Displaced cratonic mantle concentrates deep carbon during continental rifting

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Continental rifts are important sources of mantle carbon dioxide (CO_2) emission into Earth's atmosphere. Because deep carbon is stored for long periods in the lithospheric mantle, rift CO_2 flux depends on lithospheric processes that control melt and volatile transport. In particular, the influence of compositional and thickness differences between Archaean (cratonic) and Proterozoic (orogenic) lithosphere on deep-carbon fluxes remains untested.

In this project (Muirhead et al., 2020), we collected water samples from springs in the Natron, Manyara and Balangida regions of Tanzania that cross the boundary between orogenic and cratonic lithosphere (Fig. 1). We also measured diffuse CO_2 flux in these regions. Based on the helium and carbon isotopes and CO_2 fluxes obtained, we propose that displacement of carbon-enriched Tanzanian cratonic mantle concentrates deep carbon below parts of the East African Rift System, which is released during rifting and also facilitates the rifting process. Sources and fluxes of CO_2 and helium over this 350-kilometre-long transect crossing the boundary between orogenic (Natron and Magadi basins) and cratonic (Balangida and Manyara basins) lithosphere from south to north show striking and systematic differences. Areas of diffuse CO_2 degassing exhibit increasing mantle CO_2 flux and $^3He/^4He$ ratios as the rift transitions from Archaean (cratonic) to Proterozoic (orogenic) lithosphere. Active carbonatite magmatism also occurs near the craton edge supplying significant amounts of mantle-derived CO_2 to the atmosphere. We combine our geochemical data with geophysical results that illuminate the rift-craton transition in the lithosphere and mantle as well as with existing numerical models of rift evolution. This multi-disciplinary analyses of all data indicates that advection of the root of thick Archaean lithosphere laterally to the base of the much thinner adjacent Proterozoic lithosphere creates a zone of highly concentrated deep carbon (Fig. 2). This mode of deep-carbon extraction may increase CO_2 fluxes in some continental rifts, helping to control the production and location of carbonate-rich magmas as well as facilitate the rifting process. ■

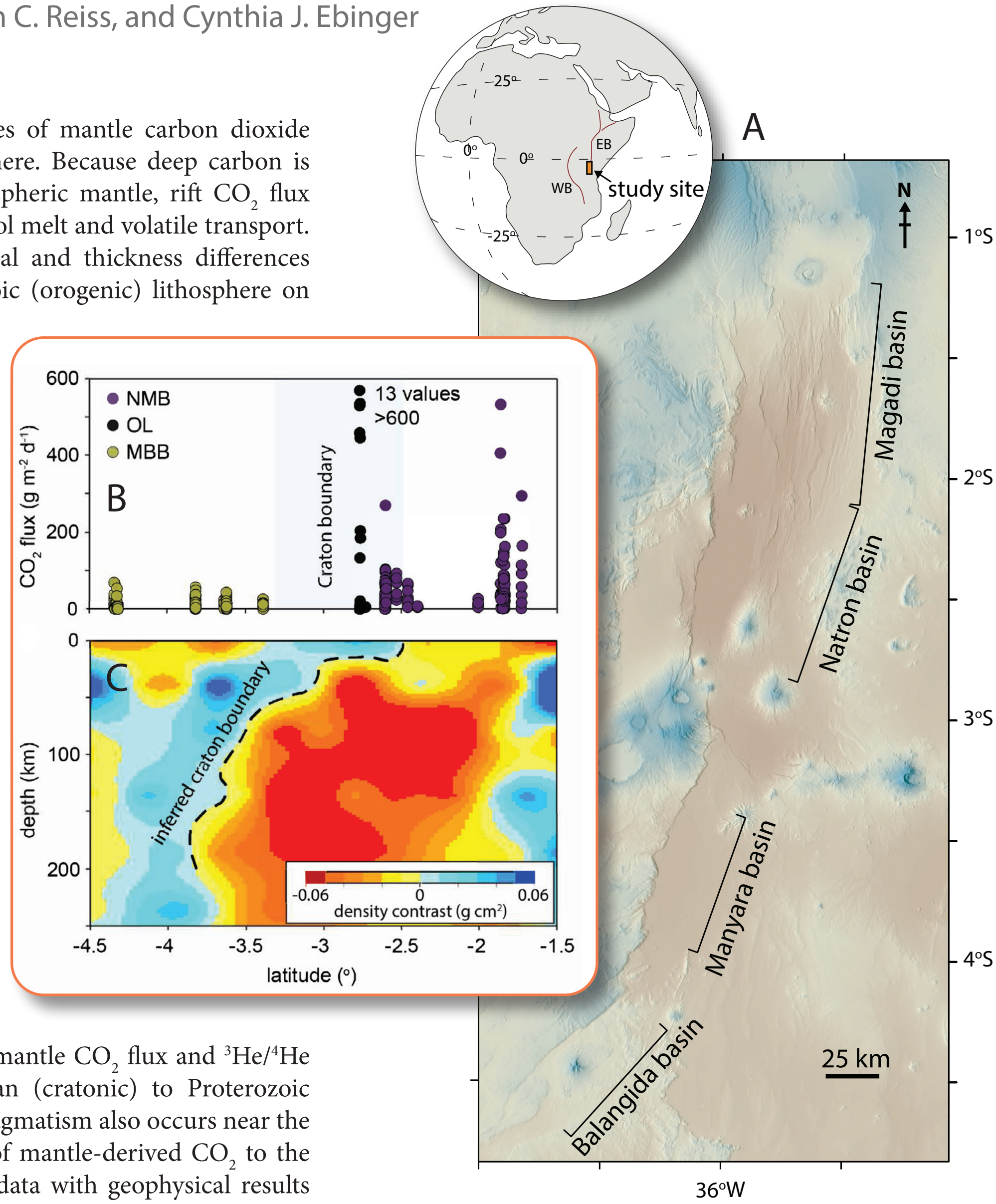

Figure 1. Example of gas data (modified from Muirhead et al. 2020) collected and analysed by the MODeSt project, with these figures and data presented in full in Muirhead et al. (2020). A) Locations of examined rift basins in the East African Rift System. Cross-section line from X to X' shows the southern and north extents of the seismic velocity data profile presented in C. B) Diffuse CO_2 vs latitude for data collected in the study region presented in A. C) Cross-section through the lithosphere density model of Tiberi et al. (2019).

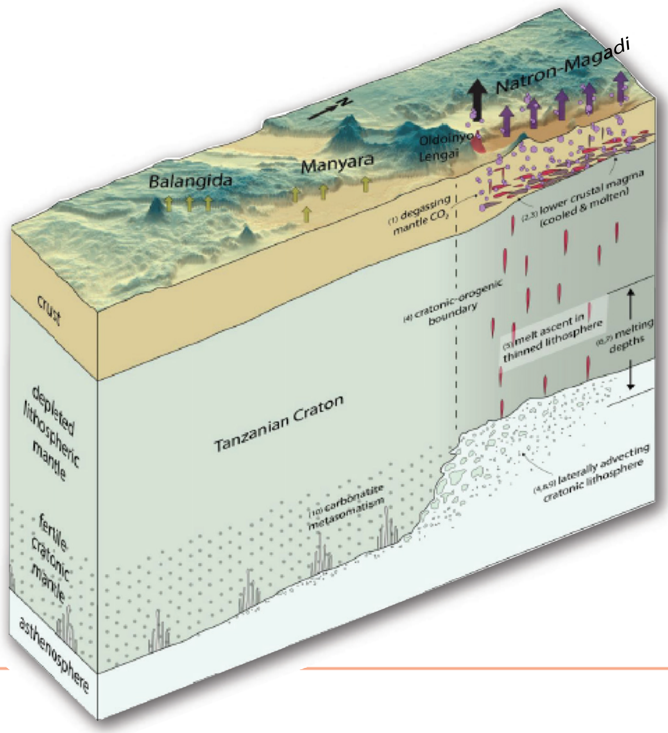

Photo above. Tobias Fischer sampling an actively degassing vent on the western border fault to the Natron Basin in Tanzania, with the Oldoinyo Lengai in the background. Photo credit: J. Muirhead.

Figure 2. Schematic diagram from Muirhead et al., (2020) showing the process of lateral advection of the root of thick Archean lithosphere to the base of much thinner adjacent Proterozoic lithosphere. This process creates a zone of highly concentrated deep carbon that can facilitate melting and rifting.

References

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