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Accessary Minerals SIMS U-Th-Pb Dating for Kimberlite and Lamproite

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Kimberlite and lamproite, the major source of diamonds, are volatile-rich potassic ultramafic rocks that originate from the deep lithospheric mantle. These rocks are important for deciphering the composition and structure of the lithosphere. Determinations of precise emplacement ages for kimberlite and lamproite, however, are complicated due to the severe alteration and the presence of xenoliths and xenocrysts. We developed SIMS U-Th-Pb dating methods on several accessary minerals using the large double focusing CAMECA 1280 SIMS at institute of Geology and Geophysics, Chinese Academy of Sciences, which are applied for determining the emplacement age of kimberlite/lamproite in North china Craton and Yangtz Craton.

Perovskite ($CaTiSiO_3$), a common Th- and U-enriched mineral crystallised from kimberlitic magma, is thought to be an important geochronometer for dating the emplacement of kimberlite. However, variable incorporation of common lead into the perovskite crystal structure makes it difficult for evaluation on U-Pb concordance. We developed in this work new procedure of simultaneous independent U-Pb and Th-Pb dating of perovskite, allowing an internal examination of age concordance in absence of precise Pb-Pb age due to high abundance of common lead in most peroskite crystals (Li et al., 2010a). Kimberlitic perovskites from Mengyin, Shandong province and Dahongshan, Hubei province were dated at 480 ± 4 Ma (Li et al., 2011a), 481 ± 5 Ma, respectively.

Baddeleyite (ZrO_2) is has long been recognized as one of the most important U-bearing minerals for dating silica undersaturated igneous rocks. Precise SIMS U-Pb dating has been hampered for Phanerozoic baddeleyite owing to crystal orientation effects that bias Pb/U ratio measured in baddeleyite. We carried out in this study a series of tests of U-Pb and Pb-Pb measurements on Phanerozoic baddeleyite using a multi-collector Cameca 1280 SIMS with oxygen flooding technique. Our results demonstrate that the oxygen flooding can not only enhance secondary Pb^+ ion yield by a fact of 7 for baddeleyite, but also depress the baddeleyite U/Pb orientation effect down to ~2% (1 RSD). Therefore, Phanerozoic (as young as Cenozoic) baddeleyite can be precisely dated by SIMS Pb-Pb and/or U-Pb measurements with precision of 1-3% (2 RSE) (Li et al., 2010b). Baddeleyite from Mengyin and Fuxian kimberlite were dated at 480.4 ± 3.9 Ma, 479.6 ± 4.9 Ma, respectively (Li et al., 2011a).

Rutile (TiO_2) is an accessory mineral in a variety of metamorphic and igneous rocks, including kimberlite/ lamporite. Rutile contains few to hundreds ppm uranium making U-Pb dating possible. However, Rutile from mafic rocks typically contains much lower U. We developed SIMS rutile U-Pb dating procedure and rutile standard reference materials (Li et al., 2011b). Rutile from Zhenyuan kimberlite in Guizhou province was dated at 479 ± 5 Ma by SIMS U-Pb dating method. One may doubt that rutile in kimberlite could be from elcogite xenolith. Though it is possible, the rutile U-Pb age should record the emplacement age of host kimberlite due to its closure temperature of around 500 °C.

Apatite [Ca5(PO4)3(F,Cl, OH)] is an ubiquitous accessory mineral occurring in almost all major rock types. The crystal structure of apatite can accommodate a number of substitutions, such as Sr, Mn, Mg, Lu, Hf, Pb, U and Th. The radioactivity of U and Th in apatite makes it an ideal mineral not only for thermochronology studies by U/Th–He and fission track dating, but also for dating emplacement age of rapidly cooled plutonic rocks using U-Pb system, especially when other minerals suitable for dating are not readily available. Apatite from mantle-derived rocks and meteorites usually has very low U content (<10 ppm), thus high common lead proportion. We developed both analytical and data reduction protocols for in-situ U–Pb analyses on apatite using Cameca IMS 1280 SIMS. Which could be used for apatite with <3 ppm U and >50% common Pb (Li et al., 2012). The apatite from Zhenyuan lamporite in Guizhou province contains ~

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3 ppm U and > 60% common Pb, and was dated at 473 ± 21 Ma.

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