1.5.2 GEOLOGY OF THE STUDY AREA

(1) Outlines of Geological Features in the Study Area

The study area covers both Tertiary volcanic rocks and Tertiary limestone distribution area and Quaternary volcanic products distribution area metioned in section 1.4.2. Geology of the survey area is largely divided into Tertiary system of south and Quaternary system of north. Tertiary system and Quaternary system are respectively divided into several layers as shown in Table-1.5.1.

Tertiary system of the survey area is composed mostly of such volcanic rocks as andesite, lava, tuff breccia, etc. As sedimentary rocks, only limestone is distributed in a very narrow sphere near the estuary of K. Glidik.

Quaternary system of the study area, as discussed in section 1.4.1, is composed of volcanic ejecta from the Tengger mountain range, volcanic ejecta from Jambangan volcanic complex and volcanic ejecta from Semeru volcano. The oldest is volcanic ejecta from jambangan volcanic complex and the youngest is volcanic ejecta from Semeru volcano. In this report, volcanic ejecta from the Tengger mountain range and Jambangan volcanic complex are collectively called Older Volcanic Products and volcanic ejecta from Semeru volcano are called Younger Volcanic Products.

Younger volcanic products from Semeru volcano are further classified into several layers as shown in Table-1.5.1 from the standpoint of composition, mode of occurrence, compactness and solidity.

The Schematic relationship of Tertiary system and Quaternary system as given above is shown in Fig.-1.5.3.

Table-1.5.1 Sequence of Strata of the Study Area

Age	Layer		Facies
Holocene	Alluvial Deposits		Sand, round-subangular gravels, silt, clay storatified.
↑	Younger Volcanic Products (From Semeru Volcano)	Primary Volcanic Products	Andesite to basaltic lava, pyroclastic deposits, ash, bomb, lapilli, etc. very loose.
		Younger Lahar Deposits	Loose sand and angular gravels.
		Older Lahar Deposits	Compact sand and angular gravels.
Pleistocene	Older Volcanic Products (From Jambangan Volcanic Complex and Tengger Mountain Range)		Andesitic to basaltic lava, Pyroclastic deposits, ash, bomb, lappilli, Lahar deposits, etc., weathered.
↑	Volcanic Breccia		Volcanic breccia partly intercalated sandy tuff and andesite lava.
	Tuff		Tuff partly intercalated tuff breccia, tufficious mudstone, tufficious sand, andesite lava and pumice layer.
	Alternation of andesite Lava and Volcanic Breccia		Alternation of andesite lava and volcanic breccia.
	Limestone		Chalky limestone, partly calcarenite.
Miocene	Green Tuff		Green tuff, green volcanic breccia, green tuff breccia, propylite, acidic welded tuff, liparite, etc.

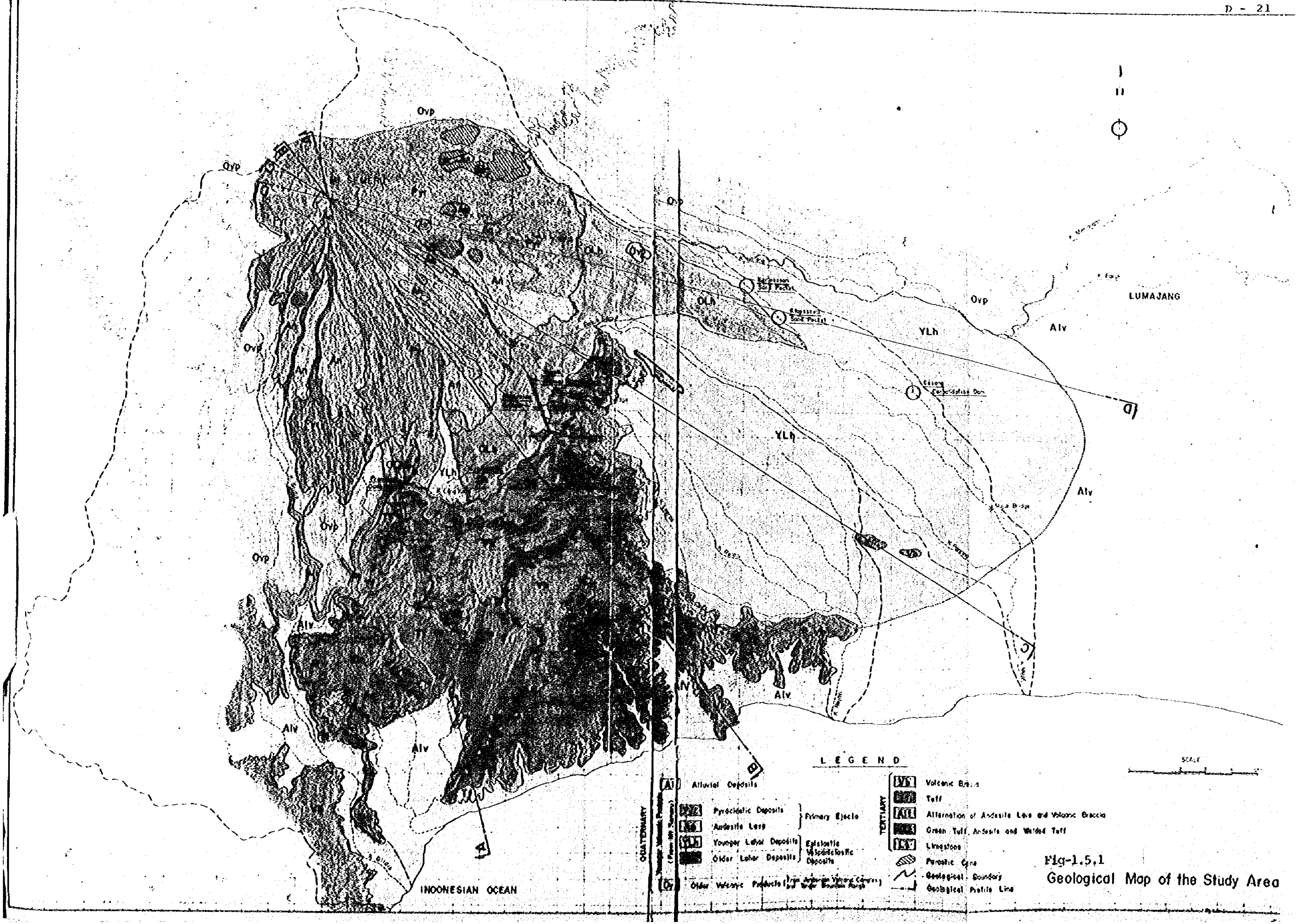


Fig-1.5.1
Geological Map of the Study Area

GEOLOGICAL PROFILE OF PROJECT AREA

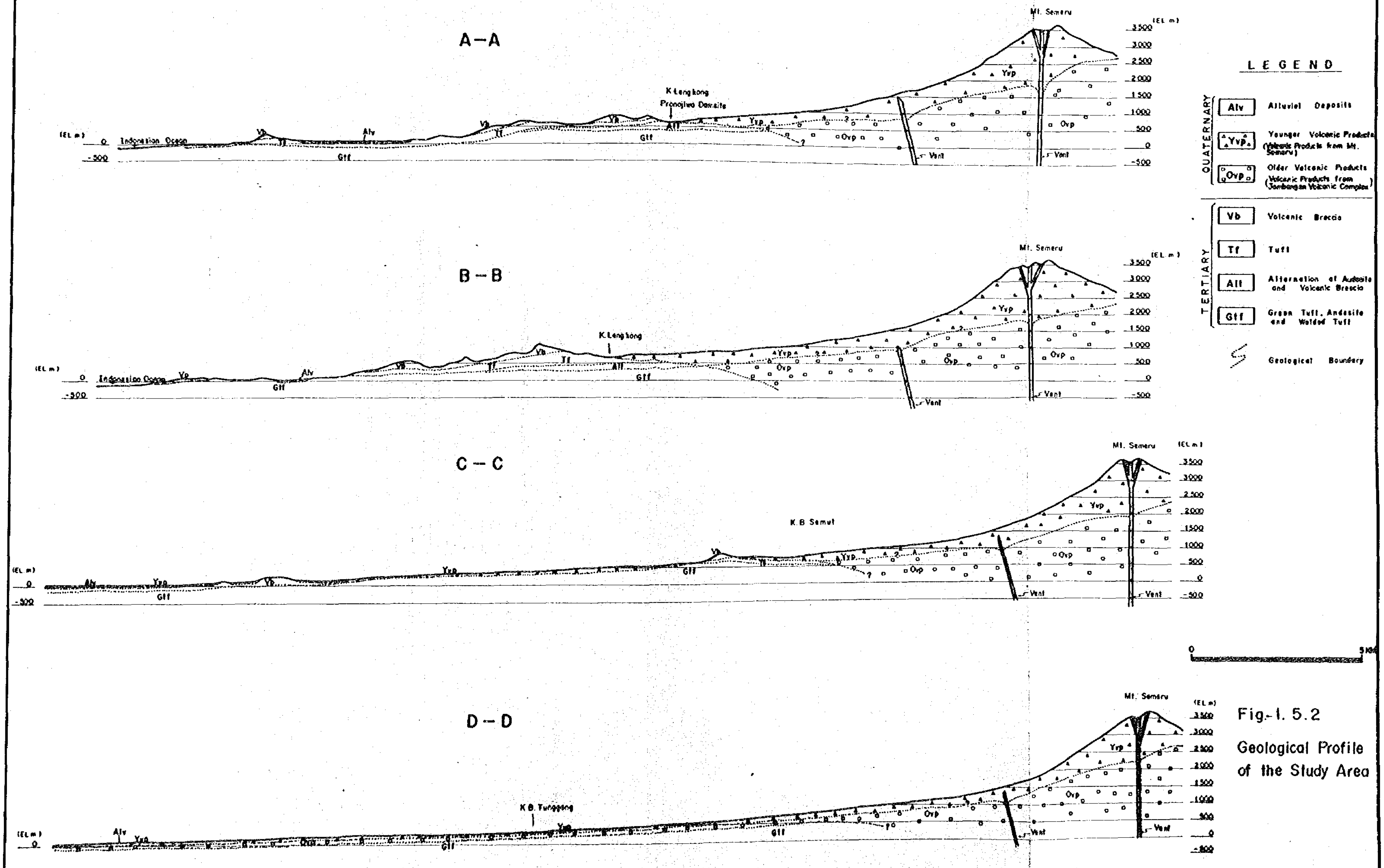
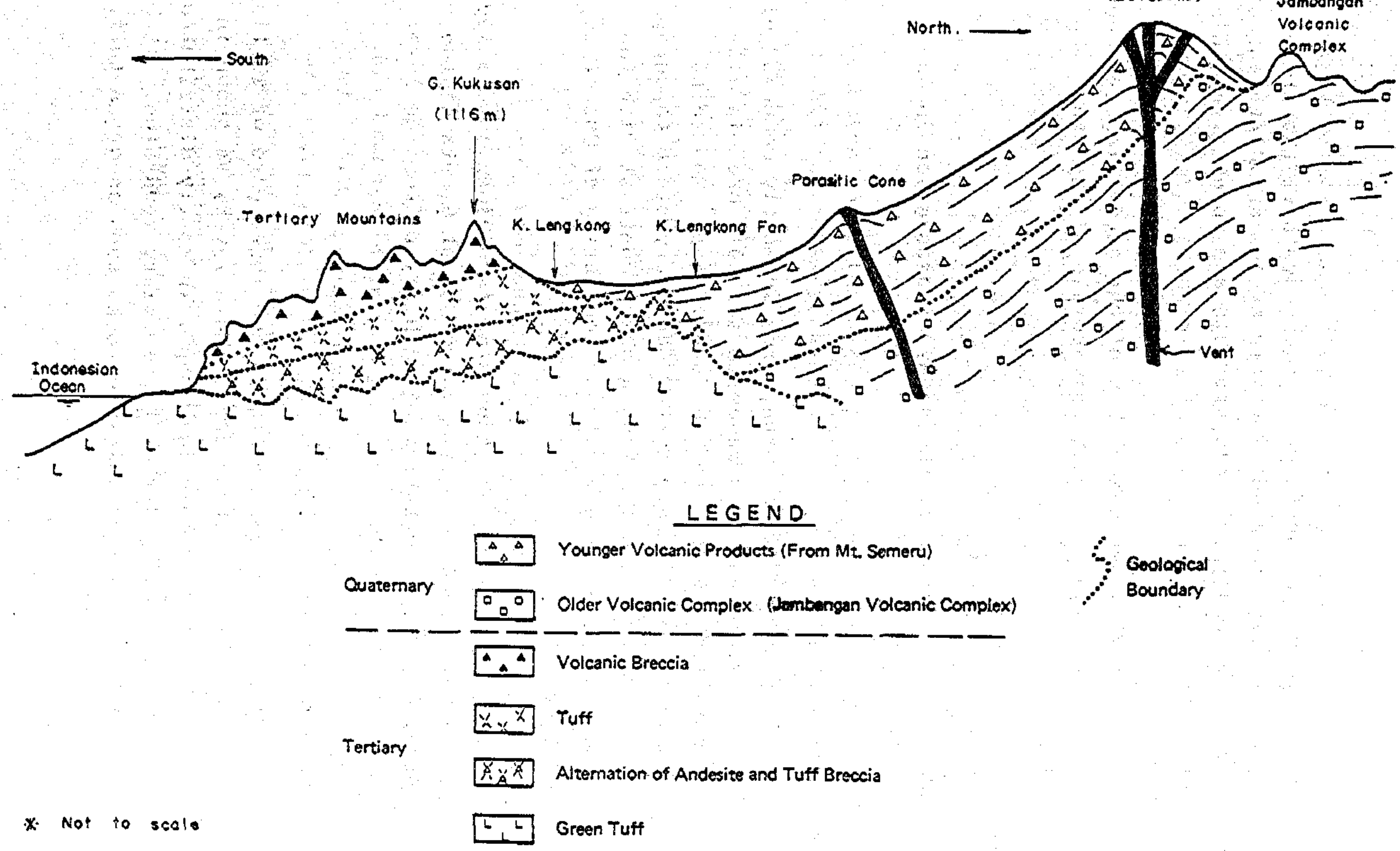


Fig.-I. 5.2 Geological Profile of the Study Area

Fig.- 1.5.3 Schematic Geological Profile of the Study Area



As indicated in the figure, in the south of the study area, basement rocks of Tertiary system are distributed, abutted by older volcanic products and younger volcanic products.

In Fig.-1.5.1, Geological Map of the study area is shown and in Fig.-1.5.2, Geological Profile of the study area is given.

(2) Sequence of Strata

Sequence of strata of the study area is given in Table-1.5.1.

(3) Tertiary System

Tertiary system of the study area is mostly composed of such volcanic rocks as andesite and tuff breccia distributed in the south of the study area. Mountains consisting of Tertiary system show very steep topography of the mature stage, making a sharp contrast with the smooth slope of Semeru Volcano consisting of Quaternary system.

Tertiary system of the study area is divided into 5 layers as shown in Table.-1.5.1. "Sequence of Strata of the Study Area". Description of each layer from the lower layer is given below:

-: Green Tuff

Green tuff seems to lie at the lower pare of Tertiary system of the study area. This layer, as shown in Fig.-1.5.1, "Geological Map", is mostly distributed in the eastern border of the Tertiary mountains. It consists of various volcanic rocks such as green tuff,

tuff breccia, andesite, propylite, rhyolite acidic welded tuff, etc. The geological structure of this layer is much complilated, altered and very similar to so called "Green Tuff" in Japan. Thickess of this layer in the study area is over 150 m.

-: Limestone Layer

Limestone in the study area, as shown in Fig.-1.5.1 is exposed only at the estuary of K. Glidik. It extends as wide as some 10 km as like a belt along the southern coast of Java Island about 10 km westwards from the west of K. Glidik.

Limestone near the estuary of K. Glidik is well stratified, chalky, sandy. Partly caves are often observed in this layer. At Umbul Sari, abundant spring water is observed in the caves. As this layer is greatly limited in distribution, the stratigraphical relation with green tuff is not known. Thcikness of this layer is over 70 m.

-: Alternation of Andesite/Tuff Breccia

This layer is composed of andesite and tuff breccia (or volcanic breccia) with thickness of each stratum ranging from 5 to 20 m. Andesite is very compact and also phenocyst of olivine is particularly noticeable. Tuff breccia is grey-brown, weak and partly turned to clay. Most of them show a autobrecciated condition. This layer is distributed from the downstream of K. Lengkong to the middle - downstream of K. Glidik and the downstream of C. Kobo'an check dam on the both banks, forming a steep cliff. Especially on both banks along K. Glidik, a very steep cliff as high as

100 to 150 m in a relative elevation is formed. On the downstream of C. Kobo'an check dam, this layer is observed discordantly underlain by lower green tuff. According to seismic sounding, andesite in this layer shows a very high value of P wave velocity at 4.2 km/sec. Electric sounding shows a resistivity value of over 10,000 Ωm of the alternation of andesite/tuff. Thickness of the layer is about 300 m in northwestern part of the Tertiary mountains but in southeastern part of the mountains it seems to be very thin or non-existent.

From the geomorphological view point, on the other hand, it can be presumed that this layer does not belong to Tertiary system but is a product from Quaternary Jambangan complex, abutting the Tertiary mountains. Since no actual abutting outcrop has been found, however, this report takes a veiw that it belongs to Tertiary system.

-: Tuff

This layer is mostly composed of tuff, sandy tuff, mudstone and sometimes intercalating tuff breccia and andesite lava. In the tuff layer, cross lamina is often observed. According to geophysical sounding, the velocity of P wave of this layer is 1.5 km/sec and the resistivity value is 5 - 40 Ωm. This layer is presumed to be in conformity with the alternation of andesite/tuff breccia at the underneath. Thickness of this layer is about 200 m in the west of the Tertiary mountains but seems to be much thinner or missing in the east. There is possibility that this layer also belongs to Quaternary system as well as Alternation of andesite/tuff breccia from the view point of geomorphology.

-: Volcanic Breccia

This layer is composed mostly of volcanic breccia with intercalating sandy tuff and andesite lava. Gravels in tuff breccia are mostly andesite but some include basalt. Also in volcanic breccia, many autobrecciated lava are observed. This layer forms the top of the mountains as well as a steep ridge in a sawteeth shape. This layer is in conformity with the underlying tuff layer. Thickness of the layer is over 200 m.

(4) Quaternary System

Quaternary system of the study area is largely classified from lower to upper into older volcanic products of Tengger Mountain Range, Jambangan volcanic complex, younger volcanic products which is presently being supplied from Semeru Volcano and alluvium which is being deposited in the volcanic piedmont periphery. Volcanic products from Semeru Volcano are classified according to their origin, primary volcanic products, younger Lahar deposits and older Lahar deposits.

The primary volcanic ejecta are those directly emitted from the center crater or parasitic volcanos and have not shifted from their original place with water. The Lahar deposits are secondary volcanic deposits which have been shifted from their original place with water and redeposited. The secondary volcanic products such as Lahar deposits are called Epiclastic Volcaniclastic Deposits in terms of Volcanology.

They are summarized as follows:

i) Alluvium

Younger Volcanic Products ii) Primary volcanic ejecta

iii) Younger Lahar deposits

iv) Older Lahar deposits

v) Older Volcanic Products

The distribution of volcanic products from Semeru Volcano and its topography is closely related in the following manner.

Geology		Topography	
• Primary Volcanic Products (Primary Ejecta)		Main Part of Cone	
		Ladu fan	Volcanic Fan
Epiclastic Volcaniclastic Deposits	• Younger Lahar Deposits	Lahar fan-A	
	• Older Lahar Deposits	Lahar fan-B	
• Alluvium		Volcanic Piedmont Periphery	

The primary volcanic ejecta are distributed over main part of the cone. On the Ladu fan, a mixture of younger Lahar deposits and primary volcanic ejecta is distributed, but since primary volcanic ejecta are predominant, in Fig.-1.5.1, Geological Map, it is shown as a distribution area of primary volcanic ejecta (Pyroclastic deposits). On Lahar fan-A (the steep sloped fan), both the younger Lahar deposits and older Lahar deposits are distributed but younger Lahar completely cover the older Lahar deposits in Lahar fan-B (the slow sloped fan). On the volcanic piedmont periphery, alluvium of flood deposits are distributed.

Characteristics of the foregoing five deposits are given below.

-: Older Volcanic Products

Older volcanic products, shown in Fig.-1.5.1, Geological Map, are distributed over north eastern part (north of K. Lateng) and western part (west of K.B. Supit) of the study area. Older volcanic products are ejecta from Janbangan volcanic complex and Tengger mountain range and are supplied from R. Kumbolo volcano, R. Hegeyo volcano, Ayeg-ayeg volcano and G. Kepela volcano, etc. Older volcanic products consist of pyroclastic flow sediments (sediments such as Nuée Ardente, pumice flow, etc.), falling volcanic ash, falling pumice, Lahar deposits and andesite - basalt lava, etc. The composition of older volcanic products is very similar to that of younger volcanic products but it is generally well compacted and shows brown to reddish brown color due to weathering. The areas with older volcanic products are well dissected forming steep valleys which suggests long interruption of supply of ejecta from volcanos. In areas between K. Rejali and K. Mujur near the coastline, many mudflow hills of less than 10 m of relative height and about 2 to 40 m in diameter are observed. They contain large boulders of 2 to 4 m dia. in reddish brown laterite. They might have originated in the very big scale volcanic mudflow in the distant past.

-: Older Lahar Deposits

Older Lahar deposits consist of grey - brownish colored, well compacted volcanic ash and gravels. The composition materials are identical to those of younger Lahar deposits. They are classified into older and younger deposits according to the degree of compactness. Older Lahar deposits form old fan (K. Poh Fan, etc.) and are distributed over the upper basin of K. Mujur and in the north of K.Lengkong. In other areas, they have also been observed in many places sporadically exposed on the riverbed and on both banks of rivers. Among these deposits, some show weak stratification. Also carbonated wood pieces are often observed in this deposits.

-: Younger Lahar Deposits

Younger Lahar deposits consist of unconsolidated volcanic ash, sand and gravels. They are very loose and easily broken by hammer. Volcanic ash, silt and sand comprising the matrix of the deposits easily turn slimy when water is added. These younger Lahar deposits form a new fan of B. Sat Fan, B. Semet Fan, K. Rejali Fan and K. Lengkong Fan which covered most of the study area. Younger Lahar deposits thinly cover the whole of older Lahar deposits, with estimated maxiumum thickness of about 50 m to the minimum of several centimeters at the thin part. Younger Lahar deposits generally have thick stratum on the upper stream, containing huge boulders with poor stratification. The diameter of boulders gets smaller, going downstream and the shape of gravels turns from angular to subround. Also each stratum becomes thinner and stratification becomes clearer in the downstream. Some younger Lahar deposits contain pieces of fresh or burned wood.

-: Primary Volcanic Products (Primary Ejecta)

Primary volcanic products consist of ejecta directly emitted from the center crater and craters of parasitic volcanos. They have not been removed by rain water, etc. The consist of Nuée Ardente deposits, lava flow, pumice flow, volcanic bomb, falling volcanic ash and pumice, etc. Excluding lava, they are generally very loose. The main part of cone from EL. 1,500to top, consists of these primary volcanic ejecta only. On both banks of the gali, alternating layers of lava and various primary volcanic products are clearly observed in aerial photo. Since the deposits in the area are very loose, there are many landslides and collapsings. Especially around EL. 2,500 m a big scale collapsing can be observed. Between EL. 1,500 to 800 m, the so called Ladu Fan, younger Lahar deposits formed by re-shifting of primary volcanic ejecta due to rain, etc. and primary volcanic products which have not been re-shifted are intricately intermingled. Also in this area, many lava flows are formed characteristically which are mostly andesite. From aerial photo, characteristics of topography of lava flow which are wrincles, marginal natural embankment, etc., can be clearly observed. Another characteristics is that parasitic volcanos located between EL. 1,000 to 1,500 m have craters from which much lava came down.

-: Alluvium Deposits

Alluvium deposits are distributed at the Volcanic piedmont periphery surrounding volcanic fan, coveing the whole Lumajang plain. They are comprised mostly of sand, silt, round pebbles and sub-angular pebbles which are deposited in unconsolidated condition. There is no clear distinction between alluvium deposits and Lahar deposits at the end of the fan since the change is gradual. The distribution of brown consolidated gravels and sand layers is observed in lower part of the unconsolidated alluvium in some places. This is presumed to be old flood plain sediments deposited at the time of creation of older Lahar depsoits.

According to the data of well in Semeru Project Office (NO. SUMUR TW 36EJ TOMPO KERSAN), even though drilling was made through to a depth of 125 m, the bedrock was not reached, for sand and silt layers, with sporadically interposing gravel layers continued. Also pieces of wood were collected from each layer.

(5) Geological Structure of the Study Area

The study area comprises Tertiary system and Quaternary system, but since the respective structure differs greatly, they are discussed separately below.

-: Geological Structure of Tertiary System

Green tuff, layers at the bottom of Tertiary system in the study area repeat foldings and are dissected by faults at many places, showing a very complicated geological structure. Also at many places alteration along faults, fissures and cracks has caused them to turn into caly. Also intrusion of dacite (rhyolitic) is observed downstream of C. Kobo'an. According to Van Bemmelen in 1938, such complicated geological structure of green tuff, etc. (so called Old Andesite), deformation and Alteration are explained as due to the intrusion of granite batholith in the middle Miocene period.

The bedding plane of limestone distributed near the estuary of K. Glidik, is generally horizontal with caves developing along the bedding plane. As shown in Fig.-1.5.1, Geological Map, both ends of limestone come in contact with tuff breccia and whether limestone layer overlain by the tuff breccia is exposed as Fenster without faults or bordered by faults at both ends is not known.

Alternation of andesite/volcanic breccia, tuff layer and tuff breccia layer are presumed to be continuously superposed without long hiatas covering discordantly green tuff layer of underneath. Small folds are observed in these layers and they gently slope towards south (toward Indonesian Ocean). Faults are rarely observed in these layers.

-: Geological Structure of Quaternary System

Areas where older volcanic products and younger volcanic products are thickly distributed are called Solo Zone and are a series of large depression zones of basement. Volcanic products of Quaternary priod filled the depression zones up toward to the sky. In those older and younger volcanic products of Quaternary period, folds and faults by crustal movement are not observed but sometimes small folds and faults due to compaction settlement are observed.

The internal structure of stratovolcano is not generally well known despite its prevalence all over the world. Fig.-1.5.4 shows a schematic profile of the presumed structure of Semeru volcano. From EL. 1,500 m to top, primary volcanic products distributed and from EL. 1,500 m to 800 m, primary volcanic products and epiclastic volcaniclastic deposits (Lahar deposits) are intermized and below El. 800 m, epiclastic volcaniclastic deposits are distributed on the mountain surface. Between EL. 800 to 1,500 m it is considered as interfinger section of primary volcanic products and epiclastic volcaniclastic deposits (Lahar deposits). As shown in Fig.-1.5.4, bedding plane of volcanic products is considered to be roughly parallel with the present slope of volcano.

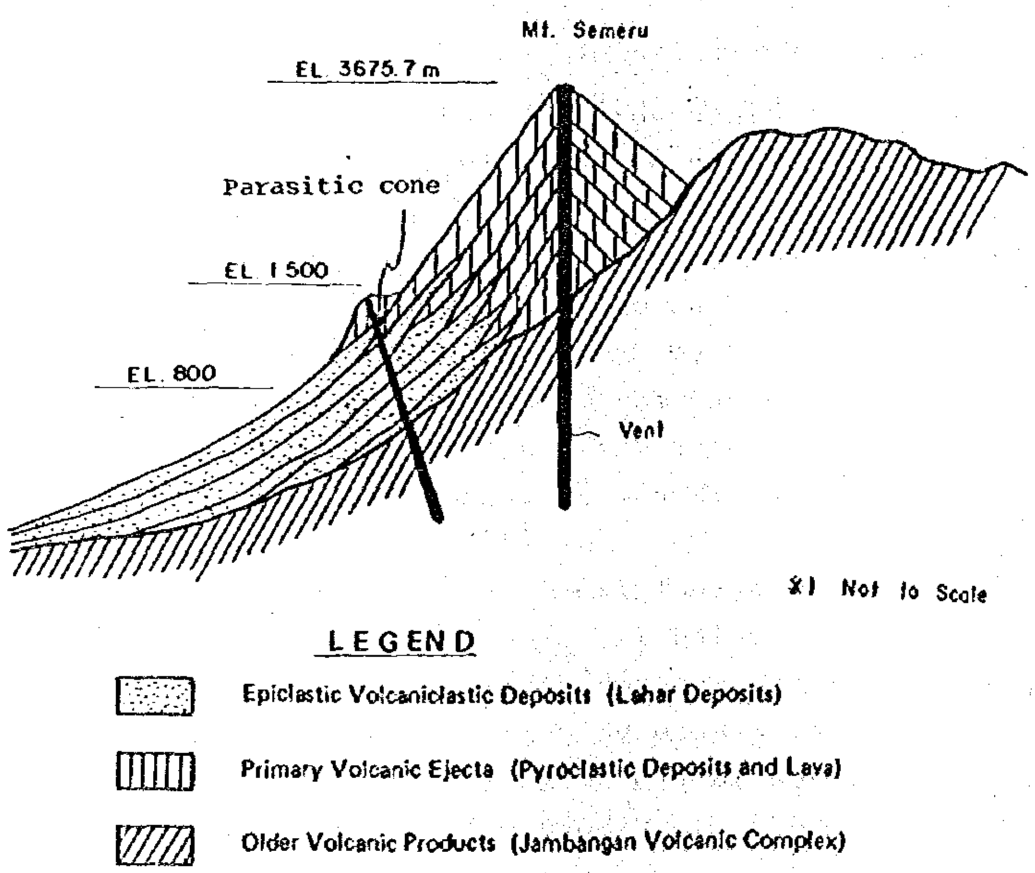


Fig.- 1.5.4 Schematic Structural Profile of Mt. Semeru

On the ring at EL. 1,500 m around Semeru volcano, several parasitic volcanos are lined up where a circular fault is presumed to exist. Also as shown in Fig.-1.4.1, a volcanic row of Tengger - Semeru consists of a series of volcano whose craters extend in N-S direction and volcanic row crosses Solo Zone extending in E-W direction at right angles. For this reason it is presumed that a large transverse fault zone runs cutting across Java Island along Tengger - Semeru volcanic row extending in N-S direction.

(6) Classification of Volcanic Products

In this study, younger volcanic products from Semeru volcano are classified into following two categories according to their origin.

a) Primary volcanic products

b) Epiclastic volcaniclastic deposits (Lahar deposits)

-: Primary Volcanic Products (Primary Ejecta)

Primary volcanic products, which have not been re-shifted by precipitation, and/or graded by water, are directly derived from the center crater and parasitic volcanos. They are comprised lava flow, volcanic ash, scoria, pumice, volcanic blocks, etc. These are, as shown in Fig.-1.5.1, distributed mostly above EL. 800 m.

We often hear the word "Ladu". This word is not founded on any academic background but it seems to be an inhabitants' word indicating the general pyroclastic flow phenomena. According to Mr. Suryo of the Geological Survey of Indonesia, "Ladu" as shown in Fig.-1.5.6 and Fig.1.5.7, indicates a dense mixture of hot volcanic ash and breccia in lower part of Nuee Ardente, and low density part consisting of hot volcanic ash and gas in upper part of Nuee Ardente is called "Awan Panas" (hot cloud) in Indonesia.

-: Epiclastic Volcaniclastic Deposits (Lahar deposits)

When unconsolidated Primary volcanic products mix with water from precipitation thus losing their solidity, landslides and collapsings will occur causing dense mass of debris (2 ton/m^3) over-saturated with water to rush down. This is the so called Lahar. Lahar while rushing down erodes the surroundings and gradually increases its volume. Most disasters around Semeru volcano are caused by Lahar. This is because Lahar extends to densely populated areas causing overflows of the channels. Such Lahar deposits are called Epiclastic Volcaniclastic deposits in terms of volcanology.

When Lahar is caused by heavy rainfall, it is called rain Lahar. When its source is hot pyroclastic materials and Lahar is also hot, it is called hot Lahar. As Lahar rushes down, it deposits gravels and sand, finally becoming flood flow consisting of water and clay, silt, sand and fine gravels. This is the so called Banjir in Indonesian language. But the term Banjir is not necessarily limited to this usage, for in most cases Lahar and Banjir are used interchangebly by inhabitants. The definition of the term is ambiguous.

In this report, epiclastic volcaniclastic deposits of younger volcanic products (Lahar deposits) derived from Semeru volcano are broadly classified into the following two types based on compactness, which differ greatly between the two. Although there may be some epiclastic volcanistic deposits contained in alluvium deposits, it is not classified as epiclastic volcaniclastic deposits, since it contains many non-pyroclastic deposits such as clay layers.

- Younger Lahar deposits (Very loose and fresh)
- Older Lahar deposits (Very compact and somewhat weathered)

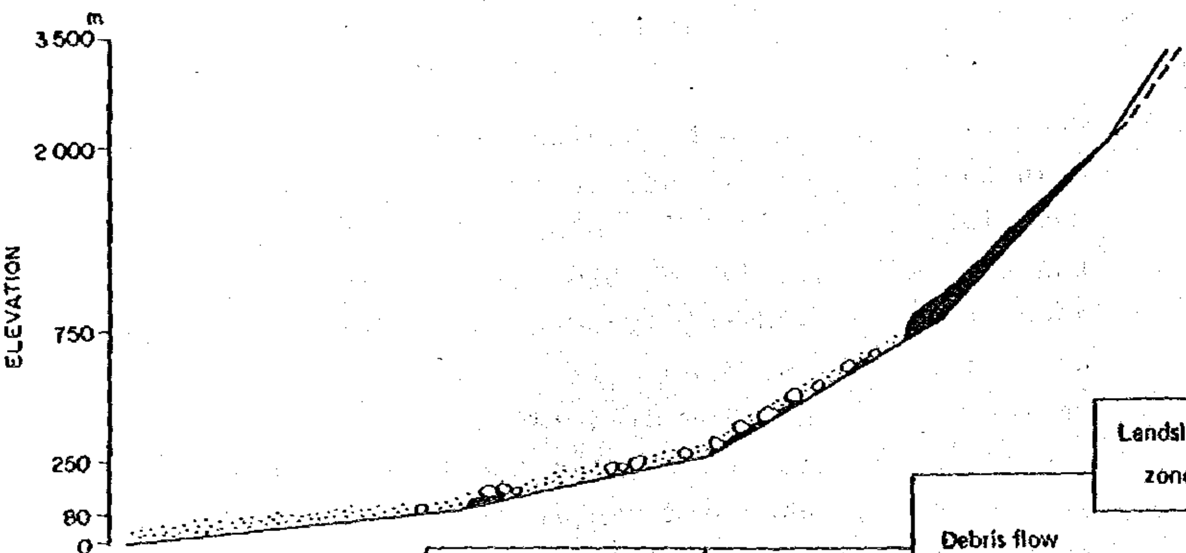
In Supporting Report (5) Part J, Debris Flow, for new deposits of Lahar disaster in 1981, epiclastic volcaniclastic deposits (Lahar deposits) are classified into the following 4 types based on the mode of occurrence.

i) Debris flow deposits

ii) Mudflow deposits A

iii) Mudflow deposits B

iv) Bedload flow deposits (Same as alluvium deposits)



Classification of Deposits	Bed load flow deposits zone	Mud flow zone – B	Mud flow zone – A	Debris flow deposits zone	Landslide zone
		Mud flow deposits zone			
Remarks	All parts are bed load flow deposits	Some parts are of mud flow deposits. Some parts are of bed load flow deposits.	Most parts are of mud flow deposits.		
Topography	Peliphery	Lahar fan (Gentle slope)	Lahar fan (Steep slope)	Ladu fan	
Regional Geological Study	(Alluvial Deposits)	Younger Lahar Deposits		Primary Volcanic Ejecta	

Fig. -1.5.5 Zone Classification by Sediment Type
(From Supporting Report (5), Part J - Debris Flow)

For details of the above 4 types, please refer to Supporting Report (5) Part J, Debris Flow.

In the regional geological survey, 3 types of deposits, i.e.: debris flow, mudflow A & B are grouped together as Lahar deposits, for the simple reason that the different types of epiclastic volcaniclastic deposits (Lahar deposits) of various disasters are very intricately accumulated in one outcrop making application of the foregoing 4 classifications impossible when discussing regional geology.

Fig.-1.5.5 shows a schematic correlation among topographical classification, deposits classification in the mudflow study and classification in regional geological survey.

1.5.3. VOLCANIC ACTIVITY OF SEMERU VOLCANO

(1) Characteristics of Volcanic Activity of Semeru Volcano

In ancient time, Semeru volcano was a small volcano created at the southern end of Jambangan volcanic complex. However, its crater has been slowly moving southward to the present position. The present summit of Semeru volcano is an old crater called Mahameru and the present active crater is located at the lava dome called Joggring Seloko 650 m south of Mahameru at EL. 3,564 m.

The past volcanic activities of Semru volcano are considered to be a continuation of small eruptions judging from the distribution of the surrounding volcanic ejecta. In other words, around Semeru volcano no thick falling volcanic ash due to large scale eruptions nor welded tuff due to large scale Nuèe Ardente are observed. Also the distribution of volcanic ejecta such as volcanic bomb and lapili, etc. is limited to the high elevation (EL. 2,500 m or higher) of the volcanic cone and not very extensive. From these findings, it is assumed that Semeru volcano has not had large eruptions.

At present, eruptios of Semeru volcano are small and repeated at an interval of every 5 to 10 minutes. According to observation records compiled since 1818, Table-1.5.2 (1) to (5), several cycles of active period and dormant periods are alternately repeated as shown in Table-1.5.3. This is one characteristic of Semeru volcano. According to Fig.-1.5.3, Semeru volcano is now in an active period. Also notable is the fact that Nuèe Ardente and Lahar are concentrated on the southeastern slope of Semeru volcano or more precisely between K. Glidik and K.B. Sat and does not rush down to other areas.

Table-1.5.2 (1) Volcanic Activity of Mt. Semeru

Year		Activity
Nov.	- 1818	In this case, activity means eruption. If it is commented by "lava flow", it means that at that time, except eruption, lava flow also occurred. (A note from translator)
Feb.	- 1829	
Dec. 15, 16	- 1830	
Apr. 18	- 1832	
Aug. 3, 5	- 1836	
Jul., Oct.	- 1838	
Jan. Mar.	- 1842	
Sept.	- 1844	
Jul.	- 1845	
Feb. Aug.	- 1848	
Jan.	- 1851	
Sept. 10	- 1856	
Aug. 13, Sept.	- 1857	
Apr., Jun.	- 1860	
Jul.	- 1864	
Apr., May	- 1867	
Oct. 23	- 1872	
Apr., Sept.	- 1877	
	- 1878	
Dec. 11	- 1884	
Jan., Apr. Jul., Sept.	- 1885	Lava flow
Jan., Apr. Jul., Aug.	- 1886	
Feb., Mar. Sept. 10, Oct. 10	- 1887	Lava
Feb., Mar. May, Oct.	- 1888	
Jan., Mar. Jun., Oct., Dec.	- 1889	Lava flow
Jan., Dec.	- 1890	

Table-1.5.2 (2) Volcanic Activity of Mt. Semeru

Year		Activity
Feb., May	- 1891	Lava flow
Mar., Apr.	- 1892	
Jan., May, Dec.	- 1893	
Feb.	- 1894	
May 22, Jul. 10 Oct. 1	- 1895	Lava flow and Lahar flood. Farm land was damaged.
May, Jun.	- 1896	
Jan.	- 1897	Lava flow
Feb.	- 1898	Lava flow
Jan., Mar., Aug., Dec.	- 1899	
Mar. 29, Apr. 11	- 1900	Lava flow
Jan. 29, 30	- 1901	
Jun. 26	- 1903	
Jan. 2, 16	- 1904	
Aug. 4	- 1905	
Jan. 7, 10	- 1907	
Jan., Dec.	- 1908	
Sept., Dec.	- 1909	Nuée Ardente
Jan., Mar., Nov.	- 1910	
Jan., Feb.	- 1911	Lava flow, Nuée Ardente, Lahar flood. Farm land was damaged in Nov. - Dec. 1911.
Aug. 28	- 1912	
Jun. 23	- 1913	
Sept. 21, 1941 - Feb. 1942		Eruptin from radial cleave, lava flow rushed down to Besuk Semut river and buried Bantengan Irrigation Station. Lava flow was 5.6 km long.
Jun. 12 - 18	- 1945	

Table-1.5.2 (3) Volcanic Activity of Mt. Semeru

Year	Activity
1946	Nuée Ardente. Farm land was damaged Feb. - May, Oct. - Dec., was forming lava doom.
1947	- Mar. - Jun.
1950	- Lava flow rushed down to Besuk Semut river Jul., Nov. 23 - Dec.
1951	- Lava flow rushed down to Besuk Semut river; November.
1952	- Lava flow rushed down reaching Mt. Totogan Malang and Kobo'an river - Curah Lengkong river.
1953	- Material producted by avalanche increased.
1953	- Lava flow rushed down to Kobo'an river.
1955 - 1957	- Activity increased. Lava flow in Feb. 22, May 4, 1947.
1958	- Lava flow rushed to Glidik river 1 km long. Apr. 27 - lava doom formed.
1960	- May
1961	- April, May, August
1961	- Eruption. Pyroclastic ejected out. Forest near Besuk sat and Besuk Tompe (rivers) was burnt. Lava flow rushed to Glidik, Kembar, Bang and Kobo'an (rivers).
1962	- Lava flow rushed to Kobo'an & Curah Lengkong and Besuk Semut river. Nuée Ardente of Avalanche type rushed to Besuk Semut river.

Table-1.5.2 (4) Volcanio Activity of Mt. Semeru

Year	Activity
1963	- May 5, at 14:10 p.m. Nuée Ardente entered Curah Lengkong. Kali Pancing and Besuk Semut, about 8 km distance from the summit. Lava flow was running to Curah Lengkong, Kali Pancing and Blank Semut. The activity rested July.
1964	- The eruption blew out ash. Sometimes also blew out the greyish-white ash to 4,000 m high. Nuée Ardente rushed down to Besuk Semut, Curah Lengkong and Kembar river.
1965	- The activity was only blowing ash through the year. The ash reached up 50 - 100 m high, in April, ash reached up 500 m high above crater.
1966	- Blowing ash through the year.
1967	- Since September, it showed a new activity. Lava doom was formed at the south side of crater rim, as the upper stream of Glidik, Bang, Sat and Kobo'an river. Lava doom was formed precisely at the centre point of eruption in 1963. Secondary Lahar occurred at Glidik, Kobo'an and Rejali rivers.
1968	- Lava doom formation was continually going on. Lahar flood killed 3 persons at Sumber Wangkal village.
1969	- Lava doom formation was still going on.
1970	- Eruptions through the year and lava flow.
1971	- Eruptions went on.

Table-1.5.2 (5) Volcanic Activity of Mt. Semeru

Year	Activity
1972	- Eruptions went on. Nuèe Ardente rushed to Glidik river.
1973	- Since August, lava doom was formed and lava tongue increased. Nuee Ardente rushed to Kobo'an river.
1974	- Eruptions was still going on.
1975	- Eruption and lava flow in July.
1976	- Eruptions. Nuèe Ardente of explosion and avalanche type rushed down to Kobo'an river.
1977	- Eruptions and Nuèe Ardente rushed to Lengkong river, Kobo'an and Kembar river.
1978	- Eruptions went on. Jan. 15, 17, 23 - 1978, Nuèe Ardente rushed down to Kembar river (6,000 m - distance from top) and April 6, 13, 29 - Nuèe Ardente was rushing to Kobo'an, and Kembar river. (7,000 m distance from the top). June 2, Nuèe Ardente again rushed down to Kobo'an river (4,000 m - distance). August, Nuèe Ardente rushed down again to Kobo'an and Kembar river (7,000 m - distance).
1979	- Eruptions and Nuèe Ardente went on actively.
1980	- Gas eruptions, Nuèe Ardente rushed to Kembar river.
1981	- Gas eruptions, Nuèe Ardente rushed to Kembar river. March 28, avalanche type rushed to Bang river (10.5 km - distance from the top) and to Besuk Kembar river (4 km - distance from the top).

Table-1.5.3 Periods of Activity and Dormancy of Mt. Semeru after 1818. (A. SAKAI AND I. SURYO, 1980)

Period of Dormancy (Year)	Period of Activity (Year)	Number of Year
1818 - 1829		11
	1829 - 1848	20
1848 - 1856		8
	1856 - 1865	9
1865 - 1872		7
	1872 - 1879	7
1879 - 1885		6
	1885 - 1913	28
1913 - 1941		28
	1941 - 1942	1
1942 - 1945		3
	1945 - 1947	2
1947 - 1950		3
	1950 - Present	-

(2) Nuée Ardente

At present, Semeru volcano is frequently shooting up great amount of white smoke. Part of the smoke is observed drifting down K.B. Bang and K.B. Kembar on the south-eastern slope of the volcano. At nigh, many incandescent lava blocks can be observed rolling along the slope from the flashing crater. These are small scale Nuée Ardente and many recorded Nuée Ardente are given in the history of eruptions as shown in Table-1.5.2.

Since Nuée Ardente is very hot (about 900 centigrade around the crater) and the flow speed is very fast (90 to 100 km/hr) flowing down in near gaseous condition, easily passing over obstacles, forecasting, shielding and sheltering are very difficult. Consequently, it causes very severe damages. Although no direct damage by Nuée Ardente has been reported in the study area, in 1885 and 1895 the crater rim was broken by the ascending pressure of lava dome resulting abundant volcanic products rushing down the slope inflicting great damage to the villages. Nuée Ardente is classified into two types "Nuée Ardente Avalanche Type" and "Nuée Ardente Explosion Type". According to records of volcanic eruptions, both types of Nuée Ardente occurred at Semeru volcano. Schematic drawings of the two types of Nuée Ardente are given in Fig.-1.5.6 and Fig.-1.5.7.

-: Nuée Ardente of the Avalanche Type

While rushing down the slope, incandescent lava blocks are further broken into fine particles producing a mass of pyroclastic materials such as hot ash, sand and angular gravels, etc. This mass floating in the hot air and volcanic gas rushes down along the

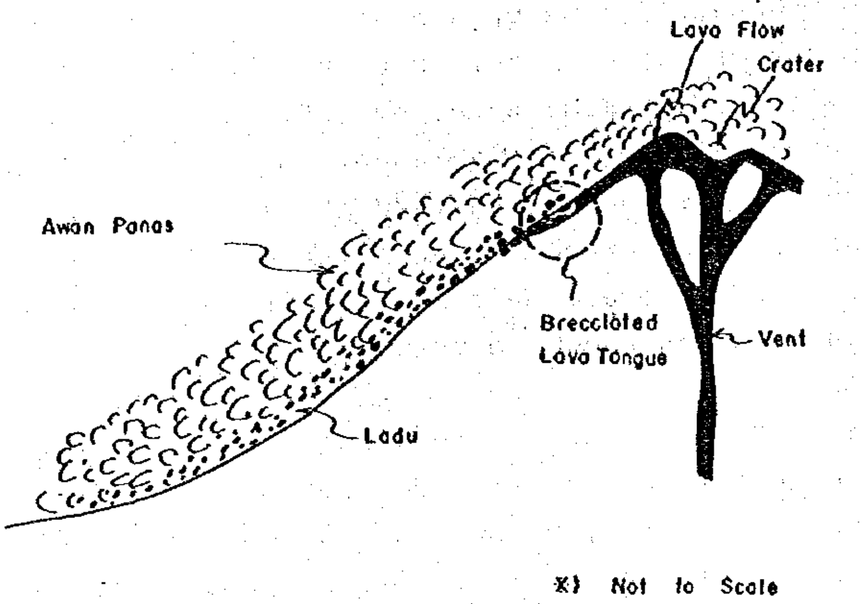


Fig. - 1.5.6 Nuée Ardente of the Avalanche Type

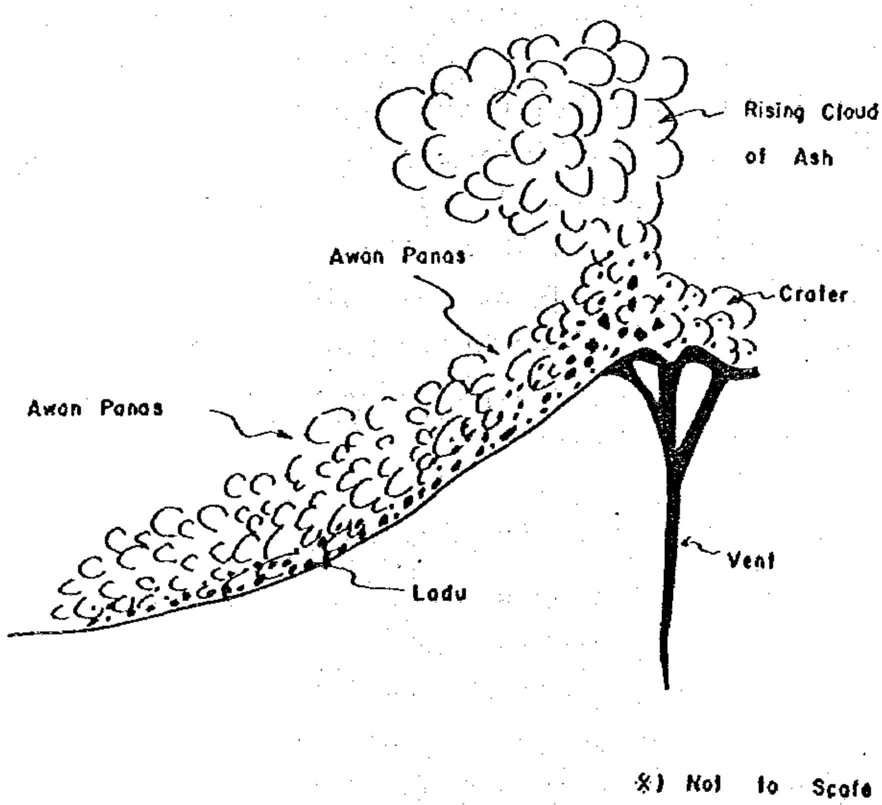


Fig. - 1.5.7 Nuée Ardente of the Explosion Type volcanic slope at a great speed. This is Nuée Ardente of the avalanche type. This Nuée Ardente of the avalanche type rushes down at a speed of 90 to 100 km/hr extending to a distance of 4 to 5 km from the central crater of Semeru volcano.

Upper part of Nuée Ardente is comprised of less dense cloud like volcanic ash and lower part is comprised of dense gruel like volcanic ash mingled with angular gravels. The former is called "Awan panas" and the latter "Ladu" in the Indonesian language.

-: Nuée Ardente of the Explosion Type

Nuée Ardente of the explosion type is direct ejecta from the crater composed of materials roughly similar to Nuée Ardente of the avalanche type. The characteristic of Nuée Ardente of the explosion type is the emission of cauliflower-like smoke from the crater when Nuée Ardente is emitted. Both Nuée Ardente of the explosion type and Nuée Ardente of the avalanche type are composed of "Awan panas" and "Ladu". The rushing down speed of Nuée Ardente of the explosion type, which is little faster than that of Nuée Ardente of the avalanche type, is about 100 km/hr extending to a distance of 6 to 7 km from the crater.

(3) Lava Flow

At Semeru volcano, a great amount of lava have been emitted from the central crater and parasitic volcano craters. Lava of Semeru Volcano sometimes changed its lithological facies from andesitic to basaltic, but andesitic facies are predominant.

The thickness of andesite lava flow of Semeru volcano is ten to several tens of meters with an apparently very slow flow speed. The surface of lava covered with smooth polyhedron blocks. Wavy lava wrinkles are clearly observed at right angles to the direction of flow. Surface and bottom parts are comprised of polyhedron shaped lava blocks. Central part is compact and homogenious.

The lava flow of such nature is generally called Block Lava often observed in relatively high viscosity lava flow such as andesitic, dacitic and rhyolitic type.

A notable example of lava flow of Semeru volcano, occurred on Sept. 21, 1941, in which lava gushed out from a fissure 1.3 km long ruinning in N - S direction on the south-eastern slope toward K.B. Semut. This was a typical Block Lava of andesite with the temperature of 1,060 C at the start. When it finally stopped in Feb., 1942 it had extended 6.9 km in length and had covered an area of 3 km . Its volume amounted to about 3,000,000 m^3. While the descending speed of lava flow was 500 m/day at the start, it suddenly slowed down. At the end of flow in Feb., 1942, it had only reached 6.9 km from the crater. The results of the chemical analysis of lava show pyroxene, augite andesite containing 57% of SiO_2. This andesite lava filled up the upper stream of K.B. Semut. As a result, the basin of the upper reaches of K.B. Semut has shifted to the basin of K. Rejali. For this reason, Lahar disasters rarely occur in K.B. Semut basin, while they are more frequent in K. Rejali basin.

(4) Relation Between Volcanic Activity and Lahar Disaster

According to records of disasters and eruptions of Semeru volcano, volcanic activities and occurrence of Lahar seem to be closely related. In other words, more Lahar occurs in the active period of Semeru volcano. After big-scale eruptions, large scale Lahar is apt to occur since primary volcanic ejecta just deposited on the slope are loose and very unstable, breaking easily with precipitation. In such cases, hot Lahar often occurs.

(5) Volcanic Activity and Rain

In "The Java, Part II" by Junghahu, local inhabitants are quoted as saying the volcanic activities become more active in the rainy season. Dr. M. Newman Van Padang, a volcanologist, however denies this theory, saying that smoke emitted in the dry season shows a grey color giving the impression of thinness, while in the rainy season the smoke shows a dark grey color giving the impression of thickness. The impression of thickness could mislead the inhabitants to judge the eruptions in the rainy season to be larger than they actually are. Also he claims that in the rainy season, because the top of Semeru volcano cannot be seen since it is covered with clouds, this may further help misleading of the inhabitants' judgement.

1.5.4 HYDROGEOLOGY

In terms of hydrogeology, it is assumed that in the present study area on the foot of Semeru volcano an impervious basement is composed of: i) andesite, tuff and volcanic breccia of Tertiary System and ii) older volcanic products of Jambagan Volcanic Complex. In short, compared with loose younger volcanic products of Semeru volcano, the degree of consolidation of Tertiary System and older volcanic products is quite high. Further, it is assumed that there is a thick layer of laterite rich in clay, produced as a result of tropical weathering, over the surface of the impervious basement.

Younger volcanic products of Semeru volcano assumed to be a relatively pervious layer are composed of primary volcanic products and epiclastic volcaniclastic deposits, as described in 5.2 "Geology
of the Study Area". Semeru volcanic fan is mostly composed of epiclastic volcaniclastic deposits. A theoretical hydrogeological model of Mt. Semeru is represented in Fig.-1.5.8.

Although part of the precipitation falling on the slope of Semeru volcano streams downward as run-off, it is suspected that some rain water would infiltrate into the volcanic cone thus forming ground water coursing in the interior of Semeru volcano. It is thought that the strato-structure of Semeru volcano shown in Fig.-1.5.4 would strongly control and influence the manner of flows of ground water created by the infiltration of rain water.

In general, as volcanic products of Semeru volcano includes a large amount of fine particles of ash, etc., its permeability is believed to be rather low being in the order of $K = 10^{-4}$ cm/sec. Ground water is thought to be coursing through water veins in the volcanic products of Semeru volcano.

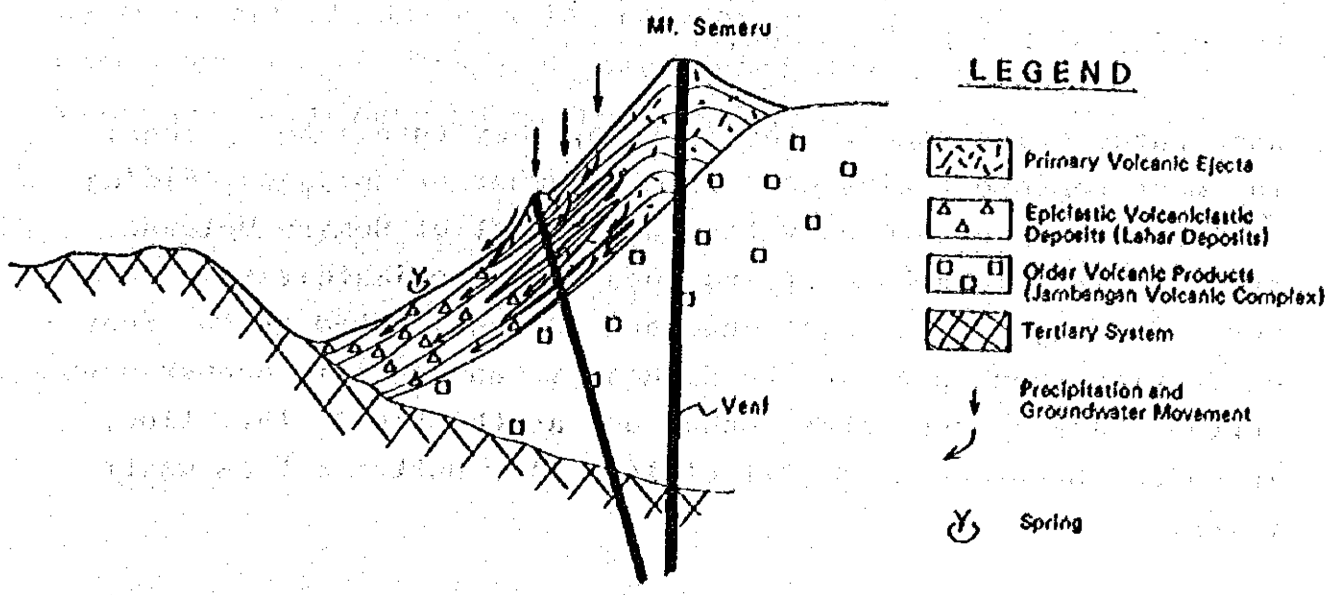


Fig.- 1.6.8 Schematic Hydrogeological Model of Mt. Semeru

The possible water veins for ground water to flow through would be: i) Lava rich in crack, auto brecciated part at the bottom of lava flow, ii) pyroclastic deposits or Lahar deposits with few fine materials, iii) filled old river courses and gullies. Through such water veins, ground water is assumed to flow along the bedding plane of volcanic deposits of Semeru volcano. The permeability coefficient of water veins is presumed to be in the order of $K = 10^{-2}$ cm/sec.

When water veins rise to the surface, they turn into springs. The most representative ones from a number of springs yielding copious volume of ground water in the foot of Semeru Volcano are at: i) Selokambang spring located approximately 5 km due west of Lumajang City, ii) Jugosari spring located at the foot of Tertiary Mountains in the K. Rejali Fan and iii) Sumber Urup spring where ground water gushes out at the tip of lava flow, in which autobrecciated part of lava flow bottom act as water veins.

Towering to the southwest of Semeru volcano, Tertiary Mountains, composed of Tertiary System believed to form the impervious basement in the foot of Semeru volcano. In the Teritary mountains ground water level is relatively high.

The Tertiary Mountains district is covered densely with vegetation. Even during the dry season, there is some water in valleys. Moreover, in the severely weathered tuff along K. Lengkong there is a tubular water vein of 1 - 2 cm in diameter providing spring water all the year round.

The Tertiary Mountains district is believed to abound in ground water. As was described in he geology section of the study area, because there are numerous existing faults with complicated geological structure in Tertiary System, its hydrogeological structure can only be assumed to be also similarly complicated.

As a particular example of springs in Tertiary System, there are caves in limestome layers distributed in a very narrow area near the mouth of K. Glidik yielding a large volume of water. Considering the small scale of rock mass of limestone layers and topographical features, it appears that this spring is issueing from K. Glidik coursing just in the back of small rock mass of limestone layers. On the other hand, because there is no limestone distributed in the foot of Semeru volcano, continuous caves capable of developing into a system of water veins are believed to be nonexistent.

1.6 GEOLOGICAL SITUATION OF THE PLANNED SITES OF MAJOR SABO FACILITIES AND WATER CONSERVATION

Fig.-1.5.1 Geological Map shows the location of the major planned sites of sabo facilities and water conservation.

1.6.1 PRONOJIWO DAMSITE

Pronojiwo damsite is an important site of debris control plan along K. Glidik.

(1) Topography

Pronojiwo damsite is located east of Pronojiwo village at the west end of the study area. It is located around the boundary between steep Tertiary mountains to the south and relatively gentle Semeru volcano mountain slope to the north. In the damsite, K. Lengkong runs westward.

The width of K. Lengkong at the damsite is 40 to 60 m with about 10 m high cliffs along both banks of the river. The right bank of the damsite is a small flat hill surrounded by K.B. Bang and K. Urung-urung. The left bank of the damsite is the foot of Mt. Kukusanseriti at EL. 945 m with terrace like topography of about 150 m in width.

Immediately downstream of the damsite, there is a fall of about 15 m in height. Further downstream from the fall, K. Lengkong dissects deeply to form a steep valley.

(2) Geology

As shown in Fig.-1.6.1 Schematic Geological Profile of Pronojiwo Damsite, the damsite is composed of Tertiary volcanic breccia and andesite lava and older Lahar deposits from Semeru volcano. On the riverbed of the

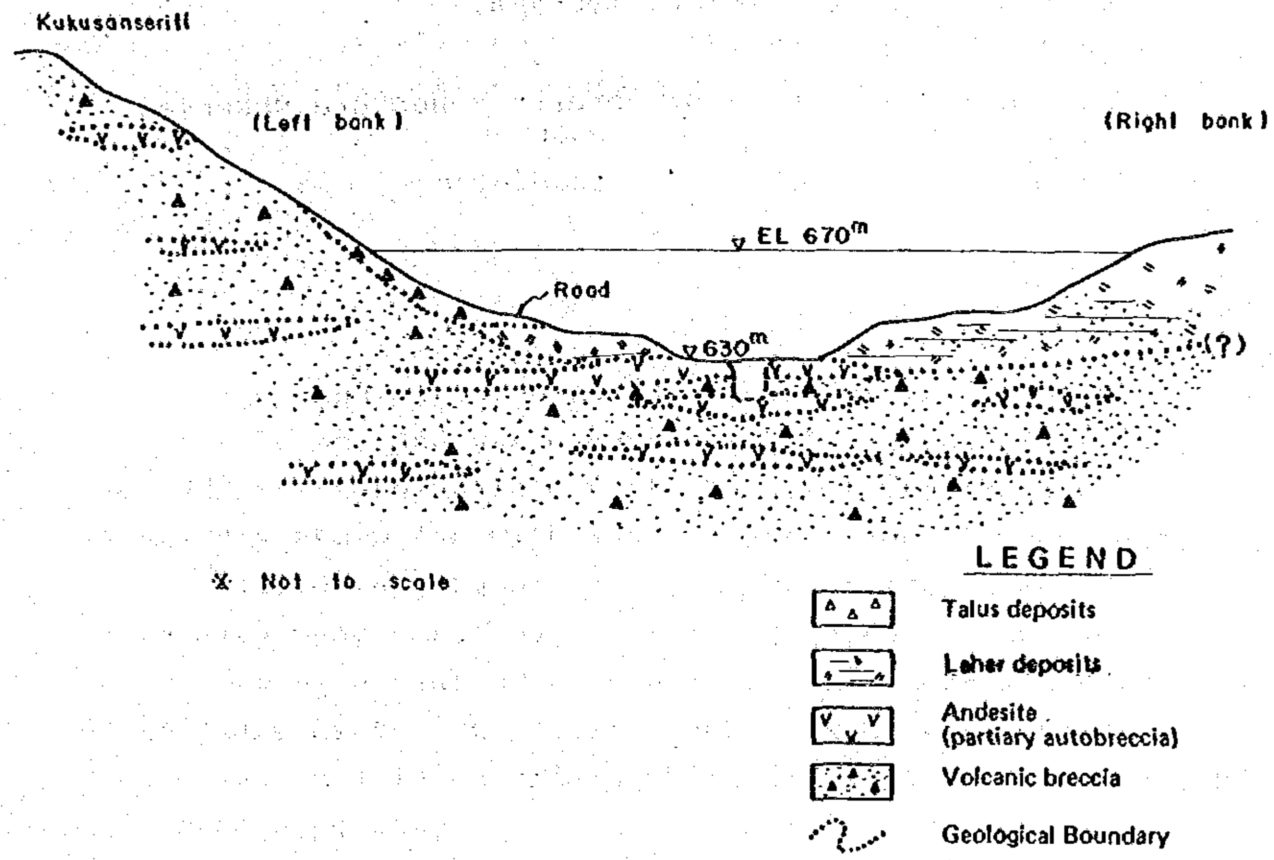


Fig.- 1.6.1 Schematic Geological Profile of Pronojiwo Damsite

damsite, andesite lava of about 10 m in thickenss is distributed roughly horizontally and is underlain by weak volcanic breccia. On both banks older Lahar deposits thickly cover these Tertiary Systems.

At the damsite no faults or sheared zones are observed.

1.6.2 K. LENGKONG FAN

At the foot of K. Lengkong Fan, K. Lengkong flows to west. By constructing a sabo dam at the foot of K. Lengkong Fan, volcanic products from Semeru volcano can be stored thus preventing re-erosion of sediments. As a subsidiary utility ground water in the stored sediments and K. Lengkong Fan and also surface water on K. Lengkong Fan can be developed. A project of this nature is being planned.

(1) Topography

K. Lengkong Fan, located in the southeastern slope of Semeru volcano, and was damaged by Lahar disaster of 1977 and 1978 tus turning into waste land. K. Lengkong Fan, a relatively steep fan with inclination of about 2 degrees, is classified topographically as Lahar steep sloped fan containing many small gullies dissected on its surface. On the opposite side of K. Lengkong Fan a mountain range of Tertiary System EL. about 1,000 m extends from east to west creating a large shield which blocks volcanic products from Semeru volcano.

(2) Geology

As shown in Fig.-1.6.2 Shematic Geological Profile, geology of K. Lengkong Fan consists of volcanic rocks of Tertiary System (tuff, andesite, etc.), consolidated older Lahar deposits of Semeru volcano covering the former discordantly and loose younger Lahar deposits of 1977 and 1978 on the surface. Also on the north of K. Lengkong Fan, there are andesite lava from parasitic volcano.

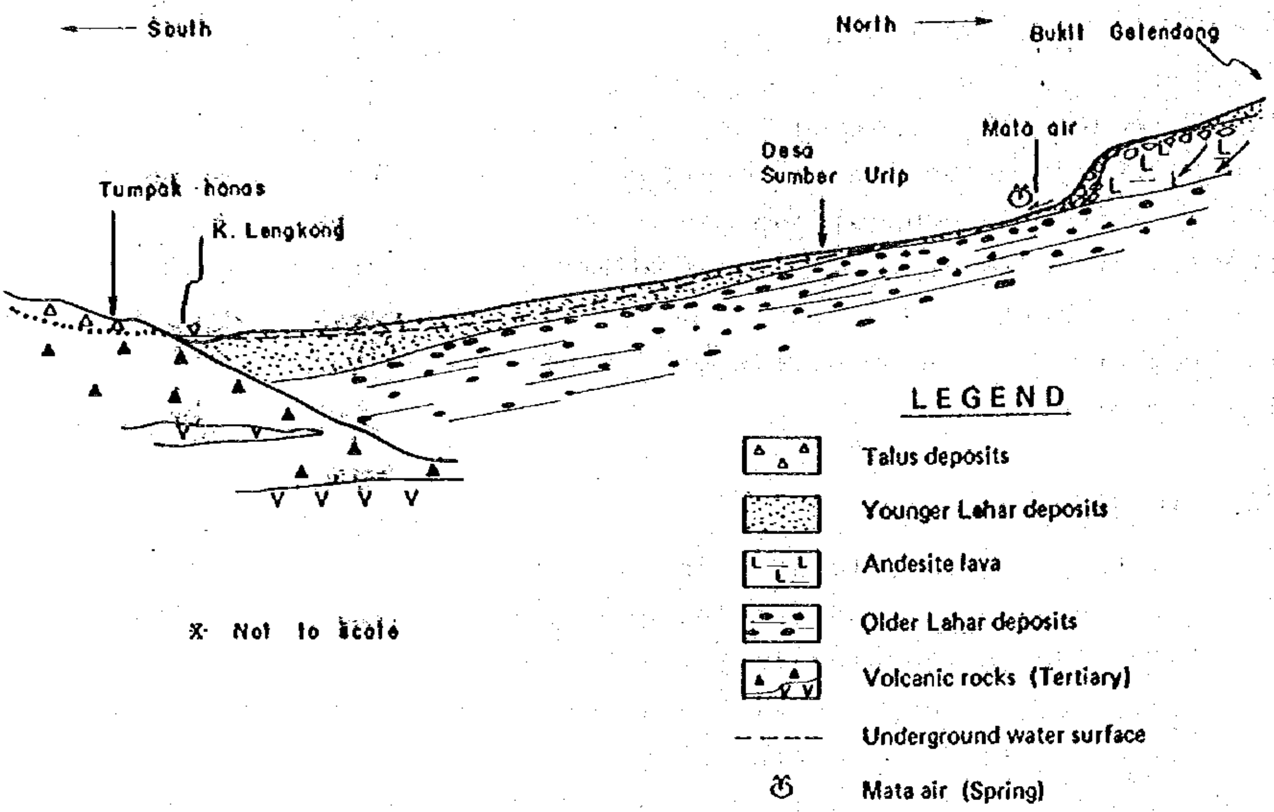


Fig.- 1.6.2 Schematic Geological Profile of Kali Lengkong Fan

Ground water of K. Lengkong Fan is located at a shallow place of 1 to 4 m from the ground surface even in the dry season according to Preliminary well inventory. Local inhabitants say that in the rainy season the ground water level generally rises about 1 m. Water is observed in the gullies even in the dry season. The spring is located at EL. 820 to 830 m. The rivers become dry at EL. 830 m or higher.

1.6.3 DIVERSION CHANNEL

Ther is a plan for a diversion channel from K. Curah Kobo'an to the upstream of K. Lengkong. The object of the diversion channel is to divert Lahar flow from K.C. Kobo'an to the upstream of K. Lengkong to protect K. Rejali fan that is a frequent Lahar disaster area on the downstream of the K.C. Kobo'an from Lahar disaster.

(1) Topography

This area is located on the relatively steep slope of Semeru volcano and its inclination is about 2 degrees. In the south of this area, mountains of Tertiary System EL. about 1,000 m rise which block volcanic products from Semeru volcano. The inlet of the diversion channel is planned between about 1.5 km to 2.5 km upstream from C. Kobo'an check dam. While K.C. Kobo'an flows in southeast direction in this section, on the downstream of this section, the river course abruptly turns toward east. The width of K.C. Kobo'an in this section is about 200 m and cliffs of relative height of about 10 to 20 m are formed on both banks.

The outlet of the diversion channel is planned at 1.5 km southeast from C. Kobo'an check dam and located at the boundary of Tertiary mountains and the foot of Semeru volcano.

(2) Geology

Geology around the planned course of the diversion channel mostly consists of older Lahar deposits of highly consolidated gravels and sand. Around the outlet, soft Tertiary tuff is distributed. On both banks of K.C. Kobo'an around the inlet, highly consolidated older Lahar deposits are exposed with loose gravels distributed on the riverbed.

Near the river course, there is no lava flow on the surface and presumably no large lava flow exists in older Lahar deposits from topographical viewpoint.

1.6.4 CURAH KOBO'AN CHECK DAM

(1) Topography

Curah Kobo'an check dam is located in front of the narrow and steep valley of Tertiary mountains. The fan of Semeru volcano (K. Poh Fan) expands on the left bank of the damsite. The right bank is composed of steep Tertiary mountans.

The left bank of the damsite has cliffs of relative height of about 20 m while the left bank is a slender ridge sticking out like a paninsula. The width of K.C. Kobo'an at the damsite is about 150 m with a fall of relative height of about 3 m immediately downstream of the damsite.

(2) Geology

As shown in Fig.-1.6.3, the bedrock of C. Kobo'an damsite from bottom to top, is composed of white altered dacite, mudstone of about 100 cm in thickness, andesite lava of about 3 m in thickness covered with alternation of tuff and tufficious mudstone. The aforesaid layers are all Tertiary System. The said Tertiary tuff and mudstone layers form mountains extending over the right bank of the damsite.

On the left bank of the damsite, older Lahar deposits are distributed discordantly covering the Tertiary System.

In older Lahar deposits immediately downstream on the left bank of the damsite, small new landslide is observed. At the border of the Tertiary System and older Lahar deposits at the foot of the landslide, springs are observed in many places.

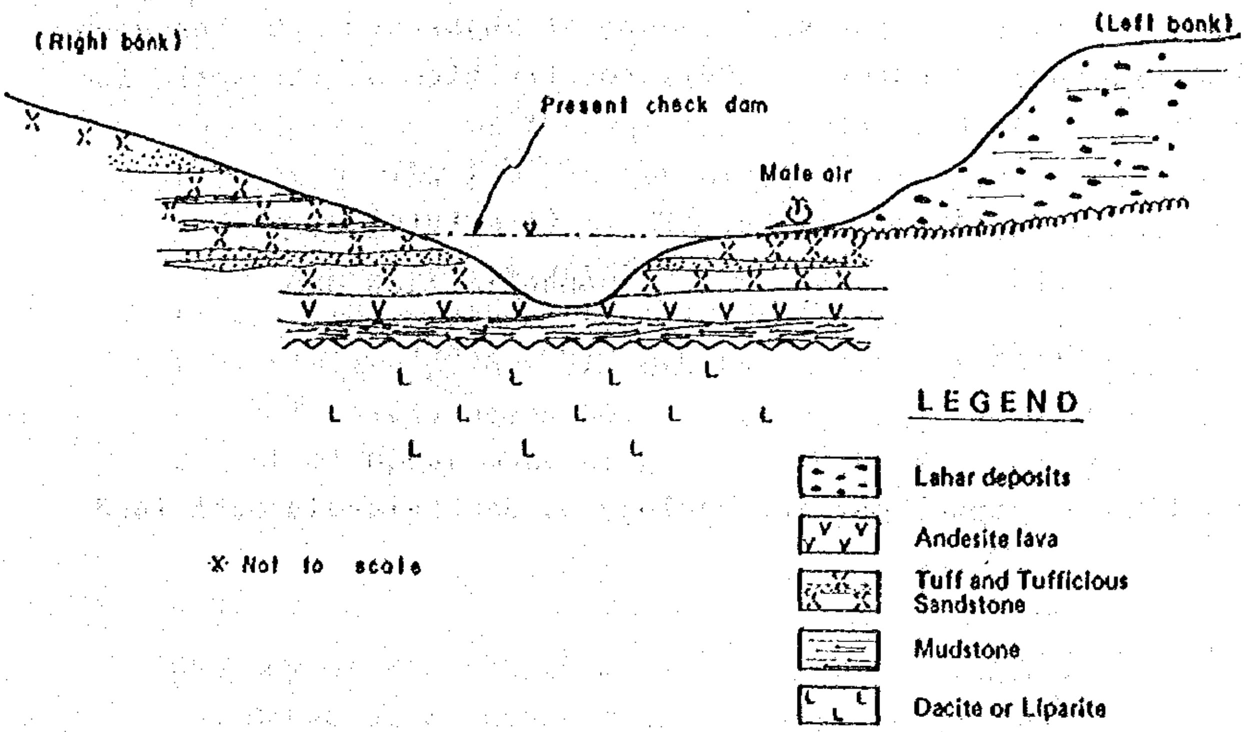


Fig.- 1.6.3 Schematic Geological Profile of Curah Koboan Damsite

1.6.5 SABO FACILITIES SITES ALONG K. MUJUR AND K.B. TUNGGENG

On three sites in the basin along K. Mujur and K.B. Tunggeng hit by Lahar disaster of 1981, construction of the following structures is proposed.

Name of Site	Structures
Gesang	Consolidation dam
Kloposawit	Sand pocket
Kertosari	Sand pocket

Outline of topography and geology of each site is described below.

(1) Gesang

-: Topography

Gesang is located in the middle reaches of K. Mujur at the central to south side of B. Sat Fan. The topographic study indicates that this proposed site is located in the gently sloped Lahar fan, (Lahar fan-B).

Here the width of K. Mujur is about 100 m with 3 to 6 m high cliffs on both banks.

-: Geology

On both banks of K. Mujur at Gesang site, highly consolidated older Lahar deposits are found, however, on the edge of both banks and on the riverbed, loose younger Lahar deposits of 1981 still remain.

The ground water table at this site seems to be shallow. Out-permeation of ground water from both banks is observed.

(2) Kloposawit

-: Topography

Kloposawit site is located around the confluence of K.B. Tunggeng and K. Poh about 1.8 km upstream from the confluence of K. Mujur and K.B. Tunggeng. This site is nearby flat in topography where Lahar was spread widely in 1981. Therefore, its surrounding area extensively covered with boulders of various sizes. The width of the riverbed is about 100 m and the relative height of both banks is as low as 1 to 3 m. This site is located at steep Lahar fan (Lahar fan-A) of upper part of B. Sat fan by topographical classification.

-: Geology

Geology of Kloposawit site consists of highly consolidated older Lahar deposits and loose younger deposits (mostly from disaster of 1981) on top. Younger Lahar deposits over older Lahar deposits are generally thin with the latter cropping out sporadically on the riverbed as fensters.

Younger Lahar deposits are not distributed over the right bank of K. Poh but are found over both banks downstream of the confluence point of K.B. Tunggeng and K. Poh.

Ground water seems to be located in shallow depth with out-permeating from both banks of K. Poh.

(3) Kertosari

-: Topography

Kertosari site is located topographically at the steep slope of Lahar fan of upper part of B. Sat fan. The width of the riverbed at Kertosari site is narrow and cliffs of relative height of about 5 m continue on both banks.

-: Geology

Geology of Kertosari site consists mainly of highly consolidated older Lahar. Over the fan on both banks, thre is a thin cover of loose younger Lahar (1981) of few centimeters in thickness. Riverbed deposits distributed on the riverbed is considered to be very thin according to the surrounding condition.

The ground water table at this site is located at shallow depth and out-permeating ground water from older Lahar deposits at several spots is observed on both banks.

1.7 CONSIDERATION

In this chapter geotechnical consideration on the proposed site of main sabo facilities and water convervation is discussed.

(1) Pronojiwo Damsite

Andesite lava distributed on the riverbed is sufficiently strong with its shear strength presumed to be more than $\tau_o = 120$ ton/m^2. But tuff breccia lying underneath is weak and a detailed study must be made on the slipping along the boundary between both layers. Over the right bank of the damsite though older Lahar deposits consisting of highly consolidated gravels are thickly deposited it cannot be used for foundation of a large concrete structure. Also topographic shape of the right bank is very poor. These are serious obstacles in designing a high dam. Considering the above topographical and geological conditions, construction of a dam of more than 40 m in height would seem to be quite difficult.

Lahar deposits, andesite lava and welded tuff of Tertiary green tuff are considered as available source of aggregate layers. Andesite lava, as shown in Fig.-1.5.2 Geological Map, is located relatively close to the damsite. Its volume is very large, and its quality is generally good, though partly porous and brittle. But since the areas where lava flow is distributed are located on the steep slopes in the middle of Semeru volcano, access may be somewhat difficult. These are dangerous areas because pyroclastic flow often rushes down upto this area. Tertiary welded tuff is distributed in the mountains in the north side of C. Kobo'an valley. It is generally hard and compact with fe fissures showing very little effect of weathering. As aggregate material, this layer has the best quality in the study area. Since these are very steep mountins, it would appear that quarrying would be difficult. Lahar deposits distributed all over the study area are excellent for quarrying. Lahar deposits contain various sizes of andesite gravels. Although different from place to place, content of gravels, by visual inspection, seems to be generally over 50%. On the other hand, however, silt which makes greater part of Lahar deposits may affect the yield.

Highly weathered tuff distributed over the foot of Tertiary mountans and highly weathered layer of green tuff are considered as available source of soil material. Highly weathered tuff very rich in fine particles, having a high content of natural water is not a good material for embankation. Its quantity is large, and is easily accessible from topographical point f view, however. While highly weathered layer of green tuff has a proper mixture of gravels and fine particles and its quality is better than weathered tuff, it is thinly distributed over very steep mountain slope, perphas making borrowing very difficult.

(2) K. Lengkong Fan

Since the ground water level in K. Lengkong Fan is very shallow (-1 m to -3 m), spring water is available even in the dry season. The area is considered to abound in ground water. As a hydrogeological structure it can be considered, on the whole, to be an aquifer of younger volcanic products on the impervious basement of Tertiary system. It is believed to be a structure regulated by strata-structure of Semeru volcano.

(3) Diversion Channel

Geology around the planned course of diversion channel consists mostly of older Lahar deposits with no thick lava flow. Geology around the outlet consists of soft, weathered Tertiary tuff. From the foregoing, in excavating a diversion channel, mechanical instruments can be used instead of explosives.

(4) Curah Kobo'an Check Dam

There are following problems with regard to geology and topography of the Curah Kobo'an Check Dam.

- Hard andesite lava distributed on the riverbed is as thin as 3 to 5 m. Beneath the lava there is weak mudstone (uniaxial compression strength is 23 kg/cm^2 - 28 kg/cm^2).

- Tuff forming a hill on the left bank is soft and highly weathered.

- The shape of the right bank is a slender ridge and its capacity is small.

- On the left bank. Older Lahar deposits are thickly deposited but they are too weak to constract any large structures.

From the foregoing, it is considered very difficult to construct a dam as high as 30 m. But since hard andesite is distributed on the riverbed, it is considered to be possible to construct a dam of about 20 m in height.

(5) Sabo Facilities Sites along K. Mujur and K.B. Tunggeng

On 3 sites of Gesang, Kloposawit and Kertosari, Younger Lahar deposits and riverbed deposits lie over older Lahar deposits. The depth of older Lahar deposits on the river-bed in Gesang site seems to be large substantial, but it seems very shallow at Kloposawit and Kertosari sites. The ground water seems to be located at shallow depth at these 3 sites.

1.8 POLICY OF GEOLOGICAL INVESTIGATION WORKS

In Chapters 1.6 and 1.7, outlines of geology and topography and geothechnical considerations are given on the planned site of major sabo facilities and water conservation. Based on the results, various geological investigation works and laboratory tests were prepared.

Table-1.8.1 summarizes the items of survey, objective, methodology, expected results and location of investigation works.

Before undertaking the studies, JICA Study Team prepared specifications of the works and submitted them to Semeru Project Office.

The specifications are summarized in Supplement Report D-1 SPECIFICATIONS OF GEOLOGICAL INVESTIGATION WORKS.

The results of various survey works and tests are discussed in Chapter 2.

Table-1.8.1 Items of Geological Investigations

Item	Objective	Methodology	Results	Location
Hydrogeological Survey	To assess the potential water utilization volume of Kali Lengkong Fan.	-Drilling work -Electric sounding -In-site permeability test. -Field geological survey in scale 1 = 10,000	Hydrogeological model of Kali Lengkong Fan.	Kali Lengkong Fan
Engineering geology of the foundation	To plan & design structures	-Drilling work -Seismic sounding -Electric sounding -Field geological survey	Engineering-geological maps and profiles of scheduled structure sites.	-Pronojiwo damsite -Gesang damsite -Kloposawit sand pocket site -Kertsari sand pocket site
Materials and soil character-istics testing	-To establish Quarry and borrow site -To study Material character-istics of Kal. Lengkong Fan for hydrogeological analysis.	-Laboratory material test -Laboratory soil test -Field density test	-Quality of quarry and borrow materials. -Relationship between permeability and material character-istics	-Surrounding area of pronojiwo damsite -Kali Lengkong Fan

2. LAND CONDITION

2.1 INTRODUCTION

This chapter i) describes the land conditions of the areas ii) presents an outline of topography and geology and iii) discusses geotechnical considerations based on the results of the study carried out on the proposed construction sites of the following structures and the planned site of water conservation.

(1) Pronojiwo Damsite

..... Proposed site of sabo dam

(2) K. Lengkong Fan

..... Proposed site of water conservation

(3) K. Mujur and K.B. Tunggeng

..... Proposed site of a consolidation dam and sand pockets

The studies were carried out for the above areas as shown in Table-2.1.1.

Of these studies, boring, seismic sounding, electric sounding, in-situ permeability test and laboratory soil test, except geological reconnaissance, were carried out by the Indonesian government. From May to september 1982 and from April through May 1983, JICA Study Team carrried out preparation of the specifications of these tests and survey works, technical advices for the field survey works and analyses of the results of the investigations and tests.

The specifications of the works and tests prepared by JICA Study Team are comprised of the following 7 volumes. The 6

Table-2.1.1 Items and quantities of Geological Investigations and Tests

Investigation Site		Item of Investigation and Test		Quantities
Pronojiwo Damsite	Damsite	Geological reconnaissance	Scale 1:2,000	About 0.5 km^2
		Boring		Total 3 holes, 87 m. Lu test 11 items
		Seismic sounding		Total 6 measured lines, 3 km
	Soil Test	Grain size analysis		2 tests
		Natural water content test		2 tests
		Specific gravity test		2 tests
		Consistency test		2 tests
		Compaction test		2 tests
		Laboratory permeability test		2 tests
	Aggregate Test	Natural water content test		6 tests
		Specific gravity and water absorption test		6 tests
		Grain size analysis		6 tests
K. Lengkong Fan	Field Survey and In-site Test	Geological reconnaissance	Scale 1:1,000	About 3 km^2
		Boring		7 holes, 43 m in '82 and 1 hole '83 60 m Total 103 m
		Electric sounding		50 points
		In-situ permeability test		5 tests
		Field density test		5 tests
	Soil Test	Natural water content test		5 tests
		Grain size analysis		5 tests
		Specific gravity test		5 tests
K. Mujur, K.B. Tunggeng	Gesang Consolidation Damsite	Geological reconnaissance	Scale 1:5,000	About 0.2 km^2
		Electric sounding		16 points
	Kloposawit Sand Pocket Site	Geological reconnaissance	Scale 1:5,000	About 0.2 km^2
		Electric sounding		8 points
	Kertosari Sand Pocket Site	Geological reconnaissance	Scale 1:5,000	About 0.1 km^2
		Electric sounding		6 points
K. Mujur and K. Rejali		Grain size analysis		24 tests
		Specific gravity test		6 tests
		Field density test		6 tests
		Measurement of grain size by photo		6 - 120 photos

volumes from a to f were submitted to Department of Public Works (hereinafter called DPU) on June 10, 1982. Volume (g) was presented to DPU at the end of April, 1983.

Based on the specifications, DPU issued a work order to Institute of Technology of Bandung (ITB) to commence investigation and testing works at the end of June, 1982.

The 7 volume specifications are compiled as Supplement Report D-1 Specification for Geological Investigation Works.

a) Specification of Drilling Work

b) Specification of Seismic Sounding

c) Specification of Electric Sounding

d) Specification of In-situ Permeability Test

e) Specification of Materials and Soil Characteristics

f) Specification of River Materials Characteristics Test

g) Specification of Additional Drilling Work in K. Lengkong Pan

2.2 OUTLINES OF THE STUDY RESULTS

(1) Pronojiwo Damsite

Pronojiwo damsite is comprised of alternation of Tertiary andesite/volcanic breccia on the left bank and the riverbed. On the right bank, Older Lahar deposits which are volcanic products from Semeru volcano are thickly distributed.

Outline of geological and topographical features of the Pronojiwo damsite is given below.

a) The topography of the left bank is sufficiently large but in the right bank K. Urung[2] sharply dissects to form a peninsular-like ridge. The ridge gets thinner at the higher portion to 150 m thick.

b) Rocks exposed on the riverbed are very hard and compact andesite, their shearing strength being estimated at more than τo = 120 ton/m^2. Also since the thickness is more than 10 m, construction of a concrete dam of about 30 m in height is considered to be possible. While volcanic breccia layers distributed below are generally medium in hardness, at places layers are porous and fragile. (Estimated shearing strength is about τo = 30 - 50 ton/m^2).

c) Older Lahar deposits thickly distributed on the right bank is considered and compact.

d) Alternation of andesite/volcanic breccia has low permeability and a zone of less than 5 Lu can be reached in about 10 m after encoutering these layers.

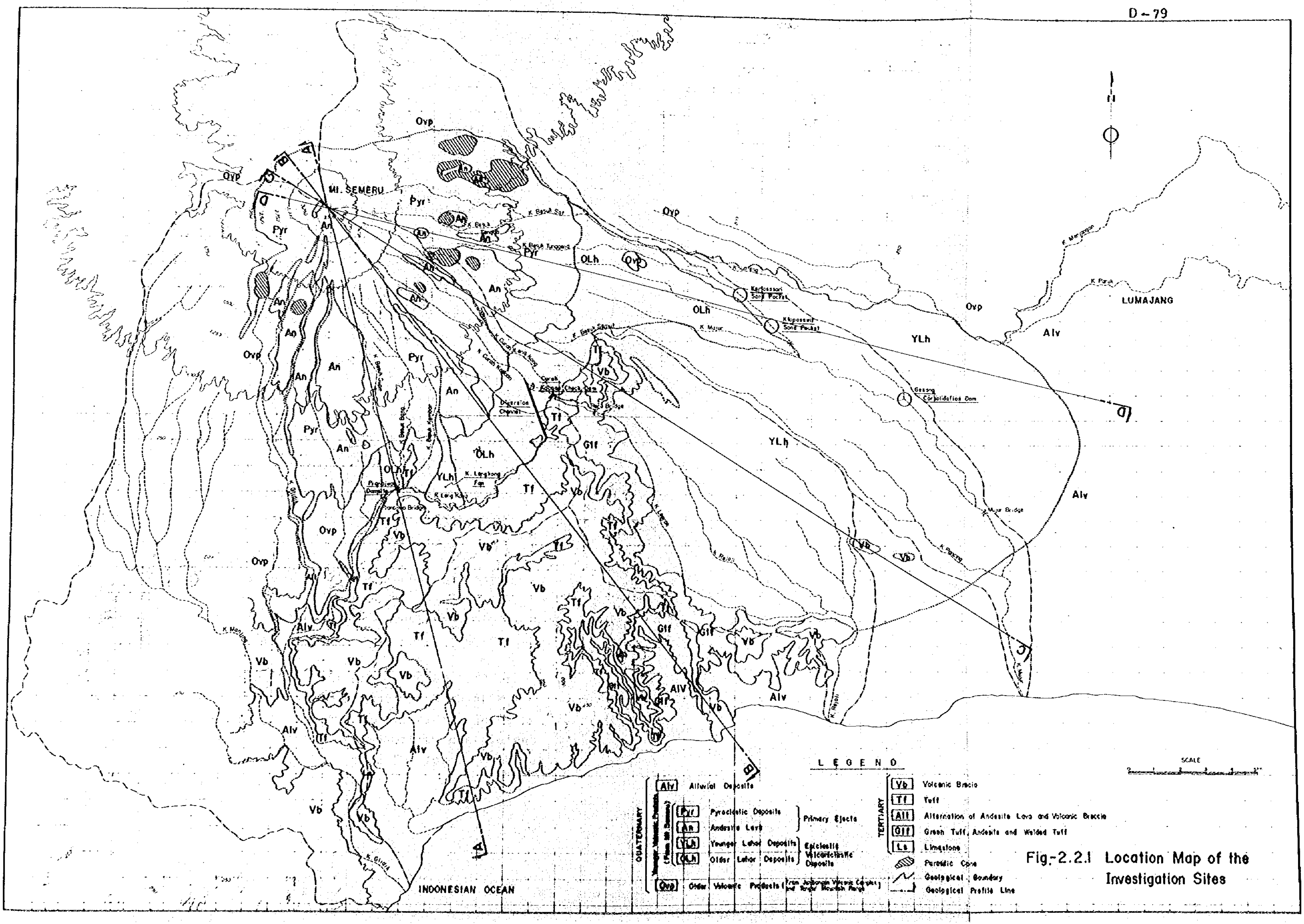


Fig.-2.2.1 Location Map of the Investigation Sites

As the subject of study of the damsite in the future, the following are considered.

a) In older Lahar deposits on the right bank of the damsite, although there are caves of 4 m in diameter at 7 to 8 m depth, their distribution and continuity must be confirmed.

b) Bearing stength and permeability of Older Lahar deposits on the right bank must be confirmed.

(2) K. Lengkong Fan

K. Lengkong Fan damaged by Lahar in 1977 and 1978 has now with turned into waste land. K. Lengkong Fan is a gentle slope with geological feature from bottom to top of tuff, alternation of andesite and tuff-breccia and tuff of Tertiary period as basement, older Lahar deposits laid on the Tertiary basement and younger Lahar deposits of 1977 and 1978 covered on the top. Next, an outline of geological features and ground water of K. Lengkong Fan will be discussed.

a) Permeability coefficient of younger Lahar deposits (1978) is low at $K = 4$ to 5×10^{-4} cm/sec. Permeability coefficient of more compact older Lahar deposits is generally lower than the above figure.

b) Permeability coefficient of highly weathred tuff of Tertiary period on the ground surface is high at $K = 1 \times 10^{-2}$ cm/sec. This is due to larger void ratio of 3 - 4.5 and higher porosity. Permeability coefficient at greater depth is estimated to be far lower, because of compaction due to greater load.

c) Water dries up at about EL. 830 m or higher, but in lower elevation spring water is observed in many places.

d) As a model of ground water of K. Lengkong Fan, basically it is considered to be stratified model strongly regulated by the strato-structure of Semeru volcano.

e) Toward the west of the fan, a ridge of Tertiary tuff runs from north to south in the underground and on the east side of the ridge, a large ground water basin is predicted.

f) The ground water level of K. Lengkong Fan is high at -1 to -4 m during the dry season rising to about 1 m from that of dry season in the rainy season.

The followings are recommended as the study themes of K. Lengkong in the future.

a) Geological structure, permeability, transmissibility, strage and specific capacity of older Lahar deposits in the underground.

b) Regional distribution of Plane of Unconformity between Tertiary system and older Lahar deposits, in other words the shape of impermeable basement.

(3) K. Mujur and K.B. Tunggeng

At 3 sites along K. Mujur and K.B. Lengkong, i.e.: Gesang, Kloposawit and Kertosari, construction of structures is planned. The results of geological survey of these 3 sites are given below.

Table-2.2.1 Geological Conditons of the Planned Site of Gesang Consolidation Dam

Resistivity Layer	Resistivity value (Ωm)	Thickness (m)	Geology
I	140 - 1,000	1.5 - 4	Moving riverbed deposits partly saturated with water, high permeability
II	120 - 280	5.5 - 15	Younger Lahar deposits saturated with water, high permeability
III	350 - 580 (50 - 120)	-	Older Lahar deposits saturated with water, highly compacted, permeability estimated low

Table-2.2.2 Geological Conditions of the Planned Site of Kloposawit Sand Pocket

Resistivity Layer	Resistivity value (Ωm)	Thickness (m)	Geology
I	80 - 1,120	3 - 9	Moving riverbed deposits or younger Lahar deposits partly saturated with water, high permeability
II	290 - 440	3 - 15	Surfaće layer of older Lahar deposits saturated with water, permeability estimated considerably high
III	400 - 710 (100 - 140)	-	Older Lahar deposits saturated with water, highly compacted and permeability estimated comsiderably low

Table-2.2.3 Geological Conditions of the Planned Site of Kertosari Sand Pocket

Resistivity Layer	Resistivity value (Ωm)	Thickness (m)	Geology
I	230 - 1,340	1 - 2.5	Moving riverbed deposits partly saturated with water, high permeability
III	230 - 540	8 - 32	Surface layer of older Lahar deposits saturated with water, permeability estimated comparatively high
IV	530 - 830	-	Older Lahar deposits saturated with water, highly compacted, permeability estimated considerably low

As the geological conditions of the above 3 sites are estimated by electric sounding, they need to be confirmed by boring in the future.

2.3 PRONOJIWO DAMSITE

2.3.1 CONTENTS OF THIS SECTION

In this section, the results of the preliminary geological survey for the foundation of the sabo dam planned at Pronojiwo are analyzed. Based on the findings, a general outline of geology of this site is discussed as well as the possibility of construction of a dam and problems of dam foundation.

2.3.2 TOPOGRAPHY AND GEOLOGY OF THE DAMSITE

Pronojiwo damsite is located to the east of Pronojiwo village at the west end of the study area. As shown on the location map of damsites Fig.-2.2.1, the place is on the boundary between steep mountains of Tertiary System and slope of Younger volcanic products from Semeru volcano. The right bank (south) is the Tertiary mountains and the left bank (north) is, gentle slope of Younger volcanic products from Semeru volcano. Also Pronojiwo damsite is located near the west end of the range of Younger volcanic products. About 1 km westward from the damsite, older volcanic products from Jambangan volcanic complex are widely distributed. Pronojiwo damsite is near the area of primary volcanic products (mostly pyroclastic flow deposits) and these products are thickly and widely distributed about 2 km north of the damsite. At the damsite, pyroclastic flow deposits called Ladu depsoits are distributed sparcely suggesting that pyroclastic flow rushed down as far as Pronojiwo damsite in the past. Explanation of the topography and geology of the Pronojiwo damsite follows.

(1) Topography

Pronojiwo damsite, as shwn in Fig.-2.3.1 Geological Map of Pronojiwo Damsite is located downstream of K. Lengkong and just directly upstream of the damsite, i.e. there lies the confluence of K. Lengkong flowing west and K.B. Bang flowing south.

The width of K. Lengkong at the damsite is about 40 to 60 m and both banks have steep cliffs of 10 to 15 m in height. About 80 m downstream from S-2 line of seismic sounding, there is a fall of about 15 m in height.

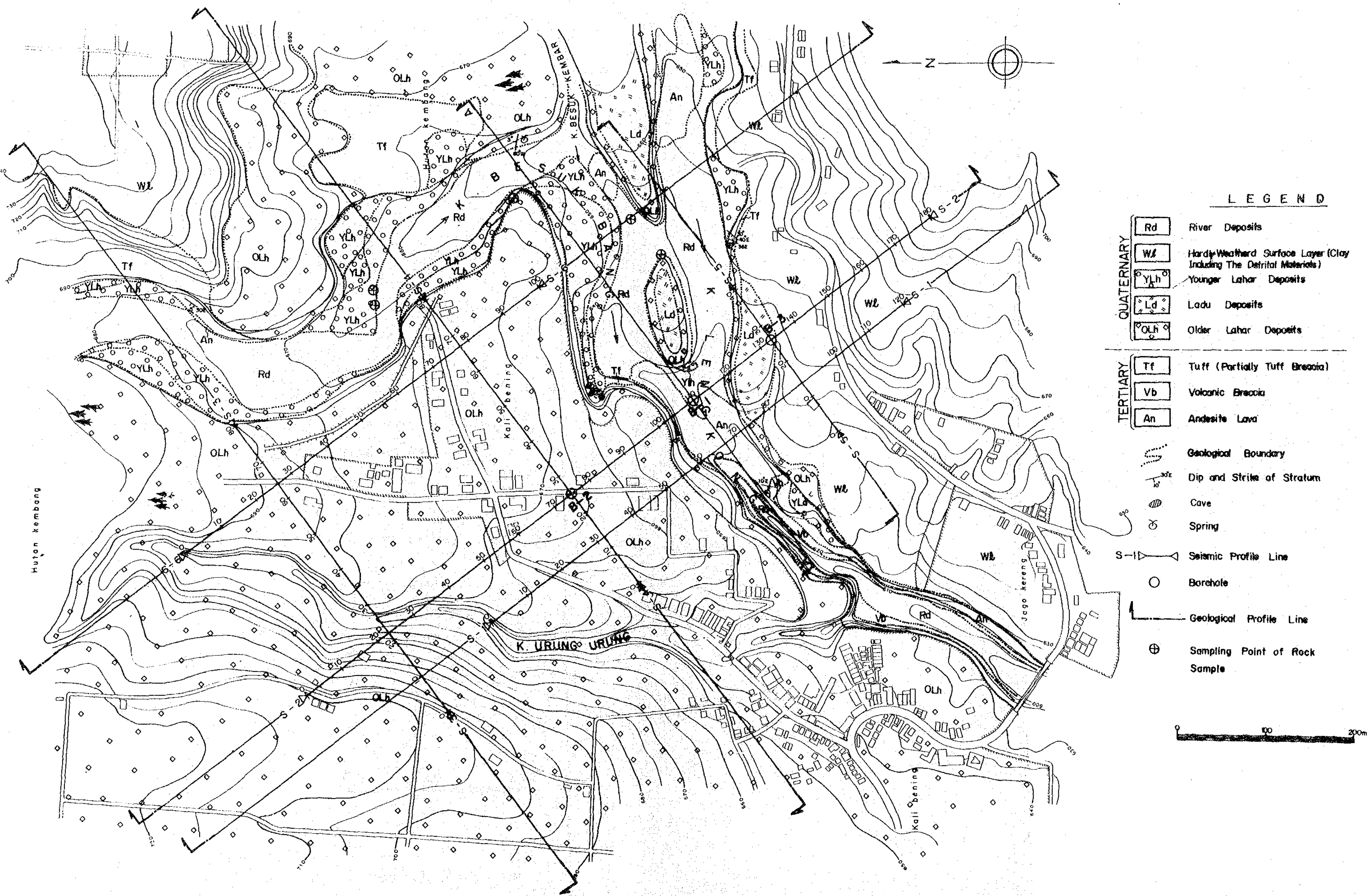


Fig.-2.3.1 Geological Map of Pronojiwo Damsite

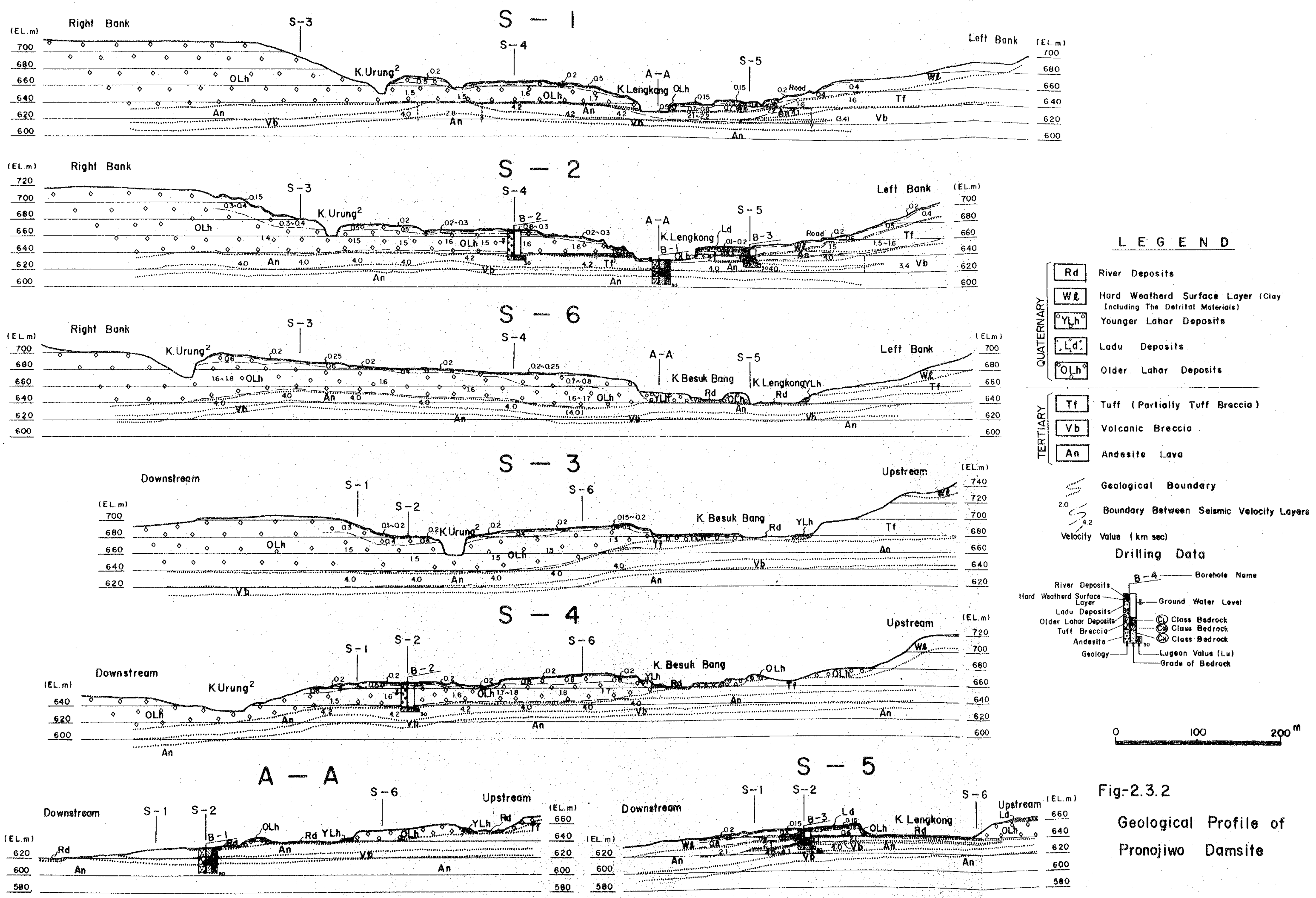


Fig-2.3.2 Geological Profile of Pronojiwo Damsite

A gorge of 10 to 20 m in width continues with steep cliffs of 15 to 20 m on both banks. There is also a very large fall of 130 m in height about 1 km downstream of the damsite.

The left bank of the damsite, situated on the foot of Mt. Kukusan Seriti of Titiary System, shows topography of slow terrace-like terrain of about 150 m in width. On the left bank, part of the mountain side from the terrace-like terrain, a steep slope of around 25 degrees develops. On the left bank of the damsite, there is no large valley dissected and the valume of foundation may be sufficiently large. For this reason there will be no obstacle in constructing a dam of about 30 to 40 m in height from topographical view.

On the right bank of the damsite, a gentle skirt terrain of Semeru Volcano widely spreads and on the upstream K.B. Bank runs to northwest and on the downstream K. Urung sharply cuts toward north. For this reason the left bank of the damsite forms a small triangle hill. When this small thin hill is used as foundation of a dam, the height of the dam and its design will be restricted by this topography.

(2) Geology

Fig.-2.3.1 shows the geological map of the damsite and Fig.-2.3.2 shows the geological profile of the damsite drawn by synthesizing the results of geological reconnaissance, seismic sounding and drilling works.

As shown in these figures, geology of Pronojiwo damsite is composed of those shown in Table-2.3.1. Sequence of Strata of Pronojiwo Damsite.

Table-2.3.1 Sequence of Strata of Pronojiwo Damsite

Age	Name of Layer	Component Material
Quaternary	Riverbed deposits	Presently moving sand and gravels along riverbed. Very loose.
	Surface highly weathered layer	The surface layer of tuff of Tertiary period which is highly weathered, somewhat creeping from the previus location.
	Younger Lahar deposits	Consisting of sand and gravels and forms a terrace along the river course, very loose.
	Ladu despoits	Consisting of volcanic ash, sand and gravels. A type of pyroclastic flow deposits, very loose.
	Older Lahar deposits	Consisting of sand and gravels. Relatively compact, distributed mainly in right bank.
Tertiary	Tuff	Consisting of soft tuff, partly tufficious sandstone and tuff breccia. Distributed roughly horizontally from above EL. 640 m on the left bank and weathering reached to deep portion.
	Alternation of andesite/volcanic breccia	Alternation of hard compact andesite lava and weak porous volcanic breccia. Thickness of each stratum about 10 to 20 m. Bedrock of damsite.

i) Alternation of Andesite/Volcanic Breccia

They are alternation of hard, compact andesite and weak porous volcanic breccia, the thickness of single layer being 10 to 20 m. Andesite is very hard with very few cracks, while tuff breccia is weak and especially poor part has fully turned to clay in which andesite fragments are mixed as shown in the section of 15.0 to 17.7 m deep of B-1 hole. Shear strength of andesite is considered to be more than τ_0 = 120 ton/m^2 and that of volcanic breccia is considered to be about τ_0 = 30 - 50 ton/m^2. Andesite is gray in color and characteristically contains olivine as phenocryst.

ii) Tuff

The tuff is distributed roughly horizontally above EL. 640 to 650 m on the left bank of the damsite. The tuff, having undergone wethering to a great degree, is so soft that a hammer can be easily driven into it. Therefore, this layer is not suitable as a dam foundation. A little high plateau-like terrain distributed over the left bank on the down-stream of K.B. Bang consists of this tuff.

iii) Older Lahar Deposits

Older Lahar deposits consists of coarse sand and breccia, poorly sorted, and is not stratified. Older Lahar deposits are comparactively well compacted and cannot be easily broken with a pick of hammer.

Older Lahar deposits are thickly distributed mostly on the left bank side and thinly attached to the foot of Mt. Kukusanseriti on the right bank. Older

Lahar deposits on the left bank extend 30 m at B-2 hole and 70 m at the end of S-3 measuring line of seismic sounding. For this reason, as shwon in Fig. -2.3.2 Geological Profile, the unconformitive plane between alternation of andesite/volcanic breccia and older Lahar deposits is roughly horizontal from riverbed. The hill on the right bank may be said to be fully composed of older Lahar deposits.

The top layer of older Lahar deposits is covered with 1 to 3 m thick surface soil presently used for caltivating. The soft and loose surface soil, containing a large amount of organic matters, is not suitable as foundation for large structures.

Three(3) Caves are observed in the older Lahar deposits about 80 m upstream from S-2 measuring line on the right bank.

The size of the caves is 5 m high, 3 to 4 m wide and about 7 to 8 m deep getting narrower and higher in the interior. From these caves, a small amount of spring water is observed. It is assumed that they were formed at the spots where pipe-like water veins in the older Lahar deposits appear on the ground surface by washing out sand and gravels with gushing spring water.

iv) Ladu Deposits

Ladu deposits are very loose pyroclastic deposits derived directly from volcanic eruptions of Seneru Volcano composed of volcanic ash, volcanic sand and small breccia. At the damsite, they are distributed on the west bank and on the confluence of K. Lengkong and K.G. Bang in a narrow range with the thickness of about 2 to 3 m. But the existence of these deposits indicates the rushing down of Pyroclastic flow (ex. Nuée Ardente) as far as Pronojiwo damsite.

v) Younger Lahar Deposits

Younger Lahar deposits consisting of very loose sand and breccia can be easily broken with a pick of hammer. At the damsite, younger Lahar deposits form a terrace along the river course. Three such terraces were observed in Sept. 1982. Younger Lahar deposits are always subjected to erosion by the rivers, repeating a cycle of new supply and erosion. Accordingly, the form of distribution is very unstable. The thickness of younger Lahar deposits is about 2 to 10 m.

vi) Highly Weathered Surface Layer

The highly weathered surface layer covers the left bank of the damsite extensively. This is a weathered surface layer of tuff of Tertiary Period. Some part of the layer are weathered at the previous position but most of them are creeped and have become secondary deposits (Talus). The highly weathered surface layer of 10 to 15 m in thickness consists of soft, loose clay and weathered, brittle gravels. Presently this layer is being used as plow land.

vii) Riverbed Deposits

These are sand and gravels presently moving over the riberbed. The riberbed around the damsite are very thin, exposing the bedrock deposits near the dam axis. On the upstream of the damsite, riberbed deposits, whose estimated thickness is about 2 to 3 m, are distributed along the riberbed.

(3) Geological Structure of the Damsite

Next, geological structure of Pronojiwo damsite will be discussed.

Alternation of andesite/tuff braccia and the tuff, both belonging to Tertiary System, are in concordant relationship showing gentle undulation locally. The inclination of the undulation is only 2 to 3 degrees toward the downstream of K. Lengkong. The Quarternary Period older Lahar deposits, Ladu deposits, Younger Lahar deposits, highly weathered surface layer (Talus) and riberbed deposits overlie the Tertiary formations. The plane of unconformity between the Tertiary formations and Quarternary formations are roughly horizontal viewed from