These authors analysed the skeletal remains of 33 modern Amerindians from early historic times, excavated from the tip of the Baja peninsula in Mexico. Surprisingly, the craniofacial features of these Baja Amerindians show closer affinity to the Palaeoamerican skulls than to other modern Amerindian remains. The Baja Amerindian and Palaeoamerican skulls have similar long and narrow braincases and relatively short, narrow faces, implying a common ancestry with the ancient inhabitants of south Asia and the Pacific Rim. González-José *et al.* confirm that modern Amerindian skulls from other areas are similar to ancient northeast Asian remains. Their new data add to accumulating evidence of morphological differences between early humans from different areas of the Americas[8,9].

The authors consider several potential explanations to account for the presence of Palaeoamerican traits in the Baja Amerindian skulls, but they suggest that the best explanation is that the Palaeoamericans were the direct ancestors of the Baja Amerindians. After the Ice Age, the increased aridity could have geographically isolated the founding Palaeoamerican population in the Baja area, and limited its gene flow with other modern Amerindian groups.

Do the new findings tell us anything more about when the first humans arrived in the Americas? The authors do not fully discuss the chronological implications of their work, but their interpretation of shared ancestry between the Palaeoamericans and the Baja Amerindians might best fit a model of Palaeoamerican arrival about 11,000–12,000 years ago. There is no direct evidence to support this view, but if the Palaeoamericans had arrived 15,000 years ago or earlier, the Baja population would have remained isolated for much longer. This seems unlikely, given the rate of population growth and movement that probably occurred after initial colonization and then after the Ice Age when the climate warmed.

But could the similarities between the ancient Palaeoamericans and the later Baja Amerindians instead reflect the influence of other evolutionary forces, such as gene flow or natural selection and convergent adaptation of different populations to similar local environments? Answering this question will depend upon finding more isolated prehistoric populations showing ancient Palaeoamerican traits, and then establishing whether parallel evolutionary forces were acting on them and whether they were derived from a single ancestry. But this will be a difficult task. Human remains from the end of the Ice Age are scarce and often fragmentary, so we have only a vague notion of the skeletal characteristics of the ancient Palaeoamericans. And we have a poor

understanding of the migration history of different American populations and what kind of evolutionary forces might have influenced them[10].

Given these limitations, the findings of González-José *et al.* do not allow us to draw firm conclusions about the relationship between the ancient Palaeoamericans and the later Baja Amerindians. But the importance of this and other studies[7,11] is that they suggest a different view of the origins and interactions of early human populations in the Americas. What we really want to know is what took place within and between these populations, how they changed over time, and how quickly they changed. These issues can be resolved only by obtaining more skeletal data[11] and by combining them with regional archaeological records, which should provide information on the social and cultural histories of the different

populations. Slowly, we are realizing that the ancestry of the Americas is as complex and as difficult to trace as that of other human lineages around the world. ■

Tom D. Dillehay is in the Department of Anthropology, University of Kentucky, Lexington, Kentucky 40506, USA.
e-mail: dilleha@uky.edu

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Earth science

Just add water

Albrecht W. Hofmann

A new model could explain why Earth's upper mantle is depleted of many trace elements. At a certain depth, minerals might release water, creating a molten filter that traps trace elements in the mantle beneath.

Sandwiched between Earth's thin crust and its metallic core lies a layer of pressurized rock at high temperature — the mantle. Convection in this layer drives plate tectonics and sea-floor spreading, but we know little about the pattern of circulation. Indeed, current thinking about mantle dynamics is in a state of turmoil. As we cannot observe convection directly, we must piece together indirect evidence from seismology, geochemistry, mineral physics, fluid dynamics and numerical simulations of convection. But the evidence is contradictory and has led to at least two conflicting views about mantle movement. On page 39 of this issue, Bercovici and Karato[1] propose a new model that might resolve this conflict. They suggest that water dissolved in the mantle might create a thin layer of melt at a depth of 400 km, causing an unexpected pattern of circulation in the mantle.

The two conflicting models for mantle convection (Fig. 1a, b, overleaf) are usually described as 'layered' convection (supported by geochemists) and 'whole-mantle' convection (supported by seismologists). Geochemists have long insisted on the two-layered model, in which the mantle consists of a relatively primitive layer below a depth of 660 km — containing primordial noble gases, trapped 4.5 billion years ago when the Earth formed — and an upper layer that is highly depleted of heat-producing elements (uranium, thorium and potassium), noble

gases and other 'incompatible' elements. The primitive layer serves as a reservoir for these elements (which were depleted from the upper mantle when Earth's crust was formed) and it is occasionally sampled by deep-mantle plumes (Fig. 1a).

Over the past several years, however, seismic tomography has given us increasingly detailed images of apparently cold 'slabs' (characterized by fast seismic velocities) descending into the deep mantle right through the 660-km boundary, effectively cutting to shreds the simple picture of the mantle convecting in two nearly isolated layers. If cold 'slabs' descend into the deep mantle, there must be a corresponding upward flow of deep-mantle material to shallow levels (Fig. 1b). No matter what specific form the exchange across the 660-km boundary takes, in this 'whole-mantle' model of mantle convection, it would within a few hundred million years destroy any compositional layering that had possibly been inherited from early in Earth's history.

Meanwhile, the geochemical arguments for a separate deep reservoir have not disappeared. Primordial noble gases are still preferentially associated with 'hot spots'[2], at least some of which seem to come from deep-mantle plumes[3]. And much of the upper mantle remains highly depleted of incompatible trace elements, including the heat-producing thorium, uranium and potassium — also suggesting the presence of a less

depleted reservoir deep within the mantle[4].

Can these conflicting data be reconciled? Some scientists have proposed that a relatively small, seismically 'invisible' primitive reservoir, which is slightly denser than ordinary mantle material, is trapped in the deep mantle[5,6]. Others suggest that the seismically anomalous, so-called D″ layer just above the core–mantle boundary can satisfy the geochemical requirements[7]. Yet another theory is that the geochemical heterogeneities are dispersed throughout the mantle but are preferentially sampled by hot-spot magmas, which therefore deliver a biased record of their source chemistry[8].

Bercovici and Karato[1] propose a new model for mantle convection that might reconcile the geochemists and the seismologists. Experimental work has shown that, at high pressure, the mantle minerals wadsleyite and ringwoodite have surprisingly high solubilities for water[9]. High-pressure forms of these minerals occur in the depth range of 410–660 km — the so-called mantle transition zone — and Bercovici and Karato postulate that this zone has a high water content (0.2–2.0% by weight). They suggest that when material in the transition zone rises through slow convective motion to depths of less than 410 km, wadsleyite is transformed into the mineral olivine and liberates water (olivine has a much lower solubility for water than wadsleyite).

Adding water to almost any rock will lower its melting point by several hundred degrees. The authors suggest that this 'dehydration melting' might create a thin (about 10-km) layer of molten silicate just above the 410-km level, which would retain most of the water as well as all those incompatible trace elements (including uranium and thorium) that do not easily fit into the crystal structures of the available solid minerals. The melt layer is trapped at 410 km, because melt is denser than solid at very high pressures, but it is ultimately entrained, refrozen and returned to the transition zone by descending cold, subducted slabs. This return flow keeps the thickness of the molten silicate approximately constant. So the melt layer acts as a filter, removing elements from rising mantle material and keeping the upper layer in a depleted state (Fig. 1c). Deep-mantle plumes are exempt from this filtering process because their higher temperature lowers the solubility for water in wadsleyite, but increases solubility in olivine, thus preventing the formation of a melt at a depth of 410 km.

The new model has not yet been tested by numerical simulations of mantle convection. But this might prove to be difficult or impossible to do in the near future because the melt layer is very thin and its mechanical behaviour is complex. But does the model satisfy the geochemical constraints? Many isotope geochemists will say that it does not,
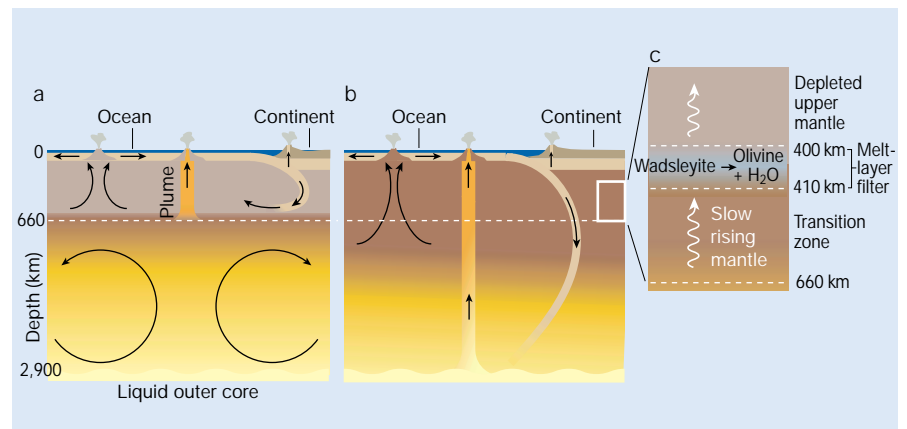
Figure 1 **Models of mantle circulation. a, Geochemists support a two-layered model in which the upper layer of mantle, depleted in 'incompatible' elements, is separated from the primitive lower mantle by a boundary at a depth of 660 km. b, Seismologists disagree. They support a 'whole-mantle' model of circulation with exchange between subducting crust and upwelling plumes. c, Bercovici and Karato[1] now propose a model that might satisfy both camps. They suggest that at depths of 410 km the mineral wadsleyite releases water and is transformed into olivine. This creates a thin layer of molten silicate that acts as a filter, removing 'incompatible' trace elements from slowly uprising mantle.**

but I am not so sure. The difficulty comes in reconciling Bercovici and Karato's hypothesis with our view of how the mid-ocean ridge forms. This part of Earth's crust is thought to be derived from the upper mantle, whereas ocean islands are made from deeper mantle plumes. These different source materials can be traced by the composition of strontium isotopes in the basalt rock — mid-ocean ridge basalts have lower $^{87}Sr/^{86}Sr$ ratios than ocean island basalts. The ^{87}Sr isotope is created by the very slow decay of ^{87}Rb (with a half-life of about 47 billion years), so the isotopic differences between the upper mantle and the deeper mantle take a very long time to develop, typically 1–2 billion years.

In the Bercovici–Karato model, the upper mantle is continuously replenished by slowly rising deep-mantle material. The melt layer at 410 km removes water and incompatible elements, but this does not change the isotopic composition of the rising dehydrated solid. According to the isotopic differences, to fit Bercovici and Karato's model, the deep mantle rises at a very slow speed of about 1 mm per year or even less. So it would take more than 400 million years to traverse the 400-km distance towards the melting region beneath ocean ridges. But upwelling rates in the immediate vicinity of mid-ocean ridges are significantly greater, and this would tend to minimize the time available for isotopic differences to develop. Still, opinions differ rather widely as to how great the isotopic difference actually is between average mantle samples from mid-ocean-ridge basalts and from plumes. Moreover, it is likely that plume-source material does not represent average lower mantle; instead, its composition is probably biased towards segregated subducted former oceanic crust[10,11].

Another concern is that the model depends on the assumption that the mantle transition zone contains enough water to cause the postulated melting. There is at least circumstantial evidence that the mantle is rather severely dehydrated during subduction[12], and estimates based on trace-element ratios[13] limit the water content of the primitive silicate mantle to less than about 0.05% — much lower than Bercovici and Karato's estimate of 0.1–1.5% for the transition zone. But these measurements may not necessarily be applicable to the transition zone in the new model.

Bercovici and Karato's hypothesis is intriguing, but wouldn't such a mid-mantle melt layer have been detected long ago by seismologists? Perhaps it was[14,15], but the evidence is patchy. Features less than 10 km thick are easily missed in seismic records and will have to be carefully searched for in the future. ∎

Albrecht W. Hofmann is at the Max-Planck-Institut für Chemie, Postfach 3060, 55020 Mainz, Germany.
e-mail: hofmann@mpch-mainz.mpg.de

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