# Reaching new boundaries for *in-situ* U-Th geochronology

J.P. Bernal

Centro de Geociencias, Universidad Nacional Autónoma de México, Campus UNAM Juriquilla, Querétaro, 76230 México

Micro-beam sampling coupled to mass spectrometric techniques have revolutionized geochronology by providing fast, accurate and precise measurement of isotopic and elemental compositions with high spatial resolution and, importantly, with the potential to provide such information within a textural context. Since its inception, the main application has been U-Pb dating of accessory minerals, mainly zircon. However, the use of microbeam techniques for *in-situ* U-Th dating of late Quaternary mineral phases remains as one of the most challenging applications, due to the very low abundance of the decay products of $^{238}U$ ($^{230}Th$ and $^{234}U$) and the very small sampling volumes characteristic of microbeam techniques (usually few $\mu m^3$). This has limited our understanding of many recent geological processes, which is paradoxical, considering that the geological record for this period is, arguably, the most pristine.

Despite its challenging nature, *in-situ* U-Th dating of late-Quaternary zircons has been successfully carried out for several years using Secondary Ionization Mass Spectrometry – SIMS (e.g. Schmitt, 2011; Schmitt et al., 2006). Moreover, the latest advances in mass spectrometry have recently opened the door to LA-SFICPMPS (Guillong et al., 2015) and LA-MCICPMS (Bernal et al., 2014) into this exciting field in geochronology, thus allowing for fast data acquisition, with no sacrifice in accuracy and precision. However, because zircon is mostly found in intermediate to acidic rocks, U-Th dating of young volcanic rocks is limited to such lithologies, hence excluding basic and ultrabasic rocks such as basalts and andesites. This is about to change thanks to a recent contribution by Wu and co-workers at the University of California – Los Angeles and the Istituto Nazionale di Geofisica e Vulcanologia, Naples, Italy.

Wu et al (this issue, page---) successfully dated very young (~4 ky) and small (< 30 μm) crystals included in vesicles using SIMS and carried out a very detailed study on the geochronological significance of U-Th ages of baddeleyite. This was not an easy task. Typically, mineral separation by physical means allows to obtain a mineral concentrate from which several elemental and/or isotopic compositions can be obtained from which, subsequently, an isochron and/or an age can be obtained. However, due to the small crystal size typically displayed by baddeleyite, as well as a very intimate association with the lower-density minerals, separation by physical means proved to be quite challenging. To overcome this, Wu and co-workers identified the crystals in rock billets using Scanning Electron Microscopy and then extracted the domains where the baddeleyite was located with a diamond drill. The extracted pieces where then analyzed by SIMS and successfully dated from ($^{230}$Th/$^{232}$Th) vs ($^{238}$U/$^{232}$Th) isochrons.

If solving the analytical hurdles behind *in situ* U-Th dating of baddeleyite is not sufficiently challenging, the interpretation of the resulting ages can also represent a significant conundrum. This is because magma residence times and crystallization ages are on a similar time-scales, thus U-Th ages of accessory minerals, including baddeleyite, might not necessary reflect eruption ages. To tackle this, Wu and co-workers compare their results with other dating techniques, such as K-Ar. Moreover, they also demonstrated that the mineral associations and intricate texture of baddeleyite strongly suggest that it crystallized in a later stage of magma cooling, thus implying that the resulting ages are, for most cases, reflecting the eruption time.

The work by Wu and co-workers is an elegant solution to a complex problem; it demonstrates that modern instrumentation is opening new research opportunities in geochronology, and that if these are tackled smartly, real advances in science can be achieved. The authors also demonstrate what one of the most renowned gechronologists of our time recently stated: “***It is a good time to be a geochronologist, or to collaborate with one or more. The future looks very bright***” (Mattinson, 2013). This is the future.

References cited:

Bernal, J.P., Solari, L.A., Gómez-Tuena, A., Ortega-Obregón, C., Mori, L., Vega-González, M., and Espinosa-Arbeláez, D.G. (2014) *In-situ* $^{230}$Th/U dating of Quaternary zircons using LA-MCICPMS. Quaternary Geochronology, 23(0), 46-55.

Guillong, M., Schmitt, A.K., and Bachmann, O. (2015) Comment on “Zircon U–Th–Pb dating using LA-ICP-MS: Simultaneous U–Pb and U–Th dating on 0.1 Ma Toya Tephra, Japan” by Hisatoshi Ito. Journal of Volcanology and Geothermal Research, 296(0), 101-103.

Mattinson, J.M. (2013) The geochronology revolution. Geological Society of America Special Papers, 500, 303-320.

Schmitt, A.K. (2011) Uranium Series Accessory Crystal Dating of Magmatic Processes. Annual Review of Earth and Planetary Sciences, 39(1), 321-349.

Schmitt, A.K., Stockli, D.F., and Hausback, B.P. (2006) Eruption and magma crystallization ages of Las Tres Vírgenes (Baja California) constrained by combined 230Th/238U and (U–Th)/He dating of zircon. Journal of Volcanology and Geothermal Research, 158(3–4), 281-295.