

#### By NZASE Science Communicator Mike Stone

The kingdom of Tonga is a collection of 170 volcanic islands in the South Pacific. Many are uninhabited, ringed by white beaches and coral reefs and covered in tropical rainforest. Some are flattish shield volcanoes, others are steep-sided strato volcanoes. These volcanoes are part of a subduction zone extending from New Zealand north-northeast to Fiji. At this convergent boundary, the Pacific plate dives under the Indo-Australian plate.

Amongst these is a pair of islands called Hunga Tonga and Hunga Ha'apai, located about 65km north of Tonga's capital, Nuku'alofa. These two islands poke 100 m above sea level, but hiding below the waves is a submarine volcano rising 2,000 m from the sea floor. The Hunga Tonga – Hunga Ha'apai volcano (HTHH) is the rim of a caldera, a deep collapsed crater.

This volcano has erupted regularly in the past. Scientists found evidence of two previous mega-eruptions from the HTHH caldera in deposits on the old islands. They

The Japanese Huawai 8 Satellite recorded the eruption.





chemically matched the ash from HTHH to deposits on Tongatapu, and then used radiocarbon dates to show that big caldera eruptions occur about every 900 years, with the last one at AD1100.

HTHH had several periods of activity after 2009. The 2015 eruption joined the two old Hunga islands to create a combined landmass about 5km long (above). In December 2021 there were several violent explosions, the basaltic magma fragmenting into pyroclasts which built up around the crater to form a small tuff cone.

### **January 15 eruption**

After a precursor eruption two days earlier, HTHH erupted violently at 5.25pm on January 15, 2022. In this gigantic eruption, the cloud of ejected material reached 260 km wide and up to 20 km high before dispersing, (as reported by the Volcanic Ash Advisory Centre in Wellington). The height was estimated from satellite data – the geometry of shadows, wind correlation, and the effect of ash particles on laser light and infrared radiation. There were also over 100,000 lightning strikes.

While the 2009 and 2015 eruptions occurred mainly at the edge of the caldera, very big eruptions, as on January 15, come





#### Stratosphere

from the caldera itself. These eruptions are so large the walls collapse inward, deepening the caldera.

When hot magma meets cold seawater slowly there is no eruption. When it suddenly meets water the explosion is large; these are known as phreatomagmatic eruptions, due to the steam involved. However, the HTHH eruption was extremely violent, causing blasts at supersonic speeds, which may indicate that the magma was charged with gas.

HTHH sent ejecta into the stratosphere, unusual for a volcanic eruption. When volcanic materials reach this relatively dry layer of the atmosphere, particles linger much longer and travel much farther than if they remain in the lower, wetter troposphere.

The volcano also released sulphur dioxide, SO<sub>2</sub>, during and after the eruption. This gas can be measured by satellite sensors. Large amounts of stratospheric SO<sub>2</sub> can reflect incoming sunlight and lower temperatures (Pinatubo's eruption in 1991 cooled the earth by 1° for 18 months). However, in this case only 0.4 megatonnes of sulfur dioxide was injected into the upper atmosphere (compared with 12 MT from Pinatubo), so it is not expected to cool global temperatures.

This SO<sub>2</sub> lingering over the region – a toxic, invisible pollutant. It reacted with moisture to form sulfuric acid droplets and generated acid rain over Tonga and Fiji. Residents were urged to stay inside during rain, not to drink tank water, and to wash any vegetables and produce. Sulphuric acid aerosols can reduce ozone levels, which could have an effect on the climate.

Tonga is connected to the world by a single cable, roughly the width of a garden hose, which carries optic fibres across the ocean bed to Fiji. The eruption broke this cable, leaving satellite phones the only form of contact. This meant that little information was immediately available on the extent of damage and casualties. Only three people died, but New Zealand and Australian relief flights observed catastrophic destruction in many areas.

The whole country was covered in a thick layer of ash (acidic from the SO<sub>2</sub>), which damaged metal and crops, and caused





Sulphur dioxide in the stratosphere. Left: How sulphur dioxide was spread by high level winds. NIWA.

breathing difficulties for some people. Ash impacted marine life and also covered runways needed for relief assistance. The ash fall also reduced the light getting through, so that the sky over Tongatapu was darkened by 6.20pm (sunset was not due until 7.30pm).

### **Pressure wave**

The eruption set off a massive atmospheric shockwave travelling at about 300 m/s, the speed of sound. This was detected in Europe and circled the planet three times before dissipating. In Aotearoa/NZ even backyard weather stations recorded the pressure wave at ~7 hPa.

Near the eruption, the explosion damaged property, including shattering windows. Close Pacific islands heard loud booms, some describing it as loud thunder. In Aotearoa/NZ





we heard rumbles and felt vibrations as the pressure wave passed through. A boom was heard in Alaska seven hours after the eruption.

## Tsunami

The HTHH eruption triggered a tsunami that flooded coastal areas across the Tongan islands in a series of waves. This tsunami travelled the globe, being felt in other Pacific islands, Aotearoa New Zealand, Australia, Japan and South America.

A tsunami is a series of large, destructive waves caused by the rapid displacement of large volumes of water. This one was unusual – it was larger and so arrived earlier than expected, making it difficult to issue timely and accurate warnings. Because of this, scientists are not clear about the exact cause of this tsunami. These waves may have been generated by the pressure wave itself, as in the 1883 Krakatoa eruption, or by the caldera collapsing as the magma chamber emptied.

Nuku'alofa recorded waves of 1.2m, while waves on the west coast of Tongatapu reached up to 15m. In Tonga, tsunami caused a lot of damage, and completely inundated some lowlying islands, making them uninhabitable. The waves washed away cars, flattened trees, took down power lines, and damaged or destroyed hundreds of buildings on several islands.

The largest tsunami in Aotearoa New Zealand, at 1.3m, was on Great Barrier Island. There was much damage in Tutukaka – 20 boats were sunk or damaged and marina structures broken as unusual tides surged.

# Pacific stories and knowledge

Tongan Caroline Matamua says Maui is an important figure in Pacific origin stories. In one, Maui Kisikisi cast his fusifonua (land fishing hook) on a long rope that went deep into the ocean. He and his brothers fished up first Tokelau and then Tonga, naming it after Tonga Matamoana.

Some of the islands were not fished up by Maui but instead were stones thrown down by his sister Hikule'o, God of Pūlotu, the realm of the ancestors. The submarine eruptions



that form land such as Hunga Tonga-Hunga Ha'apai are believed to be such stones that rose to the surface.

There are many Pacific chants and stories about eruptions and tsunami, as ancestors discovered the Pacific and travelled between the Islands. One is a portion of a Hawai'ian chant: "He aina loa'a i ka moana, I hoea mai loko o ka ale, I ka halehale poipu a Kanaloa…" (A land discovered in the ocean, Risen up out of the waves, From the very depths of the sea.)

Hunga-Tonga and Hunga-Ha'apai are just the tips of the volcano, the bulk of which is underwater. Science Focus, © Frederik Ruys.

From <u>Paekupu</u>

Peau Kula (red wave) is the Tongan term for tsunami, named from the tafitoto of the langi (blood-stained or red skies) that appear beforehand, differentiating them from other large waves. Many Pacific stories about the ancient Tui Tonga dynasty, and from seafarers, mention peau kula in songs and chants.

## References

<u>1 News</u>, January 18, 2022

NASA Earth Observatory, <u>January 15</u>; <u>January 17</u>; <u>January 25</u>. *New Scientist*, January 18, <u>Instagram</u>. <u>NZ Herald</u>, January 16. <u>NIWA weather</u>, January 17, Facebook. <u>Pacific Marine Environmental Lab</u>, January 21. <u>US Geological Survey</u> on FB, January 16. <u>Wall Street Journal</u>, January 20. Wikipedia, <u>February 9</u>; <u>February 10</u>.

# Ngā Kupu

Amiorangi hori – Artificial satellite Kōhaupapa – Stratosphere Puia – Volcano Pungarehu – Ash Pungatara hāora-rua – Sulphur dioxide Tainiwhaniwha – Tsunami Tawhā – Caldera Tokarewa – Magma.

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