S-WAVE SEISMIC ANISOTROPY IN THE FOREARC ABOVE THE SUBDUCTED NAZCA PLATE BETWEEN 33º S AND 34.5º S

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ABSTRACT

S-wave splitting, from local earthquakes within the Nazca plate that are deeper than the interplate seismogenic zone, allowed determinations of fast velocity direction Φ and lag time δt in the overriding plate forearc. Data are collected from 20 seismic stations, mostly of them temporary ones, deployed above the normal subduction section south of ~33.5ºS and also above the transitional section to flat subduction north of this latitude. Φ shows a complex pattern and δt are generally between 0.6 and 1.0 sec. We restrict here our interpretations assuming that the seismic anisotropy is located within the upper mantle wedge of the overriding plate. Interpretations are heavily based on already published v_p, v_s and v_p/v_s tomography and possible temperature ranges. We visualize the anisotropy within three distinctive volumes in the north and two in the south, each of these reaching different depth levels. In the north, the most superficial with trench-parallel Φ by aligned serpentinite fabric, or flow by lateral pressure gradients as a consequence of plate dip variation; the intermediate with two predominant Φ directions might be by overlapping of two different horizontal anisotropic layers, the deepest with probable C type olivine and approximated trench-perpendicular flow. In the south, trench-parallel Φ between 95km to 100km depths, might be originated by aligned melt peridotite pockets or bands, or olivine B type flow, and between 80 to 95km trench-perpendicular Φ by depleted and frozen peridotite probably left over in a previous flattening plate process.

METHODOLOGY AND DATA

A seismic shear-wave crossing an anisotropic medium split in two orthogonal components travelling at different speeds (Silver and Chan 1991). The two components are separated by a lag time "δt" and the polarization direction of them become rotated respect to the initial polarization of the wave (Figure 2). We call "Φ" the orientation of the fast S-wave polarization wave. Φ and δt, the shear-wave splitting parameters, may be linked to patterns of deformation at depths sampled by the rays. We used SPLITLAB (Wüstefeld et al. 2008) to obtain these parameters for subducted Nazca plate events. The SPLITLAB is thought to deal with teleseismic shear wave splitting, but we modified the code to obtain shear wave splitting from local data. SPLITLAB allows the use of three inversion single event techniques to obtain the measure of splitting parameters, cross correlation (Bowman and Ando 1987), eigenvalue method (Silver & Chan, 1991) and Minimum energy method (Silver & Chan 1991). These three methods assume a single layer of anisotropy, with fast and slow polarization directions within a horizontal plane. In this work the eigenvalue method was used because it can be used even when the initial polarization of the shear wave is unknown as in the "S local wave" case.
Data are from December/2005 to March/2006 and were recorded by the CHASE Experiment*. We selected S phases from the subducted Nazca plate events registered in 9 broadband and 11 (three components) short period stations (Figure 1).

***CHASE** (**CH**ile **A**rgentina **S**eismic **E**xperiment) developed inside the project *"Crustal seismicity and velocity structure in the principal cordillera of central Chile 33°-34.5°S: implications on andean geodynamic and seismic hazard"*, FONDECYT 1050758, Chile, Director: Dr. Mario Pardo (Departamento de Geofísica, Universidad de Chile)

We first locate seismicity (all magnitudes are less than 3.5) with Hypocenter (Liener 1995), which is an iterative and single event software. Then, we improved locations with GMEL (Rodi 2006), this is a grid search algorithm to find location parameters within a cluster of events and solves station travel-time corrections simultaneously. The dense network (area: ~100km in NS direction and ~95km in EW direction) and location error less than ± 5km (Nacif and Triep 2010), allow us to select hypocenters between 60 to 120 km in depth, for which the rays to the station make angles not greater than 30° from the vertical.

RESULTS AND CONCLUSIONS

There is only one previous local shear-wave splitting work in the study region (Anderson et al. 2005), but its anisotropy determinations only slightly overlap our northern determinations within the forearc and we do not know their interpretations. We have obtained 30 pairs of anisotropy parameters (Figure 3 shows schematic representation for these measurements). We make the assumption that the anisotropy is localized in the upper plate mantle wedge, that is, there is no anisotropic contribution for the path waves within the subducted plate and within the upper plate crust. These are assumptions usually considered, in the first case for the short length of the path and in the second case because it is found that generally in the crust δt is not greater than 0.3 sec (example, Yang et al. 2011). Consequently, we need to plot in a map the Φ and δt parameters not at each station (this plot is not shown in this work) but in a projection from a representative location point within the upper mantle wedge. For that we chose points at a distance from the subducted slab earthquake of 1/3 of the total path ray length (example, Levin et al. 2004). Φ shows a complex spatial pattern, and δt values are mostly between 0.6 and 1.0 sec. To comprehend the Φ pattern we need to refer to the subducted Nazca plate morphology in the region (Nacif and Triep 2010). This morphology is flat north of 33°S, normal south of 33.5°S, and transitional from one to the other in between these latitudes. The upper plate morphology, and hence the one of the upper mantle wedge, is directly related to the lower plate morphology (Nacif and Triep 2010). Particularly, contour lines of this morphology tend to curve to the east from about 33.25°S to the north at depths larger than ~100km. Based on the Φ orientations and depth distributions of the anisotropic upper mantle wedge locations we distinguish three anisotropic volumes in the north and two in the south (Figure 3). These volumes are: A (80 to 90km depth), B (90 to 100km), C (~100 to 110km), D (95 to 100km) and E (80 to 95km).
Interpretations are based in v_p, v_s and v_p/v_s upper mantle tomography in the region by Wagner et al. 2005 (see their figures, 12 and 13), and possible thermal structure in the mantle wedge zones (example, Oleskevich et al. 1999).
Pattern of fast axis orientation in the transition region (between 33°S and 33.5°S) is attributed to changes in the morphology of the subducted plate, and variations in depth of the intersection point between the overriding Moho plate and the surface of Nazca plate. Volume A with proximally trench-parallel Φ, produced by aligned serpentinite fabric, and/or flow by lateral pressure gradients as a consequence of plate dip variation; volume B with two predominant Φ directions might be by overlapping of two different horizontal anisotropic layers, and volume C with probable C type olivine and approximated trench-perpendicular flow (Figure 3).
South of 33.5°S in the normal subducted plate section volume D shows trench-parallel fast axis which could be originated by aligned melt peridotite pockets or bands (in agreement with Wagner et al. 2005), and/or the presence of B-type olivine fabric (Jung and Karato 2001). Finally, volume E shows trench-perpendicular Φ by depleted and frozen peridotite probably left over in a previous flattening plate process.

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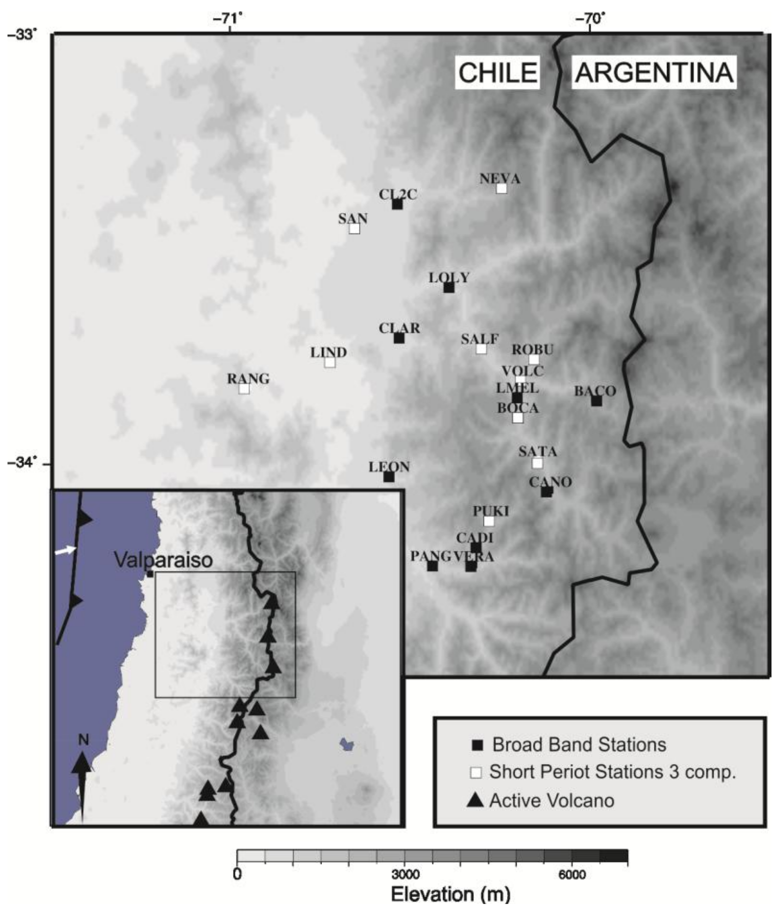

Figure 1. Broad band and short period stations from CHASE experiment used to obtain shear wave splitting determinations.

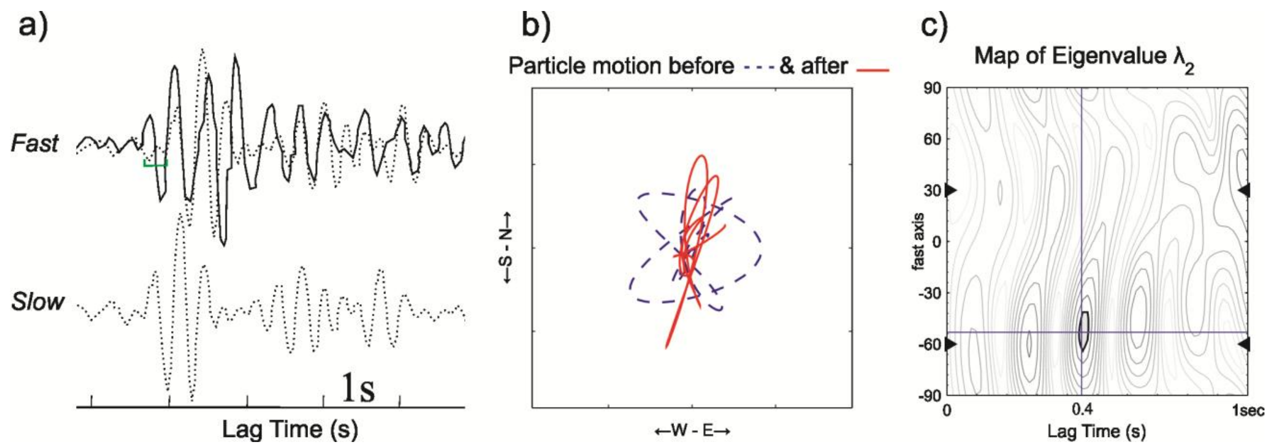

Figure 2. Processing example and results. **a)** Fast and slow components after be rotated. Green segment shows lag time δt. **b)** Particle motion before and after be corrected. **c)** Polarization direction of the fast axis Φ= -53.1±10° and lag time δt=4±0.02s.

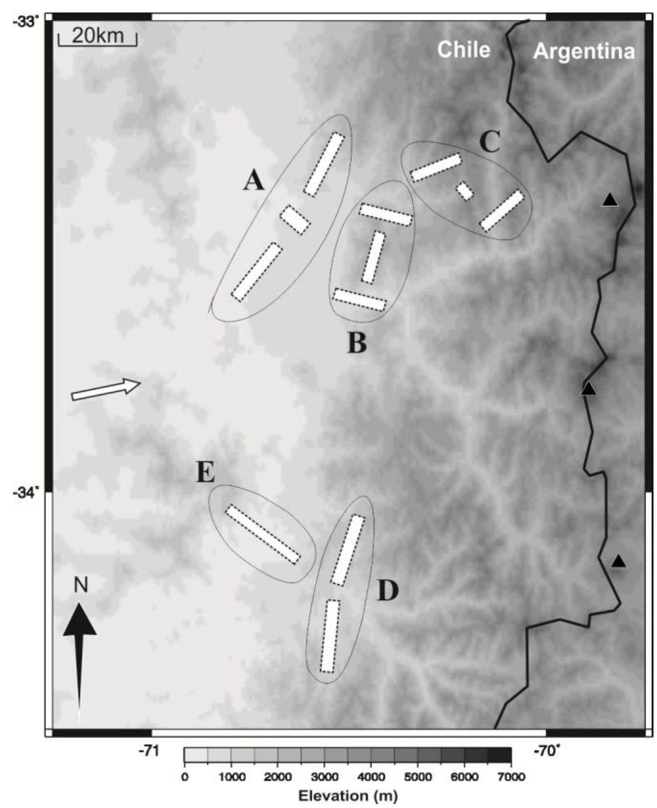

Figure 3. Scheme based in Φ orientations and depth distributions of the anisotropy in upper mantle wedge.