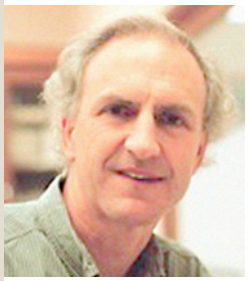
TIME'S ARROW AND TIME'S CYCLE



John W. Valley

Are geological processes cyclical or random? This seemingly simple question represents an ancient philosophical dichotomy. For example, Gould (1987) reexamined the metaphor of "time's arrow" when discussing what James Hutton and Charles Lyell had to say on deep time. "Time's arrow" describes history that is an "irreversible sequence of unrepeatable events," while "time's cycle" suggests that events "are parts of repeating cycles, and differences of the past will be realities of the future (and thus) time has no direction." Hutton's views are clear: if there is "no vestige of a beginning, no prospect of an end" and "the present is the key to the past," cyclicity is required. The rock cycle includes the progression of uplift, erosion, deposition, lithification, and more uplift, much as Hutton envisioned for the famous unconformity at Siccar Point on the coast near Edinburgh (Scotland), his most convincing evidence for uniformitarianism. A modern view might include opening and closing oceans, magmatism and metamorphism, but the repetition of events persists. One might ask if cyclicity of some natural phenomena excludes randomness in others. We know the Earth is cooling and that radioactive heat production is declining. The planet formed without a buoyant crust, plate tectonics or life, yet all have evolved. In fact, many secular changes are recognized (Bradley 2011). Is "arrow versus cycle" a false dichotomy?

For at least three billion years, the Earth's tectonics have been dominated by orogenies, and cyclicity is suggested by the igneous, metamorphic, and sedimentary rock record. One apparent manifestation of cyclicity is the age distribution of igneous zircon, which correlates to the ages inferred for the assembly of supercontinents (Fig. 1). Interpreting these correlations is an area of active research and debate. One view is that supercontinents form in cyclic events and, thus, that crust growth was episodic (Bradley 2011; Voice et al. 2011; Condie and Kröner 2013). An opposite view is that gaps in the zircon record result from the different preservation potential of rocks in different tectonic settings and that growth of crust is continuous (Cawood et al. 2013).

Figure 2 Green grossular (tsavorite) from graphitic schists at Mengare Swamp, Tsavo, Kenya. Photo: Vincent Pardieu, Gubelin Gem Lab

This issue of *Elements* explores the tempo of tectonic cycles for a variety of space–time–volume scales. Time's cycle is documented. Magmatic "flare-ups" in the Phanerozoic are resolved at a finer scale than in the Precambrian: periodicities are on the order of 30–70 My versus 500 My. The authors use recently acquired, large data sets to establish temporal patterns. This is not an "irreversible sequence of unrepeatable events." The age spectra from detrital zircon are shown to be more comprehensive and representative than those of zircon from exposed igneous rocks. Apparently, there is order to the "punctuated equilibrium" of magmatism. In detail, the controlling factors include mantle flow, convergence rate, slab dip, slab rollback, slab break-off, and slab windows.

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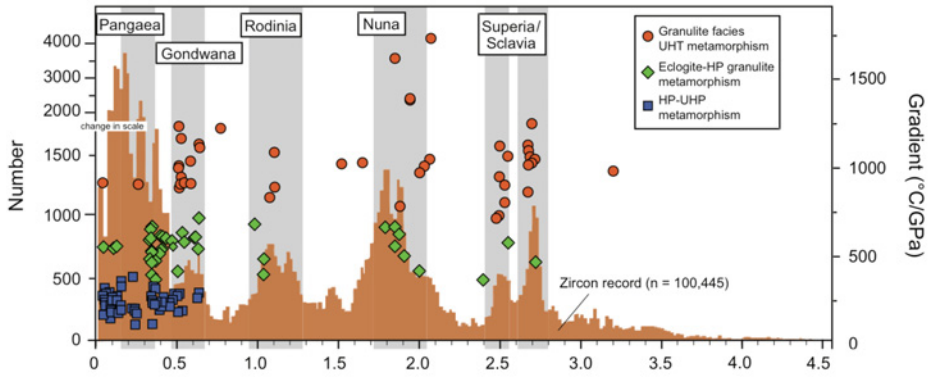

Figure 1 Histogram of U–Pb crystallization ages for over 100,000 detrital zircon grains (Voice et al. 2011) and metamorphic thermal gradients (Brown 2007). The zircon peaks and occurrences of ultra-high temperature metamorphism correlate to the ages of supercontinent assembly (from Cawood et al. 2013).