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Structural characterization of the Magallanes-Fagnano transform fault, Tierra del Fuego, South America

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ABSTRACT

Structural analyses in the area of Fagnano and Deseado lakes show different deformational events that took place in the southernmost South America. The compressional structures represent at least two deformational episodes associated with the Upper Cretaceous Andean Orogeny. A series of NE-vergent thrust faults, product of this compression, show that these faults have accommodate some sinistral motion during Upper Cretaceous times. The NE orientation of reverse faults in the Monte Hope area may indicate the later rotation of these faults by the left-lateral strike-slip motion of the Magallanes-Fagnano fault. The secondary faults of the Deseado and Magallanes-Fagnano fault zones fit quiet well with the Riedel shear model, and some of the normal faults cut the Quaternary sediments, indicating a recent activity. These faults may be the evidence of a significant extensional component of the transcurrent system.

KEY WORDS: Active fault, Andean Orogenesis, Southernmost South America, Transcurrent regime.

INTRODUCTION

The central area of the Tierra del Fuego Island is an interesting region in a geological point of view, as it preserves the evidence of a long geologic history and a tectonic activity that extends until today. Since the Middle Jurassic, a generalized extensional event, associated with the drift of the southern Gondwana, led to the development of the Rocas Verdes marginal basin along the southernmost Pacific margin (Dalziel et al., 1974; Uliana & Biddle, 1987). This basin appears as a 1000 km-long NW-SE-oriented belt of mafic rocks, interpreted as part of quasi-oceanic crust, associated with a silicic magmatism product of the lithospheric thinning and continental rifting (Dalziel et al., 1974; Bruhn et al., 1978).

The variation in the drift motion of the plates resulted in a new regional compressive tectonic regime that led to the Andean Orogenesis. Since the Late Cretaceous onwards, the Andean compression was responsible for closure, shortening and inversion of the Rocas Verdes basin, and the development of the northeast-vergent Magallanes fold-and-thrust belt and the Magallanes Foreland basin (fig.1a) (Dalziel et al., 1974; Nelson et al., 1980; Cunningham, 1995).

Successively, since the Oligocene, the region was affected by a transcurrent regime and associated sinistral strike-slip faults as a result of the Weddell Sea rifting and, particularly, the Scotia Plate formation. The present-day South America-Scotia plate boundary is mostly represented by the Magallanes-Fagnano and Deseado fault zones (fig.1a,b) (Dalziel, 1989; Winslow, 1982; Klepeis, 1994b; Lodolo et al., 2003; Cenni et al., 2006; Menichetti et al., 2007).

GEOLOGICAL SETTING

The area located between the Fagnano and Deseado lakes is included in the Magallanes fold-and-thrust belt (fig.1a), one of the several geologic provinces in the region of Tierra del Fuego Island (Winslow, 1982).

The oldest outcropping stratigraphic unit in the area is the Middle Triassic Tobífera Formation (fig.1b) (Thomas, 1949), mostly composed of crystal and vitric rhyolitic/dacitic tuffs and volcaniclastic rocks, and well exposed in the Fuegian Andes hinterland thrust sheets. The primary textures and mineralogy, were variably overprinted by sea-floor metamorphism (during the extensional stage) and later reworked by the Andean Orogenesis, responsible for the very low to low-grade metamorphism that affected the rocks.

The Tobífera Formation represent the Rocas Verdes marginal basin infill, together with the overlying marine sedimentary and volcaniclastic deposits of Río Jackson (Cortés & Valenzuela, 1960; Klepeis, 1994a) and La Paciencia (Cortés & Valenzuela, 1960) Formations. The Upper Cretaceous sedimentary rocks of the Cerro Matrero Formation (Cortés & Valenzuela, 1960) complete the stratigraphy, and represent the beginning of the foreland sedimentation in the Magallanes basin (Winslow, 1982).

Between the Lower Cretaceous succession and the Lemaire Formation, the thrust detachment levels of the principal structures are located (fig.1d).

The structures associated with the Tertiary-Quaternary transcurrent system, reactivate and cut precedent contractional structures.

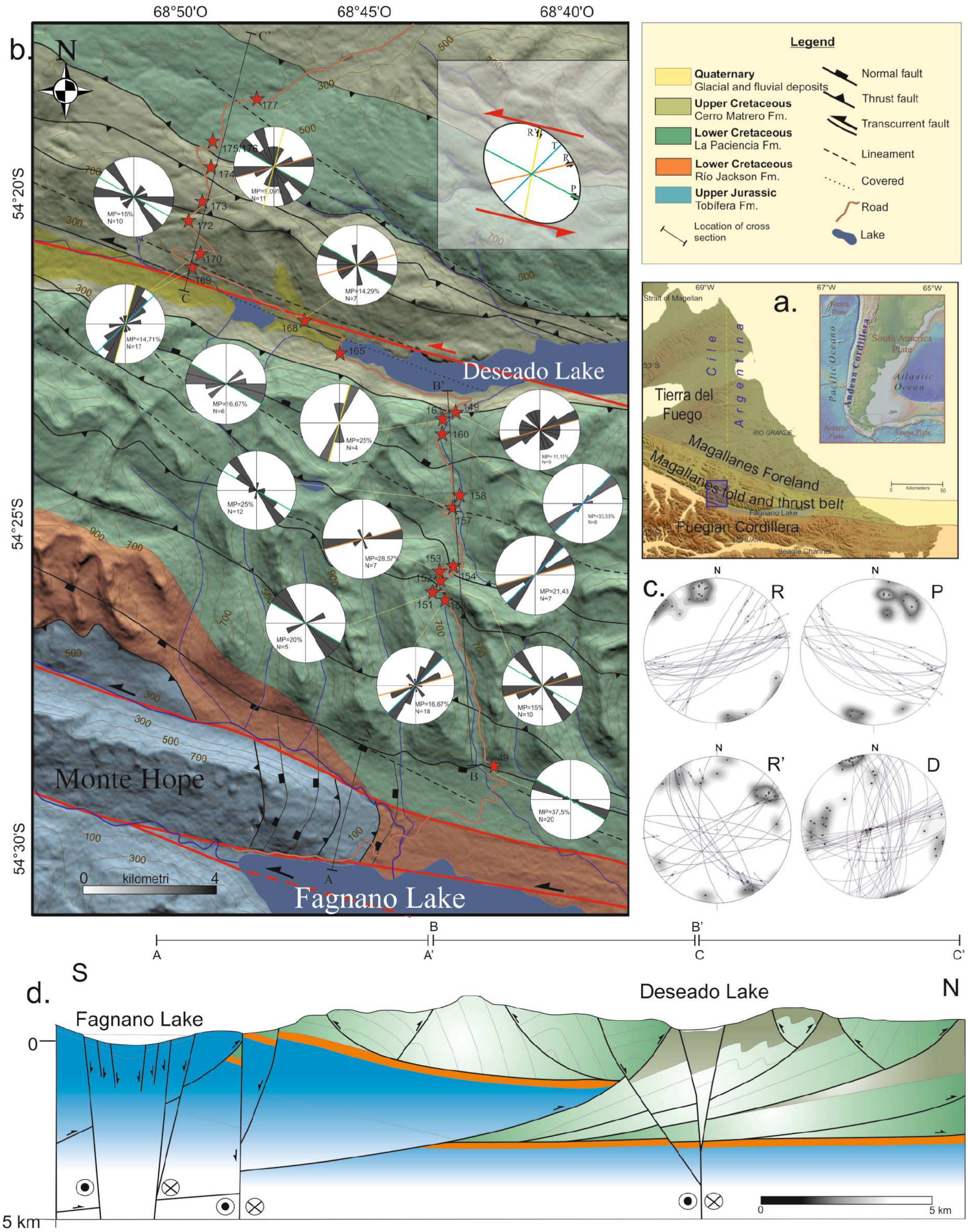

Fig. 1 – a) Map of Tierra del Fuego Island; violet rectangle indicates the studied area, located within the Magallanes fold-and-thrust belt. Inset box shows the current plate boundaries in the southern South America region. b) Geologic map of the western areas of the Deseado and Fagnano lakes. Geology was derived from field work conducted by the authors and other sources (Klepeis, 1994a,b; Zanolla et al., 2011). Stars represent the structural sites of measurements. The faults associated with the Deseado and Magallanes-Fagnano fault zones are analyzed as Riedel shear structures according to a left-lateral strike-slip model. The number of faults (N), the maximum percentage (MP) and the secondary R, P, R' and T Riedel shears are indicated within each rose. The trace of the cross section of figure 1d is indicated. c) Stereoplots of R and P sinistral and dextral (R') faults of the whole investigate area, and stereoplots of the normal faults (D) of the Monte Hope area. d) Cross section of the transect shown in Figure 1b. No vertical exaggeration.

Fig. 2 – Normal fault cutting Quaternary glacio-lacustrine deposits.

ANDEAN COMPRESSIONAL STRUCTURES

In the Monte Hope area, the rocks of the Tobífera and Río Jackson Formations are well exposed in the northern margin of the Fagnano Lake (fig.1b). Here, the rocks are deformed by two superposed foliations. The first cleavage S1, defined by preferred alignment of laminar minerals, dips to the SSE with angles between 60° to 30°, and is axial planar to the F1 folds. The F1 open symmetrical anticlines, fold the S0 bedding planes of the mentioned units with wavelengths of about 1 meter. The cleavage S1 and a series of quartz veins that parallel S1, are deformed by kink bands and north vergent F2 kink folds. These folds are small, asymmetric and open, with gently ENE-to-ESE plunging axes. A second subvertical S2 foliation cuts the first one. It is a discontinuous, poorly defined and moderately spaced E-W trending cleavage.

Along the northwestern shore of the Fagnano Lake, a series of SW-striking and steeply NW dipping reverse faults deform the volcanic-volcaniclastic rocks of the Tobífera Formation into decimeter thick cataclastic zones, and uplift these rocks over those of the Río Jackson Formation (fig.1b). A second subvertical to steeply south dipping population of reverse faults trending in an E-W direction, cut the first one. The slickenside striae and further kinematic indicators show a reverse slip with a minor component of sinistral motion. These faults seem to be associated with and parallel to the S2 cleavage.

North of the Fagnano Lake, the bedding planes in Lower Cretaceous rocks dip to the north (fig.1d) probably as result of the development of a wide-scale fold situated 10 km to the south, denominated Cerro Verde anticline (Klepeis, 1994a,b).

Two important back thrusts, and associated secondary north vergent thrust, deform the layers of the La Paciencia Formation into decametric anticline folds. A finely spaced cleavage that steeply dips to the south is observed. A north vergent thrust fault that uplift the slates of the La Paciencia Formation over the younger Cerro Matrero Formation is observed in the southern shore of the Deseado Lake. Furthermore, the northern area of the lake is characterized by the presence of near vertical to steeply SW dipping reverse faults, that deform cataclastically the Lower Cretaceous rocks, and cut open anticlines and synclines folds. The alternation between subvertical NNW dipping and moderately south dipping beddings planes is interpreted as a larger-scale N-NNE vergent folds series, associated with the deep thrust fault (fig.1d). A near vertical to steeply W-to-NW dipping cleavage, defined by the preferred alignment of laminar minerals, deform the Upper Cretaceous rocks.

Towards the foreland, a system of thrust and back thrust put in tectonic contact the rocks of the La Paciencia with those of the Cerro Matrero Formation.

Steeply SE dipping reverse faults with a small sinistral component of movement, are also part of the compressive structures.

TRASCURRENT STRUCTURES

The Lago Deseado fault zone is a ESE trending active structure that extends over several kilometers with significant morphostructural evidences (Klepeis, 1994b). It lies in the valley filled with glacio-lacustrine and fluvial sediments situated west of the Deseado Lake (fig.1b). On the other hand, the Magallanes-Fagnano fault zone is a 600-km-long left-lateral transform system that traverse the whole Tierra del Fuego Island, and is the principal segment of the South America-Scotia plate boundary.

The measurable structures associated with the mentioned fault zones are predominantly sinistral strike-slip and normal faults that reactivate and cut the compressive structures developed during the Andean Orogenesis. Subvertical to steeply SE and NW dipping sinistral faults trending in a NE direction, deform the Cretaceous succession. These include largely left-lateral strike-slip faults and oblique-slip faults with a normal component of movement (rakes near 20°). Faults dipping 50° to 70° to the SSW, and near-vertical NNE dipping faults, integrate a second group of sinistral faults. As in the previous ones, the striae indicate a minor normal component of movement. Subvertical dextral faults, located in proximity to the Deseado Lake, dip predominantly to the SW, with minor NW and SE dipping faults.

The orientation and sense of movement of the faults seem to represent a Riedel shear geometry (fig.1b,c) (Riedel, 1929; Tchalenko, 1970). The first group of faults is synthetic to the main faults and may be assigned to the secondary R Riedel shears, according to a sinistral shear model. Furthermore, the second group of sinistral faults correspond to the synthetic P Riedel shear, while the right-lateral strike-slip should represent the antithetic R' secondary system, which is not very clear (fig.1b,c).

The moderately E to SSE dipping normal faults (fig.1c) include those with predominant slip-dip movement and the faults with non recognizable striae. Some of these faults cut the quaternary glacio-lacustrine and detrital deposits (fig.2), indicating a recent activity.

Within the studied area, the northernmost segment of the Magallanes-Fagnano fault extends along the northern shore of the Fagnano Lake (fig.1b). Here, the normal faults can be separated in two populations. The first one includes near-vertical E-NE oriented faults, which cut the cleavages and reverse faults that deform the rocks of the Tobífera Formation. The faults and normal shear zones of the second population dip moderately to almost vertically to the E (fig.1c).

DISCUSSION

The new data obtained in the region of the Deseado and Fagnano lakes, reflect the activity of different tectonic events that have occurred in the last 100 Ma.

The temporal relation between the compressive structures, like cleavages and folds, suggests the existence of at least two deformational events associated with the Andean Orogenesis. The two populations of reverse faults recognized in the Monte Hope area, may also represent these two different moments during the north migration of the deformation and development of the fold and thrust belt. The NE strike of the first population, may be the result of later rotation of these faults by the sinistral strike-slip motion of the Magallanes-Fagnano fault. The reverse faults of the second population confirm the participation of a sinistral strike-slip component during the compression (Cunningham, 1993).

The secondary transcurrent faults can be explained according the Riedel shear model, although the dextral faults do not precisely fit. The normal faults that deform the Quaternary deposits may represent an important extensional component associated with the general Oligo-Miocene transcurrent regime. Evidence of this distension is found throughout the Fuegian Cordillera.

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