coupling between the electron spin on the dot and the neighboring electron spins in the electrodes. The corresponding coupling energy can be expressed as a characteristic temperature, the Kondo temperature T_K. Below this temperature, the spin on the dot is screened by the formation of a cloud of electrons on the electrodes, having a spin polarization antiparallel to the spin on the dot. The formation of the screening cloud enhances the density of states in the electrodes and leads to a high-conductance state. The hallmark of the Kondo effect is a pronounced peak in the differential conductance with width k_BT_K (where k_B is the Boltzmann constant), which gradually disappears at temperatures above T_K. In the presence of a magnetic field, this peak shows a Zeeman splitting.

Until recently, the prospects for using the Kondo effect in quantum dots in applications were poor because it required temperatures below 1 K. The use of molecules as quantum dots has pushed the Kondo temperature up to 30 K (*8*, *9*). However, at this high T_K, very large external magnetic fields are required to split the Kondo resonance, again precluding applications in magnetoelectronics.

The situation is changed completely by the experiment of Pasupathy *et al.* (*5*). The use of ferromagnetic electrodes puts the antiferromagnetic Kondo interaction in competition with the ferromagnetic spin alignment by the ferromagnet's exchange field. The exchange field is responsible for the spontaneous spin polarization of the ferromagnet and acts also on the single spin trapped on the quantum dot. It has an effect similar to that of an external magnetic field. However, the corresponding Zeeman energy is given by the Curie temperature, T_C, which is 20 to 30 times larger than T_K. The exchange field is much larger than laboratory-scale magnetic fields.

Moreover, in devices with symmetric coupling, the exchange fields of the two electrodes cancel each other if their magnetization is antiparallel. Hence, a huge effective magnetic field can be controlled by the tiny external magnetic fields required to switch the magnetization of the two electrodes. By virtue of the ferromagnetic hysteresis, the molecular device turns out to be a bistable switch, which can be controlled precisely in the same way as more conventional magnetoelectronic devices—with the advantage that the magnetoresistance is enhanced by the Kondo resonance and much larger than the usual tunneling magnetoresistance (see the figure).

The main drawback of the new devices is that so far, their fabrication relies on chance. Only 30 out of 1000 devices show the Kondo effect. This is typical for the current state of molecular electronics. The control of the electronic transport properties of molecular devices requires a positioning of the device components with an accuracy far better than 1 nm. The assembly of carbon nanotube field-effect transistors has been demonstrated using DNA templates (*10*), but does not yet allow a sufficient level of precision. Here is much scope for future developments. Nevertheless, the experiment of Pasupathy *et al.* is an important proof of principle and will fuel progress in fundamental physics, sample fabrication, and device applications.

References

1. S. J. Tans, A. R. M. Verschueren, C. Dekker, *Nature* **393**, 49 (1998).
2. C. Joachim, J. K. Gimzewski, R. Schittler, C. Chavy, *Phys. Rev. Lett.* **74**, 2102 (1995).
3. J. Reichert *et al.*, *Phys. Rev. Lett.* **88**, 176804 (2002).
4. S. A. Wolf *et al.*, *Science* **294**, 1488 (2001).
5. A. N. Pasupathy *et al.*, *Science* **306**, 86 (2004).
6. D. Goldhaber-Gordon *et al.*, *Nature* **391**, 156 (1998).
7. S. M. Cronenwett, T. H. Oosterkamp, L. P. Kouwenhoven, *Science* **281**, 540 (1998).
8. J. Park *et al.*, *Nature* **417**, 722 (2002).
9. W. Liang *et al.*, *Nature* **417**, 725 (2002).
10. K. Keren *et al.*, *Science* **302**, 1380 (2003).

GEOPHYSICS

Are Earth's Core and Mantle on Speaking Terms?

Cin-Ty Aeolus Lee

Earth's interior is divided into a central core made of an iron-nickel alloy and a rocky mantle made of silicate and oxide minerals. Earth scientists often ignore the core in their treatments of the chemical and dynamic evolution of the mantle after core-mantle segregation. However, there has been growing debate on whether there may be significant chemical interaction between the core and the mantle. On page 91 of this issue, Humayun *et al.* (*1*) present data that suggest that the lower mantle may be enriched in iron compared to the upper mantle, and that this iron enrichment may indeed be due to core-mantle interaction.

If the lower mantle is enriched in iron through chemical reactions between the lower mantle and the liquid outer part of the Earth's core (*2*), then the dynamics of the core and mantle must be coupled. The iron enrichment will also influence the physical properties of the lower mantle (such as its density, elasticity, and electrical conductivity). However, direct evidence for an iron-rich lower mantle is lacking. Moreover, even if the lower mantle is enriched in iron, other explanations are plausible. For example, the mantle may retain a primordial compositional stratification. Alternatively, subduction of oceanic crust or deep-sea marine sediments, some of which may be enriched in iron and manganese, may cause the enrichment.

It is widely believed that volcanic hotspots are the surface manifestations of plumes rising up from the lower mantle or core-mantle boundary. Earth scientists therefore use hotspot volcanoes as windows into Earth's deep interior. Humayun *et al.* (*1*) report the Fe/Mn ratios of basaltic lavas associated with a well-known hotspot, Hawaii. They show that the Hawaiian lavas have higher Fe/Mn ratios than basalts from mid-ocean ridges; the latter only tap the upper mantle (see the figure, inset).

The authors argue that the partitioning of iron and manganese between melts and the mantle is roughly equal, and that the Fe/Mn ratio of a melt should therefore closely reflect the Fe/Mn ratio of the melt source region. They thus suggest that the high Fe/Mn ratios of the Hawaiian lavas reflect a lower mantle enriched in iron, possibly due to long-term chemical interaction between the core and the mantle.

If this interpretation is correct, then the results provide the second observational evidence for a core component to the Hawaiian mantle source. The first evidence came from anomalously high concentrations of the isotope ^{186}Os in Hawaiian lavas (*3*), which were attributed to a Hawaiian mantle source that has incorporated small amounts of outer-core material. The latter is hypothesized to have elevated ^{186}Os due to its high Pt/Os ratio and radioactive decay of ^{190}Pt to ^{186}Os (*3*). Others have argued that the ^{186}Os anomalies are more likely to result from incorporation of subducted Fe-Mn–rich marine sediments (*4*, *5*), which also have high Pt/Os ratios. However, such sediments have low Fe/Mn ratios, which is inconsistent with the high Fe/Mn ratios of Hawaiian lavas reported by Humayun *et al.* (*1*).

Why were the consistently high Fe/Mn ratios in Hawaiian lavas not recognized earlier, given that iron and manganese have been routinely measured for decades? Humayun *et al.* suggest that the existing database of iron and manganese in Hawaiian lavas and mid-ocean ridge basalts

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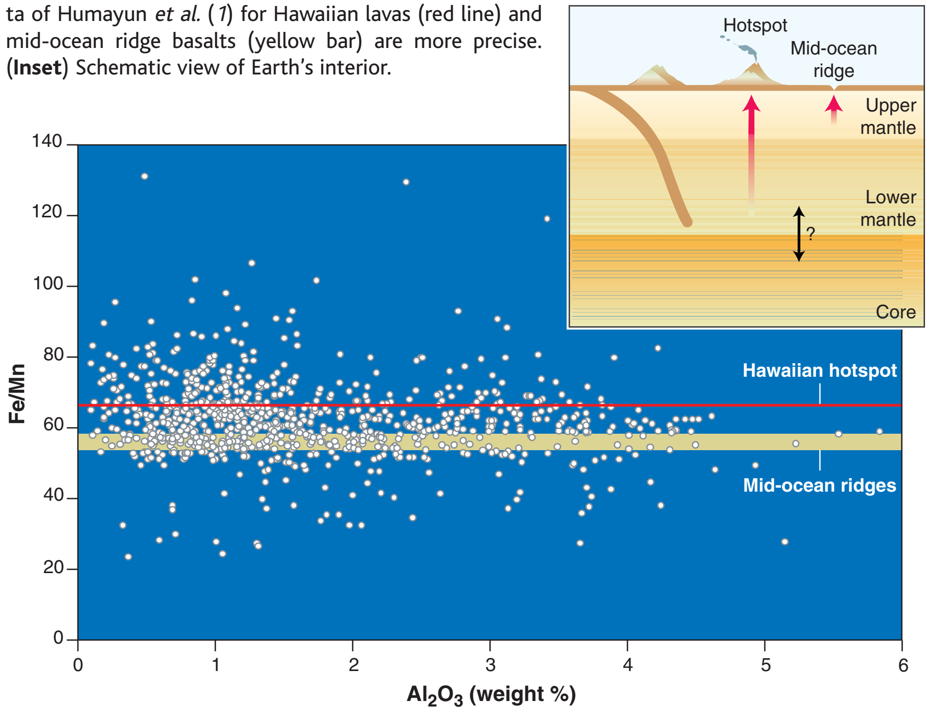
A window into Earth's interior? Literature data of Fe/Mn ratios in fresh mantle rocks (open circles) (*6*) are plotted against their Al_2O_3 content, which is a proxy for the degree of melt extraction (the Al_2O_3 content decreases during melting). The new data of Humayun *et al.* (*1*) for Hawaiian lavas (red line) and mid-ocean ridge basalts (yellow bar) are more precise. (**Inset**) Schematic view of Earth's interior.



[figure S2 in (*1*)] may be affected by interlaboratory biases, which obscure systematic differences between lavas. They show that a more precise and internally consistent database reveals systematic differences between the Fe/Mn ratios of Hawaiian lavas and mid-ocean ridge basalts.

In light of a more precise and internally consistent dataset on basalts, it may be worth revisiting whether there are intrinsic variations in Fe/Mn ratios in the upper mantle that may not necessarily be associated with iron enrichment due to core-mantle interaction. For example, a compilation of Fe/Mn data in upper-mantle samples (see the figure) shows that the Fe/Mn ratio of the upper mantle is roughly 60 ± 20 (2 standard deviations), corresponding to a total variation of ~60%. The difference between the Fe/Mn ratios of Hawaiian lavas and mid-ocean ridge basalts measured by Humayun *et al.* is less than 15%, well within the scatter seen in upper-mantle samples (see the figure).

It is not entirely clear whether the large scatter in the mantle samples is real or a result of interlaboratory bias. If it is real, the implication is that high-Fe/Mn regions exist in the upper mantle that could yield high-Fe/Mn magmas upon melting. In fact, previously melted mantle may well develop high Fe/Mn ratios because such mantle would be richer in olivine (an abundant mineral in the upper mantle), which preferentially incorporates iron over manganese [figure 3A in (*1*)]. Remelting of previously melted mantle could therefore give rise to high Fe/Mn magmas.

If the lower mantle is indeed iron-rich, our understanding of mantle circulation and Earth's bulk composition may need to be revised. It is thus necessary to explore alternative explanations for high Fe/Mn ratios in magmas. To do so, a combination of petrology and high-precision measurements of iron and manganese in mantle rocks is crucial. It may also be worth considering other first-series transition elements (such as Cr, V, Co, and Ni), because the abundance patterns of these elements imparted by partial melting differ from those imparted by core-mantle interaction. Regardless of the outcome of these studies, the work of Humayun *et al.* may rekindle an interest in first-series transition metals in the geosciences.

References

1. M. Humayun, L. Qin, M. D. Norman, *Science* **306**, 91 (2004).
2. E. Garnero, *Science* **304**, 834 (2004).
3. A. D. Brandon *et al.*, *Science* **280**, 1570 (1998).
4. G. Ravizza, J. Blusztajn, H. M. Prichard, *Earth Planet. Sci. Lett.* **188**, 369 (2001).
5. A. Schersten *et al.*, *Nature* **427**, 234 (2004).
6. W. F. McDonough, S.-S. Sun, *Chem. Geol.* **120**, 223 (1995).

VIROLOGY

Src Launches Vaccinia

Alan Hall

Contrary to popular belief, pathogens have evolved not with the sole purpose of killing their hosts, but rather to multiply and spread efficiently under the pressure of natural selection. Our need to develop smart new therapeutic strategies to deal with bacterial and viral infections has stimulated serious efforts to understand the intimate relationship between host and pathogen. An unexpected spinoff from this work has been fresh insight into the molecular mechanisms underlying mammalian cell biology, particularly the organization and control of the actin and microtubule cytoskeletons. Bacteria and viruses have both exploited the unique properties of these dynamic, filamentous structures to facilitate their own life cycles. The report by Newsome *et al.* (*1*) on page 124 of this issue describes a mechanism by which vaccinia virus commandeers a host cell tyrosine kinase called Src to allow a smooth switch from microtubule-driven intracellular transport to actin-driven extracellular extrusion.

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content/full/306/5693/65

Vaccinia virus is one of humanity's best friends: It has lent its name to the most successful strategy yet for preventing infection and is responsible for eradicating smallpox from our planet. This virus is surrounded by an envelope and its DNA encodes close to 200 genes. After entering the cell, the viral core attaches to microtubules and moves to the perinuclear region of the host cell where the virus then replicates its DNA (*2*). A complex series of maturation steps leads to a viral core particle surrounded by two concentric membranes—this intracellular enveloped virus (IEV) then must make its way to the plasma membrane; for release. It has been estimated that because of its large size, this process would take more than 10 hours by diffusion. In fact, it takes the vaccinia virus less than a minute because the virus hitches a ride on kinesin, a host motor protein that normally transports cargo (protein complexes or vesicles) along microtubules to the cell periphery (see the figure, step 1). The viral A36R protein, which is the focus of the Newsome *et al.* report, plays a key role in this process. This protein is present

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