IAG
GEOMORPHOLOGY
GEOMORPHOLOGIE
AIG

11TH IAG INTERNATIONAL CONFERENCE ON GEOMORPHOLOGY

FIELDTRIP GUIDE

LANDSCAPE LAYERS OF TE PĀTAKA-O-RĀKAIHAUTŪ BANKS PENINSULA: VOLCANIC AND SOIL GEOMORPHOLOGY AND THEIR CONNECTIONS TO PLACE

2026

11TH IAG INTERNATIONAL CONFERENCE ON GEOMORPHOLOGY

2–6 February 2026

Christchurch, New Zealand (Ōtautahi, Aotearoa)

COMPILED FOR THE 11TH IAG INTERNATIONAL CONFERENCE ON GEOMORPHOLOGY

ŌTAUTAHI, AOTEAROA
CHRISTCHURCH, NEW ZEALAND
2026

Cover Photos: Wairongomai-Mangarara (Credit: Ian Fuller), Aoraki Mt. Cook National Park (Credit: Sam McColl), and Waikato at Taupo (Credit: Sarah McSweeney).

Landscape Layers of Te Pātaka-o-Rākaihautū Banks Peninsula: Volcanic and soil geomorphology and their connections to place

Sam Hampton[1], Peter Almond[2]

Affiliation 1. Te Pātaka-o-Rākaihautū Banks Peninsula Geopark Trust (email: bankspeninsulageopark@gmail.com)

Affiliation 2. Department of Soil and Environmental Sciences, Lincoln University, Lincoln, New Zealand

Introduction

This field trip explores the eroded Miocene volcanic landscape of Te Pātaka o Rākaihautū Banks Peninsula (Figure 1). It looks to showcase the processes that have left their geomorphic signatures in the landscape. But the trip goes beyond the physical landscape by layering the cultural, historical and environmental dimensions and how these are being developed as the basis for a Geopark on Te Pātaka o Rākaihautū Banks Peninsula. The field trip will cross into private land to an isolated and rarely visited coastal exposure with spectacular cliffs, volcanic deposits, valley fill sequences, and a NZ fur seal colony. This tour will take you to a spectacular location that will give you the essence of Te Pātaka-o-Rākaihautū.

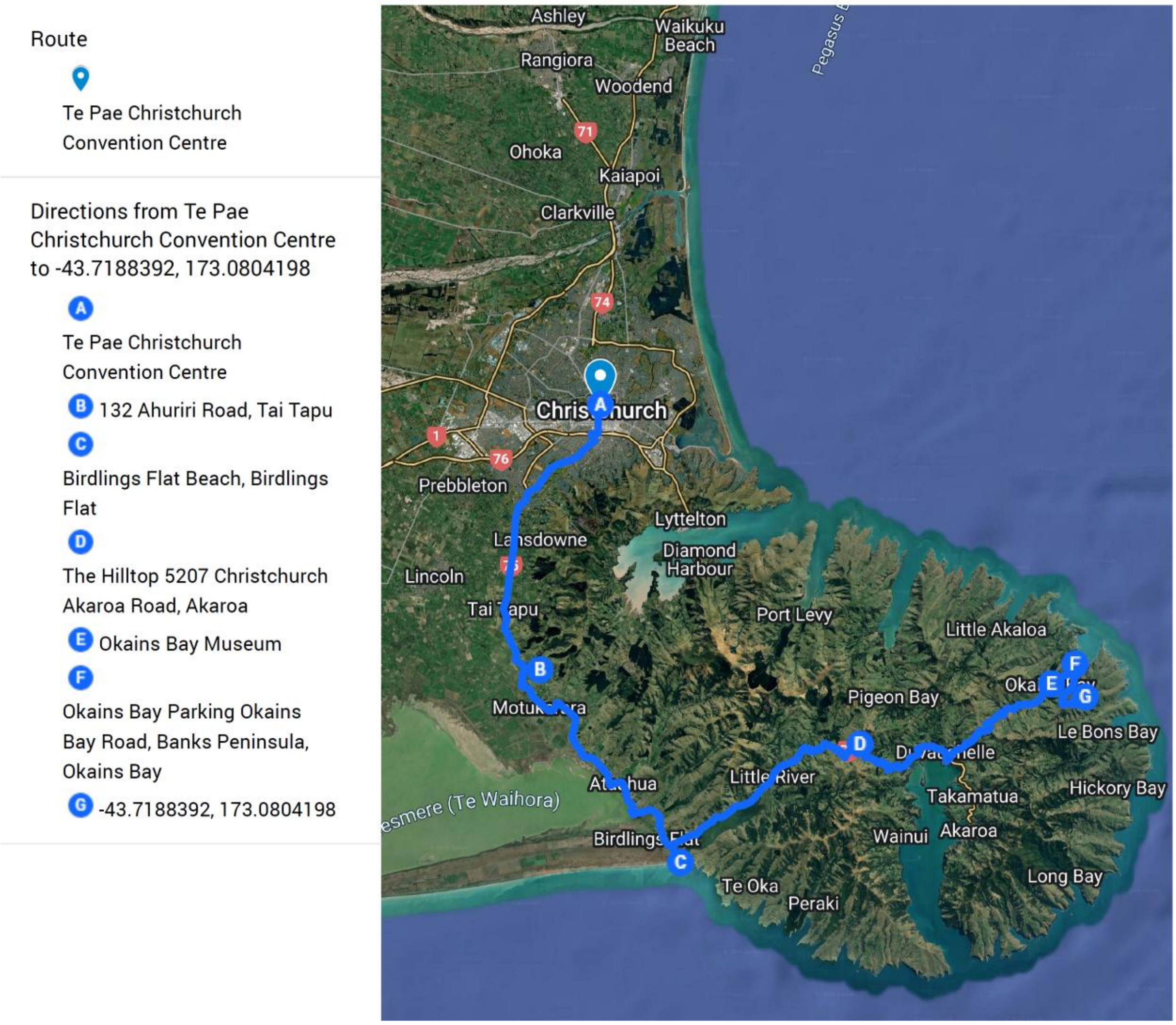

Figure 1. *Route map.*

Geology and Geomorphology of Banks Peninsula

The bays, harbours and valleys around the Peninsula are sculpted. For Papatipu Rūnanga, this sculpting was at tip of Rakiahautu's kō (digging stick), which now rests at Tuhiraki (Mount Bossu). Geologists prescribe this sculpting to long-lived processes driven by rain, wind, oceans, and waterways.

But what was here before the sculpting? The shape of Banks Peninsula is the result of four episodes of volcanism 12 – 5.8 million years ago (Figure 2). This grew the two large volcanic complexes of Whakaraupō / Lyttelton and Akaroa. Between these two larger volcanic edifices, eruptions of the Te Ahu Patiki / Mt Herbert occurred, infilling the area between the Whakaraupō / Lyttelton and Akaroa with lava flows descending to the valleys below. Smaller discrete eruptions (Diamond Harbour Volcanics) then occurred about the Peninsula. The largest and latter stages of these Diamond Harbour eruptions flowed into the already eroded crater of Whakaraupō / Lyttelton, which at this point had large rivers draining out to sea via the same route as the present-day harbour (between 7-5.8 million years ago).

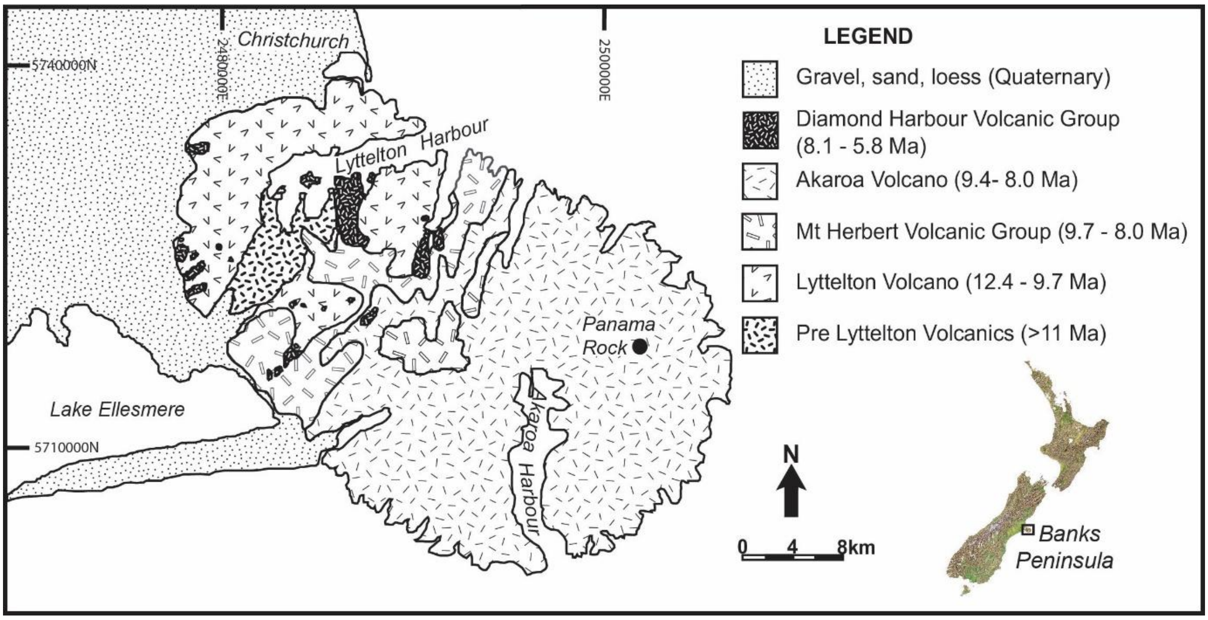

Figure 2. *Geological map of Banks Peninsula, illustrating the location and age range of the five main volcanic groups at Banks Peninsula (adapted from Hampton and Cole, 2009).*

Overlying the volcanics and contrasting starkly are thick yellow "clay" deposits. An amateur, John Hardcastle, a newspaper editor from Timaru, working on loess near his hometown late in the 19th century, deduced it accumulated slowly as dust trapped by vegetation. He also noted it was separated into distinct, thick, layers. His lasting contribution was the realisation that the periods when loess accumulated were times of cold climate, when long glaciers snaking down the valleys of the Southern Alps spewed masses of finely ground rock to be spread by the rivers flowing across the plains and then blown by strong glacial winds. The periods between the layers correspond to the intervening warm periods, when glaciers retreated to their high alpine refuges and the supply of ground rock diminished.

So, the thick “clay” you see on the hillsides of Banks Peninsula is mostly silty dust blown from the riverbeds of the Rakaia and Waimakariri Rivers. Thanks to Hardcastle we also know that this serves as a record of environments and climates of the past.

The loess now blanketing the Peninsula is of course not the pristine dust blown from the riverbeds. Accumulating slowly and residing for tens to hundreds of thousands of years, it has been modified by soil forming processes. In fact, it is the soil profiles that form in the warm periods with little loess accumulation that allow us to distinguish the different periods of loess accumulation.

How those soil processes have altered the loess varies from the lower flanks to the summit ridges of the Peninsula. Down on the dry lower flanks, the loess is only weakly affected by chemical weathering processes, and it has a pale colour, acknowledged in its classification as a Pallic Soil in the New Zealand Soil Classification. The dry summers and wet winters cause a compact subsurface pan to form, known as a fragipan. These soils are prone to cracking. Together, the pan, cracked upper horizons and a perched water table above the fragipan lead to a characteristic erosion pattern on steeper slopes mantled with thick loess.

Water flowing down cracks disrupts the weakly weathered soil, and as the water flows downhill above the fragipan, it forms small tunnels. Over time, especially where the water can gush back out to the ground surface lower down the slope, the dispersed soil flows out, the tunnels quickly enlarge, and they eventually collapse to form a long open gully. This erosion style is called tunnel gully erosion and it is most notable on the north facing slopes on the lower flanks. Good examples are seen on the north facing slopes of Prices and Kaituna Valleys.

The barrier to water percolation provided by the fragipan means that deeper into the loess it is not well flushed with water (leached), it is alkaline, and there can even be concentrations of lime. These conditions are favourable to preserving bone, and it is possible to find well preserved moa bones deep in the loess outcrops.

Higher up the more humid climate has weathered the loess more, the soils are browner and more humus rich, again reflected in their classification as Brown Soils. Because the rainfall is higher and more equally spread through the year there is no fragipan and the soils drain well. The tunnel gully erosion disappears but soil slips become more common. Spectacular examples, whose scars are still evident, occurred in and around Hinewai at higher elevations in storms in 2021. Both kinds of erosion have probably increased markedly since the removal of the cloak of forest on the peninsula, although they would always have occurred to an extent.

Higher on the peninsula, further from its source, the loess is thinner, it tends to have more clay, and erosion processes have mixed it more with the underlying basaltic volcanic rock. Consequently, it is more enriched in important nutrient elements like calcium, magnesium and phosphorus. The minerals found in the dust blowing from the riverbeds owe their origin to the greywacke sandstone of the Southern Alps, a much more nutrient deprived rock.

Te Pātaka-o-Rākaihautū/Banks Peninsula was a volcanic island connected only recently to the mainland by building out of the Canterbury Plains by the braided rivers. But long before that connection, a wind bridge linked the two, bringing sediment of the Southern Alps in the form of loess to contribute to the great variety of soil, habitat, vegetation and culture on Banks Peninsula.

A Scarred Landscape

When pakeha arrived, the Peninsula was clad in dense podocarp forest (tōtara, mataī, kahikatea). Yet it was towards the sea that the first resource was discovered and exploited. Whalers found bountiful sources near shore, in the form of Right whales and migrating Humpback whales. Various whaling stations developed in bays with sheltered waters and available lookout points. On the land the whale carcasses were flensed and butchered and the blubber processed into oil by boiling in trypots. Nearby timber was cut and used for the whaling infrastructure and for fuelling the fires under the trypots. Today trypots and scattered whale bones are all that is left of this boisterous but destructive industry.

However, the call of the forests followed. Once great trees were felled, with the timber harvested being processed in locally developed sawmills. At first the felled logs were sawn by hand in dug sawpits, with the processing evolving to the use of steam driven mills. This dressed timber, exported by sea, went towards the construction of Christchurch City. Not only mills were built – jetties were constructed, and bush rail tracks laid down connecting mills to jetties. Today little remains of the podocarp forests, the sawmills, and the wharfs, but the scars in the landscape remain as stark reminders. Tōtara stumps, resistant to decay due to a natural chemical Totarol, remain as grey ghosts scattered amongst the grassed paddocks. Hand dug chutes where logs slid are now angular grooves in the valley sides.

Once the prized timber was harvested, deliberately lit fires destroyed the unvalued trees and the under-bush which remained, thereby clearing the land to make way for the sowing of grass, to reap its seed, much needed to help create Aotearoa/New Zealand as a pastoral country. For many years the cocksfooting industry exported grass seed throughout New Zealand and as far as Australia. Clear-felling and burning ravaged a land already under attack. Only the wetter and inaccessible forest areas escaped, becoming isolated arks or refuges amongst the introduced grasslands. With the loss of the great forests, and inevitably, further loss of life followed, and loss of an abundance of life at all levels. A loss of local systems, a loss of balance, a loss of mauri (life force).

Valley floors with their flats became dairy farms, local dairy processing factories were built, with products shipped offshore from local jetties. Remnants of rusting jetty pylons may still be seen in many bays today. On the surrounding hill slopes pastoral farming predominated. Sheep and cattle roamed the hills in paddocks, fenced with wire and tōtara fence posts. As a testament to the longevity of totara, totara fence posts still stand throughout the Peninsula.

For many settlers, transport by sea was the only option. It was not until later that tracks, and then roads, were cut into the valleys, hills, and ridges. And later still, quarries were carved into cliffs for fill for tracks and roads, for ballast for rail, for rocks for breakwaters. The crushed rock transported, the railway embankments built, hastened the connection of Wairewa / Little River to Christchurch by steam train. The trains are long gone, but the embankments remain, now used as cycle tracks.

Today, in many of the valleys, you can still find the descendants of these early pioneers, with many still working the land. However, present farming practices follow a style of low impact, low intensity farming, with farmers reading the land, the climate, the soils, and balancing stock to the seasons.

The forest remnants, by chance or by characteristics, that survived the ravages of pakeha settlement are today jewels in the crown of the Peninsula. These arks or refuges are biodiversity hotspots, now encouraged to spread, supported by eager communities.

A Geopark on Banks Peninsula

A Geopark on Banks Peninsula would provide a mechanism that can collaboratively educate and promote learning about and on the Peninsula while creating opportunities and forming a mechanism that is focussed on "slow" tourism and engaging our local populations. It provides a guide for visitors to discover extraordinary landscapes, places, and people. It's a soft framework, with no restrictions or constraints, but a vehicle that together, as a community, can celebrate the Peninsula.

The Banks Peninsula Geopark Trust has developed a Geopark model, tailored for the Peninsula. This is a holistic model, that weaves together the layers that make the Peninsula what it is today (geological heritage, natural heritage, cultural heritage, intangible heritage, human histories, and communities). On the ground the Geopark would be comprised of interpretation panels scattered along publicly accessible tracks or virtually hosted, passing on knowledge, informing behaviours, connecting people to places, sharing intertwined stories (past, present, future) and creating kaitiaki (guardians).

Supporting this network of connected sites would be learning and engagement activities, creating open-air classrooms, and making available the local learning to not only the wider populace of Canterbury, but to other visitors both domestic and overseas. To further enhance the knowledge being passed on by the interpretation panels, visitors would be able to engage local expert guides or be directed to local knowledge holders or locations.

In many respects the Peninsula is already a de facto Geopark. We have communities, organisations, people, and places that are behaving in many ways as that components of overseas Geoparks do. We have visitors (local and from further afield) that visit our places. We have deep connections with our environment. And a holistic Geopark provides a way that we can wrap these together, to guide people within our backyards, and to enhance and learn about our heritage, history, origins, environment, and ecology.

A Geopark allows a holistic way to celebrate all things of and on the Peninsula. As community is at the heart of this Geopark model, the journey to collectively bring together many voices and views takes time, and many discussions. With the Geopark concept relatively new within New Zealand development has been slow and considered but the aspiration remains.

Stop 1: Ahuriri Loess Quarry

The loess deposits of Banks Peninsula are categorized into two distinct types: Birdlings Flat loess and Barrys Bay loess. While these types differ in texture and composition, they are considered different facies of the same loess, originating from the same source—the floodplain and fan of the Waimakariri River—and deposited during approximately the same periods. The primary differences between the two types are determined by their proximity to the sediment source and the moisture regimes of the areas where they were deposited. Birdlings Flat loess is proximal to source and Barrys Bay loess, distal.

Table 1. *Comparison of Loess Types on Banks Peninsula.*

Feature	Birdlings Flat Loess	Barrys Bay Loess
Texture	Coarse; loamy fine sand to fine sandy loam	Fine; predominantly silt loam
Composition	Quartzo-feldspathic with secondary carbonate and various salts	Quartzo-feldspathic
Stratigraphy	Two major layers separated by gravelly colluvium	Three major layers and a minor fourth layer separated by paleosols
Landscape setting	Lower flanks of the peninsula on the north-western margin	Inner valleys and eastern-southern portions
Climate Zone	Sub-humid (650–900 mm rainfall)	Humid (>900 mm rainfall)
Soils	Fragic Pallic Soils	Perch-gley Pallic Soils

At Ahuriri quarry we will see a now partly overgrown exposure (plus new houses) of Birdlings Flat loess. The type section is further along our journey near Birdlings Flat and you will be able to see it from the bus. Griffiths (1973) subdivided Birdlings Flat loess into two units separated by a slightly stony colluvial layer that interestingly was made up of stones not found on the peninsula, which ids dominantly basaltic, but by lithologies common on the beaches. Griffiths (1973) subdivided Birdlings Flat loess into two units separated by a slightly stony colluvial layer that interestingly was made up of stones not found on the peninsula, which is dominantly basaltic, but by lithologies common on the beaches. The upper unit, about 9 m thick at Birdlings flat was silt loam to fine sandy loam in texture and pale coloured (2.5Y hue). The ~1 m-thick colluvial layer was pale but had a silty clay loam texture. The underlying Unit 2 was browner (10 YR hue) and fine sandy loam. These two units were subdivided into subunits according to their content of secondary carbonate and mottling.

At Ahuriri Quarry there was originally about 20 m of stepped exposure but because of the dip of the beds the same units repeated in the steps. Overall, there is about 16 m of loess. Below the surface soil Almond et al. (2007) recognised five soil stratigraphic units (SSU) with the upper four within Griffiths' Unit 1 and the lowermost (Basal SSU; Fig 3) probably equivalent to the top of Griffith's Unit 2. Through the whole thickness of loess there were zones with high secondary carbonate abundances that took on different morphological forms (rhizomorphs, coatings, nodules, worm burrow infills) and carbonate free zones. The soil stratigraphic units were recognised largely where carbonate was abundant.

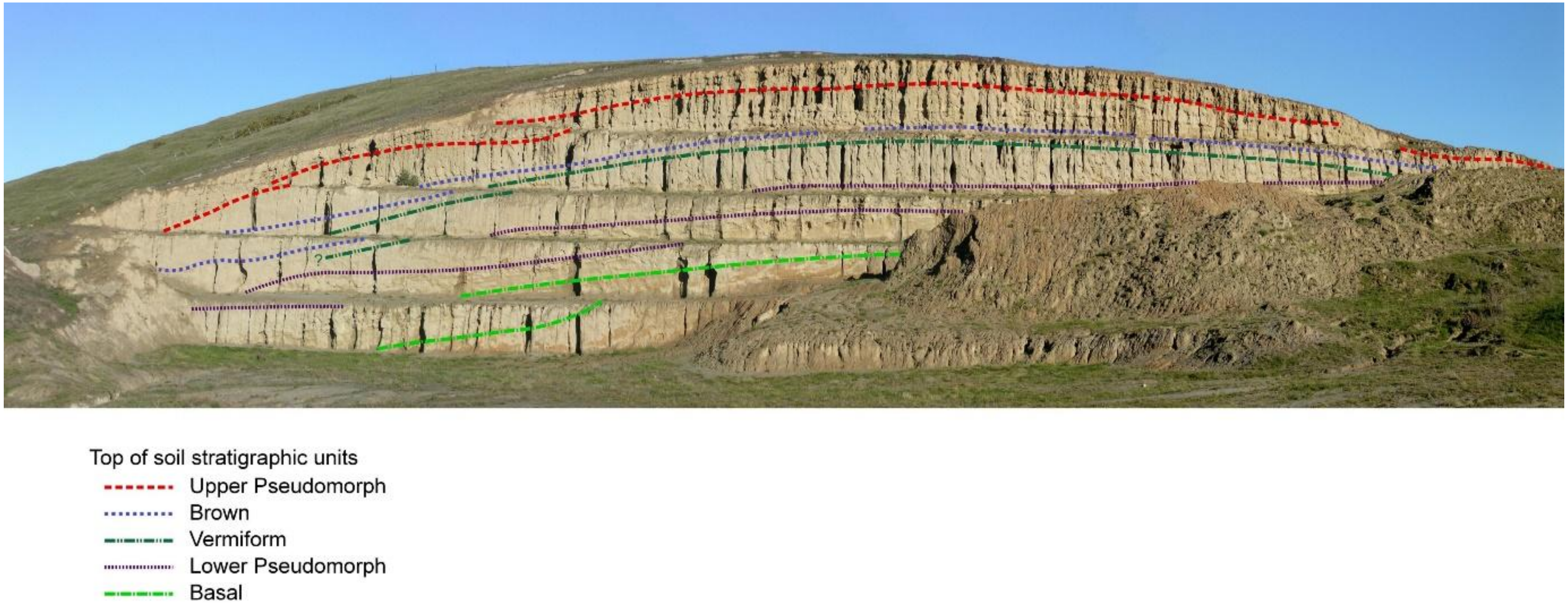

Figure 3. *The exposure of the quarry at Ahuriri as of 2003. The upper boundaries of soil stratigraphic units are indicated.*

The loess showed very interesting patterns of carbonate content, pH and electrical conductivity (EC).

- Where pH was high, EC was low and carbonate content was high. The pH was higher than could be attributed to the presence of free lime, however: in the presence of lime one can expect a pH of 8.3, whereas pH values as high as 9.6 were recorded.
- Where pH was low, EC was high (salts present) and the loess was carbonate free.

We'll discuss this chemistry in the field.

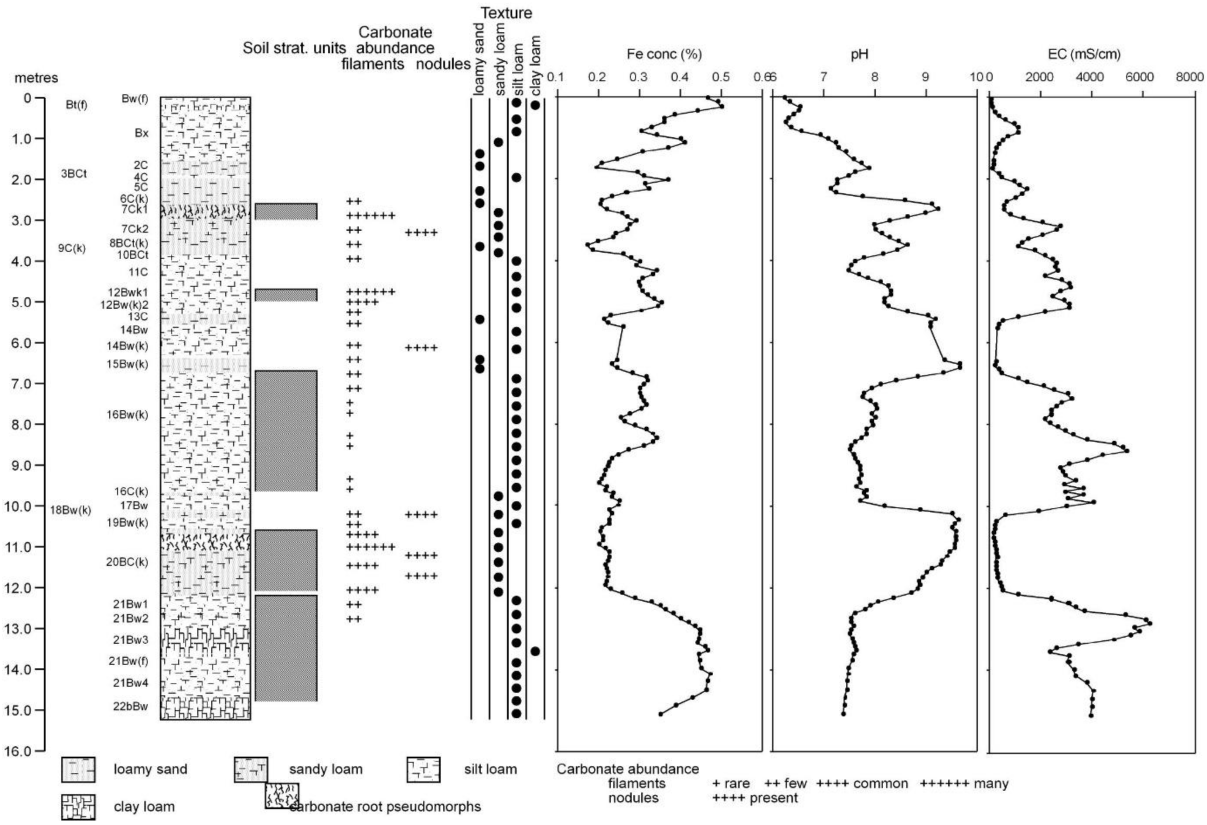

Figure 4. *Stratigraphy, morphology and chemistry of the loess at Ahuriri quarry (Almond et al., 2007).*

Almond et al.'s (2007) aim was to improve the chronology of deposition of loess on Banks Peninsula. There had been earlier attempts applying radiocarbon dating and thermoluminescence to the Barry's Bay loess. To date the loess they applied infra-red stimulated luminescence (IRSL), radiocarbon dating and exploited a tephra-isochron, the 25.4 k cal. yr B.P. Kawakawa Tephra sourced from the Taupō volcanic zone in the North Island. Note the update from 26.5 ka since Fig. ^ was published.

The important results are:

- Kawakawa tephra, which fell in the last glacial maximum (LGM), was found as cryptotephra with the peak at about 1.4 m depth implying ~ 14 m of loess is older than the LGM;
- Radiocarbon ages from carbonate imply carbonate was precipitated at significant depth below the land surface. The equivalent aged carbonate to the 25.4 ka Kawakawa tephra is at least 3 m below the isochron implying carbonate was precipitated at least 3 m below the surface at that time.
- IRSL ages show age reversal with respect to Kawakawa tephra and carbonate radiocarbon ages and are hence unreliable. There remains a need to test luminescence ages further in South Island loess because there are more than a few examples of poor accuracy and precision.

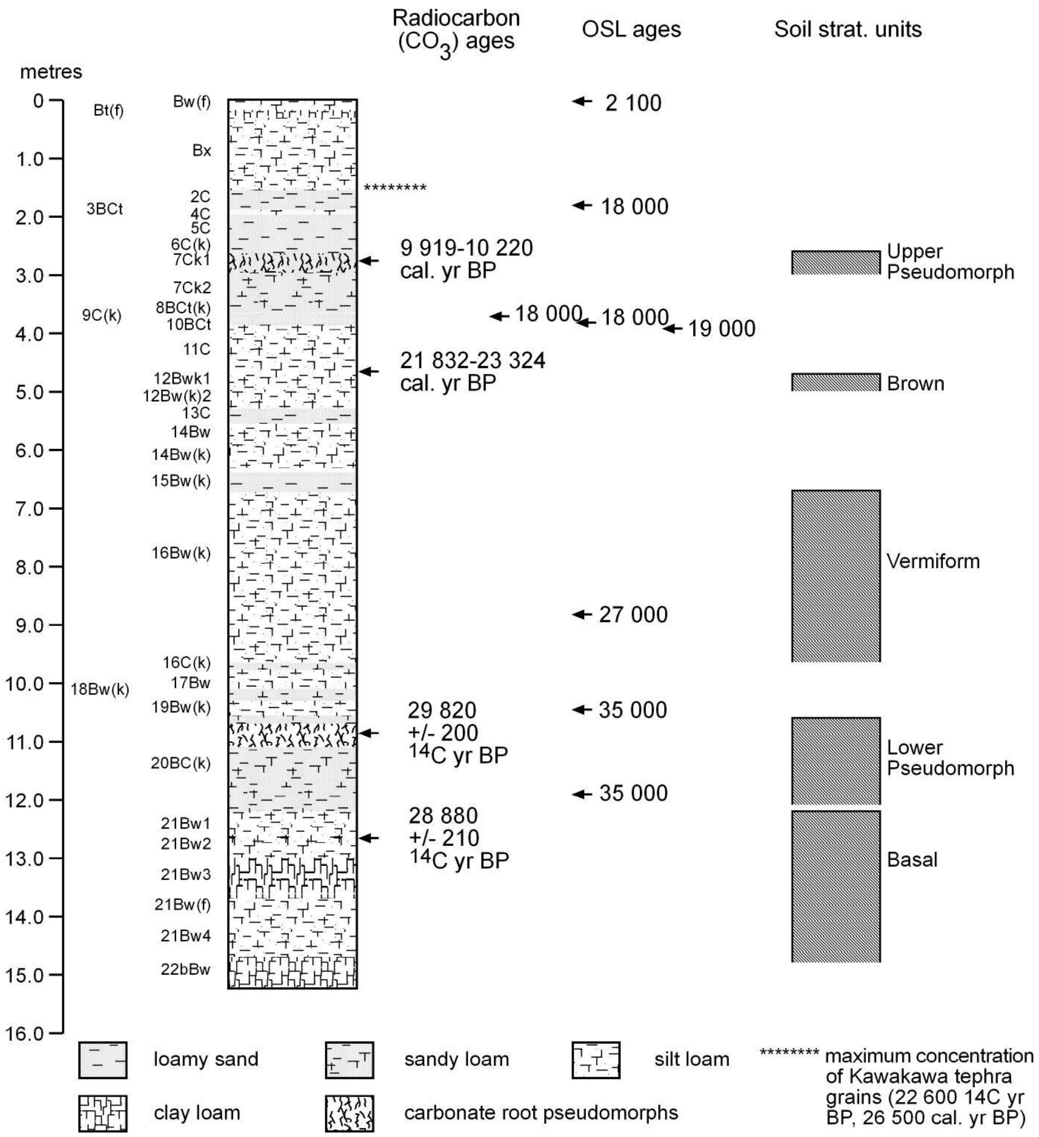

Figure 5. *Stratigraphy and chronology of Birdlings Flat loess at Ahuriri quarry (Almond et al., 2007). Note the revision of the age of Kawakawa tephra from 26,500 cal. yr B.P. to 25,400 cal. yr B.P.*

The lowermost radiocarbon ages can now be calibrated using the SHCal20 dataset and they indicate an age of at least 33.9-34.6 ka for the top of the second unit. This would seem to align with the IRSL ages but we must remember that carbonate is postdepositional and therefore provides a minimum age, whereas the IRSL ages should date loess deposition. This discrepancy notwithstanding, it would appear that Birdlings Flat loess is probably of last glacial age whereas there is compelling evidence to suggest Barrys Bay loess represents multiple glacials.

Motukarara to Te Mata Hapuku / Birdlings Flat

The valleys of the Western Port Hills and central Banks Peninsula record a history of infill, related to the recent formation and connection of Kā Pākihi

Whakatekateka o Waitaha / Canterbury Plains to the Peninsula and the push seaward of the coastline. In some you don't have to dig far to find estuarine muds. Recent uncovering of an ancient Kahikatea forest in Hoon Hay Valley tells of a time of freshwater swamps – there is still much hidden below the ground.

Sediments of the Canterbury Plains are derived from the Southern Alps, transported and deposited by the large, braided rivers Waimakariri, Rangitata, and Rakaia. Unlike today, these rivers were able to wander across the land's surface. Today these sinuous ancient riverbeds are etched within the mosaic of the paddocks within the Canterbury Plains. As the rivers wandered, they spread their sediment, onlapping and burying the much older volcanic landscape of Te Pātaka o Rākaihautū / Banks Peninsula.

As you travel towards and along the edge of Te Waihora / Lake Ellesmere you'll find a mixture of remnant lake shorelines and raised beaches, now disconnected from their original water bodies. These valleys, like those of the Port Hills, are infilled by the invasive sediments of the Canterbury Plains, with a hint of loess and volcanics from upslope sources.

The landscapes of Kaitorete, Te Waihora / Lake Ellesmere, Te Roto o Wairewa / Lake Forsyth, and Te Mata Hapuku/ Birdlings Flat record more recent and rapidly changing coastal environments (Figure 6).

The geologic connection of the Peninsula, in its origins a stand-alone island, to the mainland, the creation of the Peninsula itself, has been a repeated, recurring, process over hundreds of thousands of years, driven by sea level rise and fall. With each connection another invasion of species could occur – the island/peninsula an ark with populations separated from the mainland, on their own evolution pathways, creating our diversity of endemic species.

Our most recent reconnection is reflected in the bands of Muehlenbeckia astonii (shrubby tororaro) of Kaitorete that follow abandoned gravel beach ridges. Each ridge was formed as the coastal currents pushed the rounded gravels of the Rakaia and Rangitata Rivers northward, towards the Peninsula, building out the coastline. These gravels, sourced from the Southern Alps, enclosed Te Waihora / Lake Ellesmere and Te Roto o Wairewa / Lake Forsyth, creating the ecosystems within.


0.5 0.25 0 0.5 1 1.5 2
Kilometers
N
W
E
S

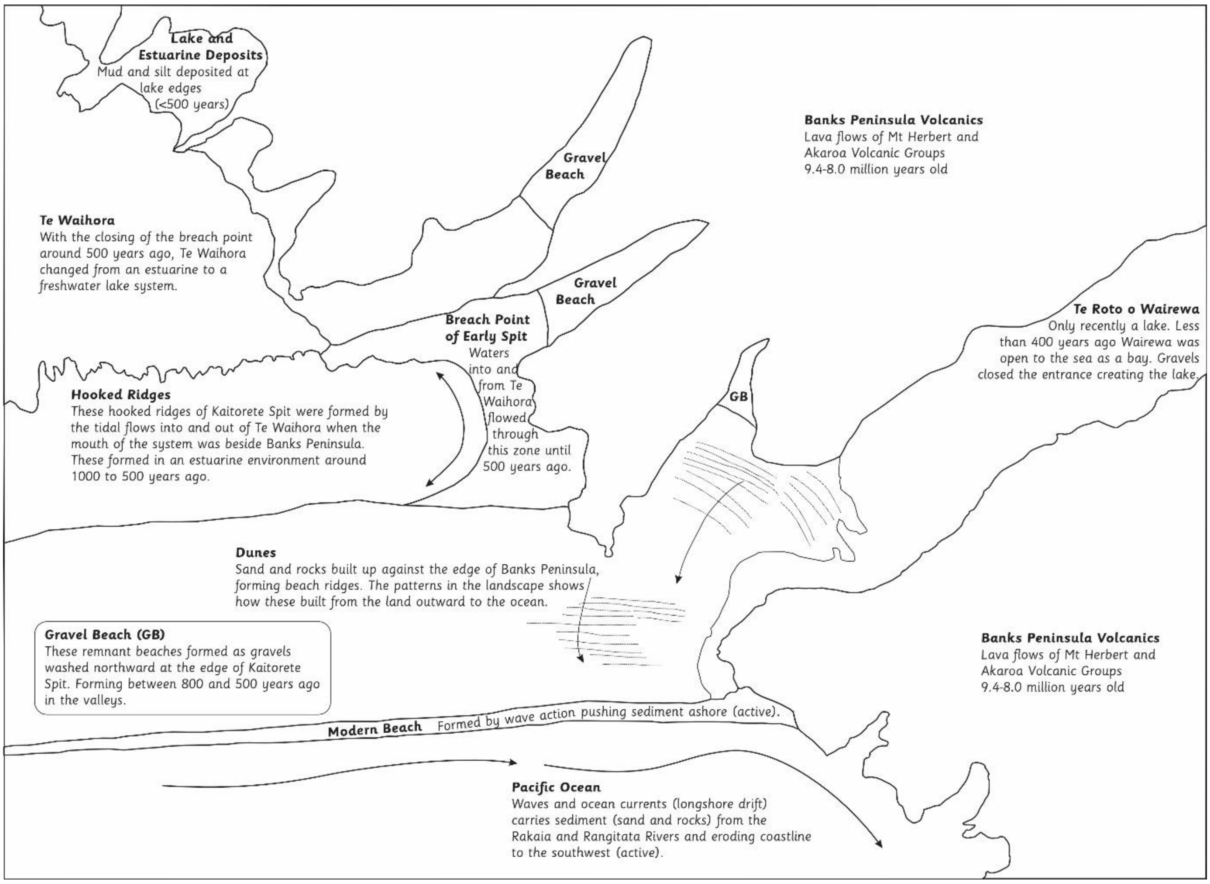
Lake and Estuarine Deposits
Mud and silt deposited at lake edges (<500 years)
Gravel Beach
Banks Peninsula Volcanics
Lava flows of Mt Herbert and Akaroa Volcanic Groups
9.4-8.0 million years old
Te Waihora
With the closing of the breach point around 500 years ago, Te Waihora changed from an estuarine to a freshwater lake system.
Gravel Beach
Breach Point of Early Spit
Waters into and from Te Waihora flowed through this zone until 500 years ago.
Te Roto o Wairewa
Only recently a lake. Less than 400 years ago Wairewa was open to the sea as a bay. Gravels closed the entrance creating the lake.
Hooked Ridges
These hooked ridges of Kaitorete Spit were formed by the tidal flows into and out of Te Waihora when the mouth of the system was beside Banks Peninsula. These formed in an estuarine environment around 1000 to 500 years ago.
GB
Dunes
Sand and rocks built up against the edge of Banks Peninsula, forming beach ridges. The patterns in the landscape shows how these built from the land outward to the ocean.
Gravel Beach (GB)
These remnant beaches formed as gravels washed northward at the edge of Kaitorete Spit. Forming between 800 and 500 years ago in the valleys.
Banks Peninsula Volcanics
Lava flows of Mt Herbert and Akaroa Volcanic Groups
9.4-8.0 million years old
Modern Beach Formed by wave action pushing sediment ashore (active).
Pacific Ocean
Waves and ocean currents (longshore drift) carries sediment (sand and rocks) from the Rakaia and Rangitata Rivers and eroding coastline to the southwest (active).

Figure 6. *Landscape development features, processes and timeframes that have formed Kaitorete, Te Waihora / Lake Ellesmere, Te Roto o Wairewa / Lake Forsyth, and Te Mata Hapuku/ Birdlings Flat.*

Stop 2: Te Mata Hapuku / Birdlings Flat

The landscapes around us hold many values, stories, uniqueness's. And those equipped with knowledge interpret these in varying ways. Knowledge leads us to how we engage, navigate, interact and connect with locations. And for many places without this knowledge the uniqueness of, values within, and stories behind remain untold, hidden. Birdlings Flat is a unique location in the where a multi-lens interpretation of a place can occur (Figure 7).

Why? Well place is a way that connects all these varying elements. Each place contains its own unique stories and knowledge. By communicating these this knowledge can be passed on. Understanding and acknowledgment comes with knowledge, and the resultant messages conveyed can influence behaviours.

The Geopark concept is a holistic way that we can package and showcase these varying layers with each of our unique places throughout Te Pātaka o Rākaihautū Banks Peninsula. In providing knowledge and learning experiences deeper interactions with place are created. This may mean a visitor stays longer to explore, a volunteer travels to plant and weed, a landowner places a covenant, a new behaviour is learnt, or a new story heard.

Figure 7. *A visual showcase of the layers encountered near the mouth of Te Roto o Wairewa. View of the mouth of Te Roto o Wairewa, the outlet, the beach and settlement of Birdlings Flat (modified from GoogleEarth).*

Stop 3: Summit Road (Hilltop): Akaroa Volcanic Complex

Dating of the rocks and their relationships (older rocks usually lie beneath younger) gives us the order of events that formed the landscape, but what can we tell about the size and shape of these volcanic landforms? On the outer bays, seaward cliffs, valley and harbour sides, there are layers of grey rock. Each of these layers is a lava flow that once flowed away from central vents. These layers can be imagined as surfaces extending towards the now eroded vents, and to approximate the height of the volcanoes (Figures 8 and 9). Also hidden within plain site are remnants of multiple overlapping volcanic cones that built up over millions of years to form the volcanic complexes (a volcano that is made up of multiple overlapping volcanoes) of Whakaraupō / Lyttelton and Akaroa.

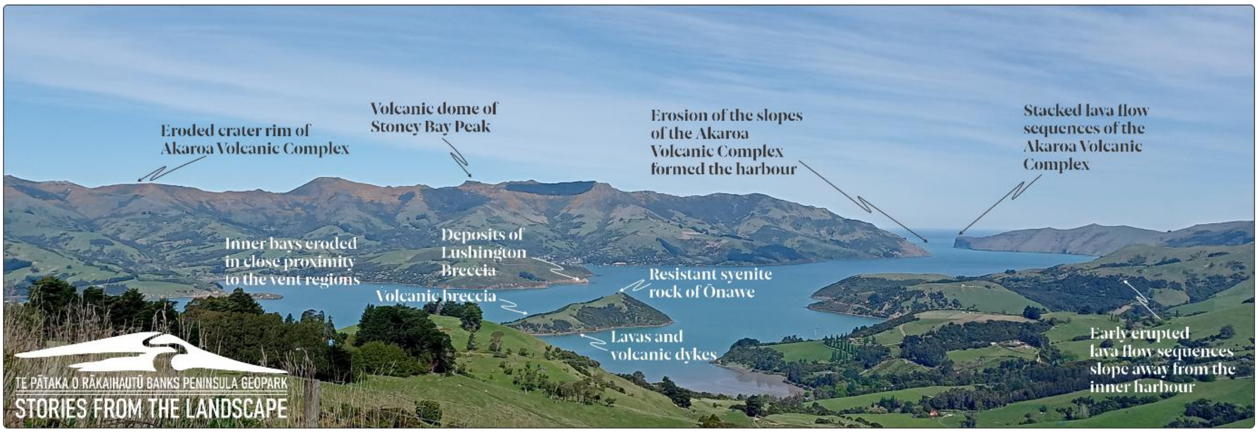

Figure 8. *Akaroa views. A selection of features and processes that have combined to form the landscape of Akaroa Harbour.*

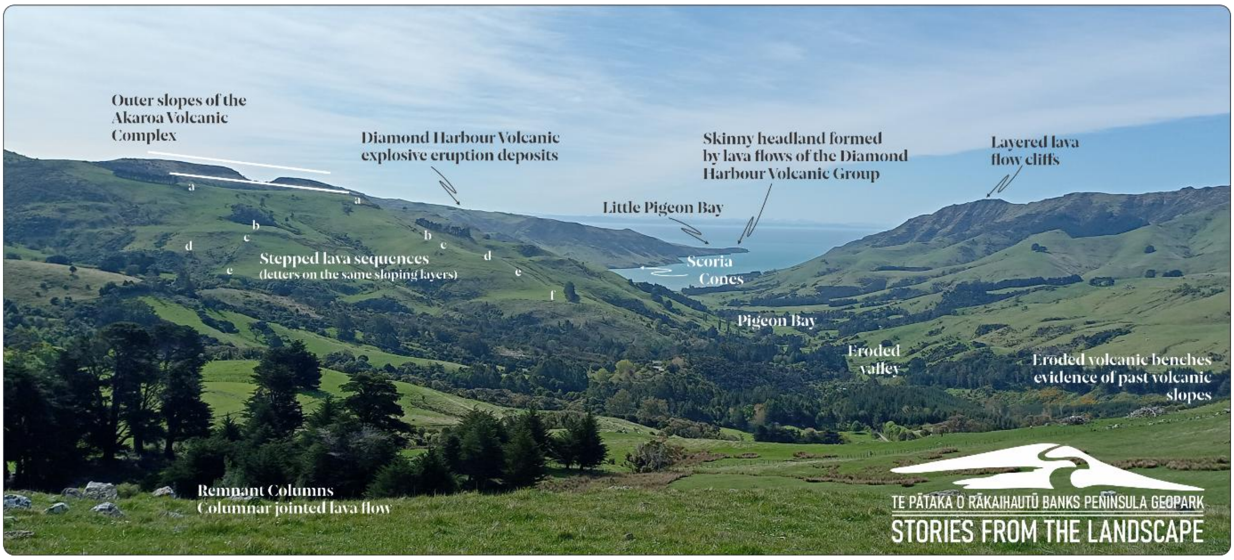

Figure 9. *Pigeon Bay lies on the outer of the Akaroa Volcanic Complex. The east side is all Akaroa volcanics, while to the northwest later eruptives of the Diamond Harbour Volcanics can be found.*

So where can we see evidence of this in the landscape of Akaroa's overlapping volcanoes? To answer this, you need to deconstruct the landscape to reconstruct it, represented on the interpretation map (Figures 10, 11 and 12). The result is a breaking down of the landscape into distinct areas, with each area having a crater rim and a curved seaward extent (Figure 10 and 12). Each of these areas is a record of a stage of volcanic growth, that formed its own volcano, with some of these reaching 1800m high (Figure 11).

Today we describe Akaroa Volcano as a volcanic complex, a volcanic landscape formed by multiple overlapping volcanoes (Figure 10). When each volcanic cone grew it also eroded, cutting radial valleys into the slopes like the spokes on a bike wheel. Today the smaller outer bay valleys are remnants of these. The larger outer bays (i.e. Ōtānerito) formed at the intersection of overlapping cones. If you look again at the Interpretation Map (Figure 12), you will see these larger valleys at the intersection of cone areas (Figure 10). Akaroa Harbour initially developed as one of these larger intersection valleys, which over time became the dominant drainage, enabling it to cut deep into the more altered rocks within the heart of the volcano. It is thought the scalloped bays within Akaroa Harbour may be the areas beneath the vents of the now eroded overlapping volcanoes of the volcanic complex (Figure 12).

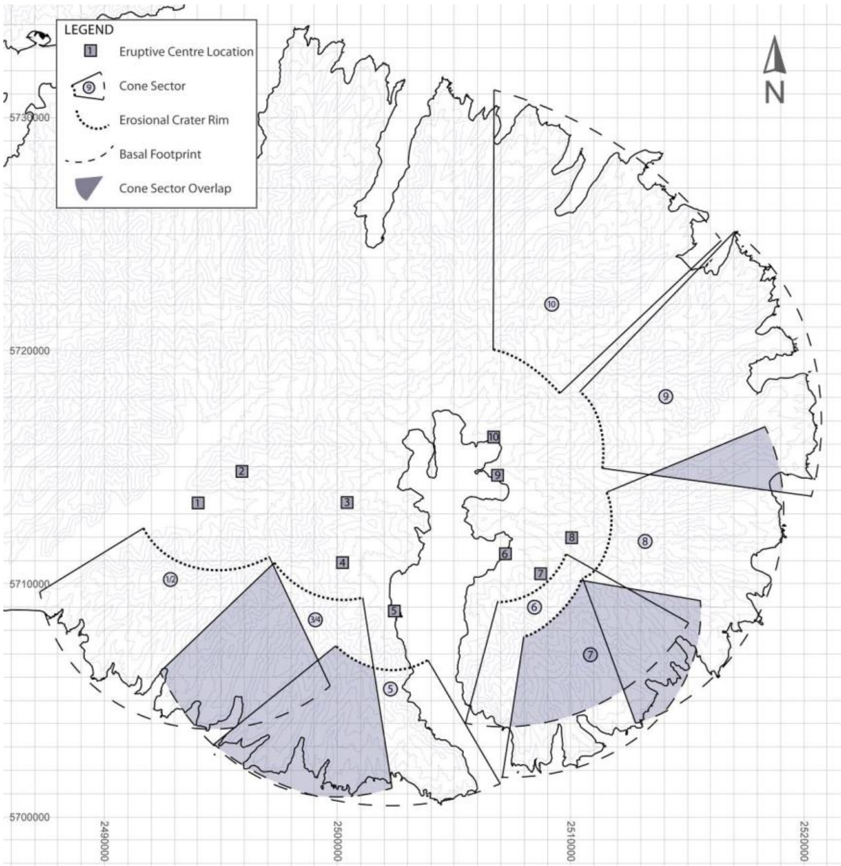

Figure 10. *Cone sectors of each eruptive centre. Cones 1/2 and 3/4 represent cones for two eruptive centres (from Hobbs, Hampton and Gravley 2012).*

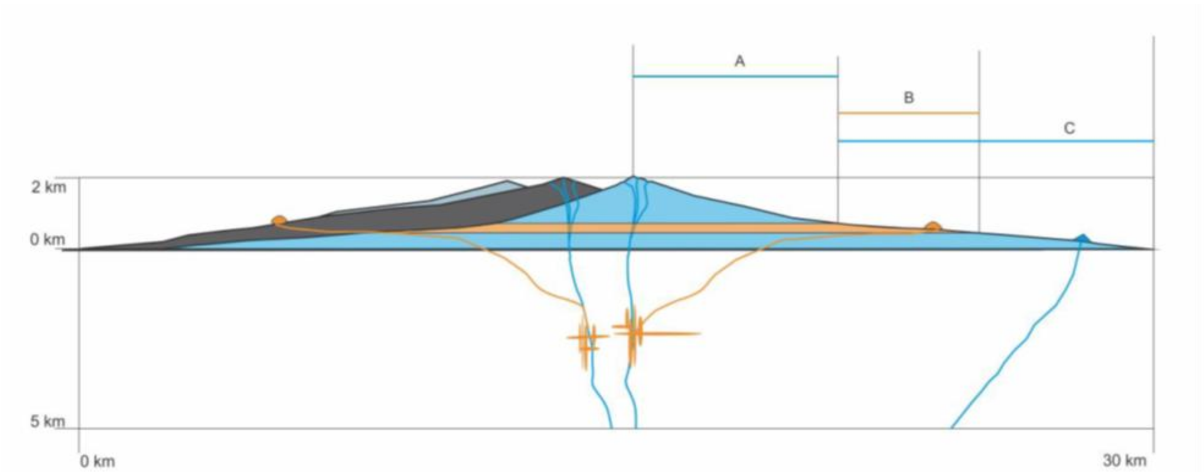

Figure 11. *Interpretative model / cross section of Akaroa Volcanic Complex – comprised of multicentred overlapping volcanoes. A, B, and C are representative zones within the complex where different volcanic activity occurred. A) Summit lavas and volcanic dyking. B) Zone of intrusion of volcanic domes. C) Zone of flank eruptions (scoria cones). Blue lines represent basaltic magmas, whereas orange represent movement of evolved magmas (from Gaddis and Hampton 2014).*

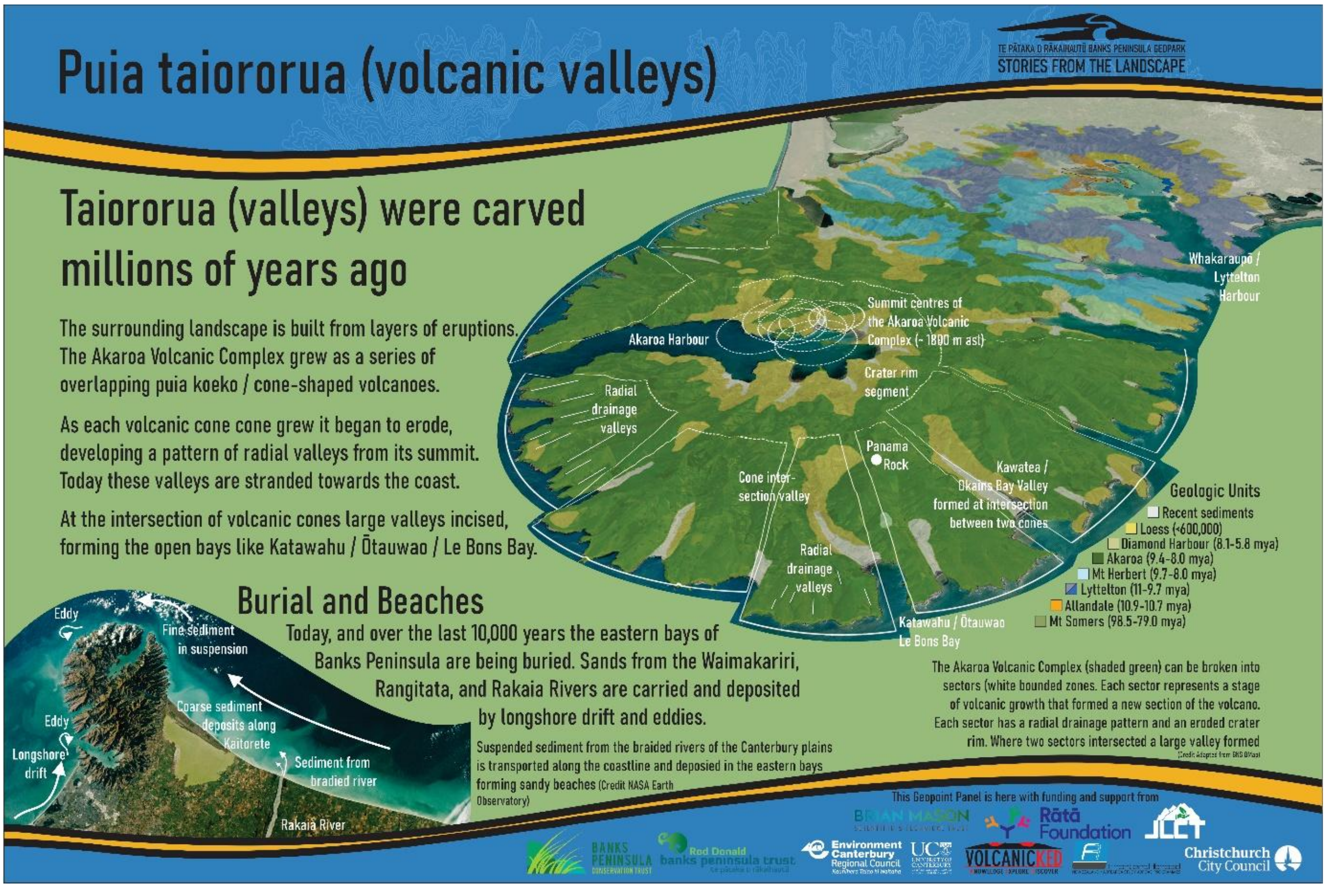

Figure 12. *A proposed Geopark interpretation panel, designed to be displayed within the Panama Reserve, Le Bons Bay, highlighting the hypothesised overlapping relationships of the Akaroa Volcanic Complex.*

Summit Road to Okains Bay

Following the eroded crater rim of Akaroa Volcanic Complex, the summit road provides views into Akaroa Harbour and towards the radiating bays and valleys (Pigeon Bay, Little Akaloa, and Okains Bay). On a clear day the route provides distant views of Pegasus Bay, the cliffed coastline between Amberly and Motunau, and the more distant Kaikoura Peninsula, and seaward Kaikoura mountain range.

Today, hillslopes are primarily pastoral farmland, a mix of sheep and beef farms. Areas of indigenous bush are slowly reclaiming areas of less productive land, or areas that have been actively retired. Silvered stumps of Totara trees remain in many of the roadside paddocks, remnants of the podocarp forests that once covered these slopes, prior to European arrival (Figure 13).

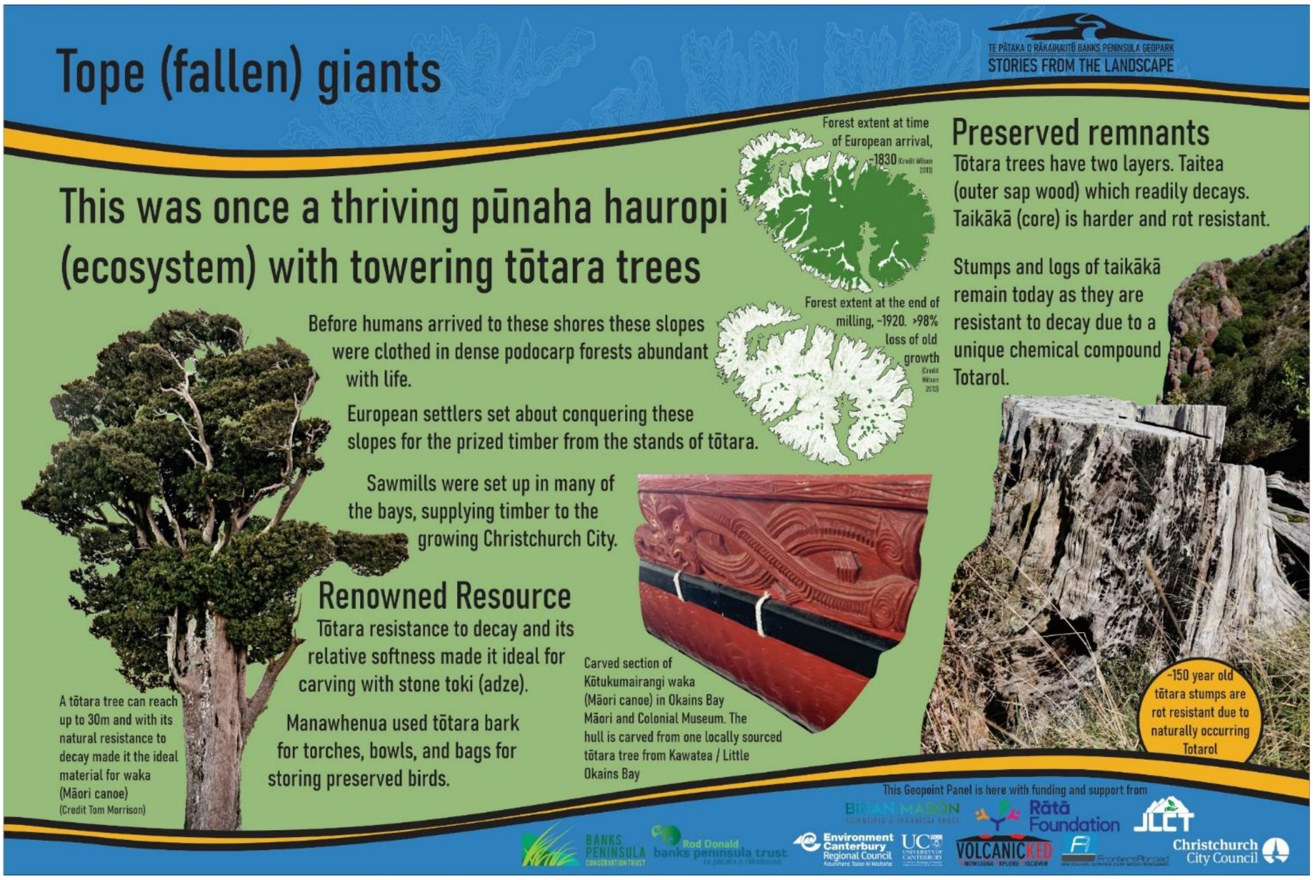

Figure 13. *Interpretation panel within the proposed Panama Reserve Geosite at Lebons Bay, focussing on the value of tōtara. Panel colours reflect the rohe (territory) of Te Rūnanga of Koukourarata.*

Stop 4: Okains Bay Māori and Colonial Museum

With over 20,000 items on display, the Okains Bay Māori and Colonial Museum vividly convey the stories of early Māori and Pākehā life through its impressive collections which include items from the Banks Peninsula area associated with whaling, farming and colonial rural life and a nationally significant collection of taonga Māori that rivals those of New Zealand's larger metropolitan museums.

Stop 5: Kawatea / Okains Bay Beach

Okains Bay beach is a popular holiday destination. With a low gradient and fine sand, the beach is a safe swimming location. Sands of the beach are sourced from the Southern Alps, transported by the braided rivers across the Canterbury Plains to the Pacific Ocean. There suspended sediment is transported towards Banks Peninsula via northward moving longshore currents. Much of the finer sediment remains suspended within the water column, eventually falling out on the eastern side of Banks Peninsula forming Banner Bank. Eddying currents transport this fine suspended sediment into eastern facing bays, where it is deposited, forming prograding beaches (Figure 14).

Figure 14. *Colour adjusted GoogleEarth image highlighting the tidal currents within Kawatea Okains Bay. Image source GoogleEarth*

Historically beach progradation has increased in rate since European occupation. Evidence of this lies within the landscape as now stranded jetty piles and also in comparison to past maps (Figure 15). Progressive wharf / jetty constructions highlight the competitive nature between maintaining a vital connection, transport and trade via sea. The initial wharf location was once mid beach, now and area mid campground. Due to the shallowing due to increased sedimentation loss of draft, a second wharf was constructed on the east side volcanic cliffs. This required the development of the wharf road, cutting into the southeastern volcanic cliff sequences. With further time, this wharf also succumbed to the shallowing due to sedimentation, and a further wharf was built, more seaward towards the little island. Wharfs became less vital for Okains Bay, once road networks were established, providing a more reliable pathway for the transport of goods and people.

Figure 15. *Okains Bay valley floor is infilled by coastal sediments forming dune systems. Today these systems show in the valley floor as the green and brown cross valley strips – hummocks and dunes. Comparing the "Black Maps" to today's beach front one can see how much "new" land has accumulated (imagery from canterburymaps.govt.nz).*

Okains Bay Geomorphology (Valley infilling, tsunami)

Okains Bay itself is an incised valley on the outer flanks of the Akaroa Volcanic Complex (Figure 12). The valley sides cut through volcanic sequences, primarily stratified basaltic lava flows, however interspersed within are localised eruptive deposits (i.e., scoria cones), more regionally dispersed airfall ash deposits (red, orange, cream layers), and intersection volcanic dykes, which exposures varies depending on their angle of interception. Slopes are mantled in loess, with thinner deposits at higher altitudes, and thicker redeposited areas in lower slopes.

The floor of Okains Bay valley is relatively flat when compared to the steep sides. The Opara River flows through the valley, widening when reaching the valley floor, and is tidally influenced. Halfway down the valley floor the Opara Stream develops into an intertidal estuary and lagoon, before reaching the ocean at the northern end of the beach.

Evidence of the progradation of the Okains Bay beach and the infilling of the valley floor is today visible as hummocky dune and ridge sequences (Figures 15 and 16). Depending on the season, vegetation cover provides a colour contrast, that highlights these subtle topographic signatures. These paleo dunes provided a ridge and trough network, that has promoted drainage pathways to form almost at right angles to the valley slopes, with waterways forming within the troughs and draining to the NW into the Opara River (Figure 16).

Buried within the dune sequences are horizons that record inundation events. Tsunami, both local and far-field have impacted Okains Bay, historically and further into the past. Being an east facing bay, Okains is exposed to local tsunami sources along the Canterbury to Kaikoura coastline, offshore fault systems, and sediment laden canyon systems. Further north lies to Hikurangi subduction margin, and the tsunami generating potential of the North Islands, eastern subduction system. Farfield events, lie from across the Pacific, to South America. It is from here that in 1960 Chilean Tsunami caused widespread inundation and damage. The Report on the Effects of Tsunamis in New Zealand (Works and Development Services Corporation (NZ) Ltd, 1988) record that in Okains Bay the “bridge 3.2km from the sea was washed away. The water level rose 3m above normal high water and covered the main road to a depth of 1.5m. Water marks on the remaining bridges were 1.8 m above high-water level.”

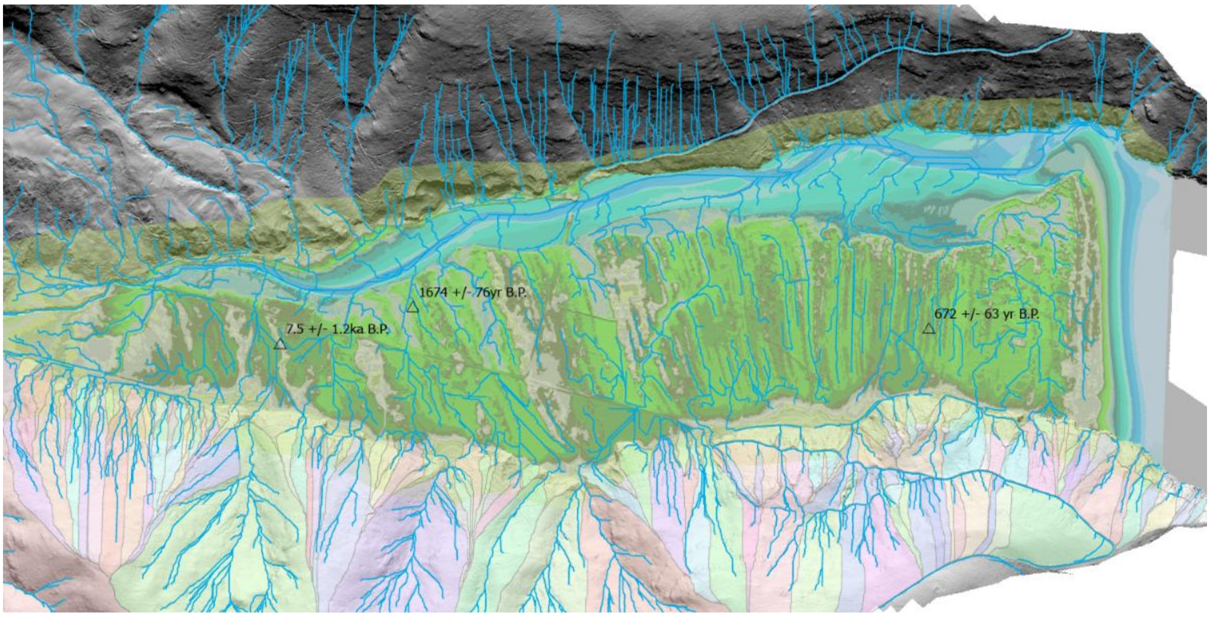

Figure 16. *Coloured lidar image of Okains Bay valley. On the valley floor blue to light green represents intertidal to low-lying. Darker green to light brown represents higher topography, more commonly dune crests. Variable pastel colouration on hillslopes are individual catchment boundaries. Dates shown are those from Stephenson and Shulmeister (1999).*

Okains Bay to Pa Bay

Pa Bay lies between the eastern bays of Le Bons and Okains. Situated along the steeply cliffed section of coastline, Pa Bay is today a relatively inaccessible refuge for wildlife. Private farm ownership restricts public access to Pa Bay, and its visitation is within this field trip is under the permission of local landowners.

Pa Bay is a unique location on Banks Peninsula where the layers within the landscape tell stories of occupation, an evolving landscape with varied slope process tied closely to the marine, and a foundation shaped by the volcanic processes that erupted on the land and within the sea.

Stop 6: Pa Bay Pa Evidence in the Landscape

Cut into the slopes, crossing the cliffs, and abutting natural barriers are the earthen remains of a Pa (fortified defensive position), kainga (village), and large-scale gardens. Excavations by local farmers Kerry and Murray Thacker of this site uncovered the foundations of many a building, storage pits, fire hearths, and an extensive collection of Māori artefacts. Of which provided the foundation for the collections at the Okains Bay Māori and Colonial Museum. Expressions of these earthen features that lie in the landscape and are visible in subtle vegetation colourations. Additional image analysis, ArcGIS analysis, and 3d perspectives provide enhanced views that highlight the complexity of this site (Figure 17).

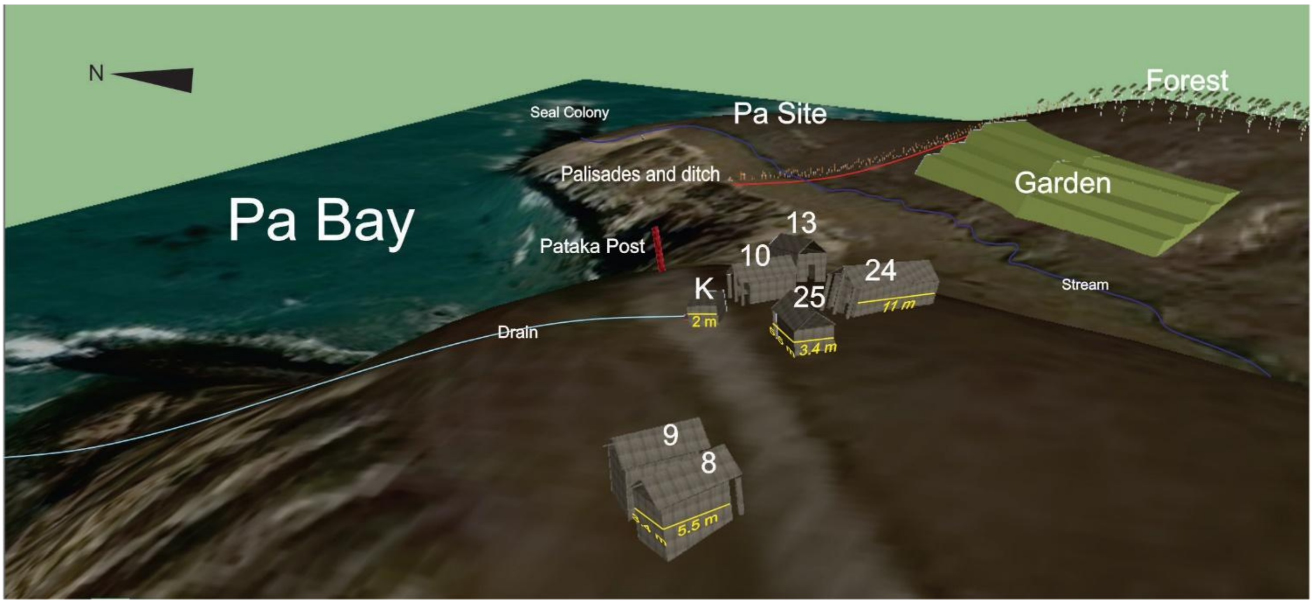

***Figure 17.** Chewiphasa et al (2013) Google SketchUp© model of the Pa Bay site. Dimensions of known rectangular house units have been derived from the Murray Thacker excavation (Brailsford, 1981). The Unit K drain depression slopes towards the cliff face allowing for gravity to dictate flow direction.*

Soils and Geomorphology, Valley Infilling, Kawakawa Tephra

The surficial layers of Pa Bay reflect the underlying nature of the eroded volcanics, the deposition and reworking of loess, and the nature of erosion and deposition occurring on the slopes of Banks Peninsula (Figure 18). Exposed along the cliffs of Pa Bay southeastern headland is a sequence that records the interaction between a sequence of scoria cones, erosive processes from the last sea level highstand, and fluvial deposition of reworked loess all culminated to form a preserved valley fill sequence.

Preserved within the sequence is a distinctive fine white horizon that has been identified as the Kawakawa/Oruanui tephra (~25.5 ka), a key chronostratigraphic marker within Last Glacial Maximum sediments in New Zealand. The Kawakawa/Oruanui tephra is a product of the Oruanui super-eruption from Taupo volcano, North Island.

Figure 18. *View overlooking Pa Bay Pa site and underlying geology. Cream white reflect loess derived deposits. Pink orange of the shore platform is one flank of an eroded scoria cone. An unconformity between scoria and loess is relative horizontal, proposing the influence of high stand sea level erosion for a raised shore platform.*

Volcanic Geomorphology

The foundation of the landscape lies in the sequence of eruptions that formed in this location. Erosion of these deposits and their contrasting rock masses have influenced the landscape geomorphology expressed today. The exposures of Pa Bay are the result of flank eruptives, parasitic cones that have been later covered by lava flows from the main Akaroa Volcanic Complex, and over time have been exposed by the sea and incision. Deposits display a range of explosive eruptive styles, including Hawaiian, Strombolian and phreatomagmatic, and are from point sources and eruptive fissures (Figure 19).

Figure 19. *View towards Pa Island. Loess deposits sit atop a wave cut surface of a scoria cone on the right (south). Fissure eruption deposits from the northern shoreline and the rocky reef. Distal Pa Island and cliffs are formed by stratified phreatomagmatic eruptives.*

Geodiversity

Pa Bay provides a backdrop where the influences of the underlying geology, soils, water, climatic systems, are of influence on the surrounding biodiversity. This diversity exists on both land and water, and can be linked to the inherited structures, features and compositions of the local geology (Figure 20). These variables provide a foundation for habitat, and ecosystems to support life.

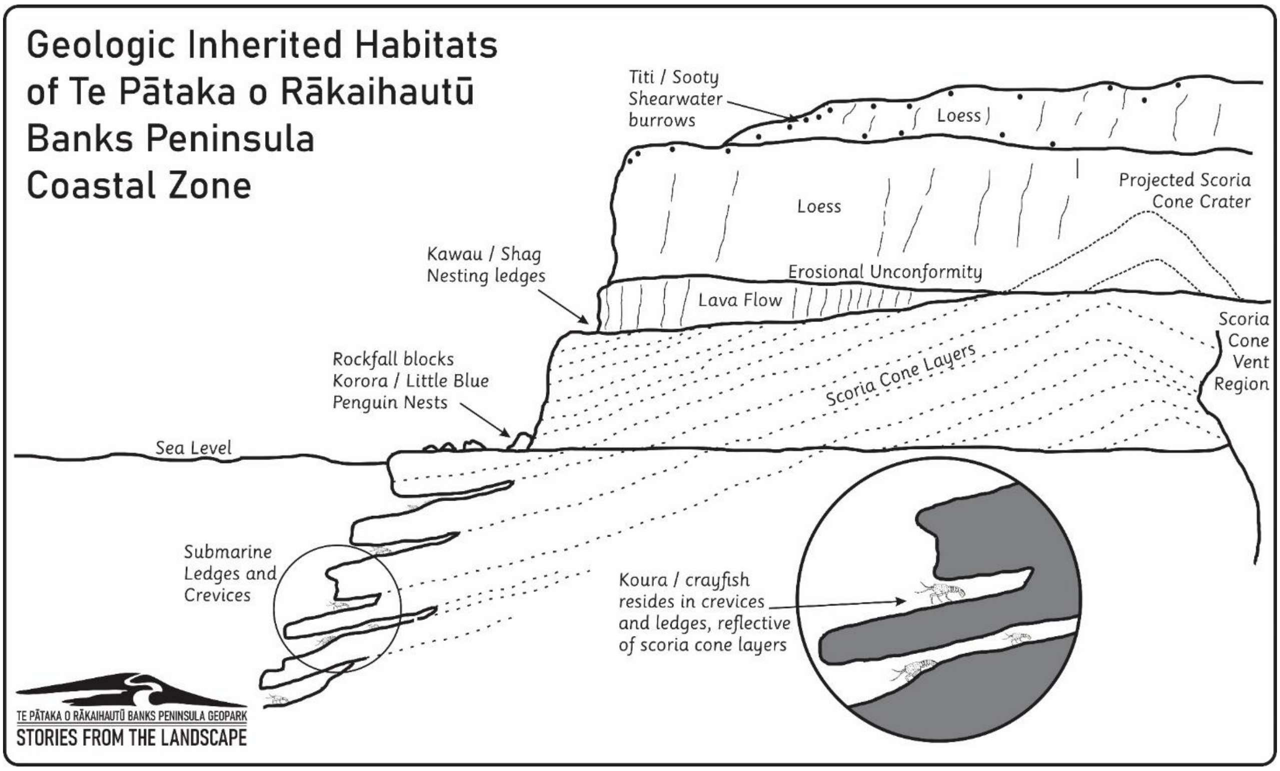

Figure 20. *Schematic interpretation of the geologic inherited habitats of Te Pātaka o Rākaihautū Banks Peninsula coastal environment. Note, on the coastal platform only one half a scoria cone is exposed.*

References

Almond, P. C., Shanhun, F. L., Rieser, U., and Shulmeister, J., 2007, An OSL, radiocarbon and tephra isochron-based chronology for Birdlings Flat loess at Ahuriri Quarry, Banks Peninsula, Canterbury, New Zealand: Quaternary Geochronology, v. 2, p. 4-8.

Griffiths, E., 1973, Loess of Banks Peninsula: New Zealand Journal of Geology and Geophysics, v. 16, no. 3, p. 657-675.

Hampton, S., and Cole, J., 2009, Lyttelton Volcano, Banks Peninsula, New Zealand: primary volcanic landforms and eruptive centre identification: Geomorphology, v. 104, no. 3-4, p. 284-298.

Works and Development Services Corporation (NZ) Ltd, 1988, The effects of tsunamis in New Zealand: Works and Development Services Corporation (NZ) Ltd.

PLATINUM SPONSOR

Earth Sciences New Zealand

GOLD SPONSORS

Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

UC University of Canterbury
Te Whare Wānanga o Waitaha
Christchurch New Zealand

SILVER SPONSORS

luminescence dating. VICUS

Natural Hazards Commission
Toka Tū Ake

BRONZE SPONSOR + YOUNG GEOMORPHOLOGY TRAINING PROGRAM SPONSORS

Zealandia Consulting

EGU European Geosciences Union

BSG British Society for Geomorphology

11th IAG International Conference on Geomorphology