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Lithospheric structure of an incipient rift basin: Results from receiver function analysis of Bransfield Strait, NW Antarctic Peninsula

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ABSTRACT

Bransfield Basin (BB), located northwest of the Antarctic Peninsula (AP) and southeast of the South Shetland Islands (SSI), is the most active section of the Antarctic continental margin. The region has long been (50 Ma) a convergent plate boundary where the Phoenix plate was subducting beneath the Antarctic Plate and is characterized by long-lived arc magmatism and accretion. However, the collision of the Antarctic-Phoenix spreading center with the subduction front near SSI (ca. 4 Ma) gave way to the opening of slab windows and dramatic decrease in the subduction rate of the Phoenix plate beneath AP and SSI. Consequently, the Phoenix slab began to rollback slowly along the South Shetland Trench (SST), giving way to slow extension in the back-arc region and rifting along the BB. Although there is consensus on the factors that control the current deformation and extension of the BB, the origin of the BB and the tectonic configuration of the basin are still unclear. Most of the controversy stems from uncertainties regarding the crustal thickness of the BB. Hence, we computed teleseismic receiver functions for 10 broadband stations in the region that belong to existing permanent and temporary deployments in order obtain robust constraints on the lithospheric structure and crustal thickness of the BB, as well as the AP and SSI. Our results indicate that the crust is thinning from 30 km to 26 km from the AP towards the South Shetland trench and Central BB showing the asymmetrical character of the rift basin. The crustal thickness and Vp/Vs variations are less pronounced along the AP but very significant across the SSB indicating the lithospheric scale segmentation of the South Shetland Block (SSB) and the incipient rift basin under the control of the opening of slab window and the roll-back of stalled Phoenix slab. High Vp/Vs ratios (~1.9) beneath BB and SSI, agree well with the nascent rift character of BB, the presence of a steep Phoenix slab and consequently a wider mantle wedge characterized by the presence of underplating partial melts beneath SSI and BB.

1. Introduction

Subduction plate margins are sites of key Earth processes that include an abundance of destructive Earthquakes, recycling of oceanic lithosphere, arc volcanism and volcanic eruptions, as well as continental growth. Hence, they contribute significantly to our understanding of the Earth's structure and processes. However, various complications can alter the usual pattern of these processes and how they operate. One of these complications is the existence of windows in the lithosphere (slab) descending into the mantle due to subduction of spreading ridges (Thorkelson, 1996). The initiation and widening of such a gap in the slab may lead to a major reconfiguration of the plate margin, significant changes in the character of tectonism. Today, various subduction segments along the Pacific margin of the North and South America Plates display these effects clearly where spreading centers subduct beneath these plates (i.e. Western U.S., Mexico, Costa Rica, Patagonia) (McCrory et al., 2009). However, the relationships between attributes of the slab windows and the deformation and reconfiguration of the plate margin remain unclear (van Wijk et al., 2001; Guillaume et al., 2010). The opening of gaps in the slab in a convergent plate margin can also lead to the gradual demise of the convergence and subduction in the remnant part of the convergent plate margin. A good example for slab window opening and stalled subduction is located at the northwestern margin of Antarctica Plate. Various studies have linked the significant tectonic reconfiguration of the Antarctica Plate margin and cessation of subduction in the vicinity of the Bransfield Strait to the opening of a slab window beneath the Antarctic Peninsula (Hole and Larter, 1993; Barker and Austin, 1998). Hence, this is a premier location to study characteristics of slab windows and stalled subduction as well as their contribution to factors that govern the

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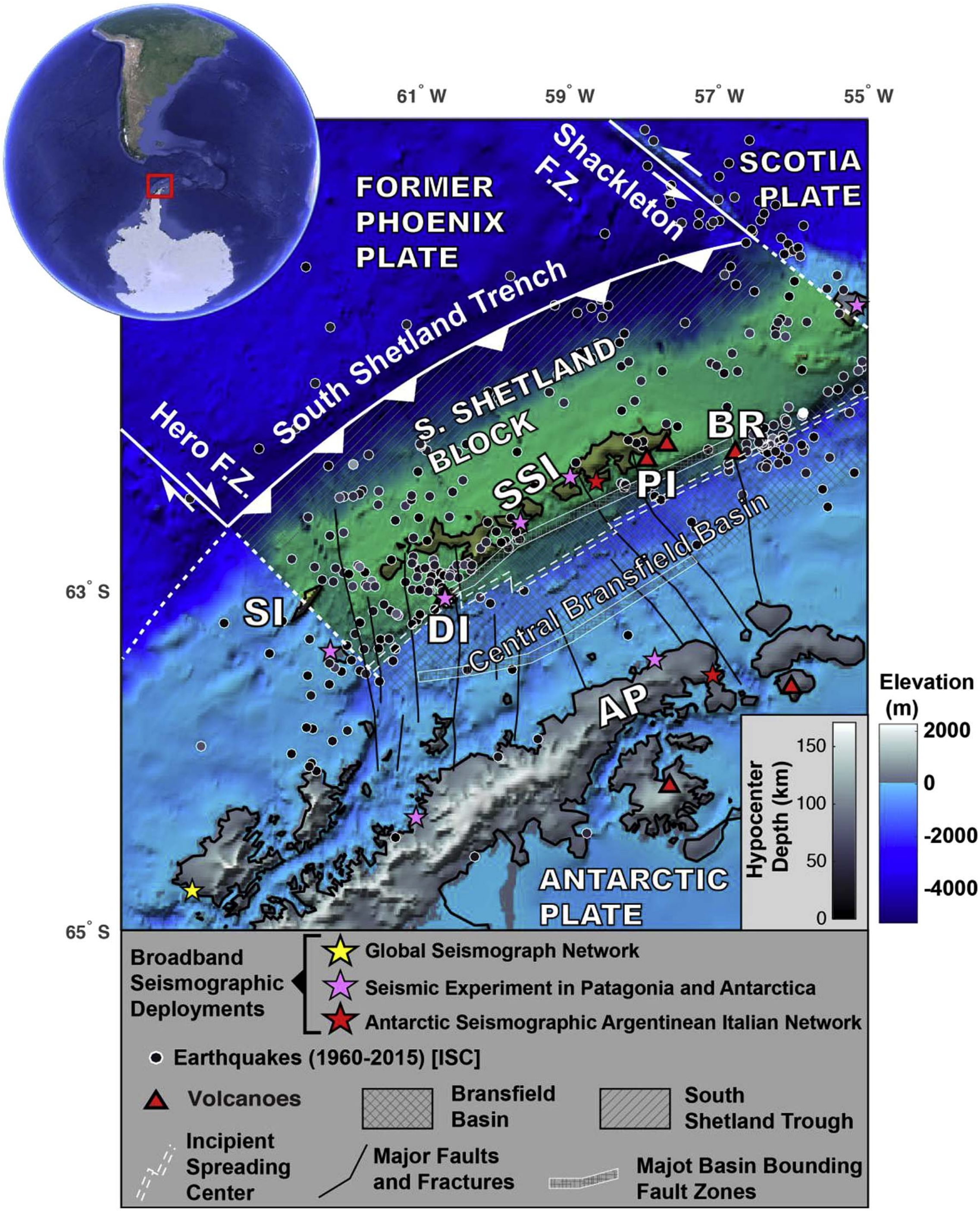

Fig. 1. Map of the Bransfield Strait, the South Shetland Islands, and the Antarctic Peninsula. The map shows locations and affiliations of seismic deployments in the region as well as the locations of major volcanic centers and earthquakes retrieved from the International Seismological Center (ISC) catalog. Major fractures, faults, and basin bounding fault zones are also illustrated (Grad et al., 1992). Plate boundaries and major tectonic features are illustrated by white lines. The SSB is shaded in green. DI = Deception island; PI = Penguin Island; BR = Bridgeman Island; SI = Smith Island.

rheology, volcanism, and tectonism of the associated plate margin and the Bransfield Straight.

The Bransfield Straight hosts the Bransfield Basin (BB), and the region is one of the most active sections of the Antarctica Plate (Maurice et al., 2003). The Antarctic Peninsula (AP) to the southeast and South Shetland Islands (SSI) to the northwest border the basin (Fig. 1). The current geology and the structure of the region are partly governed by the long-lived plate convergence and subduction of the Phoenix Plate southeastward beneath the Antarctica Plate (Dalziel, 1984; Keller et al., 1991). This region is thus characterized by prolonged arc magmatism and accretion, giving way to metamorphism and uplift of Mesozoic-Cenozoic accretionary wedge material that forms the AP and SSI (Birkenmajer et al., 1986; Machado et al., 2005). Upon collision of the Antarctic-Phoenix spreading center with the subduction front near SSI (ca. 4 Ma), spreading deactivated and the oceanic Phoenix plate became a part of the Antarctic Plate (Barker and Dalziel, 1983; Larter and Barker, 1991). The collision of the spreading center gave way to the opening of slab windows where the subduction trench meets the spreading ridge (Hole and Larter, 1993). After the cessation of spreading along the Phoenix-Antarctic spreading ridge, subduction of