on comparative gene expression data, is also going to have to start grappling with the message of the lost children of the Cambrian too. ■

Graham E. Budd is in the Department of Earth Sciences, Palaeobiology, Norbyvägen 22, University of Uppsala, Uppsala 752 36, Sweden.
e-mail: graham.budd@pal.uu.se

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Earth science

Keeping score on the core

Erik Hauri

Getting to the bottom of events at the boundary between Earth's core and mantle is fiendishly difficult. The latest analysis invokes evidence from an isotope of tungsten to conclude that the two do not interact.

The report by Scherstén and colleagues (page 234 of this issue[1]) bears on one of the liveliest debates in Earth science — the extent to which Earth's core exchanges matter with the mantle. This topic has been addressed by many groups, and from a number of observational, experimental and theoretical directions[2]. In particular, however, many analyses have centred on the geochemistry of highly metallic elements in mantle rocks, with recent efforts focusing on volcanic hotspots such as Hawaii. Hotspots form above plumes of material, rising up through the mantle, that may (or may not) originate from the core–mantle boundary at the base of the mantle. Over the past few years, persuasive arguments in favour of core–mantle exchange have been made on the basis of osmium isotopes in hotspot lavas, especially the small anomalies in ^{186}Os that may have been derived from the decay of an isotope of platinum (^{190}Pt) in the Earth's outer core[3,4].

Scherstén *et al.*[1] take a new approach to the issue of core–mantle exchange, by looking for anomalies in the isotopes of tungsten (W) in mantle-derived lavas. Tungsten is a highly siderophile — 'iron-loving' — element thought to be present in large quantities in the Earth's core. Its parent isotope ^{182}Hf decays radioactively to ^{182}W with a geologically rapid half-life of about 9 million years. As a result, all of the ^{182}W derived from ^{182}Hf decay was formed within the first 60 million years of Earth's history at a time that encompasses the formation of the Earth's core[5–8]. Searching for anomalies in ^{182}W is thus a powerful approach to studying the flux of material from the core to the mantle, because all of the action in the hafnium–tungsten isotope system occurred in the first 60 million years of Earth's history. Subsequent processes (such as mantle convection, formation of the continental crust and plate subduction) serve only to mix the mantle and thus reduce any primordial differences in ^{182}W that may have existed between different parts of the mantle.

It is widely accepted that the Earth formed from chondritic (stony) meteorites, material in the early Solar System that accreted into increasingly large bodies. High-precision data on ^{182}W in chondritic meteorites[5,6] have shown that the Earth's mantle is comparatively enriched in ^{182}W (by 2 parts in 10,000, or ϵW = +2). This means that the Earth's iron core separated from the silicate mantle within the first 30 million years of accretion, while ^{182}Hf was still 'alive' and producing ^{182}W by radioactive decay. With most of the tungsten partitioned into the core and most of the hafnium remaining in the mantle, the Earth's core must be depleted in ^{182}W (though, obviously, this has not been directly measured), whereas the mantle is clearly enriched compared to chrondritic meteorites — the ϵW = +2 enrichment of the Earth's mantle in ^{182}W has been measured directly and independently by various groups[5,6].

Thus, variations in ^{182}W in mantle-derived rocks should faithfully record interaction between the core and mantle — if it takes place. The idea is that if small amounts of material from the Earth's core are added to the mantle, then such mantle should show depletions in ^{182}W (see Fig. 1a, overleaf, which depicts the preferred model of Scherstén *et al.*). Scherstén and colleagues' measurements appear to be of very high quality, and the homogeneity of these plume-related samples suggests that the modern mantle is homogeneous in tungsten isotopes. In particular, the tungsten measurements were

Astronomy

Star maker

FRANCESCO FERRARO (BOLOGNA OBSERV.)/ESA/NASA

Star formation can occur wherever interstellar gas becomes compressed and undergoes gravitational collapse. That compression might be caused by a supernova explosion, or the collision of galaxies. At last week's meeting of the American Astronomical Society in Atlanta, Georgia, Richard Rees and Kyle Cudworth presented the first evidence for star formation triggered by a new mechanism — a globular cluster of stars that punched through the disk of the Milky Way five million years ago.

The globular cluster NGC 6397 (pictured), 12 billion years old and containing a few hundred thousand stars, currently sits about 1,500 light years below the disk of the Milky Way. Its motion has been tracked by various telescopes since 1893, so Rees and Cudworth were able to extrapolate its path back, right through the plane of our Galaxy. And at the point at which the cluster crossed the disk five million years ago lies NGC 6231, a young cluster of stars estimated to have formed less than five million years ago.

The implication is that the passage of NGC 6397 through the Milky Way disk compressed the gas in that region and triggered the birth of NGC 6231 — a mechanism for star formation that was suggested in a little-noticed 1996 paper (J. F. Wallin *et al. Astrophys. J.* **459,** 555–557; 1996). There it was noted that a globular cluster passes through the disk of the Milky Way roughly every million years. So it seems that the star-making talent of globular clusters should be factored into our picture of the evolution of this, and other, galaxies.

Alison Wright

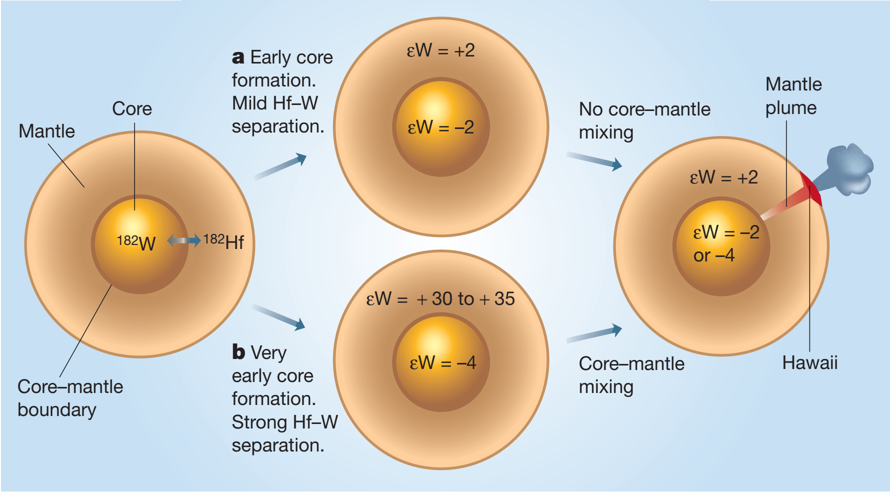

Figure 1 **Alternative interpretations of core–mantle interaction as surmised from the tungsten isotope ^{182}W. Formation of the Earth's core (left) results in separation of tungsten into the core along with iron, whereas its parent hafnium (^{182}Hf) remains in the mantle.** a, **In the preferred model of Scherstén *et al.*[1], the core forms early (some 30 million years after accretion of the Earth), with only mild separation of hafnium and tungsten. The core subsequently remains isolated from the mantle.** b, **An alternative model postulates very early core formation (say, within 5 million years), stronger hafnium–tungsten separation, and mixing at the core–mantle boundary which results in transfer of core material into the mantle. Both models could produce a modern mantle with a tungsten isotope anomaly of ϵW = + 2, as assessed from rocks, such as those on Hawaii, that are produced by an ascending mantle plume.**

made on exactly the same Hawaiian rock samples that displayed enrichments in ^{186}Os attributed to a contribution from the core, and there is no correlation between the ^{186}Os and ^{182}W isotopes.

The authors thus draw the most obvious conclusion — that lack of variation in the tungsten isotopes, and absence of a correlation with ^{186}Os, must mean that there is no contribution from the core in these Hawaiian hotspot samples. Nor, they believe, is there any such contribution in other, South African samples derived from the deep mantle (kimberlites) that they analysed. This is the simplest and most straightforward explanation of the data. The authors outline at least one way — recycling of oceanic plates in the convecting mantle — in which the ^{186}Os anomalies can be explained in the absence of ^{182}W anomalies.

This conclusion is an important one — it implies that the Earth's core has remained perfectly isolated from the mantle since it formed, and that the only thing coming out of the core is heat.

However, there remain tantalizing clues that the story may not be so simple. Mantle concentrations of highly siderophile elements have long been known to be much higher than those predicted from the behaviour of such elements in high-temperature core-formation experiments[2]. Most of these experiments were conducted at much lower pressures than those pertaining at the core–mantle boundary. So the mantle enrichment in highly siderophile elements might be merely the result of a higher pressure of core formation, and their different behaviour under such conditions.

Yet there is another possible model (Fig. 1b). It is conceivable that the differences in the ^{182}W abundances in the core and mantle are even larger than those modelled by Scherstén and colleagues. If the Earth's core formed and removed tungsten from the mantle much earlier than previously thought (say, within the first 5 million years of Earth's formation), the core could have a depleted ^{182}W abundance as low as ϵW = − 4, similar to that of some iron meteorites that are themselves the ancient cores of fragmented protoplanets[7,8]. If so, then ^{182}Hf decay in the mantle over the next 60 million years will have produced an enormous anomaly in ^{182}W (perhaps as high as ϵW = + 30 to + 35). In this case, the only way to produce a modern mantle with a small ^{182}W anomaly (ϵW = + 2) is to postulate very early core formation on the Earth, and then later transfer of some material from the core to the mantle over the next 4.5 billion years of Earth's history[9]. Still, Scherstén *et al.* do outline a convincing case for isolation of the core from the remainder of the Earth, and their work should provide fertile ground for improved ^{182}W studies in all manner of rocks and meteorites.

Erik Hauri is in the Department of Terrestrial Magnetism, Carnegie Institution of Washington, 5241 Broad Branch Road NW, Washington DC 20015, USA.
e-mail: hauri@dtm.ciw.edu

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Evolutionary biology

Our relative genetics

David Penny

Data on the chimpanzee genome help in detecting differential selection on individual genes, and in judging whether normal microevolutionary processes are sufficient to account for human origins.

Increasingly accurate versions of the human genome sequence are being produced. But to find out what biologically makes us human we also need the sequenced genome of our nearest relative, the chimpanzee, to see whether there is anything in our genetic constitution that could not have arisen by well-understood genetic processes. Last month, a selected version of the chimpanzee genome was published by Clark *et al.* in *Science*[1]. The group sequenced about 200,000 protein-coding regions, and combined them with human sequences to give over 20,000 chimp–human gene alignments. The mouse genome was then used as an 'outgroup', standard practice in this form of analysis, to leave 7,645 chimp and human genes for comparative analysis.

The fundamental issue here is Darwin's bold claim that "numerous, successive, slight modifications" are sufficient for all of evolution (Fig. 1). This can be paraphrased, in later terms, as "microevolution is sufficient to explain macroevolution"[2]. The historical context is that evolutionary biology can be divided into two phases[3]: first, the acceptance in the 1860s that evolution (macroevolution) had indeed occurred; second, the realization in the mid-1900s that the processes of microevolution (natural selection working through genetics) were necessary for evolution to occur.

Over the past 30 years, with the rise of molecular biology, the search has been on for support for Darwin's claim and to demonstrate the sufficiency[2], not just the necessity, of slight modifications in explaining macroevolution. The changes seen within populations and closely related species are by