Hellish conditions a scientific gold mine for drilling project

Attempt to reach earthquake source fell short but yielded surprisingly hot rocks.

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Julian Thompson/GNS Science

The Deep Fault Drilling Project attempted to bore 1,300 metres into the source of great earthquakes in the South Island of New Zealand.

A failed effort to drill through a dangerous fault in New Zealand has served up unexpected scientific results that could help researchers to better understand how earthquakes happen. The project measured temperatures in excess of 100 ºC at just 830 metres below the surface — an exceptionally high value at such a shallow depth.

“This is really a remarkable result and not predicted by anyone,” says Rupert Sutherland, a co-leader of the international project that sought to drill through the Alpine Fault on New Zealand's South Island. The temperature results suggest that a future drill hole in this region might give researchers their first chance to observe directly the most dangerous part of a fault — where large quakes are born and release most of their energy. This high-temperature zone is normally too deep to reach, but it appears to be much more shallow at the drilling site, says Sutherland, a geophysicist at GNS Science, a government-run Earth-science organization in Lower Hutt. He and other project scientists presented the results this week at a meeting of the American Geophysical Union in San Francisco, California.

The thermal measurements are just one set of results coming out of the Deep Fault Drilling Project (DFDP), which involved nearly 90 scientists from 12 countries. The project seeks to study the interior of a large fault as it approaches a major quake. The Alpine Fault marks a gash through Earth’s crust where the Pacific plate grinds past the tectonic block that carries Australia. The plates have been locked together since the last earthquake there, in 1717 — and researchers expect another one to happen soon. The average gap between magnitude-8 earthquakes at the Alpine Fault is 330 years.

The NZ$3-million (US$2-million) project differs from the handful of other attempts to drill deep boreholes into active faults in China, Taiwan, Japan and the United States. In previous cases, researchers invaded faults after a major quake. In the DFDP project, says Sutherland, “the main purpose is to understand the state of a large fault zone before an earthquake appears”.

Ground to a halt

When drilling began in August 2014, researchers planned to reach a depth of 1,300 metres. The goal was to drill through the fault to study the ambient conditions and mineral characteristics at the point where the two plates slip past each other. The team was able to channel down to 893 metres over 5 months. But the project encountered difficulty while attempting to insert a steel tube into the hole to keep it from deforming. A piece of the tube broke off without anybody realizing it, which led to a series of problems that ended the

drilling, Rutherford says.

The researchers estimate that they came within 100–200 metres of the actual fault. Although they missed the mark, members of the team say that the project paid off. “It was still a success,” says Weiren Lin, a geophysicist with the Japan Agency for Marine-Earth Science and Technology in Kochi, who is participating in the work. The team extracted rock samples from the zone above the fault, and installed a high-tech fibre-optic cable that can measure temperatures and also function as a seismometer.

After drilling ended and conditions in the hole reached equilibrium, the cable recorded temperatures of more than 110 °C at a depth of 830 metres. The typical geothermal gradient increases at a rate of just 30 °C per kilometre below ground, and a shallow borehole that the team drilled nearby in 2011 had a gradient of twice that. The gradient in the new hole reached as high as 150 °C per kilometre, the researchers reported.

“It has this very high geothermal gradient, and it’s very intriguing on that account,” says Diane Moore, a geologist with the United States Geological Survey in Menlo Park, California. Despite the problems with the Alpine Fault project, she says, “it’s a very impressive body of work that they’re getting out of it”.

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