A NEW MODEL OF CRUSTAL THICKNESSES FOR SOUTH AMERICA FROM RECEIVER FUNCTIONS AND SURFACE WAVE TOMOGRAPHY

Marcelo Assumpção [1]
Mei Feng [2]
Andres Tassara [3]
Jordi Julià [4]

[1] IAG-USP, São Paulo, Brazil, marcelo@iag.usp.br; [2] Institute of Geomechanics, Chinese Academy of Geological Sciences, Beijing, China; [3] Department of Earth Sciences, Universidad de Concepción, Concepción, Chile; [4] Departamento de Geofísica, UFRN, Natal, Brazil

INTRODUCTION

We updated previous models of crustal thicknesses in South America (Feng et al., 2007; Lloyd et al., 2010) by using an extensive compilation of seismic measurements (from receiver functions and active seismic experiments), which were used as point constraints in a joint tomographic inversion of surface waves. We built on previous compilations of seismic point constraints (Feng et al., 2007; Lloyd et al., 2010; Tassara et al., 2012; Assumpção et al., 2012a) and produced an enlarged compilation of about 760 point measurements of crustal thicknesses, 570 onshore and 190 offshore. Fig. 1 shows the distribution of the point constraints in the continent, colored according to the residual of the final Moho model (shown in light contours).

This updated compilation was used to derive two empirical relations between gravity Bouguer anomalies and crustal thickness, one along the Atlantic coast, and another along the Andean range and Pacific margin. These empirical relations were used to estimate crustal thickness in areas where our compilation has large gaps in seismic coverage, such as the Atlantic continental shelf and the northern Andes (mainly Ecuador and Colombia).

TOMOGRAPHY INVERSION

We use the tomographic inversion method of Feng et al. (2007) to derive a crustal model based on joint inversion of different kinds of data: waveform modelling, group velocity dispersion, and seismic point constraints. The waveform data was the same used by Feng et al. (2007): 1537 regional wave trains analysed with the partitioned waveform inversion method. Each waveform modelling (S + Rayleigh waves) produces an average 1D model for the epicenter-station path. To the 5700 group velocity measurements of Feng et al. (2004, 2007), we added 1031 new measurements including inter-station paths using ambient noise cross-correlation to improve coverage of the Paraná and Chaco basins. In the joint inversion, large weights are given to the seismic point constraints, and very low weights are given to the crustal thicknesses inferred from gravity anomalies. In areas with no direct seismic constraints, the crustal thickness is derived mainly from the surface-wave data.

Fig. 2 shows the resulting model where the *rms* misfit of the 760 seismic measurements is 3.5 km. The misfit of the point constraints in the stable continental interior is 1.5 km. The misfit in the Andes (Fig. 1) is larger partly because of smoothing of the model in the inversion process and partly because of larger variability of the compiled data. More details of the data processing can be found in Feng et al. (2007) and Assumpção et al. (2012b).

DISCUSSION AND CONCLUSIONS

In the stable continental interior, two regions of crust generally thicker than 40 km can be seen in the Amazon and the Atlantic shield (Fig. 2). The thick crust in the Amazon roughly correlates with the oldest Archean provinces as defined by Tassinari and Macambira (1999).

Beneath the Andes the Moho discontinuity can reach more than 70 km depth, such as in the Easten cordillera of Bolivia, and is generally deeper than 50 km in areas with elevations higher than 3000 m. A notable exception to this is observed below the northern Puna at 25°S where the crust is thinner than 55 km for elevations higher than 4000 m. This reinforces the hypothesis that a recent (<4 Ma) event of lithospheric delamination removed part of the dense lower crust. Interestingly, this region of thin crust seems to be oriented in an ENE direction that could be continued eastward into the Transbrasiliano Lineament (TBL). The SW limit of the TBL is presently characterized by a mechanically weak (Pérez-Gussinyé et al., 2007), thinned lithosphere (Assumpção et al., 2004). Although highly speculative, this hypothesis could suggest that delamination below the Puna occurred along a pre-weakened, thinned lithospheric zone inherited since the Neo-Proterozoic.

In southern Ecuador and northern Peru (around 3^{o}S), another region of relatively high elevation (near 3000 m) is underlain by a Moho that seems to be only about 40 km or less. This could be explained by regional, flexural-controlled compensation of surface topography in contrast to the local, Airy-type compensation common in the rest of the Andean cordillera. Moreover, estimates of the elastic thickness of the lithosphere (Tassara et al., 2007; Perez-Gussinye et al., 2008) are anomalously high (> 40 km) for the Ecuador-Peru border region compared to the rest of the Andes (< 20 km).

A large region of thin crust (shallower than < 35 km) is seen between the Andean range and the cratonic areas, such as in the Oriente Basin and the Chaco basin. Moho depth shallower than 30km is suggested (Fig. 2). Although our model in the sub-Andean region is mainly controlled by the surface-wave data, the few direct seismic measurements in these areas (Fig. 1) and the relatively high gravity anomalies (Tassara and Echaurren, 2012) confirm the generally thin crust east of the Altiplano-Puna plateau.

References

Assumpção, M., M. Schimmel, C. Escalante, M. Rocha, J.R. Barbosa, L.V. Barros, 2004. Intraplate seismicity in SE Brazil: Stress concentration in lithospheric thin spots. *Geophysical J. Int.*, 159, 390-399.

Assumpção, M., M. Bianchi, J. Julià, F.L. Dias, G. França, C.G. Pavão, D.F. Albuquerque, and A.E.V. Lopes, 2012a. Crustal thickness map of Brazil and adjacent areas: Data compilation and main features. *J. South American Earth Sci*., submitted.

Assumpção, M., M. Feng, A. Tassara, J. Julià, 2012b. Developing models of crustal thickness for South America from receiver functions and surface-wave tomography. *Tectonophysics*, submitted.

Feng, M., M. Assumpção, S. Van der Lee, 2004. Group-velocity tomography and lithospheric S-velocity structure of the South American continent. *Phys. Earth Planet. Ints.*, 147, 315-331.

Feng, M., S. Van der Lee and M. Assumpção, 2007. Upper mantle structure of South America from joint inversion of waveforms and fundamental-mode group velocities of Rayleigh waves. *J. Geophys. Res.,* 112,.

Lloyd, S., S. van der Lee, G.S. França, M. Assumpção, M. Feng, 2010. Moho map of South America from receiver functions and surface waves. *J. Geophys. Res*., 115, B11315, doi: 10.1029/2009JB006829.

Pérez-Gussinyé, M., Lowry, A.R., Watts, A.B., 2007. Effective elastic thickness of South America and its implications for intra-continental deformation, *Geochem. Geophys. Geosyst.*, 8, Q05009,.

Pérez-Gussinyé, M., A. R. Lowry, J. Phipps Morgan, A. Tassara, 2008. Effective elastic thickness variations along the Andean margin and their relationship to subduction geometry, *Geochem. Geophys. Geosyst.*, 9,.

Tassara, A., C. Swain, R. Hackney, J. Kirby, 2007. Elastic thickness structure of South America estimated using wavelets and satellite-derived gravity data, *Earth and Planetary Science Letters*, 253(1-2), 17-36. doi:10.1016/j.epsl.2006.10.008.

Tassara, A., A. Echaurren, 2012. Anatomy of the Chilean subduction zone: Three-dimensional density model upgraded and compared against global-scale models. *Geophys. J. Int.,* 189(1), 161-168, doi: 10.1111/j.1365-246X.2012.05397.x.

Tassinari, C.C.G., Macambira, M.J.B., 1999. Geochronological provinces of the Amazonian craton: *Episodes*, 22 (3), 174–182.

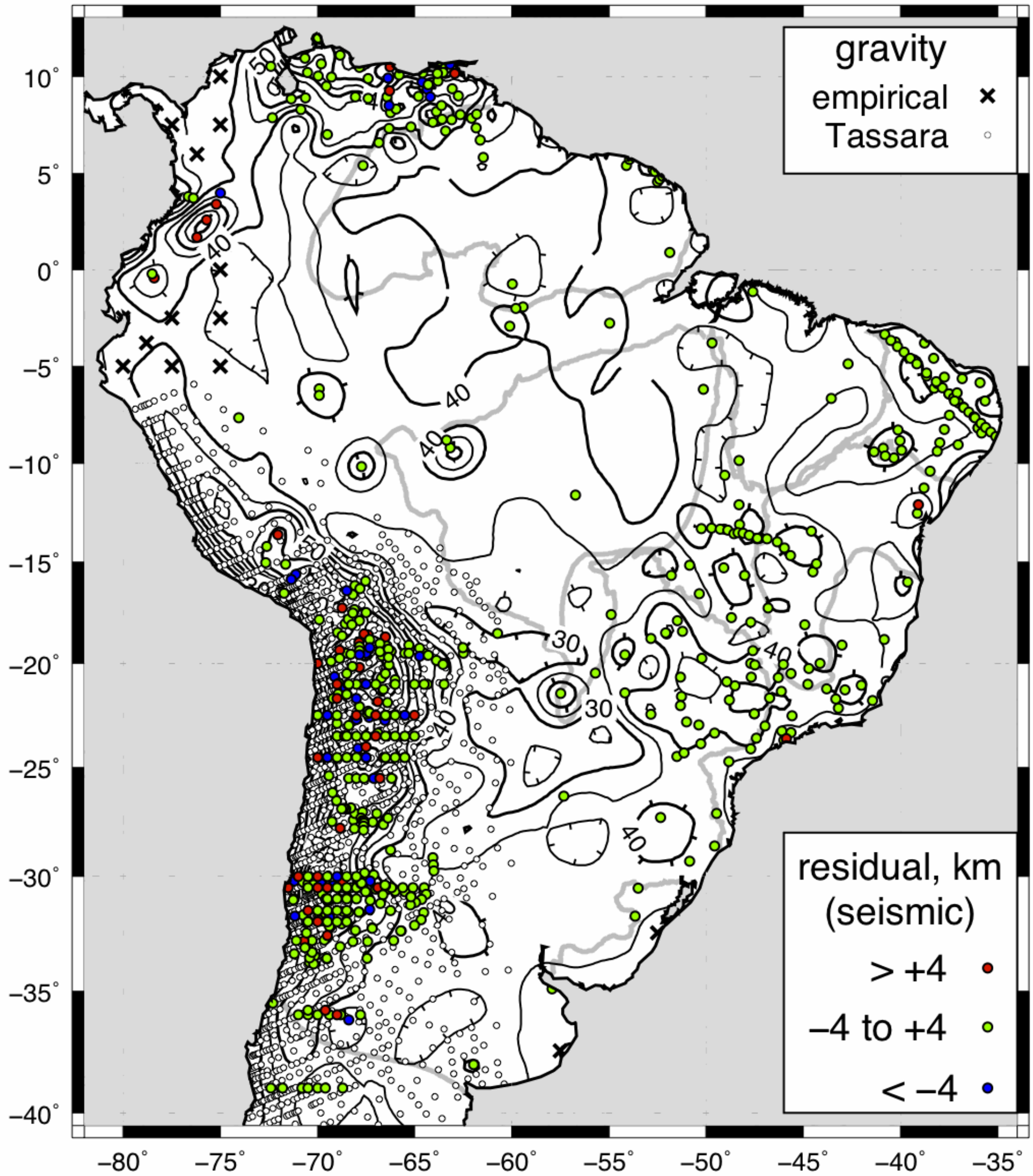

Fig.1. Fit to the crustal model. Crustal thickness contours with all point-constraints used in the continent: colored circles are the seismic constraints; *rms* misfit to all 760 data points = 3.5 km; fit to 232 points in stable continent = 1.5 km). Small open circles denote control points from Tassara and Echaurren (2012) gravity-derived model; crosses show locations of thicknesses derived from the empirical relationship with Bouguer anomaly. Gray lines are boundaries of major geological provinces.

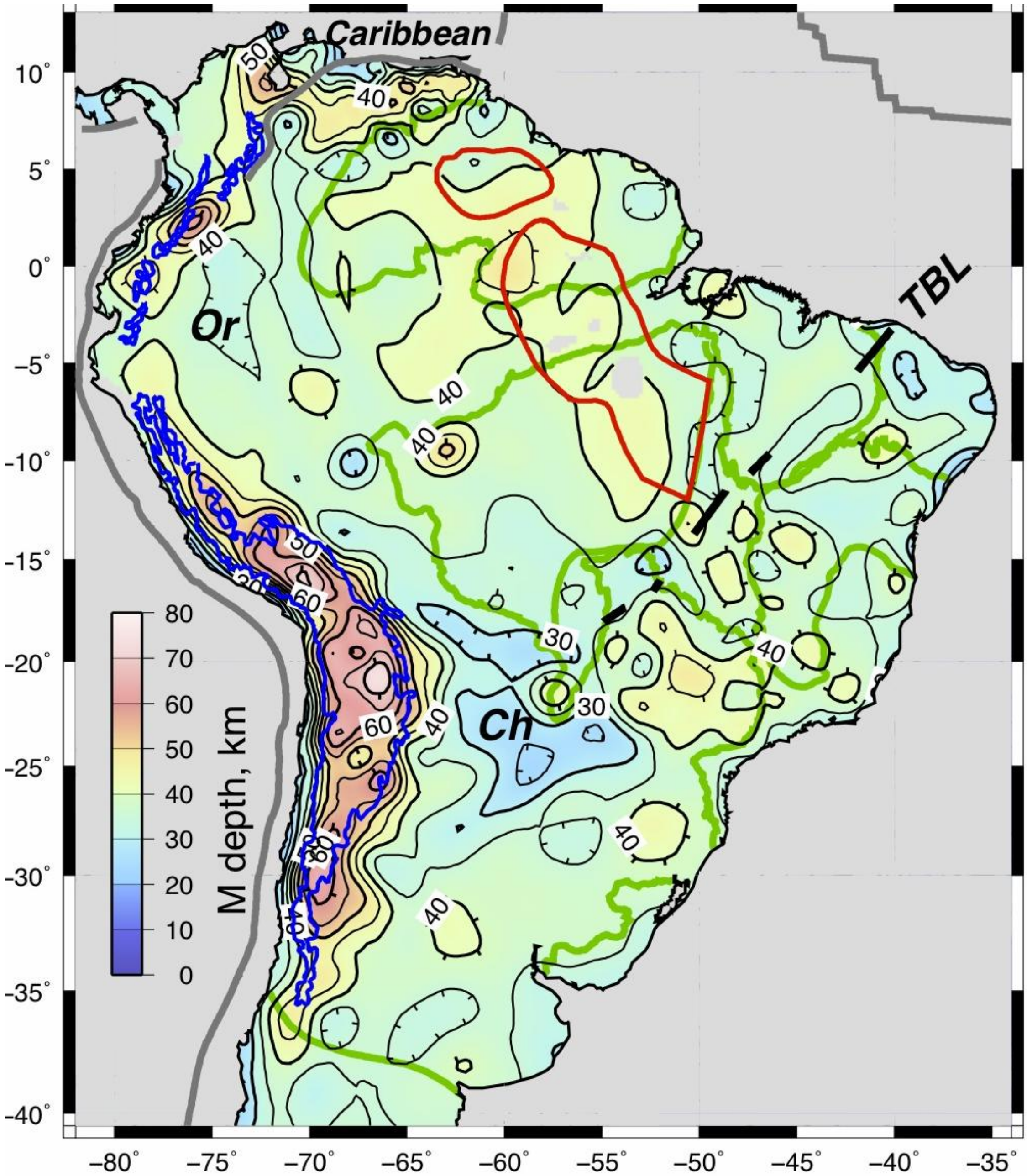

Fig. 2. Model of Moho depths using waveform modeling, group velocity dispersion, all seismic point constraints with additional depths from the model of Tassara & Echaurren (2012). Control points are shown in Fig. 1. Contour interval 5 km. Blue solid line denotes the 3000m altitude in the Andes. Dark green lines are boundarie of major geological provinces. Gray solid lines are the limits of the South American plate. Red line in the Amazon is the oldest Archean geochronological province (Tassinari & Macambira, 1999). TBL= TransBrasilian Lineament; Ch =Chaco Basin, Or=Oriente basin.