4

Results of Geological and Volcanological Investigations

4.1. Rabaul Investigated and Awards Announced

McNicoll remained in Rabaul as administrator during most of the four years following the 1937 eruption and was at the centre of the controversial discussion on the future of Rabaul. No further volcanic activity of any significance took place during this time, and Rabaul gradually recovered as roads and gardens were cleared, and trees and shrubs regenerated, providing welcome shade. However, the bleak forms of Vulcan and Tavurvur stood at the entrance to Simpson Harbour like sombre monuments to what had happened in May 1937, as Rabaul was investigated and recommendations were made on its suitability as a capital.

Sir Raphael Cilento arrived at Rabaul on 10 July 1937 and began his investigation of the 'question of all precautions of a medical nature that might be necessary either immediately or in the future' as a result of the volcanic activity, including malaria, dysentery and dust hazards such as pneumoconiosis and eye irritations (Cilento 1937a, 1). Cilento supported Dr Champion Hosking's earlier medical recommendations; however, in his comprehensive report, he noted that the medical problem was only one aspect that had to be considered by the administrator in deciding to move the population from Kokopo, where medical risks were already evident, back to Rabaul. Malaria was a primary threat; therefore, the management of surface water where mosquitos might breed was important. Cilento was also concerned about the water-rich nature of the blue-grey volcanic mud from Tavurvur that had fallen on Rabaul:

> The mud … is of a gummy consistence, very readily flowing; it appears to be hygroscopic, specimens have remained moist for weeks without the addition of water; and it has lined all the pits and depressions in the soil with a plaster-like coating which definitely prevents ready absorption or run-off of the contained water. (Cilento 1937a, 16)

Cilento supported McNicoll's controversial decision to occupy Rabaul immediately, noting that the psychological effect

> was, generally speaking, markedly favourable. The reinstitution of orderly routine activity had had a profound effect upon the confidence of the individual, and had gone far towards the re-establishment of that sense of security which is an important psychological factor. (Cilento 1937a, 20)

Sir Raphael concluded that, while there was a malarial risk, this could be 'completely controlled within fifteen months, and may, if circumstances are favourable, be controlled within six months', assuming that strenuous preventive measures continued to be adopted (Cilento 1937a, 26). Addressing the problem of the future of Rabaul from a medical standpoint, he argued that the European population should be segregated from other races by living at 1,500–2,000 feet (460–600 metres) above sea level—and thus away from the 'native and Chinese areas'. This view today can be judged as distinctly racist; indeed, some people consider Sir Raphael to have held strong right-wing views (Fisher 1994). Cilento noted in his report that the expansion of a segregated European settlement would depend on the response of the Australian Government to the results of an official volcanologists' inspection that was then being carried out in Rabaul.

Three geoscientists were involved in the volcanological investigations at Rabaul. The principal investigator was German-born Dr Charles Edgar Stehn—an experienced volcanologist and director of the Netherlands Indies (now Indonesia) Vulcanological Survey (van Bemmelen 1949). His services were requested by the Australian Government through the Government of the Netherlands East Indies (Press Release 1937). Stehn was a good choice as he had volcanological experience from studies at East Indies volcanoes, in particular that of the major 1883 eruption at Krakatau and the related formation of a caldera, which could be applied to assessing the situation at Rabaul volcano. Stehn was away from his headquarters in Bandung, Java, from 8 July until 25 October 1937. He arrived in Rabaul about 24 July accompanied by geologist Dr Walter George Woolnough, geological adviser to the Australian Government, who was to be his associate. Stehn wrote later that he was 'astonished at the exceedingly close analogies which may be drawn between Krakatau and Blanche Bay' (Stehn and Woolnough 1937a, 5).

Stehn and Woolnough were joined in Rabaul by the young Australian geologist Norman Henry Fisher, who, since 1934, had been the administration geologist at Wau where he undertook geological studies on the Morobe Goldfields (Fisher and Branch 1981; Wilkinson 1996). Fisher was assigned by the administration to give all possible assistance to the two, more senior, visiting investigators at Rabaul. The three scientists undertook fieldwork together, Stehn and Fisher focusing on building up an understanding of the history of the Rabaul volcanoes (Figure 4.1). Fisher would play a major part in the aftermath of the 1937 Rabaul eruption and, indeed, would pioneer the establishment of instrumental monitoring of the Rabaul volcanoes. He produced, in 1939, what turned out to be the standard volcanological reference work of the 1937 eruptions and of the Rabaul area in general up to that time (Fisher 1939a). He even found time to publish a popularised article on Rabaul's recent volcanic eruptions in an Australian magazine (Fisher 1939b). Fisher and Stehn also travelled to the north-central coast of New Britain where there were many young volcanoes, triggering in Fisher a broader interest in the volcanoes of the whole Territory of New Guinea (Fisher 1939c). They climbed the 2,220-metre volcano of Ulawun, or the Father, on 13–15 August 1937, possibly becoming the first Europeans to do so (Fisher 1937).

Stehn and Woolnough had been asked to comment not on maintaining Rabaul as a commercial centre, but rather on its suitability as the main administrative centre of the Mandated Territory. They were uncompromising in their official report, dated 29 September, which the Prime Minister of Australia received in November. They reported that they could

> see no reason whatever for believing that volcanic activity may not recur here at almost any time … [and] the possibility that such outbreaks may occur closer to, or even within the limits of the town area itself (as, for instance, at Sulphur Creek), cannot be eliminated. <u>We are therefore forced to the conclusion that reasonably early evacuation of Rabaul as the main administrative centre of the Territory must be seriously considered</u> [authors' emphasis] … Though it is not improbable that the intensity of vulcanism at this point may have passed its maximum and may now be in its declining phases, such a conclusion cannot be stated with any confidence. [There was also] the possibility that the whole of the capital invested in town and harbour may be jeopardised or wiped out of existence in a few hours by another and more serious eruption taking place under conditions not so extraordinarily favourable as those of the recent phenomena. (Stehn and Woolnough 1937a, 25)

Figure 4.1. Ash-covered *Durour* on slipway and Dr Stehn on foot track.
Volcanologist Charles Stehn returns along the well-worn track made by inquisitive visitors to the pumice-covered *Durour* at the former slipway near Karavia. The *Durour* was left stranded hundreds of metres inland from the new shoreline formed after the May 1937 Vulcan eruption, and was later written off and sold as scrap. The photograph was taken by N.H. Fisher in July 1937. R.W.J. Collection 10, Folder 2, NHF-envelope 5.

Among the 'extraordinarily favourable' conditions referred to by Stehn and Woolnough was the fact that the eruption had started at Vulcan, more distant from Rabaul than Tavurvur, Rabalanakaia or Sulphur Creek; that the outburst began in bright sunlight, rather than at night, so the 'terrors of darkness were not added to those of surprise'; that it took place on a Saturday afternoon when 'families were united in their homes, and motor transport was concentrated in an extraordinarily convenient way'; that the sea at Nodup was calm, allowing the large ships to stand in close; and that the organisation and equipment of the Sacred Heart Mission at Vunapope were available and adequate to meet the emergency (Stehn and Woolnough 1937a, 17–18). In their view:

> The fortuitous concurrence of so many favourable factors could scarcely have been anticipated, and it must not be taken for granted that such a combination must necessarily exist when next Rabaul has to be evacuated at short notice. (18)

Few people in Rabaul at the time of the release of Stehn and Woolnough's report were aware that the two authors had different opinions about the future of Rabaul and about the volcanology of the area. Woolnough, who was not a volcanologist, had returned to Australia after only a few days of field investigations, and had completed the report recommending the withdrawal of the administration from Rabaul while Stehn and Fisher were still in Rabaul undertaking more extensive studies over a period of six weeks. Both Stehn and Fisher believed that Rabaul could remain as the capital so long as a volcanological observatory was established to provide warnings of eruptions. Stehn sent his changes to Woolnough in Australia, but not all of these were incorporated in the report. Consequently, the jointly authored report reflected the opinions of Woolnough more than those of Stehn. Woolnough was the sole signatory of the report's appendix, which suggested the New Guinea mainland as a suitable area for the new capital, and he also wrote the final paragraph:

> The spectacular development of the gold industry in New Guinea and the very high probability of discovery of oil-fields there, together with possibilities of great expansion of timber and agricultural industries, suggest that, in the event of a decision to remove the seat of government being arrived at, selection of a reasonably central site on the New Guinea coast should receive serious consideration. (Stehn and Woolnough 1937b, 158)

That Stehn and Woolnough reached different conclusions as a result of their joint investigations would not have helped decision-makers in the Australian Government. Stehn, based on his experience with active volcanoes and instrumental monitoring in the Netherlands Indies, believed that a well-equipped volcanological observatory would be capable of providing warnings of impending eruptions sufficiently far in advance to enable the Rabaul population to be removed to places of safety. Conversely, Woolnough stated that 'the advantages of retention of the capital in its present site and the provision of elaborate warning systems should not be entertained' (Stehn and Woolnough 1937a, 28). He concluded that the required scale of such an observatory, the uncertainties of eruption prediction, the generally small industrial and commercial development in the town and the fact that the harbour might become blocked by future eruptions were all reasons why an observatory should not be constructed at Rabaul and why the town should be abandoned as the capital.

Instrumented observatories were, by 1937, a well-established feature of some of the world's best-known volcanoes, the idea deriving from the much earlier concept of astronomical observatories where instruments were directed at the stars, rather than at the internal and surface behaviour of a volcanic earth. The first volcanological observatories were built at Vesuvius, Italy, in 1841–45, and at Etna in 1878–81. The Americans had established an observatory at Kilauea volcano, Hawaii, in 1912, and Japanese observatories had been built on Aso by 1928 and at Asama by 1933. Geologist E.R. Stanley had drawn the attention of the Australian Government to the need for volcanological observatories in the Territory of New Guinea after his attendance at the Pan-Pacific Scientific Conference in Honolulu in 1920 (Stanley 1923). Stehn and Fisher were, therefore, building on something of a volcanological tradition.

The British Empire honours for the 10 Rabaul people recommended by the administrator in June were announced towards the end of 1937—around the time of the release of the Stehn and Woolnough report—and the list was published in some Australian newspapers (*Border Watch* 1937). An eleventh awardee, and top of the list, was Ramsay McNicoll himself, who received a knighthood—a decision that, predictably, served to fuel further uncomplimentary remarks about the administrator in some quarters. The list is as follows:

- Brigadier-General W.R. McNicoll: KCBE (Knight Commander of the Order of the British Empire)
- Judge F.B. Phillips of the Supreme Court of New Guinea: CBE (Commander of the Order of the British Empire)
- Honourable J.C. Mullaly, plantation owner: OBE (Officer of the Order of the British Empire)
- W.B. Ball, acting superintendent of the New Guinea police administration: OBE
- Dr R.W. Cooper, medical officer of the New Guinea administration: MBE (Member of the Order of the British Empire)
- Dr N.B. Watch, medical doctor: MBE
- W.B. Prior, acting inspector of the New Guinea police: King's Police Medal.

The following received the BEM (Medal of the British Empire, Civil Division):

- Mrs Kathleen Bignell
- L.W. Heineke
- John Barrie
- Eric Hopkins.

Bishop Gerard Vesters, a Dutchman, was also appointed OBE in recognition of the services provided by the Catholic mission at Vunapope, but only after the Netherlands Government had approved his acceptance. There were no awards for New Guineans—on the contrary, the new land that had been formed at Vulcan and taken over for gardens by local Tolai people was claimed by the administration as 'government land'. Such differences between European and traditional land laws resulted in long and bitter clashes and Tolai protests went on for years. District Commissioner Keith McCarthy, after WWII, supported Tolai claims to Vulcan and their appeal was taken to the Supreme Court, but another district commissioner declared Vulcan an industrial area and then issued a licence for the construction of a racecourse there. However, the administration eventually agreed to hand back Vulcan to the people.

4.2. Calderas and Their Origin

Stehn's, Fisher's and Woolnough's findings were reported comprehensively. Included among their findings was discussion of the origin of the Blanche Bay caldera as a whole. Fisher promoted the agreed view that a huge volcano, perhaps 'at least 9,000 feet [2,700 metres] in height', once covered the area now occupied by the Blanche Bay caldera—or else, 'as is quite likely' in its later history, a group of somewhat lower cones (Fisher 1939a, 12). In Fisher's view, it was likely that a 'tremendous outburst or series of outbursts … blew most of the mountain to fragments', scattering pieces of the central volcano around the countryside (Fisher 1939b, 13); subsidences around the periphery of the resulting explosion crater then formed the caldera, a large eruption finally producing huge thicknesses of 'pumice ash' (Figure 4.2).

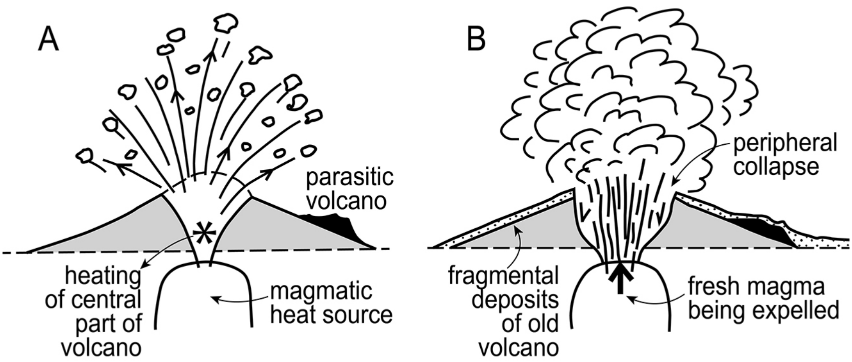

Figure 4.2. Caldera formation by outward explosion.

Simplified cross-sections of the formation of calderas by (A) initial heating and outwardly directed explosions of the central part of a volcano, followed by (B) explosive eruption of fresh magma and then by peripheral collapse of the caldera margins.

The smaller but conspicuous Rabaul volcanoes of Watom, Kabiu, Tovanumbatir and Turagunan were regarded by Fisher (1939a) as 'parasitic' or satellite volcanoes on the flanks of the proposed great ancestral mountain. Fisher noted, however, that the four volcanoes at Rabaul were aligned in a north-west–south-east direction almost at right angles to the central axis of New Britain island as a whole. He referred to Stanley's geological description of the Willaumez or Talasea Peninsula chain of young volcanoes that ran northwards into the Bismarck Sea from the central, east-west coast of New Britain (see the M–D to Garbuna volcanoes shown in Figure 0.1 in the Introduction). Control by major geological structures for both volcanic alignments was proposed by Fisher. However, he went even further, drawing attention to the fact that the north-westward–trending Watom–Turagunan Zone at Rabaul (see also Stanley 1923) paralleled the trend of the strongly elongated New Ireland to the north-east. This structural relationship would be considered again by a later generation of geologists looking into the tectonic setting and origin of this highly complex area of the world.

This interpretation for Blanche Bay by Fisher, and by Stehn and Woolnough (1937a, 1937b), was not, however, the mechanism of formation of the Krakatau caldera proposed earlier by Stehn's colleague, R.W. van Bemmelen (1929; Figure 4.3 left). Nor was it the mechanism for the general model of so-called Krakatau-type calderas that would be promoted later, and internationally, by H. Williams (1941; Figure 4.3 right). Rather, it reflected the view still held by many geologists at that time that calderas were the result of volcanoes that 'blew up', meaning exploded outwards, rather than by collapsing wholesale into underlying magma reservoirs.

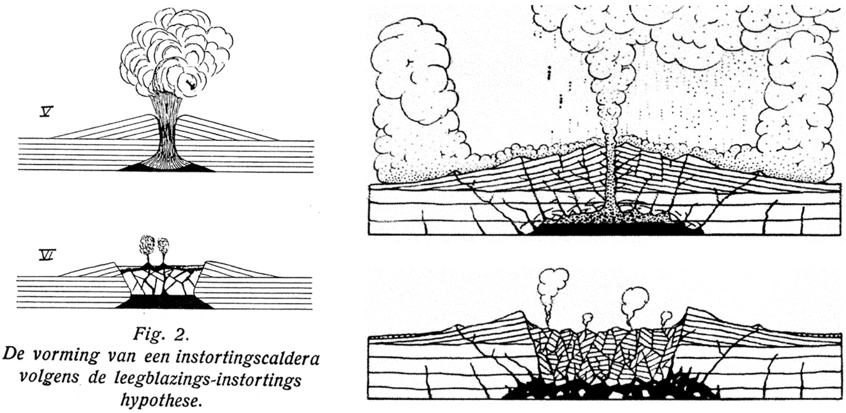

Figure 4.3. Caldera formation by inward collapse.

Two versions of the 'collapse' origin of Krakatau-type calderas are shown here. Left is a detail from van Bemmelen's 'Fig. 2' (1929). The right-hand diagram is from a paper on volcanoes by Howell Williams (1951, 51) based on his own fieldwork on Crater Lake, Oregon, United States. Magma in a shallow reservoir shown in the upper cross-sections of both diagrams is erupted rapidly as a result of a powerful volcanic eruption. The eruption shown on the right is producing pyroclastic flows that cascade down the flanks of Crater Lake volcano. This evisceration leaves the roof of the magma reservoir unsupported, and it collapses and disintegrates, as shown in the two lower diagrams. Subsequent geological studies of many eroded calderas, however, have not revealed such strong disintegration of the roof rocks as shown in these two interpretations.

Fisher, Stehn and Woolnough did not use the term *ignimbrite* for any volcanic deposits at Rabaul, 'ignimbrite' being the important volcanic rock type that had been identified by Marshall (1935) in New Zealand. These rocks or deposits were produced by large-volume lateral flows of pumiceous materials during large explosive eruptions—that is, by *pyroclastic flows* (see Figure 4.3 right). Stehn, however, did refer to 'the eruption of incandescent clouds "fire avalanches" in 1934', but at Merapi volcano in Java (Stehn and Woolnough 1937a, 16). Further, recognition of *nuées ardentes* or 'glowing clouds' at Mount Pelée, in the Caribbean, in 1902, was well recognised internationally (Fisher had access to a copy of the report on Mount Pelée by Perret [1937]) so the three investigators certainly were aware of the pyroclastic-flowage phenomenon in principle. Much later work by others would reveal the deposits of large pyroclastic flows at Rabaul and, indeed, a much more complex geological origin for Blanche Bay.

The 'pumice ash' noted by Fisher was almost certainly the deposit of large-scale pyroclastic flows. Non-use of the term 'ignimbrite' can also be readily understood, as the older New Zealand examples were of the 'welded' type—that is, formed where the great thicknesses of 'pumice ash' of the pyroclastic

flows become strongly compacted and flattened after deposition, forming a distinctive lens-like pattern in rock exposures. *Welded* ignimbrites, we now know, are much rarer at Rabaul. Further, Marshall's paper had been published just two years previously and its significance and importance were not yet recognised internationally. Fisher and Stehn did not make any reference either to smaller pyroclastic flows during the eruptive activity at Vulcan in 1937.

4.3. Mapping the Active Volcanoes of Blanche Bay

Stehn, Fisher and Woolnough, during their assessment of Rabaul's volcanic safety, appear to have directed special attention, quite naturally, to the volcanoes immediately south-east of Rabaul township—namely, Rabalanakaia and Sulphur Creek, which were closest to the town, and to Tavurvur, further south-east (Figure 4.4). All three volcanoes had conspicuous geothermal manifestations—fumaroles, hot springs and solfataras—both before and at the time of their visit. We can here refer to the whole area as the Greet Geothermal Field. The north-eastern margin of the field coincides with the south-east-facing caldera wall defining this north-eastern side of Blanche Bay. Rabaul town is immediately adjacent to its north-eastern margin. The significance of the quasi-permanent Greet Geothermal Field is that it must be underlaid by a long-lived heat source, most likely a body of magma or else hot, partially molten rock.

Rabalanakaia had grown not only within the older Palangiangia crater but also directly on the projected trace of the caldera wall. The south-western side of Palangiangia may have collapsed when the caldera itself was created. The flat floor of Rabalanakaia has a distinctive ring or circle of fumaroles marked by mounds of mud and sulphur (Fisher 1939a, upper photograph on p. 56; see also the aerial-photograph image in Figure 7.6). Its previous eruption may have been in 1767, as shown in Figure 1.4. The long, narrow and thermally active Sulphur Creek on the harbour shore trends eastwards towards Rabalanakaia. Fisher believed it may have originated by 'a fissure type eruption of volcanic eruptions' (Fisher 1939a, 39). Three extinct craters were mapped east of the head of the creek, the more south-easterly of which had a freshwater pool in which the Department of Public Health kept its supply of gambusia (fish) because of their reputation for mosquito control.

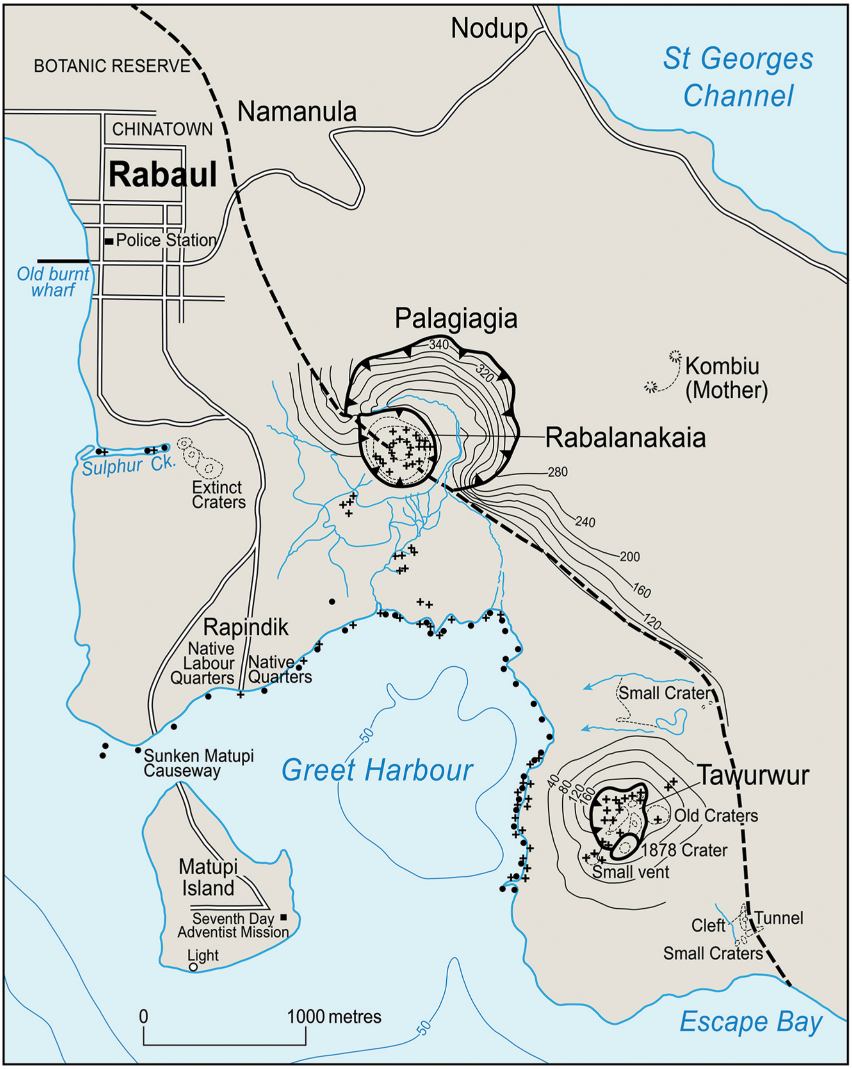

Figure 4.4. Map of the Greet Geothermal Field and Rabaul town.

Features of the Greet Geothermal Field are shown in this detail adapted from the chart published by Fisher (1939a, Plate A1). The bold dashed line refers to the trace of the south-west-facing caldera wall, drawn as if it were at sea level, as envisaged by Fisher (see also Figure 4.5). Note that the small craters near Tavurvur are very close to the trace of the caldera. The spelling is the same as used by Fisher. Contours are in 40-metre intervals (post-eruption) and isobaths are in 50-metre intervals (pre-eruption). Fisher mapped in considerable detail the distribution of 'steam' emanations (crosses) and 'gas ebullitions' around parts of Greet Harbour (filled circles).

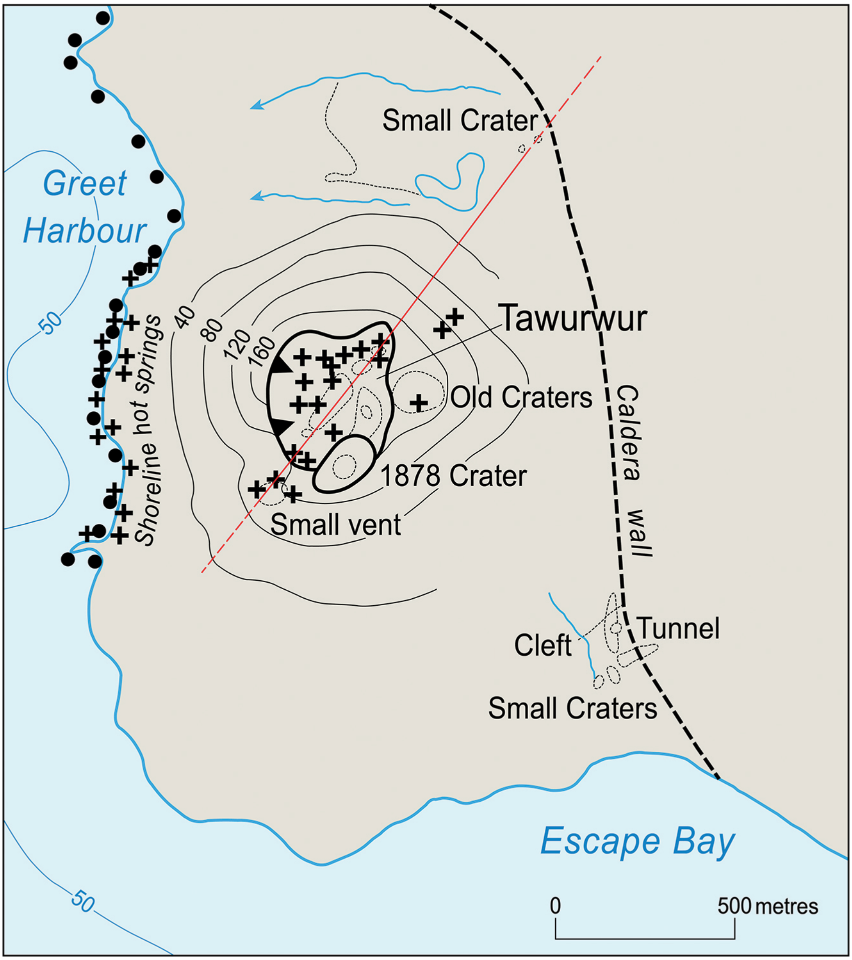

Figure 4.5. Map of Tavurvur and the Escape Bay area.

This is a detail from a map prepared by N.H. Fisher (1939a, Plate A1; see also Figure 4.4; compare with Figure 6.8). Note the strong north-easterly alignment of the craters of Tavurvur (red line) and the proximity of the two 'Small Crater' areas to the trace of the caldera wall.

The most conspicuous geothermal areas seen after the 1937 eruption were on Tavurvur itself and along the eastern shore of Greet Harbour, extending westwards along the southern edge of Rabalanakaia past Rapindik. Fisher described the new craters of Tavurvur in some detail, pointing out that they lay a little towards the north-east of the 1878 crater (Figure 4.5). The recent eruption at Tavurvur had taken place in a narrow central fissure that ran south-westwards beyond the summit area to a small vent on the slope of the cone.

Two other crater areas active in 1937 were of interest too, despite their small size, because of their proximity to the caldera trace. They serve as evidence for minor eruptions beyond the crater area of Tavurvur itself but within the Greet Geothermal Field as a whole. One of the areas was near the shore of Escape Bay and may have been active in 1878 too. It consisted of three shallow craterlets together with a curious east-facing 'tunnel' that apparently represented a lateral 'blow-out' from beneath an old lava flow (Figures 4.5 and 4.6). Fisher noted later that he

> had the unpleasant experience of descending into the cavern south-east of Tavurvur before it was realized that a thick gas existed in the bottom. The gas was undoubtedly mostly carbon dioxide, but at least some of the after effects corresponded to those following on a small dose of carbon monoxide received once before in an abandoned mine … On returning some months later with the intention of analysing the gas, it was found to have all disappeared and no fresh gas was being given off. (Fisher 1939a, 32)

Salt water was evidently emitted from these small craters in great quantity at the time of the Tavurvur eruption,

> as a flood of water was observed by [local people] at the time, and a heavy flow of mud and sand with a considerable number of huge boulders was left between the craterlets and the shore. (Fisher 1939a, 23)

The second area of craterlets was to the north-east of Tavurvur and apparently they did not exist before the 1937 eruption (Figure 4.5). They were still warm and, again, both held evidence for the presence of the colourless, odourless and heavy volcanic gas of carbon dioxide. A considerable amount of carbon dioxide had evidently been given off at one of them during the 1937 eruption as 'numerous birds, insects and several pigs were found dead in the immediate vicinity' (Fisher 1939a, 38). Accumulations of carbon dioxide remain a potential threat to life in the Tavurvur area, including to local people digging for megapode eggs in the thermally active parts.

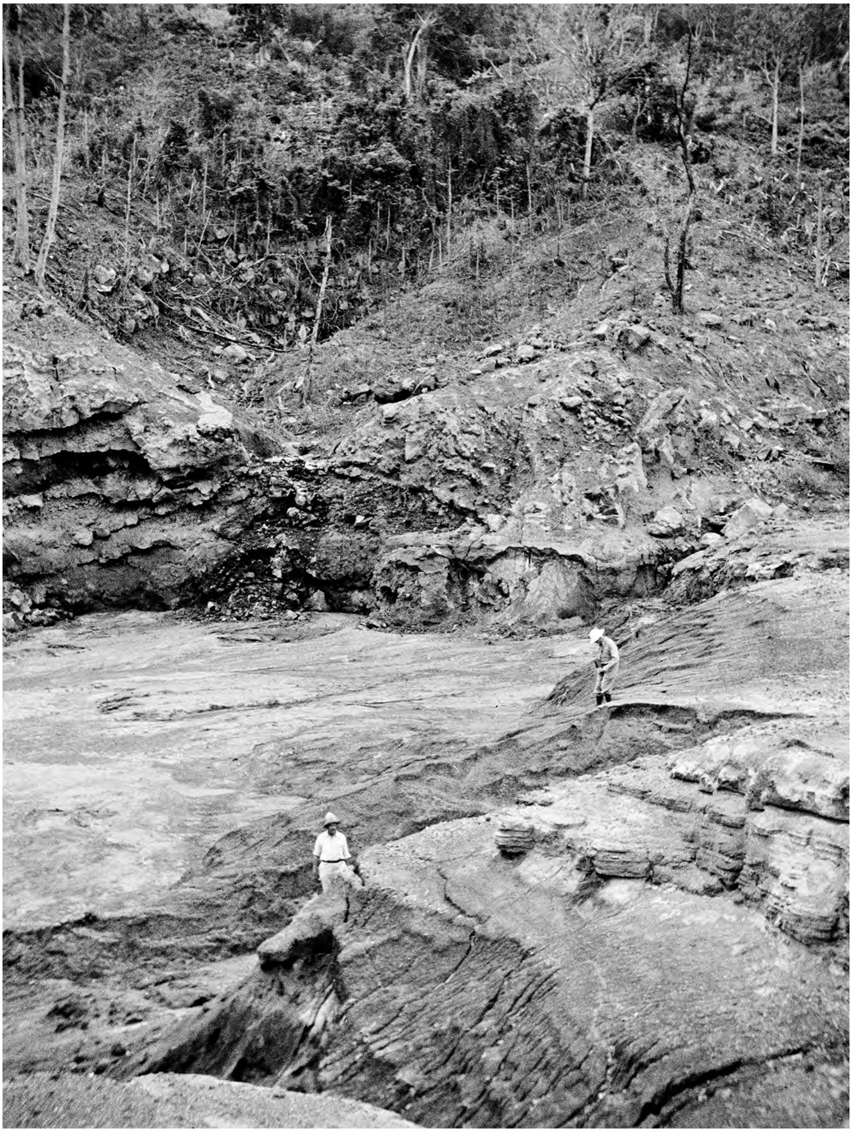

Figure 4.6. Volcanological fieldwork at Escape Bay.

Volcanologists C.E. Stehn (left) and W.G. Woolnough are seen here undertaking field work at Escape Bay, south-east of Tavurvur volcano, in late July 1937, close to where a series of minor explosion craters had developed during the Tavurvur eruption. R.W.J. Collection 10, Folder 2, NHF-envelope no. 5. High-resolution copy courtesy of the National Library of Australia.

Figure 4.7. Water-filled 1878 crater near the new Vulcan cone.

What used to be Vulcan Island was all but concealed by the pumice laid down during the 1937 Vulcan eruption. However, the 1878 crater of the island was still clearly identifiable after the 1937 eruptions as a water-filled depression, as seen in this photograph taken by N.H. Fisher probably in about July 1937. Fisher's New Guinean assistant shown here is Sokopo. The slope of Vulcan cone can be seen in the top right-hand corner and the western caldera rim in the top left. R.W.J. Collection 10, Folder 2, NHF-envelope no. 4. GA negative reference GB-2551.

Construction of a new volcanic cone on the western side of Blanche Bay as a result of the 1937 eruption represents the most conspicuous change to the volcanic landscape in the Rabaul area. The cone, which was variously given the name Vulcan, Baluan or Kalamanagunan, grew from a new vent about 1.5 kilometres north-west of the old 1878 crater, filling the gap between the former Vulcan Island and the shoreline (Figures 3.8 and 4.7). This position was closer to the caldera wall on the western side of the bay. The highest point on the north-west side of the central crater rim was, according to Fisher (1939a), in August 1937, 742 feet (226 metres) above sea level, although the general elevation of the crater rim was about 650 feet (198 metres). The crater measured 2,070 x 1,830 feet (631 x 558 metres), being slightly elongated from east to west. Thermal activity was still taking place on the lowest part of the crater floor, as well as on the south-western outer slopes including at the small blow-out craterlet. An inlet or embayment at the northern foot of the cone appears to represent a flank vent that was breached by the waters

of Blanche Bay (Figure 4.10). Thermal activity was taking place here too, but, together with all the other thermal activity on the new cone, it would die away within months. This is in marked contrast to the Greet Geothermal Field where thermal activity would continue indefinitely.

4.4. Winds, Ash Falls and Planning

Newsreels were shot of the devastation at Rabaul and the two active volcanoes, some of which were shown in theatres in Australia (NFSAA 1937a, 1937b, c. 1939). One of the films, photographed in 8-millimetre colour from HMAS *Moresby*, shows the shoreline of the affected town and wharves, as well as ash being cleared from town roofs and minor explosive activity taking place at Vulcan (NFSAA 1937a). The *Moresby* undertook a bathymetric survey of parts of the harbour floor and N.H. Fisher (1939a) used the results to estimate the amount of new material on the floor of Blanche Bay. He also mapped ash thicknesses on land throughout the affected area for both the Vulcan and the Tavurvur eruptions of 1937 (Figures 4.8 and 4.9), estimating the volumes of tephra for each one. The total volume for Vulcan, including the cone itself, was calculated to be 400 million cubic yards, or about 300 million cubic metres, although there is some uncertainty about whether this also included the amount of ash that fell over a broad area of the Bismarck Sea to the north-west. Measuring the thicknesses of the Tavurvur mud-ash in the town area cannot have been straightforward because of the flowage of the mud and its removal from roofs by hand or rain, but Fisher estimated the total volume to be 3–4 million cubic yards, or about 2.3–3 million cubic metres—that is, a hundred times smaller than the volume for Vulcan. These results, although only approximations, provide clear evidence that the Vulcan eruption of 1937 was far larger than the Tavurvur eruption, which is not surprising given that Vulcan started its activity well before, and continued after, the relatively short-lived eruption at Tavurvur, creating more devastation, including the loss of hundreds of lives.

Another useful aspect of the isopach map in Figure 4.9 is the way in which the lines of equal ash thickness appear to have been influenced by different sets of winds above the volcanoes. The Vulcan isopachs have a wide divergence, spreading downwind almost at 90 degrees to each other. This was caused by different winds at different times and at greater heights, and presumably also by creation of the volcano's own local 'weather'—including rain and lightning—as the heated water vapour clouds penetrated to higher and colder levels. The dominant trend of the isopachs for Vulcan, however,

is west-north-westerly, probably reflecting a combination of both the lower-level south-easterly winds and higher east-to-west winds above 4 kilometres. In contrast, the simple, elongated form of the Tavurvur isopachs reflects the dominant impact of the strong low-level south-east trade winds at this time of year. The distribution of some ash from Tavurvur could have been affected by the higher east-to-west winds, resulting in deposition mainly in Simpson Harbour, as discussed above with reference to Figure 3.27. Alternatively, it could have been deposited on land to the north-west in layers too thin to be measured easily, or been mixed with Vulcan ash before it was deposited on the ground.

Figure 4.8. Two ash layers exposed on a roof in Rabaul.

The preserved thicknesses of ash on this corrugated iron roof of a Rabaul building are shown clearly where parts of the ash layers have slid off onto the ground. Note, particularly, that there are two main layers of ash: the lower, light-coloured one was produced by Vulcan on the evening of 29 May 1937, and the upper one by Tavurvur beginning in the early afternoon of 30 May. The two layers are of similar thickness, meaning that this building was in the main part of Rabaul town. Measurements at different places assisted N.H. Fisher in building up the isopach map shown in Figure 4.9. Note also the damaged trees in the background. GA negative reference GB2934.

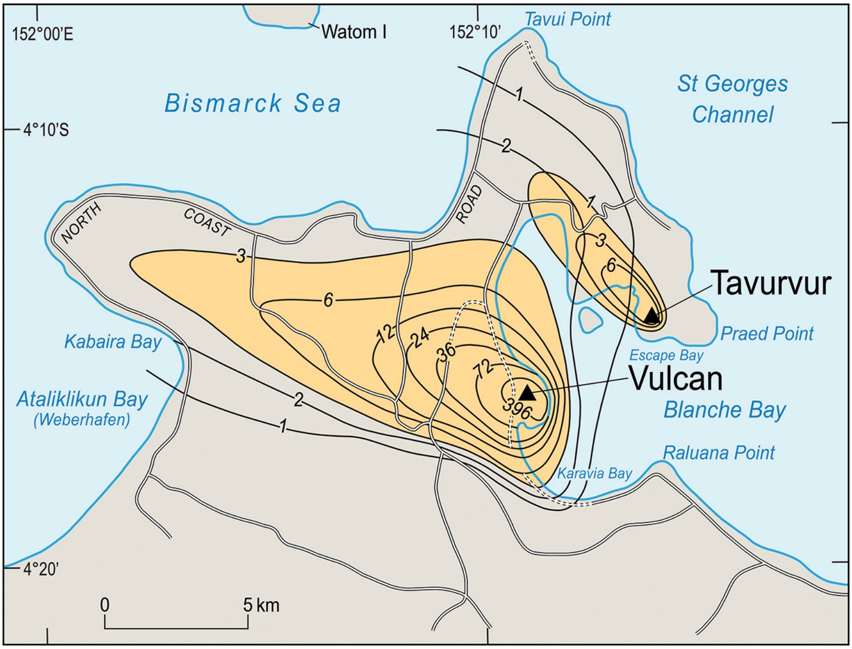

Figure 4.9. Map of contoured thicknesses of Vulcan and Tavurvur deposits.

The isopachs or 'contour' lines shown here have been taken from a comprehensive chart drawn originally by volcanologist N.H. Fisher (1939a, Plate C1). Fisher's chart was then adapted (and reduced in size) by Johnson and Threlfall (1985, 40). The isopachs provide an indication of the thicknesses, in inches, of the ash and pumice deposits produced by the 1937 volcanic eruptions at Vulcan and Tavurvur. Colour has been added here for those areas where Vulcan ash is 3 inches or more in thickness and where Tavurvur ash is 1 inch or more, in order to emphasise the differences between the main axes of ash dispersal for the two volcanoes (the Vulcan axis being more westerly). Note, however, that there is overlap between the isopachs for the two volcanoes corresponding to depths of less than both 3 and 1 inch, respectively. Fisher originally plotted names of villages and their respective number of fatalities but these have been omitted in this simplified adaptation.

The exodus of townspeople from the Rabaul area up Namanula Hill and Tunnel Hill roads in May 1937 was a spontaneous evacuation triggered by the sight of the volcanic fallout. However, most of the land west and north of Blanche Bay was affected by the volcanic fallout from both volcanoes (Figure 4.9). No contingency plans for evacuation had been drawn up by the administration, but the two roads were obvious exit routes for the trapped evacuees. Both roads were the nearest and most effective means of escape by land from within Simpson Harbour, even though they did not lead to nearby refuge points suitable for the accommodation of thousands of people. A lesson to be learnt from the 1937 Vulcan eruption is that the north-coast road would again be made unserviceable by a similar eruption

during the south-east season. Those people who used Tunnel Hill Road in 1937 and then turned westwards along the north-coast road fared much worse than those who headed north-eastwards towards Tavui Point at the northern tip of Crater Peninsula where the ash fall was very slight (Figure 4.9). The coastal strip between Nonga, Tavui Point and Nodup is less vulnerable to Vulcan ash falls in any season than other areas around Rabaul, but accommodation was lacking there for large numbers of people in 1937. The thousands of evacuees at Nodup on St Georges Channel were fortunate that the sea was calm, enabling ship embarkations to be made even in the absence of port facilities.

Dr Stehn, before leaving Rabaul, compiled a list of 14 phenomena that might precede any further volcanic outbreaks at Rabaul (Stehn and Woolnough 1937a, 1937b; Fisher 1939a, 45). These ranged from felt earthquakes (number one in the list) to seeing large quantities of dead fish (number 14). Among other recommendations, he highlighted the importance of taking measurements of any temperature changes at existing thermal areas on land and shore, collecting and identifying volcanic gases, and keeping an eye open for any new gas upwellings in places like Greet Harbour and near Vulcan (Figure 4.10). N.H. Fisher used the list after Stehn's departure for his own, ongoing, volcano-monitoring program, commenting on its usefulness in his 1939 report, although he was limited by the availability of suitable instrumentation—he had no seismograph at this time, for example. Nevertheless, Fisher eventually was able to collect some vapour and gas samples along the water's edge by adapting and using a portable gas-analysis apparatus. The dominant emissions were found to be water vapour and carbon dioxide, although Fisher was fully aware that during the eruptions themselves other important gases such as hydrogen sulphide, sulphur dioxide and hydrogen chloride had been identifiable by their distinctive smells. All of these results, he said, 'point in the same direction, namely, that the volcanic activity has reached a fairly decadent stage' (Fisher 1939a, 32).

A suite of seven samples from the 1937 eruptions at both volcanoes was sent to Australia by the Department of Agriculture for analysis at the Waite Agricultural Research Institute in Adelaide. The results were intended for agricultural purposes, but they also had some volcanological interest. Calcium sulphate (gypsum) was detected in the analysis of soluble salts extracted from the samples and was attributed to a volcanic fumarolic origin. Sodium chloride was also common and was 'undoubtedly due to contamination with sea-water' (Hosking 1938, 375; see also Fisher 1939a, Appendix 2). The acidity and alkalinity of the liquids extracted from the seven samples, as measured by pH values, ranged from 5.0 to 7.9.

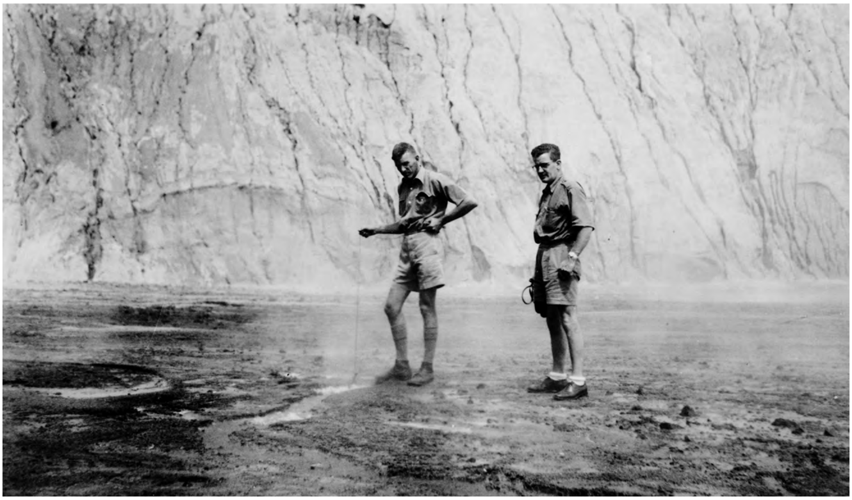

Figure 4.10. Measuring temperatures at the northern foot of Vulcan.
Volcanologist Norman Fisher (left) and Frank Anderson (a visitor from Sydney) measure temperatures in the embayment or inlet on the northern side of Vulcan cone in August 1937. GA negative reference GB2552.

4.5. Comparing and Contrasting the 1878 and 1937 Eruptions

The fact that two volcanoes, Vulcan and Tavurvur, 6 kilometres apart, were in precisely simultaneous eruption for parts of the eruptive activity in both 1878 and 1937, is a notable if not remarkable feature of Blanche Bay volcanology. Finding examples like these elsewhere in the world is a most challenging if not futile exercise. There are, however, some important differences between the eruptions of the two years, not least being that the 1878 eruption took place during the north-west monsoon season whereas the 1937 activity was in the 'dry season' of south-east trade winds. This meant that the 1937 eruptions were the most destructive to life and property north-west of the volcanoes. Rabaul town, of course, did not exist in 1878, and there is no way of knowing the numbers of people who in 1878 lived in the area destroyed by the 1937 fallout. Much more information is available as a whole for 1937 compared with 1878, so making accurate disaster-management and volcanological comparisons between the two years is also a difficult exercise.

One important difference appears to be that in 1878 Tavurvur was the first of the two volcanoes to break out in eruption and the last to cease its activity. The reverse was the case in 1937 when the Vulcan eruptions lasted about three or four days and Tavurvur for less than a day—ignoring days when post-eruption vapour and gas emissions were observed. Tavurvur in 1878 could have been in activity for upwards of a month, impacting the area towards Praed Point but depositing its pyroclastic material out to sea to the south-east. The exact duration of the Vulcan eruption in 1878 is unclear but is assumed to have been only a few days—that is, of similar duration as in 1937. Another important difference between the activity of 1878 and 1937 at Vulcan is that, in 1878, the eruption was mainly submarine, producing large amounts of floating pumice that were blown out of Blanche Bay into the surrounding sea. Only late in its 1878 activity did the eruption vent break the water surface, creating Vulcan Island and a new subaerial crater.

The volcanic products emitted from both volcanoes in 1878 and 1937 were also different. Vulcan, in both years, produced pumice, lighter ash and larger blocks of lava, all of which represented fresh volatile-rich magma erupted explosively from an underlying reservoir and influenced too by the ingestion of seawater. This contrasts sharply with the 'blue-grey gummy mud' that was expelled from Tavurvur and that fell on Rabaul town on 30 May. Fisher (1939a) called this type of volcanic activity a 'steam explosion', meaning a hydrothermal eruption caused by the heating to boiling point of water held within the volcanic cone of Tavurvur. The water was both groundwater accumulated from seasons of tropical rain and volcanic water vapour being emitted from a magmatic source beneath the Greet Geothermal Field. The water was turned to steam, which expelled the chemically altered materials of the old volcano, and forced them out as if clearing the vent. This activity could have taken place also in 1878, but the records are insufficient to be sure. However, in 1878, Wilfred Powell mentioned in his descriptions of Tavurvur a 'fiery crater … [from which] enormous stones, red hot, the size of an ordinary house' were thrown up, corresponding to strong incandescence and to eruption of molten materials—that is, to freshly erupted magma, not mud, and, therefore, to non-hydrothermal volcanic activity at that time.

Some of the descriptions of the eruptive activity from Tavurvur on the night of Sunday 30 May—such as those of Brett Hilder—refer to incandescent rocks and to an eruption column much higher than the one that deposited the mud on Rabaul. This raises the possibility that the type of eruption at Tavurvur changed at some time during the evening or overnight from

a hydrothermal, vent-clearing one to a full or part magmatic eruption, and that the fallout of ash at this time was more to the west over Simpson Harbour when the column reached higher into the atmosphere, rather than over Rabaul (Figure 4.9). The total volume of material emitted from Tavurvur in 1937 as measured by Fisher was still much lower than that produced by Vulcan in 1937, which is not necessarily the case for the longer-lasting Tavurvur eruption of 1878 whose volume could not be measured.

4.6. Discussions on Shifting the Capital, 1938–40

Public release of the 'official' Stehn and Woolnough recommendations at the end of November 1937, and their publication in the *Rabaul Times* of 3 December 1937, marked the beginning of a long period of argument, counterargument and indecision that was eventually resolved in late 1941. Such discussions had already been taking place and informally immediately after the eruptions of May 1937, but the level of debate increased resolutely in the three years between 1938 and 1940. This is illustrated best by the extensive amount of written and published material held on government files in the National Archives of Australia in Canberra, including discussions in the Australian Parliament, as reported in Hansard; government memoranda and reports; newspaper and magazine articles and editorials; lobbying by various business interests both in Rabaul and in the short-listed towns; and letters to government officials, particularly in Rabaul and Canberra. (A selection of this material is presented in R.W.J. Collection 8.)

Administrator Sir Walter McNicoll informed Minister for External Affairs Billy Hughes in Canberra that 'severe tremors' had been felt in the Blanche Bay area at 1.25 am on 8 January 1938, the main one according to Fisher's measurements registering 'Intensity 7' on the Rossi–Forel scale (Territories 1938). This information appears to have formed the basis for a ministerial press release in Australia that was picked up by several Australian newspapers. Headlines such as 'New 'Quake Hastens Rabaul Plan' (*Sun* Sydney, 10 January 1938) and 'Rabaul Shaken Again—2 Tremors' (*Herald* Melbourne, 10 January 1938) are examples. Australian Government Geologist Dr Woolnough in response stated on 11 January that, despite the uncertainties of the quoted data, 'it may be concluded that, while there is evidence of active earth movements in the area, there need be no immediate alarm in regard to [an] imminent eruption' (Woolnough 1938, 1).

A capital-site committee led by a former administrator, Brigadier-General T. Griffiths, was appointed by the Australian Government on 4 February 1938. Its members arrived in Rabaul on 20 February at the beginning of an extensive travel schedule throughout the Mandated Territory. Sixteen sites were considered (Griffiths, Thomas and Thornton 1938). The Minister for External Affairs at the time was the irascible former Australian prime minister Billy Hughes, the irascible former Australian prime minister. Hughes had maintained his interest in, and strong opinions about, the Mandated Territory and the separate Territory of Papua to the south ever since his involvement in the post-WWI treaty discussions and disputes at Versailles in 1919. Griffiths's committee focused on four potentially suitable sites on the New Guinea mainland where there were no active volcanoes but where earthquake and tsunami risk had to be borne in mind. Wau, the only inland town, was rejected because of its relative difficulty of access and because the ongoing goldmining there had a finite life. Madang on the north coast of the mainland also had some disadvantages compared with the two other coastal towns of Lae and Salamaua, both of which were in economically developed Morobe Province in the Solomon Sea. The committee eventually decided on Lae as the most appropriate site (Griffiths, Thomas and Thornton 1938). They recognised, however, that permanent anchorages and a natural harbour—such as developed magnificently at Rabaul—were not well developed at Lae. They therefore proposed the construction of a coastal road to Salamaua where the natural harbour was superior. Salamaua would, therefore, become the port town serving the new capital at Lae.

This proposal by the Griffith Committee was not accepted by the Australian Government in Canberra, and Minister Hughes went even further in proposing that Salamaua itself should become the new capital, and that a new road should be built from it over rugged terrain to Wau. This generated a good deal of criticism from people who knew the Mandated Territory well, and especially from those who knew Salamaua (NAA 1937–39). The conflict and confusion were still unresolved by the end of 1938 in part because of the costs involved but also because of international events that were diverting the attention of those in the Australian Government. The British Government's 'policy of appeasement' towards Adolf Hitler and his relentless expansionism in Europe affected New Guinea because there was the possibility of the Mandated Territory being handed back to Germany. The policy was abandoned, however, in March 1939 when Hitler completed the destruction of Czechoslovakia as a nation in defiance of the

Munich Agreement of September 1938. Japan was expanding militarily too, and its advances were much closer to the Territory of New Guinea than Adolf Hitler's.

Another committee of inquiry was set up in 1939. This one was to address the recurrent question of combining the Australian administrations of New Guinea and Papua into a single territory that would be run by Australia from a new capital. The committee chairman was F.W. Eggleston, a Melbourne lawyer, assisted by H.L. Murray and H.O. Townsend, the administration's treasurer in Rabaul. Murray was related to Sir Hubert Murray, the long-serving lieutenant-governor of the Territory of Papua, who, as his retirement approached, had a strong interest in the future of the Mandated Territory to his north and the prospect of amalgamation (West 1968). By August 1939, the Eggleston Committee had advised against the amalgamation, but it still had to address the matter of recommending a site for the new capital for the Territory of New Guinea (Eggleston, Murray and Townsend 1939). Salamaua was not recommended—a survey had been done that drew attention to its limitations—and the committee opted again for Lae, pointing out that the conditions for off-loading ships of different sizes were not as problematic as had been suggested by the Griffiths Committee (Eggleston, Murray and Townsend 1939; NAA 1941–46).

Rabaul people were becoming used to the stream of recommendations and delays in implementation. There had been no more eruptions at Vulcan and Tavurvur, and volcanologist N.H. Fisher was now on hand to report on the condition of the volcanoes, so residents were coming to the view that life in the town would be continuing as it was before the eruptions of May 1937. The Eggleston Committee had not been instructed to comment on maintaining Rabaul as the administrative capital; Rabaul clealy would continue anyway as an important commercial centre even if the big companies W.R. Carpenter and Burns Philp transferred to a new capital. Nevertheless, the committee summarised the various opinions presented to them on the matter:

> These views may be crystallised as being against the removal of administrative head-quarters at great expense from a suitable site to an inferior site (to which only a small portion of the population of Rabaul would move) in order to avoid a problematical and not extensive damage to government property once every 40 or 50 years. (Eggleston, Murray and Townsend 1939, 43)

Public notice was given in January 1938 that a special committee under the chairmanship of Treasurer H.O. Townsend would be set up in Rabaul to consider the giving of financial assistance to those people who, because of the eruption, were 'unable to carry on their means of livelihood without such assistance' (NAA 1937–50). Nineteen claims (all from non–New Guineans) had been received and partly dealt with by June. Several claims were refused, but loans were given to others, including planter J.O. Smith and A.R. Reed, who had lost his dairy. Mrs Lulu Miller and Mr Furter later received loans of £100 and £500, respectively. Mrs Jane Wallace, however, was one of those refused assistance (Wallace 1938, 1948). She and her son owned a property at Valaur that had been buried by about 10 metres of pumice and from which they had escaped 'merely in the clothes we stood up in, not one instant too soon' (Wallace 1938, 1). In addition, their car had been requisitioned and 'wrecked' by the administration during the week after the eruption. Mrs Wallace continued her appeal to the Australian Government at least as late as 1948 from her home in Nice, France (Wallace 1948). The reason for the refusal is not known, though there is some suspicion that the administration discriminated against the Wallaces because the family was considered too 'pro-native' by prewar European standards.

German forces invaded Poland on 1 September 1939 triggering World War II, and Australia became an ally of Great Britain in the same month. These momentous world events helped to delay a decision on Rabaul's future. The transfer to Lae would require funds and manpower, which were difficult to justify given wartime economic measures. Attention was directed towards the matter of Rabaul's defence should Japanese expansionism threaten the town, and there were internments of Germans (including Mr Furter) and Italian residents in Rabaul. The New Guinea Volunteer Rifles, made up of part-time civilian soldiers, was formed, and many Australian and British residents enlisted for overseas duty. War, rather than volcanic activity, was foremost in the minds of many Rabaul people.

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