been re-melted by subsequent magmatic events that the concentrated copper is released and transported to shallower depths in the continental crust to form copper-porphyry deposits.

If correct, copper porphyries are generated only after large amounts of sulphide-bearing cumulates form — a condition that is met following maturation and thickening of continental arcs. In contrast, thin island arcs do not develop thick accumulations of sulphide-bearing cumulates. So, even though the magmas that build island arcs have high copper contents, such enrichments do not seem to be sufficient to generate copper porphyries. With this view, Chiaradia joins a small but growing chorus of studies concluding that copper porphyries derive from intracrustal processes rather than from the mantle or subducting slab[1,6,7].

An important implication of this study bears on our understanding of the formation of continents, because continental crust has geochemical similarities to differentiated magmas, which are iron-depleted. It has been hinted that arc magmas would become depleted in iron as the crust thickens[14], but this suggestion has since been forgotten, discounted or ignored. Chiaradia's comprehensive study now shows conclusively that the iron-depleted nature of arc magmas increases with crustal thickness[8]. He suggests that high water contents may trigger iron depletion, implying that water plays an important role in making continental crust as well as copper deposits. Although the importance of water is not new, this result provocatively implies that the thickness of the upper plate modulates the water content of arc magmas, even though the initial source of water is thought to come from the subducting plate.

Massimo Chiaradia[8] demonstrates an inverse correlation between the copper content of magmas and crustal thickness in subduction zone arcs worldwide. These findings support the emerging view that the physics of magma transport through the lithosphere provide a key control on the chemical evolution and thus the metal content of arc magmas. ❒

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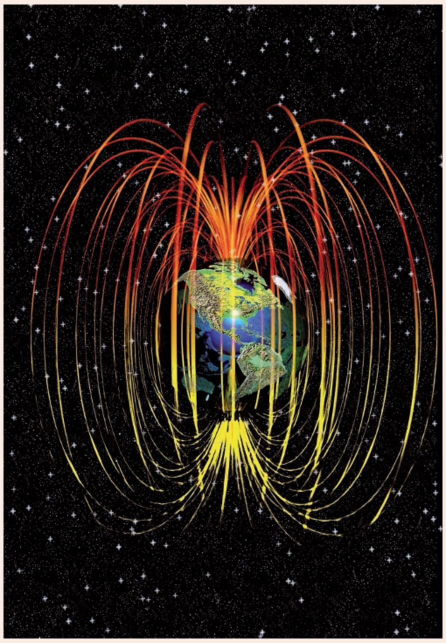
GEOMAGNETISM

Mantle-driven magnetic field?



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The Earth is shielded from the Sun's relentless barrage of charged particles by its magnetic field. Today, the geomagnetic field is generated by the convection of liquid iron in the Earth's outer core. This convection is in part driven by the crystallization of the solid inner core. It is therefore unclear how a geomagnetic field might have been generated before the inner core solidified. Yet the oldest known rocks that bear the signature of a geomagnetic field date back 3.5 billion years, well before the inner core is thought to have formed.

A close inspection of the palaeomagnetic signature of these Archaean rocks suggests that they formed under a field quite similar to that of today, complete with near-modern strength and frequent reversals. One possible but unlikely explanation is that convection in a liquid core generates a strong field even without the presence of a solid interior. Alternatively, Leah B. Ziegler and Dave R. Stegman suggest that the source of the Archaean geomagnetic field may have been located in the lowermost mantle — specifically, in an ocean of magma thought to have pooled just above the core–mantle boundary (*Geochem. Geophys. Geosys.* http://doi.org/qbh; 2013).

Crystallization of the magma ocean on early Earth may have initiated in the middle depths of the mantle, and slowly progressed downwards towards the core, leaving an ever-thinning pond of magma in the lower mantle. Ziegler and Stegman used a conceptual model to explore the effects of convection in this magma layer. They found that thermally driven convection in this layer could indeed generate a self-sustaining, planetary-scale magnetic field, not least because the liquid oxides common to magmas become weakly metallic at the temperatures and pressures found at this depth. Moreover, the presence of a basal magma ocean would actually supress heat flow from the core and prevent any magnetic field generation from the core.

Ziegler and Stegman estimate that convection within the basal magma ocean could have sustained a geomagnetic field until about 2.5 billion years ago. From that point, the onset of quick cooling would have driven enough convection in a solely liquid core to generate a magnetic field, with an additional boost from the subsequent solidification of the inner core.

Intriguingly, this model of the Earth's thermal evolution suggests that there may have been a pause in the generation of the geomagnetic field, possibly around 2.4 to 2.1 billion years ago. A gap in reported palaeomagnetic signatures from rocks of about this age has indeed been noted. Perhaps this palaeomagnetic gap does not reflect issues with rocks recording the magnetic field, but instead the lack of a strong geomagnetic field for the rocks to record.

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