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Editorial

Secular change in earth processes: Preface

1. Introduction

Uniformitarianism is a traditional approach used in many areas of geoscience that assumes the geologic processes observed today operated similarly throughout all of Earth history (Hutton, 1788; Windley, 1993), with such an ideology commonly encapsulated by the maxim "*the present is the key to the past*". This concept is closely associated with the philosophical principle of Occam's razor, as discussed by Gould (1987) in his critique of its usage in the natural sciences: "*we should try to explain the past by causes now in operation without inventing extra, fancy, or unknown causes, however plausible in logic, if available processes suffice*". Nonetheless, although the spatio-temporal constancy of many natural phenomena (e.g. the rate of decay of radiogenic nuclides) appears to promote direct comparison of the modern-day Earth with that of the past, the rock record preserves a wide range of petrological, structural, geochemical, and isotopic evidence for significant changes in earth-system processes and products over geological time.

While some of these physio-chemical changes are thought to have occurred gradually, such as secular cooling of the Earth's mantle (Herzberg et al., 2010), others likely took place over much shorter timescales, such as a rapid rise in the partial pressure of atmospheric O_2 at ca. 2.3 Ga (the Great Oxidation Event: Bekker et al., 2004). Such changes in ambient conditions may have significant effects on the geological products that are preserved in the rock record, which has implications for interpretation of past tectonic regimes. How and why these processes have changed over time is important as they affect the mechanisms of growth and reworking of the continental crust (Hawkesworth et al., 2010), contribute to long-term global climate change (Sleep, 2010), and control the location and timing of formation of mineral endowments necessary to support human ambition in the future (Goldfarb et al., 2010). Furthermore, understanding how plate tectonics developed on Earth allows us to gain greater insight into the evolution of other planetary bodies in our solar system and beyond (e.g. Noack and Breuer, 2014; Wade et al., 2017).

2. Contributions in this special issue

This special issue of Geoscience Frontiers assembles four papers authored primarily by early-career researchers that investigate various aspects of secular change throughout Earth history. These studies shed new light on the veracity of uniformitarianistic methods used to interpret the evolution of the Earth throughout geological time.

The first study in this Special Issue by Nicoli and Dyck (2018) examines the effects of secular change in the major-element composition of terrigenous sediments on the metamorphic products that they may produce during accretionary or collisional orogenesis. Indeed, a number of recent studies have spearheaded a resurgence of interest in secular change in continental crust composition since ca. 3.5 Ga (e.g. Tang et al., 2016; Greber et al., 2017), which has been an area of research focus for many decades previously (e.g. Condie, 1993). In their paper "*Exploring the metamorphic consequences of secular change in the siliciclastic compositions of continental margins*", Nicoli and Dyck (2018) applied thermodynamic phase equilibrium modeling to a range of bulk-rock compositions reported in the literature of varying age, from the Archean to the Phanerozoic, and examine the metamorphic rock types and partial melts that would form along classical Barrovian-type geotherms (Barrow, 1912). They show that the muscovite dehydration melting has become increasingly important in metamorphosed shales through geological time, and partial melt compositions have become increasingly calcic and less mafic. In addition, the potential water budget of continental margins has decreased since the Archean, which has implications for the fertility of continental crust and may account for observed changes in the volume and diversity of orogenic magmas in the geological record (e.g. Ganne et al., 2016; Moyen and Laurent, 2017).

In the second contribution, Moreira et al. (2018) take a fresh new look at what is colloquially known as the "Siderian Quiet Interval" (ca. 2.45–2.20 Ga) characterized by a global magmatic lull, when some researchers have even suggested that plate tectonics temporarily shut down altogether (Condie et al., 2009) or subduction zone magmatism had transitioned from continental settings to the lesser preserved ocean realm (Spencer et al., 2018). In this contribution entitled "*Evolution of Siderian juvenile crust to Rhyacian high Ba–Sr magmatism in the Mineiro Belt, southern São Francisco Craton*", Moreira et al. (2018) document the results of geochemical and geochronological investigation of a suite of magmatic rocks from the Mineiro Belt, Brazil, that show a compositional transition from TTG to sanukitoids, consistent with the onset of subduction. The timing of initiation of plate tectonics on Earth is a hotly debated topic (e.g. Korenaga, 2013, and references therein), and Moreira et al. (2018) provide new data that support a global onset at around the Archean–Proterozoic boundary.

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Moving towards a broader-scale tectonic focus, Zhang et al. (2018) present a paper focused on the driving forces of supercontinent breakup, which is known to have occurred multiple times throughout geological time (e.g. Bradley, 2011; Nance et al., 2014). Following on from the revolutionary paper by Forsyth and Uyeda (1975), where slab pull was shown to be the main driving force of plate tectonic motion on the Earth, Zhang et al. (2018) present the first study of its kind to quantify the relative contributions of plume push, subduction retreat, and gravitational collapse using global-scale 3D geodynamical modeling. In their paper entitled "*The dominant driving force for supercontinent breakup: Plume push or subduction retreat?*", they show that plume push is the dominant force that drives supercontinent breakup, and the associated plume-push stress is around three-times greater than that induced by subduction retreat within supercontinent interiors. Such a result has notable implications for our understanding of large-scale lithospheric dynamics and how plate tectonic force balancing has evolved throughout geological time.

Finally, in a return to the rock record itself, Palin and Dyck (2018) provide an overview of the causes, consequences, and petrological implications of secular cooling of the mantle over geological time. A hotter Archean mantle is predicted to have produced a significantly different structure and composition of primary oceanic crust than is observed today (Herzberg et al., 2010). In particular, subsolidus and suprasolidus phase relations for peridotitic mantle infer that primary oceanic crust as a whole and its uppermost basaltic portion should both be enriched in MgO in the Archean compared to today and depleted in Al_2O_3 (and others; McKenzie and Bickle, 1988), with these compositional trends supported by statistical investigation of the volcanic and magmatic rock record (e.g. Keller and Schoene, 2012). In their paper entitled "*Metamorphic consequences of secular changes in oceanic crust composition and implications for uniformitarianism in the geological record*", Palin and Dyck (2018) examine the effects of this secular change in oceanic crust composition on the metamorphosed products that would form during subduction, and show that many of the rock types observed in the Phanerozoic, which formed from relatively low-MgO mafic crust, would not have been stable in Archean or Proterozoic subduction zones. This work has key implications for the use of uniformitarianistic principles to interpret geological processes and tectonic environments in the ancient rock record (e.g. Stern, 2005; Palin and White, 2016), which has long been a cornerstone of the discipline.

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