Reconstructing Banks Peninsula's Geologic History through Sand

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Overview

Using a sand model, we can represent these stages of Banks Peninsula's volcanic activity by constructing a scaled version. The stages in making this sand model informs us of the relative style of volcanism, the morphology of the volcanoes, and the erosional process which have occurred to give us the landscape today.

This document provides the steps in creating the stages of Banks Peninsula's construction and destruction through sand modelling.

Purpose

To obtain an understanding of the stages of formation of Banks Peninsula through the construction of a sand model.

The model focuses on the volcanic evolution of Banks Peninsula, the eruptions of each stage, erosion, and the sculpting of the landscape we see today.

Required Materials:

- Tarpaulin (at least 2.5 m x 4 m)
- Map of Banks Peninsula
- Sand (any grain size)
- Shovels
- Broom and dustpan
- PVC pipes
  (any radius – 11cm diameter if wanting to use for Cola and Mentos eruptions)

Model Scale

The sand model of Banks Peninsula is replicated to scale. This is important to gain dimensions of the erupted volcanoes.

1cm = 250m   4cm = 1km

Key Ages of volcanism

Lyttelton Volcanic Group ~12 – 9.7 Million Years Ago

Mt Herbert Volcanic Group 9.7 – 8.0 Million Years Ago

Akaroa Volcanic Group 9.4 – 8.0 Million Years Ago

Diamond Harbour Volcanic Group 8.0-5.8 Million Years Ago

Model Set Up

Height Controls

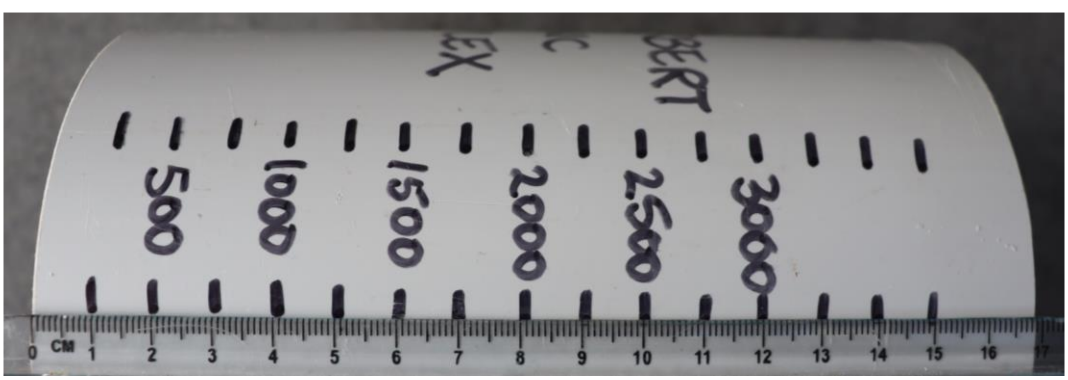
To create a scale version of Banks Peninsula we are going to use a scale in which 1cm = 250m

To help us keep track of the height of the volcanoes three height controls need to be developed. These are constructed out of 11cm diameter PVC pipe, cut into 15 cm lengths.

Height control pipes are placed at Points 1, 2 and 3 in the next stage, representing the vent locations of the volcanoes of Banks Peninsula

On each of the 15 cm PVC pipe sections

1) Draw lines at 1 cm intervals from one end – this will be the base
2) At 2 cm from the end draw a horizontal line and label 500m
3) At 4 cm from the end draw a horizontal line and label 1000m
4) At 6 cm from the end draw a horizontal line and label 1500m
5) At 8 cm from the end draw a horizontal line and label 2000m
6) At 10 cm from the end draw a horizontal line and label end label 2500m
7) At 12 cm from the end draw a horizontal line and label end label 3000m
8) Label each pipe section – Lyttelton, Mt Herbert, Akaroa



Height labelled PVC pipe section

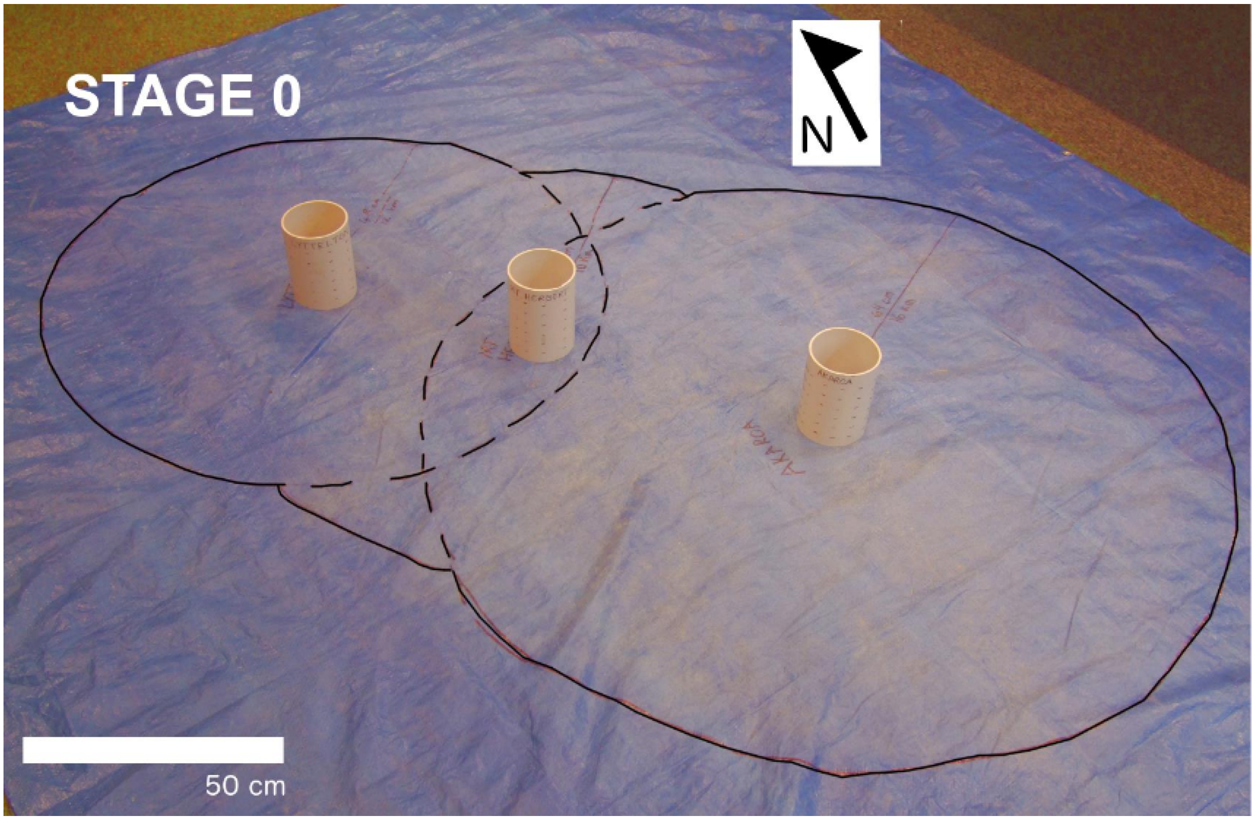
Base – Getting the Correct Proportions

We will be constructing the volcanoes to the extent of what we see in the landscape today, marked by where the land meets the sea – today's sea level.

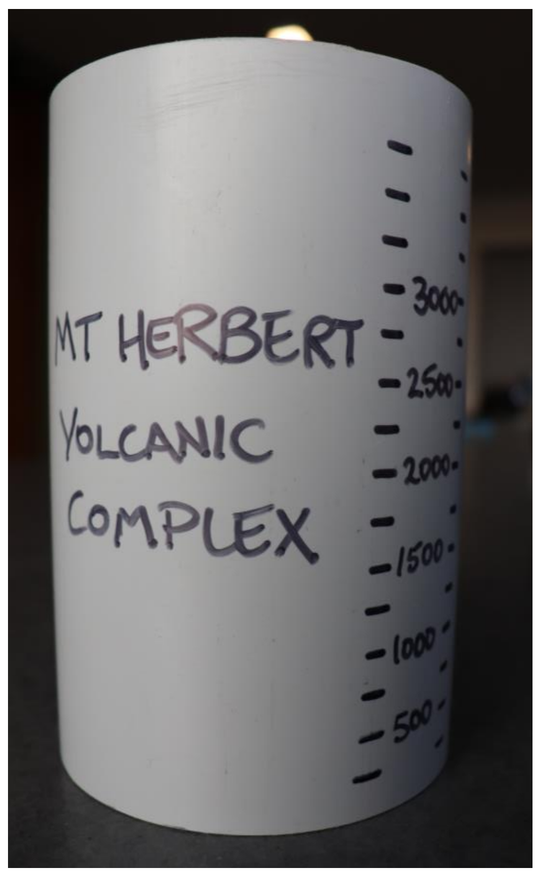
The base for the model uses a tarpaulin of at least 2.5 m x 4 m. On this tarpaulin, we will draw, using a permanent marker, the key parameters required for the sand model.

1) Find the central point within the tarpaulin and mark with an X (Point 1)
2) Imagine a bisecting diagonal line from one corner of the tarpaulin to the other that intersects Point 1
3) Along this imaginary line, measure 40cm, from Point 1, towards the top corner of the tarpaulin – mark an X at this location (Point 2)
4) Once again along the imaginary line measure 88cm from Point 2, intersecting Point 1 – mark this Point 3
5) Using Point 2 as the centre, draw a circle with a radius of 48cm – Label this centre X the Lyttelton Volcanic Complex
6) Using Point 3 as the centre, draw a with a radius of 64 cm – Label the centre X the Akaroa Volcanic Complex
7) From point 1, draw two partial arcs of a circle with a radius of 40 cm – the partial arcs should connect the space between the two larger circles – Label the centre X as Mt Herbert
8) Draw in a scale bar on the tarpaulin – Measure a 20cm line (representing 5km), at 4cm intervals draw tick marks, label these tick marks above the line with cm distances, while below label with km distances

Recommended scale bar set out for base tarpaulinaulin



Base tarpaulinaulin and PVC volcanic centres



PVC Volcanic Centre

Construction

Key to things to think about when using the sand to build the volcanoes.

- The peninsula developed over millions of years and the volcanoes were constantly being eroded. As you build your volcanoes try and incorporate not just the eruptive / constructive phases of volcanism, but the destructive / erosional processes as well

- Some eruptions occurred away from the central vents, with parasitic eruptions forming scoria cones and domes – you can add as much detail as you want

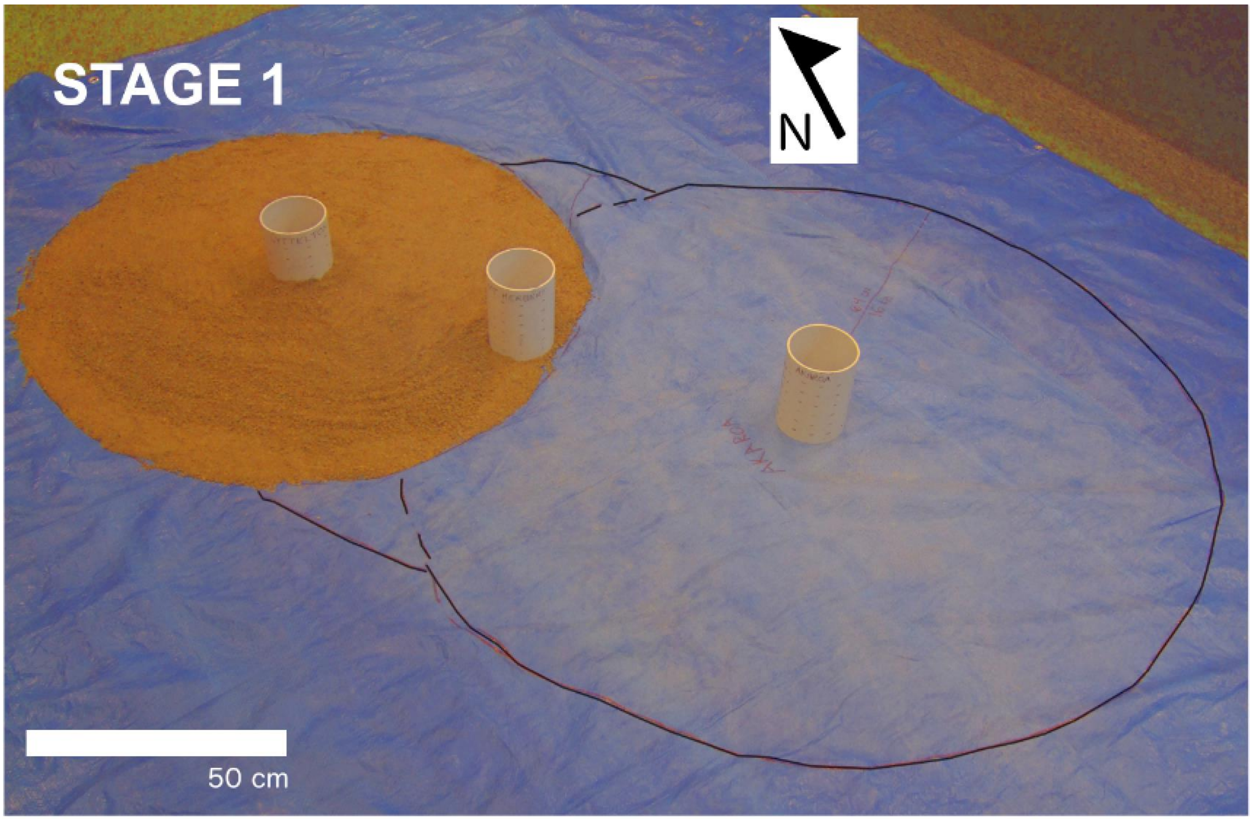
- What were the height of the volcanoes? The model can help inform us of this – it is currently highly debated – use the scale to measure the relative heights, use observations (slopes of the volcano are 8-10 degrees) look at the geomorphology – do you think this looks like a real volcano? Hint – a 9 degree slope has a rise of 160m for a run of 1000m.

- Make a cardboard slope template – measure a base line of 20cm, at one end measure a rise of 3.2cm, rule a line between the two ends of the line – this is you 9 degrees slope template.

- Start constructing the volcanoes. Begin with the oldest.

Stage 1: Volcanism of the Lyttelton Volcanic Complex

Build the Lyttelton Volcanic Complex on the tarpaulin with sand. The sand must be at ~9° angle with the lowest point being around the circumference of the circle and the highest being where the sand meets the PVC pipe.



Sand model of the Lyttelton Volcanic Complex

Questions

What is the height of the Lyttelton Volcanic Complex? (Read this off the height marker)

What is the slope and shape of the Lyttelton Volcanic Complex?

What can the slope and shape of the volcano tell us about the type of lavas that formed it?

Answers

What is the height of the Lyttelton Volcanic Complex? (Read this off the height marker)

~1400m

What is the slope and shape of the Lyttelton Volcanic Complex?

Low profile, gradual slope, shield like

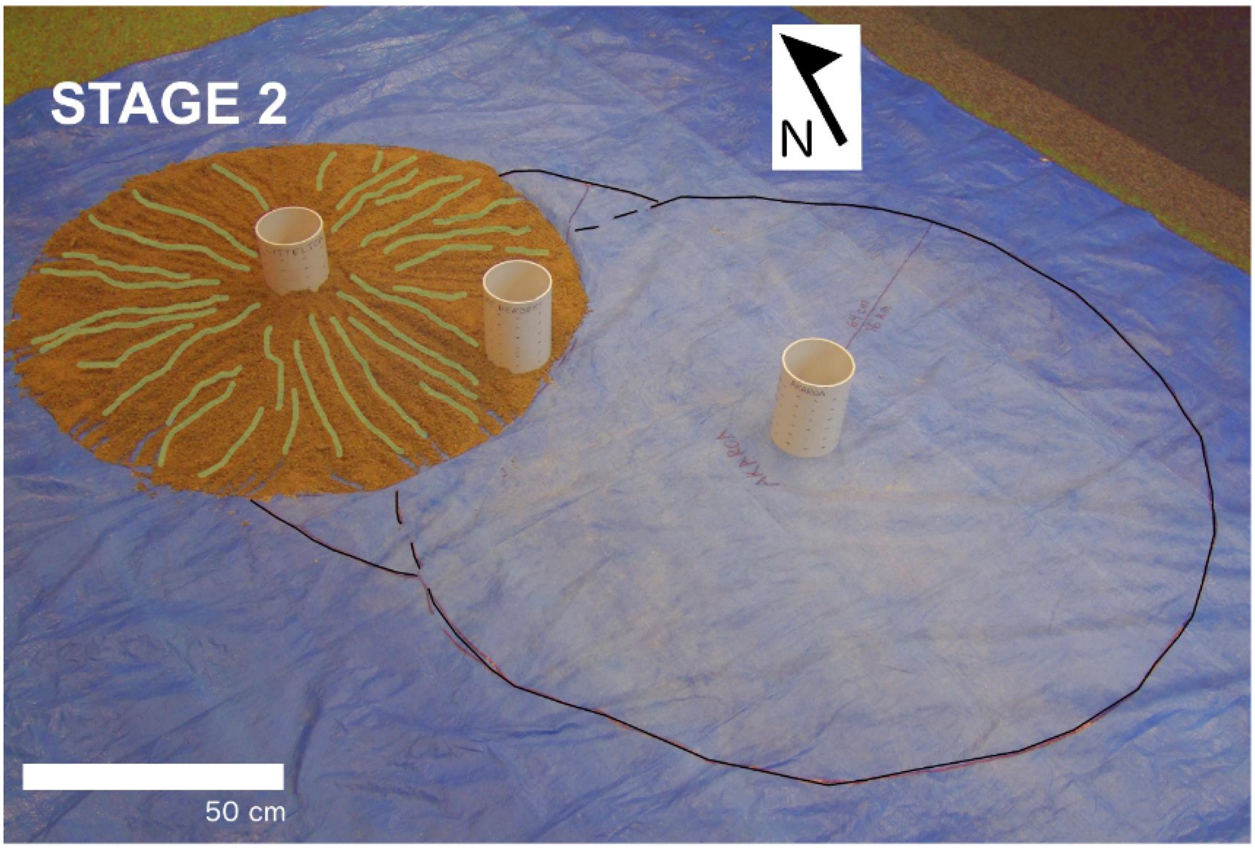
What can the slope and shape of the volcano tell us about the type of lavas that formed it?

The shape of a volcano is controlled by the type of magma / lavas erupting.
Basaltic magma Basaltic (SiO_2 45-55 wt%), fluid – gas released, low angle sloped volcanoes – Maunu Koa
Andesitic magma (SiO_2 55-65 wt%), sticky – gas stuck, steep sloped volcano – Mt Taranaki
Rhyolitic magma (SiO_2 65-75%) – very sticky – gas stuck – caldera (collapsed) – Lake Taupo

Stage 2: Radial erosion of the Lyttelton Volcanic Complex

Weathering and erosion occurred during volcanism. Erosion on a cone forms radial drainage, "like spokes on a bike wheel", creating valleys and ridges. Using your fingers, drag from the highest point of the volcano to the lowest, creating valleys.

Remove excess sand from the volcano.



Radial erosion on the sand model of the Lyttelton Volcanic Complex

Questions

Where would water flow down the sides of the volcano?

Where would have the removed material have gone?

Answers

Where would water flow down the sides of the volcano?

Water would have flowed down the sides of the volcano. As it moves it removes material, a process termed erosion. Over time, localized removal of material causes the formation of valleys, with erosion being focused in these areas further growing the valley system.

Where would have the removed material have gone?

Sea level was at a similar level to today when the volcanoes erupted. This tells us that during eruptions Banks Peninsula was an island, and that the ocean waves and currents were able to transport material away from the volcano.

Stage 3: Volcanism of the Akaroa Volcanic Complex and early Mt. Herbert Volcanic Group

Fill in the Akaroa circle of the tarpaulin with sand. Build the slopes so that they are at ~9˚ angle with the lowest point being around the circumference of the circle and the highest being where the sand meets the PVC pipe.

Build up some sand around the vent of Mt. Herbert, but do not fill out Mt. Herbert's footprint.

Mt. Herbert and Akaroa volcanism started at similar times, with Akaroa's rate of volcanism being greater than that of Mt. Herbert.

Sand model of the Akaroa Volcanic Complex (right) and early eruptions of Mt Herbert Volcanic Group (middle)

Questions

What is the height of the Akaroa Volcanic Complex? (Read this off the height marker)

What features formed between the two larger volcanic complexes of Akaroa and Lyttelton?

Answers

What is the height of the Akaroa Volcanic Complex? (Read this off the height marker)

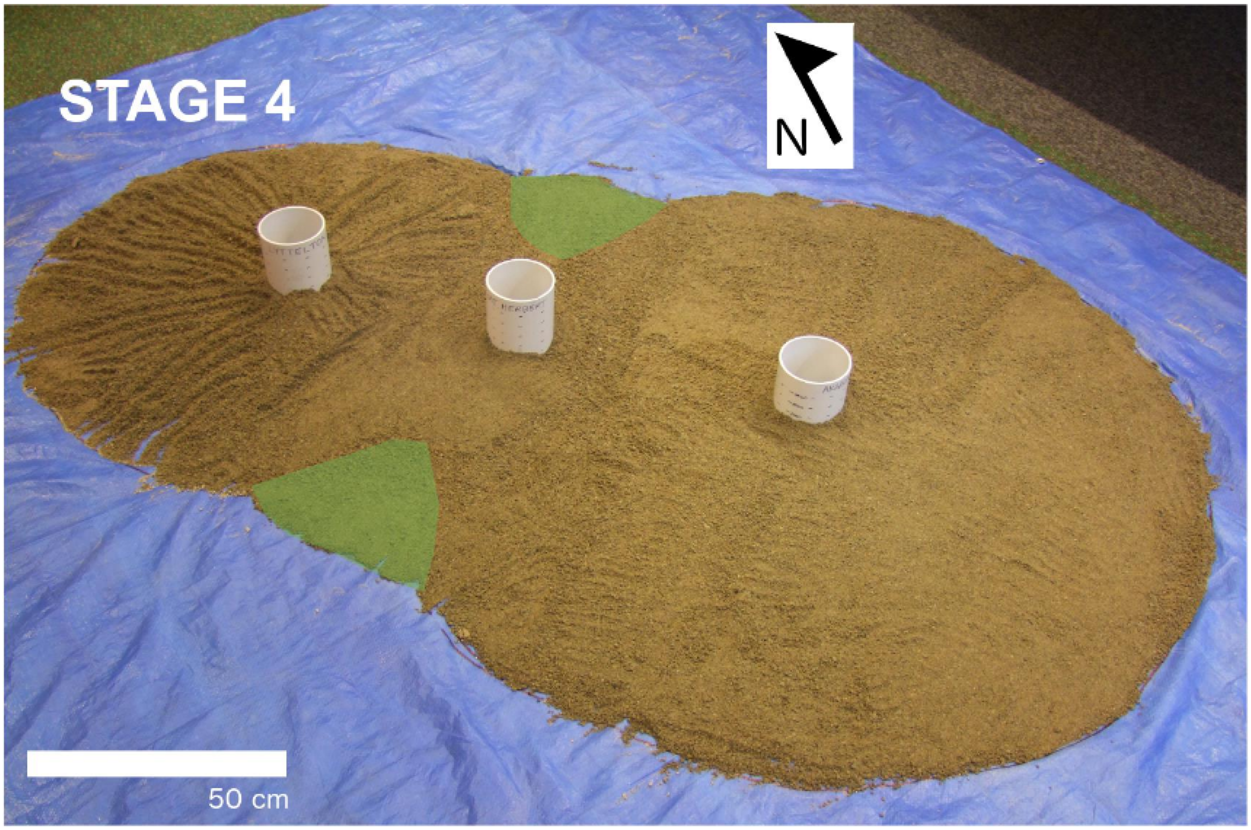
About 1800m

What features formed between the two larger volcanic complexes of Akaroa and Lyttelton?

Two large valleys formed between the slopes of Akaroa and Lyttelton Volcanic Complexes.

Stage 4: Later Eruptions of Mt. Herbert Volcanism

Due to being situated between the two larger volcanic complexes of Lyttelton or Akaroa, Mt. Herbert lavas infilled the landscape between them. Fill in the footprint of Mt. Herbert, with the sand at ~9˚ angle from the edges to the vent.



Later eruptions of the Mt Herbert volcanism infilled the areas between Lyttelton and Akaroa Volcanic Complexes

Questions

What directed where the lava flows of Mt Herbert went?

Mt Herbert is now the highest point on Banks Peninsula (922m). Mt Bradley and Mt Herbert have almost flat lying lava flows. What would have cause these to be flat lying?

Answers
What directed where the lava flows of Mt Herbert went?

The pre-existing landscape / topography. The two large valleys between Akaroa and Lyttelton Volcanic Complex.

Mt Herbert is now the highest point on Banks Peninsula (922m). Mt Bradley and Mt Herbert have almost flat lying lava flows. What would have cause these to be flat lying?

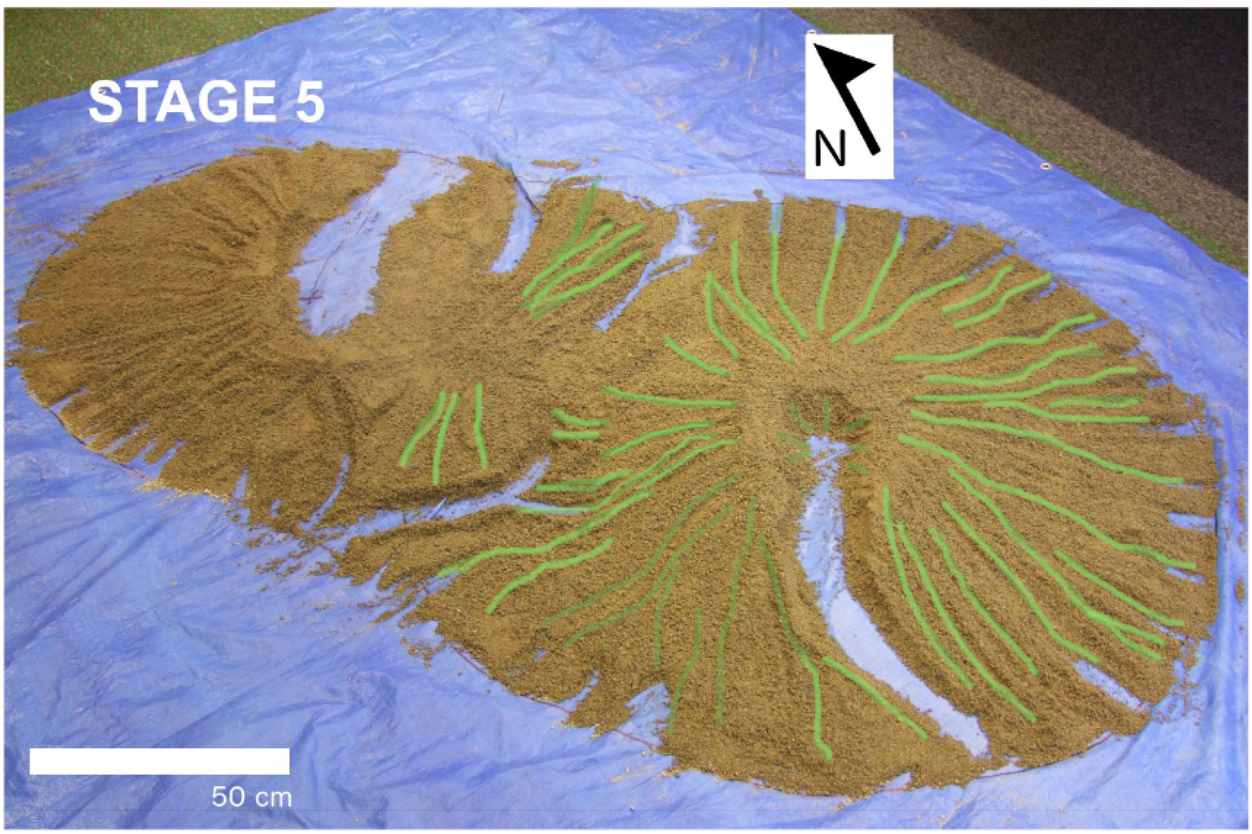
Mt Herbert flows in the inner parts of Banks Peninsula were controlled by the existing landscape. In the central parts, the large valleys on Lyttelton Volcanic Complex were infilled by lavas. Over millions of years the surrounding rocks of the Lyttelton Volcanic Complex eroded, leaving the flat lying lavas exposed.

Stage 5: Radial Erosion and Development of Lyttelton and Akaroa Harbours

Using your fingers, drag from the highest point of the Akaroa Volcanic Complex to the lowest, creating valleys. Do this also for the lava flows of Mt Herbert.

We know that extensive erosion, resulting in removal of material from Banks Peninsula occurred rapidly after the end of periods of volcanism. Remove the central PVC pipes and start to sculpt the landscape, do this be using an image of Banks Peninsula as a reference to remove the sand forming Lyttelton Harbour, Akaroa Harbour and major valleys between stages of volcanic stages.

Major valleys formed where two volcanic stages contacted, for example, Mt Herbert flows on top of Lyttelton Volcanic Complex forming Port Levy and Pigeon Bay valleys. Remove excess sand.



Radial erosion of the volcanic landscape of Akaroa and Mt Herbert Volcanoes, and removal of material in the harbours and main intersecting valleys

Questions
Why did the contact between different stages of volcanism control the development of the larger valleys and bays (Kaituna, Little River, Port Levy and Pigeon Bay)?

What is the main process that formed the harbours?

Answers

Why did the contact between different stages of volcanism control the development of the larger valleys and bays (Kaituna, Little River, Port Levy and Pigeon Bay)?

The difference in rocks type and the way that the later lava flows infilled existing topography. Lava will flow down low points in the landscape, like old valleys, if the area is not completely infilled drainage will still occur in these zones. In this case, this caused new erosion valleys to the edges of the Mt Herbert lava flows.

What is the main process that formed the harbours?

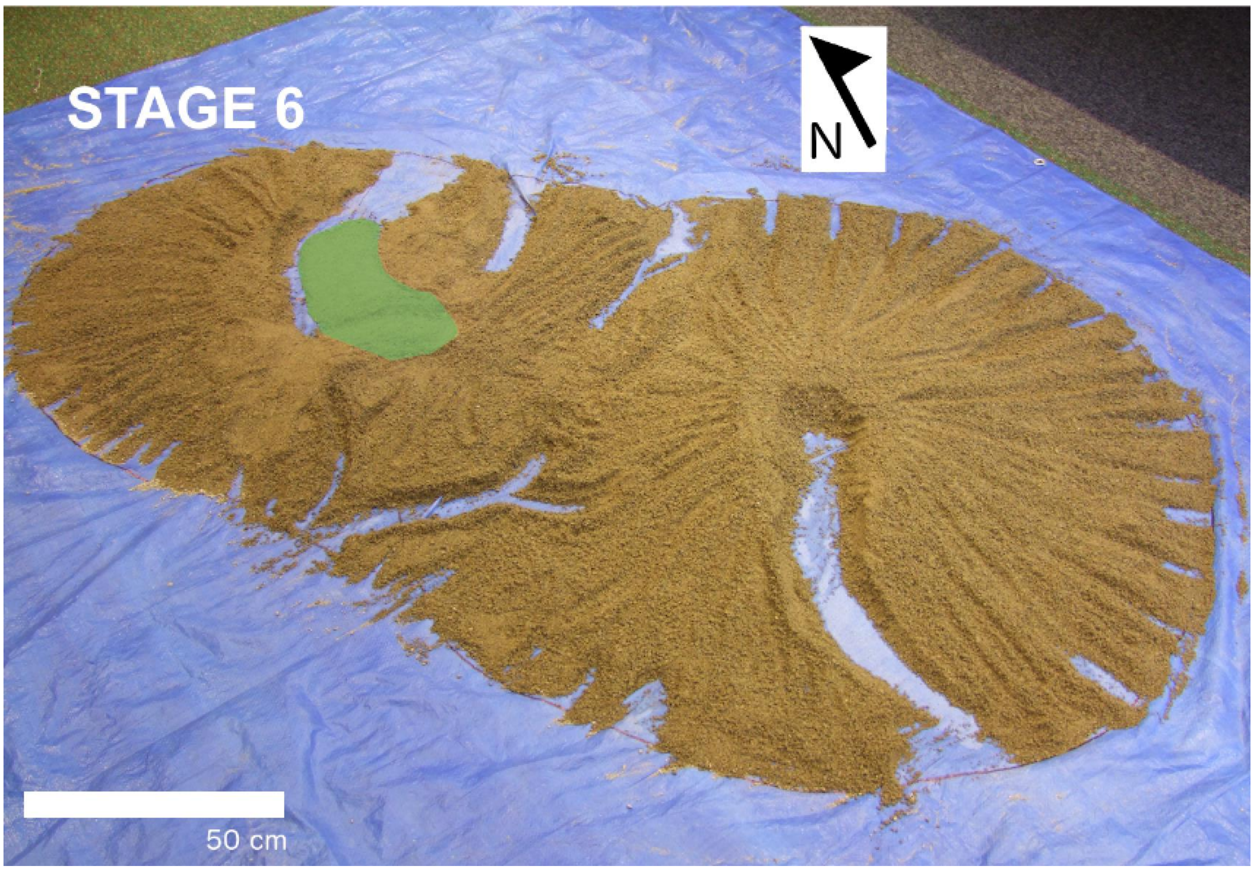
The harbours are a result of erosion. One of the main valley systems became the dominant drainage, leading to the rapid incision and erosion of the central crater area.

Stage 6: Diamond Harbour Volcanic Group Eruptions

We now have an eroded volcanic landscape on which the Diamond Harbour Volcanic Group erupted. The largest Diamond Harbour eruption occurred near the side of Mt Herbert, erupting lavas that invaded Lyttelton Harbour.

Lavas flows from these eruptions make up Diamond Harbour, the seaward end of Purau, Pile Bay, Ripapa Island, Shag Reef, Quail Island and Black Point. Using the geologic map as a guide, erupt lavas into Lyttelton Harbour.

Although this is the most significant flow of the Diamond Harbour Volcanic Group, it is not the only one.



Main eruptions of the Diamond Harbour Volcanic Group into an eroded Lyttelton Harbour

Questions

In terms of landscape evolution, what had to be in existence when the Diamond Harbour Volcanic Group eruptions happened, and how did it influence the lava flows?

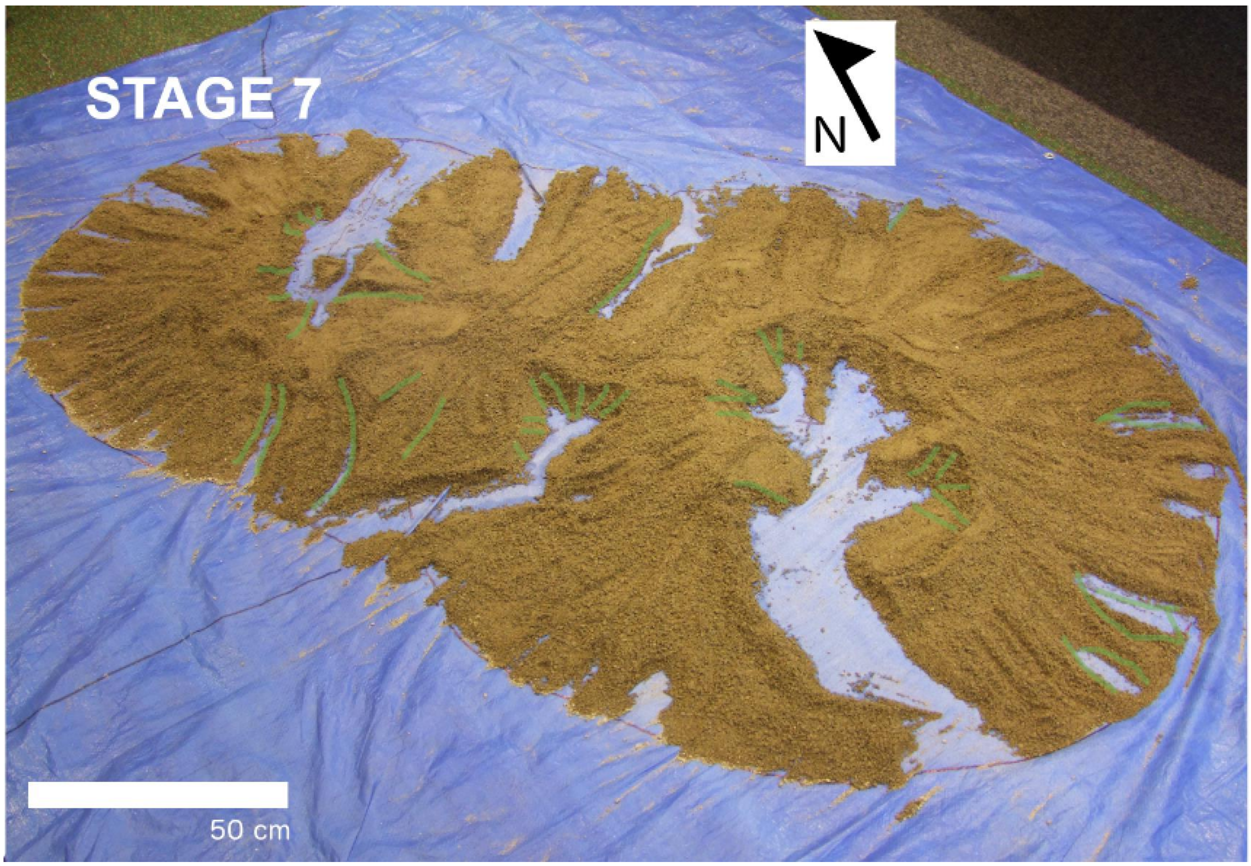
Answer
In terms of landscape evolution, what had to be in existence when the Diamond Harbour Volcanic Group eruptions happened, and how did it influence the lava flows?

Lava flows invaded Lyttelton Harbour indicating that the landscape was already highly eroded, and that a Lyttelton Harbour was already there. The eroded landscape, directed where lava flows went, following valleys and river drainages in the area.

Stage 7: Millions of Years of Erosion Creating the Current Topography

This last stage is to create your model into the landscape we see today. Using a map or image of Banks Peninsula carefully erode and shape the sand to look like today's landscape.

Remove excess sand.



Eroded present day landscape of Banks Peninsula

Questions

Does your sand model look like todays landscape? If not what is missing?

What would you need to add to your sand model to match the present landscape, and what processes are responsible for this?

Answers

Does your sand model look like todays landscape? If not what is missing?

Yes, but it is missing the connection to the mainland

What would you need to add to your sand model to match the present landscape, and what processes are responsible for this?

The connection to the mainland by the alluvial the Canterbury Plains – Braided rivers. Lakes and Estuaries – Kaitorete Spit, Brighton Spit, Ihutai / Avon – Heathcote Estuary - Fluvial processes.

Infilled beaches and bays - longshore drift currents carrying sands and gravels from the braided rivers of the Canterbury Plains.

A thin layer of windblown sand and silt (loess) – periods of glaciations in the Southern Alps

Optional Demonstration: Mentos and Cola Eruptions

Materials Needed for Three Eruptions
3 X 1.5 L Diet Coke or Diet Cola
2 X Packs of Mentos
Toothpicks
Stopwatch

Purpose
Demonstrate different types of eruptions based on magma gas content and viscosity.

Setup
Prepare three sets of Mentos. We recommend making holes through the centre of each Mentos and threading these onto a toothpick (3-5 Mentos).

Prepare lids – these provide variables for our volcanos vents. Using an electric drill with drill bits drill through the plastic caps.

1) Make one lid with a large diameter hole – represents an effusive eruption – lava flow
2) One lid with three small holes – represents an explosive eruption – fire fountaining
3) One lid with one small hold – represents an explosive eruption – ash fall

Instructions
Place each bottle in the PVC pipe.

Select cap. Thread Mentos loaded toothpick onto the lid (Mentos on the screw side).

Keep hold of the toothpick at all times.

Screw cap onto bottle – hold toothpick.

Timer – record the duration of the eruptions using stopwatch.

When ready, release the Mentos loaded toothpick and step away from eruption.

Why Mentos and Coke Reacts
The eruption is a result of a physical process rather than a chemical reaction. There is a lot of carbon dioxide dissolved in the soda, which gives it its fizz.

When you drop a Mentos into the soda, tiny bumps on the candy surface give the carbon dioxide molecules a nucleation site or place to stick. As more and more carbon dioxide molecules accumulate, bubbles form.

Mentos candies are heavy enough they sink, so they interact with carbon dioxide all the way to the bottom of the container.

The bubbles expand as they rise. The partially dissolved candy is sticky enough to trap the gas, forming a foam. Because there is so much pressure, it all happens very quickly. The varying openings of a soda bottle caps direct the foam to make an eruption.

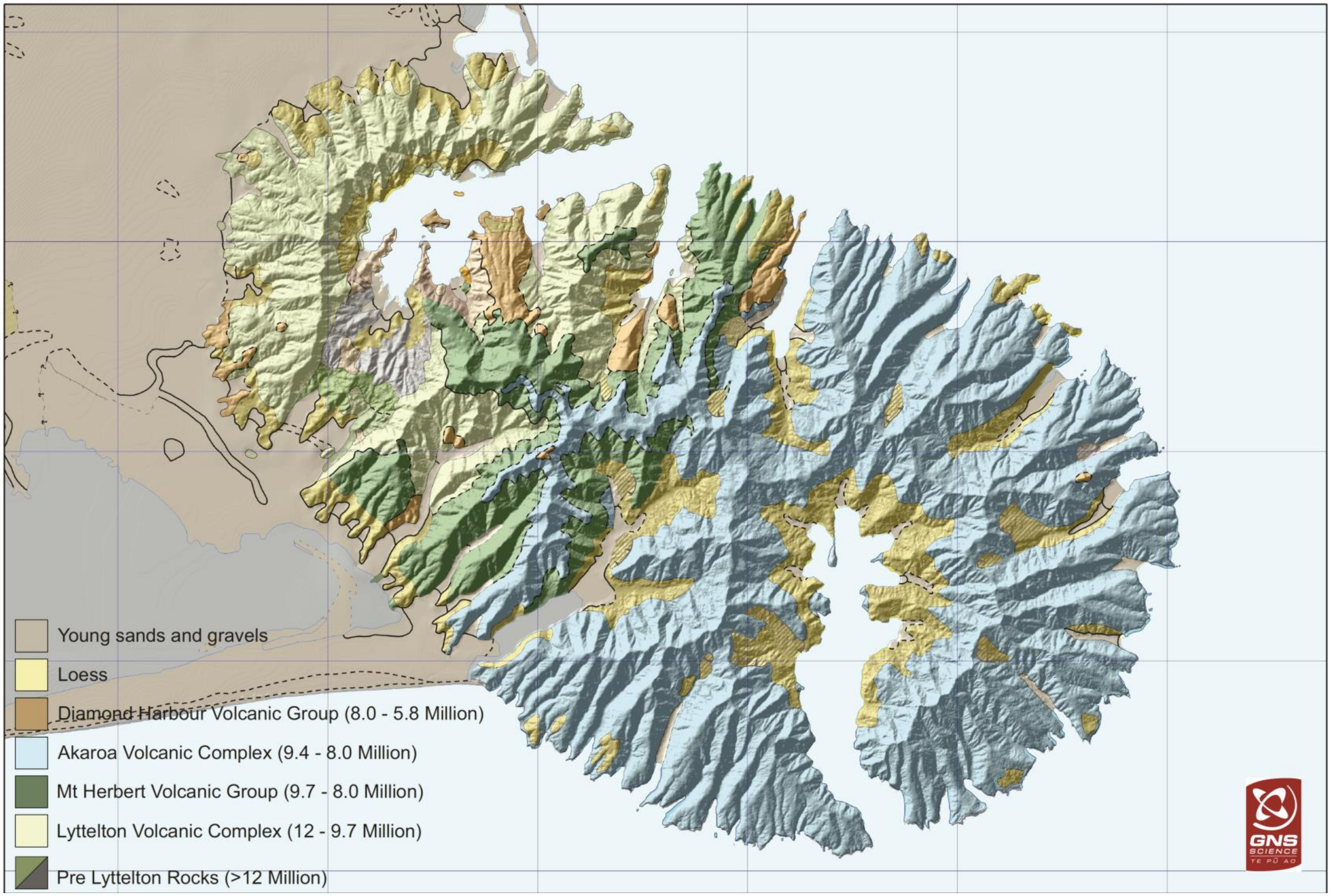
Eruption Observation Questions

Which eruption lasted the longest – why do you think it did?

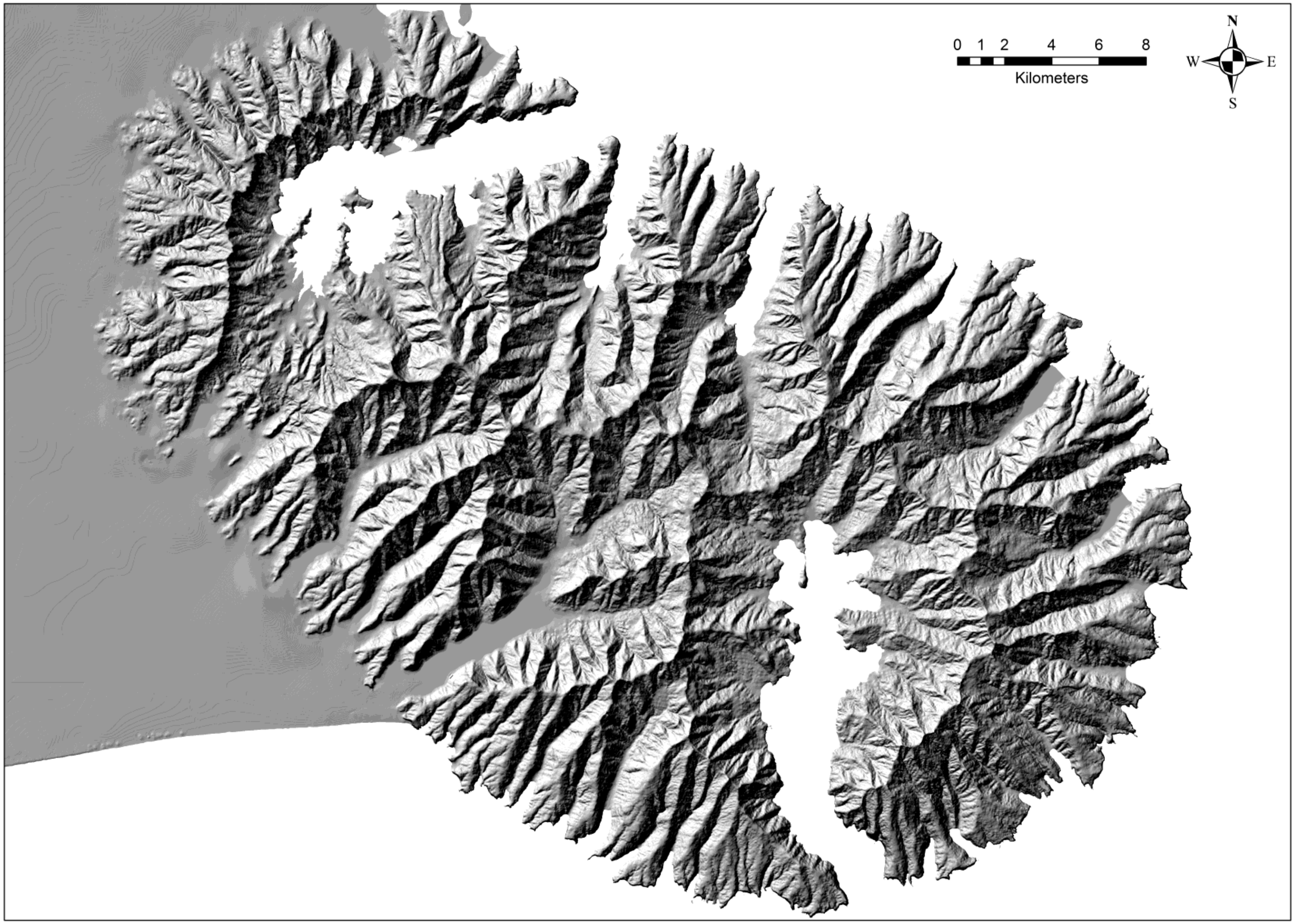
What eruption went the furthest distance?

What controlled the direction of the eruption deposits?

Additional Resources



Geological map of Banks Peninsula.



Digital elevation model of Banks Peninsula showing the present day topography.

Satellite view of Banks Peninsula – white discolouration is suspended sediment in ocean currents and eddies. (NASA)