(U-Th)/He DATING OF THE NÖRDLINGER RIES IMPACT STRUCTURE, GERMANY

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Introduction: Precise dating of impact craters is difficult because shock and post-shock events are typically insufficient to uniformly reset most commonly applied isotopic chronometers (e.g. U-Pb, Rb-Sr, K-Ar, and Ar-Ar). Impactites are incompletely preserved, and thus the amount of material with completely reset Pb, Sr, and Ar isotopic systematics is small. This is especially true for small to medium sized (<50 km) impact craters, only a few of which have well constrained isotopic ages. The Nördlinger Ries crater, Germany, is one that does. Extensive preservation of the Nördlinger Ries ejecta blanket provides a wealth of material for isotopic dating, and a variety of methods (K/Ar, $^{40}Ar/^{39}Ar$, and fission track) have led to a slow but steady refinement of the best estimate for the age of the impact: currently ~14.4 Ma.

The well-constrained age of the Nördlinger Ries crater provides an opportunity to use the impactites from this site to evaluate the utility of a new and promising impact dating technique based on the (U-Th)/He chronometer [1]. This technique may be especially useful for small to medium sized impact structures such as Ries since low He closure temperatures (ca. 230°C for zircon and ca. 105°C for apatite, calculated using the He diffusion parameters of Reiners et al. [2] and Farley [3], assuming a 100 μm crystal diameter and a cooling rate of 1000°C/Ma), combined with fast He diffusion properties might be expected to result in more effective and more rapid resetting during impact than might be the case for other, more widely applied chronometers.

Geologic setting: The Nördlinger Ries impact structure is a ~24 km wide, 600 m deep basin located in Baden-Württemberg and Bavaria, southern Germany. Although an impact origin had been proposed for the Ries basin as early as 1904 [4], most geologists believed it to be a volcanic crater. The first definitive evidence for an impact origin came in 1961 with the discovery of the high-pressure silica polymorph coesite in suevites outside the crater rim [5]. Since then, due to its great accessibility and the unusually good preservation of its impact ejecta blanket it has become one of the best studied craters in the world.

The Ries impact structure possesses a complete sequence of impactites, including various types of proximal impact ejecta (lithic impact breccias, impact melt rocks, and suevites preserved up to ~40 km radius from the center of the crater), and the Central European ('moldavite') tektite strewn field extending out to distances of 260–400 km to the east and northeast. Target rocks comprise a flat-lying sequence of predominantly Mesozoic sedimentary rocks unconformably overlying Variscan (Moldanubian) crystalline basement [6–7].

Previous age constraints: Initial K/Ar and fission track dating of suevite and tektite material in the 1960s [8–13] bracketed the age of impact to ~14.4–15.2 Ma (after recalculation in 1977 with the revised decay constants of [14]). Subsequent dating of the same material in the late 1970s and early 1980s using $^{40}Ar/^{39}Ar$ step-heating [15–16] yielded a similar range of ~14.6–15.2 Ma.

With the exception of two studies ([17]: 14.89 ± 0.10 Ma (2σ) and [18]: 14.68 ± 0.11 Ma (2σ)), more recent $^{40}Ar/^{39}Ar$ step-heating and $^{40}Ar/^{39}Ar$ laser probe analyses of suevite and tektite samples have yielded a slightly younger impact age of ~14.3–14.5 Ma [19–22]. A new $^{40}Ar/^{39}Ar$ step-heating study of recrystallized K-feldspar glass from a granite clast within an impact-metamorphosed melt rock (14.37 ± 0.30 Ma (2σ) [23]) is consistent with this younger age range.

Samples and analytical techniques: Individual zircon grains from two samples collected within the Nördlinger Ries crater were dated with the (U-Th)/He technique. The first (Ries 2) is a carbonate-bearing suevite from the Aumühle quarry on the northern margin of the crater. The second (Ries 3), from the Polsingen quarry on the northeast edge of the crater, is a sample of the same melt rock used by Buchner et al. [23] for $^{40}Ar/^{39}Ar$ step heating.

Five zircons from Ries 2 and ten zircons from Ries 3 were selected on the basis of their euhedral habit. Helium was extracted and measured by laser heating in the Noble Gas, Geochronology, and Geochemistry Laboratories (NG^3L) at ASU. The grains were then dissolved following the procedures described in [24] and U and Th measured on a Thermo X-series quadrupole ICP-MS in the Keck Laboratory at ASU.

(U-Th)/He dating results: Four out of five grains from Ries 2 yielded successful ages, one of which is anomalously young at 10.98 ± 0.35 (2σ) Ma, likely due to internal damage of the crystal. The remaining three clustered about a mean age of 13.8 ± 1.8 Ma (2σ, Fig. 1). The nine successful (U-Th)/He ages from Ries 3 had eight grains that clustered about a mean age of

13.64 ± 0.69 Ma (2σ, Fig. 2), with one older age of 19.47 ± 0.57 Ma (2σ), likely due to partial resetting. All ages were calculated using Isoplot v. 3.53 [25].

Discussion: The new (U-Th)/He zircon ages overlap at the 2σ level with previous age estimates for the Ries crater, particularly with the most recent $^{40}Ar/^{39}Ar$ age of ~14.4 Ma (Fig. 3). However, the (U-Th)/He data give a slightly younger age. This could either reflect the relatively higher imprecision of the (U-Th)/He data or be due to a post-impact process that partially reset the (U-Th)/He system. With our current data set it is difficult to speculate further, though planned (U-Th)/He analyses on apatite grains from both the suevite and melt rock samples (closure temperature of 105°C [2]) could help to narrow the possibilities.

Conclusions: New (U-Th)/He zircon data for the Nördlinger Ries impact structure give a mean age of 13.60 ± 0.58 Ma (2σ). This is slightly younger than but within error of previous age estimates for the crater.

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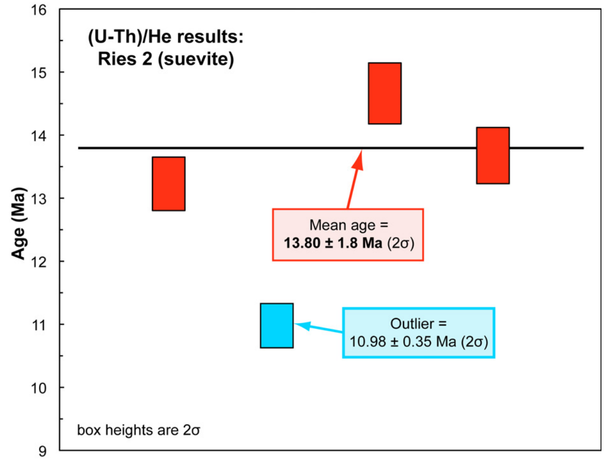

Figure 1. Ries 2 Weighted mean (U-Th)/He age plot.

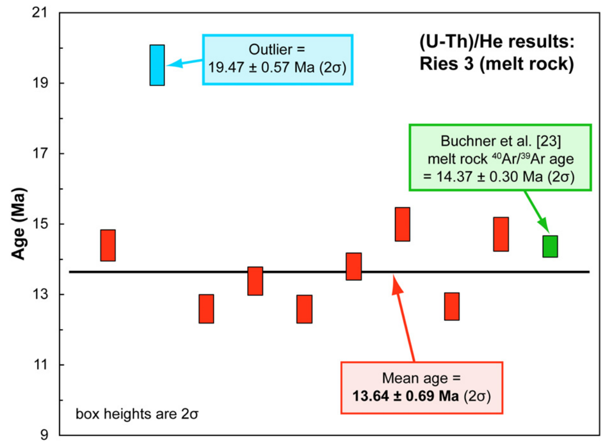

Figure 2. Ries 3 weighted mean (U-Th)/He age plot.

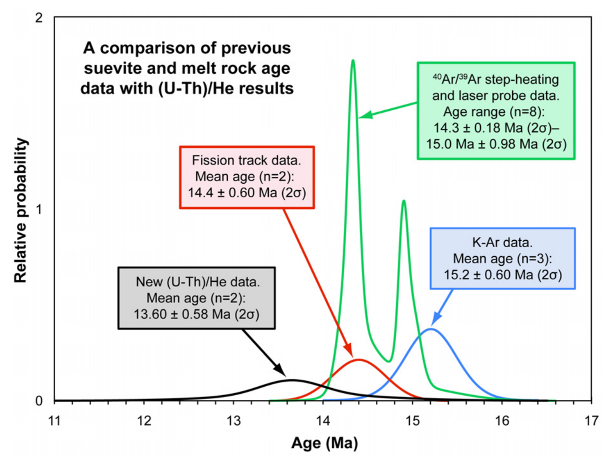

Figure 3. Age-probability plot comparing previous K-Ar, $^{40}Ar/^{39}Ar$ and fission track age data from Nördlinger Ries suevite and melt rock samples [8–13] with the new (U-Th)/He zircon data.