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# Microstructures and seismic properties of south Patagonian mantle xenoliths (Gobernador Gregores and Pali Aike)

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ABSTRACT

The subcontinental lithospheric mantle evolves through time due to tectonic events and processes as static recrystallization and melt percolation. To constrain the extent of these processes in the South Patagonian subcontinental mantle lithosphere we performed a microstructural and Electron Backscattered Diffraction (EBSD) study of a suite of 35 peridotite xenoliths brought to the surface by Plio-Pleistocene alkaline volcanic rocks from Gobernador Gregores and Pali Aike. All samples show a well-developed olivine and pyroxene crystallographic preferred orientation (CPO), consistent with deformation by dislocation creep with dominant activation of [100]{0kl} in olivine. The coarse granular or tabular textures and the low density of intracrystalline deformation features indicate that deformation was followed by annealing under static conditions. The xenoliths also show microstructural evidence of multiple episodes of reactive melt percolation. Neither annealing nor melt percolation erased the olivine CPO, which has [010]-fiber, [100]-fiber and orthorhombic patterns in Pali Aike xenoliths and essentially [010]-fiber and orthorhombic patterns in Gobernador Gregores xenoliths. Seismic properties calculated based on the CPO and modal compositions are, however, rather homogeneous, with fast S-wave polarization and P-wave propagation parallel to the [100] olivine axis. The variation in the olivine CPO solely changes the minimum S-wave birefringence direction, which is normal to the foliation for axial-[010] olivine CPO. Average samples for the two localities, obtained by adding up the individual samples CPO data in a common reference frame, show, however, a 'normal' upper mantle anisotropy with a maximum S-wave birrenfringence of ca. 5% at high angle to the both the maximum [010] and [100] axes concentrations, that is in the foliation, but normal to the lineation, and a minimum birefringence at low angle to the [100] maximum, that is parallel to the lineation.

## 1. Introduction

The formation and evolution of the subcontinental lithospheric mantle are still poorly understood. Seismic tomography and anisotropy allow probing its structure (Hess, 1964; Aki et al., 1977; Dziewonski et al., 1977), but the interpretation of these data in terms of thermal structure, compositional heterogeneity, and deformation history is not straightforward. Seismic velocity anomalies may result from both thermal heterogeneity and compositional heterogeneity. Anisotropy is directly related to the crystal preferred orientation (CPO) of olivine, which is produced by deformation in the upper mantle (e.g. Christensen, 1971; Mainprice, 2007; Nicolas and Christensen, 1987). The moderate temperatures that prevail in most of the lithospheric mantle allow the olivine CPO formed during major tectonic episodes to be preserved for very long time spans (e.g., Vauchez et al., 2005). However, are these CPO modified by processes such as heating leading to static recrystallization or melt percolation in the lithospheric mantle?

In this contribution, we studied the microstructures and CPO of olivine and pyroxenes in a collection of 35 mantle xenoliths from two volcanic localities in Southern Patagonia: Gobernador Gregores and Pali Aike (Fig. 1). These xenoliths sample the Patagonian mantle lithosphere, which underwent a complex geodynamic evolution in response to the various compressional and extensional events that affected its western and eastern margins. The analysis of the microstructures and CPO allowed partially deciphering the succession of deformation, thermal, and reactive melt percolation episodes that affected these peridotites. The modal composition, the olivine, orthopyroxene and clinopyroxene CPO data, and the equilibration temperatures and pressures from Dantas (2007) were used to calculate the seismic properties of these xenoliths and estimate the seismic anisotropy, composition and thermal state of the southern Patagonia mantle lithosphere in the vicinity of the two localities.

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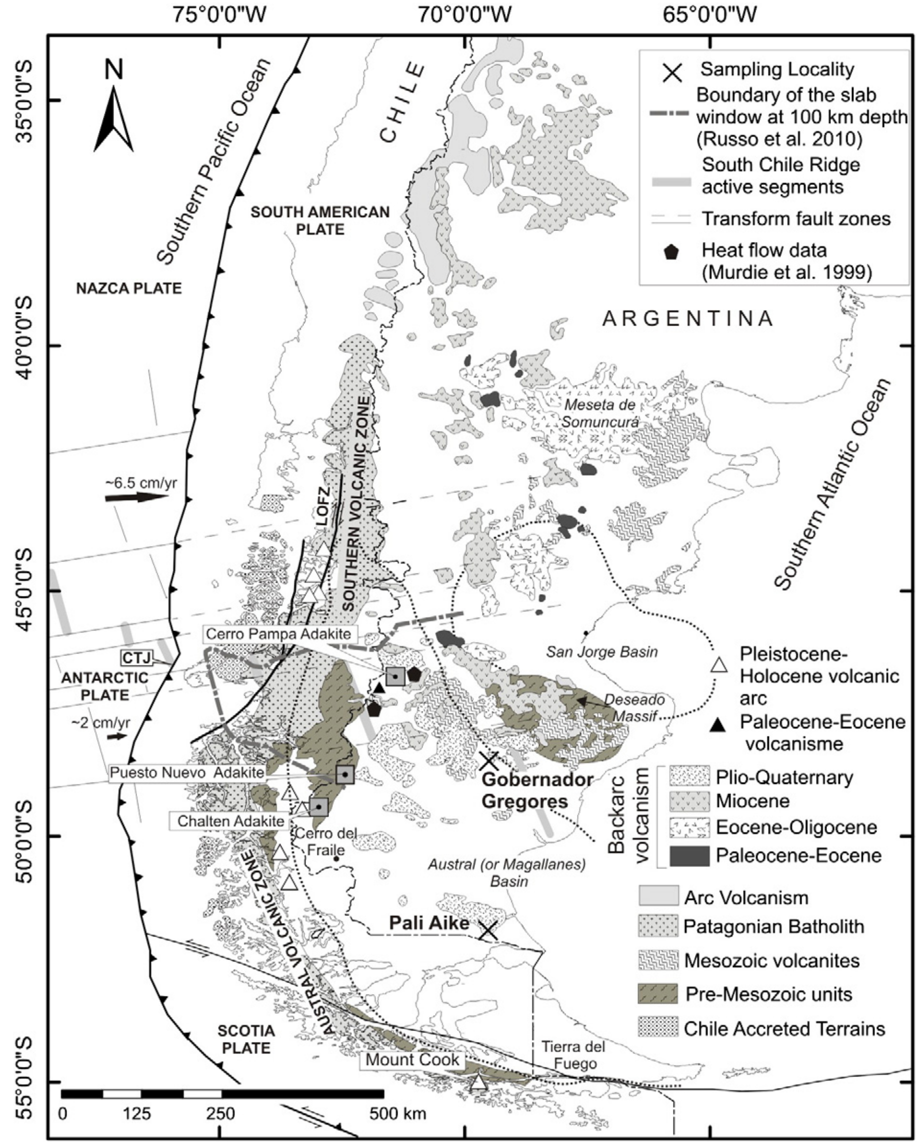

**Fig. 1.** Map showing the location of the xenolith-bearing localities relative to the main tectonic structures and geological units of Southern Patagonia. Modified from Ramos and Kay (1992), Kay et al. (1993), Lagabrielle et al. (2004), Ramos et al. (2004), Ramos (2008), Russo et al. (2010b), Castro et al. (2011). CTJ: Chile Triple Junction, LOFZ: Liquiñe–Ofqui Fault Zone.

## 2. Geodynamic setting

The southern Patagonia mantle lithosphere is at least as old as the late Proterozoic (Schilling et al., 2008). Late Proterozoic ages are also recorded in the crust. The Deseado Massif records rifting from Gondwana in the late Proterozoic to early Cambrian and re-accretion to it in the Carboniferous (Dalla Salda et al., 1992; Pankhurst et al., 2003, 2006, Fig. 1). In addition, ~530 Ma old orthogneisses were recovered from wells in northern Tierra de Fuego (Söllner et al., 2000).

More recently, two major geodynamic events affected the eastern and western margins of Patagonia: the opening of the South Atlantic and the Andean subduction, respectively. The breakup of Gondwana, which led to the opening of the South Atlantic during the Cretaceous, resulted in extension and voluminous rhyolitic volcanism in southern Patagonia ("Mesozoic volcanism" in Fig. 1, e.g., Pankhurst and Rapela, 1995; Pankhurst et al., 1998, 2000). Since then, the eastern margin of Patagonia has been dominated by subsidence and sedimentation, which formed the Austral (or Magallanes) basin (Fig. 1).

The eastward subduction along the western margin of Patagonia has been active since late Paleozoic times (e.g., Mpodozis and Ramos, 1989). This long-lived subduction has migrated and changed orientation through time (Mpodozis and Ramos, 2008; Rapela et al., 2005), attaining the present location (Fig. 1) in the late Jurassic (Breitsprecher and Thorkelson, 2009; Somoza and Ghidella, 2012). At ~14–15 Ma, the Chile ridge, which accommodates spreading between the Nazca and Antartic plates, collided with the trench forming the Chile Triple Junction (Cande and Leslie, 1986), which has since then migrated northward, being presently at 46.5° S (Fig. 1).

The Chile Triple Junction is characterized by a large negative Bouguer anomaly, interpreted as associated with upwelling of hot mantle in an asthenospheric window (Murdie, 1994; Murdie et al., 2000), and by a negative velocity anomaly relative to the surrounding asthenospheric mantle in both surface- and body-wave travel-time tomography models (Heintz et al., 2005; Russo et al., 2010b). Unusually warm asthenosphere below this region was also inferred from numerical modeling of post-glacial rebound information (Ivins and James, 1999) and from heat flow data ($103 \pm 15$ mW $m^{-2}$; Murdie et al., 1999). Teleseismic shear wave splitting patterns also change in the vicinity of the Chile triple junction; fast polarization directions rotate from the general N–S direction to an ENE trend, suggesting that the mantle flow is diverted parallel to the subducted transform faults that are supposed to bound the slab window (Russo et al., 2010a,b).