U-Pb TIMS zircon age constraints on the Tardree Rhyolite zircon fission track standard

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Friday, 07 November 2008

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The Tardree Rhyolite in NE Ireland forms part of the British and Irish Palaeogene Igneous Province, associated with the opening of the North Atlantic and the onset of the present Iceland Plume. In NE Ireland, igneous activity comprised mainly voluminous eruptions of flood basalts (Antrim Plateau lavas). A major pause in volcanism, represented by the Interbasaltic Formation, was accompanied by weathering of the basalt pile, localised eruptions of tholeiitic basalt (including the famous Giant's Causeway) and minor rhyolite domes and flows including the Tardree Rhyolite (Emeleus & Preston, 1969; Old, 1975). Figure 1 shows the sampling site, an abandoned quarry on the south-east flank of Tardree Hill that is thought to be part of a rhyolite dome complex [Irish National Grid reference IJ19219413]. Columnar jointing is clearly visible.

Figure 1. Field photograph of the sampled quarry within the Tardree Rhyolite [Irish National Grid reference IJ19219413].

The Tardree Rhyolite Formation has yielded a zircon fission track age of 65.2 ± 0.8 Ma (Fitch & Hurford, 1977). This age determination employed the external detector method and a value of 6.85×10^{-17} yr^{-1} for the decay constant (λ_f) as the ζ-calibration method had not been adopted at that time. Tardree Rhyolite zircons exhibit major U zonation, typically with a U-rich core and a U-poor rim. Figure 2 is taken from Tagami *et al.* (2003). It illustrates the typical spontaneous fission track distribution in a Tardree Rhyolite zircon, with a high track density core and low track density rim. Dobson (2006) reported LA-ICPMS data which demonstrates that the high U cores typically have U concentrations 40 times those of the rims. Uncorrected (U-Th)/He ages of the Tardree zircon are 56.2 ± 5.4 Ma (1σ) (Tagami *et al.*, 2003) and 57.8 ± 1.2 Ma (2σ) (Dobson, 2006). Mean α-ejection corrected ages are irreproducible and significantly older due to the high U-cores and strong zoning (Tagami *et al.*, 2003; Hourigan *et al.*2005, Dobson, 2006).

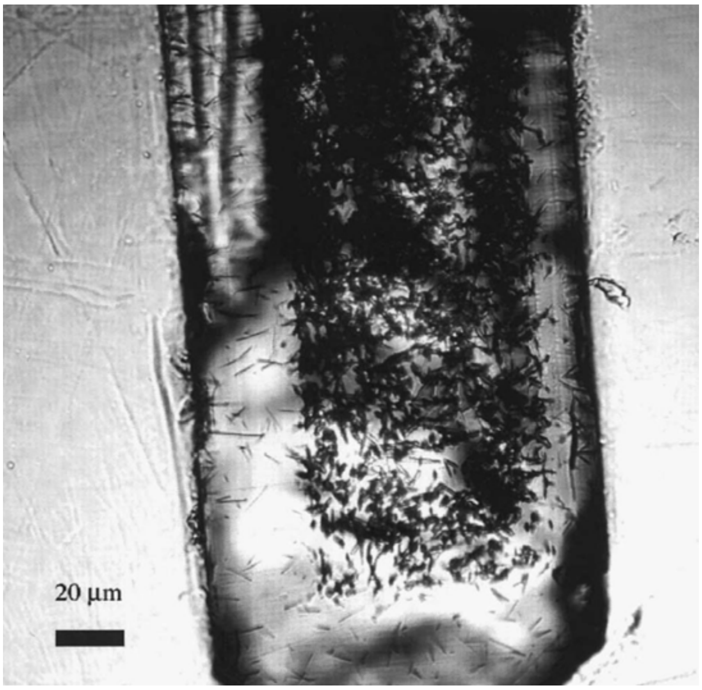

Figure 2. A photograph of etched spontaneous fission tracks in a Tardree Rhyolite zircon from Tagami *et al.* (2003)

Both zircon fission track and (U-Th)/He zircon studies of the Tardree Rhyolite use the U-Pb zircon age of 58.4 ± 0.7 Ma of Gamble *et al.* (1999) for the eruption age of the complex. This age determination employed an ion micro-probe (SHRIMP), using the SL13 zircon standard. However, several other methods have yielded older ages for the complex. Meighan *et al.* (1988) report a Rb-Sr whole rock isochron of 60.3 ± 2.3 Ma. Unpublished ^{40}Ar-^{39}Ar sanidine ages of 60.7 ± 0.6 Ma (data by Lux & Gibson quoted in Meighan *et al.*, 1988) and 59.1 and 60.2 Ma (data by Hurford & Hammerschmidt quoted in Tagami *et al.*, 2003) are all demonstrably older than the U-Pb SHRIMP zircon age of Gamble *et al.* (1999).

100 kg of Tardree Rhyolite was sampled from the abandoned quarry site in Fig. 1 to provide a substantial fraction for a zircon reference material. The sample was crushed and sieved to below 300 microns and a heavy fraction was obtained using a Gemeni mineral separation table. An aliquot of this heavy fraction was separated using heavy liquids and a magnetic separator. No apatite was found in the non-magnetic fraction between 2.9 and 3.3 g/cm^3, but the >3.3 g/cm^3 non-magnetic fraction yielded abundant zircon. The zircon fraction is comprised of prismatic grains up to 300 microns long with aspect ratios of between 3 and 10:1. A small aliquot of zircon was analysed by isotope dilution thermal ionization mass spectrometry (TIMS) at the Geological Museum in Oslo, Norway. The zircon grains were pre-treated using the chemical abrasion method ("CA-TIMS") of Mattinson (2005). This method employs high temperature treatment of the zircon grains (in the range of 850°C for 36 h) to anneal zircon lattice radiation damage from natural alpha, alpha recoil, and spontaneous fission processes. The annealed zircon fraction is then subjected to a partial dissolution step in concentrated HF and HNO_3 at 220°C for 16 h which removes zircon sub-domains with high U and Th concentrations. These sub-domains are invariably slightly to strongly discordant due to Pb loss. The remaining portion of the zircon crystal (in samples that lack inheritance) are completely free from Pb loss.

Six single grain zircon analyses were undertaken (Fig. 3), four of which employed the CA-TIMS approach. These four single grains yield a Concordia age of 61.23 ± 0.11 Ma (2σ, MSWD = 1.01). Two grains were treated by conventional mechanical abrasion to remove outer zones which may have undergone Pb loss. These two grains yield a Concordia age of 60.97 ± 0.39 Ma, slightly younger than the CA-TIMS age. The CA-TIMS age is taken as the crystallisation age of the Tardree Rhyolite and it is recommended that this value is adopted as the fission track age of the zircon standard. Aliquots of the Tardree Rhyolite are available and can be obtained by emailing chewd@tcd.ie .

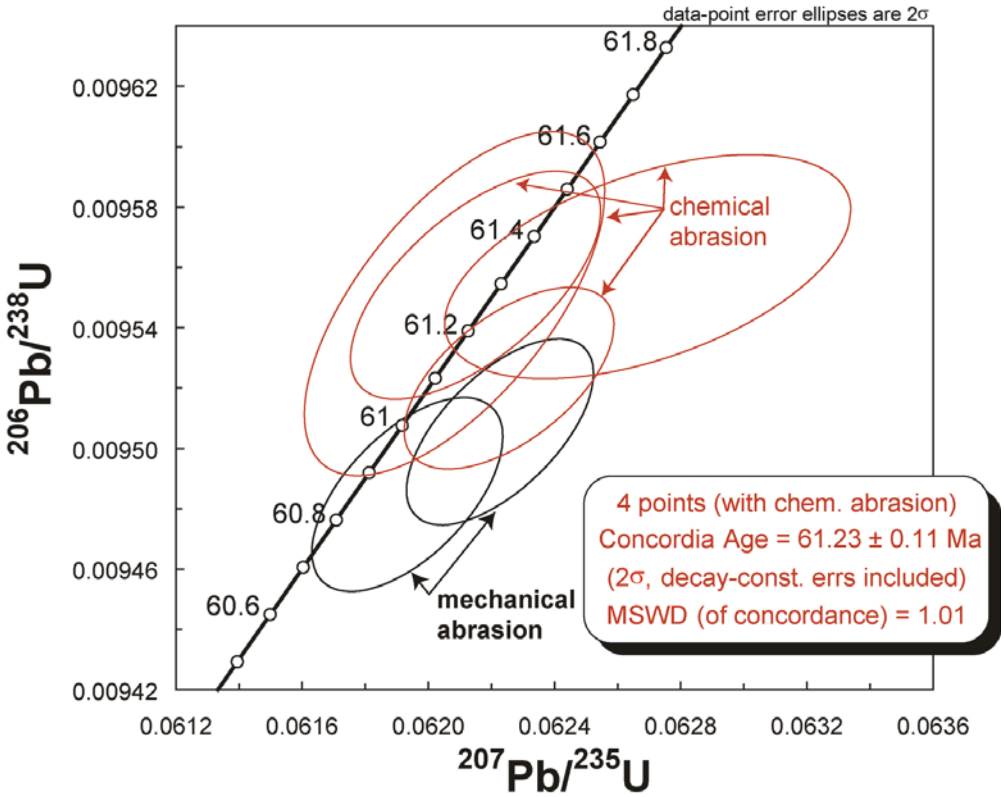

Figure 3. U-Pb Concordia diagram of ID-TIMS data for the dated Tardree Rhyolite sample. Zircon grains treated by chemical abrasion are represented by the red uncertainty ellipses.

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Last Updated (Monday, 01 December 2008)

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