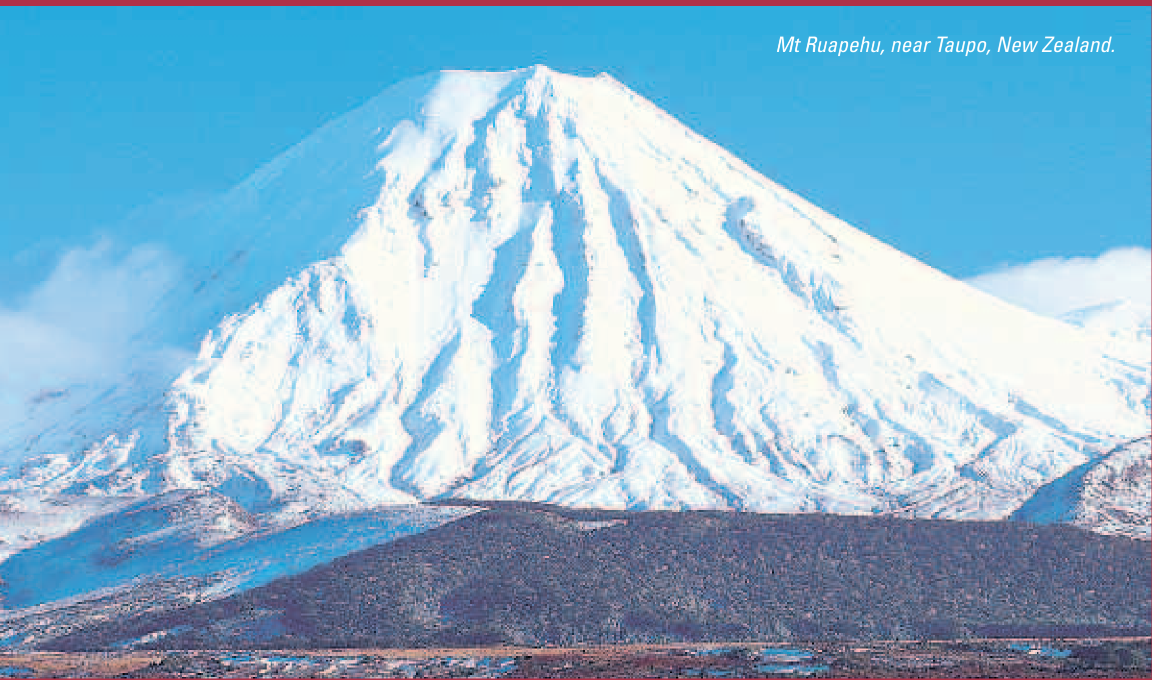
That sinking feeling


Mt Ruapehu, near Taupo, New Zealand.

A violent, explosive volcano is recharging its system after a 28,000 year break. **Bob White** travelled to New Zealand to take a peek beneath the surface.

The North Island of New Zealand is slowly tearing apart. Offshore to the north, the splitting seafloor has already created new oceanic crust. The split is now moving southward down the centre of the island. It is opening the land rather like undoing a zipper. So far the zipper has reached halfway down the island. A cluster of active volcanoes, the biggest of which is Ruapehu to the south of the town of Taupo, mark the southern tip of the zip.

The slopes of Ruapehu are a popular ski area, reaching nearly 2800 metres high. Since 1945, Ruapehu has erupted over 50 times: an inconvenience to skiers because it forces the ski-runs to close. But nothing compares to the inconvenience that would have been caused by the eruption of Taupo some 28,500 years ago. Fortunately no one lived in New Zealand at the time, because this was one of the biggest known eruptions on Earth. Over 500 cubic kilometres of magma spewed explosively from the Taupo crater in over a dozen closely spaced eruptions. To put that in context, it is equivalent to excavating the entire area of Greater London within the M25 to a depth of 200 metres and blasting the pulverised remains up into the atmosphere.

The reason for this combination of massive volcanic activity and tearing apart, or rifting, of the Earth's outer skin is the Pacific plate pushing down beneath the eastern edge of the Australian plate on which New Zealand sits – a process known as subduction. As the Pacific plate descends into the Earth's mantle, it heats up and releases water and other volatiles, such as carbon dioxide, which lower the melting point of the mantle above it. This causes massive volcanism and is often accompanied by rifting and the creation of a geological feature known as a back-arc basin, which forms behind the subduction zone (see diagram).

Almost all the world's back-arc basins are under water, as will be much of the North Island of New Zealand in a few million years. But in the meantime, it offers a perfect natural laboratory for studying rifting and molten rock generation that accompany the breakup of a continent by back-arc extension.

In a series of experiments between 2000 and 2003 a team from Cambridge University used the newly purchased seismometers of the SEIS-UK consortium based at Leicester University to investigate the structure beneath the Taupo rift, the volcano of Ruapehu and another classic back-arc volcano called Mount Taranaki in western North Island. For the Taupo experiment they joined with New Zealand researchers from the Institute of Geological and Nuclear Sciences and Victoria University to set up a long chain of seismic instruments right across North Island (acronym NIGHT, which with some grammatical gymnastics stands for

North Island GeopHysical Traverse). The 200 NIGHT instruments extended across the entire plate tectonic system from the offshore oceanic Pacific plate in the east, over the Taupo back-arc rift system and onto the stable continental Australian plate in the west. We spaced them sufficiently closely to give excellent detail on the structure of the crust, providing the first whole-crustal view of the subduction and back-arc system.

Seismic profiles allow scientists to probe the structure of the deep crust by recording the speed at which sound energy from a seismic source, a large explosion say, moves through successively deeper layers of the crust. We can use tomography, a technique developed by doctors to produce a cross-section of the human body, to generate a cross-section of the whole crust. To get a cross-section many tens of kilometres thick we needed pretty substantial seismic sources. These came in the form of nine half-tonne explosions detonated in boreholes along the profile. Because New Zealand has many earthquakes, mainly caused by the plate subduction responsible for the back-arc basin, we could also make use of the seismic waves they generated for imaging the crust.

> New Zealand's North Island will be under water in a few million years.

Earthquakes have much more energy than most explosive shots, and even more significantly, they generate a lot of shear wave energy in addition to compressional wave energy. Explosions only generate the latter. Compressional waves are created when pressure waves move away from an explosion; sometimes they are called acoustic waves, because they are the way we hear one another talk. In contrast, shear waves oscillate perpendicular to the direction in which the wave is travelling, like when you tie a string to a tree and wave the free end up and down.

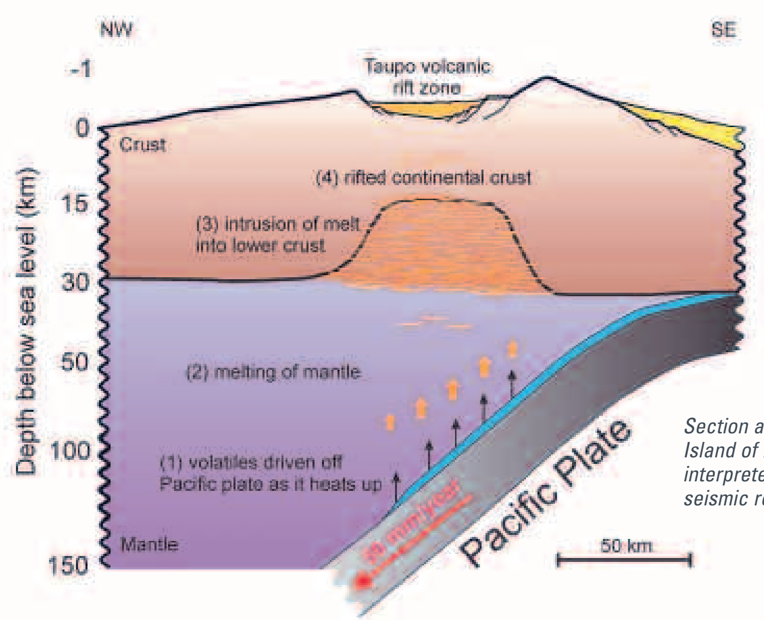
Compressional waves can travel through fluids, which is why you can hear sounds under water, or indeed in normal air. Shear waves, by contrast, only travel through solids: they cannot propagate through liquids. So if the shear wave signal drops off or disappears, or if it travels much more slowly than usual, this indicates the presence of molten rock.

We found that beneath Taupo stretching of the crust in the back-arc rift had thinned it to only about half of its original thickness. However, there was about three kilometres of volcanic ash and debris from the many eruptions lying on top of the stretched crust. At the base of the crust was another surprise: a 10-15 kilometre thick layer of rock with unusually high seismic velocities compared to normal crust – the acoustic waves passing through this region travelled much faster than expected. This we interpret as the frozen remnants of deep crustal magma chambers, once filled with molten rock.

The huge volume of molten rock which erupted cataclysmically from Taupo 28,500 years ago did not all arrive in the crust instantaneously. Careful analysis of the erupted lavas by Professor Colin Wilson of Auckland University suggests that it accumulated in the lower crust by a trickle of much smaller amounts of melt from deep beneath the rift over a period of about 40,000 years. As it did so, it partially melted the older crust and reacted with it to make lavas which, when they eventually erupted, did so explosively in massive outbursts.

But we didn't just find evidence of stretching and intrusion of igneous rocks (solidified magma) in the crust. Intriguingly, the shear waves propagating from earthquakes beneath the Taupo rift dropped off in amplitude and slowed down in the lower crust. Our analysis suggests that this could be explained by the presence of around one percent of molten rock right now in the lower crust under Taupo. That adds up to an enormous volume of magma, which without doubt will one day erupt in the Taupo region. We can only hope that it leaks out in smaller, less dangerous batches than the previous violent eruptions, and that there are sufficient warnings to evacuate people from danger.

Three former Cambridge PhD students, Dan Rowlands, Tony Harrison and Steve Sherburn oversaw the bulk of our fieldwork in New Zealand and the data analysis back in Cambridge. The latter two have both taken jobs in New Zealand, and Steve Sherburn, has a particular responsibility for hazard monitoring and assessment of the volcanoes we studied. So it is good to see scientists putting their academic work to immediate practical use.



Section across North Island of New Zealand interpreted from our seismic results.

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