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Rayleigh waves from correlation of seismic noise in Great Island of Tierra del Fuego, Argentina: Constraints on upper crustal structure

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In this study, the ambient seismic noise cross-correlation technique is applied to estimate the upper structure of the crust beneath Great Island of Tierra del Fuego (TdF), Argentina, by the analysis of short-period Rayleigh wave group velocities. The island, situated in the southernmost South America, is a key area of investigation among the interaction between the South American and Scotia plates and is considered as a very seismically active one. Through cross-correlating the vertical components of ambient seismic noise registered at four broadband stations in TdF, we were able to extract Rayleigh waves which were used to estimate group velocities in the period band of 2.5–16 s using a time-frequency analysis. Although ambient noise sources are distributed inhomogeneously, robust empirical Green's functions could be recovered from the cross-correlation of 12 months of ambient noise. The observed group velocities were inverted considering a non-linear iterative damped least-squares inversion procedure and several 1-D shear wave velocity models of the upper crust were obtained. According to the inversion results, the S-wave velocity ranges between 1.75 and 3.7 km/s in the first 10 km of crust, depending on the pair of stations considered. These results are in agreement to the major known surface and sub-surface geological and tectonic features known in the area. This study represents the first ambient seismic noise analysis in TdF in order to constraint the upper crust beneath this region. It can also be considered as a successful feasibility study for future analyses with a denser station deployment for a more detailed imaging of structure.

1. Introduction

The Great Island of TdF (Tierra del Fuego), southernmost South America, is transversed by a transform tectonic boundary between the South American and Scotia plates [1,2]. This boundary is characterized by a left-lateral strike slip regime represented by the MFFS (Magallanes-Fagnano Fault System). The main fault of the MFFS, named the MFF (Magallanes-Fagnano Fault), runs from the western part of north Scotia ridge towards the Chile trench at about 50°S [3,4] and splits the island into two continental blocks (Fig. 1). Recent geodetic studies indicate that the movement in connection with the geodynamic process along the MFF is 5.9 ± 0.2 mm/year [5].

The present geological and tectonic environment of TdF is the result of the interaction between the South American, Scotia and Antarctic plates that involved the evolution of southernmost South America associated with the Andean orogenic cycle during the Mesozoic–Cenozoic. This evolution can be summarized by three tectonic episodes: an extensive regime (Late Jurassic- Early Cretaceous), a compression period (Cretaceous-Paleocene) and finally a strike-slip movement since the Oligocene [6]. The recent tectonic evolution of South America is associated with the geodynamic of

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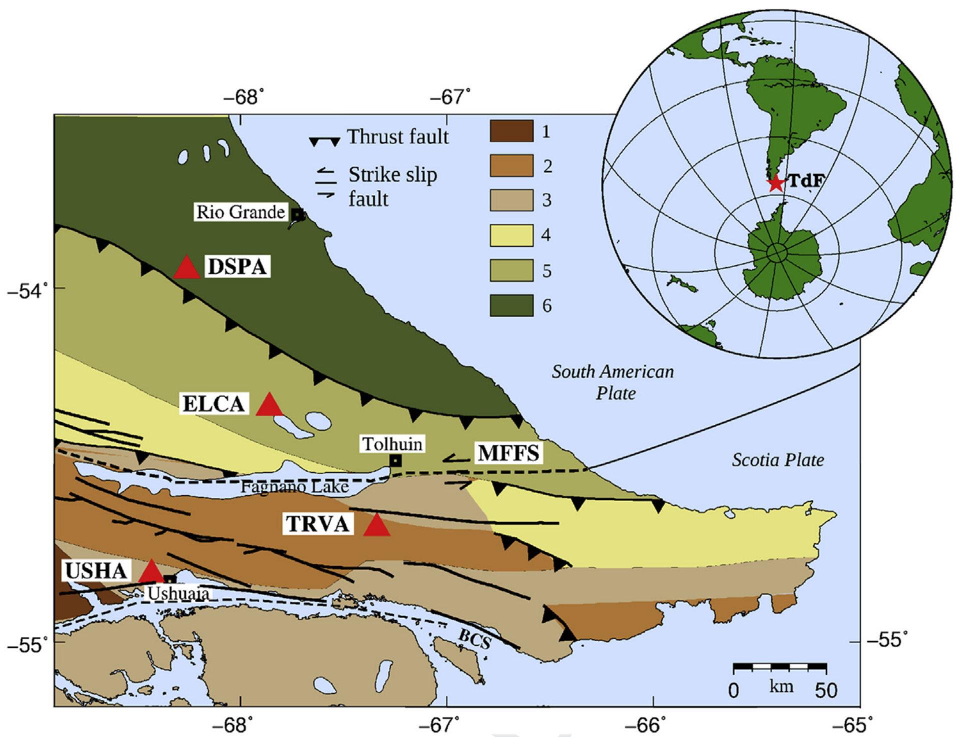

Fig. 1. Simplified geologic map of TdF adapted from Tassone et al. [8]. BCS, Beagle Channel fault system, MFFS, Magallanes-Fagnano Fault System. 1. Basement (Paleozoic–Jurassic), 2. Rhyolites, basalts, conglomerates, tuff and turbidites from Upper Jurassic (Lemaire Formation), 3. Lower Cretacic deposits (Yaghan and Beauvoir Formations), 4. Upper Cretacic deposits, 5. Deformed Tertiary deposits, 6. Undeformed Tertiary deposits. DSPA, ELCA, TRVA and USHA are the seismic stations used in this study. Rio Grande, Tolhuin and Ushuaia are the major cities. The different geologic units were determinated by several authors [2,9–11].

the Scotia plate that moved continental fragments more than 1000 km away from TdF [7].

The MFFS controls the present-day tectonic setting in this area [12]. Geological and geomorphological evidences indicate that the MFF is parallel to the 105 km long Fagnano Lake [13]. The region situated to the south of the lake belongs to the Scotia plate that moves to the east. Geologically, this area is characterized by the Fuegian Cordillera composed by a Paleozoic basement and above this volcanic rocks that correspond to Middle to Upper Jurassic. These rocks are covered by Upper Cretacic and Tertiary deposits. Tectonically, the southern part of TdF presents morphological evidence of Quaternary activity related to the strike-slip regime. The area situated to the north of Fagnano Lake belongs to the South American plate that moves to the west and presents a geological stable extra-andean environment. This region is affected by a tectonic period of extension associated with normal faults to the east of the Magallanes Strait [6]. Other sub-parallel secondary faults that belong to the MFFS are: the Beagle Channel, the Deseado, the Lasifashaj, the Carbajal and the Rio Turbio faults [6,13]. Some of these are associated with normal faults dipping to N in the southern part of TdF. Furthermore, several normal faults with NO-SW strike and dipping to NE and SO were identified in the central and northern part of the island [6].

Since the 90s, a local seismic network started to register seismic movements associated with the MFFS. The seismicity in TdF is characterized by low magnitude events [12,14–17], regardless that this area is considered as a very seismically active one. The historical earthquake records include a magnitude 7.0 event in 1879 [18], several earthquakes of magnitude >6 during 1930 and 1944 and two important events on 1949 December 17 of magnitude 7.5 and 7.8 [19].

At present little information about the crustal structure of TdF is available. Some authors estimated crustal thickness ranging from 29 to 36 km near our study area through seismic refraction profiles [20], regional seismograms inversion [21] and receiver function and surface wave analyses [22]. In this study, we present new constraints on upper crustal structure beneath the Argentinian part of TdF considering the ambient seismic noise registered at 4 broadband stations. This method is more advantageous than other classical seismic techniques because it does not depend on earthquakes seismicity and source parameters and since it is a low cost and simple operation method.

It has been theoretically demonstrated that the cross-correlation of the recorded diffuse wavefields, such as ambient seismic noise, can provide an estimate of the empirical Green's function which mostly consists of fundamental Rayleigh waves that travel between the two stations as if they would be generated at one of the stations. These empirical Green's functions provide information of the structure of the crust between the station pairs [23–27]. We applied the cross-correlation technique to records of ambient seismic noise from the microseismic frequency band. The corresponding sources are in the oceans due to gravity wave activity caused by atmospheric perturbations [28–31]. Here we present shear wave velocity models inferred from the Rayleigh wave group velocities inversion obtained from ambient seismic noise cross-correlation. This study represents the first analysis of ambient seismic noise registered in TdF in order to constrain the upper crust beneath this region.

2. Methodology

2.1. Data

In order to study the upper crustal structure we used data recorded at four broadband seismic stations installed in the Argentinian part of TdF: DSPA, ELCA and TRVA belong to the Faculty