American Mineralogist, Volume 101, pages 241–242, 2016

Highlights and Breakthroughs

The deep continental crust has a larger Mg isotopic variation than previously thought

Zhao-Feng Zhang[1,*]

[1]State Key Laboratory of Isotope Geochemistry, Guangzhou Institute of Geochemistry, the Chinese Academy of Sciences, Guangzhou 510640, China

Abstract: Magnesium isotope compositions of the bulk continental crust is a key to understand Mg isotope behaviors during crustal processes, and is the prerequisite to study mantle-crust material exchange/reaction by Mg isotopes. However, thus far, little is known about Mg isotopic compositions of the middle and lower continental crust. In the article by Yang et al. in this issue entitled "Magnesium isotopic composition of the deep continental crust," the authors present high-precision Mg isotopic analyses of high-grade metamorphic terrane samples and granulite xenoliths from China, which represent the middle and lower continental crust, respectively. Large Mg isotopic variation is observed in the deep continental crust, reflecting the combination of several processes, such as continental weathering, involvement of supracrustal materials, and fluid metasomatism. In addition, this article also provides an average Mg isotope composition of the bulk continental crust, which is crucial to future applications of Mg isotopes.

Keywords: Magnesium isotope, deep continental crust, high-grade metamorphic terrane, granulite xenolith

It is well known that the variation of Mg isotope compositions is limited during high-temperature geological processes (Teng et al. 2007, 2010a; Handler et al. 2009; Yang et al. 2009; Bourdon et al. 2010; Dauphas et al. 2010; Li et al. 2010; Pogge von Strandmann et al. 2011; Xiao et al. 2013), but is quite large during low-temperature processes (Pogge von Strandmann et al. 2008; Teng et al. 2010b; Tipper et al. 2010; Huang et al. 2012; Liu et al. 2014). Just like other fluid-mobile elements, Mg displays a highly variable and remarkably discrepant isotope composition in the upper continental crust (Shen et al. 2009; Li et al. 2010; Huang et al. 2013) and the hydrosphere (Tipper et al. 2006; Foster et al. 2010; Ling et al. 2011) when compared with the relatively homogeneous mantle (δ^{26}Mg = –0.25 ± 0.07‰, Teng et al. 2010a). The main processes responsible for such large isotopic variation are continental weathering and/or carbonate deposition that occurred among sedimentary systems/upper continental crust and hydrosphere (Pogge von Strandmann et al. 2008; Teng et al. 2010b; Tipper et al. 2010; Huang et al. 2012; Liu et al. 2014). During continental weathering, light Mg isotopes favor the hydrosphere to weathered residue, whereas during carbonate deposition, light Mg isotopes prefer carbonate minerals to the hydrosphere.

* E-mail: zfzhang@gig.ac.cn

The distinct Mg isotopic behaviors during these different processes provide the potential to use Mg isotopes to study mantle-crust material exchange/reaction. Although Mg isotope compositions of most reservoirs have been well studied, the continental crust, especially of the lower crust, remains poorly constrained. Teng et al. (2013) reported Mg isotopic data for some lower crustal xenoliths, but this study did not involve any middle crustal samples. Furthermore, whether or not such a large Mg isotopic variation represents a global signature of the lower crust or just is a local arbitrary case, needs further investigation.

Yang et al. (2016) provides inseparable continuity to obtain new data to better understand the Mg isotope compositions of the middle and lower crust. In this study, they chose a series of typical middle and lower crustal rocks from eastern China, did careful analyses and calculations, and placed strong constraints to understand the isotope compositions of the middle and lower crust. They found large Mg isotopic variations (δ^{26}Mg = –0.76 to +0.12‰) in both the middle and lower crustal rocks, which may reflect the combination of several processes, such as continental weathering, involvement of supracrustal materials, and fluid metasomatism. This study thus confirms the deep crust is indeed globally heterogeneous in terms of Mg isotopes.

It is surprising that the deep continental crust beneath eastern China displays such a large Mg isotopic variation, which was previously considered to be homogeneous because granites derived from this region have a small Mg isotopic variation (δ^{26}Mg = –0.35 to –0.14‰) (Li et al. 2010). Therefore, the new results are very helpful in understanding the deep crustal processes, suggesting that partial melting and granite differentiation may homogenize Mg isotope composition of the deep crustal source rocks, and erase the detailed information of the deep continental crust.

Yang et al. (2016) also provided an average Mg isotope composition of the bulk continental crust. Although there are large Mg isotopic variations in both the middle and lower crust, the bulk continental crust as indicated by Yang et al. (2016) remains a mantle-like Mg isotopic composition (δ^{26}Mg = –0.24 ± 0.07‰).

To summarize, Yang et al. (2016) present a new data set of Mg isotope compositions of the deep continental crust, which reveal a larger variation than previously indicated by granites. This study is very helpful in understanding the Mg isotopic behavior during deep crustal processes, and constraints average Mg isotope composition of the bulk continental crust.

References cited

Bourdon, B., Tipper, E.T., Fitoussi, C., and Stracke, A. (2010) Chondritic Mg isotope composition of the Earth. Geochimica et Cosmochimica Acta, 74, 5069–5083.

Dauphas, N., Teng, F.-Z., and Arndt, N.T. (2010) Magnesium and iron isotopes in 2.7 Ga Alexo komatiites: Mantle signatures, no evidence for Soret diffu-

sion, and identification of diffusive transport in zoned olivine. Geochimica et Cosmochimica Acta, 74, 3274–3291.
Foster, G., von Strandmann, P., and Rae, J. (2010) Boron and magnesium isotopic composition of seawater. Geochemistry, Geophysics, Geosystems, 11(8), Q08015.
Handler, M.R., Baker, J.A., Schiller, M., Bennett, V.C., and Yaxley, G.M. (2009) Magnesium stable isotope composition of Earth's upper mantle. Earth and Planetary Science Letters, 282, 306–313.
Huang, K.-J., Teng, F.-Z., Wei, G.-J., Ma, J.-L., and Bao, Z.-Y. (2012) Adsorption- and desorption-controlled magnesium isotope fractionation during extreme weathering of basalt in Hainan Island, China. Earth and Planetary Science Letters, 359–360, 73–83.
Huang, K.-J., Teng, F.-Z., Elsenouy, A., Li, W.-Y., and Bao, Z.-Y. (2013) Magnesium isotopic variations in loess: Origins and implications. Earth and Planetary Science Letters, 374, 60–70.
Li, W.Y., Teng, F.Z., Ke, S., Rudnick, R.L., Gao, S., Wu, F.Y., and Chappell, B.W. (2010) Heterogeneous magnesium isotopic composition of the upper continental crust. Geochimica et Cosmochimica Acta, 74, 6867–6884.
Ling, M.-X., Sedaghatpour, F., Teng, F.-Z., Hays, P.D., Strauss, J., and Sun, W. (2011) Homogeneous magnesium isotopic composition of seawater: an excellent geostandard for Mg isotope analysis. Rapid Communications in Mass Spectrometry, 25, 2828–2836.
Liu, S.-A., Teng, F.-Z., He, Y., Ke, S., and Li, S. (2010) Investigation of magnesium isotope fractionation during granite differentiation: Implication for Mg isotopic composition of the continental crust. Earth and Planetary Science Letters, 297, 646–654.
Liu, X.-M., Teng, F.-Z., Rudnick, R.L., McDonough, W.F., and Cummings, M.L. (2014) Massive magnesium depletion and isotope fractionation in weathered basalts. Geochimica et Cosmochimica Acta, 135, 336–349.
Pogge von Strandmann, P.A.E., James, R.H., van Calsteren, P., Gislason, S.R., and Burton, K.W. (2008) Lithium, magnesium and uranium isotope behaviour in the estuarine environment of basaltic islands. Earth and Planetary Science Letters, 274, 462–471.
Pogge von Strandmann, P.A.E., Elliott, T., Marschall, H.R., Coath, C., Lai, Y.-J., Jeffcoate, A.B., and Ionov, D.A. (2011) Variations of Li and Mg isotope ratios in bulk chondrites and mantle xenoliths. Geochimica et Cosmochimica Acta, 75, 5247–5268.
Shen, B., Jacobsen, B., Lee, C.T.A., Yin, Q.Z., and Morton, D.M. (2009) The Mg isotopic systematics of granitoids in continental arcs and implications for the role of chemical weathering in crust formation. Proceedings of the National Academy of Sciences, 106, 20,652–20,657.
Teng, F.Z., Wadhwa, M., and Helz, R.T. (2007) Investigation of magnesium isotope fractionation during basalt differentiation: Implications for a chondritic composition of the terrestrial mantle. Earth and Planetary Science Letters, 261, 84–92.
Teng, F.-Z., Li, W.-Y., Ke, S., Marty, B., Dauphas, N., Huang, S., Wu, F.-Y., and Pourmand, A. (2010a) Magnesium isotopic composition of the Earth and chondrites. Geochimica et Cosmochimica Acta, 74, 4150–4166.
Teng, F.Z., Li, W.Y., Rudnick, R.L., and Gardner, L.R. (2010b) Contrasting lithium and magnesium isotope fractionation during continental weathering. Earth and Planetary Science Letters, 300, 63–71.
Teng, F.Z., Yang, W., Rudnick, R.L., and Hu, Y. (2013) Heterogeneous magnesium isotopic composition of the lower continental crust: A xenolith perspective. Geochemistry, Geophysics, Geosystems, 14, 3844–3856.
Tipper, E.T., Galy, A., Gaillardet, J., Bickle, M.J., Elderfield, H., and Carder, E.A. (2006) The magnesium isotope budget of the modern ocean: Constraints from riverine magnesium isotope ratios. Earth and Planetary Science Letters, 250, 241–253.
Tipper, E.T., Gaillardet, J., Louvat, P., Capmas, F., and White, A.F. (2010) Mg isotope constraints on soil pore-fluid chemistry: Evidence from Santa Cruz, California. Geochimica et Cosmochimica Acta, 74, 3883–3896.
Xiao, Y., Teng, F.-Z., Zhang, H.-F., and Yang, W. (2013) Large magnesium isotope fractionation in peridotite xenoliths from eastern North China craton: Product of melt–rock interaction. Geochimica et Cosmochimica Acta, 115, 241–261.
Yang, W., Teng, F.-Z., and Zhang, H.-F. (2009) Chondritic magnesium isotopic composition of the terrestrial mantle: A case study of peridotite xenoliths from the North China craton. Earth and Planetary Science Letters, 288, 475–482.
Yang, W., Teng, F.Z., Li, W.Y., Liu, S.-A., Ke, S., Liu, Y.S., Zhang, H.F., and Gao, S. (2016) Magnesium isotopic composition of the deep continental crust. American Mineralogist, 101, 243–252.

Manuscript received June 30, 2015
Manuscript accepted July 10, 2015
Manuscript handled by Keith Putirka