Geophysical Research Abstracts, Vol. 8, 01024, 2006
SRef-ID: 1607-7962/gra/EGU06-A-01024

The Emerging Aerobic Earth System through Archaean-Palaeoproterozoic Transition: Problems and Perspectives

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The development of new analytical techniques, and improved models for planetary evolution, has intensified research into the evolution of the Earth System and targeted several critical intervals in Earth history when the biota, hydrosphere and atmosphere were experiencing global-scale changes. It is common knowledge that the Archaean Earth System ($>$ 2.5 Ga) functioned differently from that in the recent past because of the absence of an oxygen-rich atmosphere. Oxygen-rich habitats were restricted to microbial mats or perhaps ephemeral oxygen oases in the surface ocean or in lakes, and so biogeochemical recycling of buried organic matter in the Archaean largely depended on fermentative decomposition. Given the lack of oxidative weathering, it remains unclear how organic matter preserved in marine sediments was recycled upon uplift and exposure. The first 500 million years of the early Palaeoproterozoic was a time of environmental upheaval that heralded the emergence of the modern, aerobic Earth System. Global intracontinental rifting and associated mafic volcanism accompanied by widespread deposition of banded iron formation was followed by the oldest known world-wide glaciation(s), a rise in atmospheric oxygen, the largest ever positive excursion of $\delta^{13}C_{carb}$ (Lomagundi-Jatulian Paradox), and then, enigmatically, abundant deposition of anomalously organic-carbon-rich sediments forming the oldest known significant petroleum deposits (Shunga Event). The remaining 1500 Myr of the Proterozoic exhibits evidence that the Earth operated much as it does today, with most biogeochemical recycling, in the oceans and on land, dependent on highly ener-

getic aerobic pathways. The available data provide only a relative chronology of these major Archaean-Palaeoproterozoic events and several fundamental questions remain unanswered. Why is the oldest known significant accumulation of organic-carbon-rich sediments and petroleum deposits only at 2000 Ma when microbial life is known to have persisted through the Archaean? Why did an oxygen-rich atmosphere appear around 2300 Ma even though oxygen-rich habitats existed since 2700 Ma? Why, given an oxygen-rich atmosphere at 2300 Ma, was there a 300 Myr lag in the development of deep biosphere and aerobic pathways in biogeochemical recycling of organic matter at around 2000 Ma? Why did the first global glaciations occur at around 2400 Ma and why do the first-order features of the marine carbon isotope record indicate that global carbon cycle operated in the Archaean much as it does today? Other key unresolved problems at the Archaean-Proterozic transition include: (***i***) the nature and timescales of the Proterozoic carbon cycle; (***ii***) the sulphur, phosphorous and nitrogen cycles; (***iii***) the redox-state of the mantle and its possible impact on oxidation state of the hydrosphere-atmosphere; (***iv***) the origins and timing of the rise in atmospheric oxygen; (***v***) seawater composition and marine sulphate reservoir.

What is required now is new data as the basis for self-consistent models to explain the genesis and timing of the abrupt establishment of the aerobic Earth System. In order to address some of these fundamental questions in Earth System evolution, a multi-disciplinary, international research group has been awarded a new research initiative within the framework of the International Continental Scientific Drilling Program. The ultimate goal of this initiative is to develop a scientific drilling project on the Fennoscandian Shield and create a self-consistent model explaining the establishment of the aerobic Earth system out of the biogeochemical paroxysms of Palaeoproterozoic time. We welcome the participation and collaboration of our colleagues (many of whom are now organised around the new IGCP project 509 “Palaeoproterozoic Supercontinents and Global Evolution”) as we explore this critical interval of Earth history as its recorded on the Fennoscandian Shield.