that is being distorted as it enters the lower mantle.

The velocities of seismic waves are determined by the strength and density of rock through which the waves are passing. Those properties, in turn, are a function of temperature, pressure, the mineral constitution of the rock, and the phase the minerals are in.

Anisotropy in seismic wave velocities arises in two different ways. First, many minerals in the mantle have an intrinsically anisotropic crystal structure. When such crystals are aligned over mantle regions that are large enough to be sensed by seismic waves, variations in wave velocity occur both with propagation direction and with polarization of particle motion. For example, much of the anisotropy in the upper mantle can be attributed to a mix of anisotropic olivine and orthopyroxene crystals that have been aligned either by present-day mantle flow or, in some regions of the lithosphere (the crust and uppermost mantle), by past deformation. Second, anisotropy in wave velocities can be caused by mineral fabrics such as alternating layers with different chemical compositions, or physical phases, when the scale of the fabric is small compared with the wavelength of a seismic wave.

When a seismic wave known as a shear wave enters anisotropic media, its particle motion is 'split' into two orthogonal components with different propagation velocities. The fast and slow vibration directions reflect the intrinsic geometry of the anisotropy, and the time delay between them is a function of the strength of the anisotropy and the propagation distance through the anisotropic region. The shear waves studied by seismologists are classified according to the routes they have taken: S waves have passed directly through the mantle, whereas SKS waves have passed through the core as well, and ScS waves have reflected from the top of the core. Each type of wave conveys different information.

Wookey *et al.*[1] measured splitting in S waves that propagated from earthquakes in the Tonga subduction zone to seismic stations in Australia (see Fig. 1 here, and the map on page 778). In the Tonga subduction zone, one lithospheric plate is diving beneath another, deep into the mantle, generating earthquakes to depths of 660 km. The key to Wookey and colleagues' conclusions is that 15 of their 35 highest-quality S-wave splitting times are between 2 and 7 seconds, values that are much larger than those commonly observed.

To isolate the effects of anisotropy in the transition zone and lower mantle, Wookey *et al.* had to quantify wave splitting caused by anisotropy in the upper mantle. They tested a model for the Australian upper mantle that is 'transversely isotropic' (horizontal plane fast, vertical axis slow), and that matches both the lack of strong splitting in SKS phases that travelled to the Australian stations on nearly vertical paths and the large effects of anisotropy in horizontally propagating surface waves[2]. This model predicts less than 2 seconds of splitting for the S waves from Tonga. Based on the predictions of models that include anisotropy over a variety of depth ranges, the authors conclude that there must be significant anisotropy at depths of 660–900 km.

However, other estimates of upper-mantle anisotropy beneath Australia are potentially in conflict with those used by Wookey *et al.* For instance, different surface-wave investigations produced models of anisotropy with a more complex form[3,4] and greater depth[4]. But these models[3,4] are not obviously consistent with the observed absence of strong SKS-wave splitting. And they cannot explain more than 3–4 seconds of the S-wave splitting seen by Wookey *et al.*

Another question concerns the large scatter in the S-wave splitting times observed by Wookey *et al.*[1]. In particular, sources in a narrow latitude range (17.5° S to 22.5° S) yielded both the seven largest splitting times and numerous times in the range 0.5–2.0 seconds. In some cases, S phases on similar paths, but with different particle-motion polarizations, produced both large and small splitting times. These measurements require strong lateral variation in the strength of anisotropy, and an anisotropic symmetry that differs from the simple transverse isotropy assumed in the models tested by Wookey *et al.* But given the large splitting times from some of the deepest sources (550 km or more), and the maximum apparent magnitude of upper-mantle anisotropy beneath Australia, it seems that there must be significant mid-mantle anisotropy in this region.

As Wookey *et al.* acknowledge, there are various explanations for the origin of the anisotropy. In Fig. 3 of their paper (page 779) they present models in which the anisotropy is produced by the subducting Tonga lithospheric slab interacting with the top of the lower mantle. One appealing idea is that the anisotropy stems from lower-mantle minerals that have been aligned by dislocation creep in a region around the slab. Dislocation creep is a process of plastic deformation that aligns crystal axes with respect to strain geometry. When deformation occurs by a different process — diffusion creep — no such alignment occurs.

This hypothesis is in striking agreement with the numerical models of McNamara *et al.*[5] that predict the existence of dislocation creep near slabs and diffusion creep elsewhere in the lower mantle. Shearing of perovskite, the most abundant and anisotropic mineral at the top of the lower mantle, would produce anisotropy that is inconsistent with the observed fast, horizontal S polarizations if the phases propagated parallel to the shear

100 YEARS AGO

Messrs. Sanders and Crowhurst have sent us for examination a number of brilliant lantern slides of birds and other zoological subjects. Photography has been a helpful handmaid to many branches of science, but none of its performances are more widely appreciated than those in the field of natural history. Drawings of animals may have artistic merit, but they do not inspire the feeling of life which is conveyed by good photographs of objects in their natural surroundings. The lantern slides sent by Messrs. Sanders and Crowhurst are from photographs of birds, nests, eggs and young and other living animals taken by Mr. Oliver G. Pike. To lecturers on natural history such true pictures of living creatures must be invaluable, and no better source of encouragement to study nature could be desired. By the side of such beautiful photographic pictures as are now available for projection upon a screen or for the illustration of books, the drawings which did duty in natural history instruction seem but a vain show. Messrs. Sanders and Crowhurst send us with their slides an ingenious arrangement for viewing lantern slides under a low magnifying power. The arrangement, though simple, is very effective, and a pleasant half hour can be passed by using it to look at lantern slides.

From *Nature* 13 February 1902.

50 YEARS AGO

There are so many examples of the adaptation of an animal to its environment which at first sight would appear to find their simplest explanation in the supposition that the effects of the environment have become inherited, that theories of this kind have continued to retain a following in spite of the lack of clear experimental evidence in their support. This following has been composed mainly of naturalists; experimentalists and geneticists have recently tended to adopt an attitude similar to that of Dobzhansky, who writes: "This question has been discussed almost *ad nauseam* in the old biological literature… so that we may refrain from the discussion of it altogether". In dismissing the matter so cavalierly, Dobzhansky was explicitly referring to "direct adaptation", that is, the hypothesis that when the environment produces an alteration in the development of an animal, it simultaneously causes a change in its hereditary qualities such that the developmental alteration tends to be inherited.

From *Nature* 16 February 1952.