BEST NEWSPAPER MAGAZINE QANTAS MEDIA AWARDS

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your weekend

Crunch zone

The world is watching our Alpine Fault

Whitebait
'IT'S TIME TO FISH'

Fashion
RETURN OF THE SUIT

CRUNCH ZONE

BY PAUL GORMAN

It starts in Marlborough's windswept Wairau Valley, heads south-west to run through the St Arnaud camping ground, swings past Springs Junction, along nearly 10 kilometres of the Arthur's Pass highway and through prime dairying country at the back of Hokitika, bulges underneath the main street of Franz Josef, skulks along within South Westland bush, and finally heads out to sea near the entrance to Milford Sound.

From space, the Alpine Fault looks like a knife edge, one of the straightest lines on the planet. It is the South Island's most dangerous feature, but without it the island would hardly be recognisable. In fact, it would not exist.

Without the fault, there would be no Southern Alps, no high rainfall and pristine rainforest on the western side, no ski-fields, no hot nor'westers on the eastern side, no Canterbury Plains. Banks Peninsula might still be Banks Island. It's the great musterer that has shaped the South Island into the form we see today.

Scientists have been drawn to the fault like bees to a seismological honey pot. At any one time all kinds of investigations are going on along its 650km length. The most audacious plan on the books is to drill through the Alps and into the fault to understand what is happening deep down.

The fault is due to split and splinter again. This is a fault that does nothing at the surface for 300 years then all hell breaks loose. And then it goes quiet for another 300 years.

NEW ZEALAND has just had a very lucky escape from widespread destruction, injury and even death. Almost the entire country went for a rollercoaster ride on the evening of July 15, when soft rocks about 30 kilometres under Resolution Island in Fiordland's Dusky Sound "lurched" – in the words of the scientists – and generated an earthquake of magnitude 7.8 – the largest since the Hawke's Bay February 1931 shake that killed 256 people. An earthquake of that scale occurring on the Wellington or Wairarapa faults on a busy weekday hardly bears thinking about.

Neither does the inevitable, even larger, earthquake some say is due, or overdue, on the South Island's Alpine Fault. Sixty of the world's top earthquake scientists and engineers converged on Franz Josef township in March to draw up a plan of future Alpine Fault research, inching towards a multimillion-dollar drilling programme. It was an appropriate venue – the tourist-focused settlement straddles the fault, with the northern half of the main street on the Australian Plate and the southern half on the Pacific Plate. Franz Josef is well-recognised as one of the most hazardous places to live in New Zealand, with fears it will be cut off for several months after the Alpine Fault's next rupture.

That could be this morning. The spring is well-wound. Researchers want to drill into the fault before the next "big one" strikes. And it will be big. Huge in fact.

The Alpine Fault is entering what scientists quaintly term "its window of opportunity". Over millions of years, it has offset land by

MAIN PHOTO In this NASA image of the South Island in winter, the straight line of the Alpine Fault is visible at the western edge of the snow cover.

more than 450 kilometres, with rocks that were once in South Westland now making up the Marlborough Sounds.

The trouble is that the Pacific Plate and the Australian Plate, which the South Island sits astride, are slowly moving and rotating relative to one another at around 36 millimetres a year. But where they meet, the schism we know as the Alpine Fault, the rocks are jammed against each other unable to move, all the while absorbing the extra pressure. One day soon, probably in the next 50 to 100 years, almost certainly in the next 100 or so years, the tension will become too much and they will snap, ripping open many kilometres of the surface and generating a magnitude eight earthquake.

Scientists have a pretty good idea of what happened the last time this crevice in the Earth jumped and of the colossal forces it unleashed. Some time in 1717, the fault ruptured. In the space of a second, a 450km-long section of the West Coast between Milford Sound and Inchbonnie, near Lake Brunner, was shunted eight metres further north and lifted up three metres. The ground acceleration from the close-to-magnitude eight quake is estimated to have been greater than 0.4g, meaning the mountains were hurled upwards at more than four-tenths the acceleration of gravity.

While last month's Dusky Sound earthquake was not on the Alpine Fault, which at that point lies about 50 kilometres offshore of Fiordland, it was pretty close to it. Instead it was centred where the Australian Plate is diving under part of the South Island on the Pacific Plate. It ruptured upwards from about 30 kilometres down, ripping a six-metre gap between the plates throughout an area about 70 kilometres along the Fiordland coastline.

It also warped the south of the South Island, shoving Puysegur Point, at the southwest tip of the island, 300 millimetres closer to Australia. Te Anau moved 100 millimetre west and Bluff headed about 30 millimetres west.

Researchers have used a variety of methods to date recent, in geological terms, movements of the fault. They have studied landslides shaken loose by earthquakes, looked at the movement of river terraces, and calculated the age of forests that have re-established themselves after destruction by using tree rings, which record stress. They have also collected organic material from trenches dug across the fault trace and had it radiocarbon-dated.

LEFT Earthquake Central: The Alpine Fault runs left to right in this photo of Franz Josef, under the main street and then under the forecourt of the service station.
Photo: Paul Gorman

The consensus is the 1717 quake had an estimated magnitude of 7.9 (plus or minus 0.3). The next most recent event, in around 1620, was of magnitude 7.6 (plus or minus 0.3), and an earlier shake, around 1430, was of magnitude 7.9 (plus or minus 0.4). Another major earthquake has been calculated as occurring around 1150.

The fact there have been four such "great" quakes – between eight and 8.9 in magnitude are officially termed "great" earthquakes – in the space of less than 300 years and none in the past 291 years has seismologists worried. It also shows how dynamic our landscape is. Otago University geology professor Richard Norris points out the "great land uplifted high" that Dutch explorer Abel Tasman famously remarked upon is now higher and of a different shape than when he first saw the South Island in December 1642.

"Since his visit, some 30 cubic kilometres of crust has been raised above sea-level and a similar amount eroded and washed down the rivers," Norris says.

GNS Science geomorphologist Mauri McSaveney says one calculation is that the tension along the fault is "wound" ready for a rupture of at least 7.7 metres, and is increasing by about 27 millimetres a year. "Just how much more elastic strain energy has to accumulate before the fault can be expected to rupture is the big question."

Whenever that release may be, the next time the Alpine Fault uncoils it is expected to produce at least a minute of violent shaking within tens of kilometres of the break, along with potentially damaging long-period rolling in susceptible ground hundreds of kilometres away.

The quake will kill some and injure many more, wreck buildings and badly damage or destroy bridges, roads, power and phone lines, water supplies and sewerage systems. Some townships are expected to be isolated for several months, and the Arthur's Pass highway could be closed for more than six months.

On the eastern side of the Alps, it is likely to be the strongest earthquake felt in the last 150 years, with parts of Canterbury and Christchurch experiencing liquefaction of soils, damaging buildings and structures. Liquefaction occurs during very strong ground shaking, when some soils lose their strength and behave more like liquid. Water fountains, sand volcanoes and large cracks in the ground can result, with buildings sinking, tilting and collapsing.

THE BOFFINS from Australia, France, Germany, Britain, the United States and Canada joined local scientists at Franz Josef for a heady week of talks and planning. As well as offering them the chance to cross the Alpine Fault every day by walking down the main street, the group went on field trips to nearby Gaunt Creek and Hare Mare Creek, well-known sites where the fault and its effects on rocks are visible in exposed rock-faces.

At the workshop, GNS Science communications manager John Callan said the area was a superb natural laboratory for earth scientists. "The American scientists especially are all really interested in this part of the world. You can find out a lot for every dollar spent"

The scientists are proposing a range of geological and geo-physical research that will eventually include drilling several kilometres into the fault to penetrate the zone where earthquake processes occur. Funding applications for work are under way and surface studies are expected to begin at key points along the fault this summer.

By drilling a deep hole into the crust, instruments can be lowered into the heart of the fault to measure crucial factors including pressure, temperature, rock fracturing, and the chemistry of fluids, rocks and gases. Similar equipment has already been put inside major faults in the US, Taiwan and Japan, and experts involved in those projects were at Franz Josef.

Millions of dollars in funding from New Zealand and overseas will be necessary to turn the drill-hole dream into reality. One scientist quotes drilling costs as about $US400 a metre of drill, meaning a $US1.6m price tag to drill four kilometres down, not including other associated costs.

Workshop organiser John Townend, the EQC fellow in seismic studies at Victoria University in Wellington, says Kiwi researchers are good at seeking and securing long-term international funding for geoscience projects.

"We will be leveraging contributions from a variety of organisations, trying to get domestic and international support, but we really need to demonstrate we have good science and a good strategy before we do that."

Victoria University of Wellington professor of geophysics Tim Stern has been leading one of the many research projects already under way on the fault. Ultra-sensitive seismographs have been placed in shallow boreholes, between two and 100 metres deep, along a seemingly "quiet" part of the fault to measure microearthquakes, ground motions too small for humans to feel.

ABOVE Drilling on the $US25m San Andreas Fault Observatory at Depth (SAFOD) project; and the fault being studied. Photos: Photolibrary and Getty

WHAT CAUSES EARTHQUAKES?

Immense levels of stress build up where the Earth's huge crustal plates meet, zones known as faults. Like compressing a spring, the more the rocks on either side of the plate become jammed together, the greater the energy released when they finally do rip apart.

This sudden movement and release of energy sends out waves through and across the surface of the Earth. These waves are what we feel as earthquakes. The intensity of the earthquake depends on how much of a fault has moved and how far, and how deep the rupture was.

The primary waves come first, followed by secondary waves, and these are clearly seen on seismograph charts. Shallow quakes cause more violent shaking than those of the same magnitude but deeper. In large quakes, aftershocks, as the rocks settle into place again, can continue for months.

Earthquake magnitude measures how much energy has been released, with each unit of magnitude indicating a large increase. A magnitude six quake releases more than 30 times the energy of a magnitude five shake, and a magnitude seven more than 900 times the energy of a magnitude five.

In the magnitude 7.8 Dusky Sound earthquake, which occurred at 9.22pm on Wednesday July 15, the predominant motion was a rolling movement, felt across much of the country.

BELOW Otago University geologists Virginia Toy and Alan Cooper on an Alpine Fault field trip near South Westland. Photo: Dave Prior

The "quiet" central section of the fault, between about Harihari and Fox Glacier, has very low seismicity but the highest rates of uplift along the Alps, shown by the country's tallest peaks in the adjacent Mount Cook region. It is also the part of the fault believed most likely to rupture.

Stern says the way the physical characteristics of the West Coast interact with the fault make it unique. "It's a very anomalous area. The weather systems are so strong, the rocks are eroded so quickly, and the exhumation rates along the fault are some of the highest in the world. Those rates are around five to eight millimetres a year, measured by GPS (global positioning system), but the rate quoted most often from other studies is more like eight to ten millimetres a year. The rocks have come from around 20 kilometres down."

The high exhumation rates of rocks up and out of the fault are directly related to extreme erosion rates caused by incredible annual rainfalls of more than 10 metres just west of the Main Divide.

Stern explains that to equalise fluid pressures in the mantle, the layer of the Earth below the crust, mountains have to be balanced by a "root" that is often five times the height of the above-surface peak. When erosion carves a hole into a mountain, the pressure in the mantle is reduced and it consequently pushes upwards, enhancing the uplift of basement rocks at the surface.

GNS Science researcher Rob Langridge is another scientist actively involved in Alpine Fault work, digging trenches at various locations near Hokitika and at Inchbonnie to date organic material found there.

Preliminary data from new trenches dug across the fault at the Toaroha River appear to confirm the dates of the most recent Alpine Fault earthquakes.

"Trenching at Inchbonnie has also confirmed there have been up to three ruptures in the last 1000 years. Understanding the nature of landscape change in the valley has been instrumental in dating the earthquakes. This is the crux of what we're trying to work out – how stable are these dates we are coming up with? Other landscape change is also happening at the same time from beyond the Alpine Fault. As well as that shaking there's shaking from other quakes and natural landslides."

Langridge has been working with the West Coast Regional Council to map the high-impact areas along the fault. "If you think about the fault, 90 percent is covered with bush but in those areas where it isn't farmland, open urbanised areas, it is important to have very accurate locations for the fault. One of the hazards involved in a large earthquake of magnitude seven to eight is surface rupture, which has an immediate impact on built structures. Surface rupture hazard is something we can design for and where possible we should try to avoid that."

Strong support for the Alpine Fault drilling programme is coming from one of the leaders of a major drilling project into California's San Andreas Fault.

Bill Ellsworth, of the US Geological Survey, says scientists need to drill into the Alpine Fault before it is too late.

The $US25m San Andreas Fault Observatory at Depth (SAFOD) project has monitoring equipment inserted in a three kilometre-deep drill hole that penetrates the fault.

"The project to drill the San Andreas was the first to poke into a major plate boundary fault. We have always had the interest and the hope to drill into the part of the fault that will produce an earthquake some day. To do that we needed to have a compelling scientific rationale.

"Why we drilled is much the same as for the Alpine Fault. The rocks here get stuck for centuries – every two to four centuries they have earthquakes, then it's dormant for two to four centuries. Like the San Andreas, it is going to produce a pretty big earthquake.

"By drilling, we have the opportunity to look at these rocks where they are in action. That is one of the really unique things about this (South Island) geological setting – the rocks are being transported to the surface. They are now at the surface and being pushed along.

"How deep to drill? We don't know. If we had unlimited resources, we would certainly want to drill holes to multiple depths in that area, six to seven to eight to nine kilometres deep, but that needs a big budget. It took about 10 years on the San Andreas project from workshop to drilling the pilot hole and another two before drilling into the fault began in earnest.

"One of the hopes is that we are successful in drilling into the fault before the earthquake. Some of the most important unresolved questions in fault mechanics can best be addressed by observing a fault right after the rupture, but we want to know what it looked like right before as well," Ellsworth says.

Also at the workshop was University of Wisconsin geophysicist Harold Tobin, who is involved in an undersea drilling project into faults off the south coast of Japan. He says the outcome of such research is more important than its price tag.

"Geologists can run around at the surface looking at things, but the Earth is three-dimensional and we need to know what is down there. I'm really excited about the Alpine Fault project. The fact is, we don't really understand how earthquakes work very well.

"It's expensive, but if you want to take the next step, drilling is the natural one to take."

Ellsworth says the Alpine Fault is straining. "It's being loaded. It has been loaded for the last three centuries so it means it is ready to go – we just don't know when.

"None of us want to wish the great earthquake on the rest of you, but it is going to happen one day." **YW**

Senior Press writer Paul Gorman has a degree in physical geography, and three summers ago spent a week driving from one end of the Alpine Fault to almost the other.