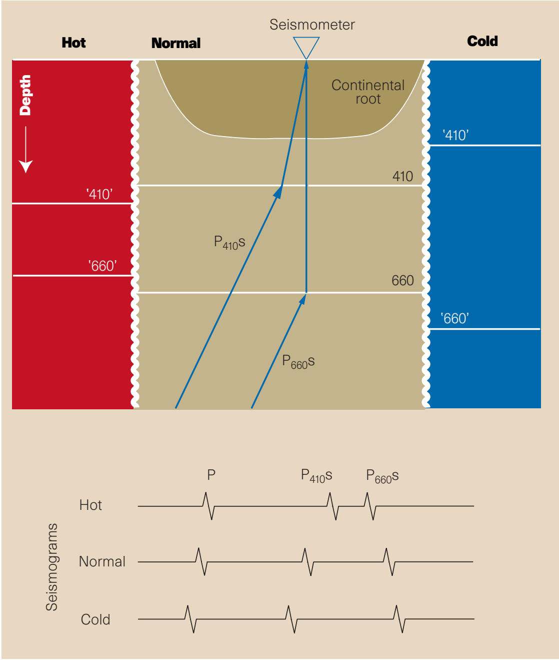

Figure 1 **The approach used by Li *et al.*[1] to analyse mantle temperature in eastern North America. Temperature changes in the mantle affect the depth of the seismic discontinuities nominally at 410 and 660 km. In a cold mantle, their spacing widens (right), and in a hot mantle it narrows (left). Seismic waves from distant earthquakes interact with the discontinuities, forming 'echoes' (P-to-S conversions at 410 and 660 km depth; $P_{410}s$ and $P_{660}s$), whose time lags after the first-arriving P wave yield the conversion depth. This is one way to tell whether a continental root, which might extend down to 300 km (centre), cools the mantle.**

nents are faster than the average elsewhere at the same depth, which is also compatible with cooler temperatures. So there are good reasons to expect a chilling subcontinental ambience.

Li *et al.*[1] take the temperature of the eastern North American mantle by measuring the seismic waves produced when the wavefields from distant earthquakes interact with the discontinuities at 410 and 660 km depth (Fig. 1). These changes correspond to mineralogical transitions in the mantle. Conveniently, in a cool mantle the level of the 410 transition rises and that of the 660 falls owing to the transitions' respective thermodynamic properties (and conversely in a warm mantle). This is a particular example of a broadly applicable technique by which the mantle's temperature and chemical structure can be gauged[4–7]. The mantle transitions create 'echoes' of the main seismic waves, which, by their time lags after their predecessors, yield the depth to the transition. Thus, by seeing how these depths change where the continental root deepens, one probes its internal temperature.

During 1995 and 1996, an array of 18 portable seismic stations was deployed across the eastern United States, running from the northeastern seaboard into Missouri, to record distant earthquakes. The transect spans a region of deepening continental draft, and it is this region that Li *et al.* now report on. Astonishingly, the study finds no 410 deflection — at odds with the expected behaviour of a continental coldfinger. More paradoxically, on approaching the continental interior, the deeper discontinuity gets deeper still whereas the shallower one holds a steady level. This seems to preclude any large-scale, vertically coherent downwelling beneath eastern North America.

One escape from this conundrum is that the downwelling could be time-dependent[8] and that we are unlucky to be looking for it just now. Perhaps 50 million years of patient waiting will reveal one. A quicker verdict, barring mendacity on the Earth's part, could come from investigations of other continental interiors, which might catch downwelling elsewhere. But a worrying result from a sparser but broader-scale survey of North America using the same method reveals nothing more widely suggestive of cooler temperatures or downwelling[9].

Alternatively, the methodology may suffer from unknown deficiencies of a frequency-dependent nature. Short-wavelength topography estimates on the corresponding discontinuities in the western Pacific differ by factors of up to four depending on the seismic frequencies used[10,11]. Similar small-scale features may lurk unobserved under continents as well, and may be involved in mantle cooling. At present, we can only adopt a wait-and-see attitude akin to the Fleming character: once is happenstance; twice is coincidence; the third time is Earth-like behaviour. ☐

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Daedalus

Cruise micromissiles

The Crookes radiometer is a glass bulb containing a little 'mill' that spins in sunlight. Each vane of the mill is blackened on one face, which warms up compared with the other, reflective, face. Gas molecules hitting a vane edge flow back along it from the cold side to the hot one, and drive the vane by their reaction. This 'thermal transpiration' is most efficient when the mean free path of the gas molecules matches the vane thickness, which for vanes 0.1 mm thick implies a low pressure around 5 pascals.

Daedalus once devised a radiometer helicopter rotor, to fly in the low pressures at high altitude. He now points out that the mean free path in air at ground level is about 10 nm; so a radiometer could spin in ambient air if it had blades 10 nm thick. No macroscopic blade could be made so thin. But imagine, says Daedalus, a 10-nm wire, heated by a current or radiative absorption, and moving sideways through ordinary air. Its leading edge would be selectively cooled by the impacting air molecules, thus establishing a front-to-rear temperature difference. So those molecules would be impelled backwards by thermal transpiration, driving the wire forward and augmenting its speed. Given a starting push, the wire would continue to accelerate in that direction, like a ramjet.

So Daedalus's 'ram radiometer' is simply a fine grid of 10-nm wires in a duct about a millimetre across. It is the smallest possible aero-engine. Several such engines distributed about a tiny winged airframe will complete an 'artificial fly'. Modern microfabrication methods will shape the wire grids, form the tiny photovoltaic cells that power them, and lay down the steering electronics. This will turn different engines on and off in response to infrared digital codes beamed at the photocells.

Powered by daylight and controlled by an infrared unit rather like a TV-channel changer, the artificial fly will be an elegant and unobtrusive remote-sensing and transmitting gadget. Carrying a tiny microphone or a set of chemical sensors, it could snoop and soar, sniffing out leaks in a chemical plant, conversations in a crowd, or the microclimate in a forest. Daedalus likes the idea of forming a number of them into a personal defence squadron against real flies and mosquitoes. They could defeat the pests by ramming — insect wings are notoriously vulnerable to mechanical damage — or even, with sufficiently cunning control programs, by seduction.

David Jones