

# The Snellius-II Expedition

## Progress Report



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Theme I  
Geology and Geophysics  
of the Banda Arc and adjacent areas

Campaign GF 5  
Volcanology and petrology  
in East Sunda and Banda Arcs  
July – August 1984

M.J. van Bergen  
R.P.E. Poorter  
J.C. Varekamp  
May 1985



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# 1. Preface

Throughout history volcanoes have been among the most intriguing geological features. As creators of fertile lands and thermal and mineral resources, and as unreliable sites of devastating eruptions, they are both highly beneficial and damaging. Studded with about 70 recently active and innumerable extinct volcanoes it needs no argument that large parts of Indonesia are faced with profound impacts of each kind on human life and landscape. Snellius-II Campaign GF 5 was an on-shore volcanology program carried out on 14 islands in the Banda Sea, with logistic support of the Indonesian research vessel KRI Jalanidhi. The programme included investigation of 9 active volcanoes in this remote area.

Current volcanological research occupies with a wide variety of aspects ranging from predominantly applied to purely scientific, and encompasses geological disciplines such as field geology, petrology, geochemistry, isotope-geology and geophysics. The prevention of risks and exploration of resources are important objectives, while the study of volcanoes is also a powerful tool in elucidating the tectonic history of geologically complex regions like Eastern Indonesia. Since this is one of the foremost objectives of Theme I, the GF 5 programme not only focuses on active parts but also on some extinct segments of the arc system.

## 2. Introduction

Volcanism in the East Sunda Arc (ESA) and Banda Arc (BA) is closely related with tectonic processes acting at the converging Asian and Indian-Australian plate boundaries. The inner BA consists of a series of active island volcanoes (Banda, Manuk, Serua, Nila, Teon, Damar) which are separated from the active ESA volcanoes of the eastern-most Lesser Sunda Islands (Pantar, Lomblen, Batu Tara) by a segment north of Timor where recent volcanic activity is lacking (Romang, Wetar, Alor). Ambon and adjacent islands represent another extinct part of the BA. Campaign GF 5 has studied and sampled locations on all of the islands mentioned (fig. 1, encl.3) covering a large part of the East Indonesian arc structure. Fitting within the general framework of Theme I, the volcanology programme aims at contributing to our insight into magma evolution and eruptive history of the ESA and BA.

Recent petrological and geochemical work in the Indonesian volcanic arc (received by Hutchison, 1981) has provided much valuable information on the western Sumatra-Java-Bali segment of the Sunda Arc (e.g., Whitford, 1975; Whitford et al., 1979; Nicholls et al., 1980; Nicholls and Whitford, 1983), and similar results on the central Lombok-Sumbawa segment are also available (e.g., Foden and Varne, 1980; Foden, 1983). However, modern data on the eastern Flores-Lomblen-Pantar segment are scarce (e.g., Whitford et al., 1977). This part is particularly interesting since it is situated east of some major structural discontinuities postulated near Sumbawa, Sumba and Flores (Katili, 1970; Hamilton, 1972; Audley Charles, 1975), which would dissect the arc and seem to have influenced the volcanic setting. Moreover, the vicinity of the Australian continental margin and its presumed involvement in tectonic processes are expected to impose constraints on magma genesis that are sensibly distinct from those in other segments of the Sunda Arc, and are possibly more comparable to the Banda Arc. Our study of volcanoes in the Lesser Sunda Islands is meant to expose chemical, isotopic and mineralogical characteristics that could confirm or disprove this hypothesis, and it will thus help to unravel the complex tectonic history of this region. At the same time the favourable spatial distribution of coeval volcanoes allows testing of generalized systematics in the relationship between magma composition and depth of the underlying Benioff zone in island arc settings.

Regional studies in the Banda Arc have provided insight

into overall composition and evolution of the magmas (e.g. Jezek and Hutchison, 1978; Whitford and Jezek, 1979, Magaritz et al, 1978), but also raised geochemical and tectonic questions which emphasize the need for more detailed work on selected islands. Furthermore, little is known about the magmatic processes in former and present magma reservoirs under the individual volcanoes in this area. Since these processes not only modify the primary compositions of uprising magmas but also determine eruption characteristics, their detection and study are relevant for magma genesis and related tectonics as well as for the identification of potential candidates for future explosive events. GF 5 research is directed towards amplifying petrological and geochemical data of key islands, with the aim to clarify petrogenetic and related problems, and towards gaining information on eruptive mechanisms.

For nearly all BA and ESA volcanoes extensive records of historic and recent eruptions exist (e.g. Kusumadinata, 1979), witnessing of variable types and frequencies of activity. Some of the small BA islands represent the uppermost summit of volcanoes that are among the highest in Indonesia, taking the considerable depths of the Banda Sea into account. As especially Indonesia's experience has shown, volcanic dangers to human lives, properties and arable land are manifold, ranging from lava and mud flows to glowing avalanches, ash falls, poisonous gases and tsunamis. Consequently the striving for accurate forecasting of type and timing of eruptive events, and the planning of hazard prevention programmes are of utmost importance for any inhabited volcanic region. Regular field inspection of potential active volcanoes is required, especially if sophisticated seismic and geochemical long-term monitoring is impracticable. Campaign GF 5 in combination with previous and future observations contributes to the knowledge of the nature and state of activity of the remote BA and ESA volcanoes.

Volcanism is often associated with thermal and mineral resources. Hot-springs and related waters occur on many islands of the BA and ESA, but detailed studies are lacking. Our programme accounts for an inventory of the geochemical characteristics of hot-springs including those on some islands where volcanic activity is supposed to be extinct.

In summary, the GF 5 programme combines scientific with practical volcanological objectives for the area investigated by the Snellius-II Expedition. It is executed using the following methods:

- Collection of rock samples and pyroclastics on the volcanic islands for petrological and geochemical investigations and radiometric age dating.
- Sampling of gases in fumarolic vents inside the craters

and on the flanks of active volcanoes for geochemical analysis.

- Sampling of hot-spring and related waters for geochemical analysis.
- Field observations with respect to present volcanic activity and sampling strategy.
- Seismic measurements on Banda Api volcano.
- Extensive laboratory studies of the collected material using various analytical techniques (encl. 6).

### 3. Progress of the Campaign GF 5

Participants of the GF 5 Campaign and their affiliations are listed in enclosure 1. The actual campaign was carried out from July 21 to August 26 1984 (see encl. 2 for a summary of field activities and a map of the cruise made with the KRI Jalanidhi). The chronological report below was completed in September 1984.

#### Sunday, July 15

The Dutch scientists leave Amsterdam (Schiphol).

#### Monday, July 16 - Thursday, July 19

They arrive in Jakarta (Halim). After having received the research permits, they leave by train for Bandung on July 17, to meet the Indonesian scientists. The schedule and aims of the expedition are thoroughly discussed during joint meetings together with Drs. Totong Suhanda (Directorate of Volcanology) on the next two days. Aerial photographs and maps are studied. The Dutch group is also welcomed by Drs. Hartono, co-ordinator of Theme I. The equipment had already been transferred from the TYRO to the KRI Jalanidhi an Indonesian Navy vessel used for hydrographic surveys. It appears that the ship has to restock on supplies after two weeks sailing, preferably during a quick return to Ambon. Consequently an alternative sailing plan has to be devised and discussed. Van Bergen becomes ill with fever during this period in Bandung.

#### Friday, July 20 - Saturday, July 21

Maps are copied and we shortly visit Tankuban Prahu volcano as an illustration of what to expect. That same night Sriwana and the Dutch group drive to Jakarta and take the plane to Ambon early in the morning of the next day, leaving Van Bergen behind. Wirakusuma and Erfan will follow two days later.

#### Sunday, July 22

We get organized and prepare fieldwork. In Ambon the Dutch group finds generous support for accomodation and transport from Ir. P. Bennema, Dutch expert at Bappeda Dati I Maluku.

Monday, July 23 - Tuesday, July 31

July 23 is a reconnaissance field day to get ourselves acquainted with the various rock types. From then on the group will be split into two or even three separate teams composed on both Indonesian and Dutch participants. Every day a specific problem is attacked in parallel sections. In the evenings we jointly discuss daily topics, pack and label samples, write a complete field book and plan the next day. This turns out to be an extremely efficient method of working, promoting co-operation between individual members as well as between the groups, and giving maximum access to the field data. We sample granites and several volcanic rock types along various sections and establish stratigraphic relations between the distinct units. Meanwhile Wirakusumah flies to Banda to install a seismometer and discuss procedures with technicians present at the local volcanological observatory. His return to Ambon will be delayed by aircraft troubles. On the last two days hot-springs are sampled and the neighbouring island of Haruku is visited. Van Bergen has joined the group on July 26 and Suharyono arrives from Bandung on July 31. The evening of July 31 we transfer our belongings and samples to the KRI Jalanidhi

Wednesday, August 1 - Thursday, August 2

In the morning of August 1 we leave Ambon, setting sail for Banda. In consultation with the commander it is decided to use Kupang (Timor) as a bunkering stop. After about 20 hours sailing we arrive in Banda Naira where the ship can moor. Two teams spend the rest of the day sampling along the coasts.

Friday, August 3

In the morning the whole group ascends Banda Api, the active volcano of the island group. Vroon suffers from coldness and overexhaustion and is out of action for a few days. The weather at Banda is cold and wet.

Saturday, August 4

This day we work on Banda Besar (Lonthor) and Banda Naira. We are assisted by the crew in rubber boats.

Sunday, August 5 - Monday, August 6

The top of Banda Api is climbed again in pouring rain and freezing cold, with not much success since the older crater lacks significant fumarolic activity. The young flows of the volcano are sampled extensively. Because of the promising results we decide to stay an extra day to complete sampling on Banda Besar and Banda Naira, flexible adaptations of the cruise scheme having been taken into account.

Tuesday, August 7 - Friday, August 10

During the night of August 6 we sail to Manuk where anchoring difficulties are foreseen but the commander succeeds. Two teams go up the mountain, while a third team samples coastal exposures from the rubber boat. The terrain is steep, rugged and without trails. There are no inhabitants except for birds. The summit area is covered with recent lava flows, but no gas samples are taken since fumarolic activity is minimal.

The next island is Serua where we spend two days. Gases are sampled at the young cone, and many lava samples are collected. We find giant pumice lumps suggesting explosive eruptive activity from this centre. In the lavas we detect obvious signs of magma mixing. As on most islands we employ local guides whose knowledge of the terrain, skill in hacking pathways through dense jungle and ability to carry heavy loads of equipment and rocks are indispensable. Again at night we sail to Nila. Here we cannot reach the fumarolic area due to excess danger. Some of the water draining from the fumarolic site are sampled. One team succeeds in reaching the densely overgrown summit area. We visit the site of the 1968 eruption which turns out to be a small phreatic pit crater. The early reports on the magnitude of this eruption seem to be exaggerated. Large sections of the older caldera are hydrothermally altered and most historic eruptions appear to have been of the phreatic kind. Our field data suggest that the young cone has a composition different from the older caldera sequence. Again there is abundant evidence for magma mixing.

Saturday, August 11

We arrive at Teon, where coastal cliffs are sampled and the fumarolic area is visited. Two coastal exposures show an ash flow sequence which we interpret as resulting from the 1660 eruptions. We collect some charcoal from these deposits for age dating. Unfortunately the sea is too rough to go around the island. The team that investigates the summit does not manage to return on board before sunset. Crew members are sent out in the dark with the rubberboat and find them unharmed. The sailing schedule is again discussed as the KRI Jalanidhi has to be in Kupang by August 16. In order to minimize loss of time it is agreed to end the cruise on August 27 on Timor instead of returning to Ambon.

Sunday, August 12

We anchor at Damar. One team climbs the Wurlali volcano to sample gases and sulphur deposits, another team takes samples of rocks and hot-springs along the coasts. No efforts are made to obtain a complete rock collection of Damar, since at least a week is needed to cover the whole

island. Problems we had with the rotaflow valves of gas collection bottles are solved.

Monday, August 13

We spend this day on Romang to sample rocks for age dating and hot-spring waters, and to chase after a supposed fumarolic area which turns out to be a mofette. We take a gas sample.

Tuesday, August 14 - Wednesday, August 15

In the morning Iliwaki on the south coast of Wetar is shortly visited to study coastal exposures and collect samples of peraluminous granites and rhyolites for comparison with similar rocks from Ambon. We sail on to Kalabahi on Alor to stock water and arrive the next day. The local authorities provide us with information on volcanic/thermal manifestations on Alor and Pantar, and we discuss logistics for attack of Sirung volcano on the latter island. It is decided to go there by local transport while the KRI Jala-nidhi goes to Kupang. Varekamp decides to stay on board to see a doctor and is accompanied by Van Bergen.

Thursday, August 16 - Friday, August 17

The ship leaves and the rest of the group visits a previously unknown, continuously active geyser and associated hot-springs. Because of the excentric location of Kalabahi and the absence of good roads across this large island rock sampling is omitted. The next day, Indonesia's national holiday (Proklamasi), preparations are made for the trip to Pantar and some rest is taken.

Saturday, August 18 - Tuesday, August 21

August 18 is spent with travelling by boat to Pantar, and the next morning one of the local trucks is chartered to bring the group to the slopes of Sirung along a 40 km long track. This complex volcano is climbed from the north. The large and spectacular crater contains a lake with water that appears to be extremely acid (pH=2). Much steam escaping with hissing sounds and several yellow solfataric fields witness of great activity. Rocks, gases and waters are collected. The night is spent near Sirung and the next day the south coast is reached on foot for additional rock samples and hot-springs. At the end of the day the group is transported back to Blangmerang on the north coast, where hot springs are visited and the return of the KRI Jala-nidhi is awaited on August 21.

Meanwhile the ship has arrived in Kupang in the morning of August 17. Varekamp's bad health urges him to return to Holland and Van Bergen becomes the new party chief. Preliminary results are evaluated, the final part of the

expedition is discussed and a local carpenter is found who can construct boxes for transport of rock samples to Holland. On August 19 Varekamp flies to Jakarta and on to Amsterdam on August 20.

In the afternoon of August 19 the KRI Jalanidhi with Van Bergen leaves Timor and arrives the next day on Alor to stock more water. Because of the low capacity of the supplying system, filling the tanks takes about a day. Hence the ship cannot pick up the group on Pantar earlier than in afternoon of August 21. We sail immediately on to Batu Tara.

#### Wednesday, August 22

On Batu Tara we spend this day studying coastal exposures and sampling rocks. Fortunately low tide facilitates landing and access to the narrow shore strip under steep cliffs. An attempt to climb the east flank to reach the fumaroles that occur half-way up to the volcano has to be broken off because of excess danger. It was decided not to waste time going to the top of the steep volcano, as rock sampling along the coast seemed to be more promising. Indeed we obtain a fine collection of leucite bearing rocks.

#### Thursday, August 23

At sunrise we leave for Ili Lewotolo on northern Lomblen where we shall stay for two days. After the ship has anchored in a bay near the volcano we go on shore for inquiries and arrange transport. We charter two motor-cycles, the only means of transport available in this area. Using these a team succeeds going around the large volcano along a narrow track. Samples are taken and left on the way as they will be collected by a villager on horseback the next day.

#### Friday, August 24 - Saturday, August 25

We climb Ili Lewotolo starting on the southern slope and entering the crater from the west. Unfortunately, after a few hours climbing Vroon has to return because of illness. The others investigate the summit area, sample rocks and find the hottest gases of all volcanoes visited (450-500°C). The same evening we set sail to Ili Werung, a volcano situated in south Lomblen. Here we encounter insuperable problems. Under the prevailing conditions it appears to be impossible to land in the selected area near the volcano as the KRI Jalanidhi can anchor only in a bay at a remote distance. Heavy breakers cause severe difficulties for landing with the rubber boat but we manage to go on shore to size up the situation. It becomes clear that going over land to Ili Werung either on foot or on horseback will take so much time that we cannot be back at noon the next day, a

time limit set by the commander. Consequently no meaningful activity can be undertaken and we are forced to end the expedition here. We decide to sail to Kupang the same evening.

Sunday, August 26

We arrive in Kupang in the morning and need the whole day for packing samples and equipment, because the KRI Jalanidhi will leave for Kendari the next day.

Monday, August 27 - Friday, September 7

August 27 and 28 are spent with organisation, discussion of preliminary results, planning report schedules and future co-operation, and paper work. The whole team enjoys the absence of physical efforts after five weeks of practically uninterrupted field work. Especially the last period has taken a heavy toll of each one's endurance. Large and complex volcanoes, hot weather and dry terrains made working conditions in the Lesser Sunda Islands even more demanding than in the Moluccas. Moreover the loss of Varekamp had to be compensated by extra efforts of the others. Nevertheless mutual relations and team spirit remained excellent till the end. All team members agree that this as well as the continuous support of the KRI Jalanidhi's staff and crew has been a decisive factor in the success of the expedition.

Leaving Gunung Api in the central Banda Sea aside, this is probable the first time that a joint Indonesian-Dutch expedition climbed all active volcanoes in the Banda Arc as well as some in the easternmost Lesser Sunda Islands in one cruise. For petrological purposes we collected more than 400 rock samples on 14 islands including some where volcanism is extinct of which Ambon is the most important. Although gas sampling has been slightly disappointing (many fumarole temperatures were lower than expected for active volcanoes, and some bottles initially had valve problems) we sampled gases and performed in situ temperature measurements on 7 volcanoes. More than 30 waters were collected from hot springs and other occurrences on 8 islands and in each case temperature and pH were determined on the spot. Seismic readings were obtained on Banda using a portable seismometer.

Some objectives were not fulfilled: a visit of Ambelau could not be fitted into the cruise scheme without losing too much time (instead we could insert Haruku), and the N-S traverse Batu Tara - Lomblen remained incomplete, since we could not reach Ili Werung volcano due to logistic problems and lack of time. Nevertheless the field observations and samples obtained during the 28 days of effective field work represent a wealth of material of which we expect that further study will provide us with much new information on

the volcanic history of the Banda Arc and adjacent areas.

On August 28 Suharyono leaves Kupang and flies to Bandung. He will be followed by the other Indonesians. The Dutch group leaves Timor on August 29 and makes a stop-over in Bali. On August 31 Vroon flies to Jakarta and directly to Amsterdam. Poorter and Van Bergen await their day of departure in Bali and Yogyakarta and use the opportunity to visit the famous volcanic areas of Gunung Batur and the Dieng Plateau. On September 6 they fly to Jakarta for final arrangements and leave for Amsterdam at the end of the same afternoon. The next day they arrive at Schiphol Airport.

## 4. Research programme and Preliminary results

### 4.1 Igneous petrology and geochemistry

Laboratory research on rocks and pyroclastics that is being carried out or planned concerns the following subjects:

- Easternmost Sunda Arc (volcanoes of Batu Tara, Lewotolo-Lomblen, Sirung-Pantar)  
This study focuses on the origin and evolution of magmas in relation to subduction and associated tectonics. Samples of Batu Tara (potassic alkaline) and Lewotolo (high-K calcalkaline) were analysed for major elements, while results of trace elements are under way. The study of thin sections and mineral chemistry is in progress. Whole-rock oxygen isotope results obtained for Batu Tara point towards 'normal' mantle as source rocks of magma. It is aimed to correlate these with strontium and neodymium isotopic data in an attempt to establish the possible influence of the leading edge of the Australian continent on magma genesis in this extreme segment of the Sunda Arc.
- Banda Arc (Banda Islands, Manuk, Serua, Nila, Teon, Damar)  
The importance of 'continental' components in the evolution of the subduction related magmas will be tested by detailed research on samples from selected islands where bimodal magma compositions are suspected. Special attention will be paid to the possible operation of those processes in high-level magma chambers that could generate eruptions, as well as to the role of magmatic volatile constituents. Our field observations suggest, for example, that magma mixing has played a role on several islands. The laboratory study of lavas and pyroclastics may yield more compelling evidence. Furthermore, the characteristics of pyroclastics and plinian ash falls and ash flows (Banda, Serua, Teon) will be studied for possible correlations with piston-core materials.
- Extinct segments of the Banda Arc (Ambon, Haruku, Wetar)  
Unusual peraluminous acidic volcanics (so-called ambonites) of Pliocene age are wide-spread on Ambon and also occur on Haruku and Wetar. Their origin is possibly related to continent-continent collisional tectonics. The samples of ambonites and associated rock-types will be investigated primarily for their potential to yield new radiometric ages in an attempt to impose further constraints on existing data. The study of thin sections is

in progress. A comprehensive approach is expected to be of great interest for petrogenetic questions concerning continental magmas but has a lower priority given the general scope of the expedition.

#### 4.2 Fumarole and hot-spring geochemistry

Aspects of applied volcanology are important components of our research on collected gases and waters. The fumarolic emissions may provide useful information concerning the present-day state of the active volcanoes visited, the hot-springs (present both on active and extinct islands) are potential indicators of thermal and mineral resources. Studies are carried out mainly on a reconnaissance basis and are meant as a contribution to present and future monitoring and exploration programmes.

Data sets will be used to supplement existing and to initiate new data bases at the Directorate of Volcanology, Bandung, supporting its surveillance, hazard prediction and exploration efforts in the Banda Sea area.

Secondly, chemical characteristics of fumaroles and waters may provide insight into their provenance and thus be relevant for subsurface geology or magmatic processes. The investigated fumarolic vents have relatively low temperatures, exceptions being those of Lewotolo (Lomblen) and, to a lesser extent, Wurlali (Damar). Analysis of the incondensable gases indicate that these contain significant amounts of H<sub>2</sub> and N<sub>2</sub>. All gas samples will further be analysed for Cl, total S and CO<sub>2</sub>.

Preliminary data on He isotopes suggest low He<sup>3</sup>/He<sup>4</sup> ratios on certain islands, possibly reflecting a continental component. Attempts are being made to obtain supporting data on S and C isotopes.

Hot-spring and related waters will be studied rather extensively since we were able to collect a substantial amount of samples from various localities. Analytical work in Utrecht is almost completed with respect to major and a number of important trace elements, and results will be combined with those from Bandung on the same set of samples. After evaluation of the initial data it will be decided whether determination of H and O isotopes is necessary. Waters from Sirung crater lake and some drainage streams on Nila and Batu Tara have strongly deviating compositions.

#### 4.3 Seismicity

Banda Api is one of the many volcanoes in Indonesia that are continuously being watched at local observatories of the Directorate of Volcanology. In the field of eruption prediction monitoring seismic activity is an important

tool. During the expedition additional seismic readings were obtained by Indonesian team-members using a portable seismometer. Recorded tremors will be evaluated in terms of tectonic and magmatic events.

## 5. Training and education

Post-expedition training at the Institute of Earth Sciences, Utrecht is proposed for four Indonesian scientists, all participants of the expedition:

Ir. A.D. Wirakusuma (co-chief scientist)  
Drs. T. Sriwana  
Ir. R. Erfan  
Ir. K. Suharyono

Subject: Volcanic petrology and geochemistry with special reference to the East Sunda and Banda Arc.

Training will include both theoretical methods and instrumental techniques employed in Utrecht and other Dutch institutions. Practical work will include research on the samples collected during the expedition, data evaluation and processing, and reporting, in close co-operation with the Dutch participants.

Special attention will be paid to the role of magma-chamber processes in the evolution of volcanoes and to the geochemistry of fluids associated with volcanic activity. Joint post-expedition research is strongly pursued as it is considered to be a necessary prerequisite to optimize the output of the volcanology programme. Moreover, it is a natural consequence of the excellent interplay between the counterparts from Bandung, Utrecht and Middletown (U.S.A.) during the preparative and executional stages of this expedition.

## 6. Enclosures

CAMPAIGN PARTICIPANTS AND AFFILIATIONS

Enclosure 1

Dr. M.J. van Bergen	IvARUU
Ir. R.D. Erfan	DV
Dr. R.P.E. Poorter	IvARUU
Drs. T. Sriwana	DV
Ir. K. Suharyono	LGPN-LIPI
Dr. J.C. Varekamp	DEESWU
Mr. P.Z. Vroon	IvARUU
Ir. A.D. Wirakusumah	DV
Mr. Kusma	DV

General supervision of the GF 5 programme:

in Bandung: Drs. Totong Suhandu      DV  
in Utrecht: Prof.Dr. R.D. Schuiling    IvARUU

DV            : Directorate of Volcanology, Bandung  
LGPN-LIPI   : National Institute of Geology and Mining,  
                 Bandung  
IvARUU       : Institute of Earth Sciences, University of  
                 Utrecht  
DEESWU      : Department of Earth and Environmental Sciences,  
                 Wesleyan University, Middletown (Conn.), U.S.A.

## SUMMARY OF FIELD ACTIVITIES AND CRUISE MAP

Enclosure 2

Date	Activity	Location
21-7	arrival Ambon	
22-7	preparations	
23-7	field day 1	N coast of E Leitimor, Tg. Nusanive
24-7	field day 2	Sojadiatas, Hatalai
25-7	field day 3	Tg. Hatiari, G. Habaena
26-7	field day 4	W. Hatu Liliboi, W. Sikabiri
27-7	field day 5	Tg. Batuanyut Tg. Nusanive
28-7	field day 6	W. Laa, G. Kerbau Tawiri, W. Lawa
29-7	field day 7	Batugong, G. Lalata
30-7	field day 8	Waai, W. Toisai, G. Kukusan Tulehu
31-7	field day 9	W. Loi, Hila, Mamua
1-8	embarkation	
	departure Ambon	
2-8	arrival Banda	
	field day 10	coasts Banda Naira Krakah Island
3-8	field day 11	Batu Angus, G. Api, Colombo
4-8	field day 12	N coast of W Lonthor coasts G. Api
5-8	field day 13	Lonthor village, W coast of N Lonthor G. Api
6-8	field day 14	Papenberg, coasts G. Api central W Lonthor E coast Banda Naira, G. Tujuh
	departure Banda	
7-8	arrival Manuk	
	field day 15	W-NW coasts E slope and summit
	departure Manuk	
	arrival Serua	
8-8	field day 16	Larrei Bay, Jerili, Tarana, Tg. Merah Merah
9-8	field day 17	Jerili, G. Legatata, central and NE Serua G. Legatata NW coast, small island off NW coast
	departure Serua	
10-8	arrival Nila	
	field day 18	coasts NE part, SE slope N slope, G. Laworkawra
	departure Nila	

Date	Activity	Location
11-8	arrival Teon field day 19	NW area Sisisi, G. Wakiktia, Serawerna, Mesah Lajoni
12-8	departure Teon arrival Damar field day 20	Kehli Wulur G. Wurlali
13-8	departure Damar arrival Romang field day 21	S part SE coasts
14-8	departure Romang arrival Wetar field day 22	Tg. Illipoi
15-8	departure Wetar arrival Alor organisation	
16-8	field day 23 Jln. departure Alor national holiday	Pasi
18-8	Jln. arrival Kupang travel to Pantar organisation Kupang	
19-8	field day 24 Jln. departure Kupang	N slope and crater G. Sirung
20-8	field day 25	NE slope G. Sirung, Beangagang Bay, Maliang
21-8	Jln. arrival Alor Jln. departure Alor Jln. arrival Pantar departure Pantar	
22-8	arrival Batu Tara field day 26	coasts
23-8	departure Batu Tara arrival N Lomblen field day 27	around Ili Lewotolo
24-8	field day 28 departure N Lomblen	Ili Lewotolo
25-8	arrival S Lomblen departure S Lomblen	
26-8	arrival Kupang	
27-8	disembarkation	

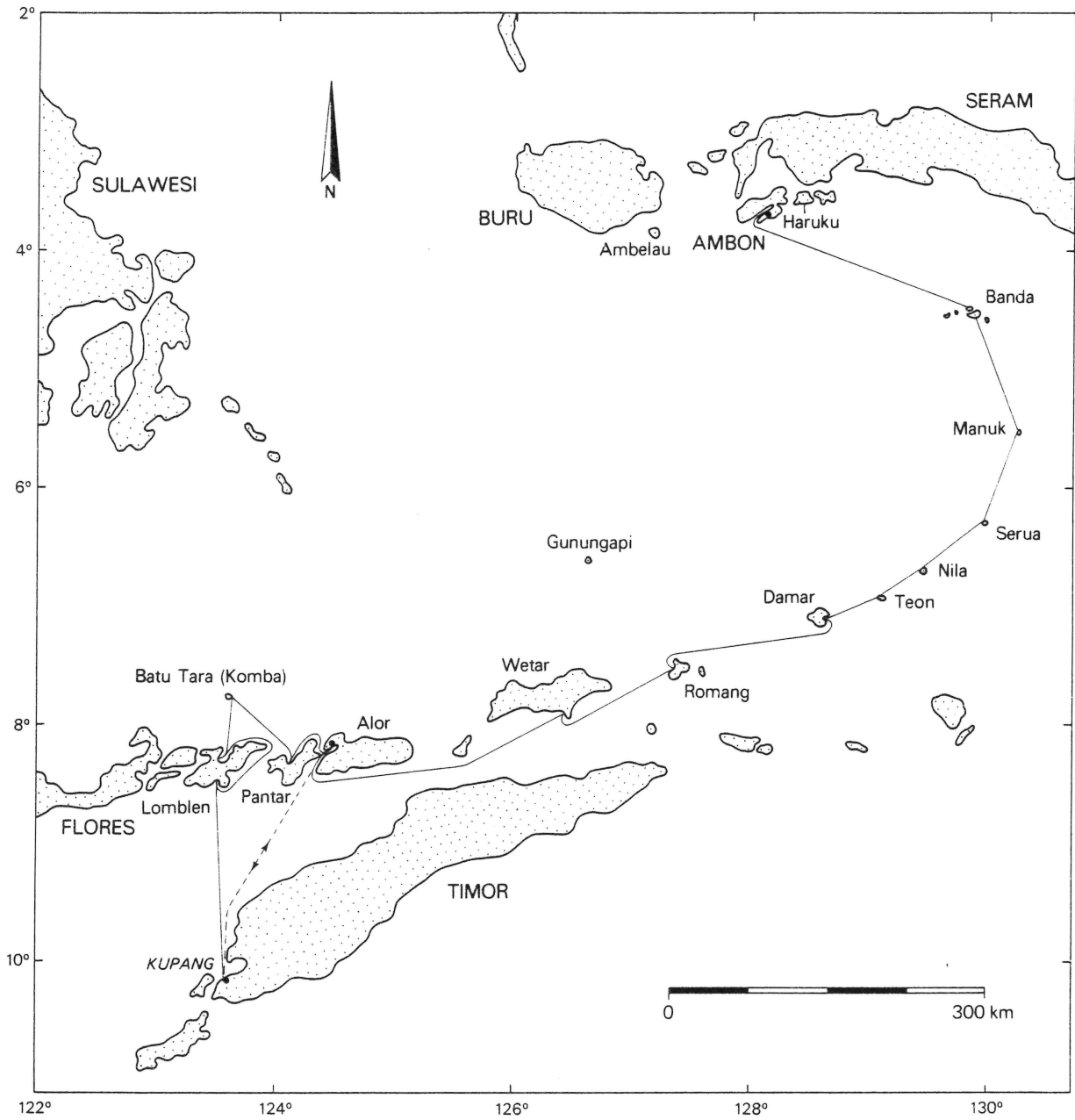


fig. 1 GF 5 cruise map

MAPS OF SAMPLE LOCATIONS

Enclosure 4

- Fig. 2 - Ambon and Haruku
- Fig. 3 - Banda Group
- Fig. 4 - Banda Api, Banda Naira and Banda Besar  
(Lonthor) (detail of fig. 3)
- Fig. 5 - Manuk
- Fig. 6 - Serua
- Fig. 7 - Serua detail
- Fig. 8 - Nila
- Fig. 9 - Teon
- Fig. 10 - Damar
- Fig. 11 - Romang
- Fig. 12 - Lesser Sunda Islands
- Fig. 13 - Pantar
- Fig. 14 - Pantar detail
- Fig. 15 - Komba (Batu Tara)
- Fig. 16 - Lomblen (Lewotolo volcano)
- Fig. 17 - Lewotolo detail

Legend of sample locations:

circles : rocks and pyroclastics  
squares : waters  
triangles: gases

Note:

The maps of sample locations are first drafts and may be subject to minor modifications.

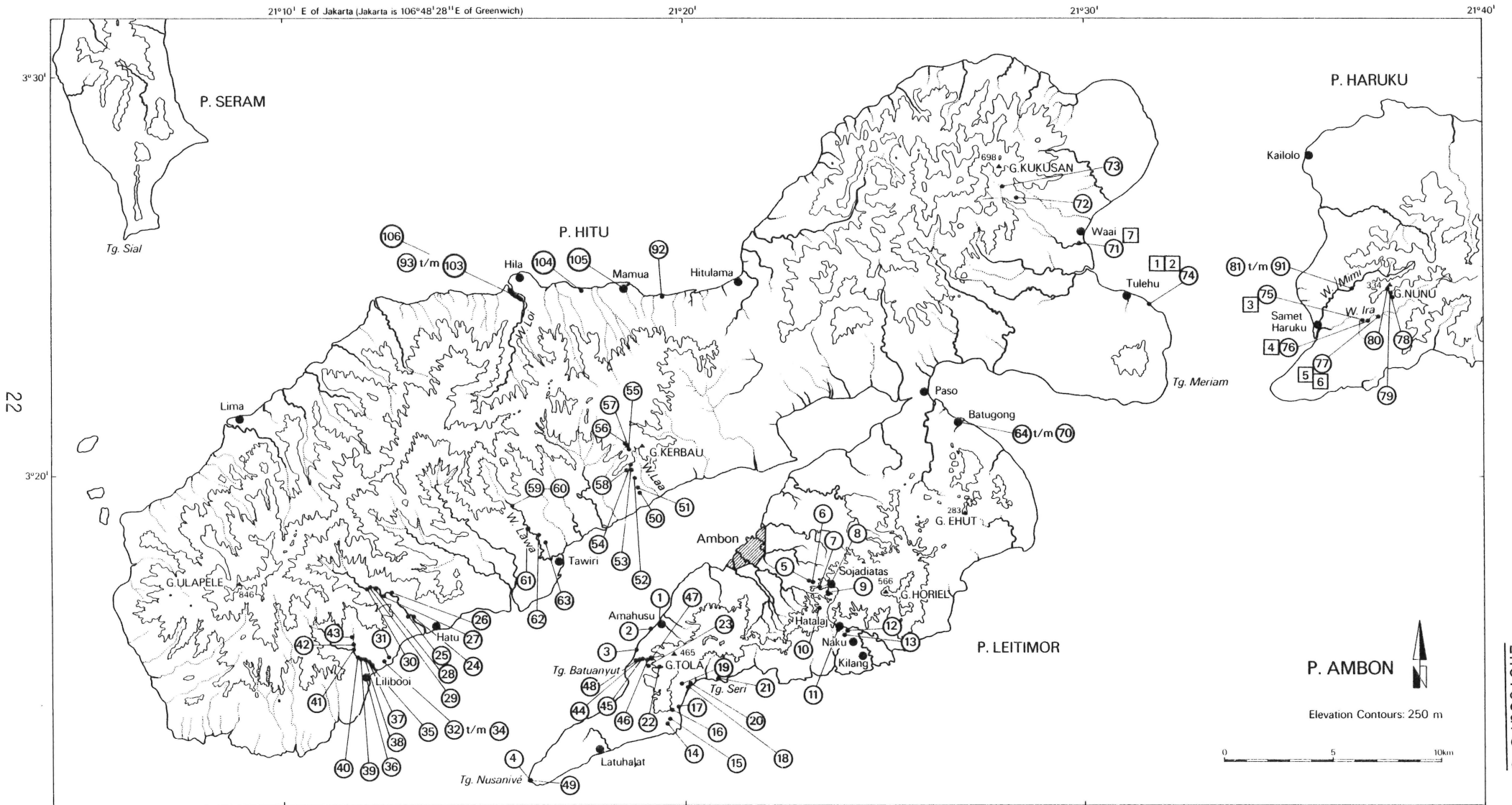


fig. 2 Ambon and Haruku

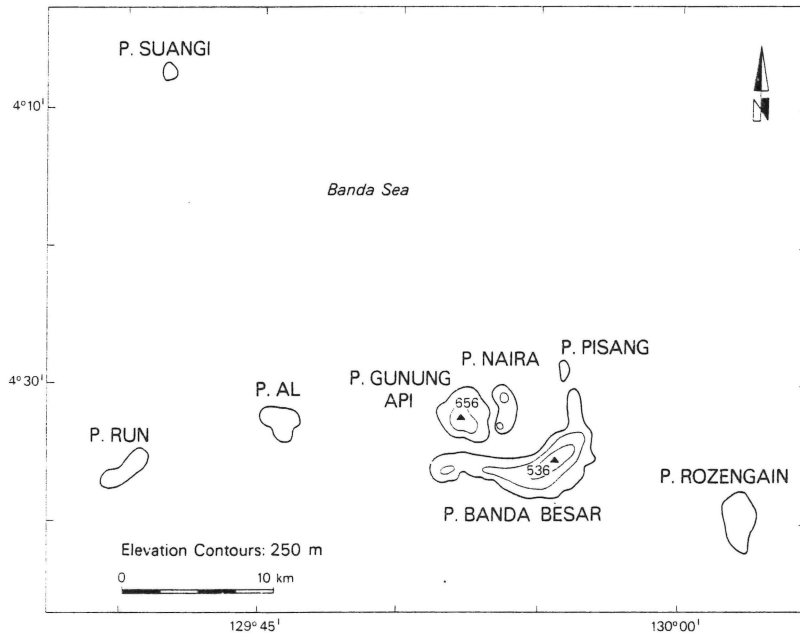


fig. 3 Banda Group

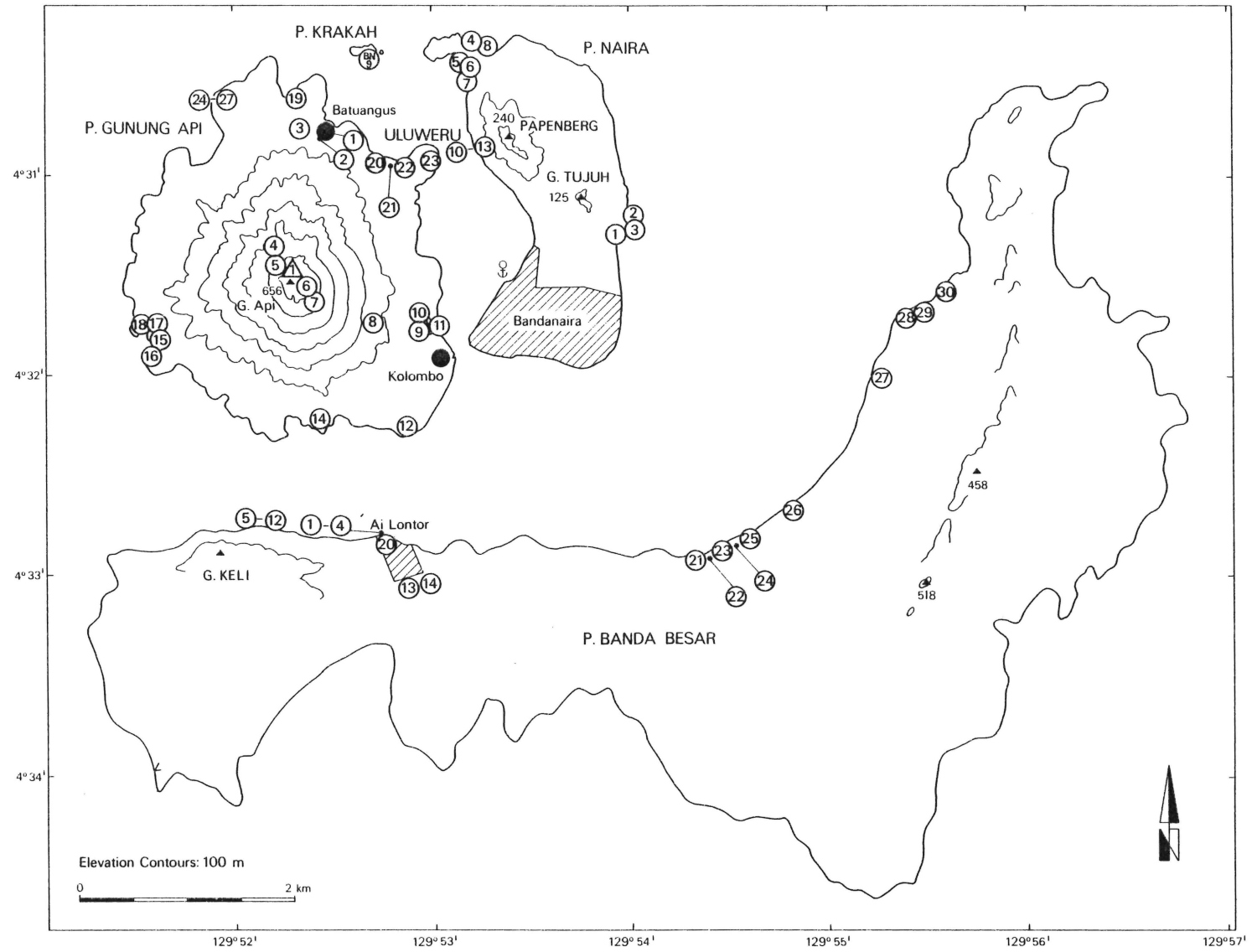


fig. 4 Banda Api, Banda Naira and Banda Besar (Lonthor) (detail of fig. 3)

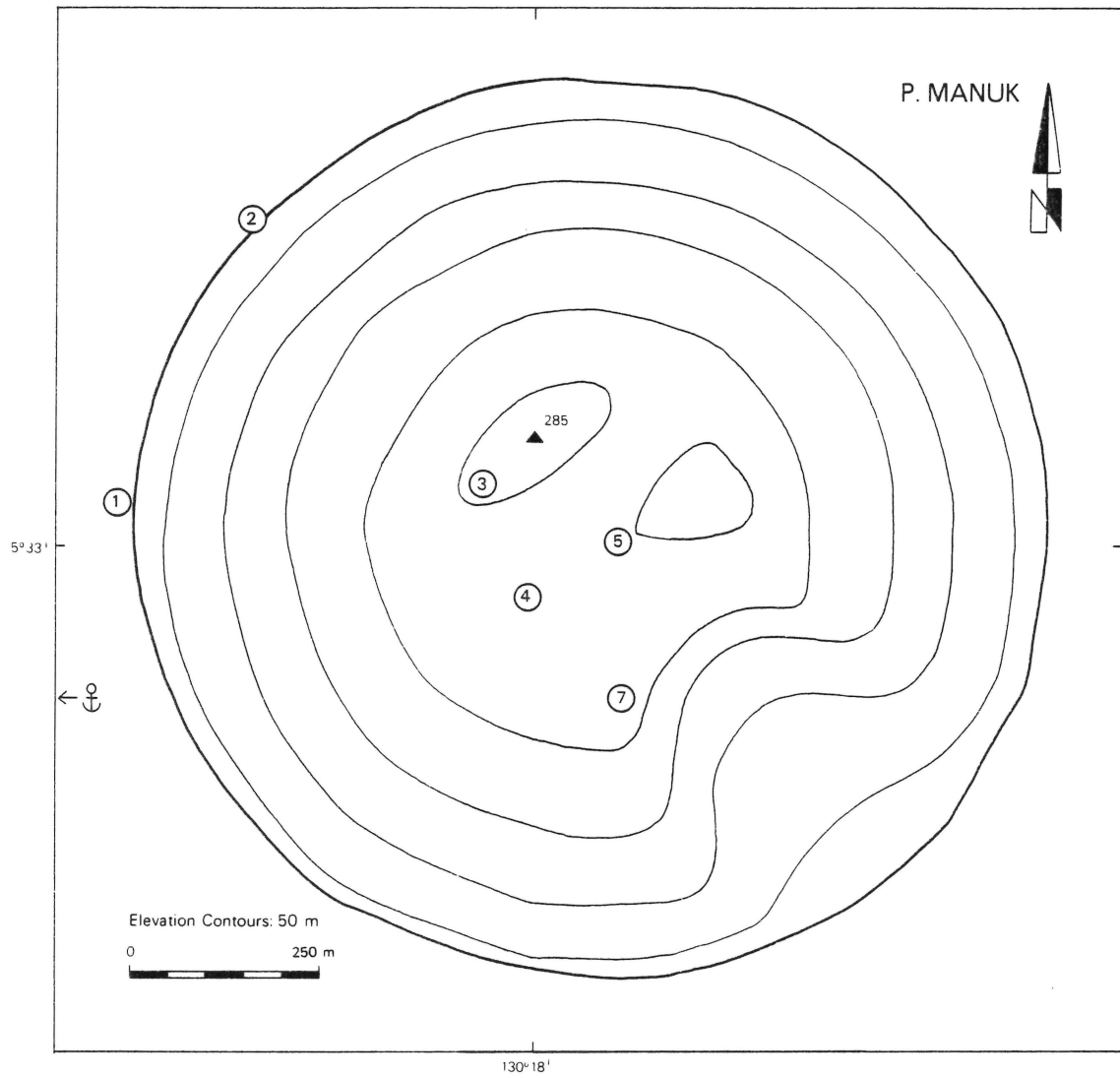


fig. 5 Manuk

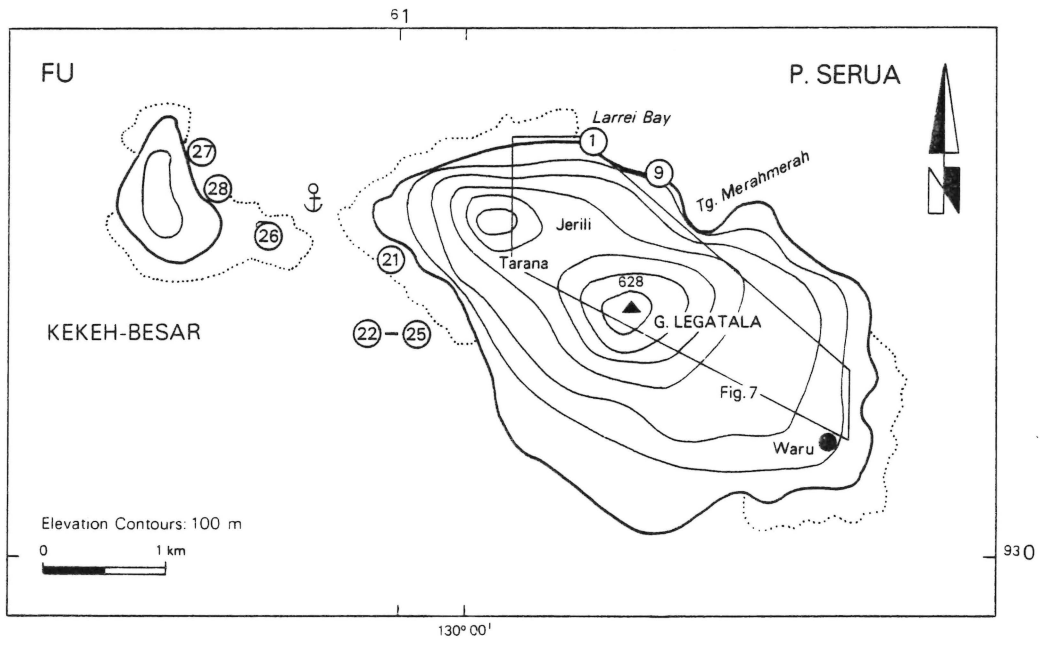


fig. 6 Serua

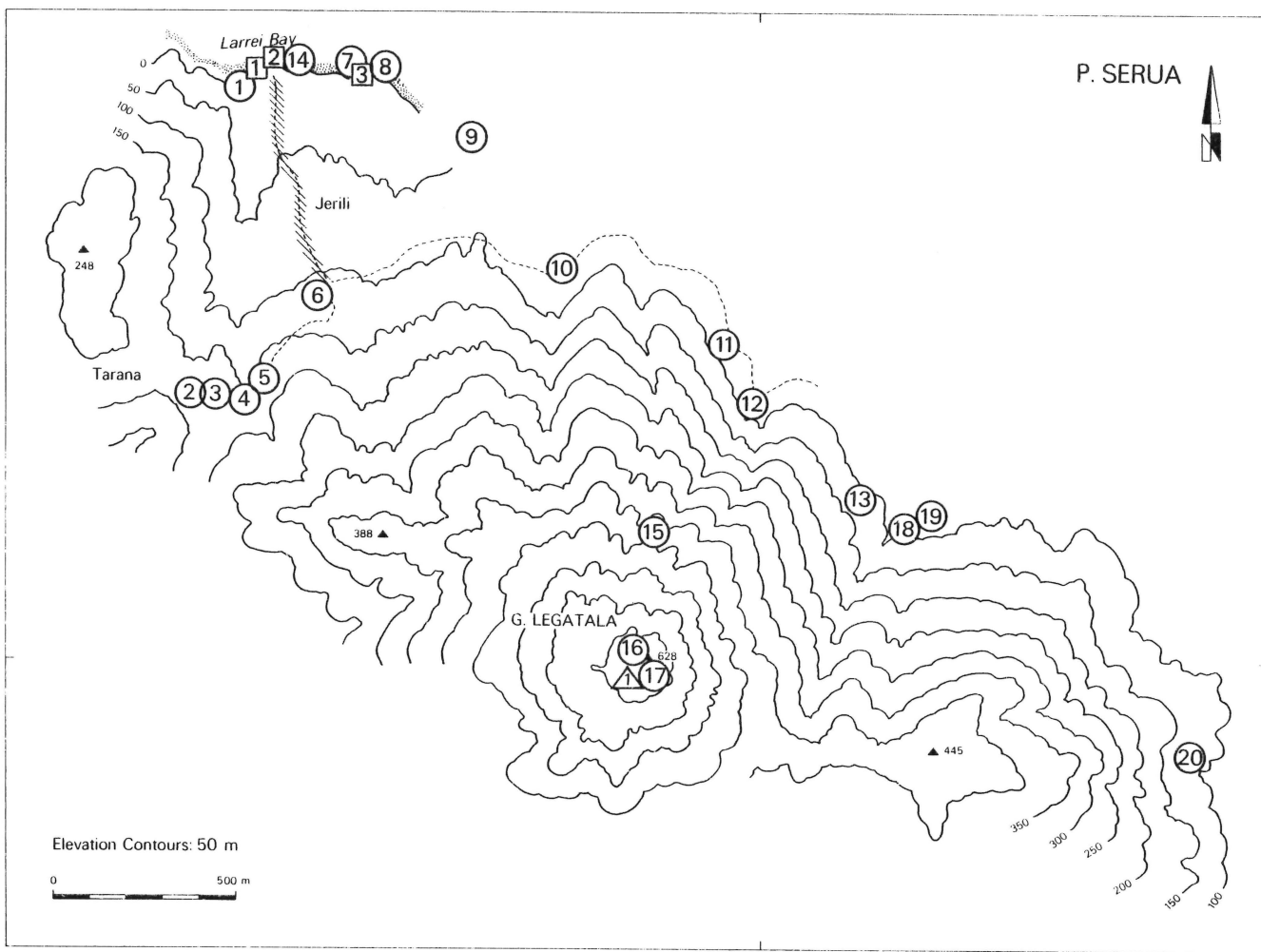


fig. 7 Serua detail

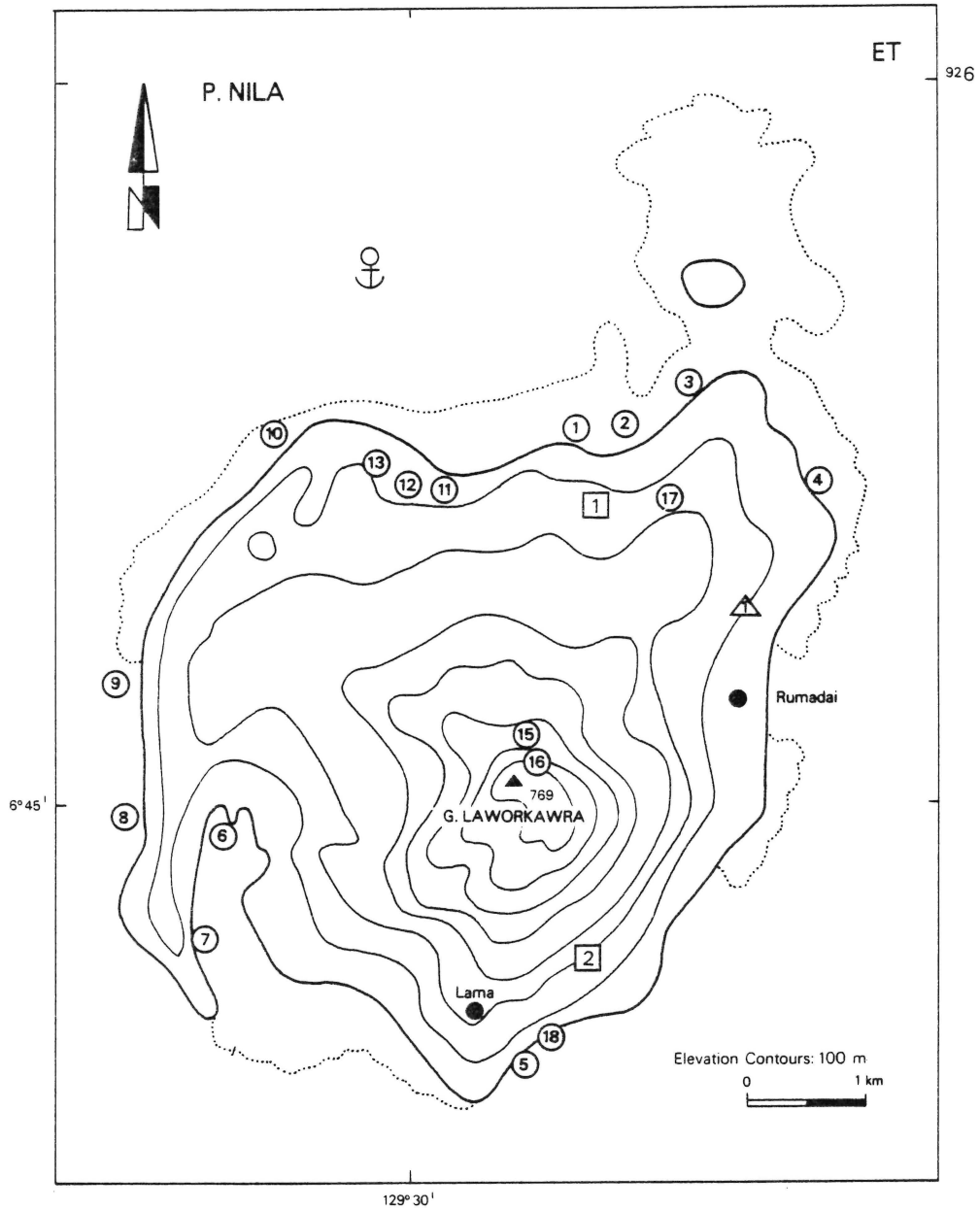


fig. 8 Nila

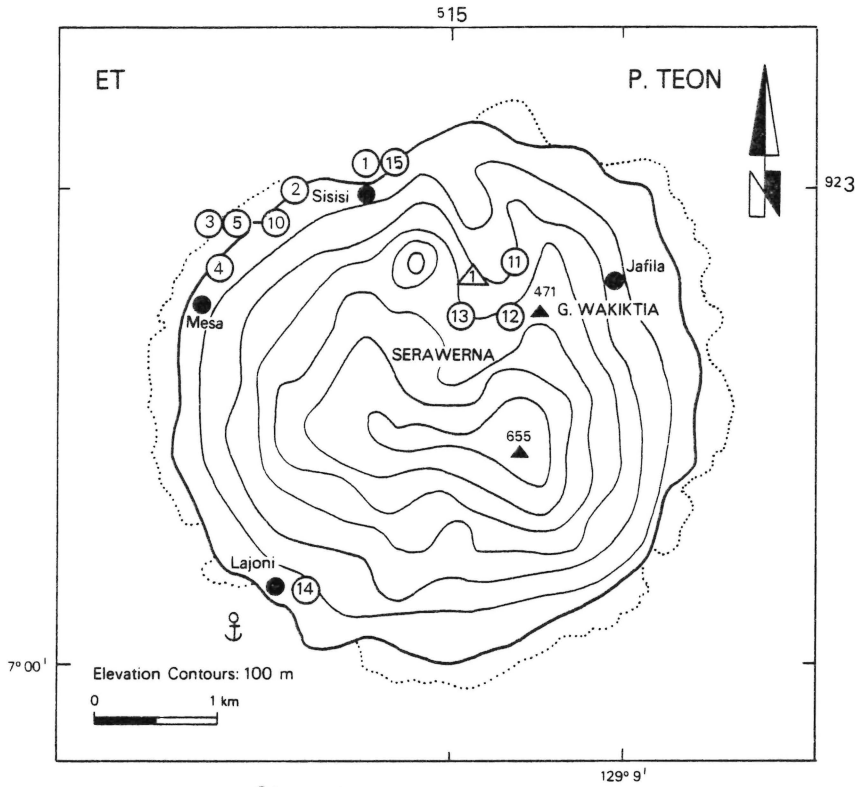


fig. 9 Teon

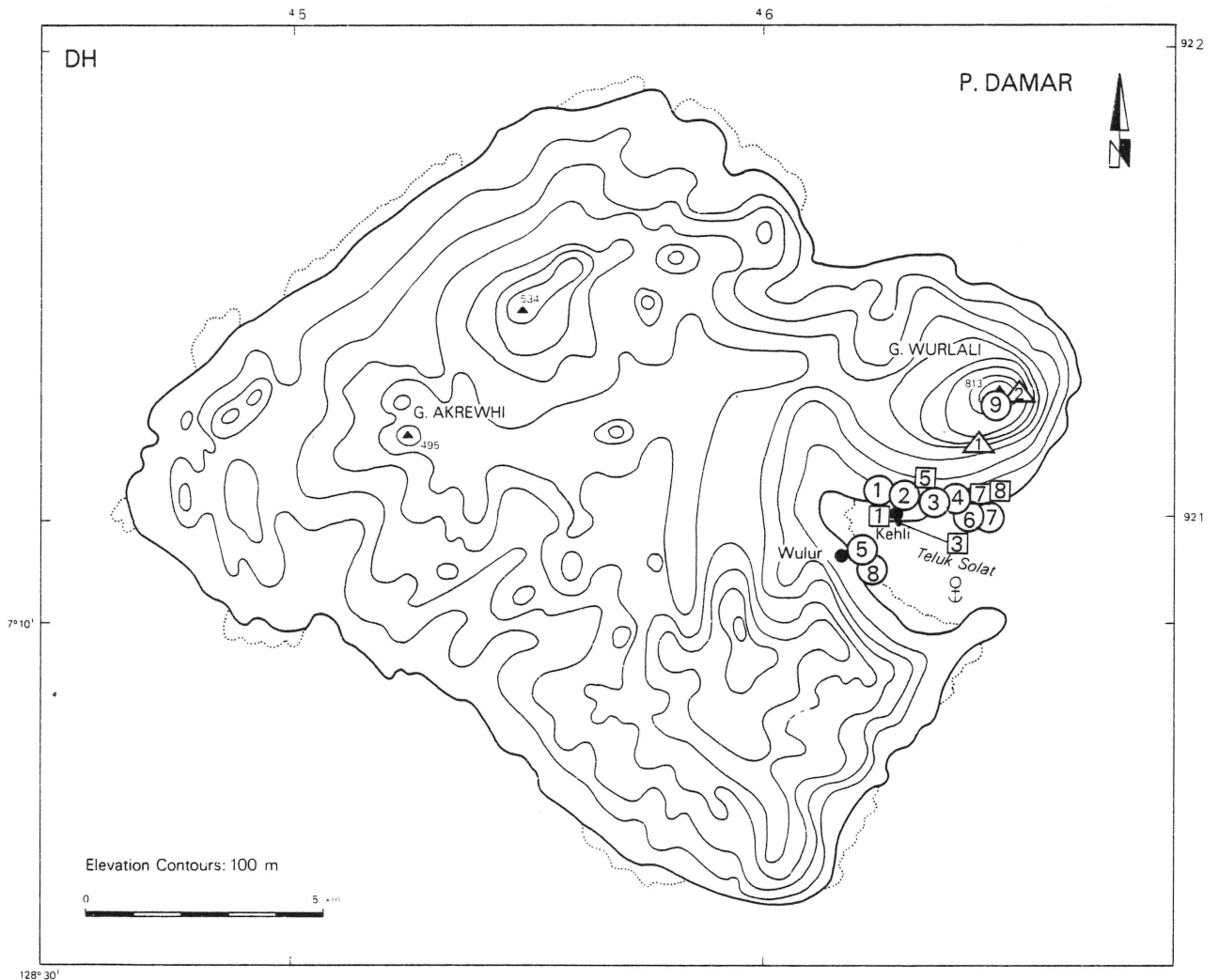


fig. 10 Damar

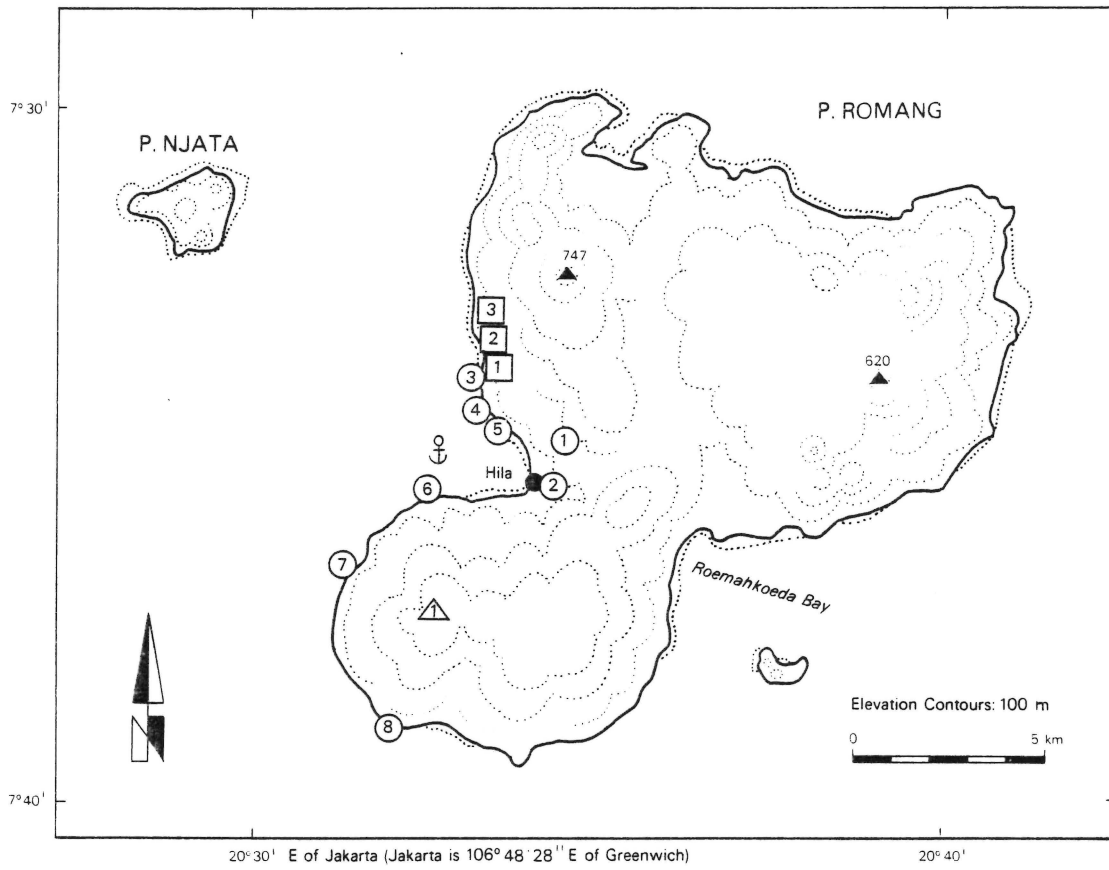


fig. 11 Romang

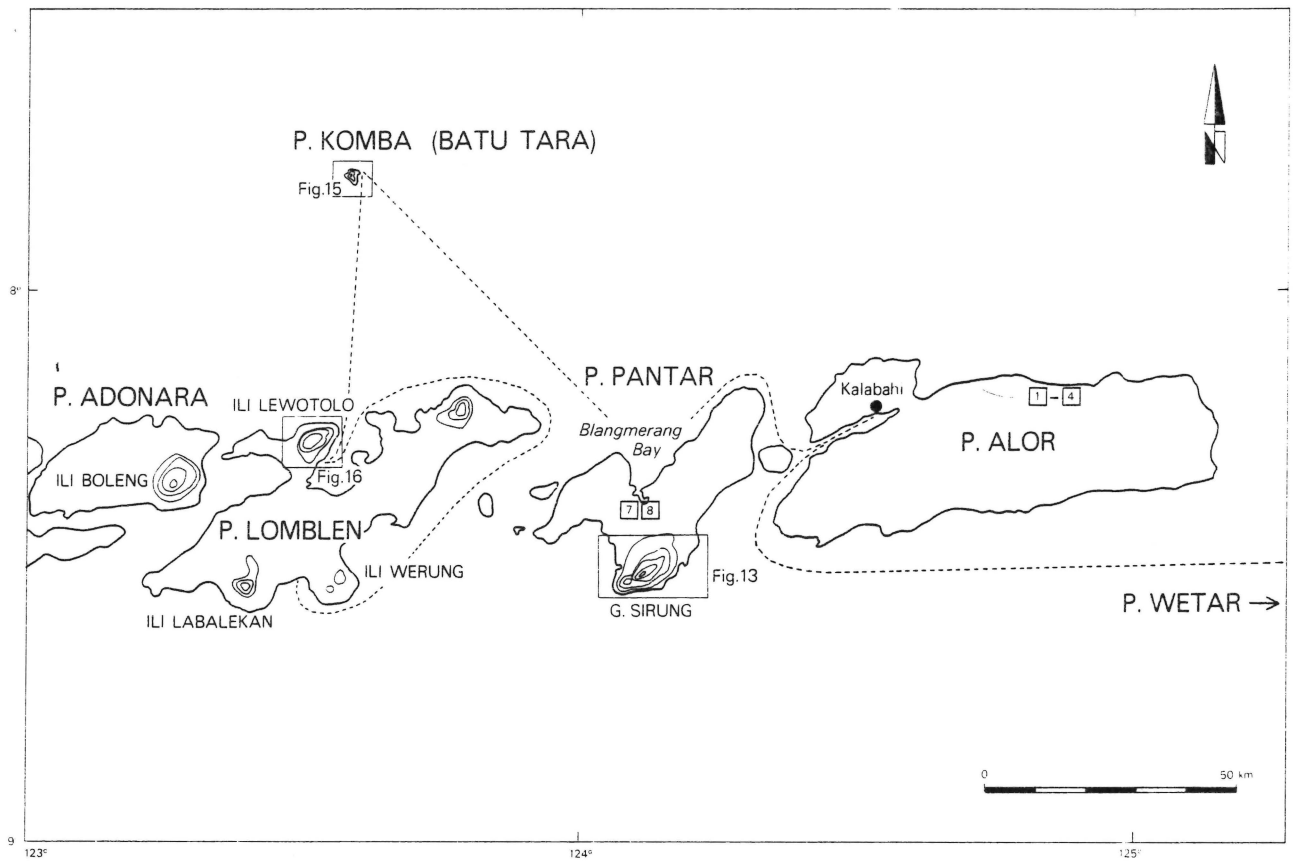


fig. 12 Lesser Sunda Islands

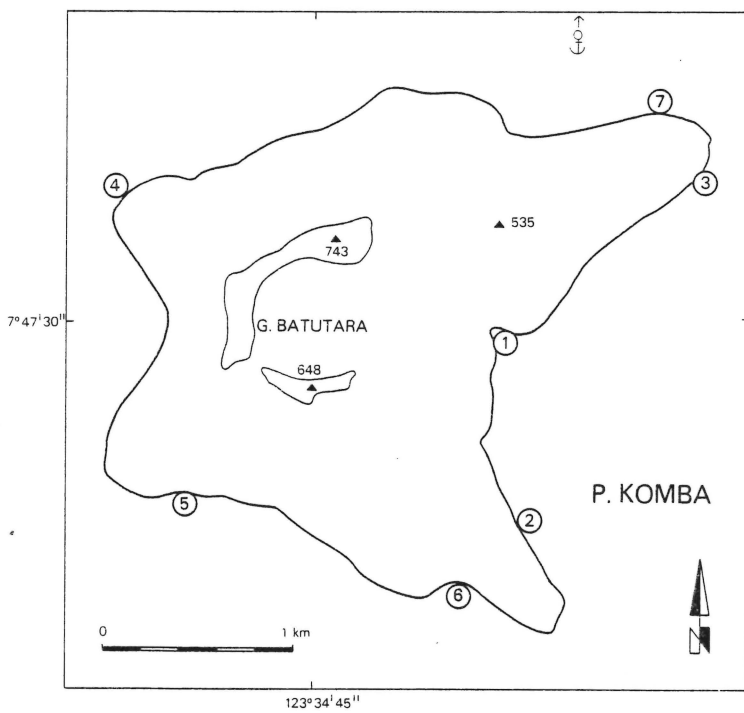


fig. 15 Komba (Batu Tara)

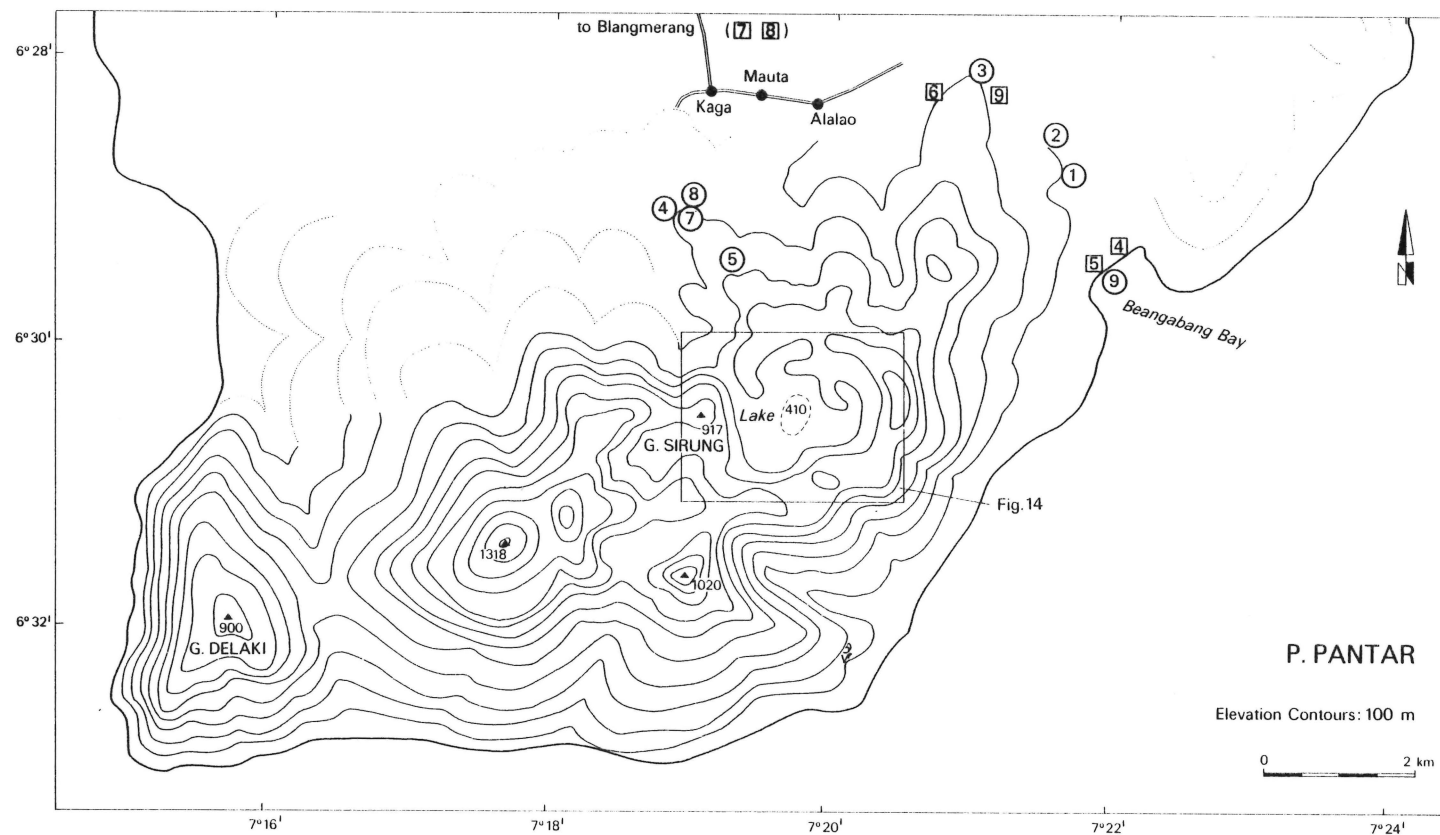


fig. 13 Pantar

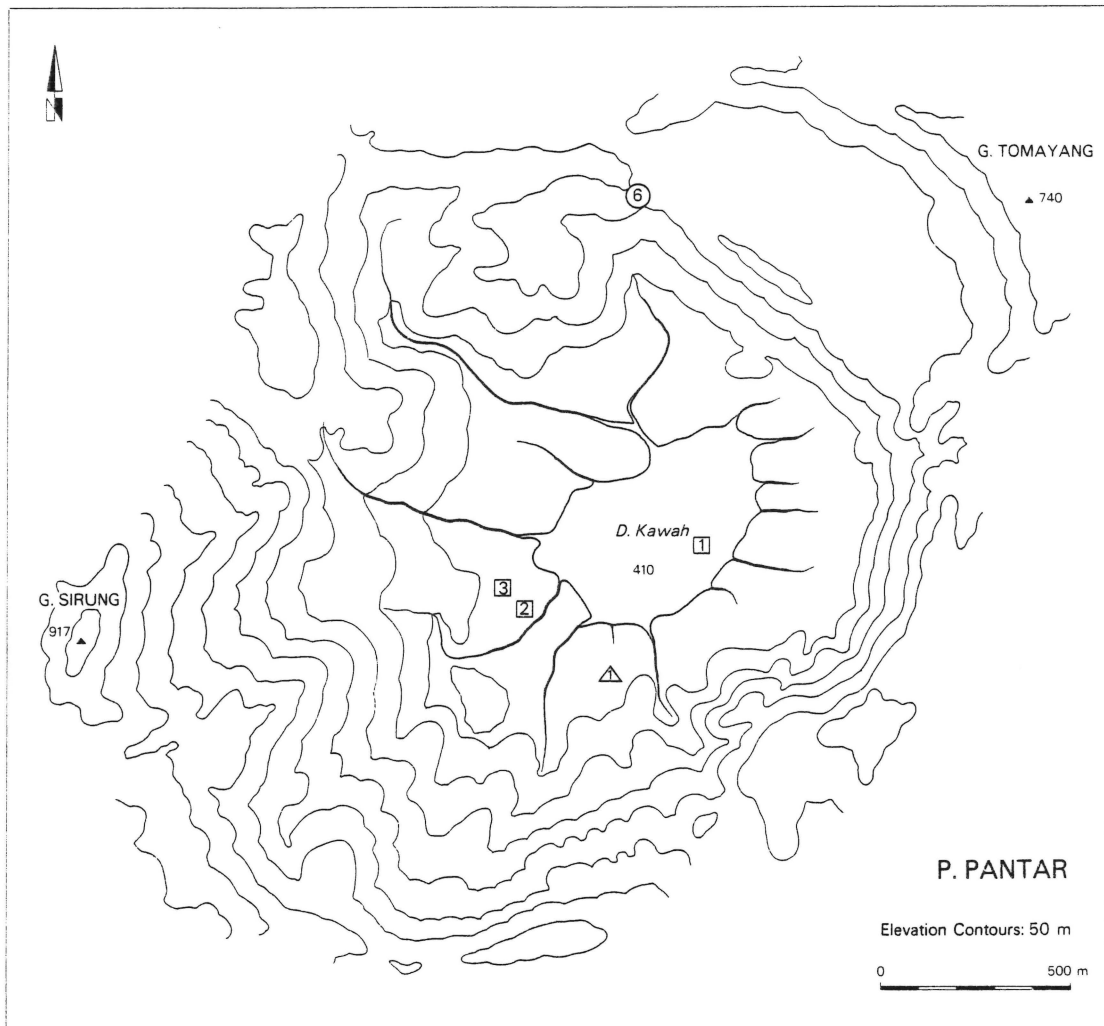


fig. 14 Pantar detail

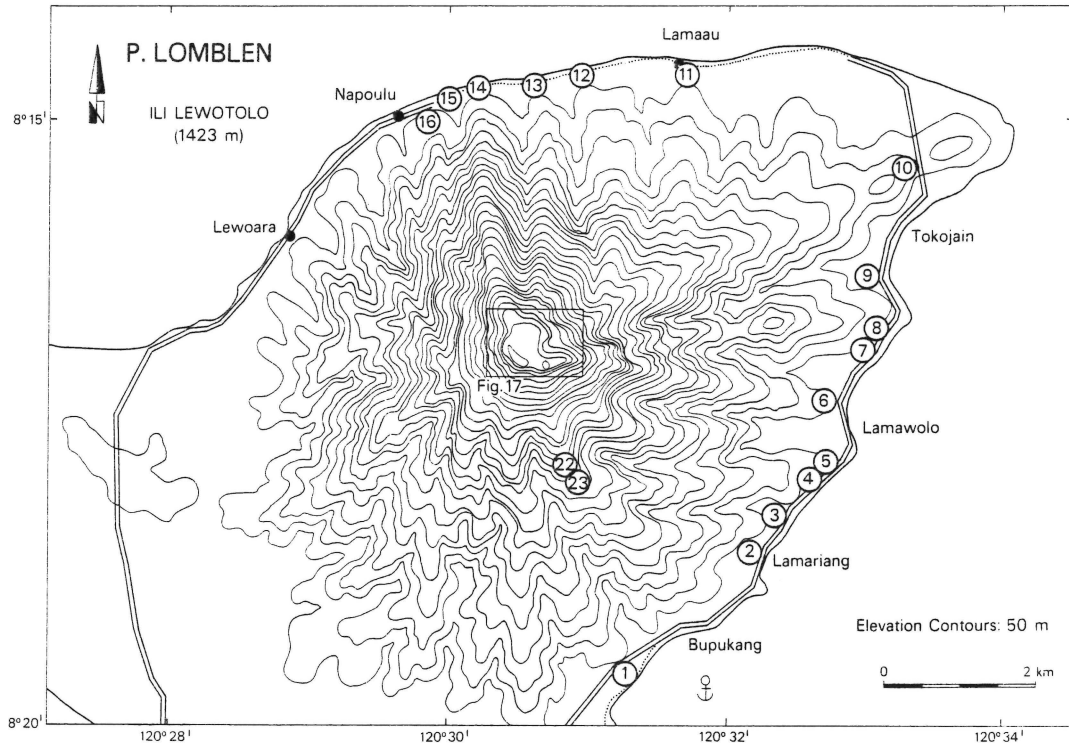
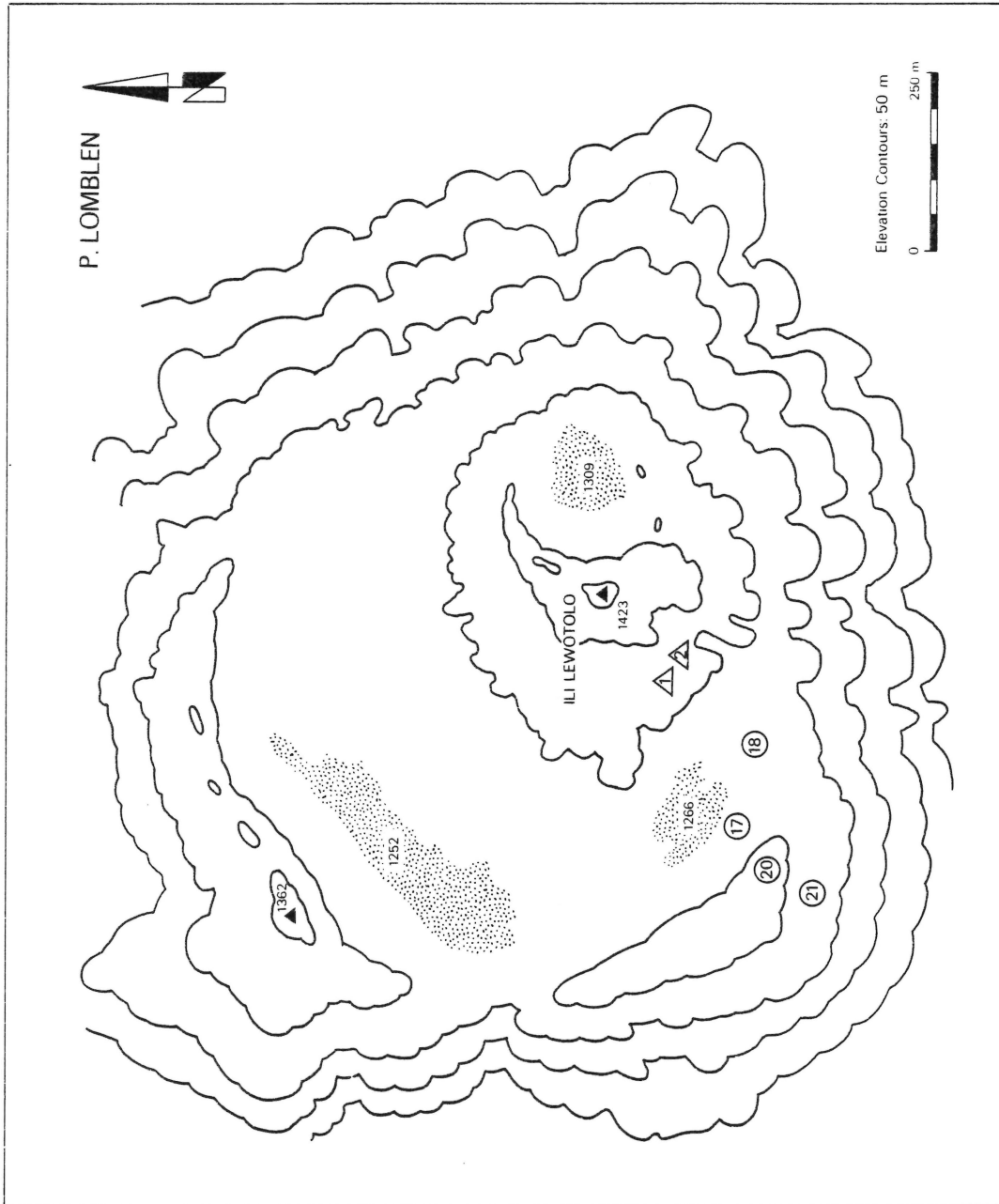


fig. 16 Lomblen (Lewotolo volcano)



P. LOMBLEN

fig. 17 Lewotolo detail

LABORATORY TECHNIQUES CURRENTLY BEING  
APPLIED OR FORESEEN FOR GF 5 SAMPLES  
AT DUTCH INSTITUTIONS

Enclosure 6

X-ray fluorescence spectrometry	IvARUU
electron probe micron analysis	IvARUU
inductive coupled plasma emission spectrometry	IvARUU
stable isotope mass spectrometry	IvARUU
gaschromatography	IvARUU
X-ray diffraction spectrometry	IvARUU
various wet-chemical techniques	IvARUU
instrumental neutron activation analysis	IRI
radiogenic isotope mass spectrometry	SIGO
laser raman microspectrometry	IvAVU

IvARUU : Institute of Earth Sciences, University of  
Utrecht  
IRI : Interuniversity Reactor Institute, Delft  
SIGO : Laboratory of Isotope-Geological Research,  
Amsterdam  
IvAVU : Institute of Earth Sciences, Free University,  
Amsterdam

Area code

AK refers to cruise leg of GF 5 expedition: Ambon-Kupang

Station codes

refer to islands visited:

AM = Ambon	Da = Damar
HA = Haruku	RO = Romang
BA = Banda Islands	WE = Wetar
MA = Manuk	AL = Alor
SE = Serua	PA = Pantar
NI = Nila	KO = Komba (=Batu Tara)
TE = Teon	LO = Lomblen

Compilation by: R.P.E. Poorter and M.J. van Bergen

Sequence numbers of rocks

are labels of the samples collected. In most cases the first two letters are the same as the station code, except for:

- 1 - rocks from Haruku which have labels as those of Ambon
- 2 - rocks from the group of Banda Islands which have labels according to the island names:
  - BA = Banda Api
  - BN = Banda Naira
  - BB = Lonthor (= Banda Besar) or
  - BL = Lonthor (= Banda Besar)
- 3 - some rocks from Lomblen which are labeled LW

'Igneous rocks' from Ambon and Haruku are undifferentiated and include extrusive and intrusive types. 'Volcanic rocks' include lavas and pyroclastics.

Sequence numbers of waters  
are labels of the samples.

Sequence numbers of gases

refer to vents where sample collection took place. Each gas sample is complex. Sampling occurred in pre-evacuated bottles and by bubbling through chemical solutions, and also included encrustations and sublimates near the vents.

Co-ordinates (latitudes and longitudes) are valid for each sheet. They should be considered as approximations. Additional topographic information is mentioned under 'Remarks' (cf. Maps of sample locations).