years. Thus the anomalous region needs to have either an unusually low density contrast with its surrounding for its seismic velocity anomaly or be within upper mantle material that is an order of magnitude more viscous than typical estimates of upper mantle viscosity.

Second, the westward motion of the South American plate relative to the deep mantle would shear the anomaly. In this case, about 3,000 km of motion between the plate and the lower mantle has occurred over a 600 km depth range. If this shear was evenly distributed with depth, an original 250-km-diameter sphere would have been smeared out over 1,250 km. For the sphere to survive, shear would have to be accommodated by an underlying low-viscosity layer.

Given these restrictions, could the low-velocity anomaly instead be associated with a more recently formed hot region? Unfortunately such regions are not expected from conventional theory. Another possibility is a normal-temperature region surrounded by cool downwellings associated with convection at the base of the lithosphere — as tomography detects only lateral viscosity contrasts, this would not be distinguished from a hot upwelling. But cool downwellings are expected to have small temperature contrasts (enough to change viscosity by a factor of e)[3,4].

A new starting plume would also need to have a small head — if there were a large head, we would expect to see volcanism, uplift and a much broader seismic anomaly today. But it is difficult to create a small starting plume head because head radius is proportional to the one-fifth power of volume flux of the plume[5,6]. In addition, starting plume heads spend most of their life in the deep high-viscosity parts of the mantle and thus should be infrequent at shallower depths. For example, if viscosity increases exponentially with depth, the derivation in ref. 5 is easily modified to show that 76 per cent of the ascent time is spent in the basal layer where viscosity is within a factor of e of its maximum value. The upward decrease of viscosity in the Earth may generate small plume heads but they are expected to reach the surface soon after the primary one[6]. Therefore a convective explanation for the anomaly would have to appeal to poorly understood processes, perhaps involving the phase change at 670 km depth or the tail of a weak plume that is not associated with a surface hotspot.

Could the anomaly be an artefact of the tomographic analysis? VanDecar *et al.*[2] have been careful in their analysis. They have correlated wave forms to pick arrival times to a precision of 0.03 s. Their successful model reduces the variance of residuals to this level. This avoids the 1-s data precision, systematic errors and slight though statistically significant reductions in variance of arrival times compiled in bulletins. They have also done a resolution analysis to show that their data would detect an anomaly of this size if it were present. At a minimum, their velocity anomaly is a viable explanation of their observations.

Undersampling of the Earth by seismic waves is a unavoidable problem in the study. Seismic waves sample a region of about a wavelength, here 8 km, around their ray paths and the distribution of sources and receivers is such that many 8-km cubes are missed altogether by ray paths. Thus it is necessary to have a much coarser model resolution, about 100 km. This is obtained by a smoothness constraint in the least-squares inversion. The alternative of using 100-km waves which do not undersample is not feasible because the arrival times cannot be accurately picked.

The smoothness constraint (or alternatively a constraint on the root-mean-square value of model perturbations) is necessary to obtain a stable inversion, but the cost is far greater than just defocusing the resolved anomaly. The amplitude of the anomaly times volume may be increased (or decreased), real strong anomalies may be suppressed and strong artefact anomalies may be created in poorly sampled regions far from the real anomalies.

In the case of downgoing slabs, strong velocity anomalies are known to exist. The common practice of using spatially uniform smoothing (or perturbation) constraints is tantamount to assuming that nothing is known about plate tectonics; it suppresses the real slab anomaly and causes artefacts elsewhere. However, no upper-mantle anomaly is expected beneath the Brazilian shield so a simple smoothing constraint is all that can be applied. A scheme for producing the observed anomaly as an artefact of strong anomalies elsewhere is certainly not evident.

In conclusion, the results of VanDecar *et al.* are puzzling but cannot be easily dismissed. Either a hot region is associated with the observed anomaly, or compositional variations or anisotropy produce velocity anomalies not associated with density. In the former case, conventional plume theory needs to be modified. In the latter, a caveat is posed for studies (such as ref. 1) that attempt to detect plume tails beneath hotspots. ☐

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DAEDALUS

Spectral shifts

COLOUR matching is a tricky visual skill, as anyone knows who has had to paint in a chip or a scratch on a car body with a matching shade. Daedalus is now inventing a single universal paint to match all possible cars.

He points out that a colour photograph is slowly and selectively decolourized by daylight. The blue and ultraviolet rays bleach out all the colours that absorb them. The result is a monochrome image in the one colour that doesn't absorb blue light — blue itself. He is now generalizing this photochemistry. DREADCO's 'UniPaint' will contain a broad mixture of dyes embracing the whole spectrum; initially, therefore, it will be black. But cunningly, each dye is bleached by light of all colours but its own. The user will coat the product onto a scratched or damaged area of his car, and quickly cover the wet surface with an opaque patch. Light will leak into this covered region round the edges of the patch, through the original paint. It will therefore be filtered to that exact colour, and will bleach away those dyes in the adjacent UniPaint that absorb that colour. The remaining ones will, of course, give the UniPaint precisely that same shade, which will filter inwards by transmission to colour the UniPaint further in, and so on. Ultimately, the outer colour will infiltrate and transform the entire painted area. The user will peel off the patch to find a dry and perfectly matched repair.

The obvious snag is that such a light-sensitive paint would soon be bleached white by daylight, ruining the match. Daedalus will counter this by coupling the bleaching process to the setting reaction of the paint. While UniPaint is wet, the bleaching agent in its formulation can diffuse to each photo-excited dye molecule and fix it in its colourless state; once it has hardened, no further chemistry is possible and the colour will be stable.

UniPaint will transform, not just the automotive touch-in market, but the whole paint business itself. Its thousands of shades will be replaced by just one. For a start, the car industry could cover every car with UniPaint, and colour it by exposure to the right illumination while the paint was setting. Mixed lighting could even give a graded finish. Indeed, any image at all could be projected onto a wet UniPaint surface, and would be stable when it had dried. Posters, stage scenery, interior decor, street notices, each could be projected from a big slide-projector onto a freshly UniPainted surface during the hours of darkness, to blaze forth in multicoloured splendour in the morning. David Jones