Hazard assessment: Auckland Volcanic Field

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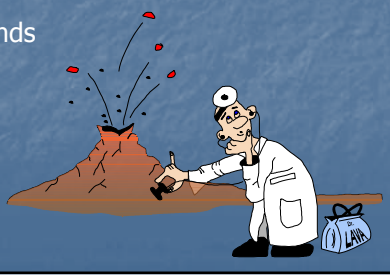
Hazard assessment

The use of all available tools to determine the *location, intensity, frequency* and *probability* of a potentially damaging volcanic event and to depict that information in a comprehensive way for civil authorities and planners, usually on a hazards map.

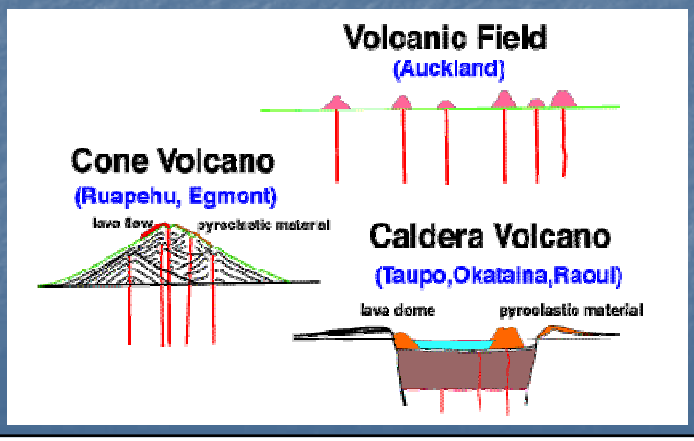
Examples of tools we can use:

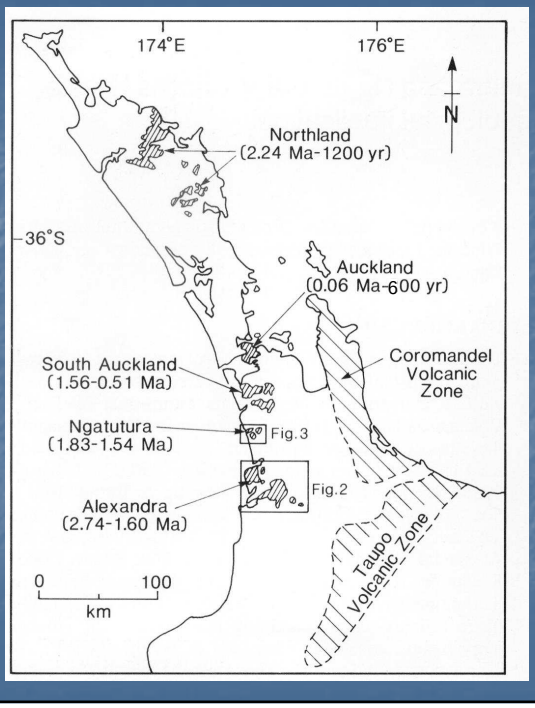
- Geological investigations (what did the volcano do in the past)
- Data from the monitoring network
- Visual appraisal of volcano and surrounds
- Comparison with other volcanoes
- Hazard modelling



Volcanoes of the North Island: 3 volcano types

- **Volcanic fields:** Small, infrequent eruptions of fluid magma (basalt)
- **Cone volcanoes**: Small to moderate, frequent eruptions of intermediate magma (andesite, dacite)
- **Caldera volcanoes:** Small to vast, infrequent eruptions of sticky magma (rhyolite)





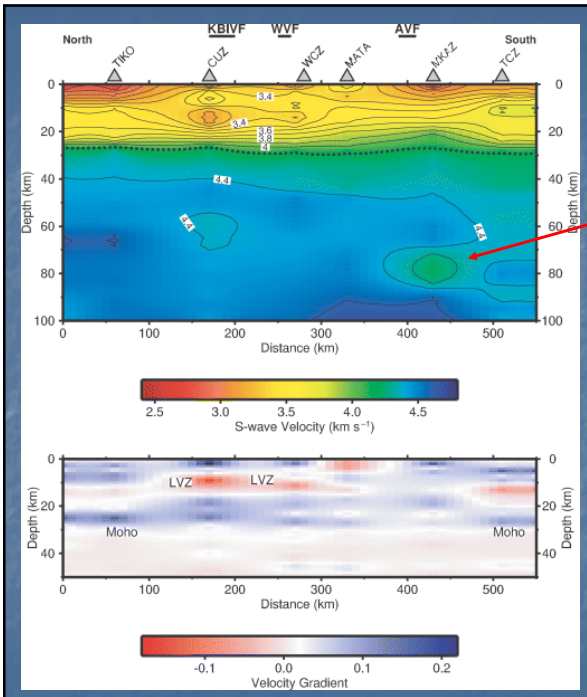
- Auckland is one of 3 active basalt fields in NZ.
- Kaikohe-Bay of islands field
- Whangarei Field

The Auckland Volcanic Field (AVF)

- small volume, intraplate, largely monogenetic, basalt field
- at least 49 volcanoes; coincident with Auckland city (1.3 million)

The Auckland Volcanic Field (AVF)

- Activity from scattered vents over the past 250,000 years
- Rangitoto most recent and largest (ca. 700 - 600 years ago)
- AVF volcanoes typically take the form of explosion craters (e.g. Lake Pupuke, Orakei basin, Onepoto Domain) or scoria cones (e.g. Mt. Eden, Mt. Wellington).
- The history of past volcanism implies the field will erupt again
- Mantle anomaly at depths of about 70-90 km beneath Auckland; interpreted as a region of 2-3% partial melt and which could be the source for AVF magmas (*Horspool et al. 2006*)



The magma is there….

Auckland volcanic field

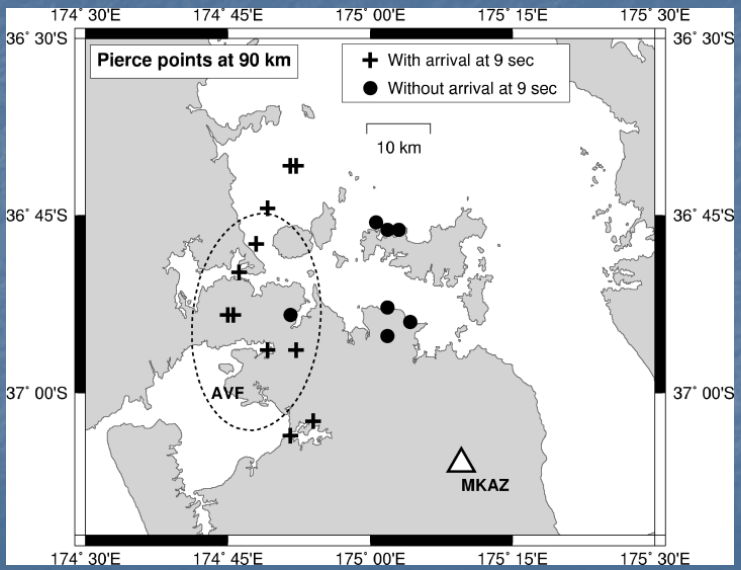
New seismic surveys (Horspool et al., 2006).

Figure from: Horspool et al., 2006, Geophys. J. Intl. 166, 1466-1483

…below our feet

Dashed circle = Auckland Volcanic Field

\+ = occurrence of low velocity zone



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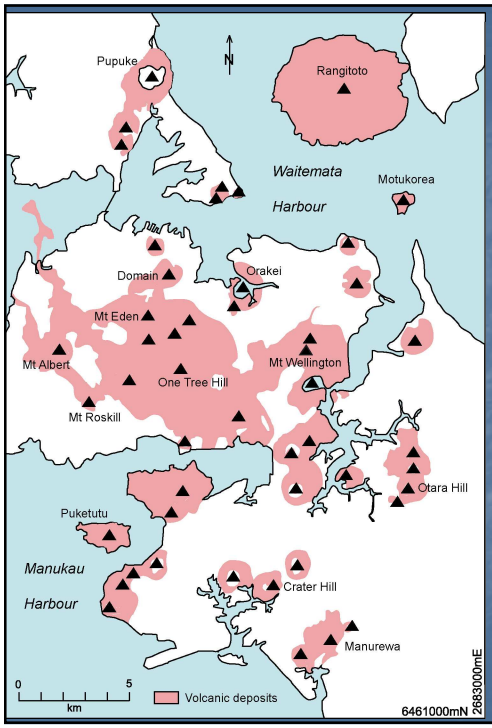


Location, location, location....

of a future vent

- no obvious trends in the location of past volcanic eruptions
- age constraints are poor
- Rangitoto possibly episodic with time breaks, but eruptions from analogue volcanic fields typically last less than few months or years

Future vent location unknown

unlikely that Rangitoto will erupt again (ca. 600 years since its last eruption)

a future eruption is likely to produce a new volcanic centre

Map courtesy L. Cotteral

Probability of a future eruption

• difficult to determine as past eruptions very difficult to date

• results from the maar drilling programme (*Shane and Hoverd 2002; Molloy and Shane pers. comm.)* reveal Auckland has been impacted by significant ash fall (>0.5 mm of preserved ash) from a local eruption on average about once every 2,500 years over the last 70,000 years

This is comparable to the recurrence rate of ash from big caldera eruptions from Okataina and Taupo reaching Auckland

The recurrence rate for Egmont ash impacting Auckland is 1,300 years

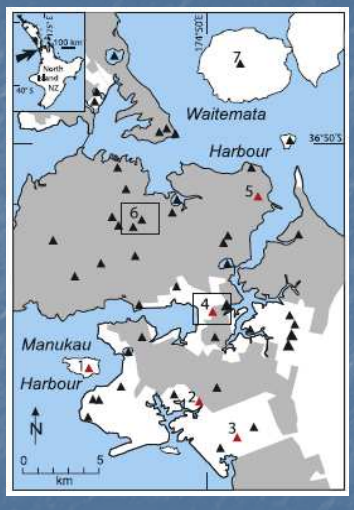
CLUSTERING OF ERUPTIONS IN TIME

There are two lines of growing evidence that activity in the field is not regular, rather that clusters of volcanoes have erupted in time, separated by long (ca. 10,000 year) quiet periods

1. The tephra record (*Molloy and Shane, pers. comm. 2007):*

- Between 20,000 and 20,000 years ago: 1 event every 1,000
- < 10,000 years = 1 (Rangitoto)

CLUSTERING OF ERUPTIONS IN TIME



(*Cassidy 2006*)

2) Geophysical evidence that 5 of the volcanoes in the AVF may have been active within a period of less than a few hundred years, about 29,000 years ago (*Cassidy 2006*); estimated average return period of 10-20 years

Discrete 'volcanoes' show the same magnetic signature

Simultaneous eruptions from different vents in similar or different parts of the field (or eruptions from different vents closely following each other in time) may occur in Auckland in the future

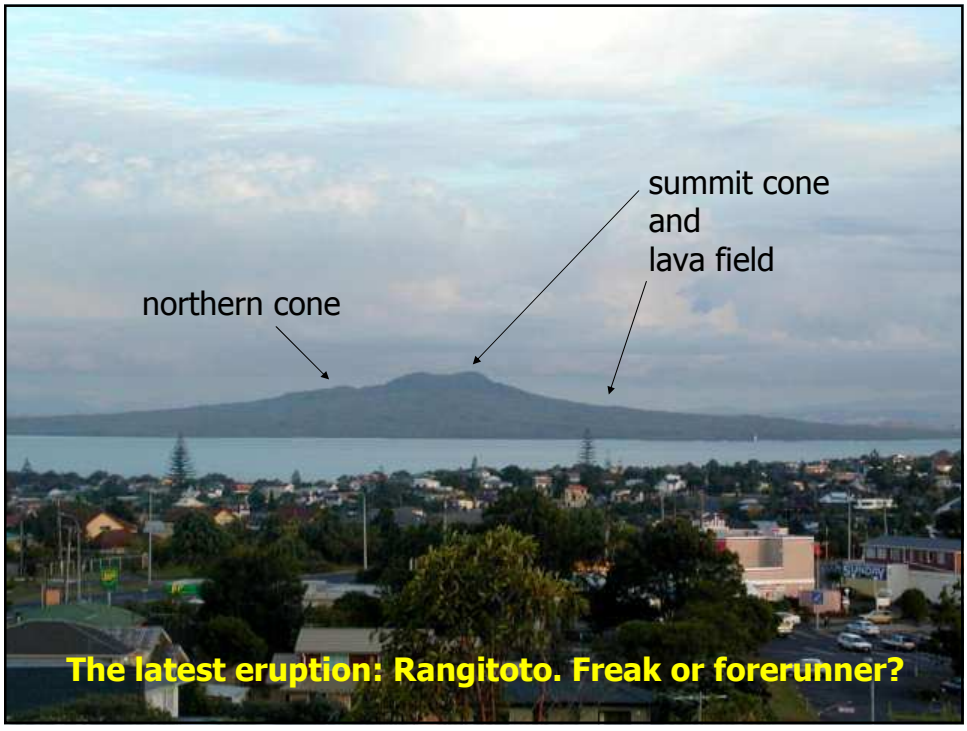
Evidence that past activity may have been episodic makes it difficult to determine likelihood of future eruption

SIZE OF A FUTURE ERUPTION

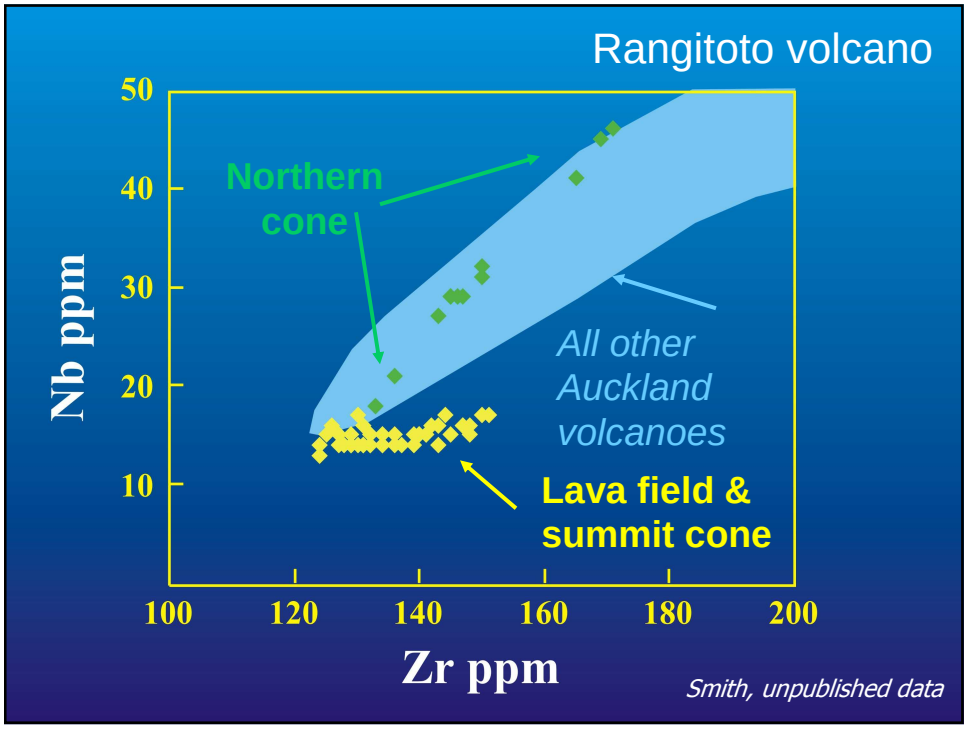
• AVF volcanoes are typically small (<150 m in height; < 0.1 km^3 in volume).

• the last two eruptions (Rangitoto and Mt. Wellington) are two of the biggest; Rangitoto ~ 10 times larger than older volcanic centers, anomalously large eruption or a centre of prolonged episodic activity from several vents now buried?

impossible to say whether the next eruption will be small, medium or large-sized



The latest eruption: Rangitoto. Freak or forerunner?



DURATION OF A FUTURE ERUPTION

- Eruptions in so-called 'monogenetic' fields may range in duration from a few hours to a decade *(Sherburn et al. 2007)*

- Most of the volcanoes in Auckland are thought to have grown by eruptions lasting a few months or possibly a few years; the entire volume of Crater Hill may have been erupted between 14 hours to 12 days *(Blake et al. 2006)*

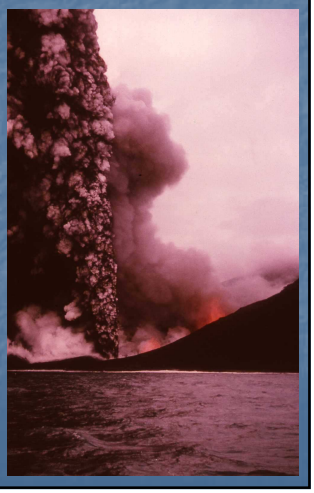
Activity may last for a few hours up to a decade, but is most likely to last for days to months

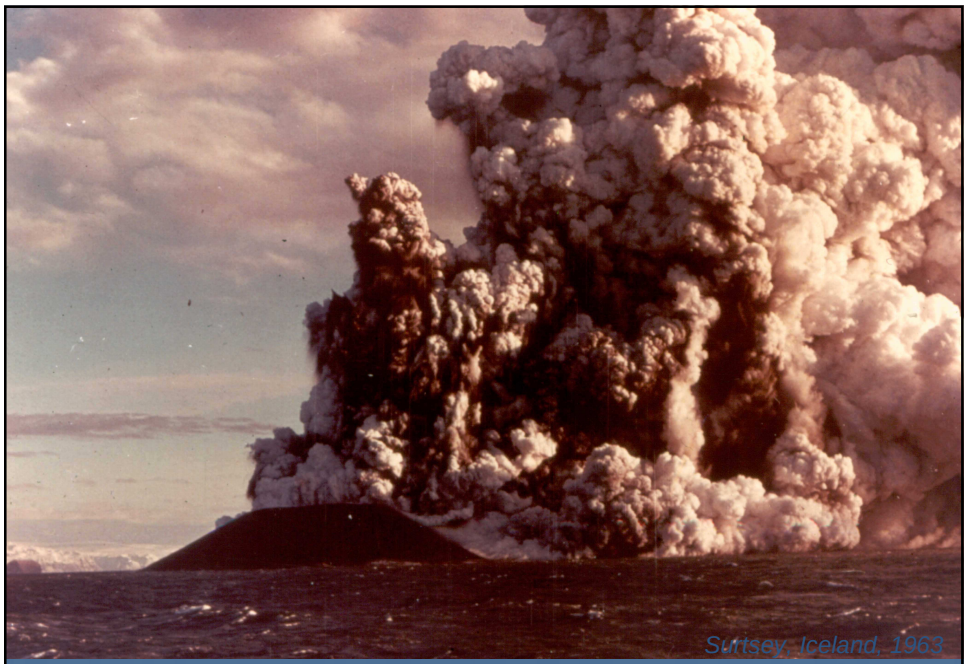
- Several volcanoes in the field (e.g. Rangitoto, One Tree Hill, Mt. Eden, Pupuke, Mt Wellington) comprise numerous volcanic features and/or satellite cones, also indicating that several eruptive episodes may have occurred during their formation, perhaps with time breaks between eruptions *(Spargo 2007; Hayward 2006).*

A new volcano may undergo complex episodes of activity rather than a single event, and these may be separated by time breaks

LIKELY STYLES OF VOLCANIC ACTIVITY

The style of future activity will depend on whether magma erupts through water. A 'wet' eruption will produce explosive phreatomagmatic activity (generating maars and tuff rings) and a 'dry' eruption lava flows or mildly explosive fire fountaining (scoria cones). Both types of activity may occur over the course of the eruption.





Explosive volcanism: 'wet' - magma-water interaction

Wide, low-lying structures (tuff rings), close to sea level

Onepoto

Crater Hill

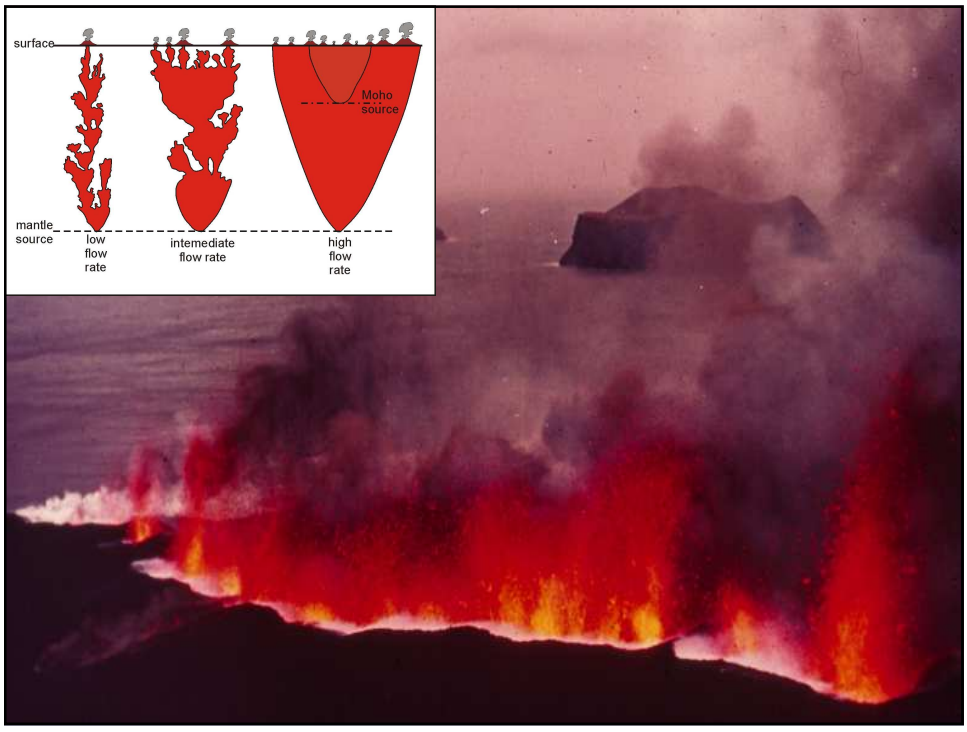
Explosive volcanism:

'wet' - magma-water interaction

Maungawhau (Mount Eden)

Explosive volcanism:

‘dry’ – driven by gases dissolved in the magma itself



Effusive volcanism:

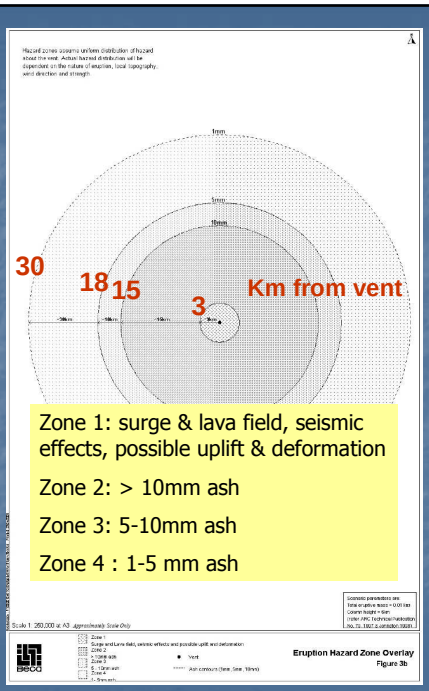
lava flows

Mount Etna

Mt Wellington

Effusive volcanism:

lava flows

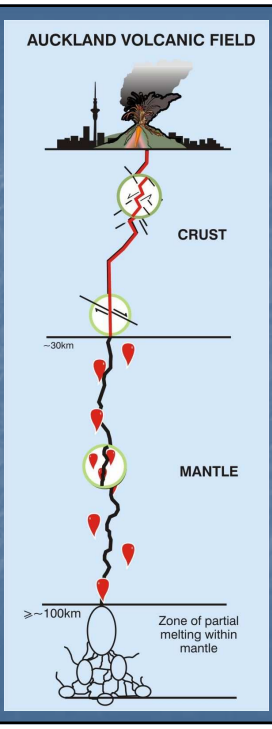


Eruption hazard zone overlay

(from Contingency plan)

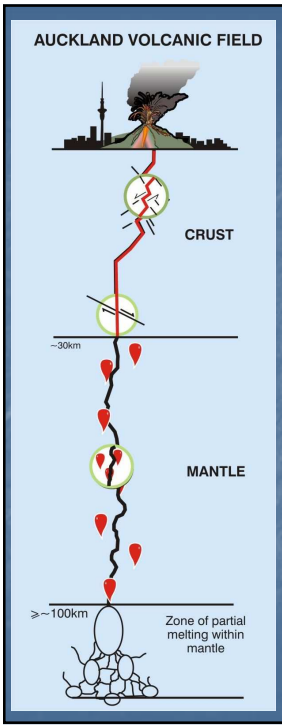
Expected activity: ash fall; ballistic ejecta; pyroclastic surges; lava flows; volcanic gases; volcanic earthquakes; atmospheric effects (e.g. lightning strikes)

Most of this activity will be confined to within a few kilometers of the vent and evacuation of this area should be carried out before the eruption to avoid loss of life



HOW MUCH WARNING WILL WE GET

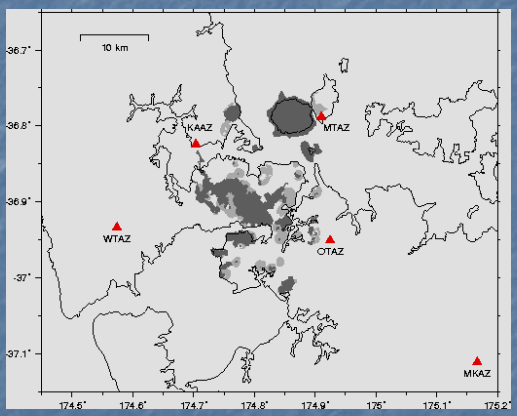
- The AVF erupts basalt magma that originates in the mantle at depths of 50 – 100 km, and which rises to the surface with little or no time spent lodged in magma chambers at crustal depths
- Models of magma flow and xenolith behaviour suggest likely rise speeds of **0.03 – 0.6 m per second (0.1 – 2.2 km per hour)** *(Blake et al 2006)*
- Magma ascent times will be fast – maybe as short as **5 weeks to 2 days** to travel from depths of 100 km to the surface



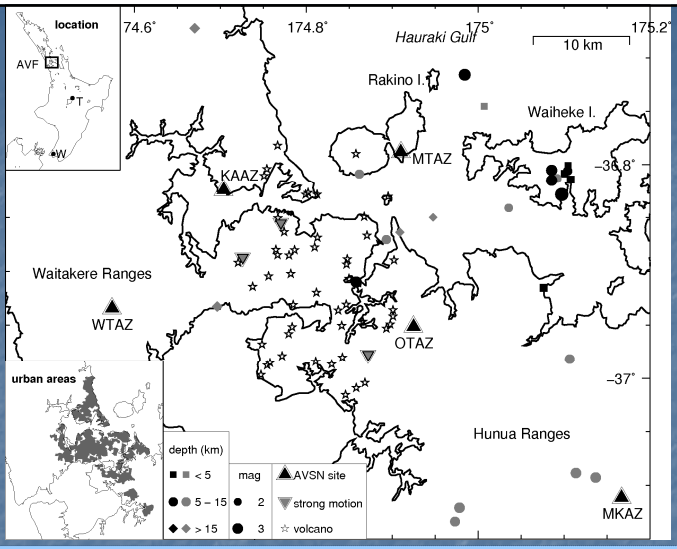
WHAT SORT OF WARNING WILL WE GET

- Possible ascent rates indicate the first sign of seismic unrest in the AVF may occur as little as **14 hours to 11 days** prior to outbreak (DLP earthquakes at 30km); historical analogue eruptions typically display several days to weeks of precursory seismicity
- Tectonic earthquakes generated before an eruption may include large events (ML 4.5 – 5.5), and may be widely felt *(Sherburn et al. 2007)*
- Magma may stall several kilometres beneath the surface and not culminate in an eruption
- Precursory seismicity may be displaced from the eventual eruption vent *(Blake et al. 2006; Sherburn et al. 2007)*

The Auckland Volcano Seismic Monitoring Network (AVSN)

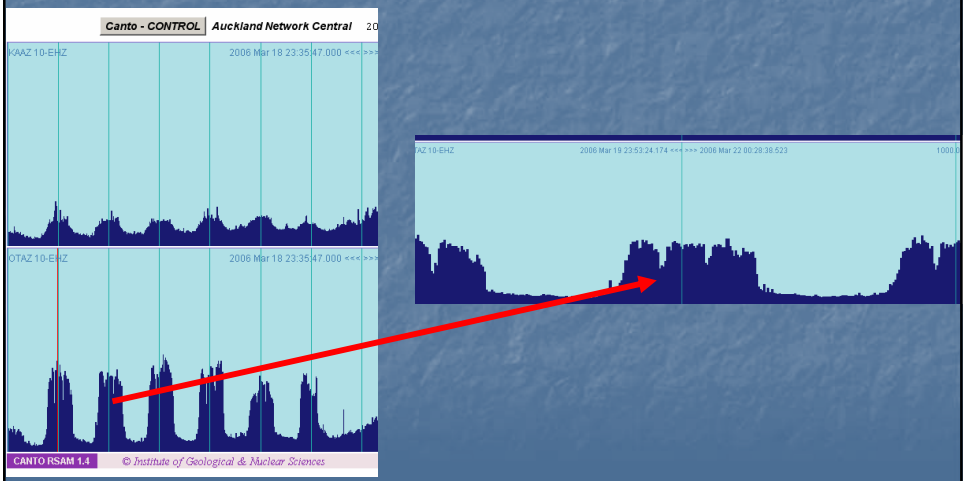


- AVSN surface network = 5 telemetered, vertical component, short-period stations
- Monitoring is carried out by GeoNet (GNS & EQC partnership)



- The high level of surface noise in the AVF makes it difficult to record and locate small magnitude earthquakes
- The existing network is only able to confidently locate earthquakes down to c. $M_L \geq 2.5$
- 24 EQs located between 1995 & 2005; magnitude 1.6 – 3.3 (most 2 - 2.5) *(Sherburn et al. 2007)*

Largest problem in Auckland is cultural noise

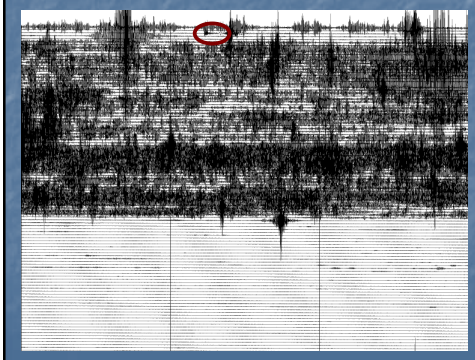


Auckland downhole seismograph experiment

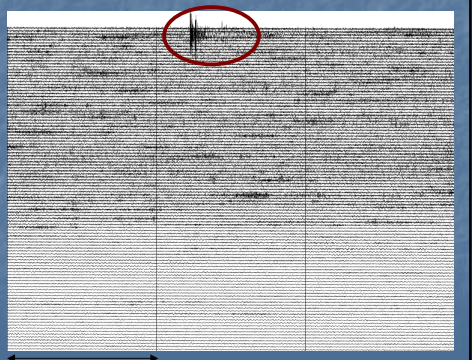
- Collaboration between IESE, GNS Science/GeoNet and the Auckland Regional Council
- ARC groundwater borehole
- Riverhead (NW boundary of AVF)
- 245 m deep
- 2 Hz natural frequency 3-component borehole seismometer (IESE)
- surface seismometer for comparison (GeoNet)
- Both sensors recording simultaneously from Nov. to Dec. 2006, and from March to May 2007

Noise differences

- Small nearby quarry blast (circled) recorded on the two seismometers (different plot gains)
- on the surface record the event is clearly much smaller than the near-sourced noise (primarily traffic noise?)
- On the borehole record the event is larger than all the non-seismic noise



surface



1 minute

borehole

Proposed AVSN upgrade to include downhole sensors

(Revised upgrade plans need to be approved by 'scientific advisory committee')

Squares : vent locations

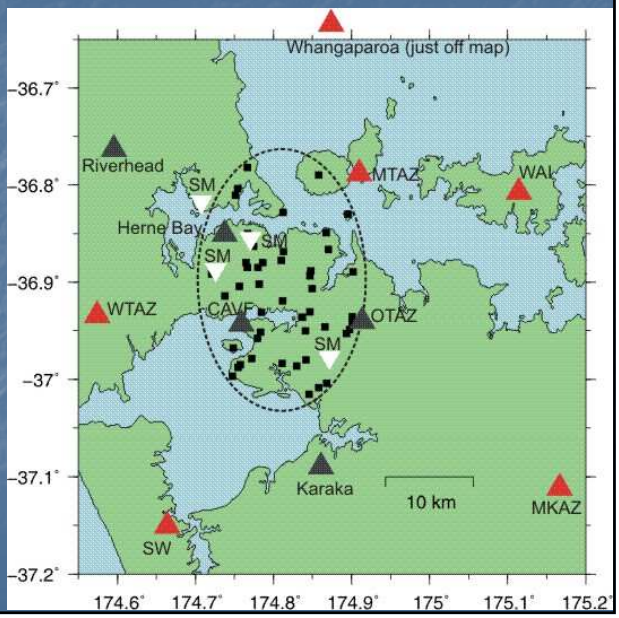
Ellipse : approximate boundary of the Auckland Volcanic Field

Red : proposed surface sites

Grey : proposed borehole sites

White : strong motion sites

Also: upgrade to digital telemetry and 3D sensors



The next Auckland volcanic eruption…