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Magmatic crystallization drives Zr isotopic variations in zircons of the granite batholith

ZHAOXIAN ZHU[1], WEN ZHANG[1], JINGLIANG GUO[1], ZAICONG WANG[1], J. ELIS HOFFMANN[2], TAO LUO[1] AND ZHAO-CHU HU[1]

[1]China University of Geosciences (Wuhan)

[2]Freie Universität Berlin

Presenting Author: zxzhu94@163.com

Magmatic zircons record abundant chemical and isotopic compositions of the magma reservoir and are powerful archives to unravel magmatic evolution and crustal differentiation. Zirconium is a major component of zircon, and its stable isotopic composition (noted as $\delta^{94/90}$Zr relative to the IPGP standard) has been increasingly explored as a powerful new tracer [1]. However, recently reported Zr isotopes of zircons exhibit complex results [2-4], and how magmatic crystallization controls Zr isotopic variation in zircons remains enigmatic. Here we employed high-spatial-resolution laser ablation MC-ICP-MS to obtain U-Pb ages, trace elements, and Hf-Zr isotope compositions on magmatic zircons of Linglong granite batholith (~ 73 wt.% SiO_2) from the Jiaodong Peninsula, eastern North China Craton to address this question. Zircons display three types of oscillation zoning in cathodoluminescence images. The identical U-Pb ages and similar Hf isotopic compositions indicate that these different types of zircons formed from a crystallizing magma system. Some types of zircons display the restricted variations of Zr isotopes and others show internal zoning with light $\delta^{94/90}$Zr cores and heavier rims. Overall, the zircon $\delta^{94/90}$Zr values increase with the decreasing temperature, Zr/Hf ratios, and an increasing Hf, U abundances. Such variations of trace element compositions in zircons reveal the melt evolution towards more evolved compositions during cooling and crystallization of the magmatic system followed by the fractionation of major and accessory minerals. Therefore, the degree of magma fractionation plays a dominant role in driving the variability of Zr isotopic compositions and explains both the intra-homogeneity and considerable Zr isotopic zonation for natural magmatic zircons. Successful application of the integrated zircon geochemistry in this relatively simple calc-alkalic pluton offers a solid basis for in-situ zircon Zr isotopes to be a novel indicator to trace the complex mush bodies.

[1] Inglis et al (2019), GCA 250, 311-323; [2] Guo et al (2020), PNAS 117, 21125-21131; [3] Zhang et al (2019), JAAS 34, 1800-1809; [4] Ibañez-Mejia and Tissot (2019), SA 5, 1-14.