THEME 6: THE EARLY EARTH AND PLANETS

Session 6.6: Early environments on Earth and their role in the evolution of life

CONVENED BY:
JEFFREY L. BADA (JBADA@UCSD.EDU)
DONALD E. CANFIELD (DEC@BIOLOGY.SDU.DK)

INVITED SPEAKERS:
JOCHEN BROCKS (JBROCKS@OEB.HARVARD.EDU)
MINIK ROSING (MINIK@SAVIK.GEOMUS.KU.DK)
MARK VAN ZUILEN (MARKVZ@CRPG.CNRS-NANCY.FR)
CHRISTOPHER HOUSE (CHOUSE@GEOSC.PSU.EDU)

Two fundamental requirements for origin of life as we know it are: liquid water and organic polymers, such as nucleic acids and proteins. Water provides the medium for chemical reaction and polymers carry out the central biological functions of replication and catalysis. The harsh conditions and high temperatures during the final phase of Earth's accretion would have made liquid water and an extensive surface organic carbon reservoir unlikely. As the Earth surface cooled, water and organic compounds from a variety of sources would have accumulated. This set the stage for the synthesis of biologically important polymers, some of which acquired a variety of simple catalytic functions. Increasingly complex macromolecules were produced and eventually molecules with the ability to catalyze their own replication appeared. Thus began the processes of multiplication, heredity and variation, and the origin of both life and evolution. This session will focus on theoretical considerations and direct observation of the types of environments likely present on the early Earth. We will consider how these early environments may have fostered both abiotic organic chemistry and the transition from abiotic reaction to autonomous self-replicating molecules capable of evolving by natural selection. We will also consider the metabolic nature of the Earth's earliest living entities and the likely structure of the earliest-Earth microbial eco-systems.

6.6.11

When did conditions appropriate for life emerge? Further results of the mission to really early Earth

T. M. HARRISON[1], S.J. MOJZSIS[2] AND THE MEMBERS OF PROJECT MTREE

[1]Research School of Earth Sciences, Australian National University, Canberra, A.C.T. 2601 AUSTRALIA
[2]Dept. of Geological Sciences, University of Colorado, Boulder, CO 80309, USA

Recent work supports the view that >3.83 Ga biomass is the most plausible source of isotopically light carbon in graphite inclusions from West Greenland. If correct, this places the emergence of life on Earth prior to the end of the Late Lunar Cataclysm (~3.85 Ga) and raises the possibility that life originated during the Hadean Eon (~4.5-4.0 Ga), a period for which there is no known rock record. If so, how can we determine when the necessary ingredients for life, notably liquid water, first appeared? Detrital zircons up to 4.38 Ga from the Jack Hills, Australia, offer unprecedented insights into surface environmental conditions during the earliest phase of Earth history. For example, 4.3 Ga whole rock $\delta^{18}O_{SMOW}$ compositions of up to +10‰ are indicated. Together with inclusions indicative of both subduction-related melting and anatexis of clay-rich protoliths, these data suggest that Jack Hills zircons formed by a variety of processes involving a global hydrosphere within ~200 m.y. of planetary accretion and challenge the view that continental and hydrosphere formation were frustrated by meteorite bombardment and basaltic igneous activity until ~4 Ga. Provided sufficient quantities of these ancient zircons can be obtained for analysis, these samples offer other opportunities to constrain the earliest evolution of the atmosphere, hydrosphere, and continental lithosphere. We have, thus far, undertaken $^{207}Pb/^{206}Pb$ age characterization of 21,500 Jack Hills zircons (typically 2 to 5 µg each) using a rapid survey method utilizing the SHRIMP II and CAMECA *ims* 1270 ion microprobes operated in multi-collector mode. The ~1000 >4 Ga zircons thus identified were then precisely U-Pb dated by ion microprobe and have been used in a variety of studies including: single crystal Xe isotopic analyses to document the terrestrial Pu/U ratio, and initial $^{176}Hf/^{177}Hf$ and $^{142}Nd/^{144}Nd$ studies to assess the presence and extent of Hadean continental crust. The inclusion mineralogy of these ancient zircons, including meta- and peraluminous assemblages, sulfides, and phosphates, points towards their origin in diverse petrogenetic settings. Isotopic results demonstrate the existence of terrestrial continental crust and a mature sedimentary cycling system operating within it as early as ca. 4.3 Ga and suggest that mantle-derived Xe isotopes cannot be interpreted in terms of the age of the atmosphere in a straightforward manner.