6.5.P02

Was Hades hot or cold?

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After the effects of the Giant Impact had abated, secular climate changes of the Hadean era depended on greenhouse gases in the atmosphere. In pre-life times these must have been predominantly CO_2 and H_2O, as photolysis of CH_4 and subsequent escape of hydrogen leads to oxidation [1]. The inorganic removal of CO_2 from the Earth's Hadean atmosphere could have occurred in two ways: (a) Direct metamorphic-metasomatic carbonatization of silicates caused by deep circulation of seawater in the oceanic crust. (b) Silicate weathering on land, transport of HCO_3^- and carbonate deposition in the marine environment.

Process (a) is favoured by high CO_2 concentrations in seawater and high oceanic heat flow. Through subduction and cycling of carbonate into the mantle, it could rapidly have led to cold conditions on Earth, particularly if the crust was amplified by impact ejecta [3]. P-T conditions traversed during subduction are however critical for this, and Archean scenarios are examined. Further, supply of CO_2 to the oceans is cut off when the surface freezes over, while volcanic re-supply of CO_2 to the atmosphere continues. This would have prevented a Hadean snowball Earth. The process of silicate weathering followed by marine carbonate deposition requires water runoff on a land surface. While weathering is favoured by high atmospheric CO_2 levels, the resulting high marine CO_2 concentration would force the equilibrium for carbonate deposition to high cation and HCO_3^- concentrations. Further, the amount of continental crust (and therefore land surface) in the Hadean is highly debated.

Climatic constraints are few. At 3.8 Ga liquid surface water existed [3], and at c. 3 Ga intense chemical weathering prevailed [4], but a glaciation also occurred [5]. Further, the apparent loss of most fissiogenic (^{144}Pu)Xe from the Earth's atmosphere indicates significant hydrodynamic escape (and thus a water vapour-rich atmosphere) as late as 100 – 200 Myrs after Earth accretion [6]. These data and models are considered in a reconciliation effort.

References

[1] Catling, D.C., Zahlne, K.J. and McKay, C.P. (2001) *Science* **293**, 839-843.

[2] Sleep, N.H. and Zahnle, K. (2001) *JGR* **106**, E1, 1373-1399.

[3] Rosing, M.T.(1999) *Science* **283**, 674-676.

[4] Fedo, C.M., Eriksson, K.A. and Krogstad, E.J. (1996) *GCA* **60**, 1751-1763.

[5] Young, G.M., von Brunn, V., Gold, D.J.C. and Minter, W.E.L. (1998) *J.Geol.* **106**, 523-528.

[6] Azbel, I.Ya. and Tolstikhin, I.N. (1993) *Meteoritics* **28**, 609-621.

6.5.P03

"Detrital" pyrite pebbles from Witwatersrand, South Africa: Evidence for an oxygenated Archean atmosphere?

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The origins of rounded grains and pebbles of pyrite (FeS_2) in late Archean and early Proterozoic gold- and uranium-rich quartz conglomerates have been debated for several decades. Some researchers have interpreted they are detrital in origin, representing remnants of pyrite crystals from igneous rocks and ore deposits, and they serve as important evidence for an anoxic Archean atmosphere [e.g., 1 & 2]. However, based on the morphologies and textures, Phillips et al. (2001) suggest the "pyrite pebbles" were created by sulfidization of iron-rich pisolites that had formed in shallow seas under an oxygenated atmosphere [3]. In order to determine the origins of the rounded pyrites, we have investigated the distributions of 30 elements (Fe, S, Si, Al, Ti, K, Na, Ni, Co, Au, Th, U, La, etc.) in and around ~100 "grains" and "pebbles" of pyrite in large rock specimens (up to ~100 cm^2) from several conglomerate horizons of the Witwatersrand Supergroup using a recently-developed X-ray chemical microscope (Horiba XGT-5000) with the 10 or 100 μm spatial resolution.

Our investigation has revealed that: (1) large (>~50 μm in diameter) pyrite "grains" and "pebbles" are almost always aggregates of micro (<10 μm) euhedral pyrite crystals; (2) the "pebbles" contain appreciable amounts of Si (~0.1 - ~10 wt%), Al (~0.1 – ~2 wt%), and other rock-forming elements, as well as Fe and S, and their elemental ratios (e.g., Fe/S, Fe/Si) are highly variable in ~10 μm scale; and (3) remnants of Si-rich micro layers, similar to the silica-rich laminae in banded iron formations and in cherts, are recognizable in many very large (>5 mm) pyrite "pebbles". These characteristics indicate that the so-called "detrital pyrite grains and pebbles" in the Au- and U-rich quartz conglomerates were created by reactions between H_2S-rich hydrothermal fluids and detrital grains and pebbles of Fe-rich rock fragments (e.g., banded iron ores, ferruginous cherts, and Fe-rich pisolites) after the deposition of host rock sediments. Therefore, these pyrite grains and pebbles cannot be used as evidence for an anoxic atmosphere. However, the Fe-rich pisolites, which were precursors of some pyrite-rich pebbles, may be used as a strong argument for an oxygenated Archean atmosphere.

References

[1] Holland H.D. (1994) *Early Life on Earth*, 237-244.

[2] England, G.L., Rasmussen, B., Krapez, B. and Groves, D.I. (2002) *Sedimentl.* **49,** 1133-1156.