Post-Flood volcanism on the Banks Peninsula, New Zealand

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The volcanic cones comprising Banks Peninsula, New Zealand, formed early in the post-Flood era during the Ice Age. This timing was established from their field relationships with other units (including Ice Age deposits), their physical scale and shape. Glaciers did not form on the volcanic cones during the Ice Age because they were surrounded by ocean, which, at that time was much warmer than it is today. The basic shape of the volcanoes was most likely sculptured by the volcanic eruptions themselves and not by weathering processes like those operating today. Based on a eustatic (global) sea-level curve and Ussher's chronology, the eruptions formed over a 75-year period from 2100–2025 BC. These dates would need to be adjusted if the volcanoes had subsided appreciably since they erupted. The reliability of these dates also depends on the validity of the sea-level curve used. Ash produced during these eruptions would have affected world climate and contributed to the conditions that advanced the Ice Age.

It is important to classify rocks in the field within a Biblical framework to determine the relative timing of the different rock units and so gain insight into the geological processes in operation. By linking the rocks in the field to the chronology of the Bible, we demonstrate that Biblical knowledge has practical application to the real world. In addition, we provide the lay person with a new perspective, as they are able to tie the landscape to Biblical events.

When we examine the geology of a region, we need to consider the broad picture of Earth history and properly evaluate all options. Our method for linking geology with the Bible needs to produce reliable results that are widely supported within creationist circles. There are a number of creationist concepts that help with the interpretation of the local geological setting,[1–3] but ongoing field testing is necessary to establish confidence in them. Here we apply the geological model by Walker[1] to an area of New Zealand and develop a new classification concept.

Naturally, when we classify rocks within the Biblical timeframe, we need to ensure that we are using real data, and not interpretations of the data that have been filtered through evolutionary presuppositions.

New Zealand

New Zealand is located in the South Pacific Ocean 1600 km SE of Australia and comprises two large islands, the North Island and the South Island (Figure 1), and several smaller ones. There are a number of characteristics that make the application of Biblical geology to New Zealand most illuminating. First, New Zealand is a relatively small landmass compared with the huge continents of Asia, Africa, America, Europe and Australia. In addition, New Zealand is isolated by thousands of kilometres of ocean from other large landmasses, and had a significant cover of ice during the Ice Age.[4] Finally, New Zealand is still very active geologically, with frequent earthquakes and active volcanic zones.[5]

One particularly interesting area is Banks Peninsula which forms a large, elliptical protrusion from the middle of the east coast of the South Island (Figure 1). The South Island is a long, rectangular landmass about 800 km long and 200 km wide. Mountains clustered around Mt Cook (3,753 m) form a central massif along the island called the Southern Alps. Glaciers descend from either flank of the Alps which are permanently ice capped. On the east, the glacier-fed rivers have deposited outwash fans forming the Canterbury Plains—the only extensive lowlands on the South Island.

The Banks Peninsula

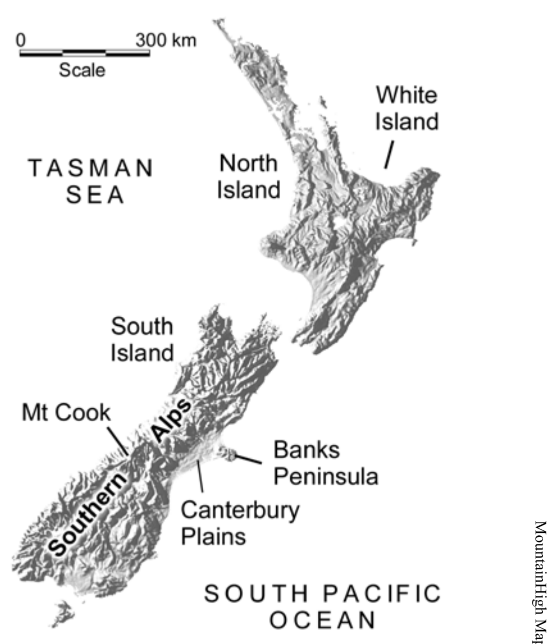

Figure 1. *New Zealand showing location of Banks Peninsula.*

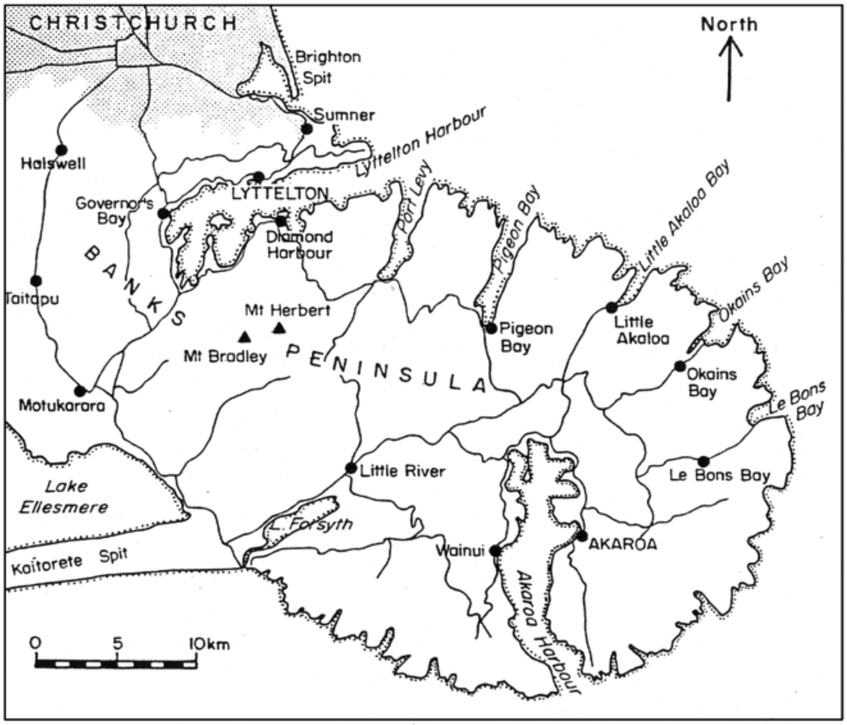

Figure 2. *Banks Peninsula.*

The Banks Peninsula (Figure 2) is composed mainly of the remnants of two large extinct volcanoes—Lyttelton in the northwest and Akaroa in the southeast. The crater areas of each volcano have been breached and eroded and now form excellent harbours.

Banks Peninsula was named after the botanist, Sir Joseph Banks (1743–1820). Sighted in 1770 from Captain Cook's *Endeavour* 16 km offshore, the peninsula appeared to these explorers as an island but it is joined to the mainland. The volcanoes were probably originally isolated from the mainland after they first erupted, but subsequently were connected by sediment eroded from the Southern Alps and transported by rivers.[6]

Geological relationships

Once we have a clearly defined Biblical geological framework (Figure 3), the first step toward classifying a geological

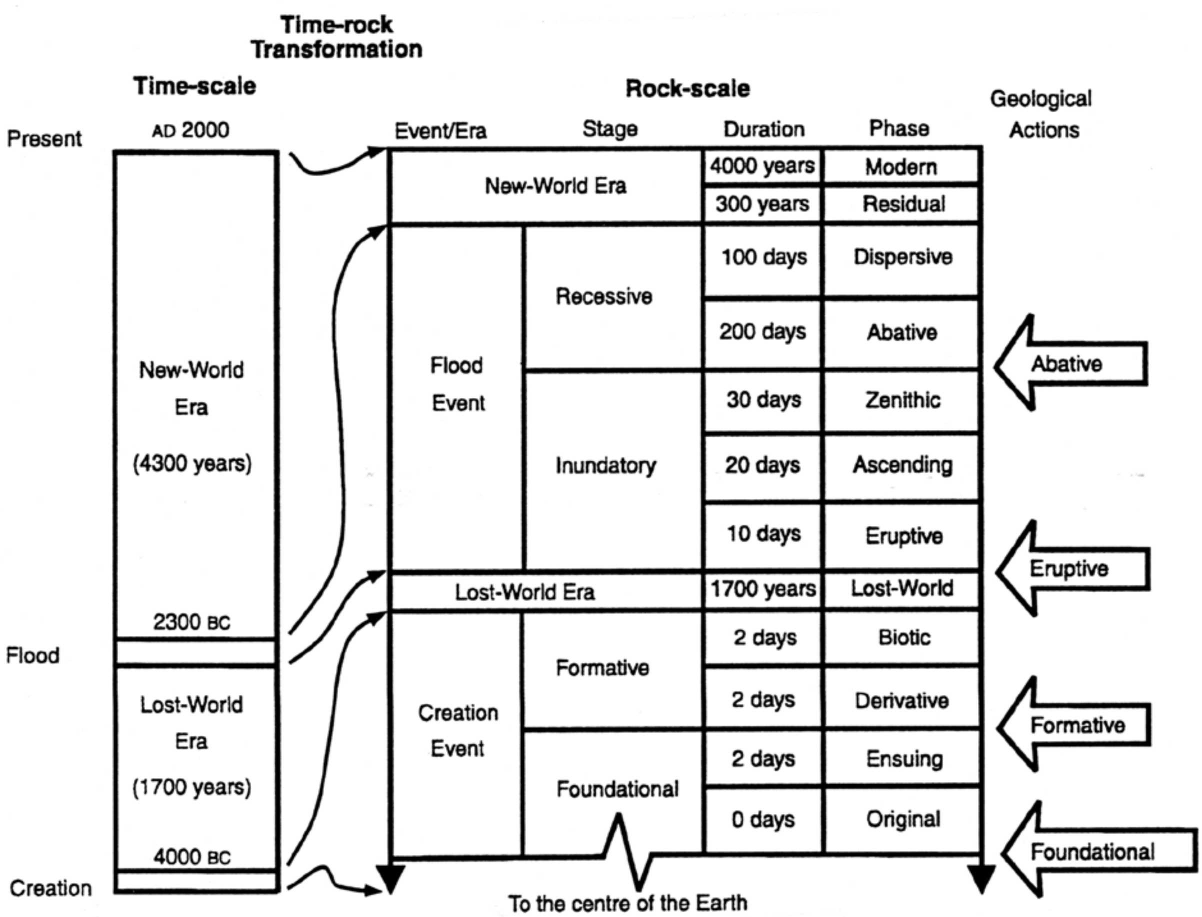

Figure 3. *The Biblical geological model used to classify the geology of Banks Peninsula (from Walker).*[1]

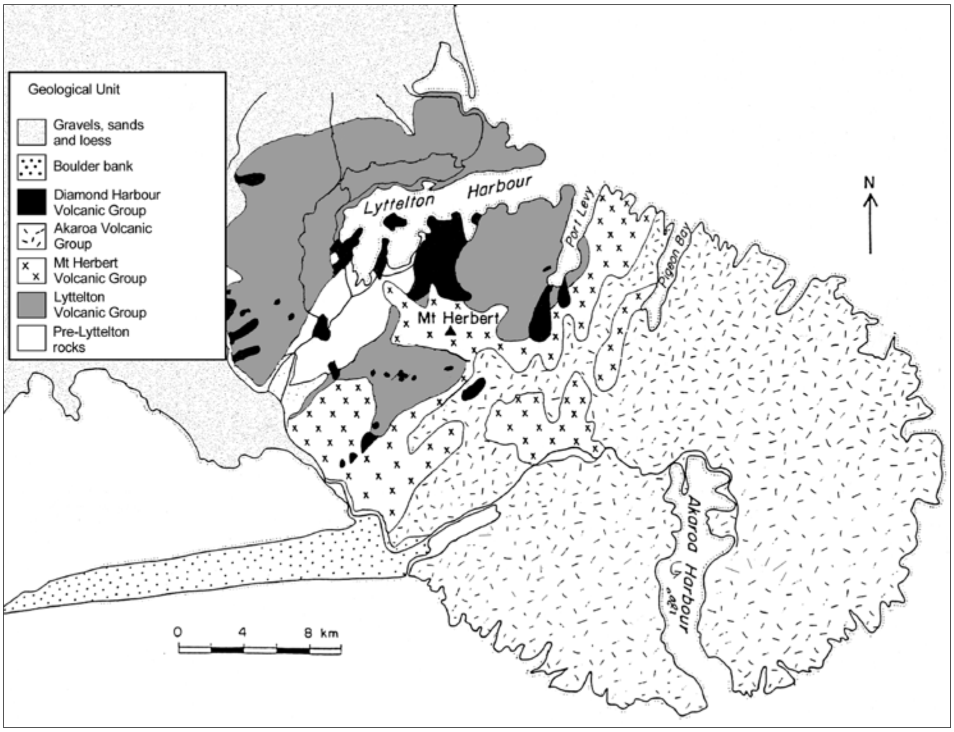

***Figure 4.** A simplified geological map of Banks Peninsula (after Weaver* et al.*).*[6]

unit is to establish its field relationships with other units in the area.[7] The geology of the Banks Peninsula is shown in Figure 4 and an interpreted geological cross section is presented in Figure 5.

The basement rocks of the area are exposed in the middle of the Lyttleton Volcano. The oldest and most extensive rocks of the basement are the sedimentary Torlesse Supergroup which are exposed over large areas of New Zealand. These are followed in order by the Mt Somers Volcanics group, the sedimentary Eyre Group and the Burnt Hill Group. The individual members of the basement rocks have not been separately defined on the geological map but on the cross section (Figure 5) the Torlesse Supergroup is shown as completely deformed. Fossils are found in the Torlesse rocks including conodonts, corals, crinoids, bryozoans, worm tubes and plants.[8] Fossils reflect death and burial, so the basement fossiliferous rocks were not formed during the Creation event, but afterwards.

The rocks overlying the basement rocks were formed during a number of volcanic eruptions. The sequence commenced with the Allandale Rhyolite and Governors Bay Andesite, and continued with the Lyttleton Volcano, the Mt Herbert Volcanics and the Akaroa Volcano, and concluded with the Diamond Harbour Volcanics.[9–11]

After the volcanic eruptions ended, the glacial and post-glacial sediments that now form the Canterbury Plains were deposited. According to Sewell *et al.*,[10] the glacial deposits are of moderately sorted, rounded gravel in a sand matrix, and locally oxidised. The early post-glacial deposits consist of well-sorted alluvial gravels, sand and silt together with drained peat swamps. The most recent deposits comprise dune sand and beach deposits, saline sand, silt and peat.[10]

During the Ice Age, blankets of wind-blown sand and silt were deposited on Banks Peninsula. Much of this material has been reworked by erosion initiated by frost-and-thaw action. Mainly derived from the Southern Alps and exposed river flats, the fine material formed thick deposits of loess. This friable, pale-white sediment has no texture or structure, and is easily eroded. Deposits up to 20 m thick are found on the north-facing slopes at low elevations, and in the crater regions of the volcanoes.[10,12]

Since the loess covers the flanks of the volcanoes, the eruptions must have been completed well before the end of the Ice Age.

Scale

One of the most useful characteristics for classifying a geological unit within the Biblical framework is the unit's physical size, or its scale.[13,14] For a body of rock to be considered a geologic unit, it needs to have appropriate unifying lithological features. The aim is to identify rocks that formed under similar geological conditions.[15] The unit may comprise sedimentary, igneous or metamorphic rocks. The 6,000-year Biblical timeframe places a tight constraint on what geological processes are acceptable, unlike the

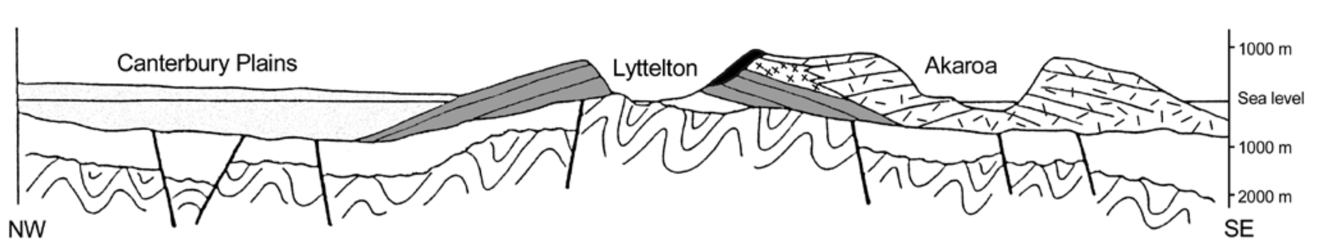

***Figure 5.** Geological cross section of Banks Peninsula (after Weaver* et al.*).*[6]

Scale	Limiting Volume (km^3)	Typical length by width by thickness (km)
World		
	100,000,000	3,00 km x 3,000 km x 10 km
Continental		
	10,000	100 km x 100 km x 1 km
Regional		
	10	10 km x 10 km x 0.1 km
Local		

***Figure 6.** A classification for the scale of geologic structures (from Walker).*[13]

uniformitarian philosophy where there is always plenty of time. Consequently, the physical scale of a unit is a good indicator of the intensity of the geological processes that formed the unit, and the intensity of geological processes are a good indicator of where the unit belongs within the Biblical model.

A number of features of a geological unit need to be examined to establish its physical scale including how the unit has been defined (e.g. lithologically and/or biologically), and how it is delineated from other units (e.g. by unconformities[16]). The Banks Peninsula comprises a volcanic suite of rocks commencing with the Allandale Rhyolite and concluding with the Diamond Harbour Volcanics. They have considerable lithological similarity compared with the earlier and later geological units in the area which are predominantly sedimentary in origin (Figure 5) and with which they are non-conformable.

Thus, the entire structure of the Banks Peninsula can be considered as one geological unit because, although the position of the vent moved during the eruption of the lava, the whole volcanic sequence represents a consistent set of geological conditions. The Lyttleton, Akaroa, Mt Herbert and Diamond Harbour lavas form a continuous series, both mineralogically and chemically, ranging from basalt to trachyte.[17] It has been proposed that the earlier Allandale and Governors Bay lavas represent the same magma suite but with initial crustal contamination.[18] Thus for our purposes we can treat all the volcanoes of the Banks Peninsula as one geological unit. There are no other major volcanoes in the area that would need to be included when assessing the scale of the geologic unit.

The volume of material erupted in the Banks Peninsula is 1,800 km^3[3,19] which by the classification criteria of Walker[20] reproduced in Figure 6, places it as a regional structure.

It is envisaged that the geologic processes operating during the Creation event and the Inundatory stage of the Flood would have been extremely intense and produced geologic structures much larger than regional scale. Smaller regional-scale structures could have been produced in those periods of Earth history when the geologic processes were less intense, such as the pre-Flood era, the Recessive stage of the Flood, or the post-Flood era. Naturally, there is a degree of subjectivity attached to such a classification because we were not present to observe what actually happened. However, our confidence in the result would improve if a similar classification were obtained using other criteria.

Disturbance and response

Other useful criteria for classifying a rock unit within the Biblical geological model include the degree of disturbance and the response of the unit to disturbance.[7,13] Rock units deposited early in the geologic history of a region have more opportunity of being disturbed by subsequent tectonic and geological activity. The response of a geologic unit to disturbance will depend on whether the unit was plastic or brittle when it was disturbed, which in turn will depend on how quickly the unit solidified after it was deposited and before it was disturbed. Both the degree of disturbance and response will depend on a number of factors including the structural strength of the basement rocks on which the unit is deposited, and the depth of burial when it was disturbed. Thus, these criteria must be used carefully.

For the Banks Peninsula, the volcanic rocks show negligible disturbance. They appear to have the same orientation as when they were emplaced, with the craters showing no indication of tilting or deformation. By way of contrast, the basement greywacke and argillite on which the volcanoes sit, the Torlesse Supergroup, are complexly deformed and slightly metamorphosed.[10] Although both the Lyttleton and Akoara volcanoes have been cut by a series of radial dykes (Figure 7),[21] this disturbance was only sufficient to crack parts of the volcanic cones and did not disturb them much.

Minimal disturbance rules out the likelihood of a pre-Flood emplacement of the units because we would expect pre-Flood deposits to have been greatly disturbed by the geologic events of the Flood. This leaves the Recessive

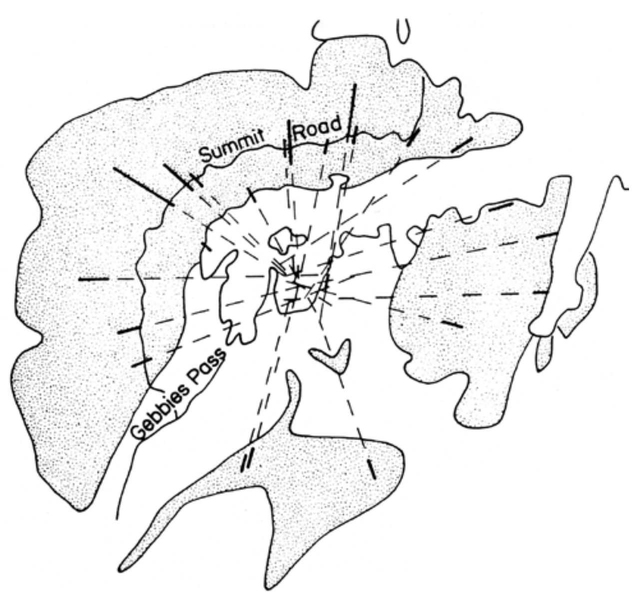

***Figure 7.** Although radial dykes on Lyttleton Volcano (shaded) cracked the structure, they did not disturb it significantly (after Weaver* et al.*).*[6]

stage and the post-Flood era (before the end of the Ice Age) as options. The brittle response would not rule out either of these because under appropriate conditions even a large volcanic eruption could have produced deposits that hardened sufficiently in the available time to allow for a brittle response.

Erosion during and after the Flood

Geomorphology, the study of landforms, can help identify the timing of geologic processes associated with the Recessive stage of the Flood and the post-Flood era. This is because the receding Flood waters, as they flowed into the newly forming ocean basins, provided the power for intense and rapid erosion.[22] Two distinct styles of erosion are anticipated—sheet erosion initially as the waters flowed from the continents in a vast coherent expanse, and channel erosion once the flow had reduced sufficiently to allow the water to concentrate into separate, large watercourses.[23] These erosive processes, because of their great power, would have carved most of the basic landforms that exist today.

The amount of erosion that could be accomplished by the receding Flood waters would depend on the size of the continent from which they flowed. The quantity of water covering a large continent such as Australia would have been immense, and taken a long time (perhaps six months or more) to drain. This would have allowed for an extended period of erosion, especially of those regions nearer the continental edges. For a smaller landmass, such as New Zealand, much less water would have flowed back into the oceans and it could have drained more quickly. Thus, the potential for erosion would have been less.

For New Zealand the situation is complicated by its geological history. Mainstream geological models based on plate tectonics and continental drift have New Zealand connected to the eastern margin of Australia up to the end of the Cretaceous.[24] In a previous study, Cretaceous deposits in Australia have been linked to the top of the Zenithic phase—the peaking of the Flood waters.[7] The intervening Tasman Sea is said to have opened up during the Tertiary,[24] which has been interpreted to be the Recessive stage of the Flood. If New Zealand were still connected to Australia as the Flood waters started to recede, there would have been the potential for large-scale sheet erosion. This issue is important for understanding the overall geological history of New Zealand from a Biblical perspective.

The landscape would also have been eroded during the post-Flood era, but by different processes and at a much slower rate than during the Recessive stage of the Flood. Instead of huge volumes of flowing water, the post-Flood agents of erosion would include normal weathering in non-glaciated areas, and ice in areas that were glaciated.

Erosion on Banks Peninsula

As previously mentioned, geomorphic considerations can help relate the timing of the eruptions with respect to the Recessive stage of the Flood and the post-Flood era. The Banks Peninsula volcanoes resemble Hawaiian-type volcanoes that construct large-diameter basaltic shields.[25] The lavas are geochemically similar to the relatively fluid Hawaiian lavas.[10] Mild eruptions must have been frequently punctuated by explosive eruptions from the main vents because of the presence of andesitic volcaniclastics, indicating a more-viscous lava.[25] Eruptions would also have occurred from parasitic cones on the flanks.[25] Occasionally the eruptions were sufficiently violent to produce ash, lapilli and bombs, and pyroclastic flows.[26]

The flanks of the volcanoes of the Banks Peninsula still preserve their distinct conical shape, rising high above the surrounding landscape. Mt Herbert, at 919 m, is the highest point of the peninsula and located between the two main volcanoes.[27] Since the basic conical shape of these volcanic remnants has been preserved, it is clear that the peninsula was not eroded by sheet flow during the Abative phase of the Flood. Otherwise there would be a flat erosion surface cut by the receding sheets of Flood waters.[28]

The rocks comprising the volcanoes include lava flows, pyroclastic deposits, welded tuff, scoraceous tuff-agglomerate, tuffaceous breccia, volcanic conglomerate, sandstone, siltstone and mudstone,[10] all of which are typical of sub-aerial deposition. There is no evidence of submarine volcanism.[29] Again, such sub-aerial eruptions could not have occurred during the Abative phase. They must have erupted after the Dispersive phase directly onto land, or out of relatively shallow water. This suggests the volcanoes likely formed in the post-Flood era.

The surface of the peninsula is cut by many large, radial erosion gullies, some of which form deep inlets around the peninsula such as Port Levy and Pigeon Bay.[30] In addition, each volcano has one very large channel that extends from a bowl shape depression at its mouth, through the rim to the ocean, creating a spacious harbour (Figure 2). Some geologists have claimed, based on extrapolating the flanks of the volcanoes, that Lyttleton was originally some 1,500 m high and Akaroa 1,800 m.[10] They envisage that normal weathering processes eroded these tall peaks to produce the harbours and the present shape of the peninsula. However, it is difficult to envisage how normal weathering could have sculptured a conical peak into such harbours, and how it could have been done in less than 4,000 years since the Ice Age. However, there are a number of features that indicate that the volcanoes have not been eroded by normal weathering processes.

The two harbours are distinctively different from the other channels on the surface of the volcanoes. First, they are exceptionally large compared with the other channels.

Second, there is only one large channel for each volcano. And finally, they extend from the mouth of the volcano, through its rim to the ocean. If all the channels had been formed by the same erosion processes of normal weathering, we would expect erosion to have been fairly even over the whole surface of the volcanic shield, and for all the channels to be of similar size. Rather than normal weathering of a much higher cone, the large size of the harbours suggests that a different process cut them, probably the eruption itself. The small volcanic island, Surtsey, south of Iceland shows how a volcanic rim can be cut and shaped by the eruption itself.[31]

We would expect the size of a channel eroded by erupted volcanic material to depend on the volume flow rate of the lava. Indeed, it may have required a large eruption of lava, together with mud, and other hot material, to cut these channels. With a large volume of lava being erupted at one time, the channels could have been cut rapidly in one or two eruptive events. Once the channel had breached the rim, normal weathering and erosion could have accelerated the formation of this feature because the bowl-shaped crater would have concentrated precipitation through the channel.

Some of the deeper inlets on the peninsula such as Port Levey and Pigeon Bay may also have been cut by erupted volcanic material. It is interesting to note that the Diamond Harbour Volcanics flow into Port Levey, and the Mt Herbert Volcanics into Pigeon Bay (Figure 4).

White Island (Figure 8), an active volcanic island north of North Island, has an analogous shape and seems to have formed the same way. The mouth of White Island breaches the rim of the volcano, and forms a sub-horizontal platform just above sea level. Erupted material from the vent flows through the gap in the rim of the volcano into the sea. The volcanic rims on Surtsey have a similar shape.[31]

Even the gullies and channels on the flanks of the Banks volcanoes have not been eroded by normal weathering. It is clear that they developed as the volcanoes erupted, because lava flows have been channelled into gullies, and lahars have accumulated in stream channels.[32]

Thus, considerations of erosion have ruled out the Recessive stage of the Flood, leaving the post-Flood era (before the end of the Ice Age) as the most likely time that the peninsula formed.

Effects of the Ice Age

Ice cover was much greater in New Zealand during the Ice Age and extended further north of Banks Peninsula, even to parts of the North Island.[33] Yet, although the peninsula is nearly 1,000 m high in places, there is no evidence that glaciers ever formed on Banks Peninsula.[34] The absence of ice cover could mean that the volcanoes erupted towards the peak of the Ice Age, when the changed environmental conditions, which caused the ice sheets to retreat, prevented ice forming on the peninsula. Heat from the freshly deposited volcanic cones would also have helped prevent any build-up of ice. Eruption at this time would have allowed time for the wind-blown loess blankets to form on the volcanic flanks. The loess would likely have been produced from the Southern Alps, exposed as the ice retreated. The steep, bare landscape would have been prone to wind erosion before vegetation became established.

However, the absence of ice cover does not necessarily eliminate the possibility of an eruption early in the Ice Age. In this case the absence of glaciers on Banks Peninsula could be explained by the volcanoes being isolated from the mainland and surrounded by warmer ocean waters during the Ice Age.[35]

Figure 8. *Aerial view of White Island volcano.*[41]

Summary

Table 1 summarises where the Banks Penisnular fits geologically within the Biblical framework. Each of the classification criteria applied is shown at the top of the table. Those phases eliminated as a possible time for the formation of the rocks on the basis of the classification criteria are marked with a cross (X).

Relationships with other units (fossiliferous basement units and glacial cover units) determined that the unit must have been deposited after the Creation event and before the end of the Ice Age. The regional scale of the volcanoes eliminated the Inundatory stage of the Flood, leaving the pre-Flood era, the Recessive stage of the Flood and the post-Flood era. That the unit has only been minimally disturbed, rules out the possibility of it being formed pre-Flood. The absence of large, flat erosion surfaces rules out the Abative phase of the Flood, and the sub-aerial deposition rules out the Dispersive phase. Thus, the Banks peninsula was formed during the Residual phase of the post-Flood era.

It would be useful for the defined length of the Residual phase on the Biblical geologic model (Figure 3) to be changed from the arbitrary 300 years to correspond with an estimate of the length of the Ice Age.

Toward a post-Flood timescale

The actual date for the Flood is not important for age-dating Flood rocks, because they were all deposited within a one-year period. We can link the timing of Flood deposits to events during the Flood itself, such as the waters rising and the waters receding. However, for post-Flood processes the date of the Flood is very important, especially when we want to tie geologic events to other historical records such as the post-Flood history of Israel, etc.

A post-Flood curve of the eustatic variation in sea level relative to today's level would be useful for estimating the timing of geologic events during the Ice Age. Oard[36] has developed a preliminary proposal (Figure 9) but unfortunately the curve has not been field calibrated. Oard puts the immediate post-flood sea level 40 m above present level, because the current polar ice caps had not formed. Based on his estimate of the volume of ice tied up in the continental ice sheets, he puts the lowest level (at glacial maximum) some 60 m below the present sea level.[37] As the ice melted at the end of the Ice Age, the sea level rose until it was some 10 m higher than the present level. Then, as the continents slowly rebounded isostatically the sea level gradually reduced to the present level. He estimates that the glacial maximum occurred 500 years after the Flood and the ice retreat took 200 years.

Oard based his calculations predominantly on Northern Hemisphere data and assumed global averages. It is likely that the advance and retreat of the Ice Age sheets was not synchronized on all continents but subject to local variations in ocean and atmosphere temperatures which in turn were affected by ocean circulation patterns.[38] Although sea level changes would be globally synchronized, different continents may have experienced different timing of tectonism, so sea-level variation would not necessarily be synchronized on all continents. Provided these limitations are appreciated, sea-level considerations should provide a reasonable starting point for linking geological events from different parts of the world.

The sea-level curve can be tied to specific dates using Biblical chronology for the Flood. The dates included on the curve on Figure 9 are based on Ussher's chronology which has the Flood in 2348 BC.[39] It is important that we improve our knowledge of the chronology of the Ice Age by advancing our understanding of the timing and extent of the Ice Age and of Biblical chronology.

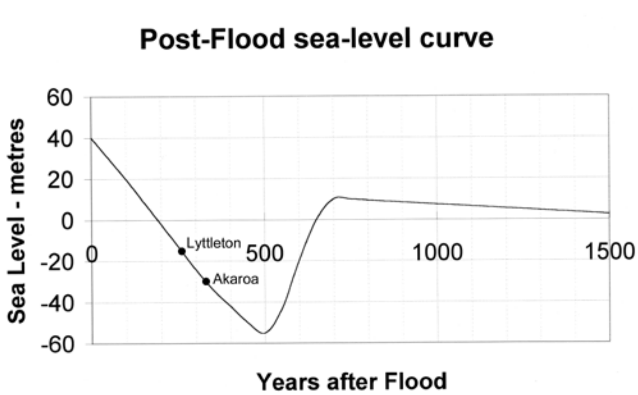

Figure 9. *Post-Flood sea-level curve (after Oard).*[36]

Table 1. *Classification of the Banks Peninsula within the Biblical geologic model. X marks phases eliminated as possible time for the formation of rocks based on the corresponding classification criteria. See 'Summary' in text for details.*

Phase	Geological Relations	Scale	Disturbance & Response	Erosion
Modern	X			
Residual				
Dispersive				X
Abative				X
Zenithic		X		X
Ascending		X		X
Eruptive		X	X	X
Lost-World			X	X
Biotic	X	X	X	X
Derivative	X	X	X	X
Ensuing	X	X	X	X
Original	X	X	X	X

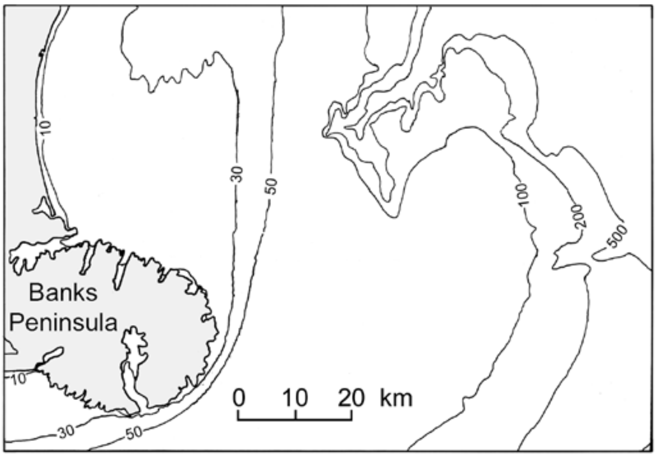

Figure 10. Bathymetry of the ocean floor in the vicinity of Banks Peninsula (depth in metres).[27]

Timing of the Banks Peninsula

There are no raised beaches on the peninsula, and no signs of submarine volcanism,[40] so when the volcanoes erupted the sea level would have been no higher than the present sea level. From the sea-level curve (Figure 9) it is clear that the volcanoes must have erupted no earlier than 200 years after the Flood, and no later than 650 years after the Flood. This is the only period before the end of the Ice Age when the sea level was lower than it is today. As previously discussed, the volcanoes would have had to erupt well before the end of the Ice Age to allow time for their flanks to be covered by the thick loess deposits.

A bathymetric map of the ocean floor off Banks Peninsula (Figure 10) shows that Lyttleton Harbour is 15 m deep at its entrance and Akaroa Harbour is even deeper at 30 m.[27] The harbour entrances were probably near sea level immediately after the products of volcanic eruptions (such as lava and mud) cut them. Sea level would be a natural limit because the erosive power of volcanic products would reduce significantly after encountering the sea. Once below sea level, buoyancy would reduce the erosive action of volcanic material moving over the floor of the channel, as would the cooling and lubricating effects of the water. This effect is observed on the active volcano, White Island (Figure 8), where the platform at the edge of the island sits at sea level. The same is observed on the platforms on Surtsey Island.[31]

Since the later-formed Akaroa Harbour is deeper than Lyttleton Harbour, the volcanic eruptions must have occurred before the glacial maximum while the sea level was falling. If we apply Oard's preliminary curve (Figure 9), it can be seen that the volcanoes would have erupted about 250 years after the Flood, and that only about 75 years separated the eruptions of Lyttleton and Akaroa. Ash and dust from these eruptions would have entered the atmosphere, reducing the intensity of incoming sunlight. The resultant effect on the climate would have enhanced the conditions that favoured the growth of the glacial ice sheets on the continents during the Ice Age.

Apart from the uncertainties with the sea-level curve, this timing estimate would be upset if the peninsula experienced subsidence or uplift since it was deposited. The absence of raised beaches on the Banks Peninsula indicates that there has probably not been significant uplift since the volcanoes formed. With subsidence, the land would have been at a higher elevation in the past, and the depth applied to the sea-level curve would need to be adjusted by the amount of subsidence. For example, if the land had subsided 10 m since the volcanoes formed, the depth applied for the Lyttleton would need to be 5 m (15 m minus 10 m) instead of the 15 m for the present depth at the mouth of the harbour. From the sea-level curve, subsidence of 10 m would mean that the volcanoes erupted about 50 years sooner after the Flood. Note that Surtsey has only subsided about 1.1 m in 24 years since it erupted.[31]

Conclusion

The conceptual model and associated methodology used for classifying rocks within a Biblical framework produced a clear, unambiguous result for the volcanic rocks of Banks Peninsula. This encourages its application to geological problems in other parts of the world.

Multiple classification criteria were applied, including the relationship of the geological unit with other units in the area, as well as the physical scale, degree of deformation and degree of erosion of the units. In broad terms, the volcanoes of the Banks Peninsula erupted in the Residual phase of the post-Flood era, during the Ice Age. It is not difficult to explain how the large, bowl-shaped craters and spacious harbours on the peninsula formed in 4,000 years. They were mostly eroded rapidly by the products of the volcanic eruptions themselves, rather than by the slow weathering processes that we observe today.

The volcanoes of Banks Peninsula illustrate clearly that not all rocks on Earth were formed during the world-wide Flood, but some significant geological structures were formed afterwards.

The length of the Residual phase in the Biblical geological model should be extended from the nominal 300 years to match the length of the Ice Age. Oard suggested this was about 700 years long, but his estimate may need to be changed with more detailed research. If Oard's estimate were adopted, the Modern phase would reduce to 3,600 years from the 4,000 years originally proposed for the geological model.

A more precise timing for the eruptions can be obtained by comparing a post-Flood eustatic sea-level curve with Ussher's chronology, assuming the harbours were originally eroded to sea level, and that the land has not subsided or uplifted. Using Oard's preliminary sea-level curve (which has not yet been field calibrated), Lyttleton Volcano would have erupted about 250 years after the Flood (~2348 BC) around 2098 BC or 4098 years ago, and Akaroa Volcano about 75 years later around 2023 BC. If land subsidence occurred since the volcanoes formed, then these estimates are too late and the volcanoes would have erupted earlier following the Flood—50 years for 10 m of subsidence. Glacial ice did not form on the volcanic cones during the Ice Age because they were surrounded by ocean, which was probably much warmer than today.

With more soundly based curves of eustatic sea level, it may be possible to accurately link geologic events in one part of the world, such as these eruptions, with events from other parts of the world—both geologic and historic. This would be most helpful for our understanding of the post-Flood history of the world.

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16. Davidson, G.E., The importance of unconformity-bounded sequences in Flood stratigraphy, *CEN Tech. J.* **9**(2):223–243, 1995.
17. Weaver *et al.*, Ref. 6, p. 17.
18. Weaver *et al.*, Ref. 6.
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20. Walker, Ref 13, p. 244.
21. Weaver *et al.*, Ref. 6, pp. 18, 21.
22. Walker, Ref. 7, pp. 386–388.
23. Oard, M.J., Antiquity of landforms: objective evidence that dating methods are wrong, *CEN Tech. J.* **14**(1):35–39, 2000.
24. Thornton, Ref. 4, pp. 17–21.
25. Weaver *et al.*, Ref. 6, p. 20.
26. Weaver *et al.*, Ref. 6, pp. 40–45, documents some of these products including pyroclastic flows and volcanic bombs.
27. *Kaikoura Peninsula to Banks Peninsula, 1:200,000 Scale Topographic Map*, NZ 63, Hydrographic Office, Royal New Zealand Navy, Auckland, 1999.
28. Oard, Ref. 23, describes some of these erosion surfaces in the US.
29. Weaver *et al.*, Ref. 6, p. 23.
30. The gullies are clear from the shape of the contours on the topographic map (Ref. 27).
31. <volcano.und.nodak.edu/vwdocs/volc_images/europe_west_asia/surtsey.html> 7 December 2000.
32. Weaver *et al.*, Ref. 6, p. 18.
33. Thornton, Ref 4, pp. 191–193.
34. Weaver *et al.*, Ref. 6, p. 24.
35. Oard, Ref. 3, p. 112, suggests that, immediately after the Flood, the average ocean temperature was some 25°C warmer than today.
36. Oard, Ref. 3, p. 174.
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