Six chronometers in one rock: Dating mafic intrusive rocks by in situ SHRIMP U-Pb geochronology

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Precise dates for mafic igneous events are essential for identifying Large Igneous Provinces and aiding tectonic reconstructions, and for understanding mantle dynamics, mass extinctions and paleoclimate. They may also provide age constraints on the deposition of sedimentary sequences which lack granitic intrusives or interbedded felsic volcanics. However, mafic intrusive rocks are more challenging to date precisely than felsic rocks.

We have found a wide range of Ti-Zr-REE-bearing accessory minerals in tholeiitic dikes and sills that can be dated using in situ SHRIMP U-Pb methods, e.g., zircon, baddeleyite, zirconolite, tranquillityite, chevkinite-perrierite, monazite, allanite and britholite. In many cases, these minerals form fine grains (<10 - 20 μm) intergrown with quartz and orthoclase in patches of late-crystallizing mesostasis, or inclusions in igneous amphibole rimming pyroxene. The small size means that the grains are generally not recovered by traditional heavy mineral separation techniques, but they can be drilled from polished thin sections for analysis by in situ techniques.

Six mineral chronometers were found in a tholeiitic sill intruding the Eel Creek Formation (previously thought to be Neoproterozoic in age) on the northeastern margin of the Pilbara Craton, Western Australia. In situ SHRIMP $^{207}Pb/^{206}Pb$ analyses were derived from zircon, baddeleyite, zirconolite, tranquillityite, chevkinite-perrierite and monazite to allow comparisons between the different minerals and evaluation of their performances as geochronometers. Although baddeleyite is more abundant, zirconolite and tranquillityite provide the most precise ages (~1.07 Ga), more precise than baddeleyite and monazite. High common Pb prevented chevkinite-perrierite from providing a reliable date whereas zircon crystals were metamict and their U-Th-Pb systematics had been disturbed.

Our results show that precise dates can be obtained for mafic igneous events using in situ ion microprobe techniques. Although tranquillityite provides a precise age for the Eel Creek sill, it is susceptible to alteration, and generally less abundant than zirconolite, leaving zirconolite as the mineral of choice for dating mafic igneous events.