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Seismicity distribution in the vicinity of the Chile Triple Junction, Aysén Region, southern Chile

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A B S T R A C T

The Aysén Region, southern Chile, is the area located at the southern end of the Nazca-South America subduction zone, to the east of the Chile Triple Junction. This region has historically presented low levels of seismicity mostly related to volcanism. Nonetheless, a seismic sequence occurred in 2007, related to the reactivation of the strike-slip Liquiñe-Ofqui Fault System (LOFS), confirmed that this region is not exempt from major seismic activity M ~ 7. Here we present results from background local seismicity of two years (2004–2005) preceding the sequence of 2007. Event magnitudes range between 0.5 and 3.4 M_L and hypocenters occur at shallow depths, mostly within the upper 10 km of crust, in the overriding South American plate. No events were detected in the area locus of the 2007 sequence, and the Wadati–Benioff (WB) plane is not observable given the lack of subduction inter-plate seismicity in the area. A third of the seismicity is related to Hudson volcano activity, and sparse crustal events can be spatially associated with the trace of the Liquiñe-Ofqui fault, showing the largest detected magnitudes, in particular at the place where the two main branches of the LOFS meet. Other minor sources of seismicity correspond to glacial calving in the terminal zones of glaciers and mining explosions.

1. Introduction

The Aysén Region, southern Chile, is located within the southern end of the rupture area of the Great 1960 Valdivia earthquake (Plafker and Savage, 1970), making of this region an area prone to tsunami hazard. Nevertheless, the Aysén region lacks of major teleseismic recordings and in general only presents sparse seismicity of intra-plate crustal origin.

This region correspond to an interesting seismotectonic environment as it is bisected by a large strike-slip fault system, the Liquiñe-Ofqui fault system (LOFS), which absorbs the trench-parallel component of the oblique convergence between Nazca and South American plates. In addition, the current subduction of an active spreading center, the Chile Ridge, has generated the presence of an asthenospheric slab window beneath the overriding continental plate (Russo et al., 2010a).

Recently in 2007, the area was locus of an earthquakes sequence related to the reactivation of the LOFS, with a peak of activity given by a M_W 6.2 earthquake that generated a landslide-induced local tsunami killing 10 people. The area affected in 2007 is of particular economic interest given the presence of salmon farms and hydroelectric resources.

Little is known about the local seismicity in this region. One important problem is the lack of local seismic studies covering the whole of the region, and the absence of maximum possible magnitudes at any given sector. Furthermore, the sources for local seismicity have not been clearly established. The geometry of the Wadatti–Benioff plane is well constrained from 43°S northwards, but not for the region south of it where the actual southern end of the Western-South America subduction margin is located.

The goal of the present study is to determine the seismicity pattern of the Aysén region and establish its main sources of activity previous to the sequence of 2007. Specific questions (objectives) we want to address are:

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1. What is the spatial distribution of earthquakes in the region and their magnitudes?
2. What are the sources of seismicity in the region?
3. Is there WB seismicity occurring? If not, why?
4. What are the effects of the main present tectonic features (e.g. slip partitioning and subduction of young lithosphere and an active ridge) on the upper plate deformation and associated seismicity pattern?
5. What are the possible maximum magnitudes at given areas of the region.
6. Was there any previous indication of seismicity in the area affected by the 2007 Aysén Fjord sequence?

Kirby et al. (1996) proposed that subduction of very young lithosphere (<15–25 Ma) and high heath flow (as in the case of the Aysén Region) produces mainly shallow earthquakes and sparse or absent volcanism. We hypothesize that seismicity in the Aysén Region occurs only at shallow depths (<~30 km), presenting low magnitudes and an absent or poorly defined WB zone. Occasionally though, maximum magnitudes in the region could reach M ~ 7 as demonstrated by the recent Aysén Fjord events related to the LOFS and an earthquake occurred in 1927 (see below).

In order to tackle these issues, data from an extensive local network deployed during 2004–2005 (Miller et al., 2005) is analyzed. We benefit from the usage of a recently derived 1-D local velocity model for the area (Agurto et al., 2012) and a non-linear location method (NonLinLoc, Lomax et al., 2000) to obtain accurate earthquake locations and associated uncertainties.

1.1. Location and geo-tectonic setting

The study region is located at the southern end of the subductive convergent margin between the Nazca and South American plates (Fig. 1), where the active Chile Ridge is currently subducting offshore of the Taitao Peninsula (Herron et al., 1981; Cande et al., 1987) at the so-called Chile Triple Junction (CTJ). This tectonic configuration corresponds to the only present-day active ridge-trench collision in which the overriding plate represents continental lithosphere. North of the CTJ, a young and buoyant portion of the Nazca plate is being subducted at a rate of 6.6 cm yr^{-1}, while to the south, the Antarctic plate is being subducted at 2 cm yr^{-1} below South America (Wang et al., 2007).

Several consequences of the Chile Ridge subduction beneath the CTJ have been observed including: tectonic erosion, plutonism near the trench and uplift during the Upper Cretaceous in the Taitao Peninsula (Cande and Leslie, 1986), emplacement of an ophiolitic complex in the Taitao Peninsula (Forsythe et al., 1986) and the displacement of a fore-arc sliver (Forsythe and Nelson, 1985; Wang et al., 2007). Another important consequence is the occurrence of a 350 km long volcanic gap within the arc (Ramos and Kay, 1992), whilst in the back-arc zone widespread basaltic-plateau volcanism takes place (e.g. Ramos and Kay, 1992; Gorring et al., 1997). Ramos and Kay (1992) argue that the most intense periods of this basaltic volcanism are related to the passage of a slab window (subducted ridge) below the plateau.

The WB seismicity observed along the southern Chile convergent margin decreases in terms of quantity and depth of subduction events from north to south until the CTJ where the age of the

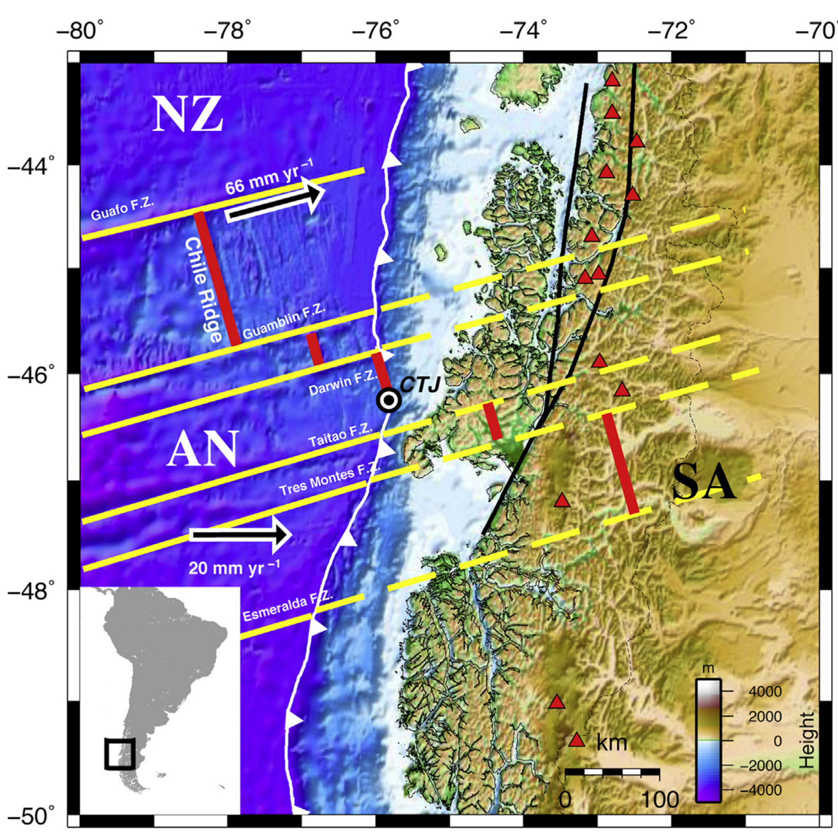

Fig. 1. Location and tectonic settings of the Aysén Region. NZ Nazca plate; AN Antarctic plate; SA South American plate; CTJ Chile Triple Junction. White line with triangles indicate the trench. Red segments show spreading centers of the Chile Ridge and their projection after subducted. Yellow lines indicate fracture zones (solid yellow lines) and their projection (dashed yellow lines). Black line depicts the Liquiñe-Ofqui Faults System (LOFS), while red triangles indicate Quaternary volcanoes. Bathymetry/Topography: GTOPO30; convergence NZ and AN: Wang et al. (2007). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)