erties built up, it has become increasingly difficult to reconcile geochemically reasonable mineralogical models with the seismic observations (as discussed in News and Views just over a year ago¹). At the meeting, however, new data, arising from rapid developments in the pressures and temperatures at which experiments can be carried out in the laboratory, came under consideration. They point the way to a resolution of this problem in terms of a chemical stratification between the uppermost mantle (about 100–410 km depth) and the underlying transition zone (410–660 km).

At pressures and temperatures corresponding to a depth of about 410 km, olivine — a solid solution $(\text{Mg,Fe})_2\text{SiO}_4$ — transforms to a denser polymorph, wadsleyite (frequently and incorrectly termed 'β-phase' or 'modified spinel'). Laboratory measurements of the elasticity of both polymorphs of Mg_2SiO_4 (B. Li *et al.*, SUNY, Stony Brook; see also ref. 2) imply that velocity changes of some 13% accompany this transition. At the same depth within the Earth, geophysical models of the variation of seismic-wave velocities with depth show corresponding velocity changes of only 3–5% (for example, see ref. 3). From these data, the olivine content of the upper mantle has been inferred to be around 40%.

However, *in situ* measurements of olivine (R. C. Liebermann *et al.*, SUNY, Stony Brook) and olivine + pyroxene mixtures⁴ at high temperatures and pressures show that their seismic wave velocities exactly match those inferred for the upper mantle at depths of 200–400 km. Because garnet has much higher seismic velocities than olivine (for example, G. D. Gwanmesia *et al.*, Delaware State Univ.), and the high-density clinopyroxenes⁵ are inferred to be as fast as olivine, these data would imply a garnet-free mantle — a petrologically unacceptable model.

In consequence, it has been proposed instead that the 410-km discontinuity arises from a pyroxene-to-garnet transformation in a sodium-rich portion of the upper mantle which is a residue of an early magma ocean (T. Gasparik, SUNY, Stony Brook). Such a model would imply that little or no convection occurs in the upper mantle, a result that is difficult to reconcile with the existence of convection-driven plate tectonic activity on the Earth.

Resolution of these views comes from consideration of the latest data, and a chemically more complex model for the upper mantle and transition zone that involves the effects of both iron and water. Whereas $(\text{Mg,Fe})_2\text{SiO}_4$ olivine in isolation would transform to a wadsleyite phase of the same composition, in the presence of garnet it reacts to give rise to a wadsleyite enriched in Fe relative to olivine (Y. Fei and C. Bertka, Carnegie Inst. Washington). Such enrichment

in Fe reduces the seismic velocities in wadsleyite (S. Sinogeikin *et al.*, Univ. Illinois). Furthermore, wadsleyite accommodates far more hydrogen within its structure than does olivine, and its presence changes the crystallographic structure (J. Smyth, Univ. Colorado); the effects on the elastic properties are as yet unknown, although one can infer from crystal chemical considerations that there is an additional general softening of the structure and an accompanying decrease in seismic velocities. So the velocity jump at 410-km depth in the Earth from olivine to wadsleyite enriched in H and Fe will be less than that which would accompany the transition if the olivine and wadsleyite had the same composition. Therefore more olivine is now required than in the previous simple isochemical model to produce the same velocity jump.

Many of these data are too new to have been incorporated into geophysical models of the upper mantle. But calculations (A. R. Calderwood, Univ. British Columbia) suggest that a pyrolite upper mantle containing about 60% olivine, accompanied by Fe-enrichment in the higher density phases of the transition zone, gives a reasonably good match to modern global seismic data sets.

So debate over the mineralogical composition of the upper mantle now seems settled. But does the outcome mean, as previously assumed, that there is no chemical stratification between the transition zone and lower mantle, and thus that whole-mantle convection occurs? Perhaps not, because a direct result of an increased olivine content of the upper mantle is a greater release of latent heat from the olivine-to-wadsleyite transition in subducting slabs, which simulations suggest would encourage the physical detachment of these slabs at the 410-km discontinuity (D. Brunet, CNRS, Toulouse). The subsequent ponding of the detached cold slabs on the 660-km discontinuity that marks the top of the lower mantle would provide at least a partial physical barrier to convection; and it would increase the possibility of the mantle convecting as double system, with perhaps intermittent catastrophic overturns⁶ that mix the upper and lower mantle on a timescale of 100 million years or more. □

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Daedalus

Visionary spectacles

Our eyes gradually lose their focusing ability with age. Reading glasses, bifocals and graded-focus spectacles are a poor substitute. Daedalus now has a better one.

His first idea was a hollow lens whose interior could be filled with a liquid. Replace that liquid by one with a different refractive index, and the lens would change its focal length. But a multi-focus lens with a range of different liquids would pose fearsome plumbing problems. A refractive gas, pumped into the lens cavity under variable pressure, seems simpler. Sadly, most gases change their refractive index only slightly with pressure.

A supercritical fluid, however, could be pressurized from an index of almost unity right up towards that of glass itself. But the pressures needed could be rather high. Supercritical xenon, for example, exerts about 60 atmospheres at its index peak; adjusted for reading, xenon-focused glasses would be a potential bomb. But Daedalus recalls how readily gases condense on absorbents such as silica gel, even at quite low pressures. And the ultimate silica gel is silica aerogel, that amazing open silica framework not much denser than air, and indeed known as 'frozen smoke'. With its vast internal surface, it must absorb gases avidly. Sadly, in its pure state it is not quite optically clear. But Daedalus argues that a little adsorbed gas will make it so. Refractive matching will reduce the scattering from its internal microstructure.

So Daedalus's new variable-focus 'Aerospecs' will have hollow lenses filled with silica aerogel, and connected to a supply of an easily condensed gas such as butane, ammonia or a suitable halocarbon. For distance viewing, the lenses contain just enough gas to keep the aerogel transparent. For closer viewing, a slight rise in pressure condenses more gas into the aerogel, and the lenses shorten their focus.

Aerospecs will be quite automatic. An auto-focus system, of the type used in many cameras, will be mounted on their frame. It will stare forward into their field of view, and will drive the reversible gas-pump that adjusts their lenses. All this machinery will be hard to pack into even the most overbearing frames; but fortunately, high accuracy is not needed. Fine focusing will be done automatically by the wearer's own eyes. He will feel that his youthful accommodation has been magically restored. One problem may be that when gas is pumped rapidly out of the lenses, desorptive cooling will mist them up. But spectacle wearers are already resigned to troubles of that sort.

David Jones