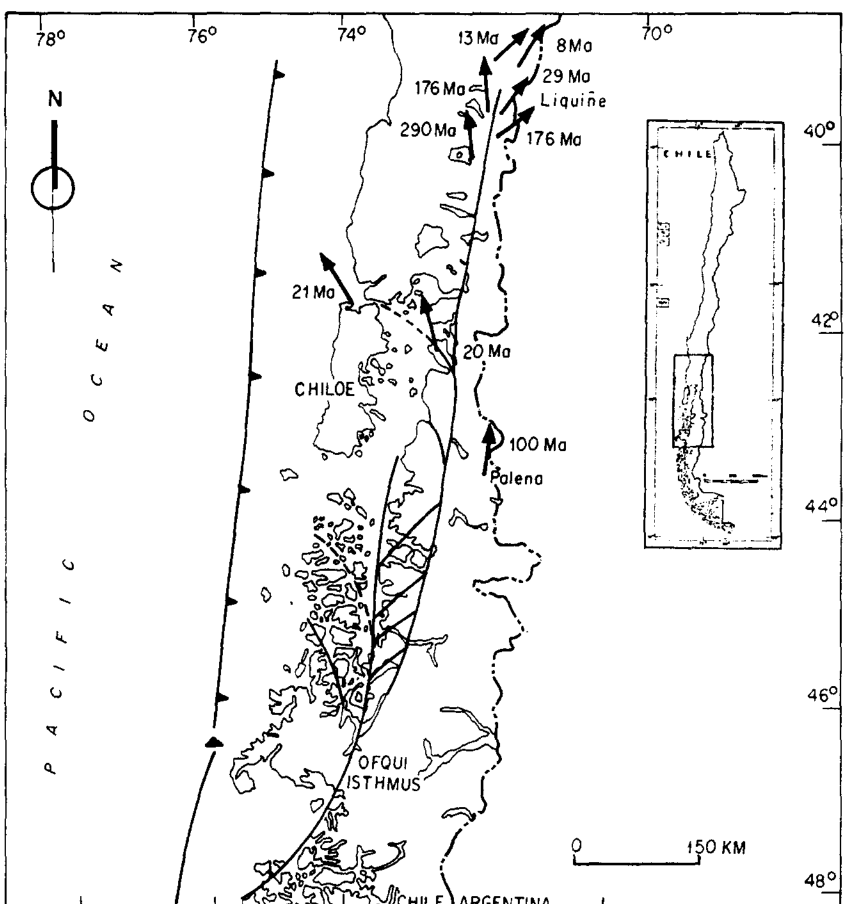


Fig. 5. Paleomagnetic rotations (small arrows) calculated from rock units of the southern Chilean Andes (García et al., 1988; Cembrano et al., 1992; Rojas et al., 1994). Counterclockwise rotations predominate to the west and clockwise rotations to the east of the LOFZ.

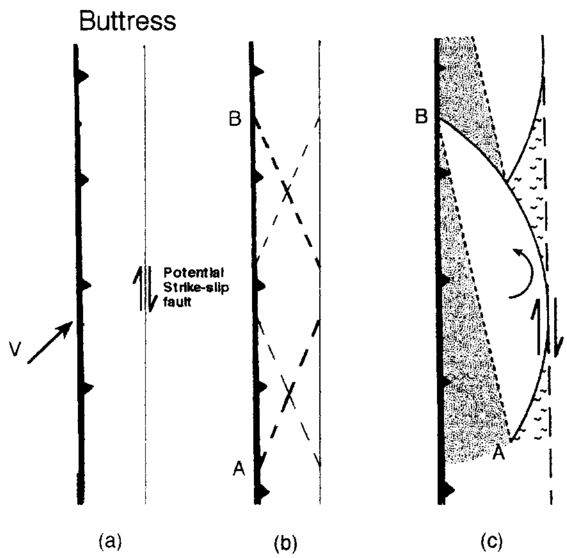


Fig. 6. Overcoming a buttress by widening the sliver (Beck et al., 1993; Rojas et al., 1994). (a) Sliver converges northward by oblique subduction but it is prevented from moving by a buttress. Trench is outlined by a thick, barbed line. Incipient master strike-slip fault shown by thin line. (b) Resulting shortening produces a system of fractures (dashed lines) with lens-shaped blocks developing along pre-existing shears. (c) Lens-shaped blocks move northward by rotating counterclockwise and overlapping one another, with widening of the sliver.

the US Western Cordillera (Beck, 1976, 1989), has demonstrated that such seems to be absent in the Chilean Andes (Beck et al., 1994). More recent research has focused on a puzzling pattern of block rotation (Fig. 5). Although the amount of data is limited, a clear pattern of counterclockwise rotation west of the LOFZ and clockwise rotation within and to the east of it is seen in Fig. 5.

The significance of counterclockwise rotations within the silver outboard of the trench-parallel strike-slip fault system is discussed in detail in Beck et al. (1993) and Rojas et al. (1994) in terms of a "buttressed fault system". The model (Fig. 6) calls for the counterclockwise rotation of half-lens-shaped blocks defined by curved faults west of the LOFZ. In response to a buttress (Beck et al., 1993) at the leading edge of a potentially detached outboard silver, the latter breaks into crescent-shaped blocks and potential northerly motion is mainly accomplished by counterclockwise rotation of the outboard blocks. However, very little northerly transport is required.

In contrast, the clockwise rotations within and to the east of the LOFZ may result from clockwise vorticity arising from dextrally oblique subduction (García et al., 1988; Beck, 1988; Cembrano et al., 1992).

## 5. Nature and timing of motion along the LOFZ

Very little is known regarding the nature and timing of motion along the LOFZ. Search for ductile and brittle kinematic indicators has recently started, but the available evidence to date is equivocal.

Possible sources of shear sense information in any fault zone include a direct source, such as offset markers or brittle/ductile kinematic indicators at the outcrop or thin section scale. Indirect sources, such as models of the tectonic regime and implied shear sense may also give valuable information but should be used with caution (i.e., spatial relationship between the overall orientation of extensional and contractional domains with respect to the shear zone orientation).

At this time regional-scale offset markers are unknown. This is not surprising for an intra-arc shear zone, where offsets markers are easily intruded or buried by continuous plutonic and/or volcanic activity (Jarrard, 1986; Sylvester, 1988).

### 5.1. Brittle and ductile kinematic indicators

Hervé (1976) studied a ca. 2-km-wide mylonitic belt at Liquiñe (39°S, Fig. 2). Based on a NNE-trending subvertical foliation and a "conjugate set" of NNE-trending dextral and ENE-trending sinistral mesoscopic faults within the mylonites, he proposed a dextral motion for the overall shear zone. Unfortunately, no mineral or stretching lineations were measured in the mylonites. An undeformed dyke cross-cutting the mylonites constrained the age of the deformation to sometime before the Oligocene (Hervé, 1976). Recent unpublished work (JC) on kinematic indicators in mylonites with subhorizontal mineral lineations has shown an apparently contradictory left-lateral shear sense (Fig. 7a). However, shear sense on brittle mesoscopic faults need not to be consistent with that obtained from earlier ductile crystal-plastic deformation fabrics.

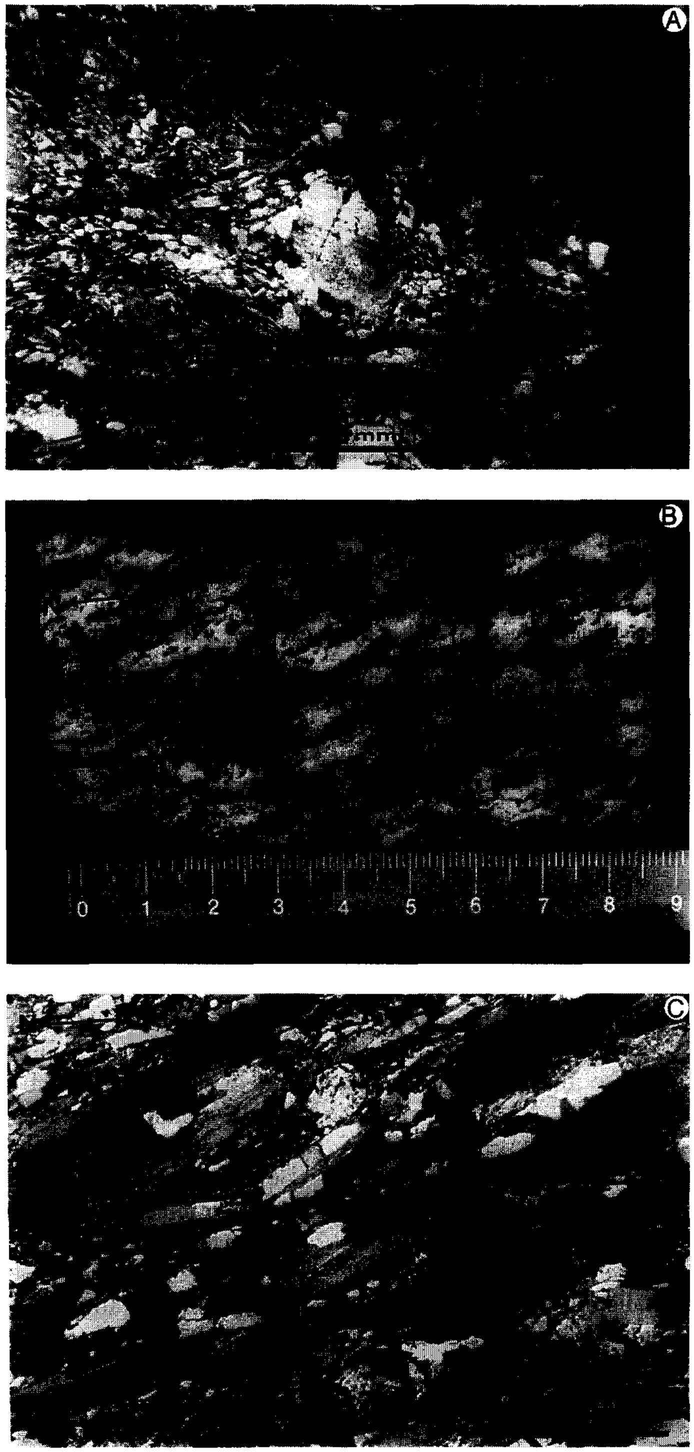


Fig. 7. Kinematic indicators in mylonites from the LOFZ. (a) Asymmetrical tails of recrystallized feldspar indicating sinistral shear. (b) Discrete shear bands oblique to schistosity on a *XZ* section of a 4.7 Ma tonalite of the LOFZ. Shear sense is dextral. (c) Mica fish in amphibolite facies mylonitic wall rock at 42°S. Shear sense is dextral. Photomicrographs (a) and (c) show *XZ* sections under crossed polars.

At 42°S weakly deformed Pliocene plutonic rocks intrude Paleozoic (?) metamorphic rocks. The geometric relationship between NNW-striking schistosity and N–S-trending shear bands observed at the outcrop scale in a 4.7 Ma tonalite indicates dextral shear (Fig. 7b). Kinematic indicators (Fig. 7c) found in the metamorphic wall rocks document dextral shear of possible late Cenozoic age if the plutonic rocks are considered to be syntectonic (Cembrano, 1992).

Ongoing investigations along two traverses crossing the LOFZ at 41 and 42°S have shown the existence of discrete structural domains within which brittle faults overprint early ductilely deformed Mio-Pliocene granitic rock. Centimeter-to-meter-scale subvertical faults with subhorizontal striae have been found in close spatial association with the main N–S-trending lineaments (Figs. 3 and 8). The two main sets of mesoscopic faults identified trend around north-northeast and N60°E and consistently show dextral and sinistral kinematic indicators, respectively (Fig. 8). A kinematic analysis applying the Carey Galhardis Mercier software (Carey, 1979; Carey and Brunier, 1974; Armijo et al., 1982), yields subhorizontal directions for the maximum and minimum principal stresses: $\sigma_1$ trends 232° and plunges 13°; $\sigma_2$ trends 45° and plunges 77°; and $\sigma_3$ trends 142° and plunges 2° (Fig. 8). The obtained stress tensor is compatible with a right-lateral deformation regime within a regional NNE-trending shear zone. Although preliminary, these data support brittle dextral faulting of the Mio-Pliocene granitic rocks along the LOFZ.

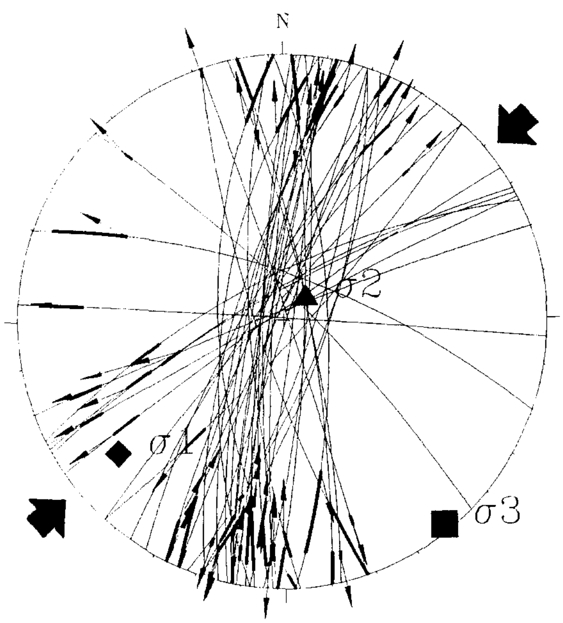


Fig. 8. Slip vector data from post-Pliocene strike-slip faults along the Liquiñe–Ofqui fault zone near Hornopirén used to compute the deviatoric stress tensor. $\sigma_1$ (compressional axis) = N232–13°; $R = 0.3$. Site location is shown in Fig. 3. Arrow attached to fault traces corresponds to the measured slip vectors (Wulff stereonet, lower hemisphere). Thick segments on the fault traces show deviations between measured and predicted slip vectors on each fault plane. Convergent large black arrows give azimuths of the computed maximum principal stress $\sigma_1$ direction. Azimuth is measured clockwise from north; dip is toward the measured azimuth. $R = \sigma_2 - \sigma_1 / \sigma_3 - \sigma_1$ is the "stress ratio" or "shape factor" of the stress tensor. Its value varies between 0 when $\sigma_2 \rightarrow \sigma_1$ and 1 as $\sigma_2 \rightarrow \sigma_3$. Fault kinematics are in good agreement with roughly NNE–SSW-trending shortening.

Both the spatial distribution of early Cenozoic basinal deposits and dykes (Hervé et al., 1993), most of which strike northeast, and the location of Recent volcanoes, coincide with the right step between the two straight lineaments at the strike-slip duplex. If such tectonic setting has been the result of NNW-directed extension oblique to the main NNE trend of the shear zone, the strike-slip duplex is extensional and the motion on the LOFZ right lateral, at least for two discrete time periods: for early Cenozoic basin formation and latest Cenozoic volcanic activity.

## 6. Plate reconstructions and LOFZ evolution

As already proposed in Pankhurst et al. (1992) the LOFZ may have initiated in the Mesozoic along the magmatic arc. Shear sense by that time is unknown but may have been sinistral as documented in pre-Oligocene mylonites of the northernmost LOFZ section. It is worth mentioning that the Atacama fault system in northern Chile also has revealed evidence for Early Cretaceous sinistral shear (Scheuber and Andriessen, 1990).

During Eocene–Miocene times (48–26 Ma), the Chilean Andes underwent right-oblique subduction at high rates (Pardo-Casas and Molnar, 1987). The LOFZ may have been either initiated or reactivated as a dextral strike-slip fault zone within the intruded and thus softer magmatic arc, the tectonic regime of which must have been transtensional. Development of Eocene–Miocene basins along extensional domains is well documented by the close spatial relationship between the Eocene–Miocene Traiguén Formation and the strike-slip duplex described above (Hervé et al., 1993).

During the Miocene, at ca. 26 Ma, a major plate reorganization led to head-on convergence, causing closure and underthrusting of the Eocene–Miocene basinal deposits beneath the plutonic complex (Bartholomew, 1984) and being followed by widespread calc-alkaline granitoid intrusive activity (Hervé et al., 1993).

At 20 Ma plate convergence became right-oblique again but at a smaller angle than in the early Cenozoic (Pardo-Casas and Molnar, 1987). The associated high convergence rate plus a very young buoyant subducting oceanic plate north of the Chile Ridge may have led to strong coupling with the upper plate. Slightly oblique convergence and strong coupling promoted dextral transpression along the magmatic arc (Jarrard, 1986; Beck, 1991). Heterogeneously deformed Mio-Pliocene plutonic rocks emplaced into highly deformed wall rock are the evidence of syntectonic intrusion within a transpressional tectonic regime for which rapid uplift and unroofing of plutonic rocks at rates in excess of 1 mm/yr has been documented by $^{40}Ar/^{39}Ar$ thermochronology on plutonic rocks (Hervé et al., 1993). For the Holocene, Hervé and Ota (1993) have documented uplift rates of more than 3 mm/yr within the fault zone.

## 7. Conclusions

The 1000-km-long Liquiñe–Ofqui fault zone (LOFZ) displays an overall spatial arrangement which matches very closely with an idealized strike-slip fault system including a duplex (Woodcock and Fisher, 1986). The close spatial coincidence of the LOFZ with the Miocene belt of the North Patagonian Batholith, the Quaternary volcanic chain and with the early Cenozoic basins is remarkable. The examination of high strain zones in plutonic rocks and metamorphic wall rocks within the LOFZ document mainly Miocene–Pliocene dextral strike-slip deformation accompanied by syntectonic pluton emplacement. According to plate motions modelling (Pardo-Casas and Molnar, 1987), it is reasonable to extrapolate such tectonic regime as far back as the Eocene–Miocene, when basin formation was to be expected within an extensional strike-slip duplex domain. However, the LOFZ activity may well go back into the Mesozoic, when deformation has been shown to have been sinistral along other Andean fault systems.

Paleomagnetism has not been able to demonstrate large-scale lateral motion along the LOFZ. However, paleomagnetic data have allowed to identify a block rotation pattern consistent with both the LOFZ geometry and the Cenozoic kinematics. Pliocene and/or post-Pliocene brittle dextral strike-slip deformation and Holocene high uplift rates characterize recent tectonics within the LOFZ.

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## References

Armijo, R., Carey, E. and Cisternas, A., 1982. The inverse problem in microtectonics and the separate tectonic phases. Tectonophysics, 82: 145–160.

Aydin, A. and Nur, A., 1982. Evolution of pull-apart basins and their scale independence. Tectonics, 1: 91–105.

Bartholomew, D.S., 1984. Geology and geochemistry of the Patagonian Batholith (45°–46°S), Chile. Ph.D. Thesis, Univ. Leicester (unpubl.).

Beck, M.E., 1976. Discordant paleomagnetic pole positions as evidence of regional shear in the Western Cordillera of North America. Am. J. Sci., 276: 694–705.

Beck, M.E., 1983. On the mechanism of tectonic transport in zones of oblique subduction. Tectonophysics, 93: 1–11.

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

Beck, M.E., 1989. Paleomagnetism of continental North America: Implications for displacement of crustal blocks within the WesternCordillera, Baja California to british Columbia. In: L.C. Pakiser and W.d. Mooney (Editors), Geophysical Framework of the Continental United States. Geol. Soc. Am. Mem., 172: 471–492.

Beck, M.E., 1991. Coastwise transport reconsidered: lateral displacements in oblique subduction zones, and tectonic consequences. Phys. Earth Planet. Inter., 68: 1–8.

Beck, M.E., Rojas, C. and Cembrano, J., 1993. On the nature of buttressing in margin-parallel strike-fault systems. Geology, 21: 755–758.

Beck, M.E., Burmester, R.F., Drake, R.E. and Riley, P.D., 1994. A tale of two continents: Some tectonic contrasts between the central Andes and the North American Cordillera, as illustrated by their paleomagnetic signatures. Tectonics, 13(1): 215–224.

Busby-Spera, C.J. and Saleeby, J.B., 1990. Intra-arc strike-slip fault exposed at batholithic levels in the southern Sierra Nevada, California. Geology, 18: 255–259.

Carey, E., 1979. Recherche des directions principales de contraintes associées au jeu d'une population de failles. Rev. Géogr. Phys. Géol. Dyn., 21(1): 57–66.

Carey, E. and Brunier, B., 1974. Analyse théorique d'un modèle mécanique élémentaire appliè à l'étude d'une population de failles. C. R. Acad. Sci. Paris, 279: 891–894.

Cembrano, J., 1990. Geología del Batolito Norpatagónico y de las rocas metamórficas de su margen occidental: 41°50′S–42°10′S. Thesis, Univ. Chile, Santiago, 67 pp. (unpubl.).

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. Comun. Univ. Chile, 43: 3–27.

Cembrano, J. and Hervé, F., 1993. The Liquiñe Ofqui Fault Zone: a major Cenozoic strike slip duplex in the Southern Andes. Second ISAG, Oxford, ORSTOM, pp. 175–178.

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

Crowell, J.C., 1974. Origin of Late Cenozoic basins in southern California. Spec. Publ., Soc. Econ. Paleontol. Mineral., 22: 190–204.

Dewey, J.F., 1980. Episodicity, sequence, and style at convergent plate boundaries. Geol. Assoc. Can., Spec. Pap., 20: 553–573.

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

Fitch, T.J., 1972. Plate convergence, transcurrent faults, and internal deformation adjacent to southeast Asia and the western Pacific. J. Geophys. Res., 77: 4432–4460.

Freund, R., 1974. Kinematics of transform and transcurrent faults. Tectonophysics, 21: 93–134.

Fuenzalida, R. and Etchart, H., 1975. Geología del territorio de Aysén comprendido entre los 43°45° y los 45° latitud Sur. Inst. Invest. Geol., Santiago, 99 pp.

García, A., Beck, M.E., Burmester, R.F., Hervé, F. and Munizaga, F., 1988. Paleomagnetic reconnaissance of the region de los Lagos, southern Chile, and its tectonic implications. Rev. Geol. Chile, 15: 13–30.

Glazner, A.F., 1991. Plutonism, oblique subduction, and continental growth: An example from the Mesozoic of California. Geology, 19: 784–786.

Hempton, M.R. and Neher, K., 1986. Experimental fracture, strain and subsidence patterns over en échelon strike-slip faults: implications for the structural evolution of pull-apart basins. J. Struct. Geol., 8: 597–605.

Hervé, M., 1976. Estudio geológico de la falla Liquiñe–Reloncaví en el área de Liquiñe; antecedentes de un movimiento transcurrente (Provincia de Valdivia). I Congr. Geol. Chil. Actas, 1: B39–B56.

Hervé, F., 1994. The southern Andes between 39° and 44°S latitude: the geological signature of a transpressive tectonic regime related to a magmatic arc. In: K.-J. Reutter, E. Scheuber and P.J. Wigger (Editors), Tectonics of the Southern Central Andes. Springer, Berlin, pp. 243–248.

Hervé, F. and Thiele, R., 1987. Estado de conocimiento de las megafallas en Chile y su significado tectónico. Comun. Univ. Chile, 38: 67–91.

Hervé, F. and Ota, Y., 1993. Fast Holocene uplift rates at the andes of Chiloé, southern Chile. Rev. Geol. Chile, 20(1): 15–23.

Hervé, F., Araya, E., Fuenzalida, J.L. and Solano, A., 1979. Edades radiométricas y tectónica neógena en el sector costero de Chiloé continental, X Región. II Congr. Geol. Chil. Actas, 1: F1–F8.

Hervé, F., Pankhurst, R.J., Suarez, M. and De la Cruz, R., 1993. Basic magmatism in a mid-Tertiary transtensional basin, Isla Magdalena, Aysen, Chile. Second ISAG, Oxford, ORSTOM, pp. 367–369.

Hervé, F., Pankhurst, R.J., Drake, R. and Beck, M.E., 1995. Pillow metabasalts in a mid-Tertiary extensional basin adjacent to the Liquiñe–Ofqui fault zone: the Isla Magdalena area, Aysén, Chile. J. S. Am. Earth Sci., 8(1): 33–46.

Hutton, D.H.W., 1988. Granite emplacement mechanisms and tectonic controls: inferences from deformation studies. Trans. R. Soc. Edinburgh Earth Sci., 79: 245–255.

Jarrard, R.D., 1986. Relations among subduction parameters. Rev. Geophys., 24(2): 217–284.

McCaffrey, R., 1992. Oblique plate convergence, slip vectors, and forearc deformation. J. Geophys. Res., 97(6): 8905–8915.

McKenzie, D. and Jackson, J., 1983. The relationship between strain rates, crustal thickening, paleomagnetism, finite strain and fault movements within a deforming zone. Earth Planet. Sci. Lett., 65: 182–202.

Munizaga, F., Hervé, F., Drake, R., Pankhurst, R., Brook, M. and Snelling, N., 1988. Geochronology of the lake region of south central Chile (39°–42°S): Preliminary results. J. S. Am. Earth Sci. 1: 309–316.

Naylor, M.A., Mandl, G. and Sijpesteijn, C.H.K., 1986. Fault geometries in basement-induced wrench faulting under different initial stress states. J. Struct. Geol., 8: 737–752.

Pankhurst, R., Hervé, F., Rojas, L. and Cembrano, J., 1992. Magmatism and tectonics in continental Chiloé, Chile (42° and 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. Rev. Bras. Geocienc., 17: 450–455.

Pardo-Casas, F. and Molnar, P., 1987. Relative motion of the Nazca (Farallon) and South American plates since Late Cretaceous times. Tectonics, 6: 233–248.

Paterson, S.R., Vernon, R.H. and Tobisch, O.T., 1989. A review of criteria for the identification of magmatic and tectonic foliations in granitoids. J. Struct. Geol., 11: 349–363.

Pilger, R.H., 1983. Kinematics of the South American subduction zone from global plate reconstructions. In: R. Cabre (Editor), Geodynamics of the Eastern Pacific Region and Caribbean and Scotia Arcs. Am. Geophys. Union, Geodyn. Ser., 9: 113–126.

Rojas, C., Beck, M.E., Burmester, R.F., Cembrano, J. and Hervé, F., 1994. Paleomagnetism of the Mid-Tertiary Ayacara Formation, southern Chile: counterclockwise rotation in a dextral shear zone. J. S. Am. Earth Sci., 7(1): 45–56.

Sanderson, D.J. and Marchini, W.R.D., 1984. Transpression. J. Struct. Geol., 6(5): 449–458.

Scheuber, E. and Andriessen, P.A.M., 1990. The kinematic and geodynamic significance of the Atacama Fault Zone, northern Chile. J. Struct. Geol., 12: 243–257.

Scheuber, E. and Reutter, K.-J., 1992. Magmatic arc tectonics in the Central Andes between 21° and 25°S. Tectonophysics, 205: 127–140.

Sylvester, A.G., 1988. Strike-slip faults. Geol. Soc. Am. Bull., 100: 1666–1703.

Thiele, R., Hervé, F., Parada, M.A. and Godoy, E., 1986. La megafalla Liquiñe-Ofqui en fiordo Reloncaví (41°30 1/2S), Chile. Comun. Univ. Chile, 37: 31–44.

Tchalenko, J.S., 1970. Similarities between shear zones of different magnitudes. Bull. Geol. Soc. Am., 81: 1625–1640.

White, S.H., Bretan, P.G. and Rutter, E.H., 1986. Fault-zone reactivation: kinematics and mechanisms. Philos. Trans. R. Soc. London, Ser. A, 317: 81–97.

Woodcock, N.H. and Fisher, M., 1986. Strike-slip duplexes. J. Struct. Geol., 8(7): 725–735.