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Variations in crustal structure in the region of the Galapagos triple junction

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Abstract

This study uses gravity data to investigate crustal structure in the region of the Galapagos triple junction. Shipboard and global gravity data are analyzed from 104˚W to 96˚W and 0˚ to 4˚N. In May 2018, the high-resolution gravity data were collected along ship tracks that run across the entire width of the Galapagos gore from the tip of the Cocos-Nazca rift (CNR) at ~101.7˚W to 98.5˚W. We calculated Residual mantle Bouguer anomaly (RMBA) and a model of gravity-derived crustal thickness. The results reveal several distinctive features in gravity and crustal structure: (1) The eastern flank of the East Pacific Rise (EPR), has systematically shallower topography and more negative RMBA than the conjugate western flank, reflecting regional density variations. (2) On the eastern flank of the EPR, the region south of the Galapagos gore is associated with more negative RMBA than the region to the north, possibly reflecting closer proximity to the Galapagos hotspot in the southern region. (3) The first ~100 km behind the propagating CNR tip (~101.7˚W to 100.8˚W) is associated with more positive RMBA (up to ~35 mGal) than the CNR rift between ~100.8˚W and 98.5˚W, suggesting locally thinner crust (up to ~1.5 – 2 km). East of 98.5˚W along the CNR, RMBA decreases gradually towards the Galapagos hotspot. (4) A region of local high topography on the southern boundary of the Galapagos microplate, where fresh basalts were sampled, is associated with negative RMBA centered at ~101.6˚W and 1.3˚N, indicating local relatively thick crust. (5) Within our study area, the CNR crust shows shallower average off-axis topography and more negative average RMBA than the EPR crust of corresponding age, which is consistent with a model of isostatic compensation of average thicker CNR crust than the surrounding EPR crust, possibly reflecting Galapagos hotspot effects.

① Study area

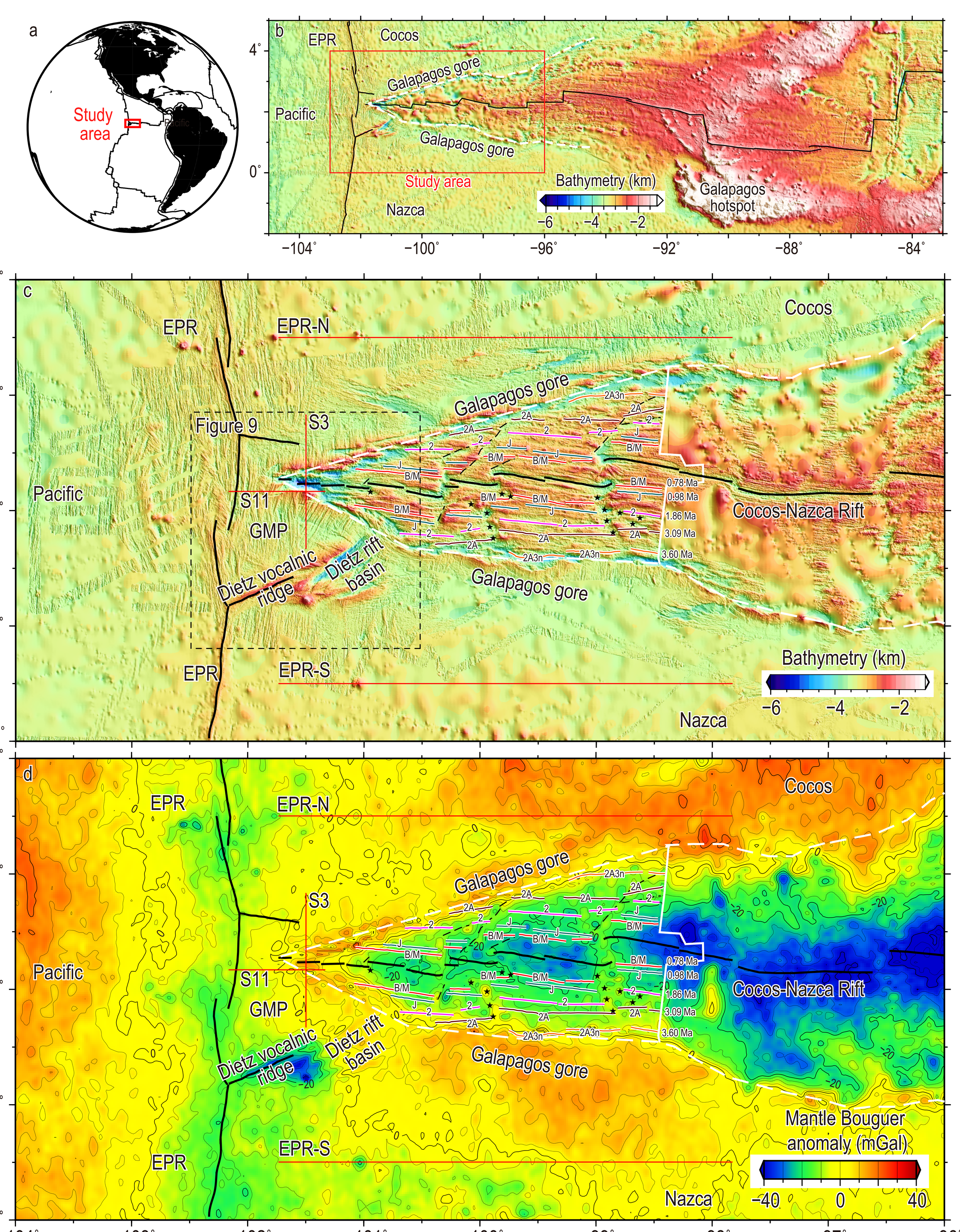

Fig. 1 (a) Global location of our study area; (b) regional bathymetry shows the location of Galapagos hotspot at the east of the study area; (c) bathymetry and (d) mantle Bouguer anomaly (MBA) within our study area. Galapagos microplate (GMP) is located at south of the CNR tip. Black lines are ridge axes; dashed white lines mark the gore; solid white line marks the eastern edge of the shipboard survey; colored lines within the gore show identified isochrons with name and age labeled; red lines S3 and S11 are seismic survey tracks from Zonenshain et al. (1980), and EPR-N and EPR-S are shown in Fig. 8.

② Thermal correction and gravity-derived crustal thickness

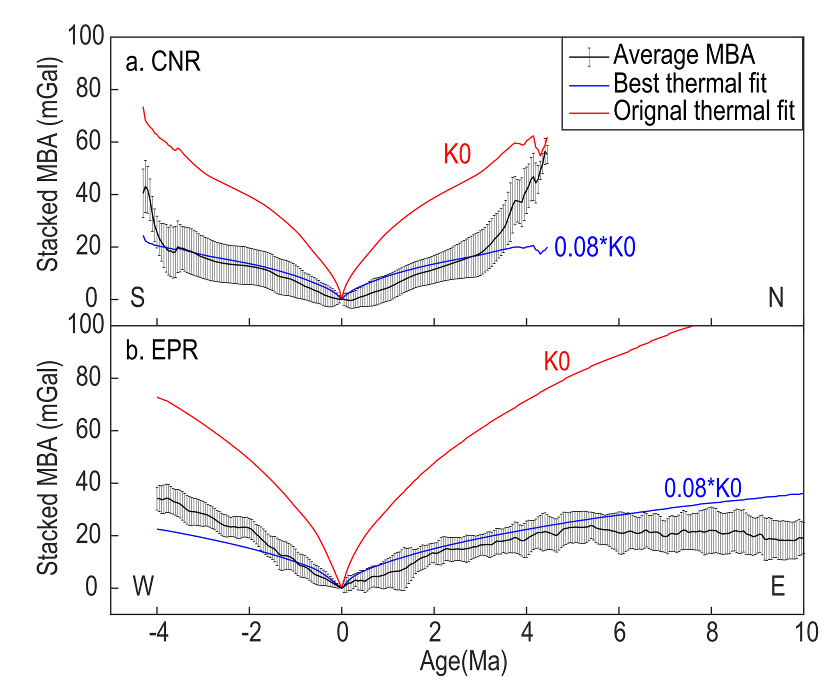

Fig. 2 Average stacked MBA and corresponding thermal effect versus age on (a) CNR and (b) EPR. For both CNR and EPR, stacked MBA (black lines) are the average of corresponding age with a standard deviation (error bar). The original predicted age-induced thermal effect from Turcotte and Schubert (2001) (K0, red line) is significantly over estimated in this region, thus a best thermal fit (0.08*K0, blue line) is applied here for better constraint. Note that MBA is asymmetric on conjugate flanks of EPR but generally symmetric at CNR.

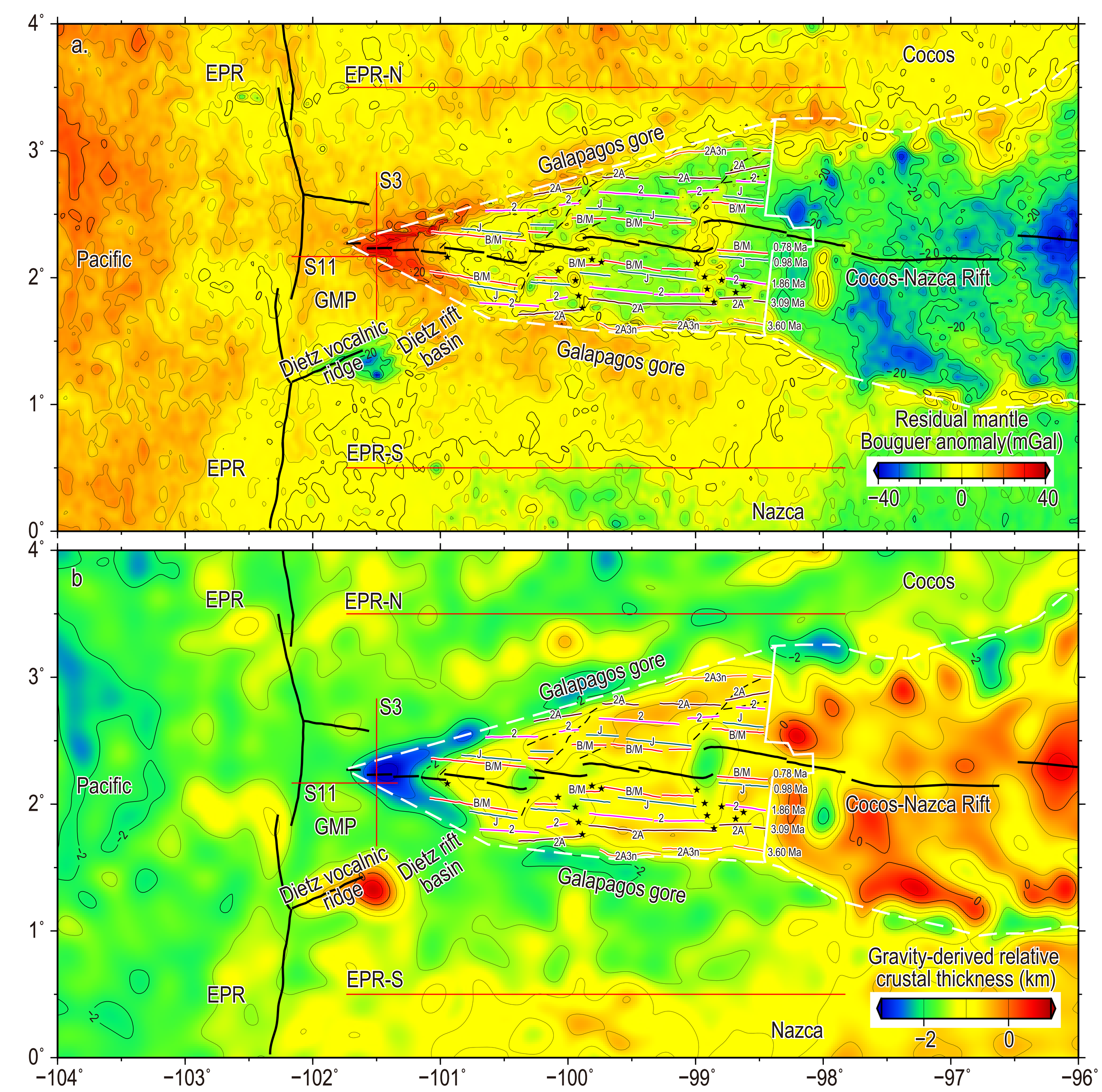

Fig. 3 (a) Residual mantle Bouguer anomaly (RMBA) and (b) gravity-derived relative crustal thickness (reference thickness = 6 km) in the study area. Labels are same as Fig. 1. The CNR region (within the gore) shows generally more negative RMBA and thicker crust than the outer region outside the gore; for the region out of Galapagos gore, the east flank of the EPR ridge axis south of the GMP is also associated with more positive RMBA and thus thicker crust than the conjugate west flank.

③ Comparison with seismic data

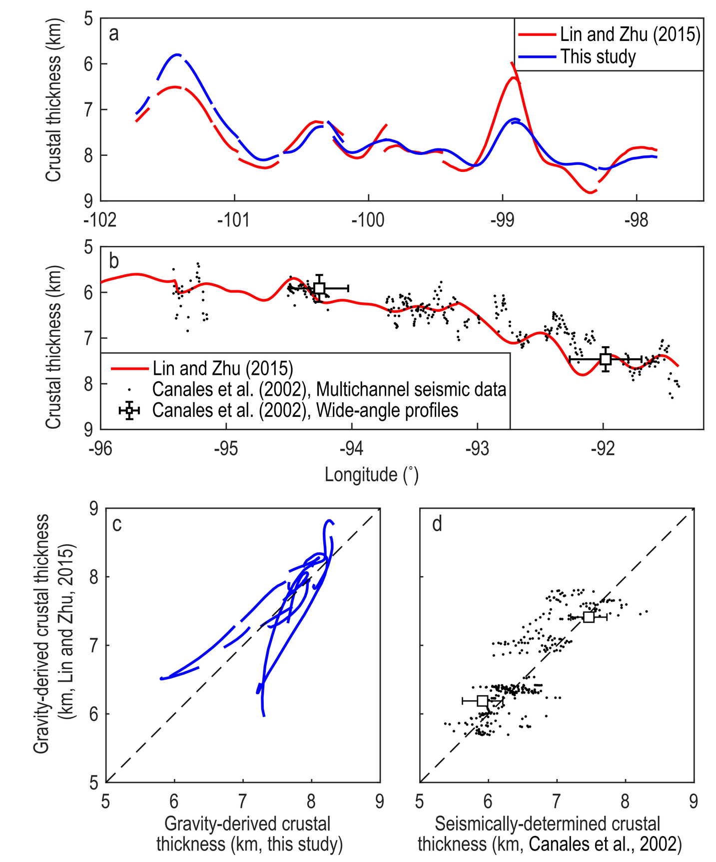

Fig. 4 Comparisons for crustal thickness variation along CNR between (a) our study and Lin and Zhu (2015) from 102.7˚W to 97.8˚W, (b) as well as Lin and Zhu (2015) and Canales et al. (2002) from 96˚W to 91.2˚W. Their corresponding correlations are shown in (c) and (d).

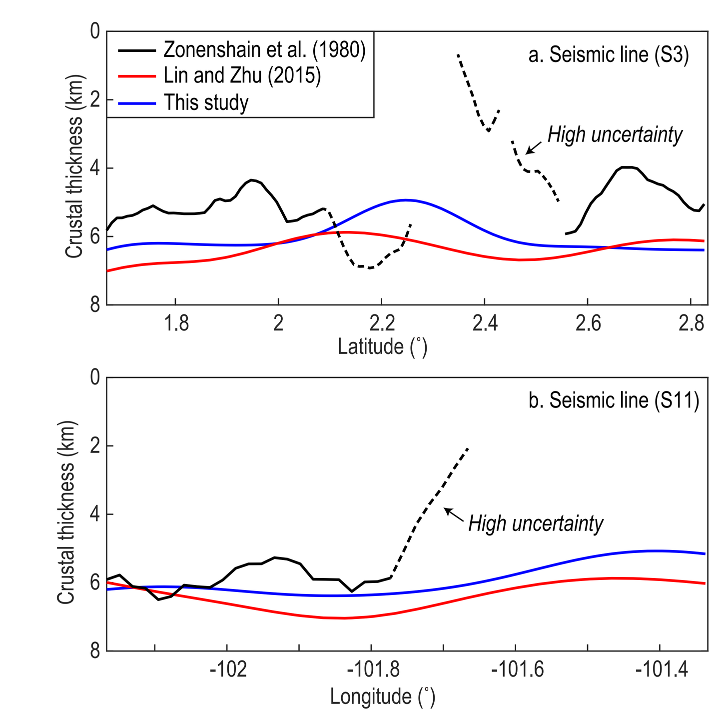

Fig. 5 Crustal structure picked from different studies along seismic survey line (a) S3 and (b) S11. Black lines are seismically-determined crustal thickness from Zonenshain et al. (1980) with some highly uncertain picks (dash lines); red lines show global crustal thickness from Lin and Zhu (2015); and blue lines are gravity-derived crustal thickness in this study.

④ Along-axis and along-isochron profiles

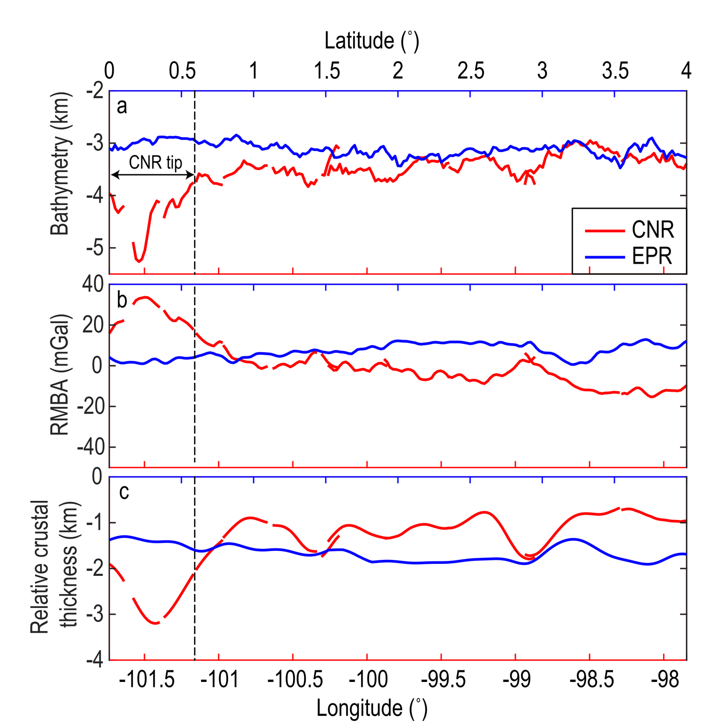

Fig. 6 Along-axis variation in (a) bathymetry, (b) RMBA, and (c) relative crustal thickness. The CNR profiles are red (correlative axis in longitude at bottom) and the EPR profiles are blue (correlative axis in latitude at top).

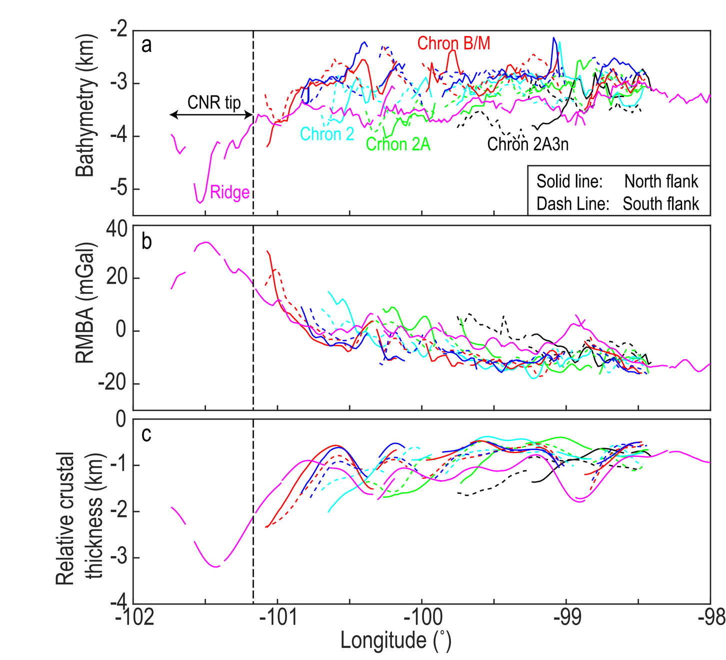

Fig. 7 Along-isochron variation on conjugate flanks of CNR in (a) bathymetry, (b) RMBA and (c) relative crustal thickness. Colored solid lines indicate north flank and dash lines indicate south flank. Chron names are labeled with corresponding colors.

⑤ Regional and local crustal structure

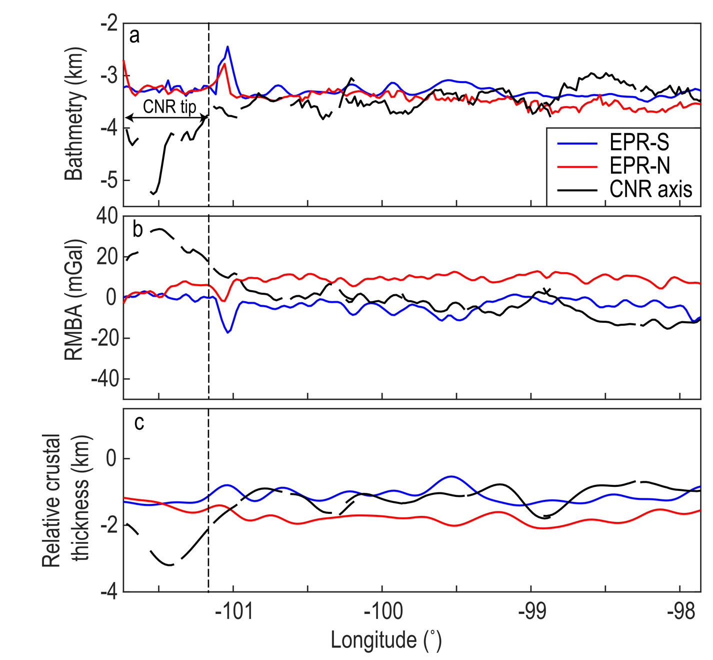

Fig. 8 West-east profiles in (a) bathymetry, (b) RMBA, (c) relative crustal thickness. CNR RMBA shows eastward long-wavelength decrease but short-wavelength decrease at the ridge tip. EPR profiles are nearly flat.

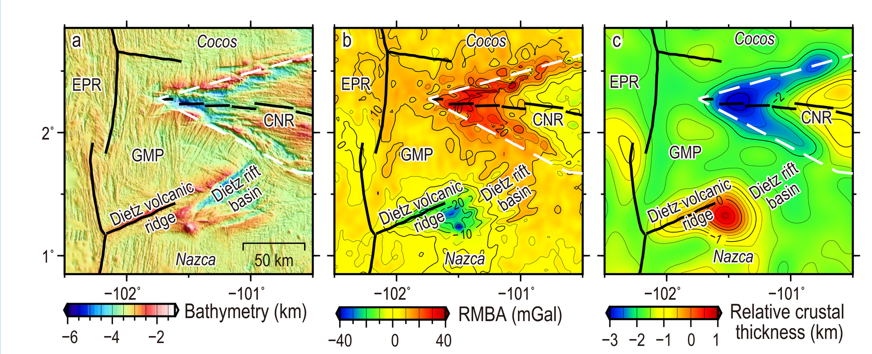

Fig. 9 Maps of GMP: (a) bathymetry, (b) RMBA and (c) relative crustal thickness. The high topography near the northeastern end of Dietz volcanic ridge is associated with more negative RMBA and thicker crust than surrounding areas; the low topography at the western CNR is associated with more positive RMBA and thinner crust.

Conclusions

1. Compared to a thermal model from Turcotte and Schubert (2001), age-related thermal effects are significantly over estimated near the ridge axes, especially on conjugate flanks of the CNR and the eastern flank of the EPR.
2. Depth and crustal thickness are generally similar along conjugate ridge flanks of the CNR, but they differ along conjugate flanks of the EPR. We suggest that the latter is controlled by proximity to the Galapagos hotspot.
3. Starting from the CNR ridge tip there is a consistent decrease in RMBA (increase in crustal thickness) toward the east. This also may be attributed to increasing proximity to the Galapagos hotspot.
4. The first ~100 km east of the propagating CNR ridge tip (~101.7°W to 100.8°W) is associated with strongly positive RMBA (up to ~35 mGal) compared to the remainder of the CNR, suggesting much thinner crust (up to ~1.5-2 km) near the ridge tip.
5. The southern boundary of the Galapagos microplate is associated with negative RMBA centered at ~101.6˚W and 1.3˚N, indicating local relatively thick crust.

References:

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