社会開発協力部報告書

No. 2

THE REPUBLIC OF INDONESIA

THE FEASIBILITY STUDY ON THE DISASTER PREVENTION PROJECT IN THE SOUTHEASTERN SLOPE OF MT. GALUNGGUNG

FINAL REPORT
SUPPORTING I
ANALYSIS & FIELDSURVEY
SUPPORTING II
DISASTER PREVENTION PLAN

DECEMBER, 1988

JAPAN INTERNATIONAL COOPERATION AGENCY

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1. Geomorphology

1.1 General

1.1.1 Objective of study

The study area has experienced some types of volcanic disaster through the historic era. Generally, disaster caused by volcanic activity is divided into two types in Indonesia. The first type is called "Nuée Ardente" which is caused directly by volcanic eruption, the second one is "Lahar" or "Banjir" which is caused by secondary movement of volcanic materials. Especially since the 1982 - 1983 eruption, the study area has been suffered from a large volume of sediment discharge due to the frequent occurrence of lahars.

The objective of this study is to understand the geomorphological landform conditions of the southeastern slope of Mt. Galunggung with reference to the hazard area concerning the possible volcanic disaster.

1.1.2 Methodology

Aerial-photo interpretation technique is very effective for the understanding of the geomorphological characteristics and the relationship between the landforms and the disaster area. In this study, the aerial photographs (scale: 1/12,000) taken in August, 1982 during the eruption were used. At the same time, a field survey was carried out mainly along the river for the observation of outcrops and riverbed materials. After that, a geomorphological landform classification map was prepared.

Considering the above mentioned objective and methodology, this chapter deals with the followings;

1) Topography of the study area
2) Volcanic activities of Mt. Galunggung
3) Landform classification
4) Landform development
5) Geomorphological characteristics of the study area
6) Preparation of Possible Disaster Area Map

1.2 Topography

Mt. Galunggung is located in about 100 km southeast of Bandung city in the West Java Province. Mt. Galunggung is one of the many active volcanoes which dot the 6,000 km-long Indonesian arc extending along the convergent boundary between the Indo-Australian and Eurasian plate, from northern Sumatera to Halmachera in the Malacca Sea.

The geomorphological study area covers approximately 200 km^2 on the south-eastern slope of Mt. Galunggung.

Galunggung volcano is the young active one and formed in the horse shoe-shaped caldera which opens to the southeast on the old Guntur volcanic cone. A new active crater named Walirancinder has about a 300 m relative height from the crater floor. The volcanic cinder cone (maximum altitude 1,035 m) came into existence in 1982 - 1983 eruption. At present, the inner crater is filled with water (making a crater lake), therefore only the summit of the cone can be seen. (As of August, 1987)

Two main rivers, the S. Cibanjaran and S. Cikunir flow down from the outer crater of Walirang to southeast and form an an alluvial fan. To the north, the S. Ciloseh and its main tributary, the S. Cimampang flow down to the southeast reaching Tasikmalaya City. The southern part has an extensive volcanic piedmont where many rivers, such as the S. Cimerah, S. Cikupang, S. Cisaruni flowing down to the S. Cikunten. These river dissect the old Guntur's body.

The study area can be largely divided into the following three parts according to their topographical characteristics.

(1) The Old Guntur Volcanic Cone

This area has not been affected directly by the volcanic activity in recent time. While the upper part (higher than 1,100 m) of this area is mainly composed of lava, the middle and lower part (between 1,100 m and 400 m in height) is composed of pyroclastic flow materials. Many erosional valleys have dissected this slope radically.

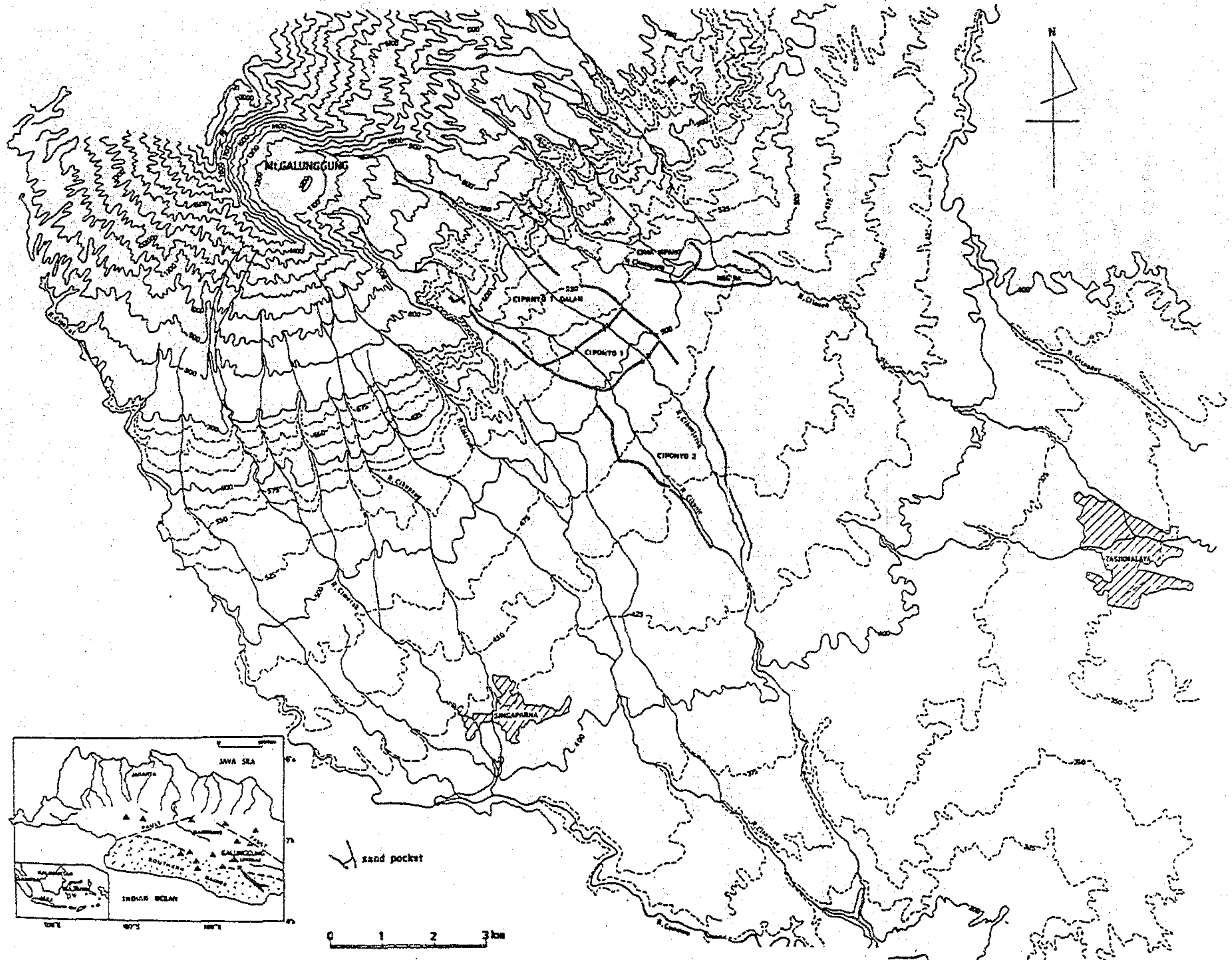


Fig - 1.1 Counter Map of the Study Area

(2) The Galunggung Volcanic Area

This area occupies the horse shoe-shaped caldera. A new crater and its volcanic slope to about 2.5 km southeast-ward have been developed. This area formed directly by the ash fall present volcanic activity is mainly composed of pyroclastic flow and ash fall deposits. Almost all parts of this area are not covered with vegetation as a result of 1982 - 1983 eruption.

(3) The Volcanic Fan Area

The volcanic fan having been developed at the southeastern slope of Mt. Galunggung can be classified into two types of fan according to their geomorphological features and inclination.

The upper-stream part is between 600 m and 475 m in height where the fluvial action is dominant and the obvious alluvial fan of the S. Cibanjaran and S. Cikunir have been formed. These alluvial fans, about 2° in slope gradient mainly consist of lahar deposits.

The lowerstream part is between 475 m and 350 m in height where Tasikmalaya is located. This area is characterized by a large number of hillrocks which dot on the surface showing the inclination of less than 1°.

1.3 Volcanic activities of Mt. Galunggung

The recorded historic activities of Mt. Galunggung occurred three times prior to the 1882 eruption. The first eruption occurred in October 1822, the next in October 1984 and the last one before 1982 was occurred in July 1918. Each document of volcanic activities is summarized in Table - 1.1, mainly based on description given by J.A. Katili and Adjat Sudradjat (1984). This summary indicates that the volcanic activity of Mt. Galunggung is characterized by quiescent intervals of several decades, interrupted by brief eruptions lasting only hours or days.

After almost 63 years of quiescence, Galunggung volcano suddenly erupted on April 5, 1982. This volcanic activity lasted over more 9 months until January of the following year. In this period, violent eruptions happened about 60 times and the small ones happened more than 300 times. Thus, compared with the previous activities, the eruption in 1982 - 1983 is considered to be an exceptional one.

It is convenient to describe the chronology of the 1982 - 1983 eruption in terms of three phases as follows:

1) Phase 1 (April 5 - mid-May)

   The first ash eruption began before dawn on April 5. Nuées ardentes travelled several kilometers down the S. Cibajaran. These explosive eruptions were characteristically accompanied by thunder and lightning. During this phase, much of the 1918 lava dome (Gunung Jadi) was destroyed.

2) Phase 2 (mid-May - November)

   Some of the most energetic eruptions of crystal-rich, juvenile materials took place during this period.

   Through August, Nuées ardentes were few and relatively small, travelling only short distances down the S. Cibanjaran and S. Cikunir. By September this activity ceased altogether, and the vigor or the eruptions began to decline. During or following substantial rainfall, lahars occurred in the stream channels.

Table - 1.1 Summary of Historical Activities of Galunggung

Date of eruption	Lava flow and ash fall	Nuée Ardentes	L a h a r	R e m a r k s
October 8, 1822 between 13:00 h and 14:00 h	An ash column rose to several thousand meters, and devastated the area as far as 40 km east and south of the volvano.	Travelling distance of 10 km along the S. Cibanjaran and S. Cikunir	Flowing the river course in the south east sector and devastated this area.	Total casualties were estimated to execeed 4.011 human lives, mostly killed by Nuées Ardentes.
17:00 h ceased	A lava dome later developed in the same year.			
October 17, 1894 (The first)	Ash fell on Tasikmalaya and Banjar some 30 and 80 km east of the volcano.	No Nuée ardente occurred.	Flowing the river course in the south east sector, similar to those of 1822.	A lava dome was entirely destroyed.
October 18 - 19, 1894 (The second)	The thickness of ash fall was 0.5 cm - 1 m on Galunggung slope.			No human died.
July 7, 1918 22:00	Ash fall was very limited on the southeastern slope with only 1 cm in thickness. Three days later, a lava dome (Gunung Jadi) emerged.	No Nuée ardente occurred	unknown	No appreciable damage.

3) Phase 3 (December 1982 - January 8, 1983)

The eruption and ejecta were almost entirely confined to the crater and its immediate vicinity and ash falls, if any, were very light even at villages close by.

By the end of December, the inner part of the crater had been filled by ejecta, a cinder cone had risen to about 60 m above the crater floor. The last significant eruptive activity at Galunggung began on New Year's Eve and continued intermittently until January 8, 1983. During this final activity, a small basaltic lava flow issued from the radial fissure near the base of the cinder cone.

1.4 Geomorphological Landform Classification

The geomorphological landform classification was carried out to identify the homogeneous topography results from the interaction of physical process (e.g. fluvial action, weathering and crustal movement.) It has acted as an important tool in many cases for rural land resource planning.

The geomorphological landform classification map of the study area was prepared on a base map of 1/25,000 scale as shown on Fig. - 1.2. Aerial-photo interpretation and field surveys were carried out for this study.

The geomorphological landform units and their explanation used in this map are described as follows:

(1) Items of geomorphological landform classification

1) Dissected old Guntur volcanic cone
   a) Upper slope, composed of lava flow materials
   b) Middle slope, composed of pyroclastic flow materials
   c) Lower slope, composed of pyroclastic flow materials

2) Landforms by large scale collapse of old Guntur peak
   a) Horse shoe-shaped caldera
   b) Debris avalanche fan
   c) Flow-mounds

3) Landform formed by the volcanic activity (prior to 1982) of Galunggung
   a) Pyroclastic flow Plateau

4) Landforms formed by the volcanic activity (1982 - 1983) of Galunggung
   a) Crater wall
   b) Cinder cone
   c) Nuée ardente (ladu) surface

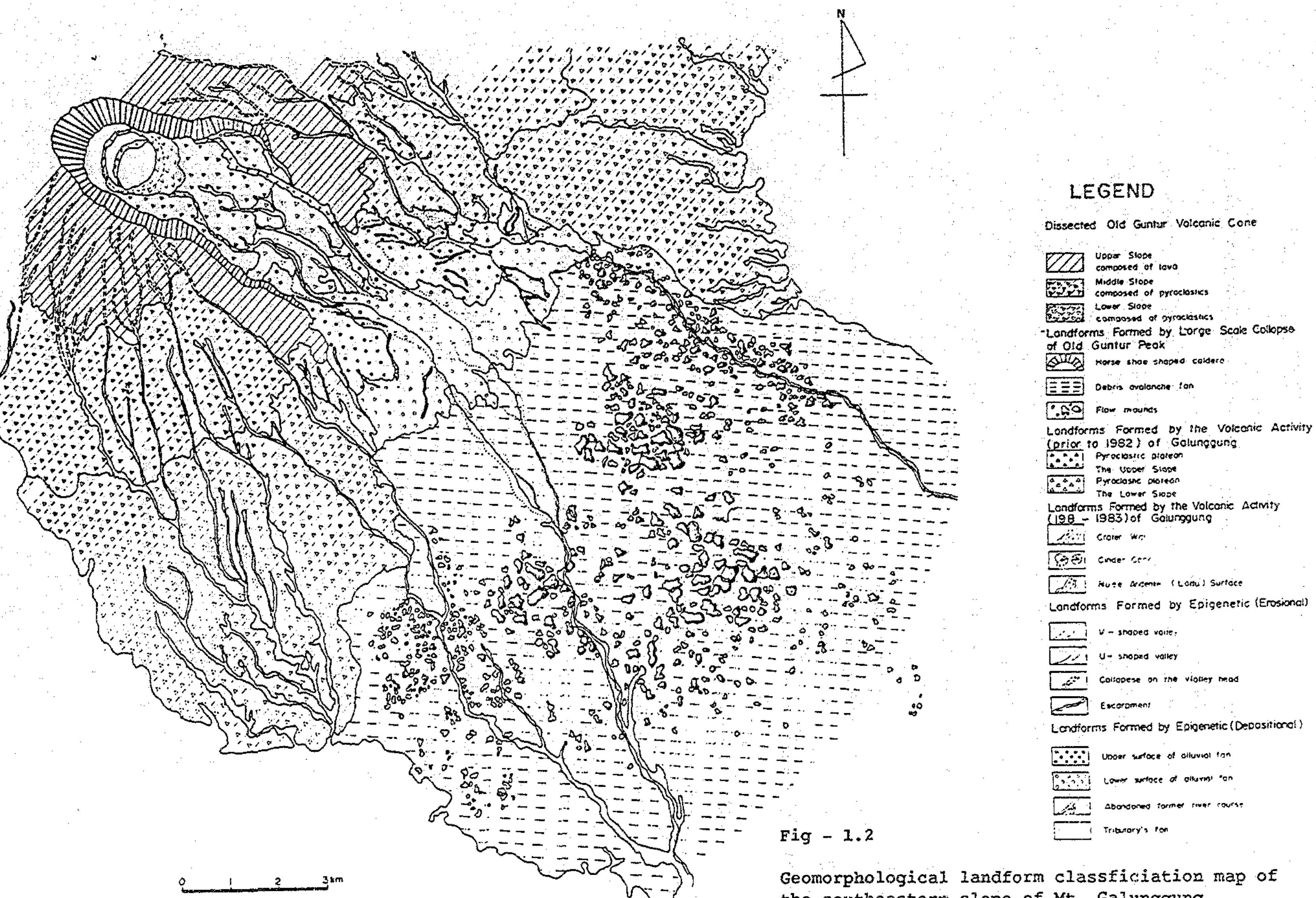


Fig - 1.2

Geomorphological landform classficiation map of the southeastern slope of Mt. Galunggung

5) Landforms formed by epigenetic (erosional) process

a) U-shaped valley

b) V-shaped valley

c) Collapse on the valley head

d) Escarpment

6) Landforms formed by epigenetic (depositional) process

a) Alluvial fan

b) Upper surface

c) Lower surface

d) Units of fan

e) Abandoned former river course

f) Channel shifting point

(2) Explanation of landform units

1) Dissected old Guntur volcanic cone

This unit extends the southern and northern parts of the study area. As had already described in the paragraph of 1.2, the landform of this unit had not been affected directly by the volcanic activity and was formed before the occurrence of the horse shoe-shaped caldera.

The volcanic surface has been dissected by many valleys, S. Cimerah, S. Cikupang and S. Gisaruni in the southern part and S. Ciloseh, S. Cimampang and S. Cimala in the northern part.

The volcanic cone can be divided into three slopes according to the difference of the geology and inclination. The upper slope consists of lava that has been deeply dissected and no topographical characteristics such as frontal scarps of lava flow or lava levee remains. The middle and lower slopes consist of pyroclastic flow and have extensive flat surface where the U-shaped valleys have been developed along the main river.

Each slope is bounded on the existence of scarps which are easily interpreted by aerial-photos. The inclination is about 8° on the middle slope and 2° on the lower slope.

2) Landforms formed by large scale collapse of old Guntur peak

The old Guntur was a magnificent symmetric stratovolcano with a summit crater probably measuring up to more than 3,000 m in height. Tens of thousands of years ago, a large scale collapse related to the direct blast produced a horseshoe-shaped caldera and a widespread volcanic fan covering over 150 km^2. The volcanic fan is mainly composed of poor-sorted gravel and lava fragments. A large number of characteristic hummocky hills consisting of volcanic breccia are distributed on the southeastern margin of the fan.

Taking into account the slight slope gradient showing about 1° of fan and the long travelling distance of gigantic breccia blocks, it is very difficult to reconcile this physical process with water saturated transformation mechanism as lahar. Judging from the similarity in size and topography to that formed in 1980 Mount St. Helens, USA by direct blast, the debris avalanche is more the reasonable way to explain the formation of the extensive volcanic fan in the study area.

However, Galunggung's prehistoric eruptive record before and after the gigantic debris avalanche is unknown.

In this report, the landform extending onto the southeastern piedmont of Galunggung volcano is called debris avalanche fan and the hummocky hills dotted on the fan are called flow-mounds.

3) Landforms formed by the volcanic activity (prior to 1982) of Galunggung

The Galunggung volcano was formed by the lateral direct blast on the southeastern flank of the old Guntur. Almost all parts of the volcano in the horseshoe-shaped caldera consist of pyroclastic flow and fall deposits related to Galunggung's eruption.

A lava dome called Gunung Jadi, about 250 m in diameter and 50 m in height situated in the crater was destroyed by the 1982 eruption and at present no landform directly formed by lava flow can be seen.

The alternation of the catchment area and the river system has occurred in the upper streams of the S. Cikunir and S. Cibanjaran due to the changes of configuration of the crater caused by eruption and some misfit valleys can be observed in this unit.

4) Landform formed by volcanic activity (1982 - 1983) of Galunggung

The crater wall called Walirang can be easily identified in aerial-photos. The crater wall is covered by the course scoria which were newly ejected materials in 1982 and at present (as of August, 1987) has no vegetation.

Three cinder cone consists of pyroclastic fall materials have been formed on the outer wall of Walirang but the central cinder cone was not yet formed at the time when the aerial-photos are taken.

The Nuée ardente which is generally called "ladu" in Indonesia is observed along the S. Cibanjaran, a travelling distance of about 5 km from the crater and about 3 km flowing down the S. Cikunir. From the outcrop observation at Sinagar of the S. Cibanjaran, the ladu is composed of fine to medium size materials with some fragments as large as pebble size. Locally, sulphur was deposited within the sediments. At present, ladu deposits filling up the S. Cibanjaran have been cut by the lateral erosion and form a river terrace.

5) Landform formed by epigenetic (erosional) process

Many erosional valleys have been radically cut mainly on the old Guntur volcanic cone. Generally, each valley has steeply inclined valley walls with a relative height of more than 20 m from the valley floor.

Through aerial-photo interpretation, the erosional valley can be divided into V-shaped valleys where the lower erosion is superior, and U-shaped valleys dominated by the lateral erosion. From the field survey, little riverbed material could be observed on the floor of V-shaped valleys.

The escarpment caused by the river's lateral erosion which is more than 10 m in relative height is drawn on this map.

6) Landform formed by epigenetic (depositial) process

An alluvial fan has been developed from the outlet of pyroclastic plateau where Sinagar and Kokoncong villages are located to the southeast along the S. Cibanjaran and S. Cikunir.

The alluvial fan can be divided into two surfaces, the upper and lower according to the existence of small scarp between them. The upper surface distributes at the elevation between 600 m and 500 m with the inclination of about 2°. This landform area has already begun to be dissected by the present river. The lower surface is formed at the lowerstream part to 475 m in height and its inclination is about 1.5°.

Geomorphologically, it is considered that the lower surface of alluvial fan is formed by the dissection of the upper surface at the younger stage.

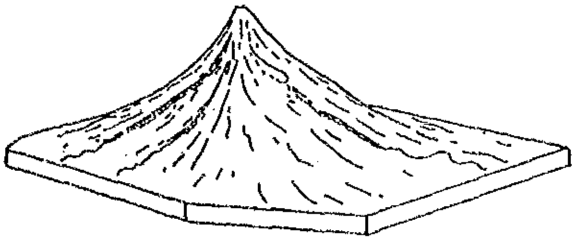
The S. Ciloseh has developed a small alluvial fan where the longitudinal length from the fan head to the margin is less than 800 m. Its inclination is about 3° steeper than that of S. Cibanjaran and S. Cikunir. This is because the catchment area of S. Cibanjaran and S. Cikunir occupies the slope of active Galunggung volcano where the ejected materials are frequently supplied. On the contrary, the catchment area of S. Ciloseh is situated on the old Guntur's body where the supply of materials is restricted to the lower or lateral erosion in gullies.

On the alluvial fan, abandoned former river courses were shown on the aerial-photos. These former channels are considered to be formed by rivers frequently shifting their courses through the fan formation.

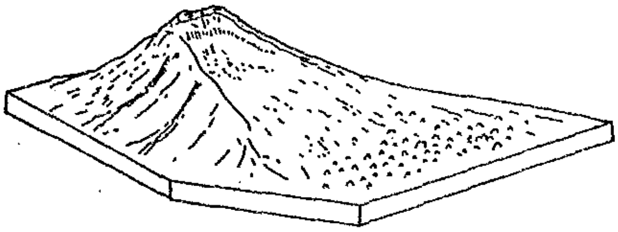
1.5 The summary of landform development

Fig. - 1.3 shows the schematic map of Geomorphological landform development in the study area.

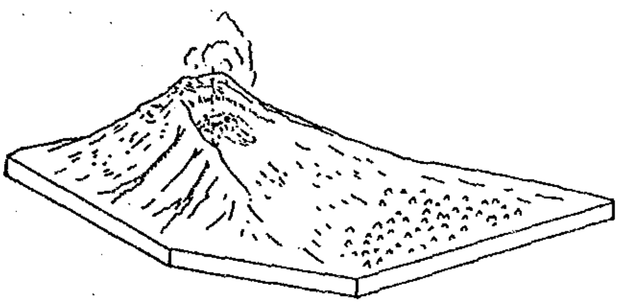
The Galunggung volcano has been developed by the direct blast on the southeastern flank of the old Guntur volcano.



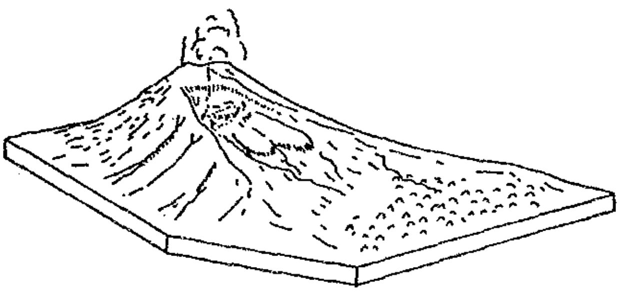
Stage I Old Guntur Volcano



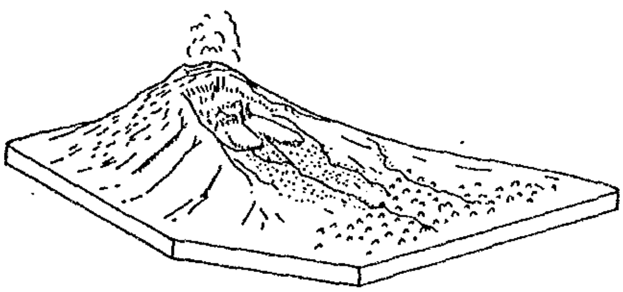
Stage II Occurence of Horse Shoe Caldera and Debris Avalanche Fan



Stage III Birth of Galunggung Volcano



Stage IV Formation of Pyroclastic Plateau



Stage V. Formation of Alluvial Fan

Fig - 1.3 Schematic Map of Geomorphological Landform Development

This direct blast which had made a horseshoe-shaped caldera provoked the gigantic debris avalanche to the southeast and formed an extensive debris avalanche fan (shown in Fig. - 1.3, stage 2). According to the geological map prepared by the volcanological survey of Indonesia (1984), the age of this catastrophic accident is dated 26,500 years B.C. by the carbon fourteen dating method.

The next phase up to 1822 eruption is unknown exactly. However, judging from the geomorphological condition showing that the volcanic slope of Galunggung is not much dissected, it is considered that its activity is continuous.

The distribution of the materials from the Galunggung volcano is limited to the southeastern slope in the horseshoe-shaped caldera and is quickly growing and developing geomorphologically.

Along the S. Cibanjaran and S. Cikunir, at first the upper alluvial fan was formed, and then it was dissected and the new lower fan advanced on the old debris avalanche fan.

1.6 Geomorphological Characteristics of the Alluvial Fan and the Disaster Area in August, 1982

It is of primary importance to understand the geomorphological characteristics of the alluvial fan before the discussion of disaster area. From the view point of Geomorphological landform development, it can be stated that the alluvial fan was formed by the accumulation of the repeated lahar deposits. To put it in different terms, there is a close relationship between the geomorphological characteristics of the alluvial fan and the lahar disaster area.

In this section, the characteristics of the disaster area attacked by the lahar during the 1982 eruption are discussed with reference to the units of alluvial fan.

As has already been described, almost all of the alluvial fan area has been formed S. Cibanjaran basin and S. Cikunir basin. The alluvial fan along the S. Cibanjaran spreads out from the fan head (altitude : 600 m) where the Sinagar village is located on its left bank and the alluvial fan along the S. Cikunir spreads out from the fan head (altitude : 625 m) where the Kokoncong village is located on its right bank.

As for the inclination, the fan head area along the S. Cikunir is steeper than that along the S. Cibanjaran. However, it becomes difficult to identify the fan unit of the S. Cikunir on the middle and lower parts. On the contrary, the fan unit of the S. Cibanjaran is continuously more evident from the fan head to its margin. This is due to the S. Cikunir fan being covered by the materials from the S. Cibanjaran which has transported probably larger quantities of sediment load. Because of this point of view, it is thought that the S. Cibanjaran is superior in terms of the ability to form an alluvial fan during the recent fan evolution.

Fig. - 1.4 shows the longitudinal riverbed profiles which are based on the results of the topographical survey carried out from June to August, 1985. Accordingly, the shape of these profiles are reflected by some disaster prevention facilities and do not indicate the natural condition of river.

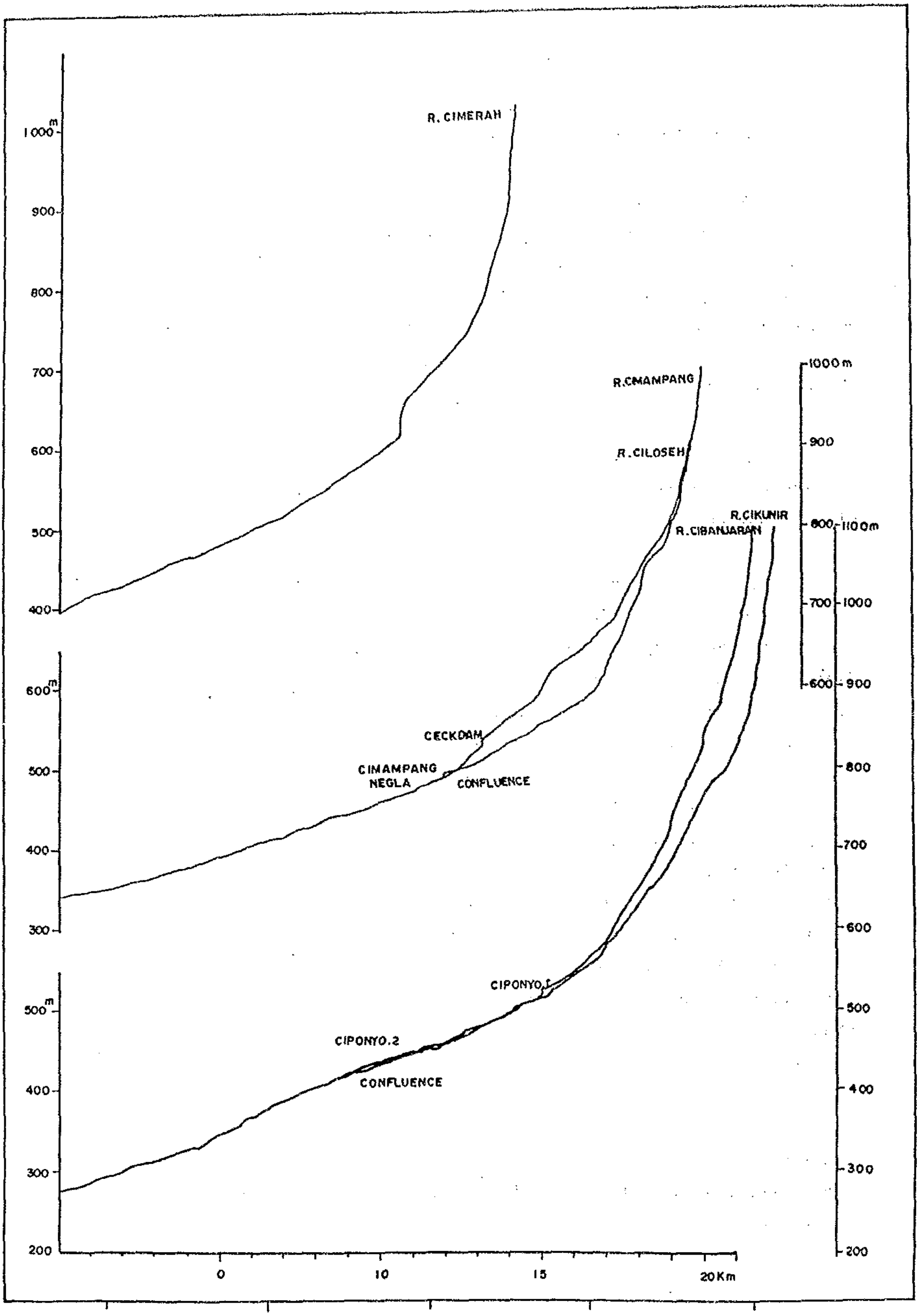


Fig - 1.4 Longitudinal rivers profiles

In regard to the characteristics of the disaster area, the covered area by lahar in August, 1982 is shown in Fig. - 1.5. The lahar covered area and the flood water courses are clearly recognizable from the aerial photographs. The thickness of lahar deposits dotted on Fig. - 1.5 are based on field observations and a questionaire for the inhabitants of the area.

Once the lahar or banjir occurs, the rivers generally overflow at the place where their channels bend sharply or where the riverbed gradients change and become more gentle (see Fig. - 1.6). These topographical changes correspond to the micro landform condition on the alluvial fan.

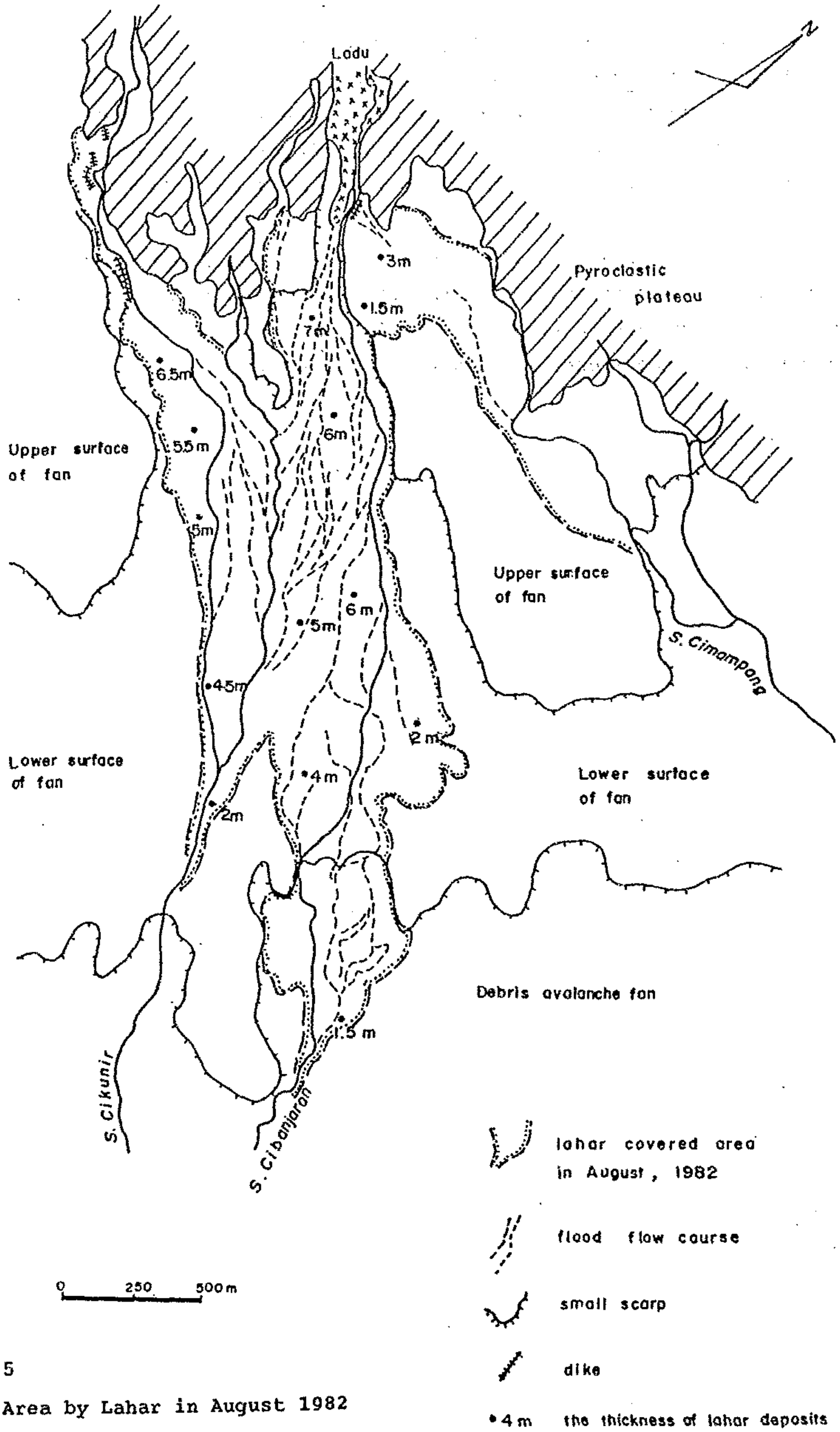
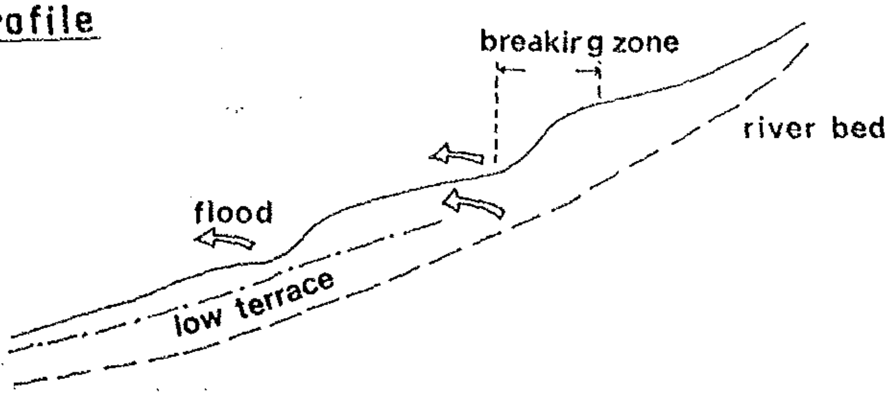


Fig - 1.5

Covered Area by Lahar in August 1982

Profile



Morphological Aspect

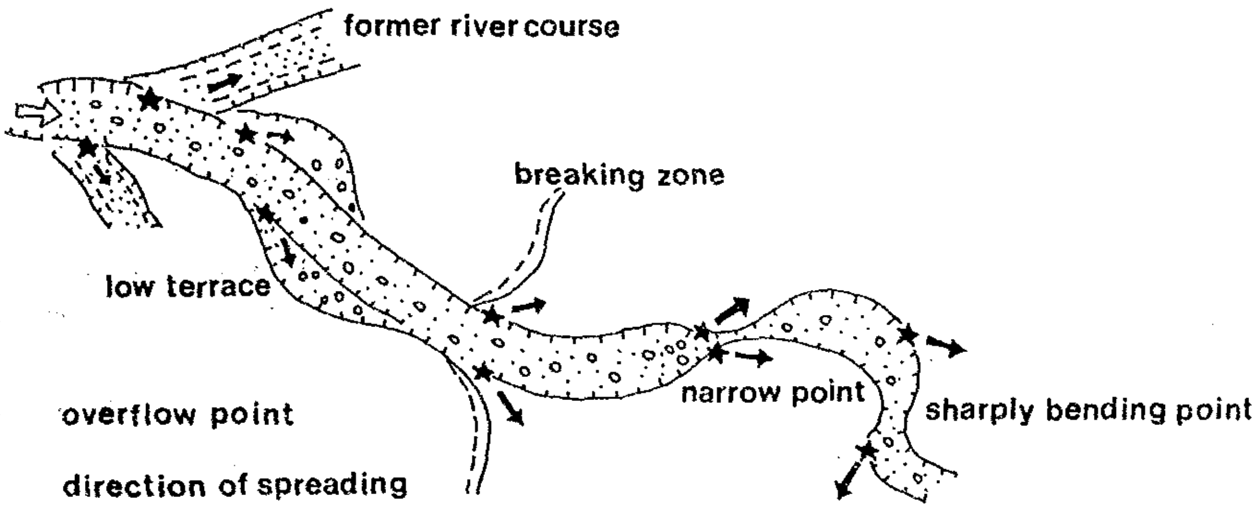


Fig - 1.6 Idealized Pattern of Overflows Occurrence

modified from MARUYAMA et al(1980)

On the whole, the same tendency with the aforementioned can be seen in the lahar covered area in this study area. Its characteristics with reference to the rivers and landforms condition are summarized as follows:

(1) Channel shifting points

Fig. - 1.5 shows that many channel shiftings of flood have occurred at the fan head of the S. Cibanjaran. Especially, the overflow at the right bank took its flood course to the S. Cimmampang and caused a lot of damage in Sinagar village and its surroundings. Therefore, the main channel shifting points exist here. For this reason, as the Nuée ardente was deposited with about 10 m in thickness in the S. Cibanjaran valley, its riverbed rapidly rose up and the longitudinal breaking point was formed. Because of this, it is thought that it becomes easy for lahar to overflow at the outlet of S. Cibanjaran at Sinagar.

The channel shifting of floods flow is rarely distributed along the S. Cikunir.

(2) The extent of flood area

Except for the overflow area to the S. Cimampang, the wide flood area is restricted at the lower surface of alluvial fan. It seems that the existence of small scarps between the upper surface of alluvial fan and the lower one or between the lower one and the debris avalanche fan, prevent the wide spreading of flood flows. This fact well coincides with the geomorphological condition showing that the lower surface of the alluvial fan is under construction.

Along the lowerstream area of the S. Cibanjaran and S. Cikunir, the main lahars flow down in the shallow valley which dissect the surface of debris avalanche fan. Even though the overlows happened, the flood materials are limited to the narrow area along the present river.

From the field observation of outcrop along the S. Cibanjaran and S. Cikunir, there is no distribution of the lahar materials covering the debris avalanche deposits.

The total area covered by lahar in August, 1982 amounts to 5 km^2 based on the measurement from the aerial-photos.

(3) The thickness of lahar deposits

The distribution of the thickness of lahar deposits indicates the energy direction of main lahar flows. The maximum thickness is estimated at 8 m on the fan head of the S. Cibanjaran based on the results of interviews with the inhabitants and geomorphological analysis. Its thickness decreases gradually to the lowerstream along the main flood courses, though a few meters of thickness varies according to the micro landform relief. At the overflow flood course from Sinagar to the S. Cimampang, lahar was deposited only between 2 and 3 m in thickness. Considering these facts, the main lahar course is judged to have originated from the S. Cibanjaran and flows down along the present S. Cibanjaran and S. Cikunir.

Consequently the total volume of 22.3 million m^3 was estimated. Its statement of accounts is shown on table - 1.2.

Near the confluence of S. Cibanjaran and S. Cikunir, lahar deposits could be seen with a thickness of less than 2 m in the valley bottom where the overlow had not occurred.

Table - 1.2 Statement of Accounts of Lahar Volume in August 1982

based on photo-interpretation

Flood area	Depositional Thickness (m)	Area ($x10^3m^2$)	Volume ($x10^3m^3$)
lowerstream of S. Cibanjaran and S. Cikunir	7	300	2,100
	6	1,270	7,620
	5	1,100	5,500
	4	790	3,160
	3	410	1,230
	2	460	920
	total	4,330	20,530
overflow area at Sinagar	3	440	1,320
	2	210	420
	total	650	1,740
	amounts	4,980	22,270

1.7 Preparation of Possible Disaster Area Map

1.7.1 Disaster Classification

The types of disaster related to the forms of sediment load, which vary according to the forces and materials, can be classified as follows:

Table - 1.3 Classification of Disaster

Types of disaster	Forms of sediment movement	Causes of disaster
Nuée Ardente (ladu)	Pyroclastic flow Avalanche	Disaster caused directly by volcanic eruptions
Lahar	Massive transport Tractive mass transport Bed load	Disaster caused by secondary movement of volvanic materials
Banjir	Individual transport (Bed load) (Suspended load)	Disaster caused by sediment deposits in river course

Forms of sediment movement correspond to the classification of disaster types or area which is based on geomorphological analysis.

The way of calculating the amount of sediment discharge varies according to the form of sediment movement. In this respect, basic information given by geomorphological analysis is very useful for the second step to the quantitative analysis. We have to keep in mind that the form at a single location also varies, however, according to the amount of discharge, water depth, particle diameter and so on.

1.7.2 Possible Disaster Area Map Preparation

The results of geomorphological and disaster studies have given a rough idea of the relationship between disaster types and landform conditions. A possible disaster area map has therefore been prepared which shows the possible disaster of Nuée ardente, lahar and banjir in different places on the basis of landforms conditions and the relative height of banks.

1) Nuée ardente zone

The available data concerning to the past disasters indicate that Nuée ardente has been limited to the valleys of the S. Cibanjaran and S. Cikunir.

The Nuée ardente zone is outlined as follows:

On the southeastern slope of Galunggung volcano it is probable that the nuée ardente reaches approximately 600 m elevation level in the vicinity of Sinagar and Coconcong villages. It extends to about 5 km of horizontal distance from the new crater.

2) Lahar zone

Since the flood area of lahar in August, 1982 well corresponds to the alluvial fan area, it is considered that the lahar zone extends to approximately 475 m elevation level of the frontal edge of alluvial fan. As for the river gradients at the lahar zone, the largest is 5.2% (3 deg.) for the top of S. Cikunir fan and the smallest is 2.1% (1.2 deg.) for the fan edge area; 3.7% (2.1 deg.) is the rough average.

On the whole, the alluvial fan is exposed to possible danger of lahar overflow.

The spreading of lahars depends largely on the overflow point related to the channel shifting or longitudinal breaking zone. On Fig. - 1.8, the channel shifting points that are particularly hazardous are marked.

3) Banjir zone

The zone downstream from the lahar zone is designated as the banjir zone. As the occurrence of overflows would be closely related to the aggradation caused by the local materials deposition, the longitudinal profiles showing the relative height of banks (cliffs) from the riverbed was prepared for the determination of overflow points (see Fig. - 1.7).

The existing data concerning the flood area also was referred, as well as field observation.

After that, the overflow points of banjir were determined for two places along the S. Ciloseh and one place along the S. Cikunir.

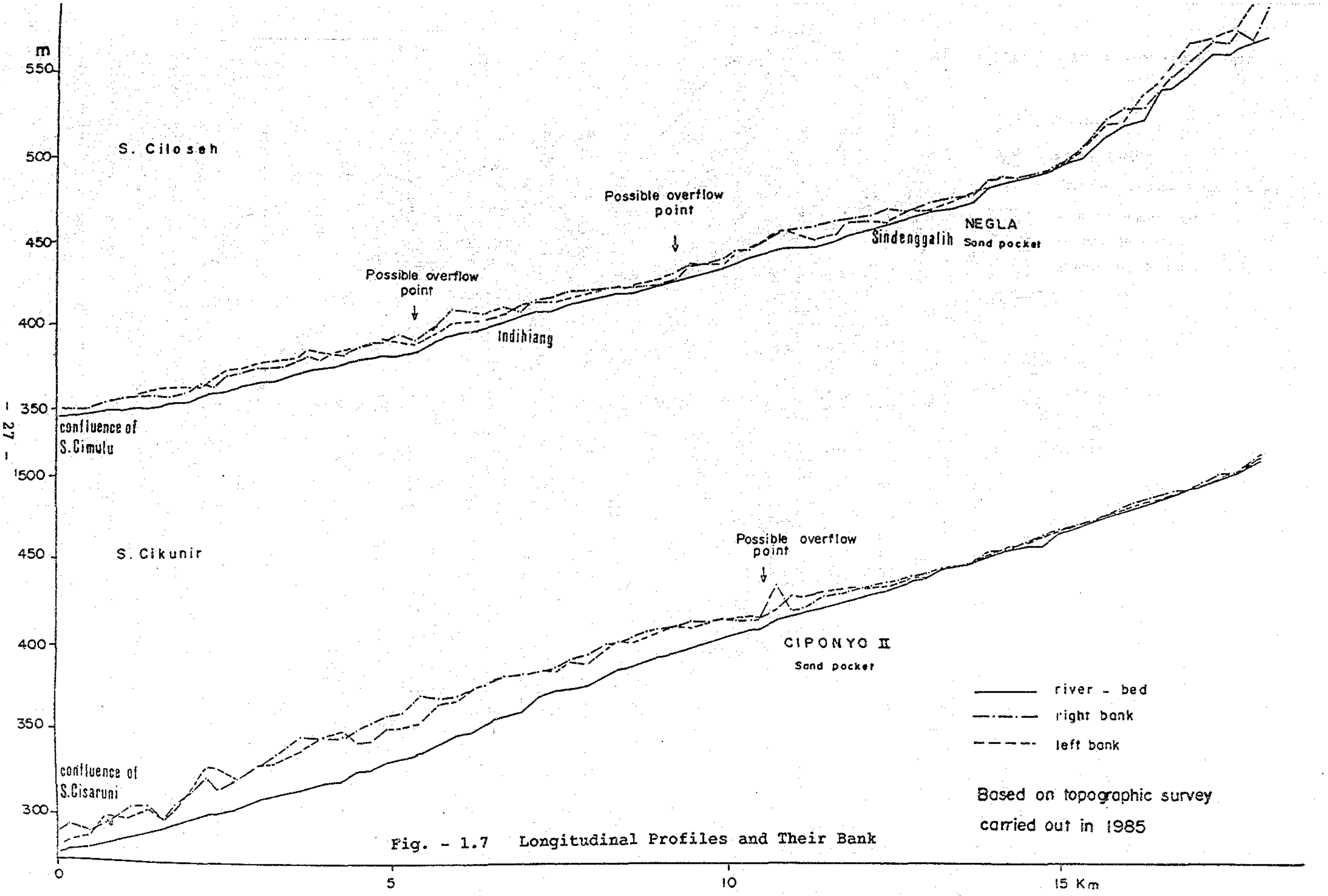


Fig. - 1.7 Longitudinal Profiles and Their Bank

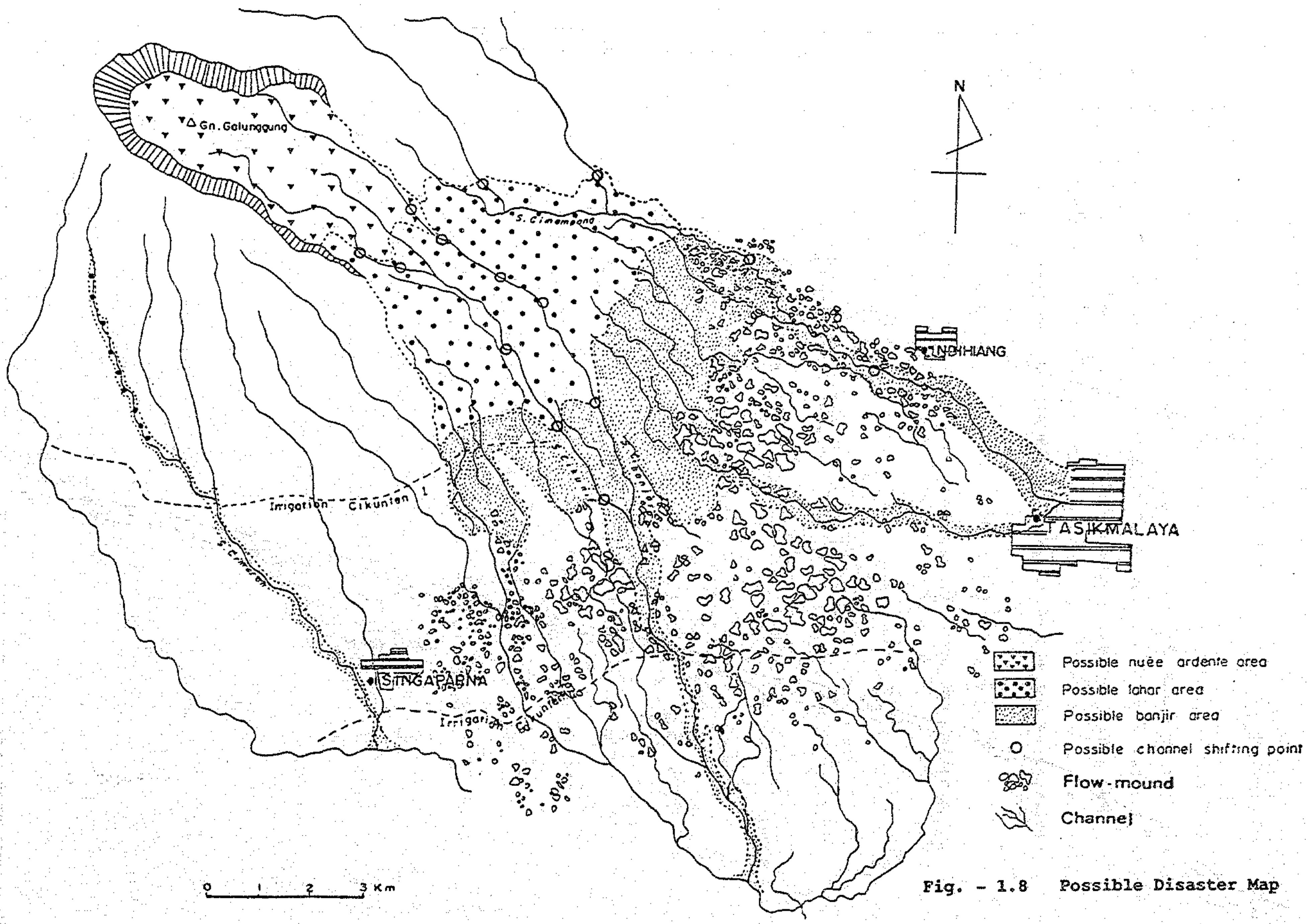


Fig. - 1.8 Possible Disaster Map

2. Geology

2.1 Introduction

2.1.1 General

This report describes the results of geological surveys, carried out for the Feasibility Study on the Disaster Prevention Project in the Southeastern Slope of Mt. Galunggung West Java, Republic of Indonesia by the JICA Study Team in 1987.

2.1.2 Work Schedule

The above-mentioned survey has been executed, basically divided into four (4) stages as described below, from the beginning of July until the middle of December, 1987.

(1) The First Stage:

JICA dispatched an expert on geology and soil mechanics as a member of JICA Study Team from 1st of July until 31st of August, 1987 and the expert performed the following:

1) Field reconnaissance in the Study Area
2) Collecting geological and soil mechanical information and reviewing previous reports.
3) Making the technical specifications for the topographical and geological survey, as attached in the appendix, and contracting with Tricon Jaya P.T., an Indonesian consulting firm in Bandung.

(2) The Second Stage:

Tricon Jaya P.T., received the order of a topographical and geological survey from the JICA Study Team on 27th of July, 1987, commenced to carry out the above survey from the beginning of August and completed it by the end of October, 1987. Final reports for each survey were submitted to the JICA Study Team at the beginning of November, 1987.

(3) The Third Stage:

In order to complete a geotechnical, detailed study with due consideration to the results of the geological survey, JICA dispatched again the expert on geological and soil mechanics from 16 th of October until 15th of November, 1987.

(4) The fourth stage:

Geological analysis of all data, obtained through the geological survey, and completion of the final report were carried out in Japan from 16th of November until 15th of December, 1987.

2.2 Information Collected and Reviewed

2.2.1 Information Collected

All of the information, collected during the study in Indonesia, is described in the list of reference and data, as shown in Appendix-1.

2.2.2 Review of Previous Reports and Data

1) Geological Map of Galunggung Volcano, West Java, in 1986 on a scale of 1/50,000 ; Volcanological Survey of Indonesia.

2) Geological Map of the Crater Lake, Mt. Galunggung in 1986 on a scale of 1/5,000 ; Volcanological Survey of Indonesia.

   The former (1/50,000) covers almost the whole study area and adds brief description of Galunggung volcanic deposits and stratigraphy. The later (1/5,000) covers the crater lake of Mt. Galunggung, and adds the geological profile. These two geological maps certain effective information to grasp the geological conditions of the study area.

3) Aerial Photographs in 1982 on a scale of 1/12,000

   These photographs have been taken during eruptions and clarifies, not only the distribution of pyroclastic and lahar deposits in 1982 - 1983, but also the previous one in the study area.

In addition to the above-mentioned geological maps and aerial photographs, the previous reports executed by DPU are as follows;

4) Final report

   Perencanaan Menyeluruh (Overall Plan) Daerah Bencana Gunung Galunggung Propinsi Jawa Barat. Laporan Utama ; Pebruari 1984 P.T. Yaramaya.

5) (1/2) Laporan Hasil

Penelitian Geologi dan Mekanika Tanah pada Sungai Cibanjaran Jawa Barat ; July 1983, P.T. Inti Cipta Utama.

6) (2/2) Laporan Hasil
Penelitian Geologi dan Mekanika Tanah pada Sungai Cikunir Jawa Barat ; September 1983, P.T. Inti Cipta Utama.

Report (4) is the final report of the "Overall Plan" of the Galunggung disaster area. As for geological items, the general geology and volcanic activities of Mt. Galunggung are summarized in the chapter 2 and 3, with reference to the previous bibliography and data. No original survey has been carried out for this report.

Reports (5) and (6) reveal the soil mechanical characteristics of the lahar deposits in Cibanjaran river and Cikunir river. These two reports are also effective to understand the basic characteristics of the riverbed materials.

7) Galunggung the 1982 - 1983 eruption ; 1985, J.A.Katili et al., V.S.I

8) Letusan Galunggung 1982 - 1983 Kumpulan Makalah Hasil Penyelidikan ; 1986, J.A. Katili et al, V.S.I

Books (7) and (8) describe in detail the volcanic phenomena related to 1982 - 1983 eruption and also contain many previous papers. These two books are very important and useful for the understanding of Mt. Galunggung.

2.3 Geomorphology and Geology

(1) General Geology

The Indonesian archipelago, stretching 5,000 km from North Sumatra to the eastern Banda Sea, is composed of many slender islands facing the Indian Ocean.

The Java subduction zone, which is the Indian-Australian plate dipping into and under the Eurasian plate at an angle of about 60°, lies parallel to those islands outside.

Indonesian volcanoes are all related to convergent plate margins and occur as chains or arcs overlying the down going plates as shown in Fig. - 2.1 Mt. Galunggung volcano is one of over 100 volcanoes which have been active since 1,600 AD (1985 I. Suryo & Clark).

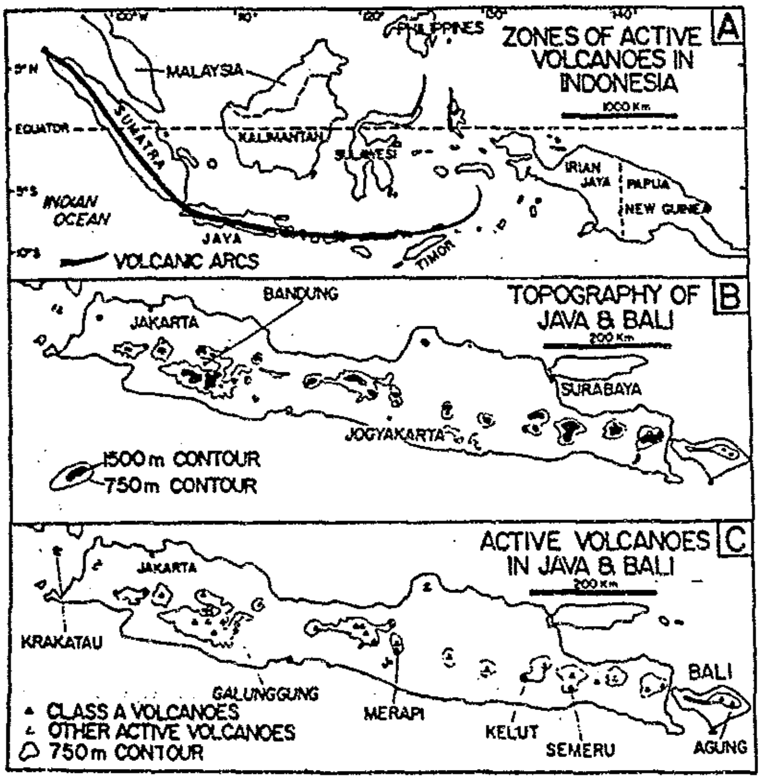


Fig. - 2.1 Distribution of Volcanoes in Indonesia
(Source: 1985 I. Suryo & Clark)

Mt. Galunggung is situated in the southeastern West Java in a tectonic block containing several active volcanoes (see Fig. - 2.2). This block is in fault contact with the northwest and the northeast. In the south, the block consists of old andesite volcanic rocks of the Southeastern Range, correlated to Moicence of the Tertiary Era and tilted southward, generating the east - west trending normal fault that forms the southern limits of the Tasikmalaya and Garut plains (1985 J.A. Katili & Adjat S).

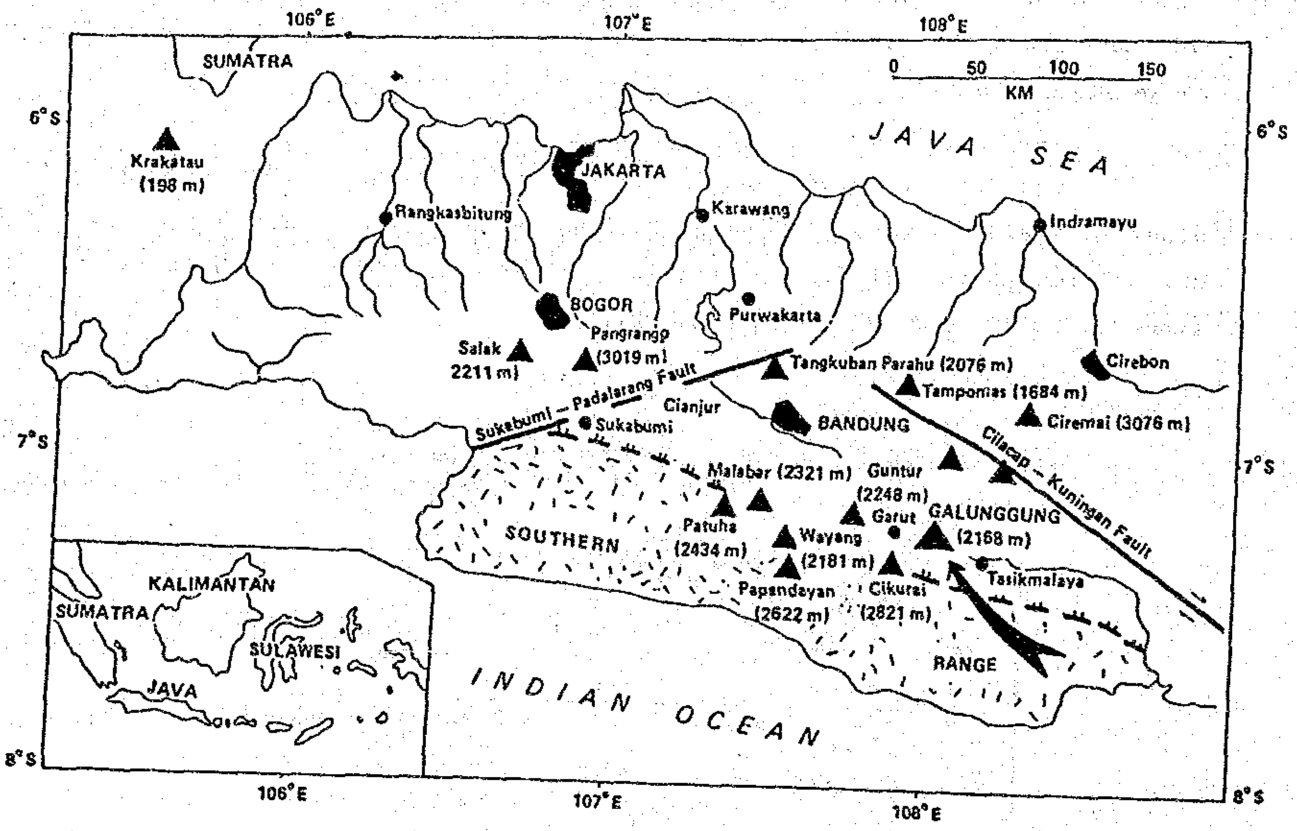


Fig. - 2.2 Schematic Geological Map in Southeastern West Java
(Source: 1984 J.A. Katili & Adjat S.)

The front line of active volcanoes in Java island is generally stretching in the direction of approximately east - west. However, the Galunggung - Talagobodas volcanic complex range, which Mt. Galunggung belongings to, lies straight from south to north.

(2) Geomorphology and Geology of Study Area

1) Geomorphology

The study area includes the Galunggung - Talagobodas range, the Tasikmalaya plain, the Ciwulan river, the Ciloseh river and their many tributaries.

Geomorphorogy in the study area is broadly divided into three zones, except the southeastern slope of Mt. Galunggung, namely i) the steep mountain area ranging from 2,200 m to approximately 700 m in elevation mostly covered by natural forest, ii) low undulating foothills extending between elevations of about 700 m and 500 m iii) the wide and nearly flat plain, lower than about 500 m in elevation dotting a few thousands of rockhill avalances. The southeastern slope of Mt. Galunggung is horseshoe - shaped and is like a table in the lower part.

Major rivers dissecting this study area come from the steep mountain area and flow down generally in the direction of southeast to south, to the Indian Ocean, with meanders remarkably in the lowerstream area.

The low hilly area and nearly flat area, possessing good sources of water and have natural drainage from the small streams. They are mostly utilized for small paddy fields. There are many small communities (Kampung) in these area.

2) Geology

Volcanic rock predominates in this area (see Fig. - 2.3 and Table - 2.1). Basement rocks exposed in the study area are the oldest volcanic rocks composed mainly of andesite lava flow and pyroclastic rocks, derived from Talagobodas, Karacak and Sawal volcanoes before the formation of Guntur volcano in Quaternary Era.

Volcanic deposits of the older Guntur volcano are distributed covering the above-mentioned volcanic rocks.

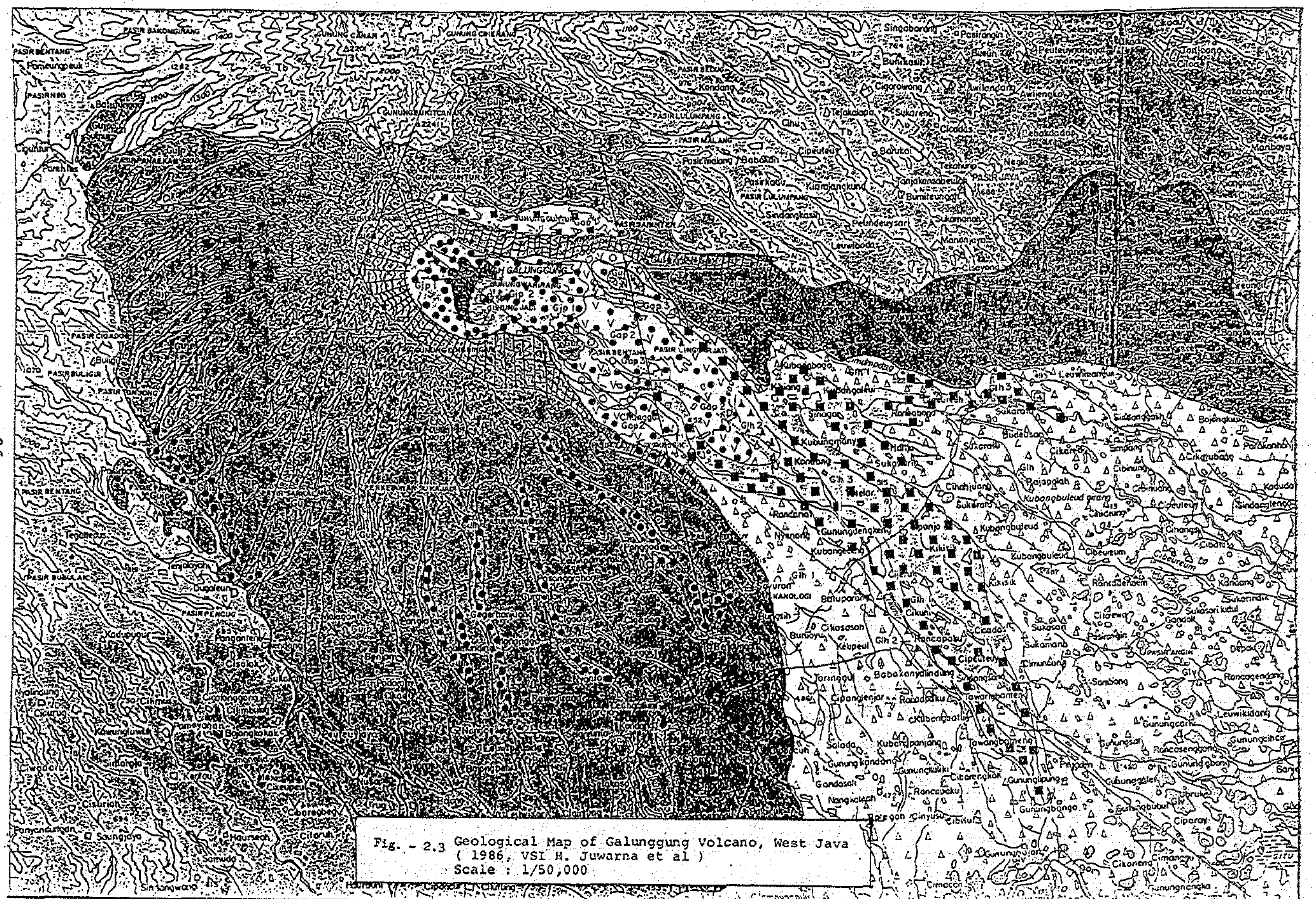
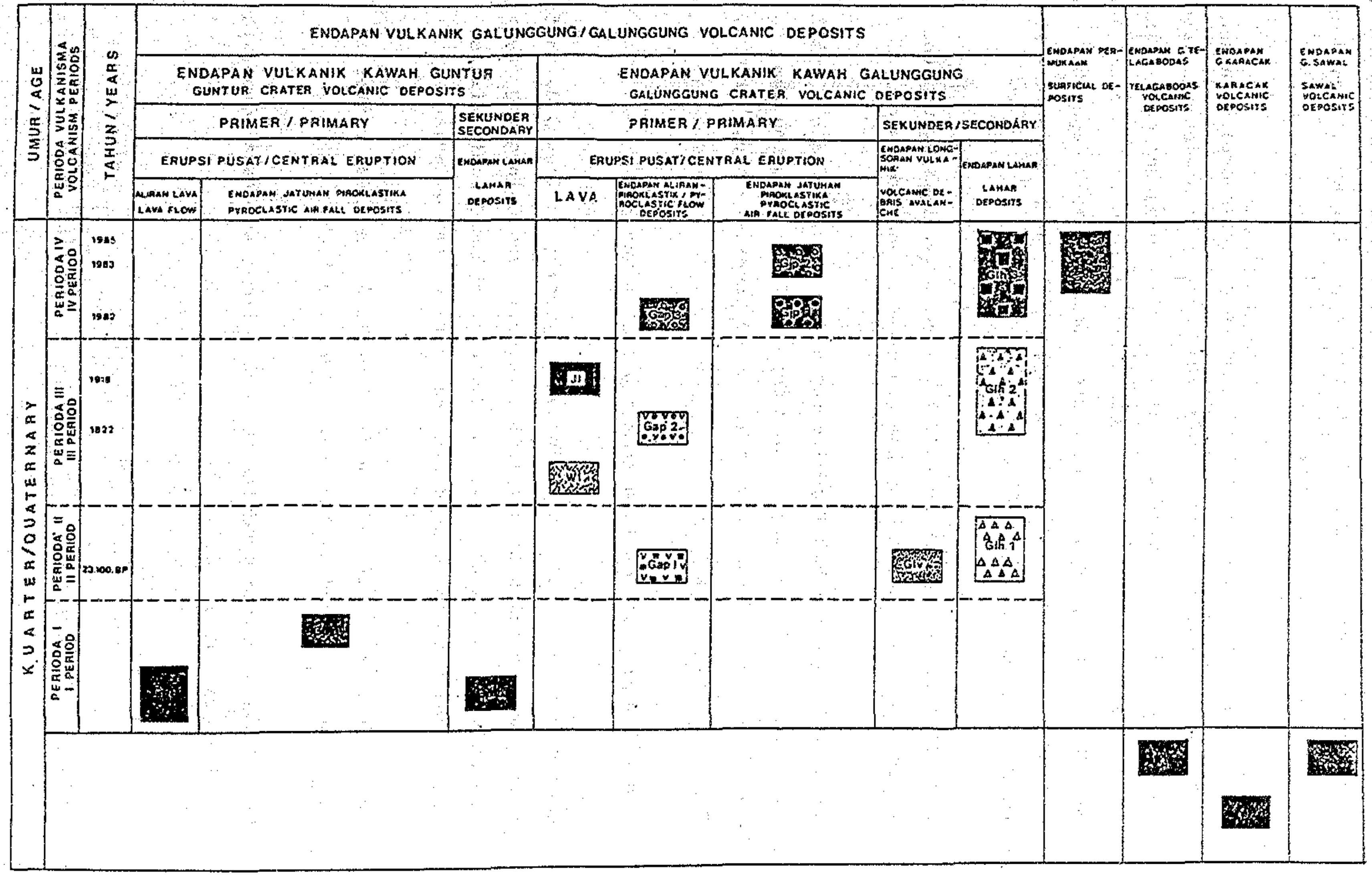


Fig. - 2.3 Geological Map of Galunggung Volcano, West Java
(1986, VSI H. Juwarna et al)
Scale : 1/50,000

Table - 2.1 Correlation of Stratigraphy in the Study Area



(Source : 1986, VSI H. Juwarna et al

The upper part of Mt. Galunggung consists of well consolidated lava flow, interbedded pyroclastic air fall deposits, ash to scoreous lapilli and Guntur lahar deposits.

After the formation of Guntur volcano, a phreatic explosion and a major sector collapse occurred in the southeastern slope 23,1000 years ago (1986, H. Juwarna et al 1/50,000 Geological Map). The horseshoe - shaped crater was formed as a result of the explosion. At the same time, it produced a great deal of lahar deposits (Galunggung lahar deposit 1), widespread in the southeastern slope of Mt. Galunggung.

Lava of Walirang, pyroxine andesite lava flow, lies around the crater which was created by the above-mentioned explosion.

Galunggung pyroclastic flow 2 deposits, composed of ash, lapilli and bomb, and Galunggung lahar 2 deposits overlie along the Cibanjaran and Cikunir rivers in the southeastern slope from 1,000 m to 500 m in elevation.

These deposits are derived from the 1822 eruption.

As the youngest deposits, Galunggung pyroclastic flow 3 deposits, Galunggung pyroclastic air fall 2 deposits and Galunggung lahar 3 deposits are along the Ciloseh, Cibanjaran and Cikunir rivers. These deposits are derived from the 1982 - 1983 eruption.

The lava of Mt. Jadi, a lava dome formed in the 1896 crater in 1981, was destroyed by the 1982 - 1983 eruption.

Stratigraphy of the pyroclastic rocks, flows and lahar deposits are as shown in Table - 2.2.

Table - 2.2 Stratigraphy of the Pyroclastic and Lahar Deposits in the Study Area (Source: 1986 VSI H. Juwarna et al)

Era	Volcanic Period	Years	Volcano	Primary			Secondary
				Lava	Pyroclastic flow	Pyroclastic air deposits	Lahar & debris avalanche
Quarter-nary	IV	1983 1982	Galunggung		Pyroclastic flow 3	Pyroclastic air flow 2 and 1	Galunggung lahar 3
	III	1918 1822	Galunggung	Lava of Jadi Lava of Walirng	Pyroclastic flow 2 (1822)		Galunggung lahar 2
	II	23,100 B.P.	Galunggung		Pyroclastic flow 1		Galunggung lahar 1 (Volcanic debris avalanche)
	I	?	Guntur	Lava flow	Pyroclastic air fall dep.		Lahar
		?	Talagabodas Karacak Sawal	Lava flow	Pyroclastic flow	Pyroclastic air fall	Lahar

2.4 Mt. Galunggung Volcano

2.4.1 Volcanic Activity

Previous eruption reports mention that historically, major activity of Galunggung volcano is recorded only three times: 1822, 1894, 1918 before the 1982 - 1983 eruption.

Geological characteristics of each eruption are summarized as follows (source: 1924 Van Es, 1986 J. Katili and Adjat S., 1986 VSI 1/50,000 Geological Map).

1) The activity in 1822

The first eruption occurred on 8th of October, 1822, and lasted for five (5) days. The conduit of explosion was presumably situated at the same place where phreatic explosion had occurred.

Nuée ardantes predominated and swept down along the S. Cibanjaran and S. Citanduy up to a distance of 10 km. Pyroclastic flow materials (now named as Galunggung pyroclastic flow 2 deposits) consist of some layers, 35 m in total thickness, ash, lapilli and bombs. A lava dome was formed later in the same year.

2) The activity in 1894

This eruption occurred on the night of 17 - 18th of October, 1894, from three eruption vents within the crater and lasted until 19th of October, 1894 (two (2) days).

Ash was at first erupted with a thickness of 0.5 meter to 1 meter on Galunggung's slope and the lava dome of 1822 was destroyed on 18 - 19th of October in 1894.

No Nuée ardantes occurred. The eruption produced a new crater, about 300 to 400 meters. The Cibanjaran river was diverted and entered the crater region, which then filled with water forming a crater lake.

3) The activity in 1918

On 17th of July at 10.00 PM, a minor earthquake was felt in Tasikmalaya. Ash fall was very limited on the southern slope, only 10 mm thick.

The new lava dome, Mt. Jadi, appeared on 19th of July in 1918, finally 200 - 250 m wide in diameter with a height of approximately 50 m above the water level.

Temperatures ranged from 50°C to 95°C in the fumaroles and 34° - 75°C in the hot springs.

4) The activity in 1982 - 1983

The first eruption occurred on 5th of April in 1982 and lasted until January in 1983 (about 10 months).

The eruption is divided into 3 phases as follows, (see Table - 2.3, 1986 J. Katili and Adjat S.)

Phase I : (April 5 - May 17-19)
Characterized by destruction of the lava dome, Nuée ardantes up to 5 km, and relatively high silica content (55%).

Phase II : Ash and bomb ejection, divided into two subphases.

A, (May 19 - August)
Characterized by the eruption of Vulcanian type, less Nuée ardantes (up to 2 km) and relatively high silica content (53%).

B, (August - November)
Characterized by the eruption of Vulcanian and Strombolian (mixed), less Nuée ardantes and relatively low silica content (50 - 53%).

Phase III: Ash and effusive ejection, divided into two subphases.

A, (November - December)
Characterized by the eruption of Strombolian to Effusive type, less Nuée ardantes (1 km) and low silica content (49%).

B, (January)
Characterized by the eruption of effusive type, no Nuée ardantes and low silica content.

2.4.2 Geological Structure

The so-called Mt. Galunggung consists mainly of Mt. Guntur (EL. 2,160), Mt. Siang (EL. 2,168), Mt. Walirang (EL. 1,182.9), crater lake and so on. Schematic geological structure is indicated in Fig. - 2.4.

Mt. Guntur, the oldest and highest mountain, is of the central strato type and possesses the old crater on the summit. Alternation of lava flows and pyroclastic deposits are clearly identified in the horseshoe - shaped crater wall.

The conduit of 1822 eruption was presumably situated in the above-mentioned crater, different from the new one in 1982 - 1983.

Mt. Jadi, a lava dome in the 1894 crater, was created in 1918 and destroyed in 1982 - 1983. Some parts of the lava dome still remain at the new crater wall formed in 1982 - 1983.

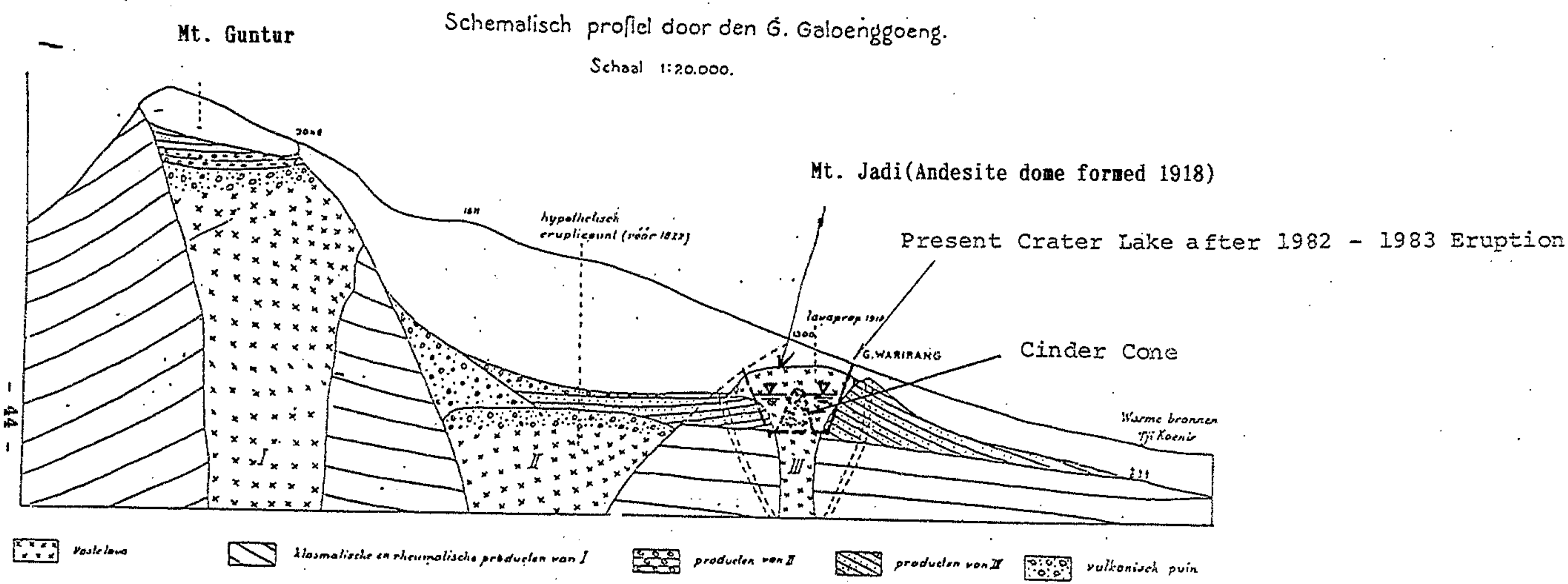
A small cinder cone, which is 1087.45 m high in elevation and blasted out andesite lava from its summit, was formed in the new crater from the volcanic activity in 1982 - 1983.

Mt. Walirang is the crater rim, formed in the 1918 and 1982 - 1983 eruptions and is composed of pyroclastic deposites.

Table - 2.3 Characteristics of Galunggung Eruption (1982- 1983)

PHASE		CHARACTERISTICS: EJECTED MATERIALS	CHARACTERISTICS: MAGMA COMPOSITION	CHARACTERISTICS: SEISMICS	CHARACTERISTICS: VISUAL OBSERVATIONS	SKETCHES
I Lava Dome Partial Destruction (April 5 May 17-19)		– Old lava dome materials (scoria, sand, lapilli, ash) – Ejected old materials are usually compact, partly oxidized (brownish colors) – New materials consist of sand, lapilli and predominantly white ash	– Silica content is relatively high (55%) – High gas pressure – Dioritic rock inclusions frequently found in the rock fragments	– Deep volcanic quakes followed by shallowed B type of 3 km depth – High frequency and wide amplitude tremors	– Glowing clouds (nuée ardente) up to 5 km	
II Ash and Bomb Ejection	A. Vulcanian Type (May 19 August)	– Mainly ash of new materials, whitish in color – Scoria, lapilli and bomb are also found – Ash plume reaches height of 15 to 20 km	– Intermediate silica content (53%) – Moderate to high gas pressure – Relatively high Mg and Fe content – Sometimes olivine is present in the fragments	– Continous volcanic tremors, low frequency with varied amplitudes – No pattern of occurrence or distribution of A and B volcanic quakes	– Less nuée ardente (up to 2 km) – Open conduit it	
	B. Vulcanian and Strombolian (Mixed) (August – November)	– Ash and bomb with scoria, sand and lapilli – Ash plume becoming weakly ejected	– Intermediately low silica content (50-53%) – Moderate to moderately high gas pressure – Relatively high Mg and Fe content – Less viscous	– No volcanic tremors – Very regular and even pattern of volcanic quakes, initiated by A type and followed by B type before the eruption	– Less nuée ardente – Open conduit it – Ash column up to less than 6000 m	
III Ash and Effusive Ejection	A. Strombolian to Effusive (November - December)	– Ash and bombs with scoria, sand and lapilli – Intensive bomb ejection – Ash plume becomes low (less than 8 km)	– Low silica content (49%) – Moderate gas pressure – Relatively high Mg and Fe content – Less viscous (basaltic)	– Continuous volcanic tremors, low frequency and low amplitudes – Uneven pattern of A and B type quake occurrence – Volcanic tremors amplitude increases shortly before the eruption	– Less nuée ardente (< 1 km) – Ash column < 8 km	
	B. Effusive (January)	– Intensive bomb ejection – Ash plume very low	– Low silica content – Low gas pressure – Less viscous	– Continuous volcanic tremors of very shallow depth with low frequency and low amplitudes – Rare A and B volcanic quake occurrence	– No nuée ardente – White ash column, low	

(Source : 1986, VSI J. Katili and Adjat S.)



(Source : 1924. Van Es)

Fig. - 2.4 Schematic Profile of Mt. Galunggung

2.4.3 Geology

The present crater lake is situated at the top of the horseshoe-shaped valley in the southeastern slope of Mt. Galunggung. The water surface is approximately 1,080 meters high in elevation and the lake is about 600 meters in diameter.

The slope of the inner wall is very steep, with an angle of 50 to 70 degrees and the one of outer very gentle, with an angle of 20 to 30 degrees.

A small cinder cone, the summit 1,086 meters high in elevation, is located in the lake.

The geology around the crater lake is composed of Quarternary pyroclastic rocks and deposits. (Fig. - 2.5)

The stratigraphy is divided into five (5) units, namely i) older volcanic breccia (Ob) ii) Andesite dome (Ad), iii) Younger volcanic breccia (Yb), iv) Pyroclastic flow deposits (py) and Tephra (Tp) in acending order.

Every unit except andesite dome is roughly parallel to each other, dipping at an angle of 20 to 30 degrees.

The andesite dome is a portion of Mt. Jadi, which was formed in 1916 and was destroyed in 1982 - 1983.

Table - 2.4 Stratigraphy around the Crater Lake

Bed	Rock or Sediments Faces	Year of Eruption
Tephra (Tp)	Scoria, pumice and ash, accompanied volcanic bomb	1982 - 1983
Pyroclastic flow deposits (Py)	Coarse sand and gravel	1982 - 1983
Younger volcanic breccia (Yb)	Matrix soft-loose, not consolidated; breccia small - big	1894
Andesite dome (Ad)	Hard, cracky, every joint opened, partially auto - breccia	1918
Older volcanic breccia (Ob)	Matrix soft - a little consolidated; breccia small - big	1822

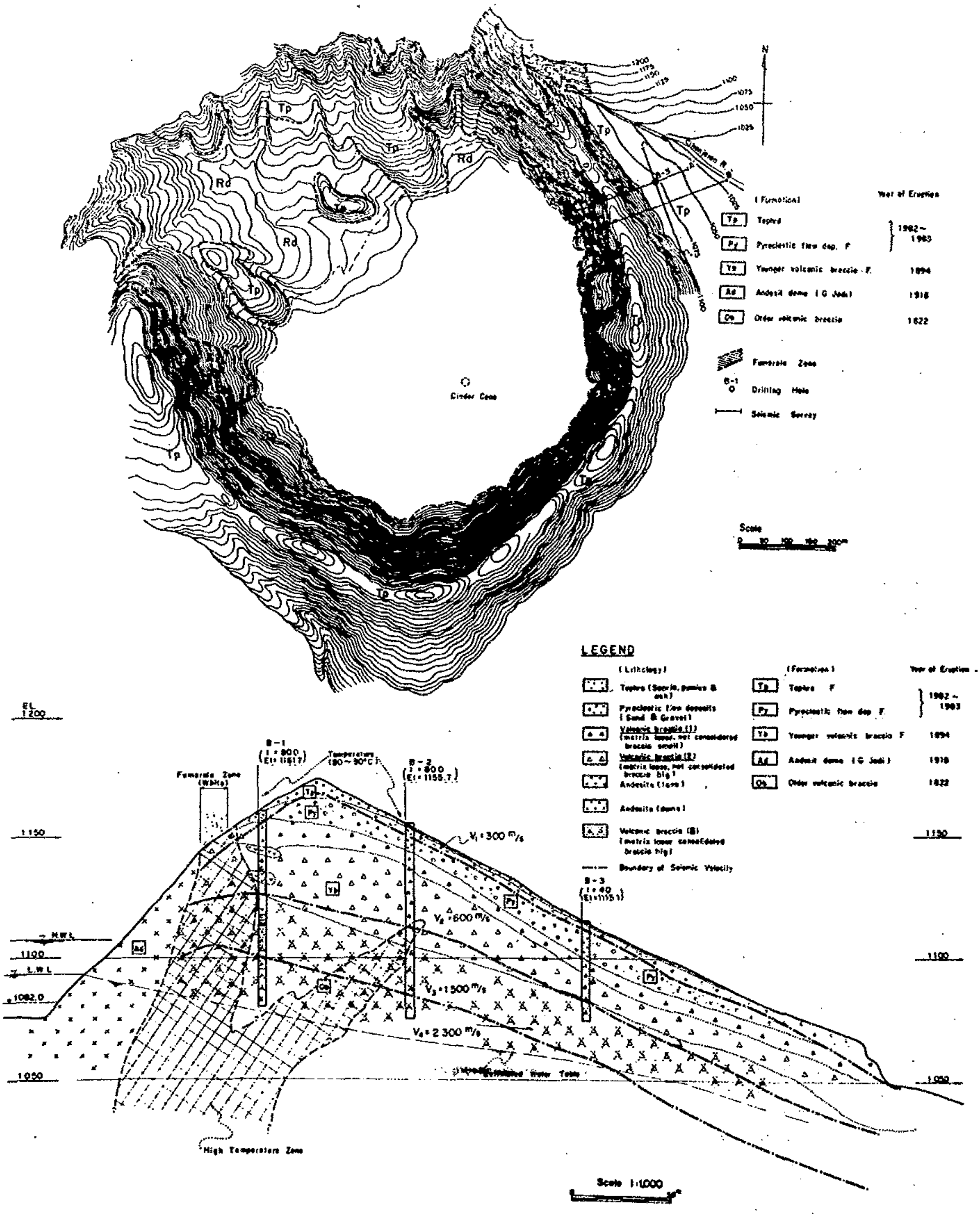


Fig.- 2.5 Geological Map of Crater Lake

2.4.4 Fumarole and Solfatara

The steam spout that blows up volcanic gas as post volcanism is divided into three kinds, namely, 1) fumarole 2) solfatara and 3) moffete according to the chemical composition of each. The first one blows up mainly H_2O, the second H_2S and sulphide, the third CO_2. The former two gases are hot ones and the last one is approximately normal temperature.

At the present time (as of November, 1987), many fumarole and a small amount of solfatara still remain around the inner wall of crater. No fumarole, however, occurs in the outer slope of Mt. Walirang.

The chemical composition and temperature of gases, collected from B-1 and B-2 drilling hole and crack on the inner wall of crater, are shown in Table - 2.5.

In each case, CO_2 is more than the threshold estimate value, 0.05%; and SO_2 is more than the threshold estimated value, 0.001%.

Table - 2.5 Chemical Analysis of Volcanic Gas

Location	Height (msl)	Temperature	Gas Composition
B_1	1,161.70 m	92°C	CO_2 : 1.32% H_2O : 50.1% H_2 : - SO_2 : 0.09% N_2 : 42.5%
B_2	1,155.90 m	94.6°C	CO_2 : 1.97% H_2O : 41.20% H_2 : - SO_2 : 0.09% N_2 : 46.73%
Fumarole at the crater rim	1,100 m	86°C	CO_2 : 1.32% H_2O : 38.96% H_2 : 7.2% SO_2 : 0.088% N_2 : 46.32%

(Analized by VSI Chemical Laboratory, Yogyakarta)

This means that poison gases endanger surroundings area, especially closed area (i.e. tunnel).

2.4.5 Landslide and Collapse of Crater Wall

The bulletion of the Volcanological Survey of Indonesia No. 106 (p. 23) describes that a big landslide occurred in 1968 causing the sources of Cibanjaran and Cikunir to join each other as the information from local administration. No more detailed information was reported concerning the scale, location, type of occurrence and so on.

The report of P.T. YARAMAYA (1984) mentions that the flood and a major damage also occurred just around the horseshoe - shaped crater in 1950.

Since the 1982 - 1983 eruption, it is not recorded that any major landslide occurred in the vicinity of the crater.

However, small collapses of the crater wall still occur, especially at cracky andesite regions and the very soft air fall deposits.

2.4.5 Leakage of Water from the Crater Lake

Casadevall (1986) describes that "three areas of thermal springs occur between 870 m and 1,000 m in elevation on the southeastern slope of Walirang ridge. These occur along the Cikunir, Cipanas and Cibanjaran drainages.

Comparing the location and temperatures of these springs with earlier measurements (1924 Van Es and Taverne), there is no evidence that the lake is losing water by increased outflow in the springs.

At only one place, near Pr. Senteng upstream of Cibukur 900 m in elevation in the south slope of Walirang, a very small hot spring was identified at the beginning of July, 1987, and it disappeared on the middle of August, 1987.

At the present, August to September, 1987, there are no leakage points or hot springs on the southeastern slope of Mt. Walirang.

2.5 *Engineering Problems for Planning of Drainage System from the Crater Lake*

Geological survey around the crater lake have revealed some serious problems for the foundation rocks. The following is a description of the geological characteristics and points to note concerning the execution phase of the crater lake wall.

(a) Weakness of the foundations ;

Every foundation except andesite is very soft, loose, not consolidated and heterogeneous, because of Quarternary volcanic deposits. Judging from the drilling core and seismic velocity (max. - V_4 = 2.30 km/sec), the strength of the four (4) foundations is thought to be very weak.

(b) High permeability ;

The foundation are highly permeable, with the permeability coefficient (k) being on the order of $k = 10^{-3}$.

(c) High temperature fumarole ;

Fumarole of 80°C to 90°C was observed 80° to 90° was blown up from B-1 and B - 2 drilling hole during drilling works, including small amount of solfatara.

High temperature was judged to be caused by post volcanic activity around the crater.

(d) Volcanic gas ;

The main chemical composition of fumaroles, collected from B-1, B-2 and crater rim, is shown in Table - 2.5

Poisonous gases, SO_2, and CO_2, are contained more than the threshold estimated value (SO_2: 0.001% and CO_2: 0.05%).

It is necessary for the planning of countermeasures to treat poisonous gases safely, especially in closed area (i.e. tunnel).

(e) Instability of excavated slopes ;

Andesite near the proposed shaft is very cracky and every joint is opened, therefore, creep occurs on the steepslopes excavated.

Near the outlet of proposed drainage tunnel, the foundation consists of pyroclastic flow deposits and it is very soft, loose and not consolidated.

2.6 Required Survey in the Next Stage

This geological survey pointed out several problems for the planning of a drainage system from the crater lake as mentioned before.

It is necessary to confirm the geological condition of the foundation along the tunnel before the design is completed in detail.

Considering the results of the geological survey and the planning of a drainage system, it is required to carried out the following geological survey described in Table - 2.6 and Fig. - 2.6.

Table - 2.6 Required Survey in the Next Stage

Item	Name	Elevation (meters)	Quantity	Remarks
	B-4		(Meters) 35.0	φ66 m/m, including Water Test and measurement of gas temperature
	B-5		90.0	"
	B-6		80.0	"
	B-7		35.0	"
	Total		240.0	
In-situ-Permeability Test	-	-	2 points	for pyroclastic rocks
Chemical Analysis of Volcanic Gas	-	-	10 samples	Collected from drilling holes and craks of ground surface.
Geological Analysis	-	-	-	

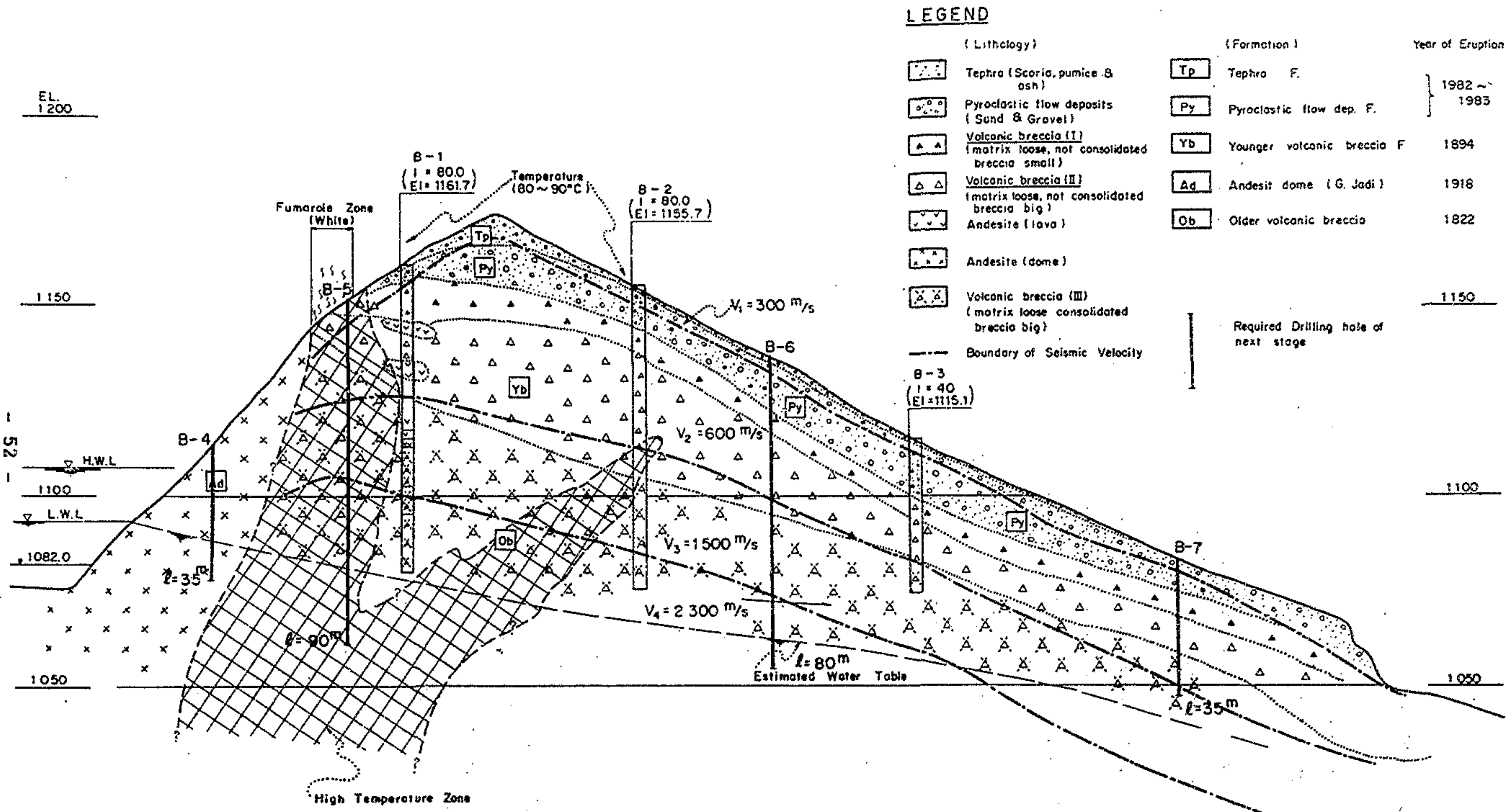


Fig. 2.6 - Required Geological Survey for Next Stage

Annex-1:

List of Reference and Data

(1) Topographic Map and aerial Photographs

G.1-1) Topographic Map in 1932 on a scale of 1/50,000;

G.1-2) Topographic Map in 19 on a scale of 1/25,000;

G.1-3) Peta Situasi Kawah G. Galunggung dan sekitarnya in 1978 on a scale of 1/10,000 ; Bag. Proy. Penelitian dan Pemetaan Gunungapi.

G.1-4) Peta Situasi Kawah G. Galunggung, Tasikmalaya, Jawa Barat in 1986 on a scale of 1/5,000 ; Direktorat Vulkanologi.

G.1-5) Aerial Photograph in August 1983 on scale of 1/12,000

(2) Geological Map

G.2-1) Geological Map of Java and Madura in 1977 on a scale of 1/2,000,000 ; Geological Survey of Indonesia

G.2-2) Geological Map of Galunggung Volcano, West Java in 1986 on a scale of 1/50,000 ; Volcanological Survey of Indonesia.

G.2-3) Geological Map of the Crater Lake, Mt. Galunggung in 1986 on a scale of 1/5,000 ; Volcanological Survey of Indonesia.

(3) Reports for the Project of Mt. Galunggung DPU

G.3-1) Final Report
Perencanaan Menyeluruh (Overall Plan) Daerah Bencana Gunung Galunggung Propinsi Jawa Barat Laporan Utama ; Februari 1984 P.T. Yaramaya.

G.3-2) (1/2) Laporan Hasil Penelitian Geologi dan Mekanika Tanah pada Sungai Cibanjaran, Jawa Barat ; Juli 1983, P.T. Intil Cipta Utama.

G.3-3) (2/2) Laporan Hasil Penelitian Geologi dan Mekanika Tanah pada Sungai Cikunir, Jawa Barat ; September 1983, P.T. Inti Cipta Utama.

(4) Bibliography for general Geology and Volcano

G.4-1) De Galoenggoeng en Telaga Bodas ; 1924
L.K.C. Van Es en N.J.M. Teverne

G.4-2) Geology of Indonesia

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(5) Reports of JICA

G.5-1) Final report of seismic survey for feasibility study on the disaster prevention project in the southeastern of Mt. Galunggung ; 1987, JICA

G.5-2) Final report of drilling survey for feasibility study on the disaster prevention project in the southeastern of Mt. Galunggung ; 1987, JICA

G.5-3) Final report of riverbed material survey for feasibility study on the disaster prevention project in the southeastern of Mt. Galunggung 1987.

G.5-4) Final report of topographic survey for feasibility study on the diaster prevention project in the southeastern of Mt. Galunggung ; 1987, JICA

VOLCANIC GAS CHEMICAL ANALYSIS OF THE WELIRANG RIDGE OF THE GALUNGGUNG CRATER

Time (work) schedule

- October 30, 1987 Yogyakarta - Bandung by bus
- October 31, 1987 Bandung - Tasikmalaya (G. Galunggung) by Toyota Jeep
- November 1 - 3, 1987 Field work (around the crater)
- November 3, 1987 (afternoon) G. Galunggung - Yogyakarta
- November 5 - 7, 1987 chemical analysis (laboratory work)

Sampling date : November 2 - 3 , 1987

Location : Gas (fumarole) from B_1, B_2 and crater rim (1100 m)
Method of sampling : Automatic Vacum Tube method
Analysis by : Yustinus Sulistiyo
Laboratory : VSI Chemical Laboratory, Yogyakarta
Method of analysis : Gas Chromatograph method

Gas Composition as follow :

Location	Height (msl)	Temperature	Gas Composition
B_1	1161,70 m	92^{o} C	CO_2 : 1.32 %
			H_2O : 50.1 %
			H_2 : -
			SO_2 : 0.09 %
			N_2 : 42.5 %
B_2	1155,90 m	94,6^{o} C	CO_2 : 1.97 %
			H_2O : 41.20 %
			H_2 : -
			SO_2 : 0.09 %
			N_2 : 46.73 %
Fumarole at the crater rim	1100 m	86^{o} C	CO_2 : 1.32 %
			H_2O : 38.96 %
			H_2 : 7.2 %
			SO_2 : 0.088 %
			N_2 : 46.32 %

Poison gases : CO_2 (threshold estimate value 0.05 %)

SO_2 (threshold estimate value 0,001 %)

Unpoison gases : H_2O, H_2 and N_2

Poison gases endanger surroundings area, especially closed area (i.e tunnel) if the precentage reach more than threshold estimate value. We have to aware of the real situation around Galunggung Crater area, possibly not yet fully quiet that's why this problem should be studied and prepare very carefully.

The Crater lake maximum water content in late December 1986 c. 7.5 millions m^3 (during heavy rainy season) and in late September 1987 (dry season) c. 2 millions m^3.

It could be the water content of the crater fluctuated between c. 2 millions m^3 (minimum) up to c. 7.5 millions m^3 (maximum).

We appreciate if you could approach the VSI office for next feasibility studies in the area (i.e. gas, heat flow etc.).

Bandung, November 10, 1987.

Sumarna Hamidi

3. Accumulated Sediment Volume Analysis

3.1 General

The yield sediment after the eruption in 1982 and the accumulated sediment volume in the sandpockets in August, 1987, examined on the basis of the existing survey data and the result of the first work in Indonesia by the JICA study team in 1987.

The ejected materials by the eruption of Mt. Galunggung in 1982 accumulated on the hillside and in the river channels as the ash deposits and the ladu deposits. Then it ran off and was accumulated in the lower sections of rivers when it rained. The runoff sediment from S. Cibanjaran, S. Cikunir basin was especially large and its part overflowed into S. Cimampang basin at Sinagar of S. Cibanjaran basin, and accumulated at the Sandpocket Negla and the Cimampang Area. That is, the deposit materials in the Sandpocket Negla and Cimampang was runoff from S. Cibanjaran.

There were the ejected materials thickly covering the southeastern slope of Mt. Galunggung caused by its eruptions at intervals of 50 years on an average. After the eruption in 1982, both the sediment from the 1982 eruption and the sediment before eruption have been likely to flow out to the lower sections of the sandpocket area in S. Cikunir, S. Cibanjaran and so on.

In this chapter, for the purpose of obtaining fundamental data for the sediment control plan, the ejected materials volume, accumulated sediment volume and unstable materials volume, are estimated on the basis of the existing data and result of sediment analysis by JICA.

After these estimates, the sediment balance after the eruption of 1982 is rearranged and spare capacity of sandpocket is calculated.

The study items in this chapter are shown as follows:

1) Ejected materials volume (ash deposit, ladu deposit)
2) Accumulated Sediment Volume in Sandpocket
3) Unstable materials volume
4) Sediment Balance
5) Spare capacity of sandpocket

Study flow for the estimate of sediment balance and for the calculation of spare capacity of sandpocket are shown in Fig. - 3.1 and 3.2.

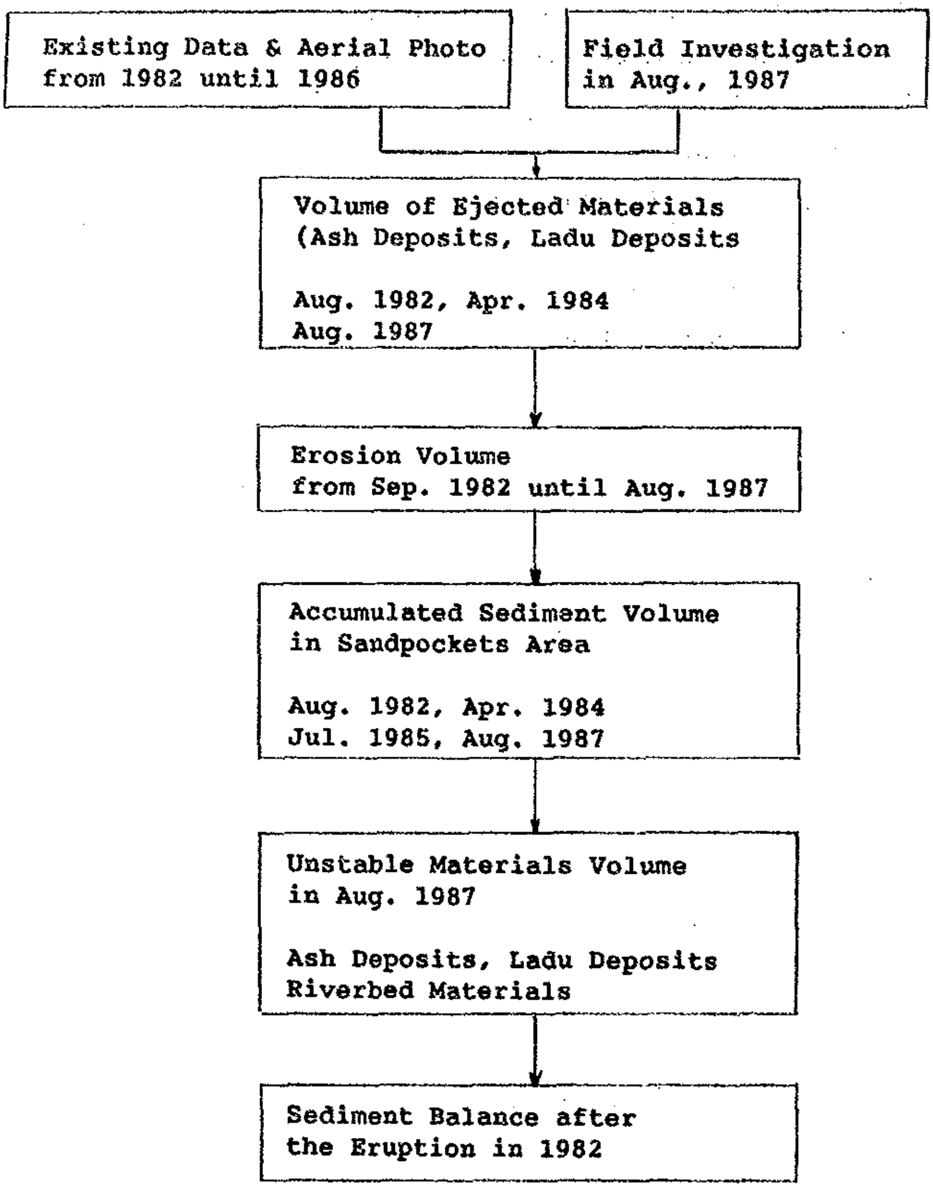

Fig. - 3.1 Study Flow of Sediment Balance in Study Area after the Eruption in 1982

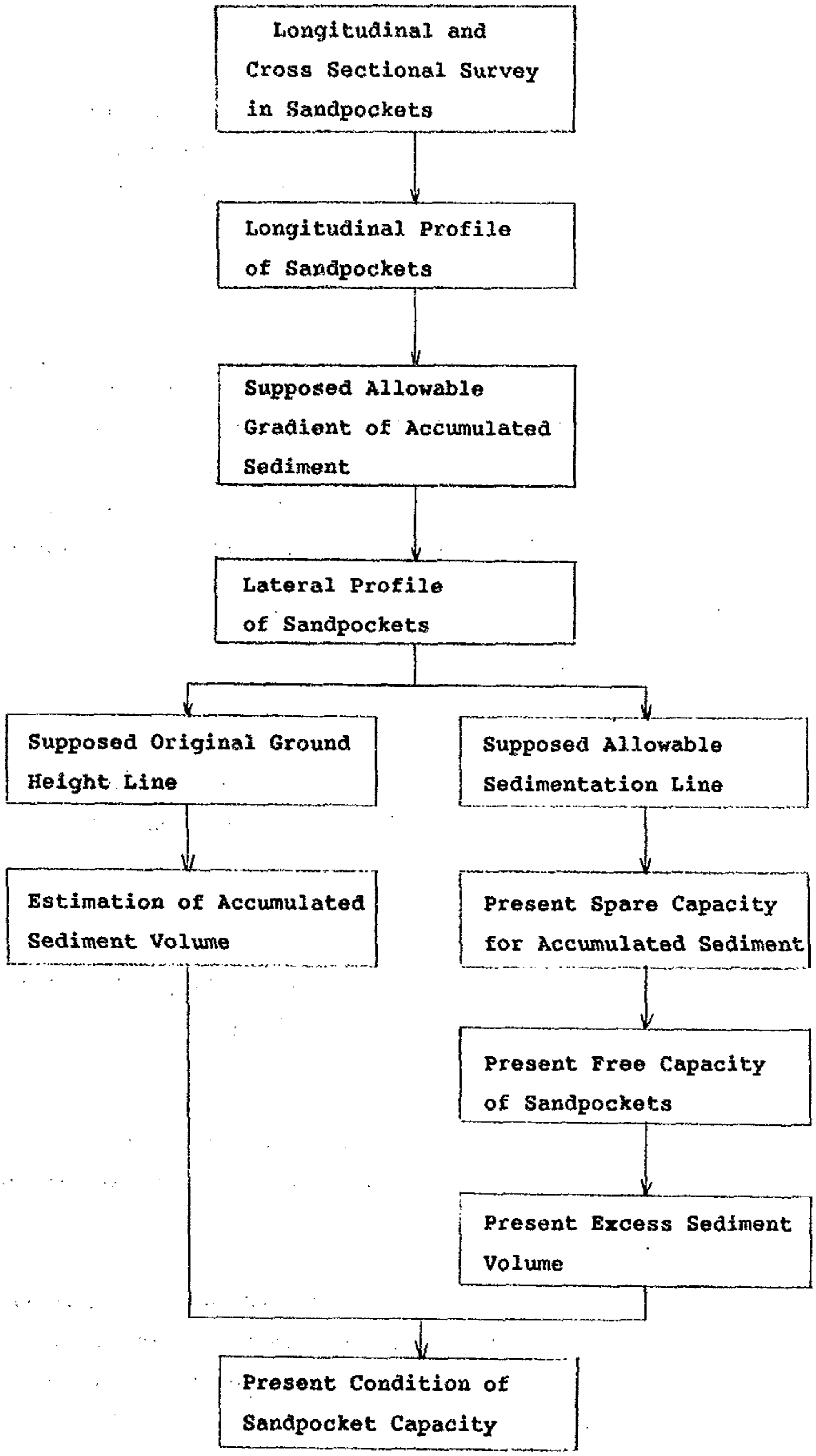

Fig. - 3.2 Study Flow of Sandpocket Capacity

3.2 Ejected Materials Volume

A review of the survey report of the ejected materials (the ash deposit and the ladu deposit) by the eruption in 1982 is arranged below according to the survey data by the Volcanological Survey of Indonesia (VSI) and by the JICA Study Team.

3.2.1 Volume of Ash Deposit

As Mt. Galunggung erupted in 1982, the investigation of the volume of the ejected materials accumulated in S. Cimampang basin, S. Ciloseh basin, S. Cibanjaran basin, S. Cikunir basin and on the southeastern slope basin has been carried out three times by the Volcanological Survey of Indonesia. The dates of investigation are as follows: The results are shown in Table - 3.1.

a. The 1st time; Aug. 1982
b. The 2nd time; Feb. 1983
c. The 3rd time; Dec. 1983

The volume was estimated multiplying the average thickness by the surveyed area after the field survey of the sediment thickness at the sampling point. The volume of ejected materials shown in Table - 3.1 is little if that volume includes the ladu deposit.

Therefore, the JICA Study Team judged that ejected materials surveyed by VSI is only ash deposit volume not including the ladu deposit in the river and the hillsides.

According to Table - 3.1, 54% - 75% of the ash accumulated on the hill side in August, 1982 ran off to the lower section of sandpocket area on rivers during 16 months till December, 1983.

In the meantime naked land is observed around the upper reaches of S. Cikunir and S. Cibanjaran while the vegetation covers the lower reaches. The ash deposit is inferred not to remain on the hillside slopes as they have runoff downstream or turned into soil.

Table - 3.1 Volume of Ejected Materials on the Slope of Mt. Galunggung

River Basin	Volume of Ejected Materials (10^3 m^3)		
	Volume *1 in Aug. 1982	Volume *2 in Aug. 1983	Volume *3 in Aug. 1983
S. Ciloseh- S. Cilmampang	7,200	2,200	1,800
S. Cibanjaran- S. Cikunir	14,200	8,300	6,600
Rivers on the Southern Slope	18,500	10,500	6,800
Total	39,900	21,000	15,200

Note: It has been estimated by the Directorate of Volcanology

*1 "J.A. KATILI & ADJAT SUDRADJAT (1981): GALUNGGUNG THE 1982 - 1983 ERUPTION, Volcanological Survey of Indonesia" Page 52.

*2 "Disaster Preparedness and Rehabilitation in Indonesia - Part (I) ... Aug., 1984 ... UNDP/11.0" Page 8

*3 "FINAL REPORT PERENCANAAN MENYELURUII (OVERALL PLAN) DAERALL BANCANA GUNUNG GALUNGGUNG ... Feb., 1981 ... Directorate of Rivers" Page V-5

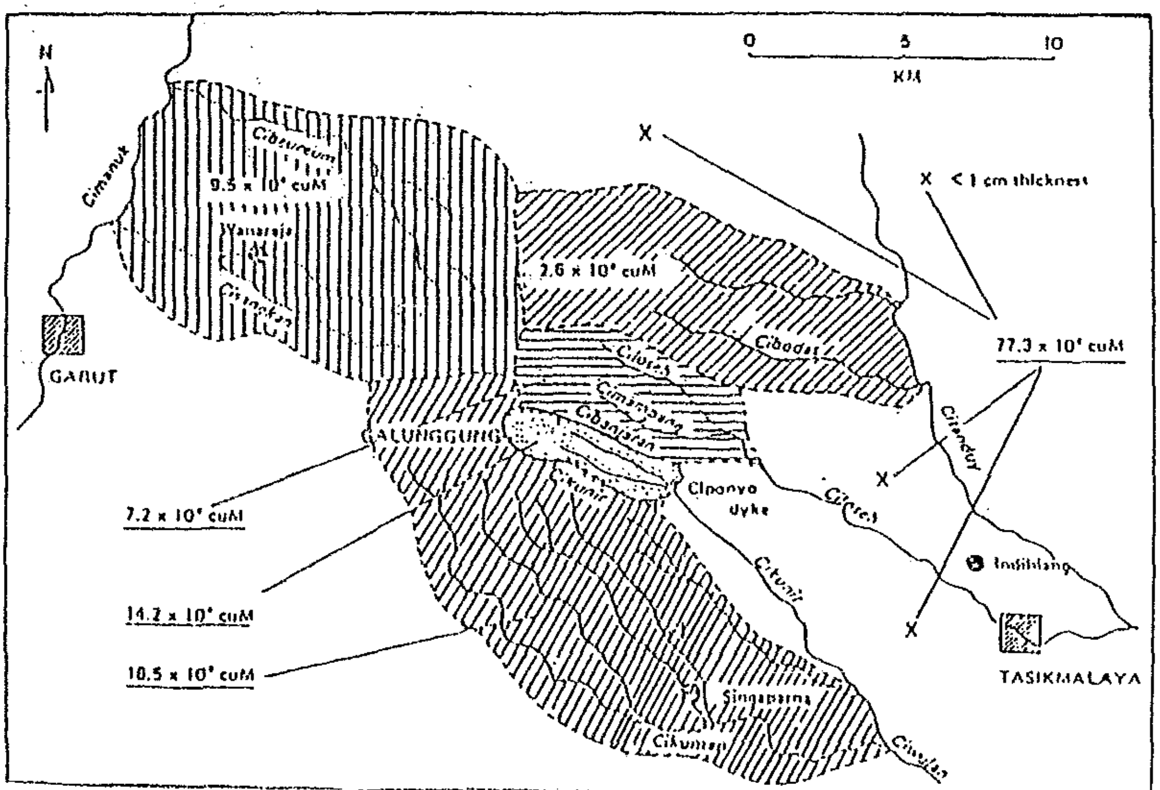

Fig. 3.3 Volume of Ejected Material Estimated by VSI

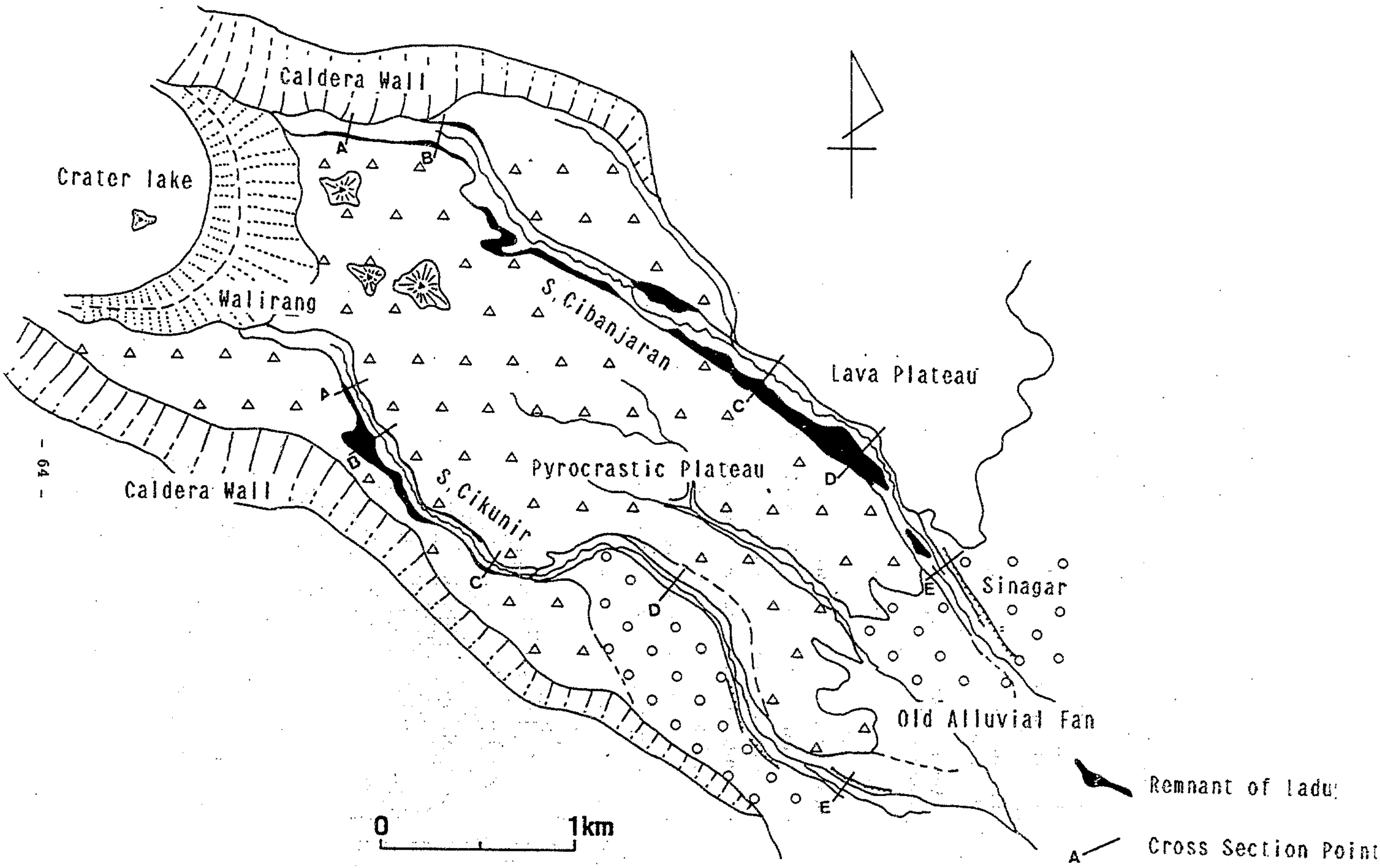

Fig. - 3.4 Map of Cross Section Survey Points

At the southern slope basin, the deposit materials of the sediment runoff of 1982's debris (the ash deposit) are found on the riverbank, the ash deposit is not found on the hillside slope. Besides, the basin is not devastated as the other rivers. Therefore, the hillside ash deposit by the eruption in 1982 on the southern slope is presumed to runoff entirely.

3.2.2 Volume of Ladu Deposit

The ladu occurred at the S. Cikunir and S. Cibanjaran basin in addition to the ash deposit in Table - 3.1, and it accumulated thickly on the hillside slope and the channels of both rivers. The ladu deposit in the river channels reached about 3 km from the crater for S. Cikunir and 5 km for S. Cibanjaran.

(1) Ladu Deposit Volume in River Channel

As for the first work by JICA in Indonesia (Aug. 1987), the volume of ladu deposit was estimated on the basis of the results of the cross sectional surveying data, the site investigation and the aerial photographs. The location of cross sectional survey is shown in Fig. - 3.4.

The method for estimating the ladu deposit volume in the river channels is described in Fig. - 3.5. The ladu deposits volume at the 1982 eruption and that which had runoff till August, 1987, among them were estimated, assuming the cross section shape of the channels just before and after the 1982 eruption by the field survey.

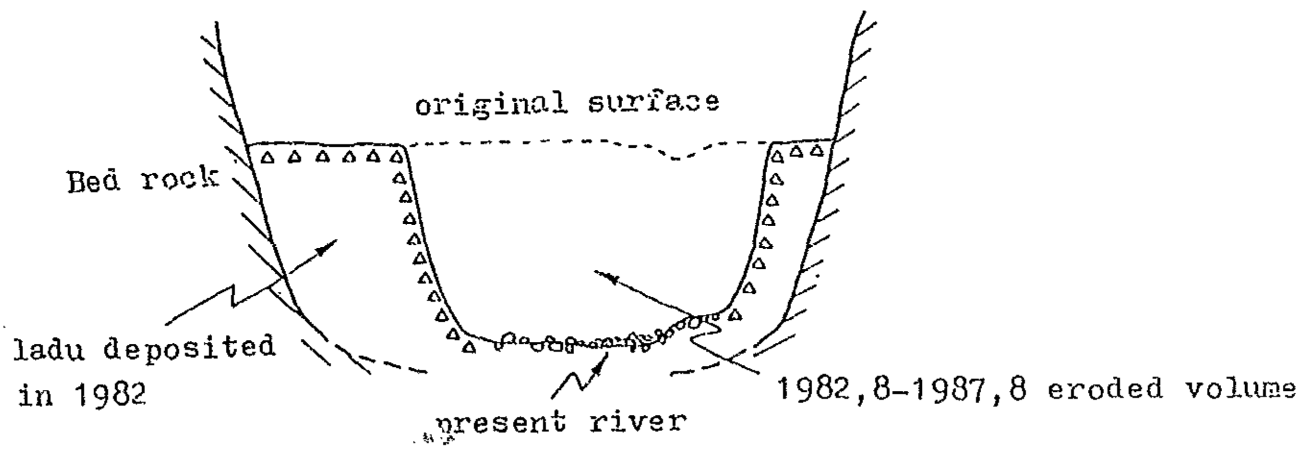

Fig. - 3.5 Estimate Method of Ladu Deposit

Table - 3.2 shows the results of the deposit volume estimate. It is presumed that the ladu deposit in both river channels of S. Cikunir and S. Cibanjaran at the 1982 eruption was 11.3 x 10^3 m^3; 78% (8,870 x 10^3 m^3) of them ranoff by erosion to the downstream of sandpocket Ciponyo I till August 1987.

Table - 3.2 Volume of Ladu Deposits in the River Channel

River Area	Ladu Deposits in the River		
	Sediment Volume in Aug. '82 (10^3 m^3)	Sediment Volume in Aug. '87 (10^3 m^3)	Erosion Volume between '82 & '87 (10^3 m^3)
S. Cibanjaran	6,500	1,800	4,700
S. Cikunir	4,800	630	4,170
Total	11,300	2,430	8,870

(2) Ladu Deposit on the Hillside

The ladu deposit is considered to be accumulated on the gentle hillside slope from Outer-Crater at Walirang to S. Cikunir and S. Cibanjaran upper reaches at the eruption 1982. Since the marks of deposition were not confirmed at the survey in August, 1987, it was estimated that the greater part of them had already runoff and it had been the considerably large volume as the source of the lahar supply.

The area of the ladu flowed out the hillside slope accounts for about 2.1 million m^2 judging from the deposit conditions of the ladu deposit in both channels of S. Cibanjaran and S. Cikunir and its present accumulating condition on the crater hill slope (See to Fig. - 3.6). The average accumulated thickness of the ladu deposits is 5-8 m by the geological survey of JICA at Mt. Walirang.

The volume of ladu deposit in August 1982 and in August 1984 is shown in Table - 3.3. According to Table - 3.3, the volume of Ladu deposit in 1982 is about 15,000 x 10^3 m^3, and 9,800 x 10^3 m^3 of it is eroded until August 1988.

Table - 3.3 Volume of Ladu Deposits on the Slope of Mt. Galunggung

River Basin	Ladu Deposits in Aug. '82			Ladu Deposits in Aug. '87		
	Sediment Area (km^2)	Sediment Thickness ness (m)	Sediment Volume (10^3 m^3)	Sediment Area (km^2)	Sediment Thick-ness (m)	Sediment Volume (10^3 m^3)
S. Cibanjaran	1.02	7	7,140	0.37	7	2,590
S. Cikunir	1.10	7	7,700	0.37	7	1,590
Total	2.12		14,940	0.74		5,180

Note: Eroded Volume between Aug. 1982 and Aug. 1987
= 14,940,000 - 5,180,000 = 9,760,000 m^3

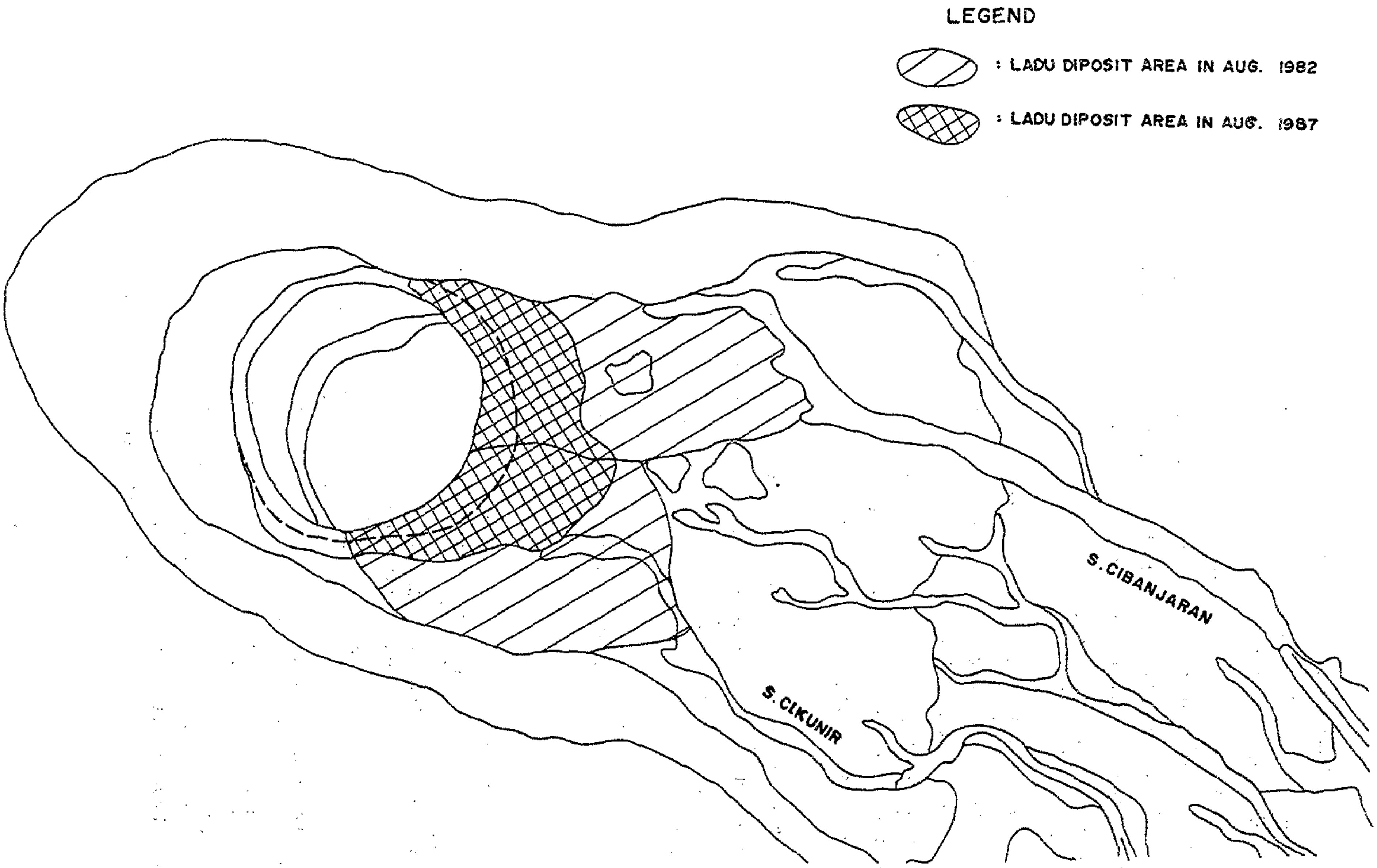

Fig. - 3.6 Ladu Diposits on the Slope OF Mt. Galunggung (S = 1/25.000)

3.3 Accumulated Sediment Volume in Sandpocket Area

The ash deposit as well as the ladu deposit by the 1982 eruption flowed as the lahar and was accumulated at the fan area of Kokoncong and Sinagar lower reaches until August, 1982 in S. Cikunir and S. Cibanjaran basin. A part of the lahar overflowed to the S. Cimampang (S. Ciloseh) basin on the left bank at the Sinagar spot of S. Cibanjaran and was accumulated around the Sandpocket Negla & Cimampang area of S. Ciloseh.

The data concerning, the accumulated sediment volume in the sandpockets surveyed by Mt. Galunggung Project Office and by JICA Study Team respectively is shown below.

The accumulated sediment volume at the time shown above summarized as follows:

1) Aerial photograph (August, 1982)
2) Topographic survey (April, 1984)
3) Topographic survey (July, 1985)
4) Topographic survey (August, 1987)

3.3.1 Accumulated Sediment Volume in Sandpockets Area in August, 1982

The area and thickness of sediment by lahar at the time of August 1982 are described in Fig. - 3.7 based on the interpretation of aerial photographs taken in August, 1982 as well as the information from people on site.

Table - 3.4 shows the lahar volume accumulated on the S. Cikunir and S. Cibanjaran fan at the time of August, 1982 through Fig. - 3.7.

A part of the sediment runoff volume of S. Cibanjaran flowed to S. Cimampang at the Sinagar spot is estimated 1,740 x 10^3 m^3. Total volume of lahar deposit in the sandpocket reaches 22,270 x 10^3 m^3.

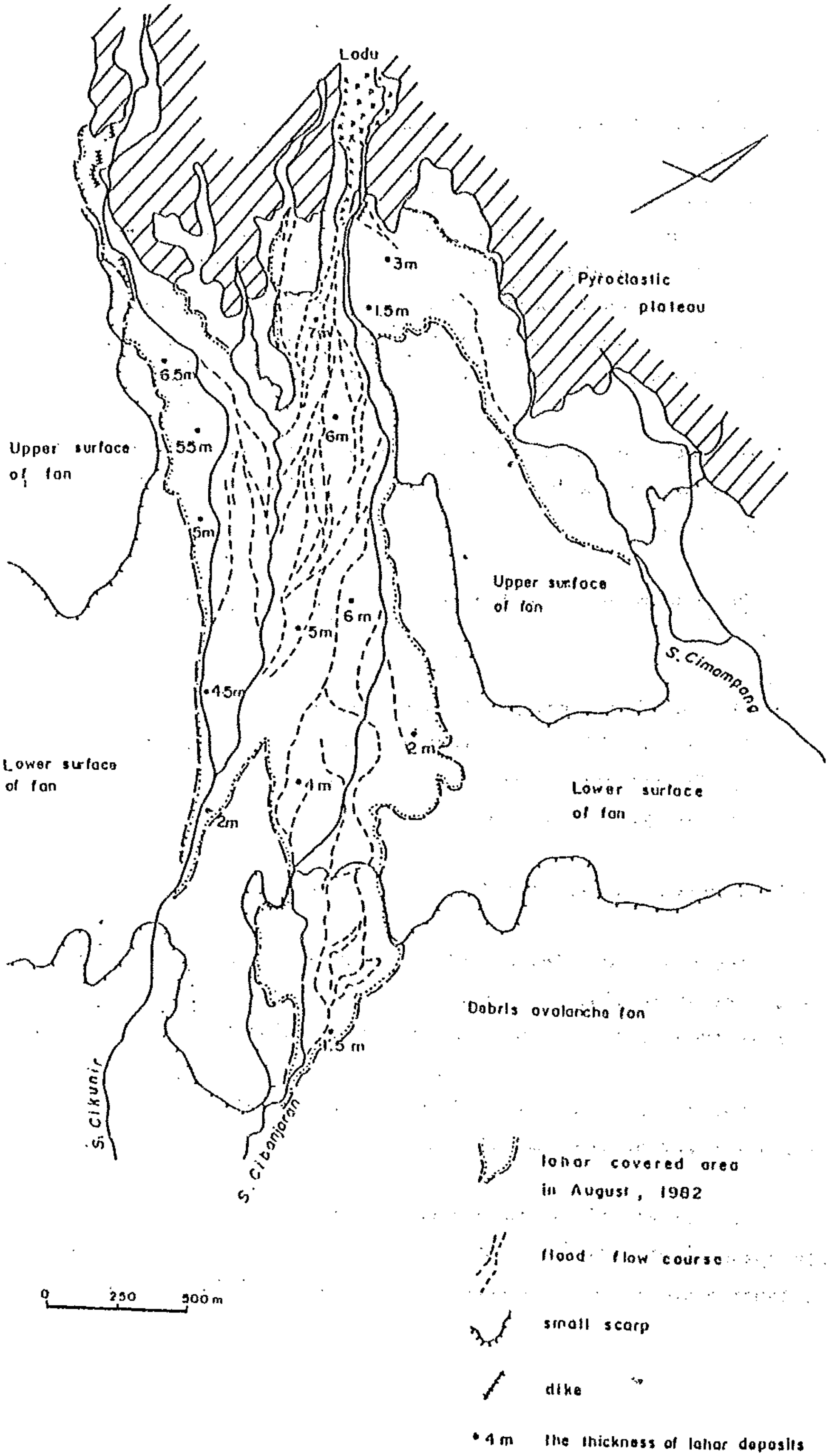

Fig. - 3.7 Lahar Covered Area of S. Cibanjaran & S. Cikunir in Aug. 1982

Table - 3.4 Lahar Deposit Volume in the Sandpocket Area in Aug. 1982 Based on Photo Interpretation

Flood Area	Thickness of Lahar Deposits (m)	Area ($x10^3$ m^3)	Volume ($x10^3$ m^3)
Lowerstream of S. Cibanjaran and S. Cikunir	7	300	2,100
	6	1,270	1,620
	5	1,100	5,500
	4	790	3,160
	3	410	1,230
	2	460	920
Sub Total	-	4,330	20,530
Overflowed Area from Sinagar	3	440	1,320
	2	210	420
Sub Total	-	650	1,740
Total	-	4,980	22,270

The sandpockets construction of Ciponyo I , Ciponyo II, Cimampang as well as Negla were started from September, 1982. This means that these sandpockets were constructed on the sediment accumulated sediment till August 1982.

3.3.2 Estimates of Accumulated Sediment Volume in the sandpockets was made twice in the past by the Mt. Galunggung Project Office.

The surveying period of the cross section in the sandpockets is shown as follows.

1) The 1st survey; April 1984
2) The 2nd survey; July 1985

Table - 3.5 shows the design storage capacity and accumulated sediment volume of sandpocket at the time of survey.

The calculating method is given below.

$$V = Vmax - Vs \quad \ldots\ldots\ldots\ldots \quad (3.1)$$

Where,

V; Sediment Volume (m^3)
Vmax; Possible Maximum Accumulated Volume of Sediment (m^3)
Vs; Spare Capacity in Sandpocket (m^3)
$Vs = a \times h \times A$
h; Average Allowance Height (m)
A; Sandpocket Area (m^2)
a; Calibration Coefficient of Conservation Storage

Table - 3.5 Accumulated Sediment Volume in Sandpocket between April 1984 and July 1985

	River	Capacity (10^3 m^3) (1)	*1 Accumulated Volume April '84 (10^3 m^3) (2)	Accumulated Volume till July '85 (10^3 m^3) (3)	Accumulated Volume '84 till July '85 (10^3 m^3) (4)=(3)-(2)
CIMAMPANG	S. Cimampang	1,760	1,000	1,650	650
NEGLA	S. Ciloseh	3,370	1,400	2,200	800
Sub Total		5,130	2,400	3,850	1,450
CIPONYO I DALAM	S. Cikunir - S. Cibanjaran	6,700	4,000	6,000	2,000
CIPONYO I LUAR	S. Cikunir - S. Cibanjaran	2,500	1,000	2,250	1,250
CIPONYO II	S. Cikunir - S. Cibanjaran	4,700	2,000	3,100	200
Sub Total		13,900	7,900	11,350	3,450
Total		19,030	10,300	15,200	4,900

Notes:

*1 Source: "Disaster Preparedness And Rehabilitation In Indonesia Part (I) ... UNDP/11.0, Aug. 1984" Page 20

*2 Source: "URALAN SINGKAT PENGAMBILAN PASIR DARI SUNGAI DAN KANTONG PASIR DI WILAYAH KERJA PROYEK GALUNGGUNG ... Dec. 1986"

The total storage capacity of sediment for 5 sandpockets is estimated as 19,030 x 10^3 m^3. Accumulated volume of sediment in the 5 (five) sandpocket is 10,300 x 10^3 m^3 in April, 1984 and 15,200 x10^3 m^3 in July, 1985, 4,900 x 10^3 m^3 is accumulated from May, 1984 to July 1985.

The accumulated sediment volume (3.85 million m^3) of sandpocket Cimampang and Negla is the one which was overflowed from S. Cibanjaran based on the information from people on site.

3.3.3 Accumulated Sediment Volume in Sandpocket Ciponyo I from August, 1985 to August, 1987.

The accumulated sediment volume from August 1985 to August 1987 in the sandpocket is calculated as $2,576 \times 10\ m^3$ by using both topographic map (1 m contour, scale = 1/5,000) surveyed by Mt. Galunggung Office in August 1985 and the cross section (100 m pitch, scale = 1/1,000 ; 1/200) surveyed by JICA team in August 1987.

Accumulated sediment volume per month (year) during 25 month (2.08 years) is $103 \times 10^3\ m^3$ ($1,235 \times 10^3\ m^3$).

Table - 3.6 Accumulated Sediment Volume in Ciponyo I from August, 1985 to August, 1987

Accumulated Sediment Volume		2,576,000
Period	m^3/month	25 month
	Year	2.08 years
Intensity of Accumulated Sediment	m^3/month	103,000
	m^3/year	1,236,000

3.4 Unstable Materials Volume

The unstable materials volume except the ladu deposits accumulated in the river channel around the S. Ciloseh - S. Cimampang basin and the S. Cikunir - S. Cibanjaran basin was estimated as shown in Table - 3.7 from the results of the field investigations and topographical surveys by JICA team.

The volume of unstable materials is estimated as 290 x 10^3 m^3 for S. Ciloseh, 210 x 10^3 m^3 for S. Cimampang, 770 x 10^3 m^3 for S. Cibanjaran and 1,100 x 10^3 m^3 for S. Cikunir respectively.

If the ladu deposits in August, 1987 of Table - 3.2 as well as Table - 3.4 and the unstable materials in river channel of Table - 3.7 make the present unstable materials, it becomes like Table - 3.8.

Table - 3.7 Unstable Materials in River Channel

River Name		Travel Distance (m)	River Width (m)	Sediment Thickness (m)	Sediment Volume (10^3m^3)
S. Ciloseh	Main River	3,600	20	2	147
	Tributary	20,100	7	1	144
	Sub Total				291
S. Cimampang	Main River	2,500	30	2	150
	Tributary	11,700	5	1	59
	Sub Total				209
S. Cimala	Main River	6,800	7	1	48
Total					548
S. Cibanjaran	Main River	2,000	70	3	420
	Tributary	3,500	50	2	350
	Sub Total				770
S. Cikunir	Main River	4,500	70	3	945
	Tributary	4,900	20	1.5	147
	Sub Total				1,092
Total					1,862

Table - 3.8 Unstable Material Volume as of August, 1987

Name of River Basin	Breakdown of River Basin	Ladu Deposit Volume (10^3 m^3)			Unstable Materials Volume in River Bed (10^3 m^3)	Total Volume ($10^3 m^3$)
		In River Channel	on the Slope	Sub Total		
Ciloseh Cimampang	S. Ciloseh	-	-	-	291	291
	S. Cimampang	-	-	-	200	209
	S. Cimala	-	-	-	48	48
	Sub Total	-	-	-	548	548
Cikunir Cibanjaran	S. Cibanjaran	1,800	2,500	4,300	770	5,160
	S. Cikunir	630	2,590	3,220	1,092	4,312
	Sub Total	2,430	5,180	7,610	1,862	9,472
T o t a l		2,430	5,180	7,610	2,410	10,020

The unstable materials volume including ladu deposit volume is approximately 550 x 10^3 m^3 in S. Ciloseh basin and is approximately 10,000 x 10^3 m^3 in S. Cikunir basin.