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Synchronising clocks in rocks

Refined isotopic decay measures increase dating accuracy

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Time information is fundamental to most geological studies, particularly in guiding resource exploration, because the date of a geological process can be crucial to assessing its potential to form mineral deposits.

In most cases the only quantitative measure of time is natural radioactive decay. Isotopic decay measures in common use in geochronology include measures of the decay of uranium to lead (U–Pb), potassium to argon (K–Ar), rubidium to strontium (Rb–Sr), and rhenium to osmium (Re–Os).

Each provides an independent geological 'clock' with specific advantages and limitations, and can provide timing constraints on different geological processes. Consequently, application of multiple geochronological methods can often provide more complete understanding than the use of any single method.

Geoscience Australia's geochronology toolkit has been augmented since 2001 by the argon^{40}/argon^{39} method—a variant of the K–Ar method. The ^{40}Ar/^{39}Ar method complements Geoscience Australia's long-established strength in U–Pb SHRIMP zircon geochronology by providing timing information from different minerals and for different geological processes.

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For example, the ^{40}Ar/^{39}Ar method can be used to:

- directly date potassium-bearing hydrothermal minerals in ore-related alteration zones
- reconstruct cooling and thermal overprinting histories in medium- to high-grade metamorphic terranes
- date mica-fabrics in shear-zones.

This information is most useful when integrated with U–Pb zircon ages from magmatic rocks to reconstruct a more complete sedimentary, magmatic, metamorphic and metallogenic history of a terrane.

However, when comparing geological ages derived from contrasting isotopic methods (for example, U–Pb versus ^{40}Ar/^{39}Ar), it must be recognised that each of these methods involves inherent uncertainties related to decay constants, the age and homogeneity of standards, and other physical parameters. At best, these so-called external uncertainties create 'fuzzy' ages and, if not properly accounted for, can lead to misleading geological interpretations.

One approach to improving the current situation is to calibrate the ^{40}Ar/^{39}Ar timescale against the U–Pb timescale based on careful comparisons of ^{40}Ar/^{39}Ar and U–Pb ages from volcanic rocks. Such intercalibration is the subject of ongoing international research, and the existing dataset indicates that the two timescales may be offset by almost 1% (for example, Min et al 2000, Villeneuve et al 2000, Kwon et al 2002).

In simple terms, the clocks are not perfectly synchronised. While a 1% offset may not sound like much, in Palaeo- and Mesoproterozoic rocks this translates to age offsets in the order of 15 to 20 million years.

Several geochronological studies carried out at Geoscience Australia over recent years illustrate the importance of improved synchronisation of the U–Pb and $^{40}Ar/^{39}Ar$ isotopic clocks. For example, discrepancies in $^{40}Ar/^{39}Ar$ and U–Pb ages for Au–Cu mineralisation at Tennant Creek have been problematic for the past decade, and have led to contrasting interpretations (Compston & McDougall 1994, Wyborn et al 1998). Reconsideration of the published $^{40}Ar/^{39}Ar$ ages in the light of improved synchronisation of the isotopic clocks reconciles the apparent discrepancy between $^{40}Ar/^{39}Ar$ and U–Pb ages (figure 1 and Fraser et al, submitted). In turn, this allows more confident interpretation of the timing of Au–Cu mineralisation and its association with local magmatic rocks, with particular mineral exploration implications.

Similar examples exist in relation to tin–tungsten–tantalum mineralisation in the Davenport Ranges region, south of Tennant Creek, and gold mineralisation in the central Gawler Craton. In each of these examples, improved synchronisation of the $^{40}Ar/^{39}Ar$ and U–Pb isotopic clocks provides improved timing relationships between mineralisation and magmatism.

Ongoing international research to improve the synchronisation of isotopic clocks is expected to provide further improvements in geological applications of geochronology.

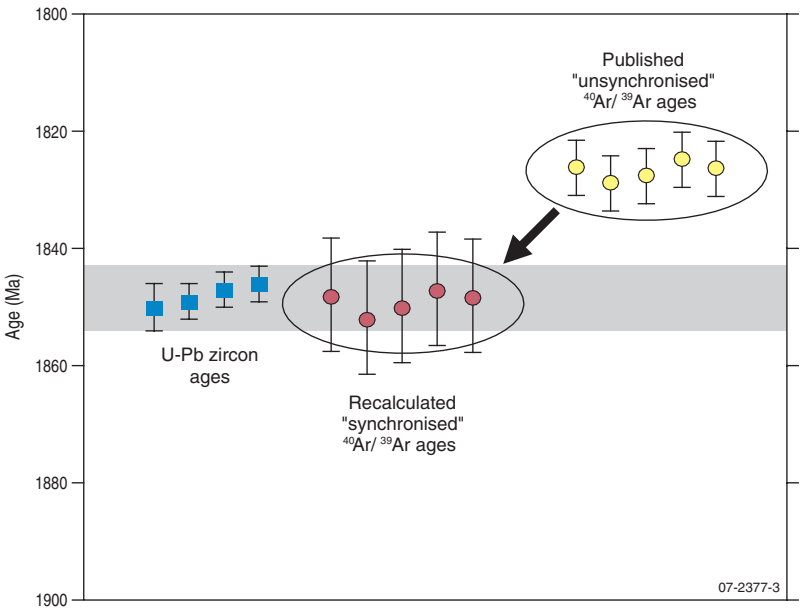

Figure 1. Isotopic age constraints for Au–Cu mineralisation at Tennant Creek, showing the effect of recalculating published $^{40}Ar/^{39}Ar$ ages using a revised potassium decay constant derived via intercalibration with the U–Pb timescale (Kwon et al 2002).

For more information

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The author

Geoff Fraser was a Distinguished Geoscience Australia Lecturer (DGAL) for 2007, and this article is based on his DGAL presentation.