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FIELDTRIP 7

WHITE ISLAND TOUR: PRODUCTS AND PROCESSES OF RECENT ACTIVITY

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INTRODUCTION

In recent years, White Island's landscape has been reconstructed by explosive eruptions, a landslide, a crater lake and gully erosion. This field excursion will highlight the products and processes of White Island's recent history and will reinforce the need for monitoring, surveillance and research of one of New Zealand's active volcanoes.

HEALTH & SAFETY

The fact is that we are visiting an active volcano that may erupt at any time. There is an open-water boat trip for about 80 minutes each way, so be prepared for sea-sickness. At the island, participants will be transferred from the main boat into an inflatable dinghy. There is a short ladder at the jetty, then a short boulder hop onto dry land. Peejay Tours will provide gas masks and hard hats for walking around the island. Covered shoes are required to provide some protection from hot ground and hot acidic water – no jandals or open-toed sandals are allowed. The ground on the tracks is generally dry and dusty, though in places it might be rough and uneven or damp with slippery mud. PeeJay Tours will give the group a safety briefing before we depart, informing us of hazards on the boat trip and at the volcano.

GEOLOGY AND ERUPTIONS OF WHITE ISLAND

White Island is the summit of a largely undersea volcano situated 48 km from Whakatane in the Bay of Plenty. The portion of the volcano above sea level forms a steep-sided and highly eroded edifice (70% of the volcano is below the sea), which is visible from the mainland. White Island has seen near continuous volcanic activity for 150,000 years and is currently New Zealand's most frequently active volcano. Intermittent volcanic activity has continued since the first observations in 1826, mostly in the form of small steam and ash eruptions that generated many craters, especially in the Western sub-crater (Figure 1).

White Island is constructed of predominantly andesite-dacite lava flows and pyroclastics, which subsequently have been hydrothermally altered (Cole et al., 2000; e.g. Hedenquist, et al. 1993). Volcanic activity on White Island currently comprises continuous hydrothermal activity and gas-steam release from numerous fumaroles, hot springs and heat flow into the lake. The temperature of the lake is currently about 65ºC (October 2007).

The largest and longest historically recorded eruption sequence began in December 1975 and continued intermittently through to July 2000. This eruption sequence included numerous small to moderate sized volcanic eruptions (Houghton et al., 1989), and formed large collapse craters. Effects on White Island vegetation show that this has been the most damaging eruption sequence for the last 200 years (Clarkson and Clarkson, 1994; Houghton and Nairn, 1991). Magma rose to shallow levels in 1976, when ground surface deformation (inflation) peaked and the largest individual eruptions occurred in 1977-78, with incandescent eruption columns observed from the coast. The largest explosive eruptions threw bombs and blocks over the entire Main Crater floor, with a major pyroclastic flow (surge) in August 1977. At times, voluminous ash clouds covered the entire island. About 10^7 m^3 of mixed lithic (old rock) and juvenile (new lava) ejecta, mostly ash sized, has been erupted in alternating wet steam explosions and dry strombolian (lava fountaining) phases (Houghton and Nairn, 1991).

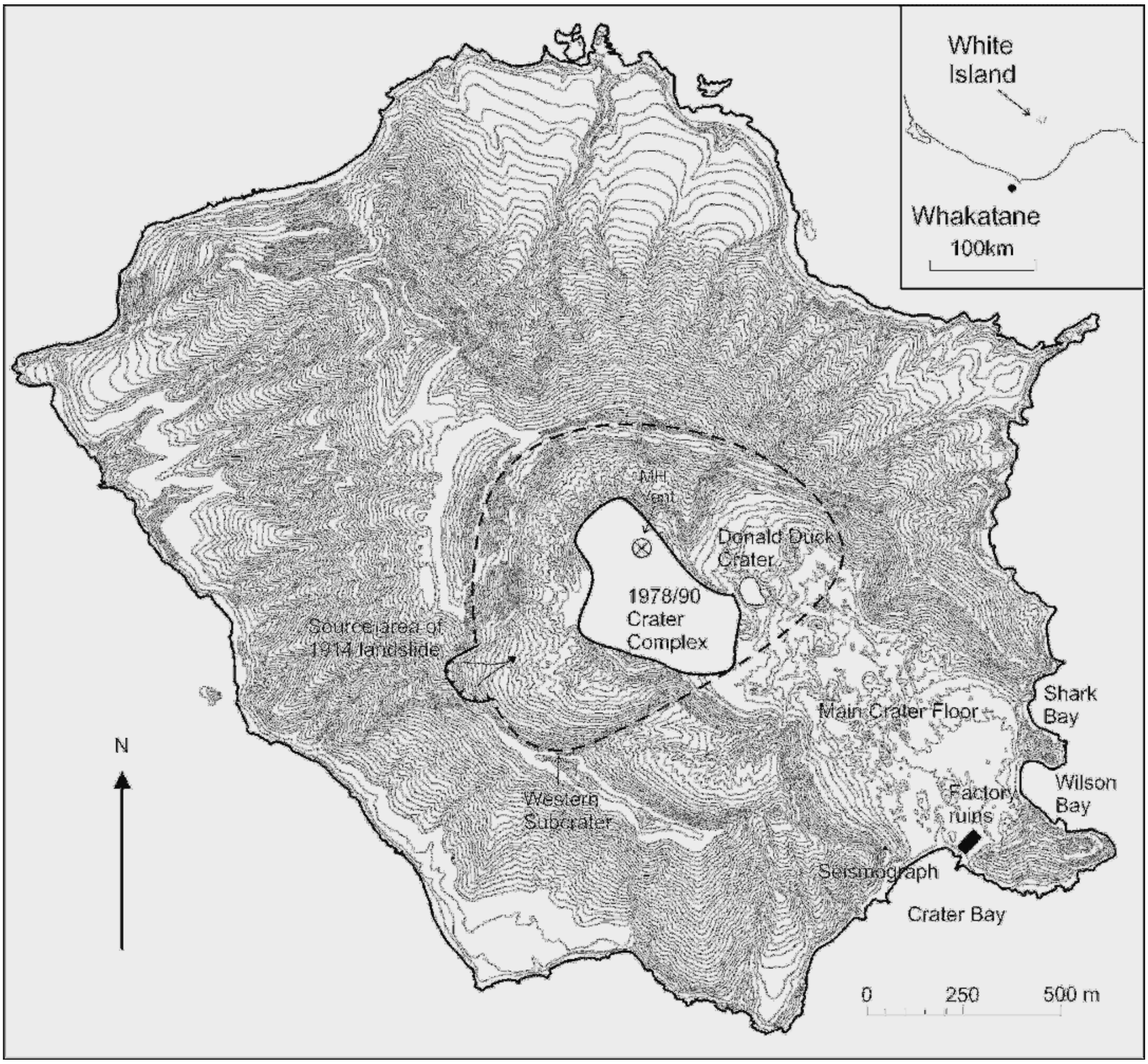

Figure 1. White Island showing locations of Western subcrater, 1978/90 Crater Complex, MH Vent, Donald Duck Crater and other features.

The lithic ejecta are derived from the partial re-excavation of the sediment infilled Western subcrater, initially forming "Christmas" and "Gibrus" craters. These craters later coalesced into the "1978 Crater Complex". Eruptions occurred less frequently in 1979-80 as the magma retreated. At times the floor of the vent was more than 200 m below sea level. During the 1980s and 1990s small scale eruptions continued, accompanied by the formation of numerous small craters within what became the “1978/90 Crater Complex”. In July 2000, an explosive strombolian eruption occurred, covering much of the Main Crater floor in scoriacious lava bombs. Conditions in the 1978/90 Crater Complex then cooled, and lakes were able to develop.

Eruptions and collapse since 1975 have excavated a significant depression that has extended below sea level in the Western sub-crater, and built a low-angle tuff cone around the margins of the 1978/90 Crater Complex. This tuff cone is about 100-150 m wide and a maximum of 8-10 m thick and is composed of unconsolidated pyroclastic fall deposits ranging in grain size from fine grained cohesive ashes to coarse rubbly scoria and block horizons. The Crater Lake in the 1978/90 Crater Complex is impounded by the tuff cone.

THE 1999-2000 ERUPTION EPISODE

For the first time in more than 20 years, a small batch of fresh magma reached the surface in 1999 and 2000, generating two small explosive eruptions from beneath the 1978/90 Crater Complex (Figure 2).

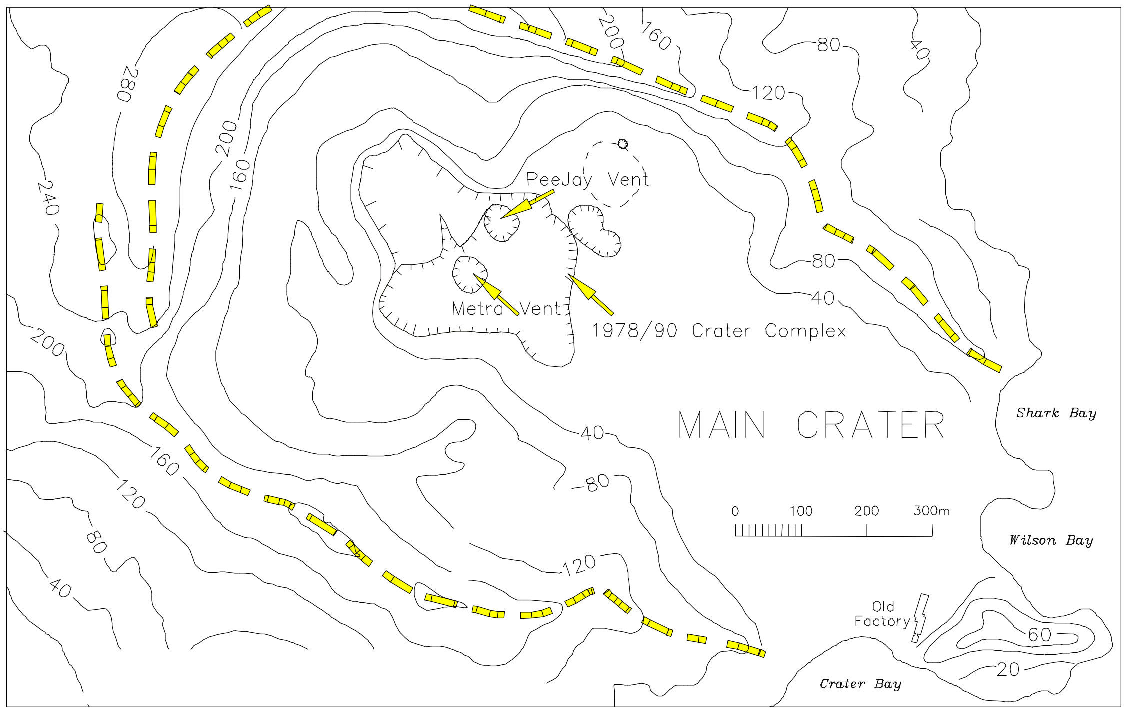

Figure 2. Sketch map of Main crater at White Island showing locations of PeeJay and Metra craters formed in 1999 within the 1978/90 Crater Complex.

April 1999

In January 1999, a surveillance trip to White Island revealed a relatively low level of eruptive activity, but found that a new vent, about 50 m diameter, had formed in 1978/90 Crater located approximately at the site of a crater (Wade Crater) that was very active in the 1980s. Frequent hydrothermal eruptions of black muddy water were occurring in the new "Metra" vent and ash-poor steam-rich plumes to 600 m were being emitted. There had been a prior increase in seismic activity which, combined with the low level of eruptive activity, suggested that magma was being intruded beneath the surface. In the next several weeks, minor ash and steam emission was sustained and sub-craters of the 1978/90 complex were occupied by a lurid lime-green lake, which by April 1999 had declined to a few small puddles of yellow-green coloured brine.

On Sunday 18th April 1999, White Island erupted and the whole of the island was thinly blanketed with light grey coloured ash. At least 10 cm of fresh ash fell within a 200m radius of the Metra source vent. Blocks and bombs (maximum 2 m x 2 m) were ejected towards the S and SW to approximately 450m and abundant centimetre size fragments impacted new ash radially to at least 600m, though distribution thinned towards the NE. Most of the large bombs were juvenile, black highly-vesicular andesite, sometimes with internal crystal (plagioclase) rich and crystal-poor banding (Figure 3). There was no evidence of plastic deformation and the largest blocks had shattered on impact. Most bombs had an outer rim of red “baked” ash. Ballistic blocks were generally smaller (< 300mm - 500mm) but relatively more abundant than the lava bombs. Poorly sorted muddy sandstone blocks (crater-fill) were the most common variety, being either “fresh” dark grey soft sandstone or harder red/yellow/pale grey (hydrothermally cemented altered) material. Hydrothermally altered andesite lava blocks were less common.

Figure 3. Left: 12 January 1999 oblique aerial view of Metra crater area with weak ash-poor eruption typical of PeeJay vent. Right: 18 April 1999 impact-fractured juvenile andesite lava bomb.

July 2000

By August of 1999, White Island activity had declined to background levels and a small shallow brine lake had formed. In March 2000, weak ash emission recommenced from a vent (“MH” vent) on the ridge southwest of the location of PeeJay vent which was active in 1999. COSPEC measurement of SO_2 in the plume was, at the time, the highest yet recorded and was interpreted as a precursor of further eruptions. During April to June, volcanic tremor increased and steam and ash plumes were commonly seen. By mid July, seismicity was at almost background levels but MH vent was producing a strong yellowish brown coloured gas and ash plume to 1500 m altitude, visible c.20 kilometres from the island. Several millimetres to several centimetres of yellowish brown coloured fresh ash covered the island and the sea-water beneath the plume was visibly discoloured by ash fall.

Between 5 pm and 10 pm on Thursday 27th July 2000, moderate-sized explosive Strombolian-style eruptions occurred from the floor of the 1978/90 crater complex. A thick deposit of ash was spread east of the crater, extending at least as far as the sea, 700 metres away. The eruption, signalled by a short period of strong seismicity, occurred during poor weather and a strong westerly wind, and the ash deposits were restricted to the eastern sector of the island. The new 120-150 m diameter explosion crater occupied the site of a shallow, warm-water lake that had filled most of the floor of the 1978/90 crater complex for more than a year. The lake completely disappeared and low-pressure steam, gas and ash were being emitted from the new crater and MH vent. MH vent, active since April, was widened to c. 50 m size and was also emitting steam, gas and ash. The eruption was of similar style and scale to the magmatic eruptions of March-April, 1977. It generated a thick deposit (up to 30 cm) of ash, rock debris and fresh mafic pumice blocks that covered much of the main crater floor, extending at least as far as the sea, 700 metres away (Figure 4). Pumice blocks up to 1.5m diameter were observed. The shapes of these blocks indicate that they impacted the ground in a semi-molten state.

Figure 4. Left: July 27th 2000 Strombolian tephra deposit (red brown colour in main crater) was clearly visible in early August 2000. Right: Fresh magmatic bombs, lapilli and ash blanketed most of the crater floor.

The focus of activity since that time (until 2003) was strong (though gradually declining) steam and gas emission from the active MH Vent. In 2000, the volcano was at Alert Level 2 for 154 days, and has been at Alert Level 1 since September 2000.

CRATER LAKE: 2003-2007

In February 2003 a large pool of water started to collect on the floor of the 1978/90 Crater Complex, drowning the vent that was active during the July 2000 eruptions. By late March the water level had risen enough to create a breach into the then active MH Vent and started to flood it. By August the water level had risen to such a height it was clear that the pool of water was growing into a semi-permanent lake within the crater. The rising water also offered easier access to the lake and a monitoring programme including an automated lake level logger and acoustic flow monitor was established to track the water level rise (Figure 5).

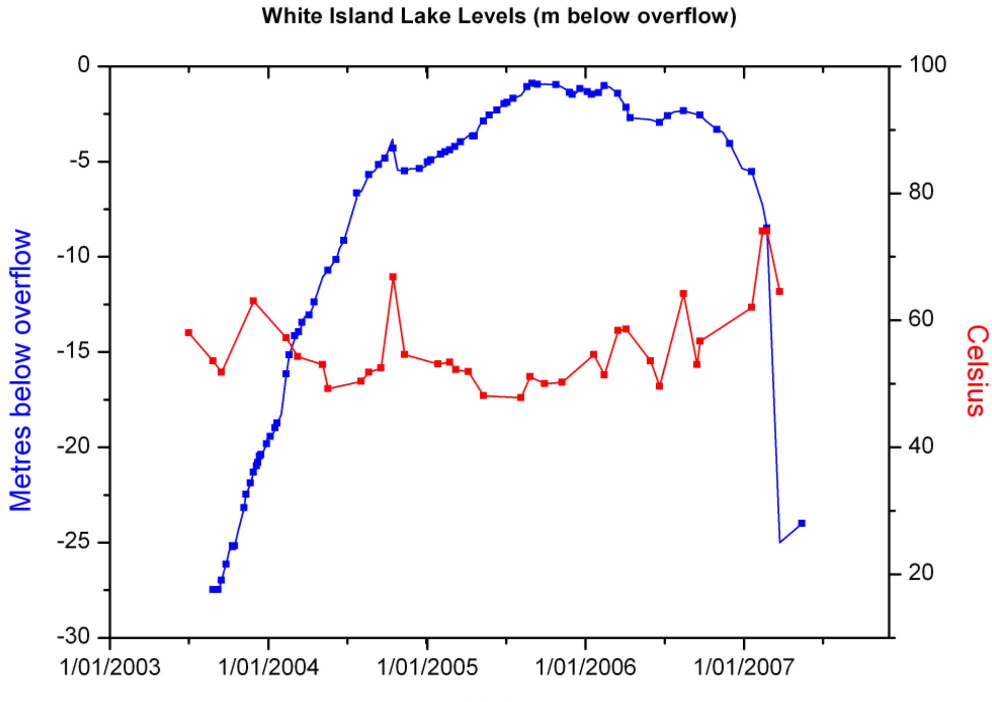

Figure 5: Time series plot of water level and temperature in the Crater Lake.

Detailed topography is available of the 1978/90 Crater Complex so it is possible to calculate lake surface areas and volumes. When full, the lake would have an area of 74850 m^2, whereas when low it only covered 24800 m^2. When (if?) the lake reaches overflow level the volume of the water in the crater will be about 1.8 million m^3. The volume in the top 5 m, which is the estimated volume of water that may drain when the lake overflows and cuts down to establish an outlet is about 351500 m^3. In August 2004, the lake was filling at 1900 m^3 per day (22 litres/sec). The primary source of water filling the lake was, and in future is likely to be, condensing steam and gas from fumaroles now beneath the lake and runoff from the surrounding crater walls.

The establishment of a semi-permanent Crater Lake at White Island has changed the range and likely impacts of the hazards to visitors on the island (Scott, et al. 2004). The new Crater Lake on White Island now presents visitors and users of the island with a range of previously undocumented hazards. In 2005, the lake filled to within 1m of overtopping, through Donald Duck Crater on its northern side. If in the future the lake reaches overflow level, hot acid lake water will flow east-southeast down an existing valley system on the northern side of the Main Crater floor; reaching the sea at Crater Bay. Flow may also reach Wilson Bay if the released flow is large enough to flood over the July 2004 landslide debris onto the flat surface to the east. Based on the outbreak flood scenario modelled (see Scott, et al. 2004) a hazard map is presented in Figure 6 which indicates areas where there may be a high, moderate, or lower risk of flooding.

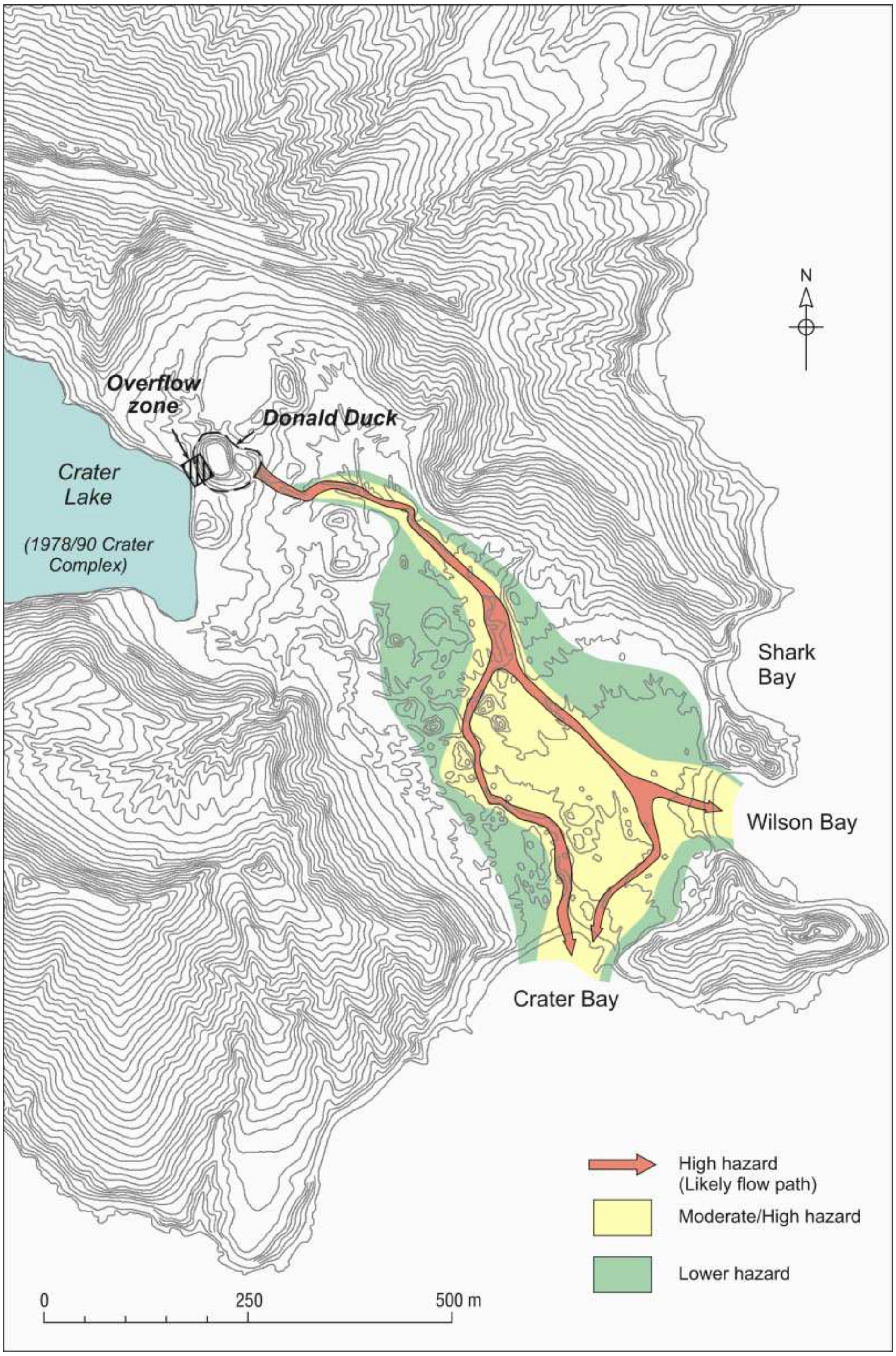

Figure 6. Hazard Map for Crater Lake Dam break scenario or an overflow from a small landslide or eruption.

MONITORING

Detailed monitoring started in 1967 with a programme coordinated by Victoria University of Wellington. This included ground temperatures, spring and fumarole chemistry, ground deformation and magnetic measurements. In 1975 a seismograph was added, with radio telemetry back to Whakatane.

The first success for the monitoring system came with the 1971 eruption, when a clear deformation signal was seen in the months before the eruption. A similar signal was seen before the 1975 activity started. The eruptions starting in 1975 were to continue through to 2000 and saw large changes on the island, along with the destruction of some monitoring sites (e.g. levelling pegs, solar panels). Today the monitoring is conducted by the GeoNet project (www.geonet.org.nz) and includes seismicity, ground deformation, soil gas flux, fumarole chemistry, spring and lake water chemistry, land and airborne gas flux measurements and near real-time web cams.

The seismic data from a broad band sensor installed in 2007 is telemetered to Whakatane, and on to the GeoNet data centres (Avalon and Wairakei), along with data from a micro barograph that can measure the airwaves from explosions. A variety of volcano seismic signals are recorded, including high and low frequency volcanic earthquakes, very low frequency (VLP) signals, volcanic tremor and complex volcanic/explosion earthquakes. The GeoNet system includes tremor detection and alarm to detect changes in the level of volcanic tremor and alert staff on duty.

The ground deformation surveying continues, based on the levelling network established in 1967. Several of the original sites were lost when 1978/90 Crater formed; hence no data is now collected from close to the active vents. The network of pegs has been modified as necessary, with time-space overlap with the old sites. The larger scale activity trends are well depicted by the levelling data (Figure 7); for example with inflation of the crater floor showing before the 1971 and 1975 outbreaks, subsidence during the 1975-1990 eruptions, and uplift before the July 2000 eruption.

Regular soil gas surveys are conducted to quantify the amount of CO_2 gas escaping through the Main Crater floor. Measurements are made at 56 sites and the data integrated to obtain the gas flux. As new magma intrudes the volcano, an increased flux to the surface is expected ahead of the ascending melt. The soil gas surveys are complimented by airborne measurements to quantify CO_2, SO_2 and H_2S, using COSPEC, Lycor and InterScan equipment. Currently the average gas fluxes are ~1000 tons/day of CO_2 ; ~100 tons/day of SO_2 and ~8 tons/day H_2S. A more recent development is a miniDOAS scanning spectrometer system that is installed outside the Main Crater. The system measures SO_2 gas flux during daylight hours and allows data collection when conditions are unsuitable for airborne measurements. A meteorological station was established in 2006 near White Island's summit and provides data vital for processing plume gas data.

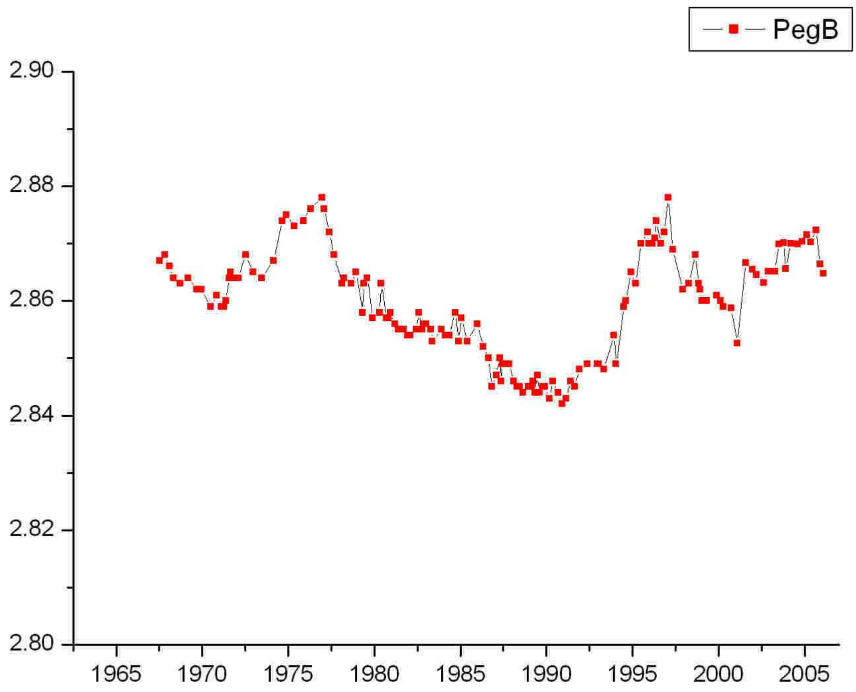

Figure 7: Time series plot showing height changes at Peg B, Main Crater floor (heights are m above sea level).

Chemical studies focus on selected high temperature fumaroles, springs and the Crater Lake. The fumarole gases include magmatic gases and their temperatures range from "background" ~110°C to over 500° C during eruptions. When the Crater Lake started to form in 2003 many new springs appeared on the Main Crater floor and the flow of acid water into the sea at Crater Bay increased significantly. Despite the island setting, there is only a minor sea water signature in the spring chemistry. The White Island waters are very acid (Table 1).

Table 1: A representative Crater Lake analysis.

pH	Li	Na	K	Ca	Mg	Cl	SO_4
-0.20	11.6	8281	1337	3525	3529	71190	22884

To allow rapid, near real time checks on activity on the island, (and for public interest) three remote cameras have been established as part of the GeoNet upgrade. One camera is located at Whakatane and two are on White Island; at the factory ruins and on the crater rim. Images from the island are transmitted to the mainland (see http://www.geonet.org.nz/volcano/images.html) and can be seen on the GeoNet web page (http://www.geonet.org.nz/volcano/volcams.html).

ACKNOWLEDGEMENTS

Our knowledge of the White Island volcano-hydrothermal system has been enhanced by data and analysis collected through the GeoNet Project, supplemented by valuable observations provided by tour operators including PeeJay Tours, Vulcan Helicopters, HeliPro and Volcanic Air Safaris. The GeoNet Project is sponsored by the New Zealand Government through its agencies: Earthquake Commission (EQC), GNS Science, and the Foundation for Research, Science & Technology (FRST).

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