6

Rebuilding Rabaul and Re-Establishing the Observatory, 1945–69

6.1. The Immediate Postwar World, 1945–50

One of the main purposes of this book is to compare the Rabaul eruptions of 1937–43 with the ones that broke out in September 1994, more than 50 years after the last eruption witnessed by Dr Kizawa in December 1943. That half-century was filled with great change, politically, socially, environmentally and scientifically (Threlfall 2012; Johnson 2013). First, the former Mandated Territory of New Guinea in the north and the former Australian Territory of Papua in the south were amalgamated after WWII. This was under a new 'Australian Trusteeship Agreement for the Territory' that was approved on 14 December 1946 by the General Assembly of the United Nations that had replaced the League of Nations (Downs 1980). Port Moresby, and neither Rabaul nor Lae, was declared the capital of the new Australian-administered Territory of Papua and New Guinea (TPNG). Colonel Jack K. Murray was appointed the administrator of the combined territories by the Australian Government, which was then held by the Australian Labor Party. He would have the responsibility of reconstructing the new territory on Australia's behalf during a period of great, accelerating postwar changes.

Another organisation that would face postwar challenges was a new Australian Government geoscience agency that combined the functions of a national geological survey and bureau of mines (Wilkinson 1996). It was

created in March 1946 and went under the unwieldy name of the Bureau of Mineral Resources, Geology and Geophysics. Its abbreviation, however, the 'BMR'—or even just 'the bureau'—soon caught on. The BMR was given the authority to carry out geological and geophysical surveys, undertake related research in both Australia and TPNG, and obtain basic earth science data by running geophysical observatories. Geologist Harold Raggatt helped create the bureau and he became its first director in 1946. There were delays in staffing the new BMR—finding suitably trained people, professionals and technicians, in the immediate postwar environment was challenging—but volcanologist N.H. Fisher was appointed to the senior position of chief geologist as early as 1946. The BMR, however, had to wait until 1949 for a resident geologist, A.K.M. Edwards, to be chosen to run a Geological Office in Port Moresby and so commence geoscientific work in the new territory.

Postwar changes included notable developments in the fields of science, engineering and technology, in part stimulated and driven by ongoing competition and conflict between nation-states for political power and domination. The relatively minor subject of volcanology, being a multidisciplinary subject, also benefited on many fronts, including volcano-monitoring instrumentation, new concepts in areas such as the tectonic setting of volcanoes, and more specialist topics such as the origin of pyroclastic rocks and the mapping of volcanic hazards and risk. The Cold War created the so-called space race when the Soviet Union in 1957 successfully launched the first satellite, the *Sputnik*, high above the earth's atmosphere. This led to extensive satellite monitoring of the earth from space, including the mapping of changes on volcanoes and the detection and analysis of eruption clouds.

BMR Chief Geologist N.H. Fisher returned to Rabaul after the end of the war and became involved in reporting on the selection of a more suitable site for the town (Fisher 1946a, 1946b). He noted in early December 1946 while undertaking fieldwork in Rabaul that the volcanoes were quiescent and that no measured temperatures were greater than 100°C, even at Tavurvur where the only detectable gas was hydrogen sulphide, which was depositing crystalline sulphur. The 1937–43 eruptive activity had ended, to all practical purposes.

Fisher, in a final BMR record, attempted to prioritise five areas in the north-eastern Gazelle Peninsula that might be considered for postwar development, at least from a geological and geophysical safety point of view. The geohazards he considered were volcanic eruptions, earthquake

ground-shaking and tsunami inundations. Fisher also gave consideration to some of the 'utilities' or assets at each of the five places, namely: water supplies; aggregates for construction purposes, especially roads and building foundations; ready access to existing ports and airfields; and local climate. These assets are what today might collectively be called 'exposure'. He excluded several other factors, such as cost and availability of land, ease of supply of building materials and suitability from a town-planning point of view, all of which were beyond his area of expertise. Fisher also presented what today can be regarded as the first geohazard map of the north-eastern Gazelle Peninsula (Figure 6.1).

Fisher preceded his analysis of each of the five prioritised areas—which are summarised below numerically—with the following statement:

> I have always maintained that while the Administrative establishment existed at Rabaul, the direct danger from volcanic eruptions was not sufficiently great to justify the expense of moving that establishment. Now, however, when it is a matter of starting practically from zero, obviously the sensible thing to do is to re-establish the administrative centre at some place not directly in the path of possible outbursts. (Fisher 1946b, 2)

1. Rabaul, the old town now destroyed by wartime bombing, was still the most exposed of all five areas to the three geophysical hazards. It also had town water supply problems, including the use of bore water contaminated by the latrines used for the Japanese prison camps and native labour compound. Rabaul's microclimate also tended to be hot and windless, the town being hemmed in by caldera walls on two sides. Rabaul scored well, however, in its relatively ready access to a port (Simpson Harbour) and airfield (Lakunai).
2. Nonga–Tavui. This coastal area in the north on Talili Bay and facing Watom Island was judged to be the least hazardous of the five areas. Its main disadvantages were poor access to both a port and an airfield.
3. Kerevat and Kabaira were on the eastern side of Ataliklikun Bay, down on the west coast and well away from the port and main airfields. The area had the advantage of running water from the Kerevat River, but it was judged to be the most susceptible of all the areas to ground-shaking from earthquakes and, being coastal, was potentially prone to tsunami impact.

4. Vunakanau–Taliligap, in the hills overlooking Blanche Bay to the north-east, had the most hospitable climate. Vunakanau Airfield was nearby, and there was virtually no tsunami threat, but it, like Kerevat–Kabaira, was also susceptible to earthquake shaking and had relatively poor access to the port.
5. The coastal Kokopo–Rapopo area west of Cape Gazelle faced northwards into St Georges Channel and was not entirely free from the impacts of any of the three geohazards. This included, however, only light falls of volcanic ash from both Vulcan and Tavurvur and then only in the north-west season (Figure 6.1). There was only some threat from tsunamis; much of inland Kokopo is actually on a raised terrace that protects it somewhat from tsunamis. The area had no major anchorage of its own but it was linked by road to the port at Rabaul. Further, surface water was available from Matanatava Creek.

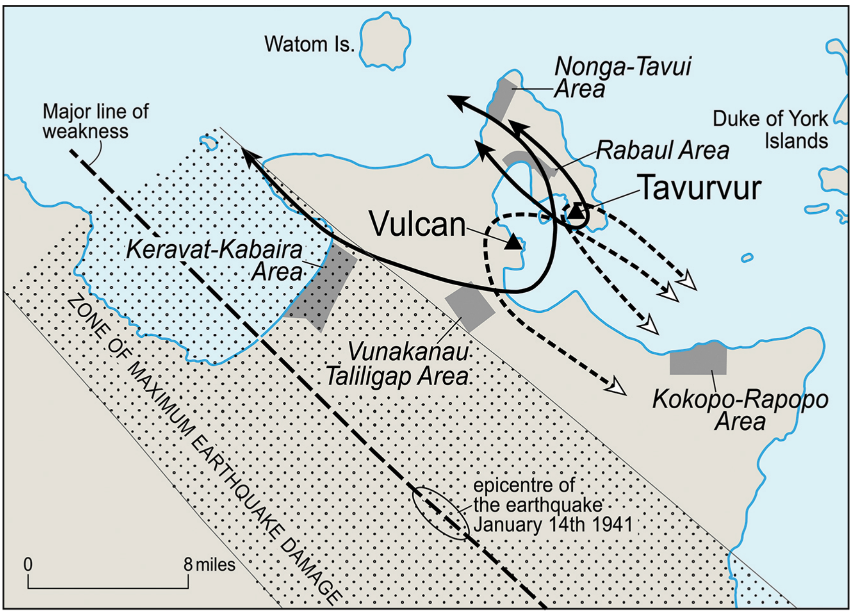

Figure 6.1. Geological hazards map for the north-eastern Gazelle Peninsula.

The five areas considered by Fisher (1946b) in his geohazards analysis are shown here in grey in this adaptation from his original map. They are seen in relation to: (1) ash fallout zones for both Vulcan and Tavurvur volcanoes; and (2) the major earthquake zone that Fisher believed ran south-eastwards across the north-eastern Gazelle Peninsula, based on his fieldwork following the 14 January 1941 earthquake (Fisher 1944). The two curves whose ends point north-westwards refer to ash deposition in the south-east season (trade winds) from both Vulcan and Tavurvur volcanoes, and the dashed curves pointing south-eastwards to deposition in the north-west season (monsoon).

In considering Tavurvur and Vulcan volcanoes as a future threat in the Rabaul District, Fisher wrote the following in his draft report:

> The 1937 eruption is regarded as having exhibited the probable maximum severity … [I]t is the most serious eruption that has occurred for hundreds, probably thousands of years … There is no evidence that volcanic activity at Matupi [Tavurvur] has ever reached the violence of the 1937 outbreak at Vulcan and it is assumed that eruptions at Matupi much more severe than those of 1937 and 1941–42 [sic] are not probable. (Fisher 1946b, 1)

These conclusions are somewhat surprising as Fisher did not mention the 1878 eruptions at both Vulcan and Tavurvur only 59 years previously (see, however, Fisher 1939a). In any case, his quoted conclusions, which are concerned with eruption periodicity or frequency, would have to be amended as more geological data on past eruptions at Rabaul came to hand, and when further eruptions took place at both Vulcan and Tavurvur later in the twentieth century.

Fisher recommended that Rabaul and Kerevat–Kabaira should be ruled out as sites for postwar rebuilding—at least on the basis of relative geohazards threat—and that the order of preference for the remaining three sites should be Nonga–Tavui, Vunakanau–Taliligap and Kokopo–Rapopo. This order would be reversed, however, when considering only the 'utilities' discussed by Fisher—that is, Kokopo–Rapopo, the area where the Germans had first established Herbertshöhe, would be the first preference. The extent to which Fisher's opinions about abandoning Rabaul would be accepted by the authorities appears to have been minimal.

Fisher, in an earlier draft, had stated strongly that 'it is most important that a decision be reached as rapidly as possible, as every day's delay makes the move from Rabaul more difficult and more expensive' (Fisher 1946a, 6), but this statement did not appear in the final version (Fisher 1946b). Importantly, reoccupation of the old town was already taking place at the time of Fisher's visit in December 1946. Populous Tolai villages could still be found in the north-eastern Gazelle Peninsula, including the Simpson Harbour area. Other New Guineans also lived in the same peninsula area. Moreover, Chinatown and Malaytown, including shops, were quickly being re-established by Asian people who had been held captive by the occupying Japanese.

Expatriate Australians and Australian businesses that had owned land and property before the Japanese invasion also returned to the Blanche Bay area, perhaps fuelled by a nostalgia-laden ambition to rebuild Rabaul and its environs, including Kokopo, as it had been in its colonial prime before the war. At the same time, this return was no doubt driven by the commercial advantages of the harbour and its now repaired wharves. Yet Rabaul would no longer be the capital, and its initial civil administration—after the departure of the Japanese and Australian military authorities from the Blanche Bay area—was based initially in the new capital of Port Moresby.

The story of indecision in the years from 1937 to 1942 concerning the future of Rabaul was repeated between 1946 and 1953. The Australian Government in Canberra, the TPNG administration, and the spontaneously growing business population in Rabaul itself all had different views about the future of the town, including the administrator, Colonel Jack Murray, who supported the move to Kokopo. Rabaul town, however, soon became re-established and its population began to grow in size and influence. Another delay related to the TPNG administration not being in an immediate position to employ suitably trained professionals; indeed, it had to wait until new postwar university graduates appeared on the market. Nevertheless, Major J.K. McCarthy—who had witnessed the 1937 eruption in Rabaul as a patrol officer and given outstanding war service—was appointed to the newly created position of District Commissioner for New Britain (McCarthy 1963). Another appointment was G.A.M. 'Tony' Taylor, a newly recruited BMR scientist who arrived in Rabaul in April 1950.

Taylor had enlisted in the Australian Imperial Force in 1942 and, by September 1945, after the Japanese surrender, had moved to Rabaul, where he was able to observe at length the volcanic nature of Rabaul (Fisher 1976a). Taylor was discharged from the army in 1947 and began a science degree at the University of Sydney under the Australian Government's postwar reconstruction scheme. He joined the BMR as a base-grade geologist in March 1950. Taylor's BMR supervisor would be the Canberra-based N.H. Fisher. Taylor's role in Rabaul was to re-establish the volcanological service for the territory administration and to reinstate the Rabaul Volcanological Observatory. It was a logical place for him to be stationed, given Rabaul's now well-known history of volcanic activity, high volcanic risk and volcano monitoring, although he would also have responsibility for the active volcanoes in the entire area of the new TPNG that included the old Territory of Papua.

Taylor's presence in Rabaul had the additional advantage—at least for those people who wanted to remain in and develop the town—of his being able to provide volcanic early warning advice, if needed, as Norm Fisher had done in 1937–42. Taylor found that the instrumental cellars of the old Australian observatory on Observatory Ridge were intact, and he was able to reinstall seismographs from Australia in a harbour network, including the Japanese Omori at Rapindik on Greet Harbour. However, the work of re-establishing the destroyed observatory buildings on the hill would take some time. Additional staff members were required and, from the beginning, Taylor would employ young, talented Tolai men to assist him in the field and office. Leslie Topue was an early recruit.

6.2. Influence of the Mount Lamington Eruption, 1951

Taylor visited Bagana volcano on Bougainville Island in December 1950, only a few weeks after a particularly powerful phase of explosive activity had taken place (Taylor 1956; Bultitude 1976). The activity during his visit was much reduced, but stronger eruptions would recur in the years ahead. Following this visit, Taylor returned to Rabaul to resume 'normal' duties (Figure 6.2), but, in the week beginning 14 January, he began hearing of volcanic unrest at Mount Lamington in the Northern District of distant Papua (*South Pacific Post* 1951a; Figure 0.2). There was some initial speculation that the reported activity might be from Goropu, or Waiowa, a Papuan volcano that had been in eruption in 1943–44. Taylor wanted to investigate the reports by visiting Mount Lamington but there were problems in facilitating immediate travel out of Rabaul. The administrator, Colonel Jack Murray, happened to be visiting East New Britain at that time (*South Pacific Post* 1951a), and Taylor received his approval to fly out with him from Rabaul on the morning of Monday 22 January. They were on their way to Lae when they heard that Mount Lamington had erupted catastrophically at 10.40 am on the previous day, Sunday 21 January 1951. Almost 3,000 people, mainly local Orokaiva, had perished and the government district headquarters at Higaturu had been destroyed, as had the Anglican mission at nearby Sangara (Taylor 1958). The Lamington eruption would have a major impact on perceptions of the extreme dangers of active volcanoes in TPNG, as well as on the international trajectory of Taylor's career as a volcanologist. The Lamington eruption came at a critical time for Rabaul, no official decision regarding the town's future having been made by 1951.

Figure 6.2. Climbing out of the crater of Tavurvur volcano.

Tony Taylor, lower left, and two unidentified expatriate colleagues are seen climbing out of the crater of Tavurvur sometime late in 1950 or in early January 1951. The photographer is unknown, but the photograph was published in the *Illustrated London News* on 3 February 1951 (Anonymous 1951, 169).

Tony Taylor and Leslie Topue became heavily involved in assessing the Lamington disaster and spent considerable time away from Rabaul. Taylor, in fact, would spend nearly two years on the monitoring and study of Lamington volcano, broken at times by other commitments in the territory. A conclusion soon recognised by Taylor at Lamington was that the 1951 eruption had similarities to the catastrophic 1902 eruption at Mount Pelée in the Caribbean, which had inundated the town of Saint-Pierre on Martinique (Lacroix 1904). The Lamington eruption, therefore, was labelled as *peléean*, a type of volcanic eruption not yet recognised in the Rabaul area and one quite different to those of 1937–43. Taylor soon established an effective working relationship with the administration officers—including the administrator himself—all of whom came into the Lamington area as part of the post-disaster rescue and relief effort, as described in greater detail elsewhere by Johnson (2020). BMR geologist John G. Best visited Taylor in the Lamington area but soon moved to Rabaul where he ran the volcanological service in Taylor's absence as part of the administration's resident staff.

Norm Fisher arrived in the Lamington area from Canberra on 31 January bringing considerable experience in volcanological work in the former Mandated Territory of New Guinea and especially at Rabaul in 1937–42. Colonel Murray was in the area too, making Fisher's presence timely, as they were able to discuss not only the disastrous Lamington situation but also the volcanic threats and risks elsewhere in the territory—most notably the ongoing question of relocating Rabaul. Fisher (1946b) had expressed the opinion four years earlier that rebuilding the town in the same place after its wartime destruction did not make sense, but the situation had changed: the town was becoming re-established almost spontaneously. Murray, in January 1951, was under pressure to allow this growth to continue, especially given that the volcanological observatory was being re-established by the BMR for eruption early warning purposes. However, on Friday 26 January 1951, the Port Moresby–based *South Pacific Post* contained the following editorial:

> The time for argument and indecision is long [past]. The matter is no longer a question of comfort or discomfort, financial gain or loss. The people of Rabaul must be removed from the possibility of a repetition of the Higaturu horror … The important and glaring necessity is to get the place moved and get it moved quickly. If the Administration wants to clutter up its routine activities with red tape then it can do so. But red tape where human life is endangered cannot be tolerated. (*South Pacific Post* 1951b, 8)

Figure 6.3. Visit to Mount Lamington, Papua, in May 1951.

A group of Rabaul residents poses in front of Lamington volcano, Papua, in the second week of May 1951. A similar photograph was published on the front cover of the July issue of *Pacific Islands Monthly*, including the statement that: 'On their return to Rabaul all were of the opinion that the sooner that volcano-encircled town was moved to a safer spot the happier they would be.' Geoscience Australia negative reference M/2438-3-1.

Murray still favoured the Kokopo area to the south of Rabaul as an alternative town site. But what was the risk that Rabaul, like Lamington, might break out in catastrophic eruption? Fisher flew to Rabaul and, on his return through Port Moresby, was able to reassure the administrator that there was

> no evidence whatever of impending [eruptive] activity for some considerable time and that in any case the present station he [Fisher] has at Rapindik [near Tavurvur volcano] can give two days notice of major eruption. (Murray Administrator 1951, 1; see also *South Pacific Post* 1951c, 2)

This information was sent by Colonel Murray to the minister, Department of External Territories, Canberra, on Wednesday 14 February—the day that Fisher returned to Australia—together with Murray's opinion 'that without compulsion [it] would be unlikely that majority of total nonnative population would move out of Rabaul township' (Murray Administrator 1951, 1). Nevertheless, in the wake of the Lamington disaster, public safety concerns in Rabaul gained new momentum. District Commissioner J.K. McCarthy cancelled a Rabaul evacuation plan dated 1950 and

introduced a new one on 15 February 1951 (McCarthy 1951). Later, the administrator visited the town intent on persuading the community to transfer Rabaul to a safer site—the administration even arranged for a representative party of Rabaul residents to visit the Lamington area for two days, leaving Rabaul on 12 May (*South Pacific Post* 1951d). According to a sub-headline in the *South Pacific Post* (1951f) the visit represented a 'Move by Administrator to Stress Horrors of Eruption' at Lamington—'apparently with the idea of impressing upon them what a volcano can do', as stated in the caption on the front cover of the July issue of the *Pacific Islands Monthly* (Figure 6.3). However, no definite decision about relocating Rabaul resulted from the visit.

Significant political changes were taking place in Canberra at this time. A cabinet reshuffle of ministerial positions was undertaken in mid-1951 by the ruling Liberal government under R.G. Menzies and Paul M.C. Hasluck was appointed minister for territories, a position he held until 1963 (Hasluck 1976; Downs 1980). Hasluck paid his first ministerial visit to TPNG in May 1951, travelling to the Lamington disaster area and to Rabaul, which he said

> was a shambles with the main port facility the upturned hull of a ship sunk in war time. Most buildings were temporary makeshifts. Chinatown was a higgledy-piggledy warren of old iron. Everywhere was the evidence of the bombings by Allied planes when it was in Japanese occupation six and seven years earlier. The chief reason why there had been scarcely any post-war building was the lack of a final decision whether … the town site should be moved. Rabaul Harbour still had scores of war-time wrecks around its shores and the war-time tunnelling of the Japanese was visible everywhere. (Hasluck 1976, 19)

Hasluck respected the Labor-appointed Jack Murray, calling him 'a good and devoted man' (Hasluck 1976, 15), and appreciated the colonel's outstanding leadership in the aftermath of the Lamington disaster (Hasluck 1976). Yet he believed that Murray's original appointment as administrator in 1946 by the Labor government 'was the wrong one' (Hasluck 1976, 50). Hasluck, therefore, issued a statement on 10 May 1952 announcing that Murray would relinquish his position as administrator from 30 June and that Donald M. Cleland, who had been appointed acting administrator when Murray went on leave in March, would continue in that role. Cleland was appointed administrator early in 1953.

Hasluck and Cleland, but not Murray, officiated at the opening of the Mount Lamington Memorial Cemetery at Popondetta in November 1952, at which Cleland gave out awards for services during the Lamington relief and recovery operation. Tony Taylor received the George Cross and Leslie Topue the British Empire Medal (Civil), awards that helped promote—not only locally but also internationally—the role of the volcanological observatory centred on Rabaul. Fisher (1976a, x) noted later that the Lamington eruption had 'catapulted Taylor, normally one of the most reserved and retiring of men, into public prominence'. An article on Taylor's early volcano-monitoring work in Rabaul had even appeared in the *Illustrated London News* of 3 February 1951 immediately after the Lamington eruption (Anonymous 1951; Figure 6.2).

The rebuilding of Rabaul town continued unofficially and resolutely on its existing site throughout 1951. Then, in June 1952, the Australian Cabinet in Canberra provided official government approval for its ongoing reconstruction (Territories 1952). Rabaul town was to be rebuilt on the same vulnerable site that had been identified by Governor Albert Hahl over 40 years previously, had been invaded by Australia in 1914, had been reoccupied after the 1937 eruptions at Tavurvur and Vulcan, and had been reoccupied after being destroyed in WWII.

Australia was experiencing important changes at this time. While stronger political alliances were established with the US, Australia remained firmly within the British Commonwealth of Nations, which had the new Queen Elizabeth II as its figurehead. Postwar immigration was being promoted, the economy was improving and family homes were being established in new suburbs, many equipped with a new technological gadget: black-and-white television.

6.3. Eruption Time-Cluster and Earthquake Mapping, 1951–59

The period 1951–57 was a particularly busy time for volcanologists at the Rabaul Volcanological Observatory. Eight volcanoes were active in different parts of TPNG during that time, requiring investigations by John Best and Tony Taylor, as well as by a new recruit, geologist Max Reynolds, who started work in late 1953 (Reynolds 2005). The eight volcanoes were:

- Lamington, 1951–52
- unnamed submarine volcano near Karkar, 1951
- Bagana, 1951 and onwards
- Long, 1953–55
- Tuluman, 1953–57
- Langila, 1954–56
- Bam, 1954–55
- Manam, 1956–57 (and up to 1966).

These volcanoes formed an eruption 'time-cluster' that, notably, did not include Rabaul volcano itself; neither did it include young volcanoes in the Dawson Strait and Esa'ala area of eastern Papua, where there had been local, and concerning, earthquake activity in 1953–55. The previous eruptions at Tavurvur and Vulcan in 1937–43 do not seem to have been part of an equivalent time series. However, the 1878 eruptions at Rabaul might have been. Eruption information is not nearly as comprehensive for the 1870s as it was for 1951–57, but the following volcanoes may constitute an eruption time-cluster for 1878–88: Bam, Manam, Ritter, Langila, Ulawun, Rabaul, Bagana, Bamus and Lolobau (Johnson 2013, Table 1). Norm Fisher in 1957 published, internationally, a major catalogue on the eruptions and active volcanoes of Melanesia, including Solomon Islands and New Hebrides (Vanuatu), but the eruption information for the 1956–57 time-cluster is incomplete because of the publication date (Fisher 1957).

A notable feature of the volcanological research carried out in the 1950s and led by Tony Taylor was consideration of the concepts that the eruptions were related in some way: (1) to regional geophysical unrest, or tectonic stress release, that affected the whole of TPNG; and (2), more controversially, to the changes in earth-tide forces caused by the motions of the moon and sun—so-called luni-solar influences—as reflected in several reports of the time (e.g. Taylor 1958, 1960) and dealt with in greater detail elsewhere (Johnson 2013). Instrumental monitoring on active volcanoes remained critical, however, and Taylor recommended that separate, permanent volcanological observatories be established on Manam Island and at Esa'ala in south-eastern Papua. Monitoring at Rabaul, where the territory's volcanological observatory was established and named 'Central Observatory', and where maintenance of the seismographs and regular temperature measurements were undertaken (Figure 6.4), continued unabated. These observatories could be used for the detection of regional earthquakes as well as local volcanic ones.

Figure 6.4. Temperature measuring on Tavurvur.

Max Reynolds and Leslie Topue are here seen taking temperatures at a fumarole on Tavurvur volcano, Rabaul, at some time when Reynolds was not investigating other volcanoes during the 1950s eruption time-cluster (Reynolds 2005, cover photograph; see also Figure 6.6).

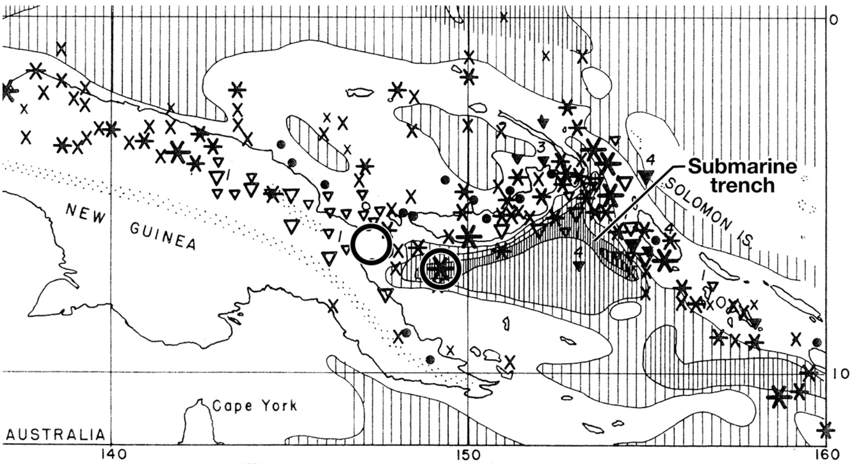

Figure 6.5. Early earthquake epicentres for the New Guinea region.

The strong concentration of earthquake epicentres in eastern New Britain, St Georges Channel and Bougainville Island (shown here as one of the 'Solomon Is.' [sic]) is illustrated in this detail from a map of Western Pacific earthquake epicentres (Gutenberg and Richter 1954, Figure 16). The epicentres are shown in relation to the conspicuous submarine trench that runs along the south coast of New Britain and south-west of Bougainville

Island. The large encircled asterisk at the south-western end of the submarine trench represents the epicentre of the large-magnitude tsunamigenic tectonic earthquake of 14 September 1906 whose effects were reported in Rabaul. This epicentre was determined by Sieberg (1910), but the International Seismological Centre later revised it to a position in the Finisterre Range of mainland New Guinea, as represented here by the large unfilled circle (McCue and Letz 2019).

Figure 6.6. Duke of Edinburgh's visit to the volcanological observatory.

Max Reynolds is seen in the centre, with his back to the camera, hosting a visit to the Rabaul observatory by the Duke of Edinburgh on 13 November 1956 when Leslie Topue wore his Medal of the British Empire (Reynolds 2005, 41; see also R.W.J. Collection 9). The district commissioner John Foldi, on the right, is checking the time.

Considerable progress was also being made in the 1950s in detecting and locating large earthquakes, both globally and regionally. The BMR in 1958 established a Geophysical Observatory in Port Moresby (PMGO) as part of a wider Australian network for the monitoring of earthquakes and local changes in the earth's gravity and magnetic fields (Brooks 1962, 1965). PMGO would work in partnership with the volcanological observatory in distant Rabaul. There had also been major global compilations published of the earth's seismicity, perhaps most notably that of Gutenberg and Richter (1954) in which the high density of earthquake epicentres for parts of TPNG—and especially the area encompassing Rabaul—was illustrated clearly (Figure 6.5; see also Brooks 1962, Figure 2).

6.4. New Instrumentation and Geoscience Surveys at Rabaul, 1960–69

There were staff increases and other employment opportunities in the 1960s at the Rabaul Volcanological Observatory. These included the beginning of overseas recruitment of graduates in geology and geophysics from countries other than Australia—Italy and Britain and later the US and France—as well as local New Guinean staff for technical and office work. A series of different overseas scientists became head of the Rabaul Volcanological Observatory (RVO) up to the 1980s. Tony Taylor maintained his commitment to the work of the RVO but took on more senior BMR positions in Canberra and Port Moresby in the 1960s and early 1970s.

Figure 6.7. Rabaul town and volcanoes as photographed from the observatory.

This view from Observatory Ridge is a famous and oft-photographed one. This shot was taken by observatory volcanologist John Barrie around 1960 or slightly earlier. Kabiu and Palangiangia volcanoes are seen on the left, and Turagunan and the light-coloured Tavurvur are behind them (see also Figure 6.8). Rabaul town hugs the foreshore around to the wharves on the right. Photograph supplied courtesy Mr Barrie.

Figure 6.8. Aerial view of Tavurvur volcano in the early 1960s.

Tavurvur volcano, Rabaul, is seen from the south-west in this oblique aerial photograph taken in the early 1960s. Thermal activity is preventing vegetation from growing on much of the volcanic cone (compare with Figure 4.5). Hot springs discharge into the waters of Greet Harbour in the foreground. St Georges Channel can be seen in the background to the left of Turagunan volcano. Digital copy provided by the State Library of New South Wales. Australian National Travel Association photograph, published in *Walkabout* magazine.

There was some international economic interest in the early 1960s in using New Zealand expertise in assessing the geothermal potential of Greet Harbour for possible electricity generation (Studt 1961; Fooks 1964). Power for the township of Rabaul was supplied by diesel-driven generators but at high cost, so the relative merits of hydro-electric and geothermal power were investigated. The New Zealand surveys, which were inconclusive, were undertaken after a geophysical survey by BMR staff in 1960 of the shallow structure of the Greet Harbour area (Wiebenga and Polak 1962). Much more attention, however, was being paid at this time to improving earthquake monitoring in the Rabaul area.

Seismologists, internationally, had been discussing in the late 1950s the value of establishing a global network of standardised seismographs (plus clocks for accurate time-recordings) to be used in the detection and measurement of earthquakes worldwide. The opportunity for doing so was realised partly as a result of Cold War discussions on the banning of nuclear tests. In the early 1960s, the US funded the establishment of a World-Wide Standardized Seismograph Network, or WWSSN, and the installation of recording stations in many countries (Peterson and Hutt 2014). Significant underground nuclear tests could be detected by the WWSSN as well as natural earthquakes. The RVO received a WWSSN station in 1962, adding significantly—in conjunction with other stations both locally and globally—to the mapping of earthquakes in the region (Latter 1966). There remained, however, the challenge of determining the location of smaller earthquakes within the Blanche Bay area that might be of volcanic, rather than tectonic origin. Could any of these relate to nearby volcanoes in the area? Could they be used for forecasting or predicting volcanic eruptions? Were any of them directly related to earlier tectonic earthquakes? Was there even any causative relationship?

The need for a more effective local seismic network for the detection of small harbour earthquakes was recognised in the early 1960s (Latter 1966). Gordon Newstead, professor of engineering physics at The Australian National University, visited Rabaul in 1963 and, in conjunction with Tony Taylor and others, recommended a five-station network in which seismic signals would be transmitted electronically to the recording room at the RVO (Newstead 1968, 1969; Myers 1976; Cooke 1977). Four of the stations were linked to the RVO recording room by telephone cables and the fifth by radio transmission, and data were transferred to a set of 'helicorders' or direct-writing recording drums (Figure 6.9). The network, however, had not yet been completed when, on 14 August 1967, two major earthquakes of magnitude 5.0 and 5.3 shook the Kokopo–Kabaleo area and nearby villages, causing some damage but no loss of life (Heming 1967; Threlfall 2021a). The two earthquakes, whose epicentres were determined by the WWSSN, took place in St Georges Channel just east of Cape Gazelle and south-east of the Duke of York Islands.

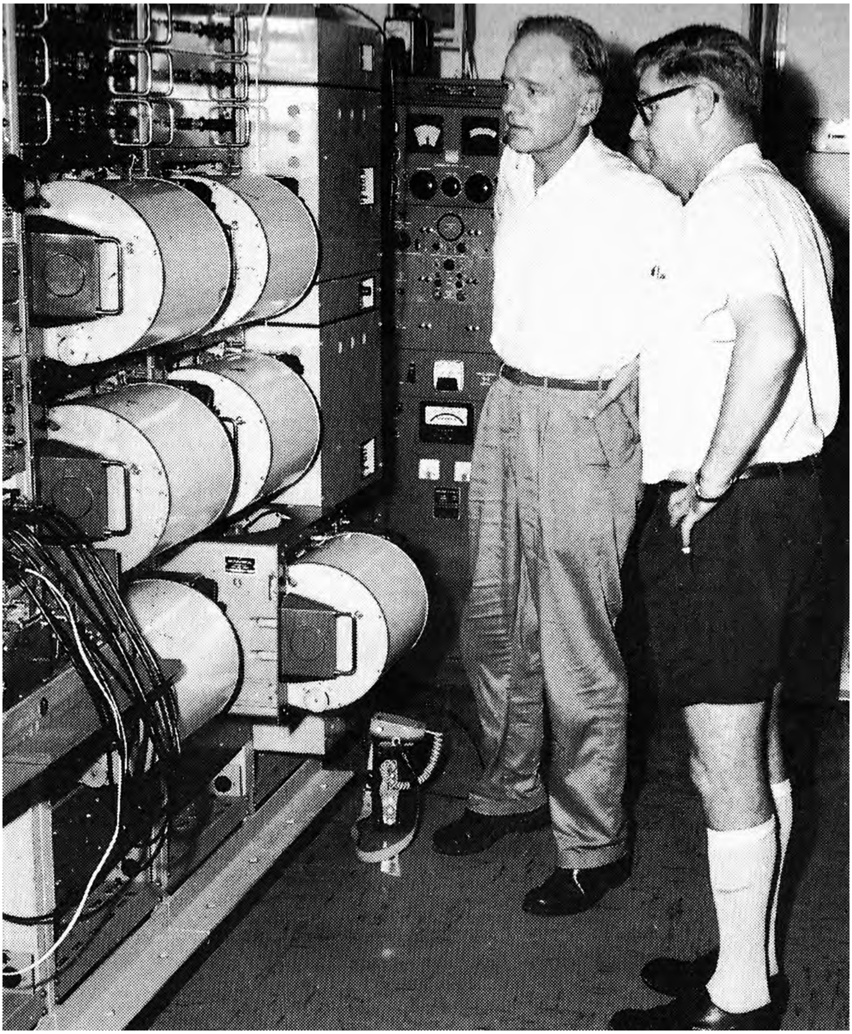

Figure 6.9. Observatory recording room in 1969.

Tony Taylor (left) and Noel Myers examining helicorder records in the Rabaul observatory recording room during the 1969 crustal survey (Wilkinson 1996, l.xii).

Another limitation on the accurate mapping of earthquakes in the north-eastern Gazelle Peninsula in the early 1960s was the dearth of knowledge on how fast earthquake waves travelled through the earth's crust at different depths—their 'seismic velocities'—before being recorded by the seismographs at Rabaul and elsewhere. This deficiency was addressed initially for the Rabaul area in 1966 using preliminary crustal seismic tests (Cifali et al. 1969). Although the results were regarded as unsatisfactory,

they triggered two major inter-agency geophysical surveys of the New Britain and New Ireland regions in 1967 and 1969 led by BMR scientists (Brooks 1971; Finlayson 1972; Finlayson et al. 1972; Wiebenga 1973), including a 'seismic refraction' survey of the region. Both surveys were truly ambitious, and resource-intensive, involving ships for letting off explosions at many points at sea, together with numerous receiving stations on land where the seismic waves were recorded. The depth of a seismically layered crust beneath the Gazelle Peninsula, including the Rabaul area, was calculated to be 32 kilometres.

A major aspect of the 1969 survey was the concurrent geological and gravity mapping of New Britain at a scale of 1:250,000, involving large field parties of geologists and geophysicists using both helicopter and fixed-wing aircraft support. Six sheet areas were completed. This included the northernmost Gazelle Peninsula where a Port Moresby–based BMR geologist, Peter R. Macnab, had been field mapping on and off since 1966, traversing the difficult, largely unpopulated and mountainous terrain of the interior (Macnab 1970; Davies 1973). Macnab defined and mapped the major and complex Baining Fault that runs across the Gazelle Peninsula from the south-east coast to Cape Lambert in the north-west; in doing so, he suggested that the January 1941 earthquake south-west of Rabaul and described by Fisher (1944; Figure 6.1) may have been related to movements along it. The outer limits of Rabaul volcano are shown on Macnab's map of regional geology (see also Figure 1.1), but more detailed geological work on the rocks of the volcano itself was being undertaken more or less concurrently by RVO volcanologist R.F. 'Bob' Heming (Heming 1973, 1974).

A major aspect of Heming's research included university laboratory work in California on numerous rock samples collected from Rabaul volcano (e.g. Heming 1973, 1974; Heming and Carmichael 1973). This work involved examining slices of rock using a petrographic microscope, chemically analysing minerals and rock-sample powders, and undertaking thermodynamic calculations in order to quantify magmatic properties. The Rabaul rocks were named basalt, andesite, dacite and rhyolite, and were distinguished serially by their silica content (SiO_2). Miyake and Sugiura (1953) had earlier published some chemical analyses of Rabaul rock samples collected by Takashi Kizawa in 1942. They noted the different chemical compositions between basaltic rocks of Tavurvur and the almost dacitic compositions of the pyroclastic rocks produced at Vulcan in 1937. Relationships between the different rock types were complex, however, and

the question remained of how two volcanoes could be in near-simultaneous eruption, as in 1937, yet produce magmas of different compositions. These and other questions would serve as a basis for future studies by others.

There had been global advances in the 1960s in understanding the nature and origin of pyroclastic—'fire broken'—rocks and the explosive eruptions that produced them. This included recognition that the rapid expulsion of large amounts of hot pumiceous material can produce extensive pyroclastic flows that leave behind 'ignimbrite', the rock type first named by Marshall (1935) in New Zealand. Calderas can be produced at the surface where the shallow roof of the now evacuated magma reservoir collapses, as discussed above (Figure 4.3). Bob Heming recognised two such ignimbrite layers at Rabaul and, using radiocarbon measurements, dated them at 1400 and 3500 BP. He related the younger (1400 BP) eruption to a collapse that produced the deep water of a caldera at Karavia Bay in the south, and the older (3500 BP) one to formation of a larger caldera that included Simpson Harbour to the north. One difference between the ignimbrites of New Zealand and those identified by Heming at Rabaul is that the former are commonly 'welded' whereas the Rabaul examples are rarely so. 'Welding' takes place when the still-soft pumice fragments of a thick, hot pyroclastic-flow deposit cool into disc-like blebs that are very distinctive in outcrops and in rock samples.

6.5. Plate Tectonics and Subduction

The late 1960s were an extraordinary period in post-WWII geosciences not just in the New Guinea region but in the world as a whole. Geologists and geophysicists had, for generations, speculated, or hypothesised, on how the islands of the New Guinea region—including New Britain—came to be what and where they are, as reviewed by Johnson (1979). Now, however, a 'new global tectonics' was emerging, based on the notion of sea floor spreading and the earlier concept of continental drift (Le Pichon 1968; Isacks, Oliver and Sykes 1968), soon to be called the theory of plate tectonics. This was a momentous time in geoscience, and the New Guinea region was soon the focus of attention because of its high level of earthquake activity and its complex configuration of both large and minor 'plates' (Figure 6.10). The earth is covered by a few major plates that move according to the principles of spherical geometry—'tectonics on sphere' (Mackenzie and Parker 1967)—some separating from each other, others moving past each other laterally,

along well-defined faults. BMR geologists Jack Thompson and Norm Fisher even wrote in 1965—somewhat prophetically—in the language of plate tectonics that the structural development of the tectonically complex New Guinea and Papua region 'has been dominated by lateral movement of the Pacific Plate relative to the Australian Continent' (Thompson and Fisher 1965, 121). The region is now recognised as being characterised by the presence of two or more minor plates in addition to the two major ones (Figure 6.10).

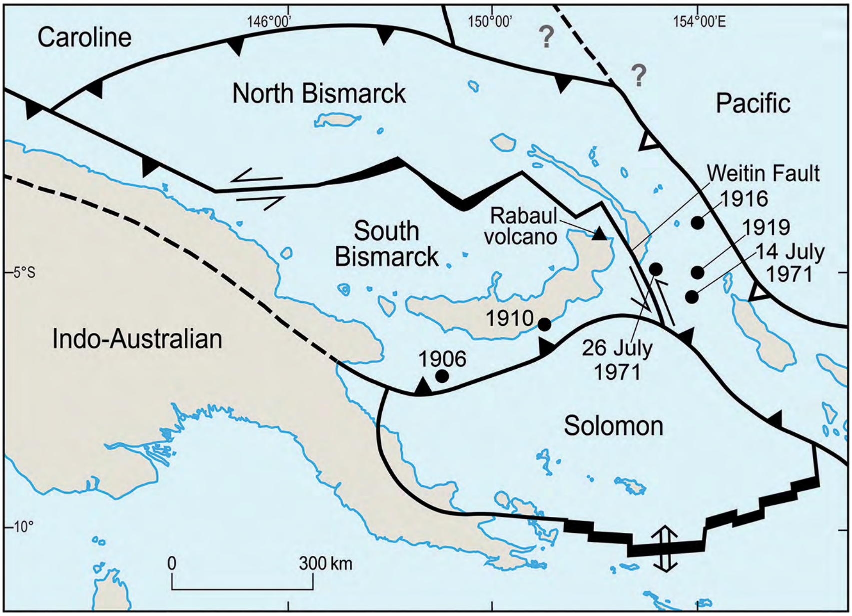

Figure 6.10. Tectonic plates of the region of the Territory of Papua New Guinea.

Three minor plates between the major Pacific and Indo-Australian plates are shown in this schematic map based on the initial study of plate tectonic relationships in the TPNG region published by Tracy Johnson and Peter Molnar (Johnson and Molnar 1972, Figure 2). Directions of plate subduction are shown by the filled arrow heads, and lateral relative plate motion by the pairs of half-headed arrows. Plates diverge at the southern and south-eastern margin of the Solomon plate (see double-stemmed arrow). Dashed lines represent places of earlier plate tectonic activity. Filled circles represent the epicentres of (1) the three high-magnitude (7–8) earthquakes from 1906–19 shown in relation to the epicentres of two others from July 1971 (see text for details). Note that Rabaul volcano is on the eastern edge of the South Bismarck plate (north-west of the Weitin Fault) and that four of the plotted earthquakes are close to the presumed (not shown for the sake of clarity) south-eastern end of the North Bismarck plate.

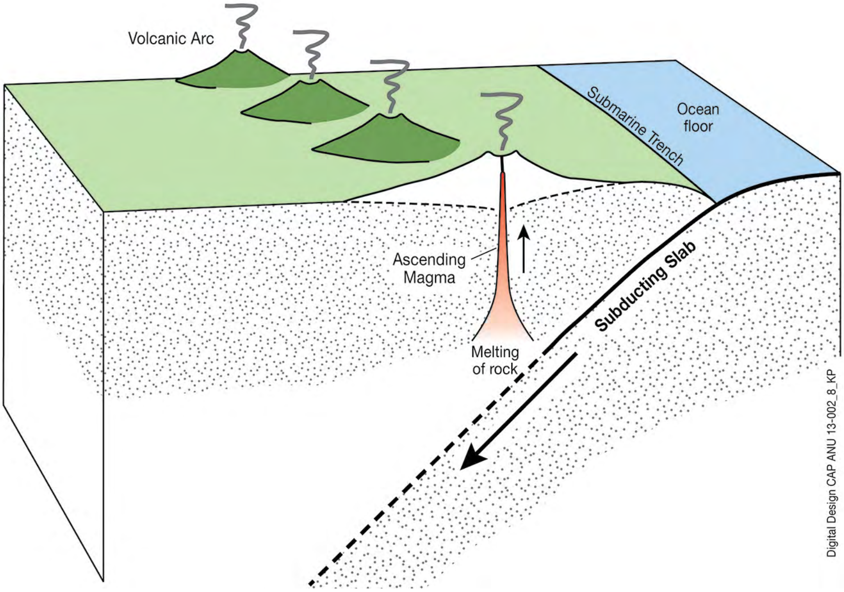

Figure 6.11. Subduction of a tectonic plate.

The process of subduction is shown schematically in this oblique sketch of a tectonic plate on the right (blue) under-thrusting the plate on the left (green) along a submarine trench and creating magmas that rise to form a line or 'arc' of subaerial volcanoes (dark green) at the surface (see also Figures 7.2 and 9.5).

Plates also descend into the deep mantle of the earth in a process that became known as 'subduction' (Figure 6.11). Port Moresby–based BMR seismologist David Denham was already signalling the importance of subduction in the case of New Britain when he published a cross-section through the island arc and plotted earthquakes of increasing depths northwards down to about 300 kilometres (Denham 1969). This represents subduction or 'under-thrusting' of the minor Solomon plate north-westwards beneath the South Bismarck plate along the New Britain–Bougainville submarine trench that had been discovered by the SMS *Planet* (Figure 1.17) during German times (Figures 6.5 and 6.11).

Plate subduction is important in understanding the origin of magmas from volcanoes along the central north coast of New Britain (Figure 0.2). Subduction is thought to drive the hydrated rocks on the Solomon Sea floor to depths of about 100–150 kilometres where they dehydrate or even melt. The fluids so formed rise and trigger partial melting of the overlying upper-mantle 'wedge'. Magmas then rise buoyantly, eventually reaching shallower levels in the earth's crust beneath the active volcanoes, where

magmatic gas pressures may increase, ready for final eruption (Figure 6.11). The formation of Rabaul volcano itself is related to subduction of the Solomon plate in what is probably the most complex and seismically active part of the region, where three plates come together in a submarine ‘triple junction’ in the northern Solomon Sea about 150 kilometres south-east of Rabaul (Figure 6.10), as discussed further below.

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