searchers show that even such a small density difference would be sufficient to inhibit mixing of the mantle layers for billions of years, even in the presence of rising plumes and descending slabs.

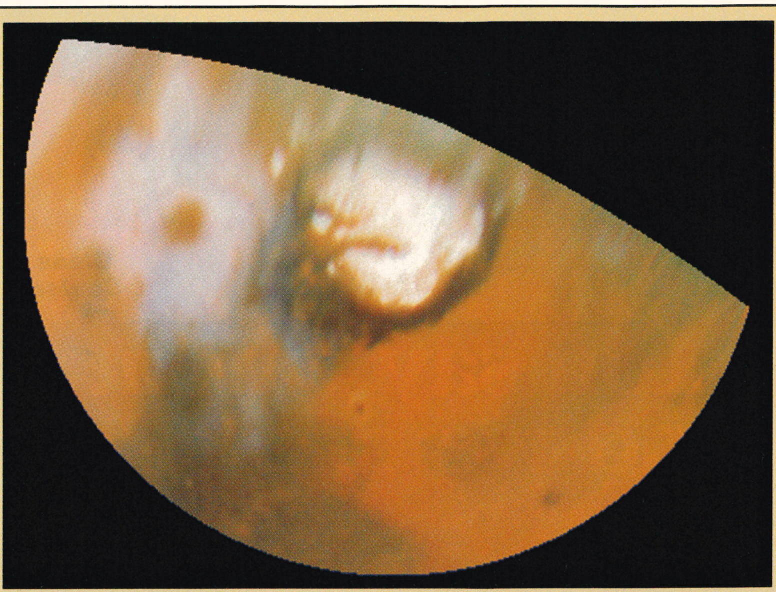
The resulting near-neutral density of the deep layer compared to that above it has the unintended consequence that the interface between layers is free to deform into arbitrarily complex topography in response to currents in the mantle, pressure from descending slabs, and so on. The complex topography would make the boundary between layers difficult to detect, especially given current resolutions of seismic tomography in the lower mantle. Further, Kellogg, Hager, and van der Hilst point out that the change observed in the seismic-wave velocity at the interface between the two regions depends not only on the additional density, but also on what elements are added. Adding iron to the deep region would result in a slower sound speed, while adding silicon could result in a faster sound speed, even while increasing the density of the medium.

An interesting challenge

With all the debate the Lava-lamp model has generated, one has to remember that the model is still in a preliminary state. Kellogg is busy responding to the wish lists of researchers for more realistic simulations. Peter Olson (Johns Hopkins University) stresses the importance of generalizing the model from two to three dimensions: "What works as a delicate balance in a two-dimensional box could change in an unconstrained three-dimensional environment." Recently, Anne Devaille (Institut de Physique du Globe de Paris) took a step in that direction,[4] demonstrating in analog experiments that such a two-layer model, heated from below, can be stable.

However, such analog experiments cannot address other concerns. Henry Pollack (University of Michigan) wonders how more realistic heating would affect the model. Because concentrations of radioactive elements decay exponentially, determining current concentrations of these elements from Earth's current heat loss requires knowing how long the heat takes to propagate through the mantle. Don Anderson (Caltech) would like the model to consider pressure effects in calculations of thermal expansion.

For their part, seismologists wonder whether the deep layer in the Lava-lamp model would be detectable at all, given the complex boundary topography and the interplay between thermal expansion and composition. Kárason's and van der Hilst's investigations seem to give some indication of structural and compositional variation in this region of the mantle. However, Guy Masters (University of California, San Diego) thinks that currently available seismic data sets for the lower mantle may be too noisy for such studies: "I don't think we are at the point where we can sort out temperature and compositional effects. Not all the data sets even show the vanishing of complexity at 1700 km that they [van der Hilst and Kárason] see." Masters, however, sees some hope of detecting the deep



An interplanetary weather forecast for Mars. Astronomers are used to seeing strange things when they turn their telescopes toward the Red Planet—some of them tantalizingly, and often deceptively, Earthlike. The image above, a stereographic projection centered on Mars's north pole, was returned by the Hubble Space Telescope Wide-Field Planetary Camera 2 on 27 April. It depicts a "spiral storm" 1600 km in diameter (the storm is a diffuse white spiral to the left of the bright ice cap) just south of the planet's northern polar ice cap. Although such storms were first observed over 20 years ago, April's tempest was three to four times the size of previously observed storms. So far detected only in Mars's northern hemisphere during its summer, the storms bear some resemblance to terrestrial polar cyclones.

On Earth, polar cyclones are driven by the temperature differences between the warm oceans and cooler atmosphere and amplified by the release of latent heat as evaporated water condenses at high altitudes. Mars's spiral storms are thought to be driven by a weaker engine—the temperature contrast between the cold, bright northern ice cap and the darker, warmer terrain to the south. Moreover, in the thin Martian atmosphere, a 200 mile-per-hour wind would pack the force of only a light terrestrial breeze. The relative weakness of the spiral storm in April is borne out by the fact that it swept up no detectable dust.

Martian storms are also short-lived, lasting only a few days. In the next Hubble image of the storm, taken six hours later, the ice clouds seemed to be sublimating in the Martian afternoon sun. Although subsequent images, taken a few days later by the Mars Global Surveyor (MGS), showed some evidence of mild continued disturbance, the striking cyclonelike structure was gone. Images of the spiral storm are available on the Space Telescope Science Institute's website at http://oposite.stsci.edu/pubinfo/1999/22/. A time-lapse sequence of the subsequent MGS images can be found on the MGS website at http://mars.jpl.nasa.gov/mgs/msss/camera/images/5_21_99_np_clouds/. The researchers who gathered and analyzed the Hubble images—James Bell (Cornell University), Michael Wolff and R. Todd Clancy (Space Science Institute, Boulder, Colorado), Steven Lee (University of Colorado, Boulder), Philip James (University of Toledo), and Michael Ravine (Malin Space Science Systems, San Diego)—are currently investigating the similarities and differences between Martian spiral storms and terrestrial polar storms.

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