Carbon isotopes of the deep Earth: Implications for Earth-forming processes and the origin of life

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Major Earth-forming processes (accretion, magma-ocean formation, Moon-forming giant impact, core segregation, late veneer) have affected the carbon budget and dynamics of the Earth's interior, which are currently very poorly understood. Mantle-derived rocks (diamonds and others) show a very well defined peak at $\delta^{13}C$~-5±3 ‰ with a very broad distribution to lower values. The processes that have produced the wide $\delta^{13}C$ distributions to the observed low $\delta^{13}C$ values in the deep Earth have been extensively debated, but few viable models have been proposed.

We recently presented a new model for understanding carbon isotope distributions within the deep Earth, involving Fe-C phases (Fe carbides and C dissolved in Fe-Ni metal) [1]. Our theoretical calculations show that Fe and Si carbides can be significantly depleted in ^{13}C relative to other C-bearing materials even at mantle temperatures. Thus, the redox-freezing and -melting cycles of lithosphere via subduction-upwelling in the deep Earth that involve the Fe-C phases can readily produce the wide distributions in the $\delta^{13}C$ values of diamonds. Our model also predicts that the core may contain C with low $\delta^{13}C$ values and that an average $\delta^{13}C$ value of the bulk Earth could be much lower (-9 to -14 ‰), depending on the degree of C-sequestration to the core. Our new estimate in the $\delta^{13}C$ value of the Earth is more consistent with those of chondrites and other planetary body. The mode of accretion, core-segregation, and late veneers are among many other key processes that can significantly change our understanding and modeling on $\delta^{13}C$ values of carbon within the Earth.

The heterogeneous and depleted $\delta^{13}C$ values of the deep Earth, along with the prebiotic biosynthesis and later veneers with likely low $\delta^{13}C$ values on the Earth surface, present us with a challenge in identifying the origin of life on the early Earth.

[1] Horita and Polyakov (2015), Proc. National Academy of Scineces of the U.S.A. 112, 31-36.