Auckland Volcanic Field Geology

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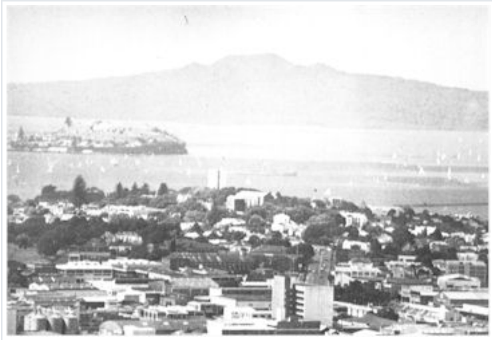
INTRODUCTION

Volcanoes are a conspicuous feature of the Auckland city landscape. In some cases their form is emphasised by their preservation as reserves and parks, while in others they have been quarried to meet the city's demand for building materials. Within a radius of about 20km centred on Auckland city there are 49 discrete volcanoes; this is the area referred to as the Auckland volcanic field. The distribution of the volcanoes is shown in figure 1.

This booklet is concerned with the nature of Auckland's volcanoes and with what may happen when the next volcanic eruption occurs in the field. The risk of this happening is small but significant and since there is likely to be only a very short warning period when it does occur it is important to be prepared.

There are no written records of the most recent eruption in the Auckland volcanic field about 600 years ago and there are only tantalising fragments of oral history from the legends of the Maori known to have been living nearby. Nonetheless there is a detailed geological record to be gleamed from this volcano and from many others in the Auckland region which shows that there have been repeated and varied volcanic eruptions within the area in the recent past. This is the basis for predicting that there will be another eruption in Auckland at some time in the future; the question is when?



Motukorea (Browns Island) – A small volcanic Island in the Hauraki Gulf. One of the many remnants of Auckland's volcanic history.

Volcanic activity from an eruption at a site within the Auckland volcanic field could produce serious problems in the day to day existence for those who live in the Auckland region and for New Zealanders supported by Auckland's business and industry. The degree of destruction will depend on the size and location of the eruption, type of activity, warning time and preparedness planning. Knowledge of the type and effects of volcanic activity are based on studies of volcanic deposits in the Auckland area and on analogues of similar eruptions from similar types of volcanoes elsewhere in the world.

Auckland's volcanoes are small by comparison with most of the world's volcanoes. The size of a volcano is usually measured in terms of the volume of material erupted during its active life, and individual eruptions are measured in terms of the volume of material erupted during a particular period of activity. The volume units used are cubic metres (m3) and cubic kilometres (1 km3 = 1,000 million m3. Try imagining a box 1 kilometre high and one kilometre on each side). The cumulative volume of all the material erupted from Auckland's 49 volcanoes is approximately 4.1km3. To put this figure into a global context the total volume of volcanic deposits in the Auckland volcanic field is only about the size of one average eruption such as the 1980 eruption of the American volcano, Mount St Helens.

Most of the volcanoes in Auckland are small cones less than 150m in height. These grew by eruptions, which lasted only a few months or possibly a few years. In some cases only a single cone resulted from the eruption but there is also evidence that some eruptions have built several adjacent cones. The type of volcanic activity which has created the Auckland volcanic field is referred to as monogenetic which means that each time there has been an eruption it has occurred at a new location and that each eruption is the result of a single batch of magma which rises from its source in the mantle about 100km beneath the city.

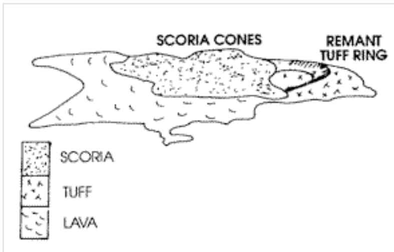
The monogenetic nature of Auckland's volcanoes has particular implications for volcanic hazards because in the event of an eruption, rather than one of the existing volcanoes becoming active, a new volcano will form. Because of this situation, a hazard map based on any one location cannot be drawn and the entire field has to be considered as under a threat of a future volcanic eruption.

Although it is at least 600 years since the last eruption in the Auckland volcanic field, there is every reason to expect eruptions in the future.

These eruptions are likely to be on a small scale compared with some recent overseas eruptions, but because the city of Auckland is built on and around potential eruption sites their effects are likely to be serious.

THE NATURE OF AUCKLAND'S VOLCANOES

Auckland's volcanoes are different from most other volcanoes in New Zealand. The volcanoes in the central North Island and Taranaki are produced by the eruption of viscous andesite and rhyolite magmas generated at the active boundary between the Pacific plate to the east and the Australian plate to the west. These magmas originate below and within the crust as part of the process of collision between the plates. The andesite and rhyolite volcanoes are fed from magma reservoirs in the crust beneath them.



Sketch showing the different eruptive domains on Motukorea. The tuff ring formed first by a series of explosive eruptions followed by the formation of the scoria cones and the eruption of lava flows.

The Auckland volcanic field owes its origin to the presence of a region of hot rock known as a hot spot or plume located about 100km beneath the city. In this hot spot, temperatures are high enough so that the rock begins to melt. When enough molten rock has accumulated (probably about 5 to 10%), it separates from the solid residue and rises toward the surface. This melted rock is basalt magma and one of its important characteristics is that it has a low viscosity (flows easily) so that it can force its way through the overlying crust quite quickly (speeds of 5 kilometres per hour have been estimated). Each volcano in the Auckland volcanic field has been fed from a deep source and each time there has been an eruption it has been of a new batch of basalt magma. An important aspect of this style of volcanism is that there is no crustal magma reservoir present between eruptions so there is no source of heat to drive geothermal systems as there is in the central North Island. The lack of surface activity in the Auckland region leads to the mistaken impression that the field is extinct whereas nothing could be further from the truth.

The only other active basalt volcanoes in New Zealand are found in Northland near Whangarei, around Kaikohe and in the Bay of Islands. It appears that these are areas where the crust is stretching and magma is able to rise through cracks. Millions of years ago similar activity built the volcanoes of Banks Peninsular and Dunedin, but these are now extinct.

ERUPTION HISTORY

One of the most serious obstacles there is in working out the volcanic history of the Auckland field is that the volcanic rocks themselves are very difficult to date. Most of the available ages of eruptions come from wood or shell material, which has been buried during an eruption. This material can be analysed for its radioactive carbon content and this information can be used to calculate an age for the eruption. The problem is that the carbon method of dating is only useful back to about 40,000 years before the present. Recently other methods of dating have been indicating that the oldest eruptions in the Auckland field may have occurred as much as 150,000 years ago.

Of the 49 eruptions in the Auckland volcanic field, 19 are known to have occurred within the last 20,000 years. Of these 19, about 18 erupted between 20,000 and 10,000 years ago. By comparison, there were only 21 eruptions between 20,000 and 100,000 years ago, and about 9 eruptions earlier than 100,000 years ago.

The area covered by each volcanic centre is generally localised (less than a kilometre across) and the total volume of erupted material is small. However, five of the volcanoes (Mt Mangere, One Tree Hill, Three Kings, Mt Eden and Mt Wellington) are of medium size. The largest, Rangitoto, is an exceptionally large volcano for the field, representing 59% of the total volume of erupted material. It is significant that the five medium-sized eruptions occurred between 20,000 to 10,000 years ago and that the largest eruption was only about 600 years ago. Also the volume of volcanic deposits produced in eruptions over the last 20,000 years is greater than in the preceding 20,000 years (see figure 2). There appears to be a trend towards an increase in the average size of eruptions but it is impossible to be sure whether the next eruption will be a small-, medium- or large- sized event.

There are no obvious trends to the location of past volcanic eruptions in Auckland although there is a general pattern of older centres in the north and younger centres in the middle of the field. The rise of magmas is probably controlled by the location of faults deep in the crust but because these have not been precisely located it is not yet possible to predict where the next eruption will occur. **VOLCANIC ERUPTIONS AND THEIR HAZARDS**

Because there is no written or oral record of volcanic activity in Auckland the history of the field has to be read from the deposits left by past eruptions. This is geological detective work requiring detailed examination of the fragmentary story revealed in road cuts, quarries and the often only temporary excavations on

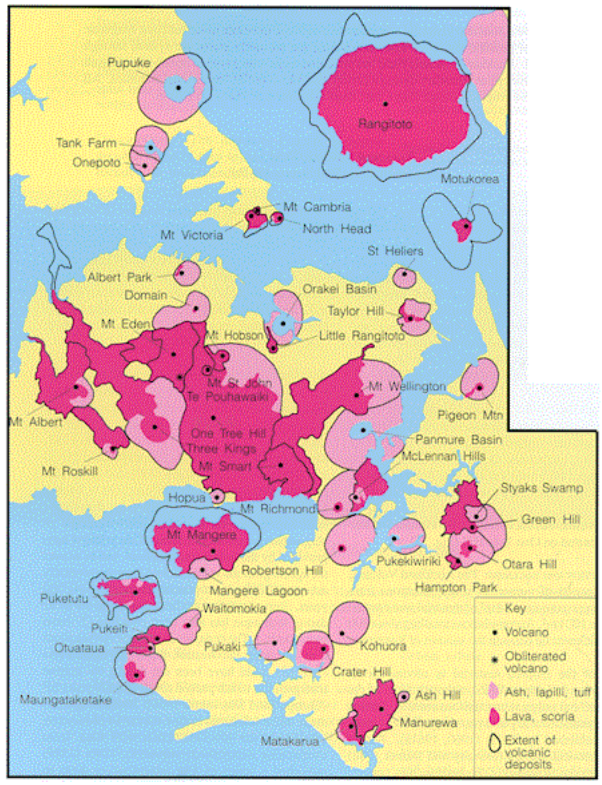


Figure 1: The distribution of volcanic centres in Auckland, know n as the Auckland volcanic field. (map by L.Kermode).

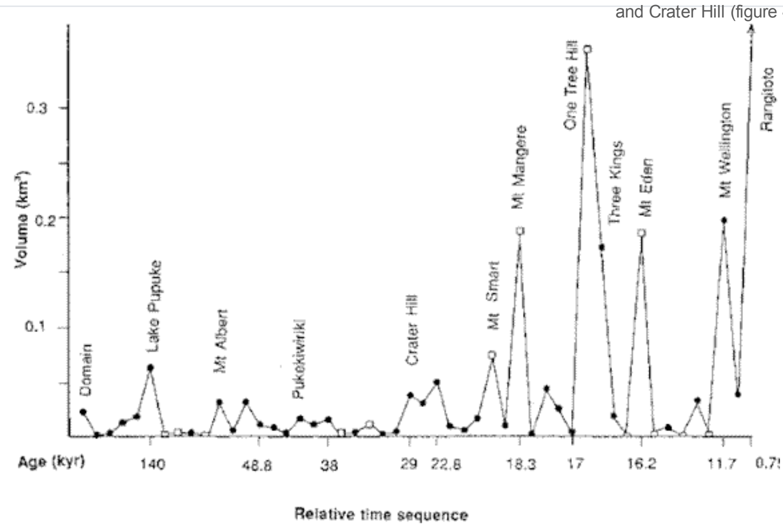


Figure 2: Generally the volume of the volcanoes is small; less than 0.1 km3. Note the increase in number of volcanoes in the last 20,000 years. Also the more voluminous volcanoes erupted in the last 20,000 years. Rangitoto in comparison is about 10 times larger in volume than any of the previous volcanic centres.

building sites.

The nature of an eruption depends on the type and volume of magma, its rate of ascent, its gas content and external influences such as whether water is present at the site where magma breaks through to the surface. All of Auckland’s volcanoes have erupted basalt magma, which is the dense rather fluid type, well known from active volcanoes in Hawaii. The volcanic deposits in Auckland show that past eruptive activity in the field can be divided into two main types.

1. If, when magma reached the surface it came into contact with water, either the sea, groundwater or a river, then an explosive eruption occurred. This type of eruption is known as **phreatomagmatic** (phreato = steam). When magma at high temperatures (about 1000 degrees celsius) mixes with water it is instantly chilled and the pressure of its contained gas breaks it up into fragments. The water when it comes into contact with the hot magma, flashes to superheat steam. The result is a violent explosion of steam, magmatic gas, fragmented lava and rocks from around the vent which forms a rapidly expanding cloud. The solid material in this cloud is **pyroclastic** (fragmented and explosively ejected) and is referred to by the general term **tephra.** Tephra is divided on the basis of size into ash (diameter less than 2mm), lapilli (2-64mm) and blocks and bombs (greater than 64mm) components. An outcrop of phreatomagmatic deposits is shown in figure 3.

In phreatomagmatic explosions, columns of tephra containing ash to gravel-sized (lapilli) fragments are ejected together with steam and magmatic gas, to form an eruption column which may rise to heights of 500m or more. Larger fragments (bombs and blocks) are thrown out from the vent on ballistic trajectories. At the base of the eruption column, explosive surges expand as a collar-like blast of tephra, gas and steam moving at speeds of hundreds of kilometres per hour, whereas at the top of the eruption column, wind disperses the tephra downwind to fall as a layer of airfall tephra.

Phreatomagmatic eruptions typically produce a wide roughly circular crater half to one kilometre in diameter surrounded by a low pyroclastic ring; this type of volcano is known as a **maar**. In Auckland, Lake Pupuke, Orakei Basin and Crater Hill (figure 4) are all examples of maars. The deposits of explosive pyroclastic eruptions are well displayed behind the Takapuna Boat Club beside Lake Pupuke, in small roadside cuttings around Three Kings Volcano and in outcrops around Orakei and Panmure Basins.

2. Without the interaction of magma with surface water, eruptive activity is driven by

magmatic gas. Gas-charged magma erupts at the surface in a fire-fountain which may play continuously (**Hawaiian** style) or pulsate discontinuously (**Strombolian** style) to build a cone of coarse tephra, commonly referred to as a **scoria** cone. An examination of the deposits making up a scoria cone reveals layers consisting of lumps of rock of various sizes (figure 5). Most of these are rounded and honeycombed with small holes known as **vesicles**. These were lumps of hot magma thrown out of the volcano in a molten state. The vesicles represent bubbles of the magmatic gases which powered the eruption (the gas has long since escaped).

Many of Auckland’s volcanoes are excellent examples of scoria cones. To name a few there are Mount Victoria, One Tree Hill, Mount Albert and Mount Mangere. (figure 6). When fire fountaining becomes particularly intense lava flows can form when hot fragments of magma fuse together as they land. Toward the end of fire fountaining episodes magma which has lost most of its gas content may form a flow which runs relatively quietly out of the vent. In some cases (e.g. Mount Mangere) the eruption of lava flows has accompanied collapse of a part of a part of the crater rim to form a breached crater.

Figure 3: Inter-bedded airfall and surge deposits from North Head. Note the w ide range of tephra sizes and the general lateral continuity of the layers.

EXPLOSIVE ERUPTIONS IN AUCKLAND

There is evidence of phreatomagmatic activity in 73% of the volcanoes in the Auckland field. Explosive phreatomagmatic eruptions, blast out pyroclastic material in the form of a vertical eruption column and a basal horizontally directed flow, called a base surge (figures 7 & 8). The base surge is the most hazardous of all the possible volcanic products from a future Auckland eruption because it is extremely violent, moves very quickly and can occur with little warning. Surges are only produced in phreatomagmatic explosions. They are turbulent, ground-hugging, flows of tephra and gas which expand radially outwards from the vent. Surges usually travel at speeds of between 15 and 30 metres/second (50-110 kilometres/hour), but sometimes move as fast as 100 metres/second (360 kilometres/hour). When it is first erupted a surge is hot (around about 110° Celsius), and consists of tephra, steam and magmatic gas. Surges move across the landscape away from the vent until their gas content escapes, their solid content is deposited and their energy dissipated. Examination of tephra deposits in Auckland show that surges from Auckland’s volcanoes have travelled up to distances of 1.5km or more. In the 1965 eruption of Taal volcano in the Philippines surges reached as much as 6-10km from the vent.

The development of an explosive surge is dependent on the magma coming into contact with water and forming a phreatomagmatic eruption. Water for a phreatomagmatic eruption could come from the harbours, rivers, streams, subsurface aquifers or from sediments at the surface. Not all of the eruptive locations will have enough water to produce such an explosion but it is possible that a phreatomagmatic eruption could occur almost anywhere in the Auckland volcanic field.

The distances that surges will travel depends on the local topography and eruption energy of the volcano. Surges initiated in a coastal environment or on flat land will be more radially dispersed than a surge initiated in steeper topography. One of the problems of volcanic prediction work in Auckland is that until a future eruption site is identified it is impossible to foresee which areas might be effected.

Explosive surges are hot, rapidly moving and totally destructive. The only practical steps to avoid the danger associated with them is to evacuate all areas likely to be affected.

Explosive eruptions create deep and relatively wide **craters** at the vent area. These craters can be observed at volcanic sites which were not covered by later volcanic products of scoria and lava. Most of the craters have been infilled by mud or have been breached by the sea. Lake Pupuke is the best preserved crater in the field. It has been protected from coastal erosion by lava flows which line the coast between Takapuna and Milford beaches. Lake Pupuke crater covers an area of about one square kilometre and the original crater was about 160 metres deep. The average size of an explosion crater in Auckland is smaller than one third of a square kilometre.

Figure 4: View south looking over the maar of Crater Hill. Crater Hill has been extensively quarried removing a small scoria cone w hich once stood in the centre of the crater.

Explosive eruptions generate an eruption column of pyroclastic material which can rise many kilometres into the air and, depending on the wind, can be dispersed many kilometres from the eruption site. Material falling from this eruption cloud produces a deposit of tephra. Because of their characteristically small size the volcanoes of Auckland probably produced eruption columns of only modest size. That is, most of the tephra will be deposited within a radius of 2 kilometres from the active vent. However, in the eruption of Rangitoto, tephra fell within a cigar-shaped area at least 12 kilometres long across Motutapu Island to the northeast and this shows that larger ash falls are possible in the future

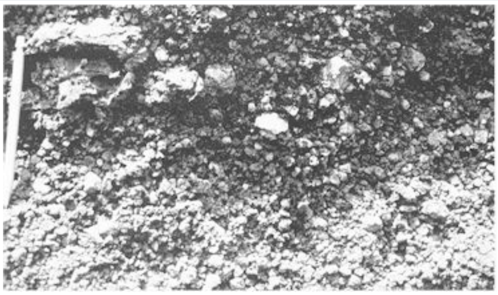
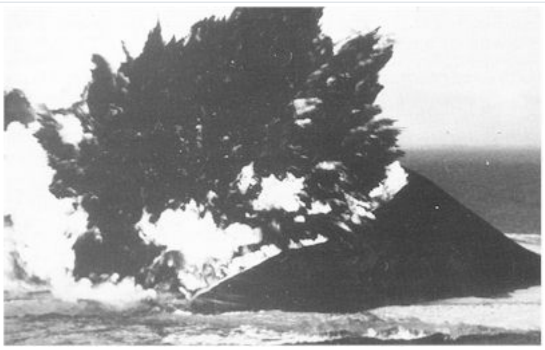


Figure 5: Vesicular tephra, otherw ise know n as scoria. Deposit of mixed Strombolian and Haw aiian style fire fountaining, from the Pupuke volcanic centre.

Airfall tephra includes all volcanic products that are aerially ejected from the vent in the form of fire-fountains (see further on), ballistic projectiles and by fall from an eruption column. The distribution of tephra is dependent on the size of the eruption, the wind direction, the wind strength and the weight of the particles. Larger particles fall closest to the vent whereas fine ash may drift tens of kilometres downwind from the vent depending on the height of the eruption column and the wind speed. The thickness of tephra decreases rapidly with distance from the vent.



Figures 7: Phreatomagmatic eruption from the new ly formed volcanic island, Surtsey, off the coast of Iceland. Initial interactions of magma w ith sea w ater produce a blast of black tephra

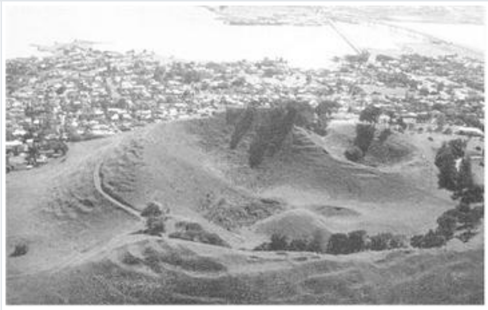


Figure 6: Mount Mangere. The view is northw ard into the crater of the scoria cone. The cone has been breached on the eastern side by a lava flow . At the end of the eruption a small lava dome built up in the crater.

In Auckland tephra is most likely to be deposited thickest to the northeast and east reflecting the predominance of westerly winds in the region. In Auckland the deposits of ash falls have been localised to zones a few kilometres downwind from their source.

Airfall tephra can hinder visibility or cause complete darkness. Ash is very abrasive and can penetrate into electrical and motor parts causing damage to machinery and immobilising vehicles. Ash can conduct electricity causing lightning strikes or inducing short circuits in radio and telephone communication systems and in electricity supplies. Even small thicknesses of ash can cause severe damage to vegetation and affect breathing of humans and animals. Airfall tephra can contribute to erosion problems. Its removal with water can clog up drainage systems which can cause flooding. Wet ash is heavier than dry ash, so rain-soaked ash from phreatomagmatic activity has a greater potential to cause destruction through burial and often causes roofs to collapse.

During an eruption airfall tephra needs to be moved from roofs and roads and stockpiled. Adequate protective clothing and personal respiratory protective devices will be required by people involved in clean-up operations close to the vent. Extra oil and air filters will be required by vehicles within ash fallout zones. There is likely to be problems with energy and water services.

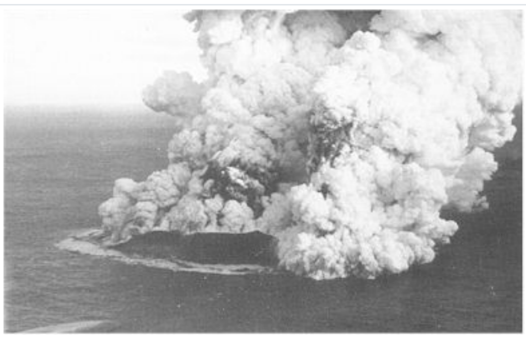


Figure 8: Phreatomagmatic eruption from the new ly formed volcanic island, Surtsey, off the coast of Iceland. Further explosions create an eruption column w hich produces airfall tephra and a basal surge cloud. Photographs by Sólarfilma, Reykjavik, Iceland.

Fire fountain eruptions

Fire fountains are spectacular effusions of hot incandescent magma which may rise hundreds of metres above an active vent (figure 9). The fountains are driven by the fragmentation of magma and the release of magmatic gas in the throat of the volcano. Lumps of cooled magma fall from the fountain as ash, lapilli and bombs. Although spectacular and destructive fire fountains do not represent the same threat to human life as explosive eruptions because their effects are more restricted and their onset more gradual.

Evidence of fire-fountaining activity is present in 77% of the volcanoes in the Auckland volcanic field. Fire-fountaining is restricted to a vent or series of vents along a fissure. The tephra produced from fire fountains falls mainly around the vent area because of the dominance of larger and heavier fragments. If the eruption continues for long enough it may build a steep sided scoria cone. Scoria cones from previous eruptions in Auckland average less than a kilometre across.

Close to the vent, tephra may be of sufficient thickness to cause burial, and blocks may still be hot enough to ignite fires or heavy enough to penetrate structures. The effects of the dense tephra from fire fountains in Auckland has generally been restricted to a radius of about 1 km. Typically such eruptions have not produced a widespread ash fall.

Lava flows

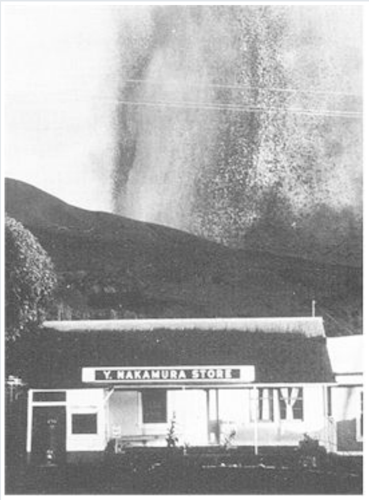


Figure 9: Fire fountaining from the 1960 Kopoho eruption, Hawaii (Pana-vue slide)

Lava flows are streams of magma which flow under the influence of gravity into adjacent low areas; in many ways their behaviour is like that of a river although they are many times more dense and viscous. Lava flows are hot, typically at least 1000oCelsius so that they can easily start fires in vegetation and buildings (figure 10).

There are two types of lava flows found in Auckland; pahoehoe and aa. Pahoehoe lava is more fluid that aa, causing thinner, faster moving flows. Pahoehoe flows may change down slope to aa but the reverse does not occur. Lava flows can explode when they come into contact with water or as a result of concentrations of the organic gases produced when hot lava overruns vegetation.

Lava flows burn, crush and bury everything in their path, but generally move at speeds slow enough for people and moveable possessions to be saved. Flows may be controlled by cooling with water, to increase their viscosity and slow them down. Barriers may be built or explosive used to divert the flow. These methods are expensive, difficult and dangerous and they may be unsuccessful.

In Auckland, lava flows have generally occurred later in the sequence of volcanic activity following fire-fountaining. Thirty of the 49 volcanoes in the Auckland volcanic field have lava flows. Since lava flows are strongly controlled by topography, the shape of the area destroyed by a flow can be predicted. The distance travelled by lava flows in Auckland varies from 0.5 to 9.5 km, depending on the volume of lava, its viscosity and the topographical gradient. Flows moving on steeper slopes, with low viscosity and a large volume, travel the greatest distance.

SECONDARY HAZARDS

There are a number of secondary hazards which would probably be associated with future eruptions from the Auckland volcanic field. The most important of these are shock waves, volcanic gases, earthquakes and tsunami.

Shock waves are sound and pressure waves which are associated with energetic eruptions. A shock wave usually propagates in all directions away from the vent. A shock wave usually travels ahead of a base surge. At some distance away from the vent, the base surge may override the shock wave. Shock waves are blasts and are therefore able to flatten trees and break windows.

Figure 10: Lava flows destroy a paw paw grove, Hawaii (Hawaiian Slide Services).

The greatest problem relating to gases from basaltic volcanism is from the asphyxiating gases of CO, CO_2 and the poisonous gas HF. Gases from volcanism in Auckland are likely to be localised to an area around the vent. CO_2 can escape from vents or from burning vegetation (caused by lava flows) and because it is denser than air can become concentrated in low lying areas. Gas masks are required if poisonous gases such as HF are present.

Earthquakes associated with volcanic eruptions are caused by the movement of magma through the crust both before and during eruptions. Such earthquakes pose most danger to structures close to the site of an eruption and also to structures built on soil and rock of low strength. Mitigation measures to prevent seismic damage are similar to those required in the event of a tectonic earthquake. Although volcanic earthquakes rarely exceed an intensity of 8 on the Modified Mercalli Scale (this scale is based on the felt intensity of an earthquake and is different from the Richter scale based on the amount of energy released), they would be destructive if an eruption occurred in or near a built up area.

Long-period sea waves (tsunami) can be generated by the sudden displacement of water in the early stages of a submarine eruption. An eruption initiated in the sea in either the Waitemata or Manukau Harbours could have sufficient energy to form a tsunami. Although no evidence of a past tsunami has been found from the Ragitoto eruption the possibility of such an event should be considered. The areas in potential danger from a tsunami are low lying areas near the coast. This includes the shipping ports of Auckland and Onehunga.

PREDICTING ERUPTIONS

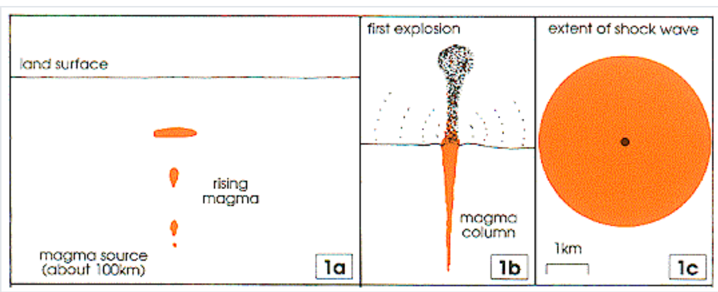
The saving of lives and property from destruction by a volcanic eruption depends on being able to predict the next eruption. Given sufficient warning, people and moveable property can be evacuated from the threatened area.

There are two parts to predicting the next eruption in the Auckland volcanic field. The first part involves the recognition that the field is in fact active and deducing the possible nature of future activity based on the record of past eruptions. This is based on detailed geological investigations and for Auckland is reasonably well known. The major uncertainty lies in the age and frequency of eruptions in the past. The second part of prediction is the recognition of precursory signs which indicate that an eruption may occur.

The next eruption in Auckland will occur when magma present forming far beneath our feet rises to the surface. As it ascends it will have to break its way through the crust and this will at first cause small tremors which can only be detected by very sensitive seismometers and later earthquakes which can be felt. A volcanic eruption in Auckland is expected to occur after only a short period of earthquakes lasting perhaps several days to a few weeks. It is therefore essential to have adequate monitoring equipment installed and running before the event, with immediate automatic analysis of the size and location of earthquakes so that the longest possible warning can be given. At present Auckland has a small network of seismometers deployed to detect small earth tremors associated with the movement of magma at depth and there are plans to expand this into a comprehensive eruption warning facility. Results from the operation of the network since 1985 have shown that the background seismicity in the region is very low so that it will be easier to detect the subtle signs of an impending eruption than it would be in area of high earthquake activity such as the central North Island.

HAZARD ZONES IN AUCKLAND

Because there is no way to pinpoint the location of the next eruption from the Auckland volcanic field it is no feasible to construct a hazard map to show areas which will definitely be affected during the eruption. In this respect the Auckland volcanic field is different from volcanoes such as Mount Egmont or Mount Ruapehu where eruptions can be expected from the present crater. However, generalised hazard zones can be estimated in advance and can be superimposed onto a map once the likely eruption site has been determined by the monitoring network. Because of the potential influence of water on the nature of the eruption and because of the variations in land use in the Auckland area the specific hazards from the next eruption are very much dependant on the location of the site.



The dominant variables for base surge activity are; the amount and recharge rate of available water in the magma conduit, the rate of magma rise and the volume of magma. The dominant variables for air fall tephra are type of eruption, volume, wind direction and wind speed. The dominant variables for lava flows are volume, viscosity and topography.

In general the rate of magma rise controls the type of activity, the volume of magma controls the magnitude of the hazard zones, whereas the topography, wind direction and wind speed can control the extent and shape of the hazard zones.

ERUPTION SCENARIO

A general eruptive sequence for Auckland's volcanoes is considered to be: initial explosions clearing the vent of water-saturated material (phreatomagmatic stage), fire-fountaining (Hawaiian to Strombolian) and finally the effusion of lava flows. The development of the complete sequence depends on the volume and rate of magma rise, the gas content of the magma, and the amount of accessible free water present at the vent. Many of Auckland's volcanoes record only one or two of these types of eruptive phenomena in their deposits.

A general sequence for an Auckland eruption is given in figure 11.

Variations in eruption scenarios

Each of Auckland's volcanoes is unique in some way. Similarly, the next eruption from the Auckland volcanic field could differ from the scenario presented in Figure 11 in one of the following ways:

1. The eruption could stop before the fire-fountaining activity (22% of the volcanoes in the Auckland volcanic field have shown this).

2. The eruption could stop after fire-fountaining but before the effusion of lava flows (as shown by 8% of Auckland's volcanoes).

3. The eruption could start with fire-fountaining rather than with phreatomagmatic explosions (27% of the Auckland volcanoes).

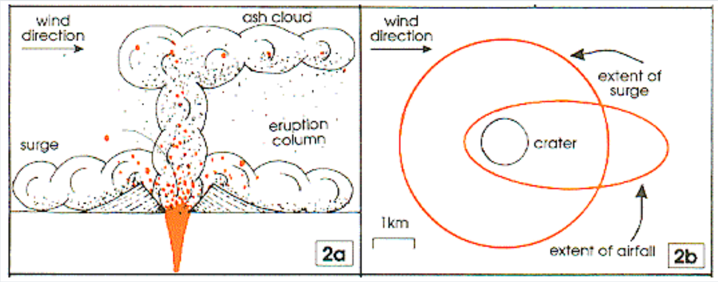
4. The eruption could have a final sequence of phreatomagmatic explosions after the effusion of lava flows (Pupuke volcano).

5. The eruption could produce spatter-fed lava flows during the fire-fountaining (Rangitoto volcano).

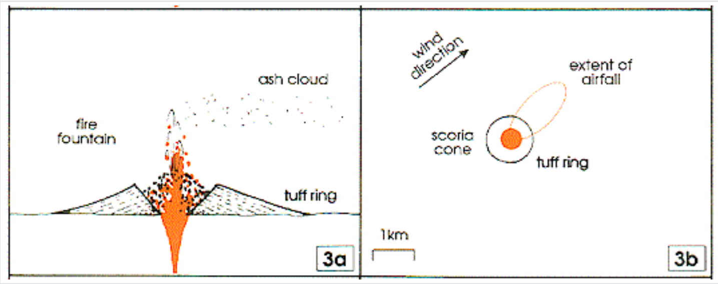
One of the more recent eruptions in the field was the eruption of Mount Wellington. In this eruption an early short lived phase of phreatomagmatic activity was followed by a major episode of fire fountaining which built the mountain. At a late stage in the eruption there was voluminous eruption of lava flows out to the south towards Onehunga. Figure 12 considers the impact which the Mount Wellington eruption would have had on the surrounding dense urban area if it were to happen today.

This series of diagrams illustrates a sequence of events which could potentially happen during the next eruption from an Auckland volcano. The sequence is based on the example of the eruption which formed Mount Wellington about 10,000 years ago.

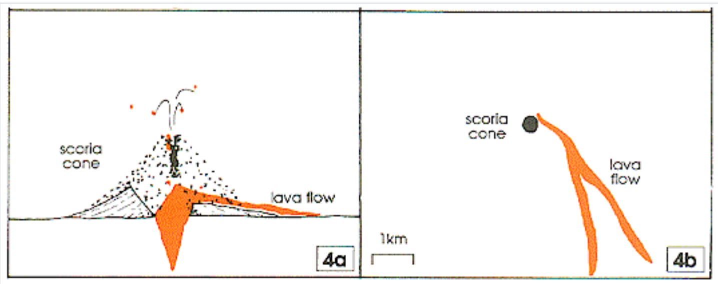
Figure 11. Eruption scenario (1a) Magma is generated from melting of the mantle about 100 km beneath Auckland. (b) Magma rises through the crust to the surface and blasts the surrounding rock to produce a small eruption column of the rock and magma. (c) This process also produces a shock wave which extends radially from the eruption centre.



2a. When the hot magma comes into contact with water, phreatomagmatic explosions occur. Surges blast outwards from the base of the eruption column and the smaller lighter tephra fragments are carried upward in a rising eruption column which is dispersed down wind. The surge and airfall deposits build up a tuff ring. (b) With the wind direction from the west, the airfall tephra is deposited mainly in the easterly direction. The base surges create a tuff ring around the crater. An area up to 1.5 km from the vent is completely devastated.



3a. Once the water no longer reaches the active vent the eruption style changes to fire fountaining. A spectacular fountain of red hot magma fragments rises to heights of several hundred metres and cooled fragments fall around the vent. The area within about 0.5 kilometres from the vent becomes dangerous because of falling hot material. Within several days fire fountains build a scoria cone. (b) The area of the scoria cone is smaller than that of the crater produced from phreatomagmatic explosions. The wind changes direction to the south-east and deposits a small amount of airfall tephra.



4a. The activity declines to spasmodic explosions from the top of the scoria cone. These throw out ballistic bombs. Lava flows emanate from the base of the scoria cone. (b) Lava flows follow low topographical areas.

The first signs of an impending eruption are likely to be small earth tremors and possibly some uplift of the earth's surface above the rising magma. If, when the magma reaches the surface, it comes into contact with water, then instantaneous and continuous phreatomagmatic explosions will occur, building a 500 m high eruption column and propagating shock waves. A large circular maar will be created and the collapse of the column will produce base surges which, with associated air fall tephra, will build a tuff ring.

Phreatomagmatic explosions will continue until the rate of magma exceeds the recharge rate of water supply. The activity will then become dominated by discrete phreatomagmatic explosions alternative between low water:magma phreatomagmatic air fall events and high water:magma base surge producing events. Discrete explosions within the maar will become increasingly dominated by Hawaiian style fire fountaining. As water is excluded from the conduit and further gas rich magma rises to the surface the fire fountaining rapidly builds a scoria cone. Toward the end of the eruption relatively degassed magma effuses out of the vents at the base of the scoria cone or through a breach in the rim to form lava flows. Tephra continues to fall throughout the eruption.

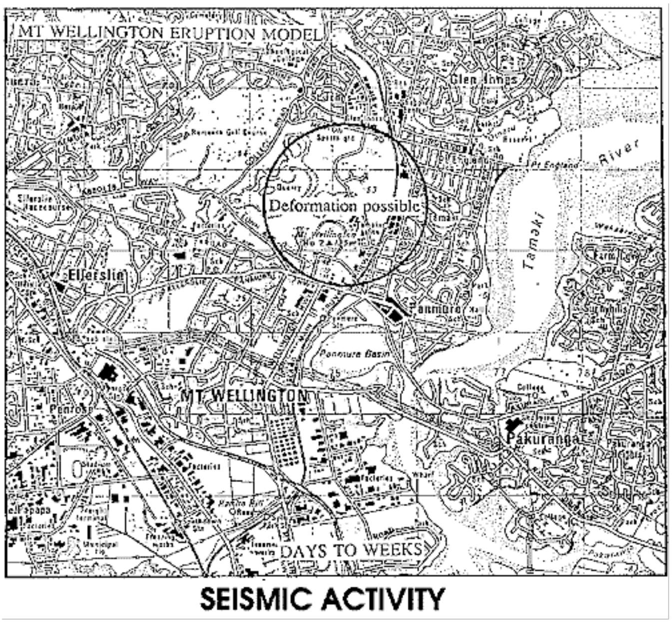


Figure 12(a). Volcanogenic earthquakes (seismic activity) may cause a zone of inflation and uplift (deformation). These events are expected to last a few days to a w eek.

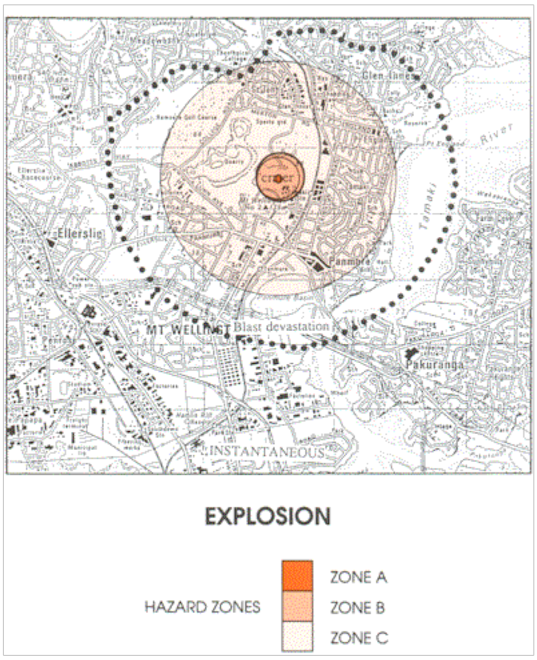


Figure 12(b). Magma reaches the surface, an initial explosion sends a shock w ave radiating out from the eruption point. The area w hich w ould have been devastate by the Mount Wellington blast is defined by the dotted line

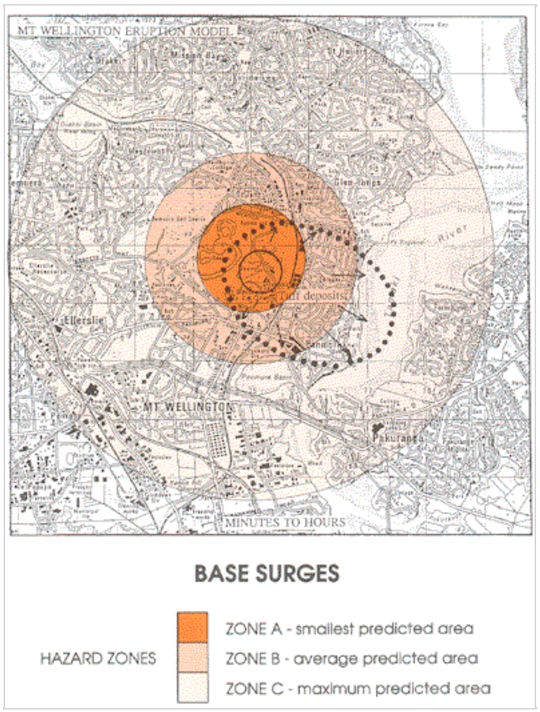


Figure 12(c). A phreatomagmatic explosion creates base surges w hich radiate out from the vent depositing tephra. The extent of the Mount Wellington surge deposit is defined by the dotted line.

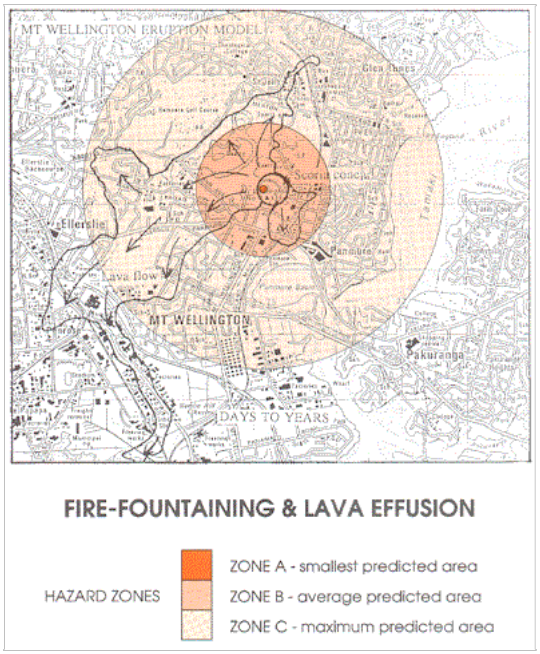


Figure 12(d). Fire fountaining and associated lava flow s build a scoria cone and its surrounding lava field. Note that the hazard zone is show n here as a circular area but in reality lava flow s w ould have been strongly directed by topography.

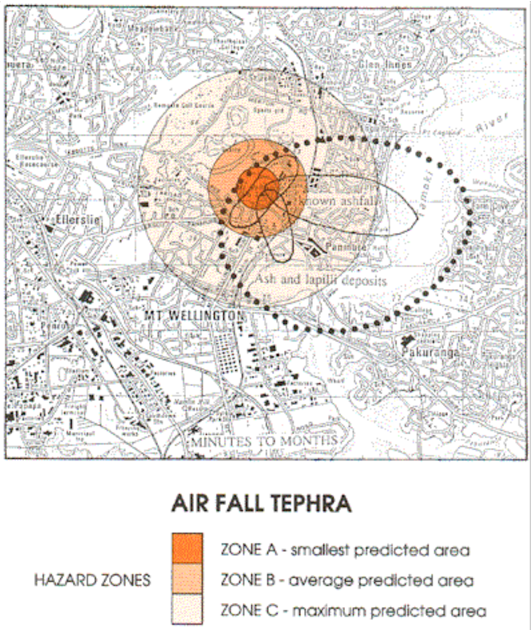


Figure 12(e). Tephra fall is associated with the fire fountaining. In this diagram wind direction has not been accounted for. The extent of the Mount Wellington air fall tephra deposits is shown by the dotted line.

RISK

Auckland is the hub of one of New Zealand's major commercial regions, and makes a significant contribution to the country's export earnings. The preliminary count from the 1991 census indicates the Auckland Region has a population of 953 058 with 321 631 occupied dwellings.

The maintenance of service facilities for the people is vital both for daily living and for an efficient emergency response. Vulnerable facilities include the transport sector (roads, rail, sea, and air), the communication sector (computers, telephone and radio), the energy sector (gas and electricity), and the health sector (water supply and waste disposal). An eruption could block roads, destroy housing and buildings, as well as cutting water supply, sewerage reticulation, electrical power, and telephone and radio services. In the vicinity of the vent total destruction would occur.

Auckland's volcanoes are small although there are indications that in the future they may be bigger. The intervals between eruptions are generations long and it is to be hoped that there will not be another eruption in our particular generation. However, it is important to remember that volcanoes are notoriously unpredictable and that the only safe way to live with volcanoes is to know about their personalities and prepare for them to misbehave.

ACKNOWLEDGEMENTS

Thanks are due to Dr John Latter for comments and support throughout the writing of this booklet.

SUPPLEMENTARY READING

Blong, R.J., 1984: Volcanic Hazards: A sourcebook on the effects of eruptions. Academic Press Sydney, 424 pages. This is the best general account of volcanic hazards available.

Kermode, L.O., 1992: Geology of the Auckland Urban Area. Institute of Geological and Nuclear Sciences Ltd.

Searle, E.J., 1981: City of volcanoes. A geology of Auckland. Longman Paul, 195 pages.

Hazard	Area Affected (km2)	Loss Expected (%)	Possibilities of Control	Immediate Risk	Prolonged Risk
maar	0.35	100	no	extreme	low
base surge	3	50-100	no	high	low
fire-fountaining	0.013	80-100	no	high	low
lava flow	2.97	20-100	yes	high	low
tephra	>2.15	up to 10	no	low	medium

Table 1. Risk classification of the hazards to Auckland. Area affected is taken as the average area covered.

VOLCANOLOGICAL TERMS

Hawaiian: Type of eruption typical of Hawaiian volcanoes in which magma is thrown upward as a fountain of incandescent fragments by the release of magmatic gas.

Maar: A volcanic cone with gently inclined outer slopes and a broad crater with steep inner slopes.

Magma: Liquid rock beneath the earth's surface.

Phreatomagmatic: A volcanic eruption caused when magma mixes with water to cause a violent explosion which is partly steam powered (phreatic) and partly driven by the release of gas from the magma (magmatic).

Pyroclastic: Refers to material which has been fragmented (clastic = broken) during a volcanic eruption (pyro = hot).

Scoria: A deposit consisting of cooled lumps of vesiculated magma ejected during an eruption.

Strombolian: A type of volcanic eruption characteristic of the Italian volcano Stromboli in which eruptions occur as discrete explosions minutes to hours apart.

Tephra: The fragmented material (magma and rocks from the vent area) aerially ejected during a volcanic eruption.

This text is taken from one of a series booklets which cover volcanic hazards at each active or potentially active volcanic centre in New Zealand.

The series was produced by the Volcanic Hazards Working Group of the Civil Defence Scientific Advisory Committee, which includes scientists from the Institute of Geological and Nuclear Sciences and the Universities.

- Booklets published in the series so far are:
- Number One 'Egmont Volcano'.
- Number Two 'Okataina Volcanic Centre'.
- Number Three 'White Island'.
- Number Four 'Kermadec Islands'
- Number Five 'Auckland Volcanic Field'
- Number Six 'Mayor Island'
- Number Seven "Taupo Volcanic Centre'

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