Archean ultra-thick crust reflects mantle overturn in early Earth

MING TANG[1,2], ROBERTA L. RUDNICK[3], CIN-TY A. LEE[1], KENT C. CONDIE[4]

[1] Department of Earth Science, Rice University, Houston, TX 77005, USA. tangmyes@gmail.com
[2] Geology Department, University of Maryland, College Park, MD 20742, USA.
[3] Department of Earth Science, University of California at Santa Barbara, Santa Barbara, CA 93106, USA
[4] New Mexico Institute of Mining and Technology, Socorro, NM 87801 USA

The geology of Archean crust provides clues to the tectonic regime and mantle dynamics of early Earth. Yet our understanding of Earth's early crust is fragmental because this crust has been largely destroyed over the past several billion years. Moreover, the lithospheric mantle beneath Archean cratons is conspicuously refractory and thick compared to its younger counterparts [1-2], but how it formed is elusive.

Here, we use a large geochemical database for igneous rocks to show that, coupled with the thick mantle keels beneath Archean cratons, widespread ultra-thick crust was present in the late Archean. Continuous garnet fractionation seen in Archean differentiation suites (dominated by 2.7 – 3.1 Ga samples), reflected in Dy/Yb– and MnO/FeO_T–SiO_2 compositional trends, is comparable to those of igneous suites from the Northern to Central Andes and Southern Tibet, where the crust is 60 – 70 km thick. Building a thick crust requires tectonic thickening or relatively rapid magmatic inflation. The paucity of rocks formed by shallow intracrustal differentiation, such as K-rich, Eu-depleted granitoids, until the end of Archean [3-4] points to a cold thickening process and a mafic bulk composition for the Late Archean crust. We propose that Archean crust and mantle lithosphere was thickened by convergent mantle flow at mantle downwelling sites. The orogenic processes that made the ultra-thick Archean crust likely had a minimum strain rate on the order of 10^{-13} – 10^{-12} s^{-1}, and requires a mantle flow that is at least 10 – 100 times faster than today to drive thickening against gravitational collapse in the crust. The fact that these features are global in scale may reflect a vigorous mantle overturn in the late Archean, which may have also initiated plate tectonics within this time window.

[1] Jordan (1988) *Journal of Petrology* Special Volume, 11-37; [2] Lee and Chin (2014) *Earth and Planetary Science Letters* 403, 273-286; [3] Condie (2008) *Geology* 36, 611-614; [4] Taylor and McLennan (1985) The Continental Crust.