WIDE-ANGLE SEISMIC CONSTRAINTS ON THE EVOLUTION OF GALAPAGOS HOTSPOT – COCOS-NAZCA SPREADING CENTER INTERACTION

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INTRODUCTION

The presence of a hotspot near to a spreading center generate melting anomalies along the ridge axis [Morgan, 1978]. Typically, the melting anomalies enable higher melt production beneath the ridge, resulting in shallower seafloor and thicker crust than that generated at normal spreading centers. This is evidenced in the long-wavelength bathymetry and gravity anomalies which extends hundreds of kilometers away from hotspots [Ito and Lin, 1995; Escartin et al., 2001]. The main parameters that control the excess of magmatism seem to the size and volume flux of the plume (mainly a function of the temperature anomaly) and the distance between the ridge and the hotspot [e. g., Ito et al., 1999; Ribe, 1996]. Since the seismic velocities are sensitive to the rock composition (and thus to the mantle temperature) and the crustal thickness is proportional to the amount of melting, crustal seismology seems to be an adequate geophysical method to constrain the volume and composition of melt. Hence, the comparison of the observed seismic structure at different periods of time along a hotspot track can give valuable information on the temporal evolution of the hotspot-ridge interaction.

The Galapagos Volcanic Province, located in the northernmost Nazca plate and adjacent Cocos plate, constitutes an excellent example to investigate mantle melting processes due to hotspot-ridge interaction. It is constituted by several blocks of thickened oceanic crust thought to have originated from the interaction between the Galapagos hotspot and the Cocos-Nazca Spreading Center during the last 20 Ma. The most prominent are the Cocos, Malpelo and Carnegie Ridges, which traces the path of the Galapagos hotspot over the Cocos and Nazca plates. In this work we compare the crustal seismic structure of these ridges along five wide-angle profiles acquired during the PAGANINI-1999 and SALIERI-2001 experiments. Two of these profiles are located in the Cocos Ridge, another one in Malpelo, and the last two in Carnegie, at the conjugate positions of Malpelo (at about 20 Ma) and southern Cocos (at about 12 Ma). The 2D velocity field and the Moho geometry along these profiles have been obtained using a joint refraction/reflection traveltime inversion method, and the uncertainty and robustness of the results have been estimated by performing a Monte Carlo-type analysis.

CONCLUSIONS

The results show that maximum crustal thickness along these profiles is highly variable, ranging from 19-20 km in northern Cocos, Malpelo, and its conjugate Carnegie profile, to 16.5 km in southern Cocos and only 13 km in its conjugate position (Figure 1). Oceanic Layer 2 thickness is quite uniform regardless of total crustal thickness variations, and thus crustal thickening is mainly accomodated in Layer 3. This velocity also shows very similar seismic velocities along all profiles. The notable temporal variations on the crustal thickness at both sides of the ridge axis suggest the existence of important variations on the Galapagos hotspot activity and/or on its relative position with respect to the spreading center. At 20 Ma, the hotspot-ridge system would be dominated by a vigorous on-ridge magmatic activity, while at 12 Ma it would show a significantly lower, off-ridge centered activity.

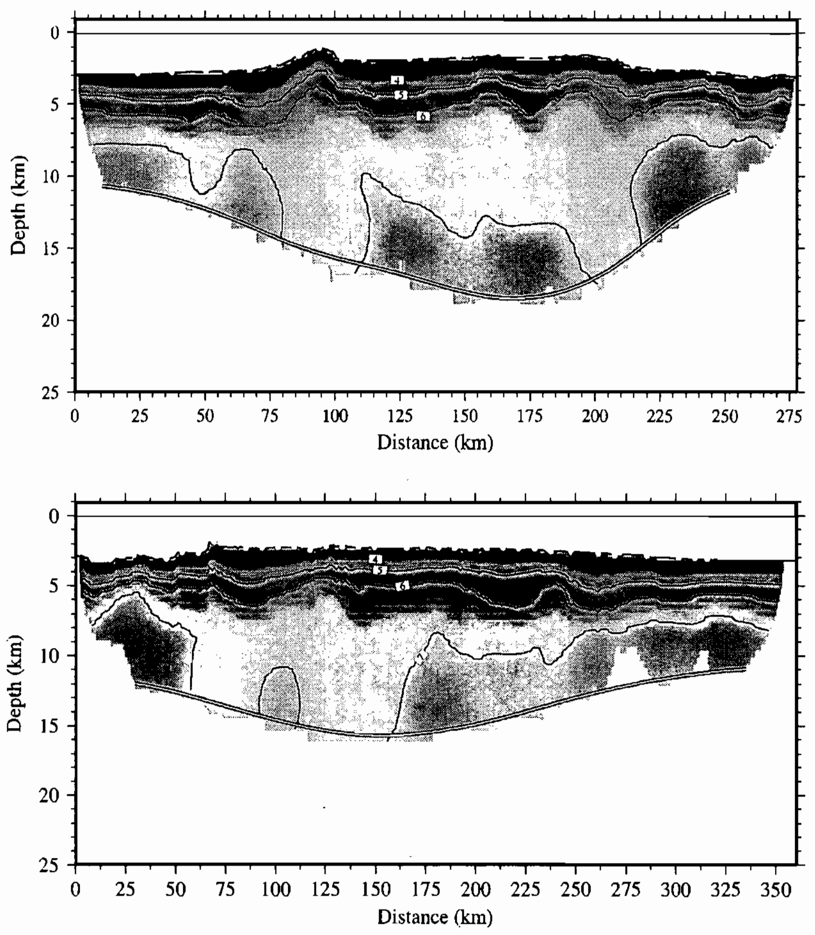

Figure 1.- Crustal seismic structure along southern Cocos profile (up) and its conjugate Carnegie Profile (down). Left side is north and right side is south. Both profiles are located over 12 Ma seafloor. White circles show receiver locations. Note the similar seismic velocities and the different crustal thicknesses.

The mean Layer 3 seismic velocities are generally lower where the crust is the thickest (Figure 1). This leads to an overall anticorrelation between crustal thickness and bulk lower crustal velocities, hence the contrary of that expected if overthickened crust were generated by passive decompression melting of an abnormally hot mantle with an uniform composition [McKenzie and Bickle, 1988; White et al., 1992]. It is thus necessary to consider active upwelling components and/or compositional heterogeneities in the mantle source, and not only high temperatures, to explain the observed seismic structure. This is in agreement with the results of recent studies in the Greenland margin [Korenaga et al., 2000] and in Iceland [McLennan et al., 2001], where active upwelling has been considered to account for the geophysical and geochemical observations. The northernmost segment of Malpelo Ridge shows a rapid crustal thinning and displays high lower crustal velocities, similarly to rifted margins. This could be an evidence of a rifting process which splitted the ancient Malpelo Ridge into Regina and Malpelo Ridges after the initiation of the movement along the Panamá Fracture Zone.

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