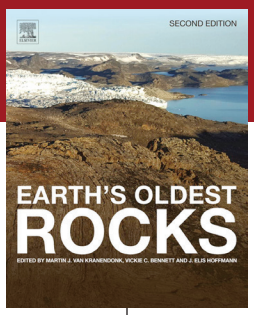
EARTH'S OLDEST ROCKS (2nd ED)[1]



The Earth's oldest rocks are those which formed in the time interval 3.0–4.0 billion years ago in the mid- to early Archaean Eon. Traces of anything even earlier, which would be from the Hadean (>4.0 billion years ago), are fragmental and preserved only in detrital zircon grains and in the isotopic memory of now long-extinct isotope systems. The time interval 3.0–4.0 billion years ago is a crucial stage in Earth history, for this is when the first continents formed, when life began, and was a time during which tectonic processes were quite different from modern (Phanerozoic) plate tectonics due to the different thermal state of the young Earth.

This second edition of *Earth's Oldest Rocks* (the first edition was published in 2007) is an edited volume that comprises articles written by a largely new collection of authors from those who contributed to the first edition and reflects the huge advances that have been made in the study of the earliest stages of our planet's history over the past decade. Those advances have come through the application of field studies, geochemistry and the advent of geodynamic modelling. The size of this book – 42 papers and almost 1,100 pages – is a tribute to the vigour with which this field has been pursued.

The opening section of the book succinctly explores the most recent data and ideas on the origins and earliest history of our planet. Principal themes include the use of meteorites in deriving the early history of the solar system, a discussion of the Moon-forming impact, core formation, the late veneer, and the lunar evidence for the late heavy bombardment. This is followed by a consideration of the nature of the Hadean atmosphere and oceans and the implications for the origin of life.

The next section of the book provides a series of overviews of early Earth's magmatic and tectonic processes. These provide a snapshot of mantle processes through the earliest stages of Earth history. During the Hadean, the planet was enclosed in a thick basic crust, and mantle processes were dominated by 'stagnant lid tectonics'. In the early Archaean, mantle dynamics are thought to have been dominated by plume processes, which have left their record in the subcontinental lithosphere. However, through the early to late Archaean, the komatiite and basalt record shows no evidence of a secular change in mantle processes. Models for the origin of granitoid (tonalite–trondhjemite–granodiorite, or TTG) magmas, from which the earliest continental crust formed, require the re-melting of an enriched basaltic protolith, which puzzlingly is not the most common type of Archaean basalt. In my view, this section of reviews is variable in quality. The discussion of Archaean TTGs, a field with which I am familiar, is masterful and comprehensive, yet one of the other contributions is more partisan and reflects more the views of a single laboratory.

Following these introductory papers, the major part of this volume is given over to reviews of areas where Hadean and early Archaean rocks are preserved. There is a particularly helpful review of the claims and counterclaims made for the nature of the Hadean Earth from the study of the famous detrital zircons from the Jack Hills in western Australia. The current consensus indicates that some of these grains are as old as 4.37 Ga and that they crystallised from a granitoid melt derived from an early mafic crust at 4.4–4.5 Ga. Their subsequent alteration supports the view that there was water on Earth prior to 4.2 Ga. Subsequent papers review the geology of regions where the very oldest rocks are preserved. These include the Yilgarn Craton (western Australia) where rocks formed at 3.73 Ga but where the oldest detrital zircons are 4.37 Ga; the North China Craton where the oldest rocks are 3.8 Ga old and there are detrital zircons 4.0 Ga old; the 3.9–3.6 Ga Itsaq Gneisses (west Greenland); and the 4.03–3.9 Ga Acasta Gneisses (northern Canada), which also contain hints of older crust from 4.2 Ga. This section also includes an important review of the age of the Nuvvuagittuq Greenstone Belt (NE Superior Province of Canada) where there are disputed claims for rocks formed at 4.3 Ga, potentially making this region the only known Hadean crust. Granite–greenstone belt terrains, with their record of surface processes, are also an important source of information about the early Earth, although there are only two regions from the early Archaean where they are well-exposed, little deformed, and of low-metamorphic grade. These are the 3.53–2.83 Ga Pilbara Craton (western Australia) and the 3.55–3.20 Ga Barberton Greenstone Belt of the Kapvaal Craton (South Africa). Previously, models for the evolution of these two very well-studied regions of similar geology have invoked radically different tectonic processes, and it is pleasing to read that new models are converging. Less well-known areas of early Archaean geology are described in the final part of this regional review section, including terrains from the USA, India, the Fennoscandian Shield, the Ukraine Shield, Zimbabwe and Antarctica.

The final section of papers is on early life. Three very useful review papers cover the significance of carbonaceous matter in understanding early life processes, the implications of the chert and carbonate isotope records, and the formation and palaeo-environmental significance of Archaean cherts. This is followed by regional case studies from localities where early life has been reported: Isua in west Greenland, the Pilbara Craton in Australia, and Barberton in South Africa.

Predictably, even though this volume is published in 2019, the subject does not stand still. There are now new data for Hadean (4.1 Ga) detrital zircons from sediments in the Barberton Greenstone Belt in South Africa. Claims for stromatolites at Isua as critical evidence for life on Earth at 3.7 Ga are now being seriously questioned. And evidence for life on Earth at 3.95 Ga in the Saglek region of northern Labrador (not reported in this volume) is now disputed.

This volume is a valuable and up-to-date summary of our current knowledge of the early Earth. And yet for me there is one contribution missing – a synthesis of our knowledge to date. To what extent are these Hadean remnants representative of our planet in Hadean times, both in terms of relative volume and the processes they record? Similarly, for the early Archaean. Could these be fragments of a much larger former crustal volume that is now destroyed or are they indicative of small volumes of emerging continents? A review of crustal growth processes and some further inferences about the nature of tectonic processes on the early Earth would have been a welcome addition.

Hugh Rollinson, University of Derby (UK)

1 Van Krandendonk M, Bennet V, Hoffmann E (eds) *Earth's Oldest Rocks*, 2nd Edition (2018), Elsevier, 1112 pp, eBook ISBN: 9780444639028 (US$191.25/€202.30), Paperback ISBN: 9780444639011 (US$191.25/€181.90

Cont'd from page 137

comprehensive reviews and make excellent further reading. Many of the encyclopedia's entries are also valuable resources for undergraduate geochemistry classes. They make ideal reading materials for students who are interested in more in-depth knowledge. For example, the "Magmatic Process Modelling" entry (by Mark Ghiorso) is well-suited to form complementary material to lectures on trace element geochemistry. The entries also make perfect reading assignments for graduate seminar classes, because they provide sufficient background for students to read more research-based articles. For instance, the "Geochronology and Radiogenic Isotopes" entry (by Jeff Vervoort) succinctly explains the fundamentals of isotope dating methods and paves the way for students to understand the applications of different geochronometers to constrain the timing of all manner of processes.

The *Encyclopedia of Geochemistry* is a comprehensive and must-have reference source for anyone interested in the geochemistry of planet Earth.

Fang-Zhen Teng
University of Washington (USA)