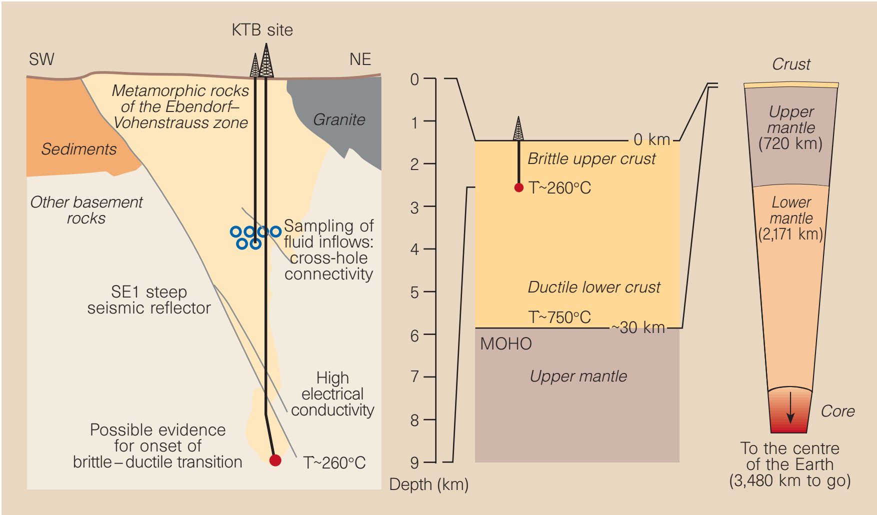

Figure 1 **The KTB drilling project, in context.** a, **This current schematic view of the deep geology of the KTB site, summarized mainly from R. Emmerman and J. Lauterjung (*J. Geophys. Res.* 102, 18,179–18,202; 1997), shows how the deep drill hole passed fortuitously through 9 km of rather uniform high-grade metamorphic rocks, rather than the predicted stack of tectonic slices. However, insights were obtained on chemical and physical properties of the crust at depth, and some of these are also indicated. Parts** b **and** c **put this direct observation in the context of the continental crust as a whole and of the rest of the Earth.**

less thoroughly monitored, sampled and investigated.

One of the highlights of the KTB project has been the information it has provided about deep crustal fluids, summarized by P. Möller *et al.* (pp. 18,233–18,254). Not only has the presence of highly saline, near-stagnant NaCl–$CaCl_2$ brines been confirmed, but samples have been collected and analysed (notably at 4,000 m) and the permeability structure of the rocks investigated. The brines are at near-hydrostatic equilibrium and occur in interconnected fractures surrounding blocks of very low-permeability crystalline rock, which retain primary isotopic characteristics — demonstrating that they have not experienced pervasive fluid flow either during metamorphism or subsequently.

Fluid flow also plays a role in explaining one of the surprising results of the drilling, the heat flow at depth. Based on near-surface measurements, it was expected that the heat-flow density would be about 55 mW m^{-2}, with a temperature gradient of 21 °C km^{-1}. Below 1,600 m, however, both the pilot and main holes showed a marked increase in heat flow and temperature gradient to 85 mW m^{-2} and 28 °C km^{-1}, respectively. C. Clauser *et al.* (pp. 18,417–18,442) ascribe this to the combined effects of advection of groundwater and a memory of the lower surface temperature during the Pleistocene, more than 10,000 years ago.

Electrical conductivity of the continental crust has been a particularly contentious issue, especially the question of whether it is a guide to the water content of the lower crust. The KTB borehole passed into a zone of anomalous conductivity more or less as predicted, which is itself a significant vindication of field conductivity measurements, and the ELEKTB collaboration, an interdisciplinary group from several German institutions (pp. 18,289–18,306), conclude that it is caused by the presence of continuous graphite films within anastomosing fault zones. This result contradicts both of the most popular current hypotheses: abundant fluids or pervasive graphite films through the grain boundary network of the rock matrix.

Several studies have indicated that the state of stress in the upper crust is close to frictional equilibrium on pre-existing faults. Measurements in the KTB hole allowed M. Brudy *et al.* (pp. 18,453–18,476) to calculate the complete stress tensor and confirm that this pattern is maintained to depths of at least 8 km. Transmission electron microscope studies of quartz retrieved from the final depth suggest that, there, recovery has begun to take place, and the stress may be less than that indicated by extrapolation from higher levels. G. Dresen *et al.* (pp. 18,443–18,452) draw the controversial conclusion that the hole reached the onset of the brittle–ductile transition. This implies the effective decoupling of middle and upper crust, and should force geologists and geophysicists to confront the very different views that they hold about processes in stable continental regions.

The KTB project has been one of the major Earth science experiments of the twentieth century, transforming our understanding of the upper continental crust. It is good to see so many of the results gathered together and publicly available — this issue of *Journal of Geophysical Research* is essential reading for all Earth scientists. □

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Daedalus

Floating on nothing

The lightest possible filling for a balloon is not hydrogen, but vacuum. But how to make it strong enough to withstand the pressure of the atmosphere, while still being light enough to rise? Daedalus's answer is a graded-cell polymeric foam.

Inspired by that foaming urethane monomer, he is devising a new liquid monomer that polymerizes with release, not of carbon dioxide, but hydrogen. It will be placed in a hollow, evacuated, spherical mould which will be spun rapidly about three axes simultaneously. The resulting uniform, radial, centrifugal force field will spread the monomer over its interior surface as an even coating. When it begins to foam, the bubbles will swell towards the centre. Their strong expansion into the central vacuum will be opposed by the centrifugal field. But this field, of course, declines towards the centre of the spinning sphere. So the more the foam advances towards the centre, the more its cells will expand, and the lower the gas pressure within them. When the reaction is over, the mould will contain a spherical foamed balloon. Its smooth outer skin will be supported by a foam whose cells grow ever larger, and contain an ever lower pressure of hydrogen, as they extend towards the centre. The largest cell, the remains of the original interior space, will occupy the central region, and will contain vacuum. At each radius, the cellular foam will just be strong enough to support the difference of pressure across it. Thus the balloon as a whole will safely withstand atmospheric pressure.

Released into the atmosphere, the new rigid vacuum balloon will rise until it reaches that height at which it has the same density as the ambient air. There it will float indefinitely, drifting randomly around the globe with the winds. The obvious use is in cellular telephony. In this application, each balloon will carry a solar-powered radio repeater, and will be designed to float perhaps 20 km up, safely above the commercial air lanes. For this height, about a thousand balloons wandering at random should ensure that anywhere on Earth, at least one will be above the horizon. They will maintain effortless global coverage far more cheaply than any satellite system. Like satellites, they will have a limited life, but will be much easier to replace. As fast as air diffuses into them, or their electronics fails, they will be punctured by laser beams fired from aircraft, and new ones lofted up to replace them.

David Jones