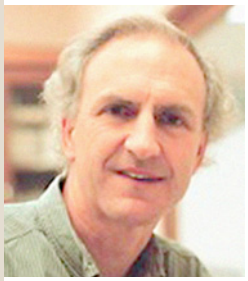
TIME'S ARROW AND TIME'S CYCLE



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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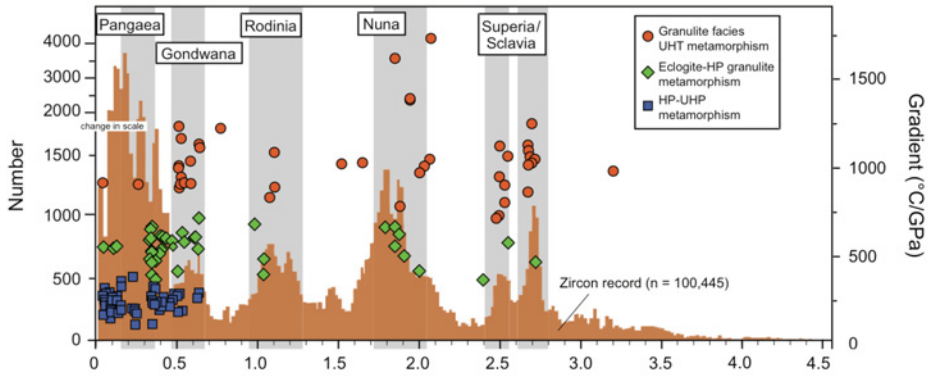

Figure 1 Histogram of U–Pb crystallization ages for over 100,000 detrital zircon grains (Voice et al. 2011) and metamorphic thermal gradients (Brown 2007). The zircon peaks and occurrences of ultra-high temperature metamorphism correlate to the ages of supercontinent assembly (from Cawood et al. 2013).

THIS ISSUE

Tempo. Pulse. Rhythm. Musical terms that may cause you to recall whimsical tunes, raucous rock concerts, symphonic masterpieces, or your favorite pop song playing on the radio or Pandora. Yet, these are terms that can also define the rhythm and beat of the Earth as tectonic plates collide at convergent boundaries. The Earth's symphony may be longer than the typical concert (by a million years or so!), but the "tune" can be discerned by those who stop to listen. This issue brings together 12 scientists who are "stopping to listen to the beat" by carefully studying the composition and dynamics of magmatic arcs. Their articles reveal just how "musical" the Earth can be! They have also provided a collection of movies to complement your reading enjoyment. Movies and other supplemental materials can be found at www.elementsmagazine.org/supplements/.

THANKS JOHN!

With this issue, John Valley retires as a principal editor of *Elements*. During his tenure, he was in charge of the following issues: Granitic Pegmatites (v8n4), One Hundred Years of Isotope Geochronology (v9n1), Continental Crust at Mantle Depths (v9n4), Asteroids: Linking Meteorites and Planets (v10n1), Ophiolites (v10n2), and Arc Magmatic Tempos (v11n2). John has been a vital asset to *Elements* for many years. In addition to serving as a principal editor, he was a guest editor in 2006 (Early Earth, v2n4) and a member of the advisory board (2004–2007). The *Elements* family has greatly benefited from John's guidance, hard work, and enthusiasm. Thank you John for all you have done to help make *Elements* the most readable and authoritative magazine in mineralogy, petrology, and geochemistry!

CALL FOR PROPOSALS – THEMATIC TOPICS 2017

Do you think your research area would make a great issue of *Elements*? Consider submitting a proposal. Would you like to read about a certain topic? Let the editors know!

At their next meeting in August, immediately preceding the 2015 Goldschmidt Conference in Prague, the editors will review the proposals on hand to determine the 2017 lineup. The six proposals chosen will represent a balance among mineralogy, geochemistry, and petrology topics and, of course, will be the most exciting and pertinent for *Elements'* audience.

Many potential guest editors first send an e-mail of enquiry to one of the editors about their idea for a topic. The "feeler" e-mails are circulated to the editorial team, and feedback on the proposed theme and the way the proposer plans to tackle it is then provided to the proposer. This enables him or her to develop a full proposal. You can download the proposal form at www.elementsmagazine.org/proposal.htm.

Don't wait! Start working on that proposal today!

BREAKING NEWS: EDITOR 2016-2018

We are thrilled to announce that **Friedhlem von Blackenburg** has accepted the invitation to join the Elements editorial team, starting in January 2016. He will replace Trish Dove whose term of office ends on 31 December 2015. We will introduce him more formally at a later date.

Trish Dove, **Gordon Brown**, **Bernie Wood**, and **Jodi Rosso**

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In the future, as these processes are further studied, the tempos of magmatic arcs will be refined. This topic is important for processes of societal interest, such as the evolution of life, mineral and energy deposits, geohazards, paleoclimate, and even gem mineral exploration. In the final article, Lee and Lackey explore the effect of magmatic cycles on climate. Flare-ups cause metamorphic release of buried sedimentary carbon in the form of the greenhouse gas CO_2 and, in the process, form calc-silicate skarns and schists, host to beautiful minerals (Fig. 2) and economic mineral deposits. On a grand scale, perhaps arc tempos are the tectonic equivalent of Milankovitch cycles (which affect climate), with long-term mantle dynamics and mantle–lithosphere interaction providing harmonic forcing to magmatic systems.

John W. Valley, Principal Editor

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