Pressure points

What happens when immovable objects confront irresistible forces? New minerals form, explains **James Wookey**.

Deep beneath your feet, around 3000 kilometres, the Earth's solid rock mantle gives way to the swirling liquid iron of the outer core – the 'core-mantle boundary'. Just before you reach the core, let's say the last few hundred kilometres, you meet the lowermost mantle, one of the most enigmatic parts of the Earth, and a place which for decades scientists have struggled, from a distance, to explore and understand.

It is not a matter of idle curiosity. The lowermost mantle's importance stems from its role as the meeting place between two titanic, constantly churning systems. The first is the rapid, turbulent swirling of hot liquid iron, the outer core, which drives the Earth's magnetic field. The second is the much slower overturn of the solid mantle—the driving force for plate tectonics—which creates, shakes and eventually destroys the Earth's surface. As a boundary for these convection systems the lowermost mantle can profoundly affect their behaviour, so understanding it is vital for understanding the Earth's long-term evolution.

The most powerful way we have to explore the inside of the Earth is seismology, the study of vibrations generated by earthquakes. By studying these 'seismic waves' at the surface (at great distances from the earthquake) we can tell a lot about the deep parts of the Earth they have travelled through. From the earliest days of modern seismology we have known that the lowermost mantle is a very different place from the rest of the mantle. Studies have alluded to a parade of curious features such as mantle plumes (see 'Too hot to handle', p8). Advances in computer speeds and access to ever-larger quantities of high-quality seismic data have generated high-resolution images of the lowermost mantle, in a similar way to ultrasound images of the human body. Despite this a definitive explanation has proved elusive, as the interpretation of these images has been, until recently, very difficult.

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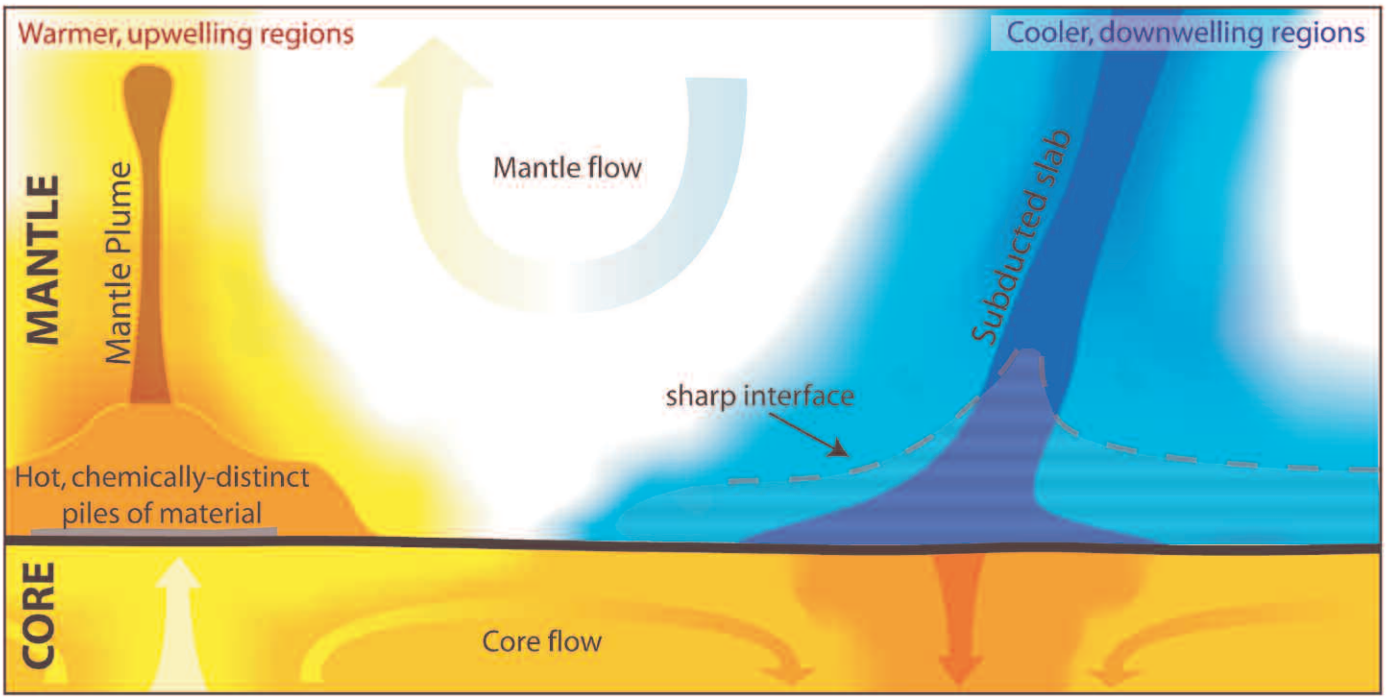
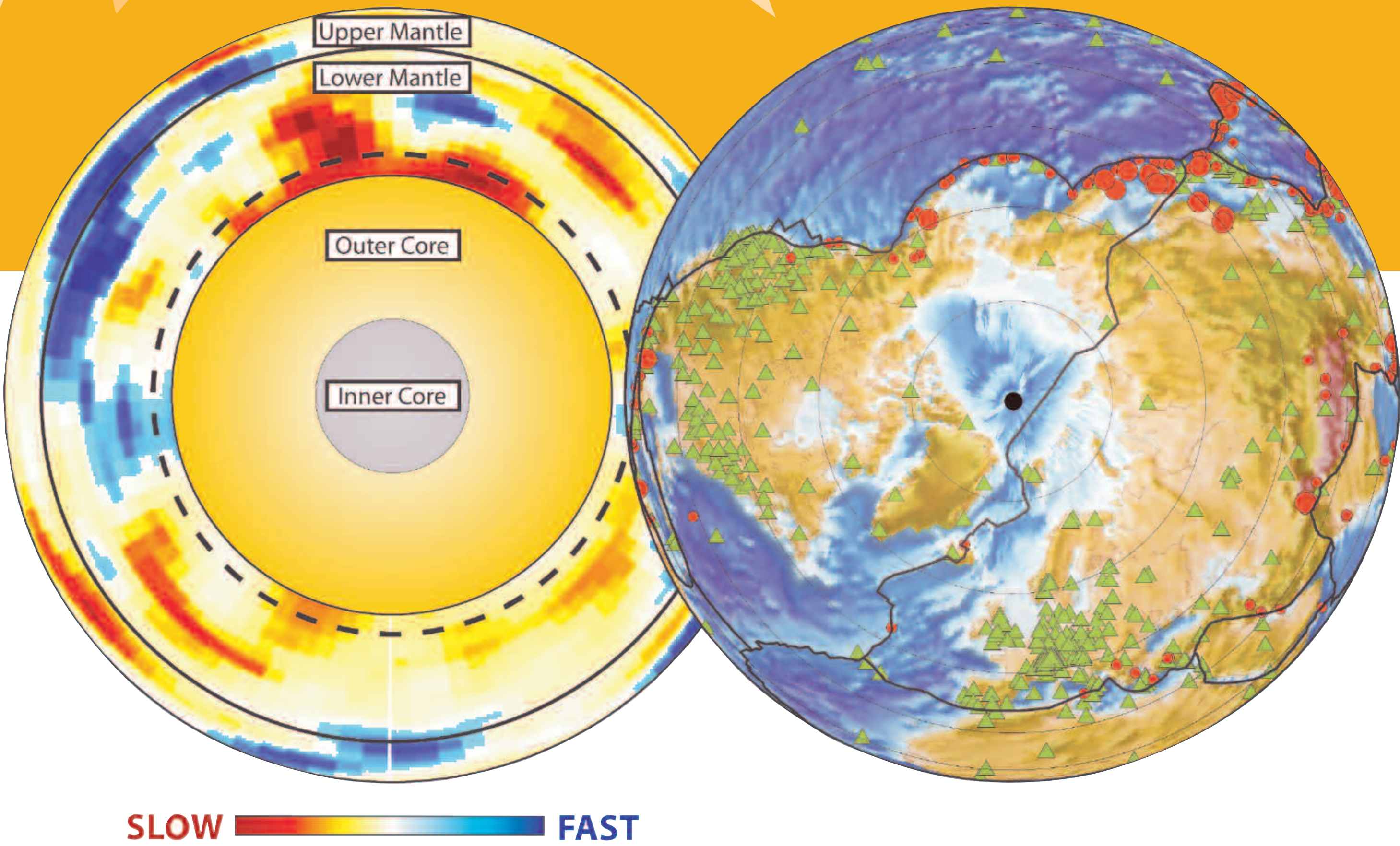
Researchers in Japan and Switzerland in 2004 took a large step towards demystifying the lowermost mantle when they discovered a new mineral that might exist at the very bottom of the mantle. It was found in the laboratory by X-raying

The lowermost mantle. Descending slabs may cool some regions creating a sharp change in seismic properties. This may mark the change to the newly-discovered post-perovskite. Mantle plumes may originate in warmer areas: studies have alluded to large piles of hot chemically altered material and a thin, very dense layer just above the core.





A seismologist's view of the Earth looking down onto the North Pole. Left: cold material sinks from the surface towards the core, while hot material wells up from the core-mantle boundary. Right: the Earth's fractured surface mirrors the turmoil beneath.

▲ *Global seismic network of observatories in the northern hemisphere.* ▬ *Tectonic plate boundaries* ● *Large earthquakes between 2001 and 2002.*

a small sample of mantle material, perovskite, subjected to pressures and temperatures similar to those near the Earth's core – more than one million atmospheres and 2,500 degrees centigrade. This new mineral was christened 'post-perovskite'. Sadly, no more imaginative name can be applied, since the rules which govern the naming of minerals require a naturally-occurring sample to be found; an unlikely prospect for something that can only exist in nature at 3000km depth. For comparison, the deepest hole ever drilled is only 12km deep.

This discovery sparked a frenetic effort in the Earth science community to describe and quantify the properties of this new material. This included our own study, published in *Nature* last year, a collaboration between scientists at Leeds, Bristol and University College, London, funded by NERC's Deep Earth Systems consortium. The study involved modelling the new mineral on an atomic scale, using theories borrowed from quantum mechanics. This is extremely computer intensive but pays rich rewards: very detailed knowledge of mineral properties at pressures and temperature still beyond the reach of laboratory experiments. After all this processing we were able to compare these mineral properties with real observations from seismology and determine that post-perovskite can indeed explain a great many of the features which have tantalised us over the last few decades. For example, in some places in the lowermost mantle we can detect a sharp change in seismic properties several hundred kilometres above the core. This feature is best explained by a mineral change, but, before post-perovskite there was no convincing candidate.

> This is an important piece of the lowermost mantle puzzle.

From this and other such studies it is becoming obvious that post-perovskite is an important piece of the puzzle of the lowermost mantle. More work remains to be done, both to continue to explore the properties of this new mineral and to improve our seismic observations of this area. Beyond that, we also need to study the wider implications of our new understanding of this enigmatic region for the broader picture of the Earth.

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