TERTIARY KINEMATICS OF THE SOUTHERN ANDES AND THE DEVELOPMENT OF THE MAGELLAN FORELAND BASIN (PATAGONIA).

Marc DIRAISON[1], Peter R. COBBOLD[1], Denis GAPAIS[1], Eduardo A. ROSSELLO[2]

[1] Géosciences-Rennes (UPR 4661 du CNRS), Université de Rennes I, 35042 RENNES Cedex, France
[2] CONICET and Universidad de Buenos Aires, Departamento de Ciencias Geológicas, Ciudad Universitaria, 1428 Buenos Aires, República Argentina

KEY WORDS: Southern Andes, Magellan Basin, Fault kinematics, Modelling.

INTRODUCTION AND GEOLOGICAL SETTING

Between the Patagonian Cordillera (trending N-S) and the Darwin Cordillera (trending E-W), the Southern Andes form an arc. This bounds the Magellan Basin on its western and southern sides (Fig. 1). Both arc and basin result from complex tectonics at the southwestern margin of Gondwana since the Late Triassic (Rapela & Pankhusrt, 1992, Storey, 1993). The basin has been through three main stages. First, a stage of regional extension (Triassic to Early Cretaceous), contemporaneous with early opening of the Southern Atlantic, formed a rift system trending NNW and led to opening of the Magellan back-arc basin (Dalziel, 1974). Second, during the Late Cretaceous, closure of the back-arc basin coincided with changes in the plate tectonics. The closure was associted with uplift of the Cordillera and thermal subsidence of the Magellan Basin (Nelson, 1982). Third, during the Tertiary, the Magellan Foreland Basin formed and deformation propagated cratonward, via a fold-and-thrust belt (Winslow, 1982, Alvarez-Marrón et al., 1993). The sedimentary infill of the basin, synchronous with deformation, is locally as much as 8 km thick. The distribution of Tertiary sediments shows a degree of mirror symmetry about the Magellan Straits (Fig. 1).

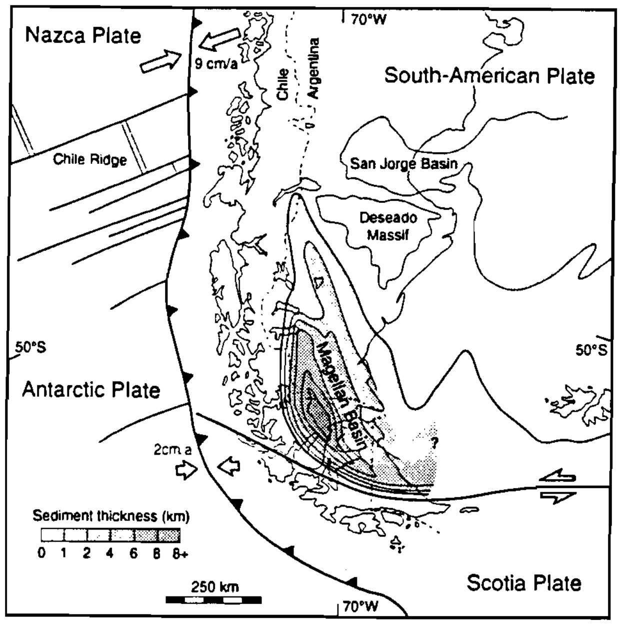

Figure 1: Map of southern South America showing tectonic setting with adjacent oceanic plates. Grey arrows indicate relative motions between plates. Sediment thicknesses in Magellan Basin are indicated in shades of grey (modified from Ramos, 1989).

We present a structural interpretation of the area, based on field observations, satellite imagery, kinematic analysis of fault data and analogue models.

FAULT KINEMATICS

We have measured over 1500 striated fault planes at 74 localities between lake Buenos Aires and Tierra del Fuego (Fig. 2). Localities are either in basement rocks or in their Mesozoic and Cenozoic cover and they are mainly along the southwestern edge of the basin. A graphical and kinematic method has been used to analyse fault-slip data. Results show that (1) the principal directions of shortening are sub-horizontal and strike sub-perpendicularly to the Cordillera, (2) the principal directions of extension are also sub-horizontal and (3) strain ellipsoids are estimated to be mainly of plane-strain to flattening type at regional scale (Fig. 2).

At outcrop scale, fault-slip data provide information on the relative proportions of strike-slip and dip-slip faulting. Strike-slip is dominant, either right-lateral and trending N along the Patagonian Cordillera or left-lateral and trending E along Cordillera Darwin. These observations are consistent with strike-slip faults interpreted on satellite imagery. We have also found normal faults trending perpendicularly to the Cordillera, especially along lakes Viedma and Argentino, and, most important, along the Magellan Straits.

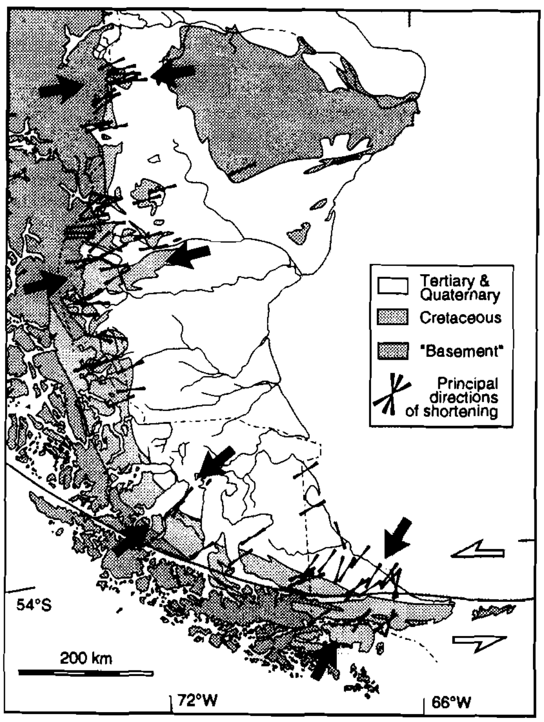

Figure 2: Schematic geological map with results of kinematic fault analyses at 74 localities. Small black arrows indicate calculated shortening directions. Large dark arrows summarize regional trends.

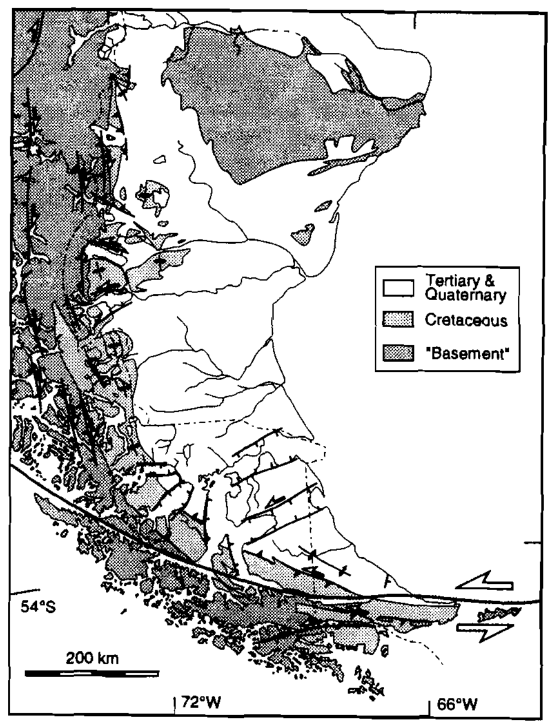

Figure 3: Schematic geological and structural map of studied area. Major reverse faults in Chilean Cordillera are partly from Landsat interpretation.

REGIONAL STRUCTURES

Major folds and thrusts have long been recognized in the Cordillera and its foothills next to the Magellan Basin (Servicio Nacional de Geología y Minería, 1980). Strike-slip faults have been less documented. A few left-lateral ones have been described in Cordillera Darwin (Cunningham, 1993, Klepeis, 1994) and the right-lateral Liquiñe-Ofqui fault system has been documented in the field and from satellite imagery in the Patagonian Andes north of latitude 45° S. Our own studies have revealed other strike-slip fault systems, including left-lateral ones, both ductile and brittle, in the Cordillera of Tierra del Fuego (Argentina) and right-lateral ones in the foothills of the Patagonian Cordillera. Using geological maps, satellite images and field observations, we have compiled a schematic map of major faults and folds (Fig. 3). Major thrusts are sub-parallel to the Cordillera but have strike-slip components. Of greatest novelty are grabens and half-grabens of Tertiary age which accommodate extension in directions sub-parallel to the Cordillera. Prominent examples lying along the Magellan Straits have partially separated Tierra del Fuego from the mainland. Some normal faults also have components of strike-slip, depending on their trends.

Some of the major Tertiary structures are reactivated faults of Mesozoic age or possibly older.

ANALOGUE MODELS

We have investigated the plate tectonics of southern South America and the possibility of inducing deformation at its southern tip, using analogue models at fully lithospheric scale. Brittle upper crust was modelled with dry sand; ductile lower continental crust and lithosperic mantle, with silicone putties of appropriate viscosities and densities. For oceanic lithosphere, the ductile lower crust was omitted. The model lithosphere floated on a less viscous asthenosphere. Continental South America was given a rectangular shape with a rounded corner. Horizontal forces and velocities were applied in a given direction to the oceanic plate, to simulate spreading at a mid-oceanic ridge.

During the experiments, subduction initiated spontaneously at the western continental margin sub-perpendicular to the applied convergence. The oceanic plate subducted at a low angle and the adjacent continent became folded at lithospheric scale. In contrast, at the southern margin, deformation was transpressive and more localized. In some experiments, rifts developed at the corner of the continent and the blocks between them underwent rotations about vertical axes. These preliminary results are consistent with structural observations made in the field and with our analyses of fault-slip data.

CONCLUSIONS

In the southern Andes and Magellan Basin, the observed structural pattern is consistent with the complex tectonic context of southern South America. Deformation within the continent is due to relative motions between the Nazca, Antractic, Scotia and South American plates. The deformation includes shortening in directions subperpendicular to the mountain belts and also components of strike-slip: right-lateral along the Southern Patagonian Andes and left-lateral along Cordillera Darwin. Between them, stretching along the arc has resulted in the formation of rift valleys.

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