1.4 独居石 LA-ICP-MS 微区原位 U-Pb 定年和微量元素分析

独居石 U-Pb 同位素定年和微量元素含量在武汉上谱分析科技有限责任公司利用 LA-ICP-MS 分析完成。GeolasPro 激光剥蚀系统由 COMPexPro 102 ArF 193 nm 准分子激光器和 MicroLas 光学系统组成，ICP-MS 型号为 Agilent 7900。激光剥蚀过程中，采用氦气作载气，氩气为补偿气以调节灵敏度。两者在进入 ICP 之前通过一个 T 型接头混合，激光剥蚀系统配置有信号平滑装置(Hu et al., 2015)。即使激光脉冲频率低达 1 Hz，采用该装置后也能获得平滑的分析信号，特别适用于高 U 含量样品的微区测试(Zong et al., 2015)。本次分析的激光束斑和频率分别为××μm 和××Hz。U-Pb 同位素定年处理中采用独居石标准物质 44069 和玻璃标准物质 NIST610 作外标分别进行同位素和微量元素分馏校正。每个时间分辨分析数据包括大约 20-30 秒空白信号和 50 秒样品信号。对分析数据的离线处理（包括对样品和空白信号的选择、仪器灵敏度漂移校正、元素含量及 U-Th-Pb 同位素比值和年龄计算）采用软件 ICPMSDataCal(Liu et al., 2008; Liu et al., 2010)完成。独居石样品的 U-Pb 年龄谐和图绘制和年龄加权平均计算采用 Isoplot/Ex_ver3 (Ludwig, 2003) 完成。

注：××代表实验中激光束斑和频率的数值，根据具体实验条件填写。独居石常规条件为 10/16 μm 和 1/2Hz。

1.4 In-situ U-Pb dating and trace element analysis of monazite by LA-ICP-MS

U-Pb dating of monazite was conducted by LA-ICP-MS at the Wuhan SampleSolution Analytical Technology Co., Ltd., Wuhan, China. Laser sampling was performed using a GeolasPro laser ablation system that consists of a COMPexPro 102 ArF excimer laser (wavelength of 193 nm and maximum energy of 200 mJ) and a MicroLas optical system. An Agilent 7900 ICP-MS instrument was used to acquire ion-signal intensities. Helium was applied as a carrier gas, while argon, serving as the make-up gas, was mixed with the carrier gas through a T-connector before entering the ICP. A “wire” signal smoothing device is included in this laser ablation system, by which smooth signals are produced even at very low laser repetition rates down to 1 Hz (Hu et al., 2015). It is very useful for *in-situ* U-Pb dating of high-U minerals (Zong et al., 2015). The spot size and frequency of the laser were set to ××μm and ××Hz, respectively. Monazite standard 44069 and glass NIST610 were used as external standards for U-Pb dating and trace element calibration, respectively. Each analysis incorporated a background acquisition of approximately 20–30 s followed by 50 s of data acquisition from the sample. An Excel-based software, ICPMSDataCal, was used to perform off-line selection and integration of background and analyzed signals, time-drift correction, and

quantitative calibration for trace element analysis and U-Pb dating (Liu et al., 2008; Liu et al., 2010). Concordia diagrams and weighted mean calculations were made using Isoplot/Ex_ver3 (Ludwig, 2003).

References

Hu, Z.C., Zhang, W., Liu, Y.S., Gao, S., Li, M., Zong, K.Q., Chen, H.H., Hu, S.H., 2015. "Wave" signal-smoothing and mercury-removing device for laser ablation quadrupole and multiple collector ICPMS analysis: application to lead isotope analysis. Analytical Chemistry, 87(2), 1152–1157.

Zong, K.Q., Chen, J.Y., Hu, Z.C., Liu, Y.S., Li, M., Fan, H.H., Meng, Y.N., 2015. In-situ U-Pb dating of uraninite by fs-LA-ICP-MS. Science China Earth Sciences, 58, 1731–1740.

Liu, Y.S., Hu, Z.C., Gao, S., Günther, D., Xu, J., Gao, C.G. and Chen, H.H., 2008. In situ analysis of major and trace elements of anhydrous minerals by LA-ICP-MS without applying an internal standard. Chemical Geology, 257(1-2): 34-43.

Liu, Y.S., Gao, S., Hu, Z.C., Gao, C.G., Zong, K.Q. and Wang, D.B., 2010. Continental and oceanic crust recycling-induced melt-peridotite interactions in the Trans-North China Orogen: U-Pb dating, Hf isotopes and trace elements in zircons of mantle xenoliths. Journal of Petrology, 51(1–2): 537–571.

Ludwig, K.R., 2003. ISOPLOT 3.00: A Geochronological Toolkit for Microsoft Excel. Berkeley Geochronology Center, California, Berkeley, 39 pp.