NATURE|Vol 461|10 September 2009

50 & 100 YEARS AGO

50 YEARS AGO

My Philosophical Development. By Bertrand Russell — All those whose study of philosophy is grounded in the empirical tradition regard Lord Russell as the greatest living philosopher ... Although one should not neglect other influences ... there is no doubt that the main responsibility for the present state of philosophy lies squarely on Russell's shoulders ... There are few philosophers in history who have written important philosophical works almost continuously for fifty years: Russell has added to the immense debt we owe him by now giving us a full-scale account of his philosophical development, written with all the clarity, verve and wit we are accustomed to expect from anything he writes. From *Nature* 12 September 1959.

100 YEARS AGO

Organic Memory. By Prof. Richard Semon — The theory of the Mneme, propounded by Prof. Semon, has attracted the attention both of psychologists and of those naturalists who are interested in the profound problems of hereditary transmission. It is founded on the statement, which everyone is ready to admit, that a stimulus must affect the quality of living matter in such a way that the matter is not the same as it was before the stimulus acted. A permanent change, which, in a sense, may be called a memory, has been effected, or, to use the terminology invented by Semon, the action has been engraphic and the change itself is an engram ... All stimuli then produce engrams, and the sum of the engrams of a living being is its mneme ... Thus a stimulus may produce effects which radiate from the organised matter first affected to organised matter throughout the whole organism, either by nerve paths or by proplasmic intercellular filaments, and in this way faint engrams may be made on the matter of the reproductive elements, ova or spermatozoids. From *Nature* 9 September 1909.

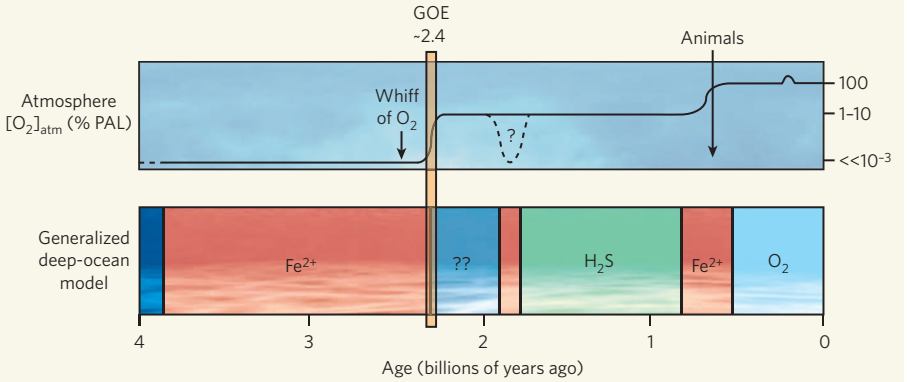

Figure 1 | Tracking oxygen above and below. A rise in atmospheric oxygen about 2.4 billion years ago at the Great Oxidation Event (GOE) coincided with the end of frequent and protracted, iron (Fe^{2+})-rich, oxygen-poor conditions in the deep ocean. Several studies[2,6,7], however, point to at least transient oxygen increases well before the GOE — evidence of early, oxygen-producing photosynthesis[5]. Through their analysis of chromium-isotope ratios in iron formations, Frei *et al.*[2] argue that the return of an iron ocean, peaking about 1.9 billion years ago, was triggered by a dramatic decline in oxygen, perhaps to values approaching those in the atmosphere before the GOE. Next, a billion years or more of ubiquitous hydrogen sulphide (H_2S) in the deep ocean may have resulted from a rise in atmospheric oxygen[2,10–12]. A major step in oxygenation then followed at the dawn of animal life[13]. Oxygen concentrations are given in per cent of the present atmospheric level (PAL). (Figure modified from refs 15 and 16.)

oxygen and the parallel chemical trends in the deep ocean remains enigmatic. In particular, researchers have been hard-pressed to explain a surprising return of iron formations half a billion years after the GOE.

Difficult questions require clever solutions, and Frei *et al.*[2] have sought insight from the iron formations themselves. Deposited with the iron were stable isotopes of chromium, which the authors interpret as a tracer for oxygen content in the atmosphere. Chromium is immobile in continental crust beneath an anoxic atmosphere and happily resides in its reduced or +3 state. But with increasing atmospheric oxygen comes the oxidation of manganese (Mn), another metal in the crust and overlying soil, and the resulting MnO_2 is able to react with chromium, oxidizing it in the process. The oxidized chromium loses electrons, with a shift in redox state or valence from +3 to +6, and it also gains mobility — meaning that rainwater can remove it from the soil, and rivers can transport it to the ocean. This mobilized chromium differs in one other notable way: during reaction with MnO_2, the heavy isotope ^{53}Cr is oxidized preferentially relative to the lighter ^{52}Cr, and this preference, too, is transferred to the ocean.

In the ocean, the ^{53}Cr-enriched chromium is once again immobilized as it is re-reduced to the +3 form through reaction with iron and is deposited within iron formations. Because of the high efficiency of this reaction, it is assumed that all the chromium is stripped from the sea water, minimizing any concerns about isotopic discrimination at this step. In other words, the isotopic properties of the initial products of weathering can be transferred to the ocean, and are captured and preserved unaltered over geological time. Measuring the chromium-isotope properties in iron formations of different ages is thus a window on to the evolving oxygenation state of the atmosphere.

Frei *et al.*[2] took a long look through this window, and found a few surprises. One of them is evidence for elevated but still low oxygen in the atmosphere long before the GOE. Enrichments of ^{53}Cr in iron formations all but confirm the biological production of oxygen by photosynthesis at least 300 million years before the GOE. This assertion is certain to please those who have come to the same conclusion by very different paths[5–7] and displease others[8,9] who consider that the first appreciable accumulation of oxygen in the atmosphere at the GOE marked its first production.

But no matter where one falls on the timing issue, most people probably imagine that once oxygen really started accumulating in the atmosphere, it never looked back. Even if you allow for a bit of a roller-coaster ride, that's nothing like what Frei *et al.* claim: a reprise of near pre-GOE values roughly 500 million years later, perhaps ushering in the return of an iron-rich ocean as indicated by a second big wave of iron formations (Fig. 1). The chromium isotopes suggest that soon after that there was another rise in atmospheric oxygen, this one large enough to have triggered more than a billion years of pervasive hydrogen sulphide accumulation in the deep ocean[10,11]. The thinking is that pyrite weathering on the continents in the presence of increasing atmospheric oxygen led to greater sulphate delivery to the still-oxygen-poor deep ocean, where bacteria re-reduced the sulphate to hydrogen sulphide (H_2S). Such conditions, rare today, could have set the course for the early evolution of