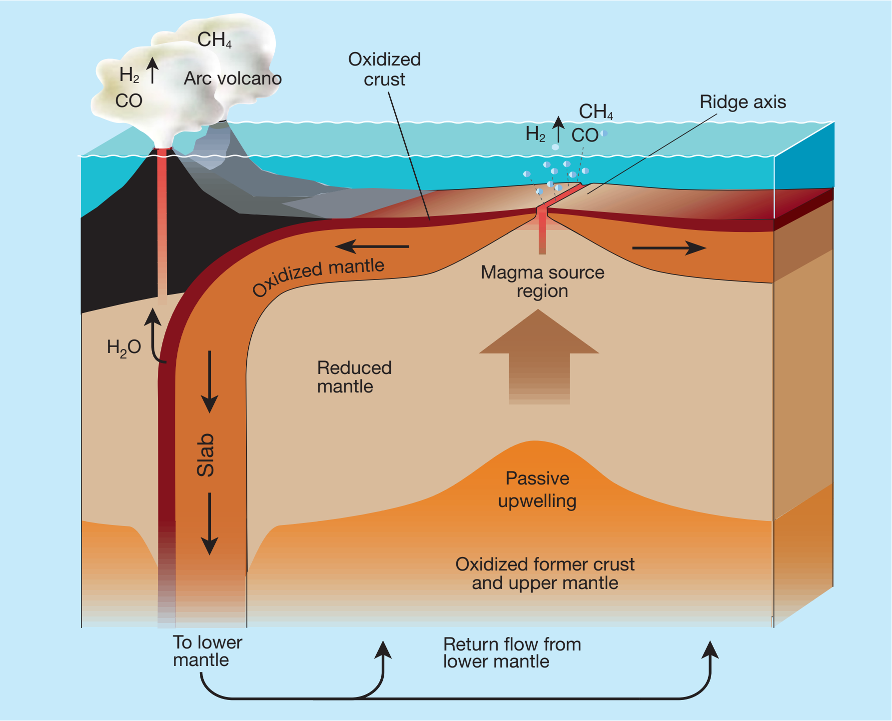

Figure 1 **Events near the end of the Archaean, around 2,500 million years ago, which led from an oxygen-depleted to an oxygen-rich atmosphere. Volcanic gases emanating at arc volcanoes and midocean ridges from a reduced mantle were themselves reduced and hence were an oxygen sink. In the crust and mantle, the oxidation of iron(II) oxide to iron(III) oxide also helped to keep oxygen levels low. According to the course of events outlined by Kump *et al.*[1], slabs of cold, dense, oxidized upper mantle and crust sank by subduction deep into the lower mantle. Heating from the core led to the rise of this oxidized material. Eventually, by overturn of the lower mantle into the upper mantle, or by filling the mantle completely, this oxidized material became the source of gases released at arc volcanoes and midocean ridges. As a result, the gases were insufficiently reduced to be a significant sink for oxygen — hence the rise in oxygen concentrations in the atmosphere.**

years ago, causing plumes of oxidized rocks to ascend towards the surface. Kump *et al.* suggest that the Archaean ended when the whole oxidized lower mantle became buoyantly unstable and overturned into the upper mantle, so that oxidized material replaced the reduced iron(II).

An alternative explanation, which gives the same outcome as far as oxygenation of the atmosphere and chemical mass balances are concerned, is that oxidized slabs filled the entire mantle by the end of the Archaean, replacing the reduced upper mantle that had never existed in slab form[2].

These events made the mantle source regions for magmas less reducing, which in turn had the same effect on the volcanic gases emanating from them. Eventually, the mantle became oxidized to the extent that volcanoes and midocean ridges vented gases that were an ineffective oxygen sink. Oxygen levels could then build up in the air, and the levels of H_2, CH_4 and CO were brought down to their present status as trace constituents of the atmosphere.

The basic geometry of the scheme proposed by Kump *et al.* works out; a plausible amount of oxidized slab material could have filled the mantle in the given time. It is also the case that the Earth's mantle is more oxidized than the material from which it formed. The success of Kump and colleagues'[1] hypothesis hinges on the time that the Earth's mantle became oxidized. At present, data from Archaean rocks come only from volcanic rocks generated by mantle plumes, which — as expected from the authors' reasoning — are oxidized. What are needed are data from Archaean volcanic rocks from an upper mantle source (such as the basalts erupted at mid-oceanic ridges), which according to Kump *et al.* should be reduced. In other words, their hypothesis is testable with data that are mostly independent of the surface carbon–oxygen cycle.

As well as looking at the rise of photosynthesis, traditional approaches to the increase of oxygen in the atmosphere have concentrated on surface biogeochemical processes. Carbon burial has been the subject of special attention because, if free to react, the amount of carbon now sequestered in sediments would be a huge oxygen sink[3]. But although carbon burial is a necessary condition for maintaining a high-oxygen atmosphere, it may not have been a sufficient one for generating it in the first place. Controls on the process — which in part depends on availability of the nutrient phosphorus from rock weathering[4] — are not well understood.

Finally, it is also plausibly the case that weathering of volcanic rocks at the surface was a controlling factor in lowering the effectiveness of the oxygen sink at the Archaean–Proterozoic transition. Quite simply, the surface sink provided by the reaction of iron (II) to iron (III) might have diminished, as basalt (an Fe(II)-rich rock) became a subordinate part of the material subjected to weathering. The process is independent of

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Animal behaviour

Greensleeves

Bats are usually thought of as roosting in caves or buildings. But there are several do-it-yourself tropical species that create tents out of large leaves. They do this by biting the leaf in such a way that the sides collapse downwards and create a sheltered area — as shown here (from within, complete with bat occupants).

These tents can stay healthy for long periods, even though much of the leaf's water supply has been cut off. How? Carol A. Peterson, Brock Fenton and colleagues have tackled the question by looking at the leaves of three plant species used by bats in Costa Rica (*Biol. J. Linn. Soc.* **72,** 179–191; 2001).

The group examined the water-conduction system in the leaves, and the damage caused to it by bats, and also performed tests with a tracer dye to follow water flow in damaged and undamaged tissue. The vein system in the leaves is complex, consisting of an apparent hierarchy of some five conducting elements. But it seems that water conduction by the smallest elements is enough to sustain the leaf, even when more major veins are severed. The authors point out that the advantage for the leaf is that it can survive damage from, say, wind or heavy rain; for the bats, it means that they are not forever making new tents.

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