across the riverbed and very gently inclined toward the downstream viewed from the longitudinal direction. At the damsite no faults or sheared zones are observed.

2.3.3. GEOLOGICAL INVESTIGATION WORKS

At this site, 6 measuring lines, 3 km length of seismic sounding and drilling survey of 3 holes of 87 m in depth were carried out. The locations of these surveys are given in Fig.-2.3. Geological Map of Damsite.

(1) Seismic Sounding

The field and measuring works of seismic sounding were carried out by the staff of Institute of Technology of Bandung (ITB), and the analysis was carried out by Mr. Nakazawa (member of JICA Study Team, in charge of Geophysical Sounding). Summary of the results of the seismic sounding analysis follows:

i) The seismic velocity structure of Pronojiwo damsite is divided into 4 or 5 velocity layers as summarized in the tables below. These seismic velocity layers are shown in Fig.-2.3 Geological Profile of Damsite.

Table-2.3.2 (1) Classification of Velocity Layers

(Right bank)

Velocity Layer	Velocity (km/sec)	Thickness of Layer (m)	Geology
I	0.1 - 0.3	0.5 - 0.5	Surface soil
II	0.3 - 0.8	1.0 - 15.0	Loose older Lahar deposits
III	1.3 - 1.8	2.5 - 51.5	Compact older Lahar deposits
IV	4.0 - 4.2 (2.8)	-	Andesite lava (tuff breccia?)

Table-2.3.2 (2) Classification of Velocity Layers

(Left bank)

Velocity Layer	Velocity (km/sec)	Thickness of Layer	Geology
I	0.1 - 0.2	0.5 - 2.5	Top soil
II_1	0.3 - 0.5	2.0 - 14.5	Loose older Lahar deposits, or highly weathered part of the Tertiary formations
II_2	0.4 - 0.8	2.5 - 14.0	Highly weathered surface layers of tuff of the Tertiary system formations having "Talus" like characteristics
III	1.5 - 1.6 2.1 - 2.2	11.5 - 17.0 7.5 - 12.5	Tuff of the Tertiary formations or weathered andesite lava
IV	4.0 - 4.1 (3.4)	-	Andesite (tuff breccia?)

ii) The riverbed is covered with river deposits of 1 to 3 m in thickness.

iii) The boundary plain of older Lahar deposits and andesite lava was detected. The shape, roughly horizontal along the cross section map of K. Lengkong, is gently inclined toward the downstream.

iv) The average thickness of older Lahar deposits on the right bank is 18 to 23 m. The thickness reaches 35 m along the measuring lines of S-3 and S-6.

v) On the left bank, weathered andesite lava (2.1 to 2.2 km/sec) is distributed over the fresh andesite lava (4.0 to 4.2 km/sec). However, weathered andesite lava could not be found on the right bank.

vi) Weathered part of Tertiary basement distributed over the foot of Mt. Kukusanseriti is very thick in excess of 30 m. The velocity value of the lowest layer in this area is 3.4 km/sec.

(2) Drilling Work

The drilling work was carried out by ITB, and the observation of core samples was performed by Mr. Sasaki, in charge of land conditions, member of JICA Study Team as well as technical advisor for the drilling work. An outline of the results of the observation and Lugeon test is given below. The results of the obvservation of cores are summarized in Fig.-2.3.4. P-Q curves of Lugeon test are shown in Fig.-2.3.5. As for the details of drilling work, please refer to the Technical Report submitted by ITB to Mt. Semeru Project Office.

i) B-1 Hole

B-1 hole was drilled on the riberbed of the damsite as shown in Fig.-2.3.1.

-: Geological Conditions

0 to -1.2 m	:	Riverbed deposits of coarse sand and angular to subangular gravels
-1.2 to -11.2 m	:	Grey compact and hard andesite. Judged as CH class.

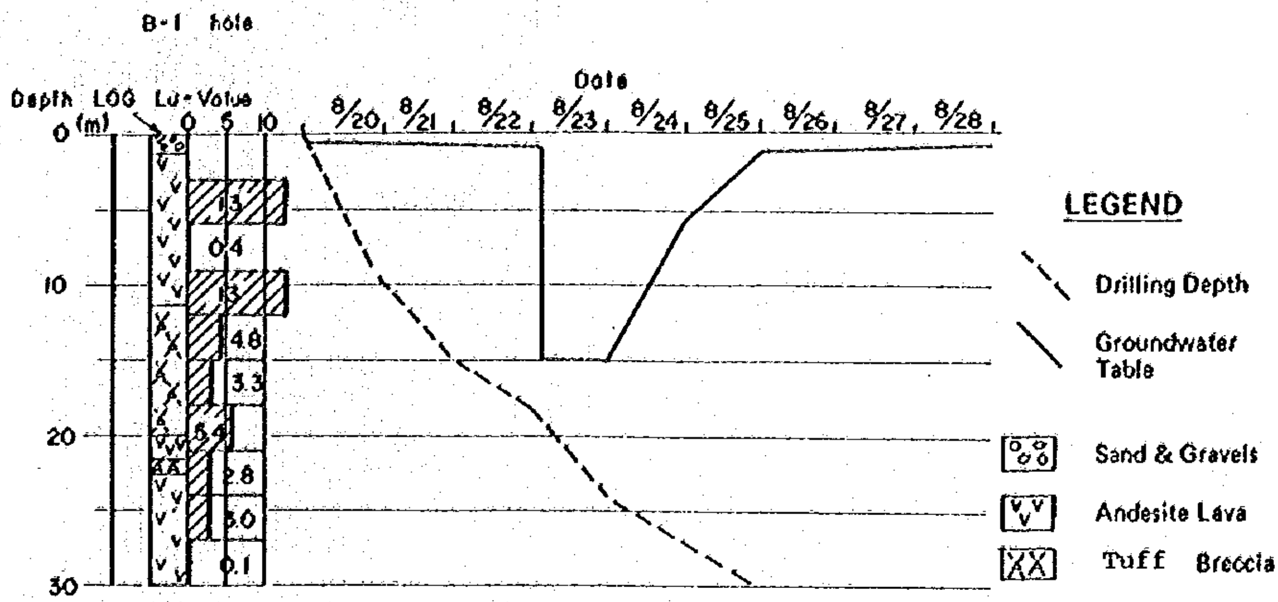
-11.2 to -20.1 m: Brown to grey color. Tuff breccia. Generally soft and considered as (CL) class. Especially between the depth of -15.0 to -17.7 m, matrix is yellowish clay and in very poor condition.

-20.1 to -30.0m: Grey compact and hard andesite. Partly between -21.7 to -22.6 m, gray porous tuff breccia is intercalated. Generally foundation condition is good and considered as (CH) class.

-: Ground water Level

At B-hole, the ground water level behaved strangely during the drilling work. While drilling from 0 to -18 m, the ground water level was stable at -0.4 m but when the depth was near -18 m, the level abruptly dropped to about -14 m. This low ground water level continued while drilling from -18 to -24 m. The ground water level started to rise after -24 m or deeper and reached-5.5 m when drilling reached -27 m depth. When B-1 hole was drilled to -30 m, PVC perforated pipe was installed. to complete the ground water observation hole. The ground water level recovered to -1.3 m. Fig-2.3.3 shows the relationship among geology, Lugeon value, depth drilling and ground water level of B-1 hole.

Fig. - 2.3.3 Relationship among Geology, Lugeon Value, Drilling Depth and Groundwater Table



A possible explanation of the above observed phenomenon is suggested below.

There are porous tuff breccia at the depth of -15 to -20 m in B-1 hole. The permeability is especially high from -18 to 29 m of tuff breccia thus forming a permeable layer. When this permeable layer was reached, ground water in the layer of comparatively small permeability above this layer flowed down into the permeable layer, suddenly dropping the ground water level. But according to the results of the Lugeon test conducted between -18 to -21 m, the Lugeon value of this section was found to be 5.4 Lu which is just higher than in other sections. But it is inconceivable to have Lu value in the high permeable layer such as to bring about a sudden drop in the ground water level. It might be suggested that before or during the Lugeon test, cutting

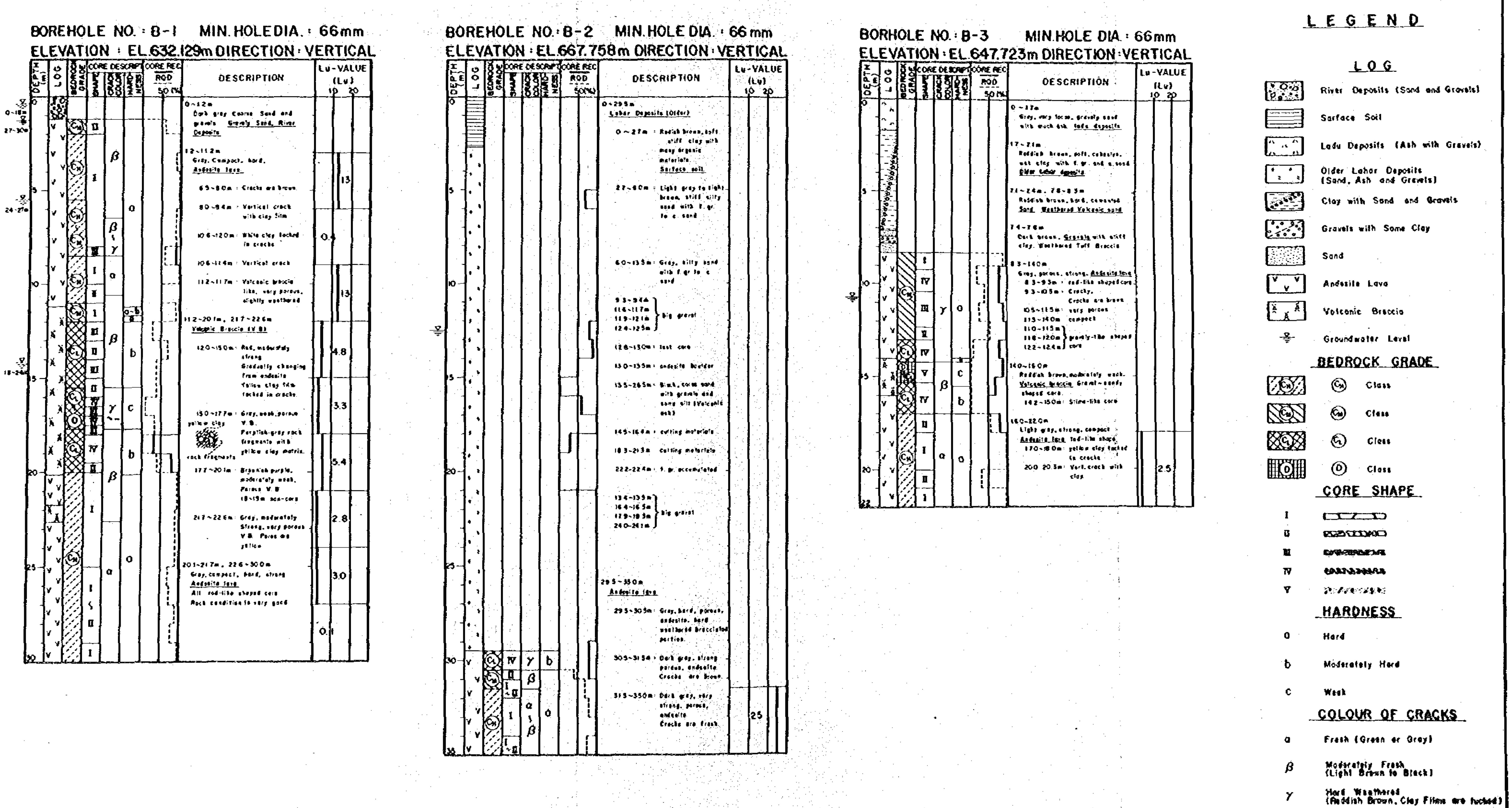


Fig-2.3.4 Geological Log (B-1 to B-3)

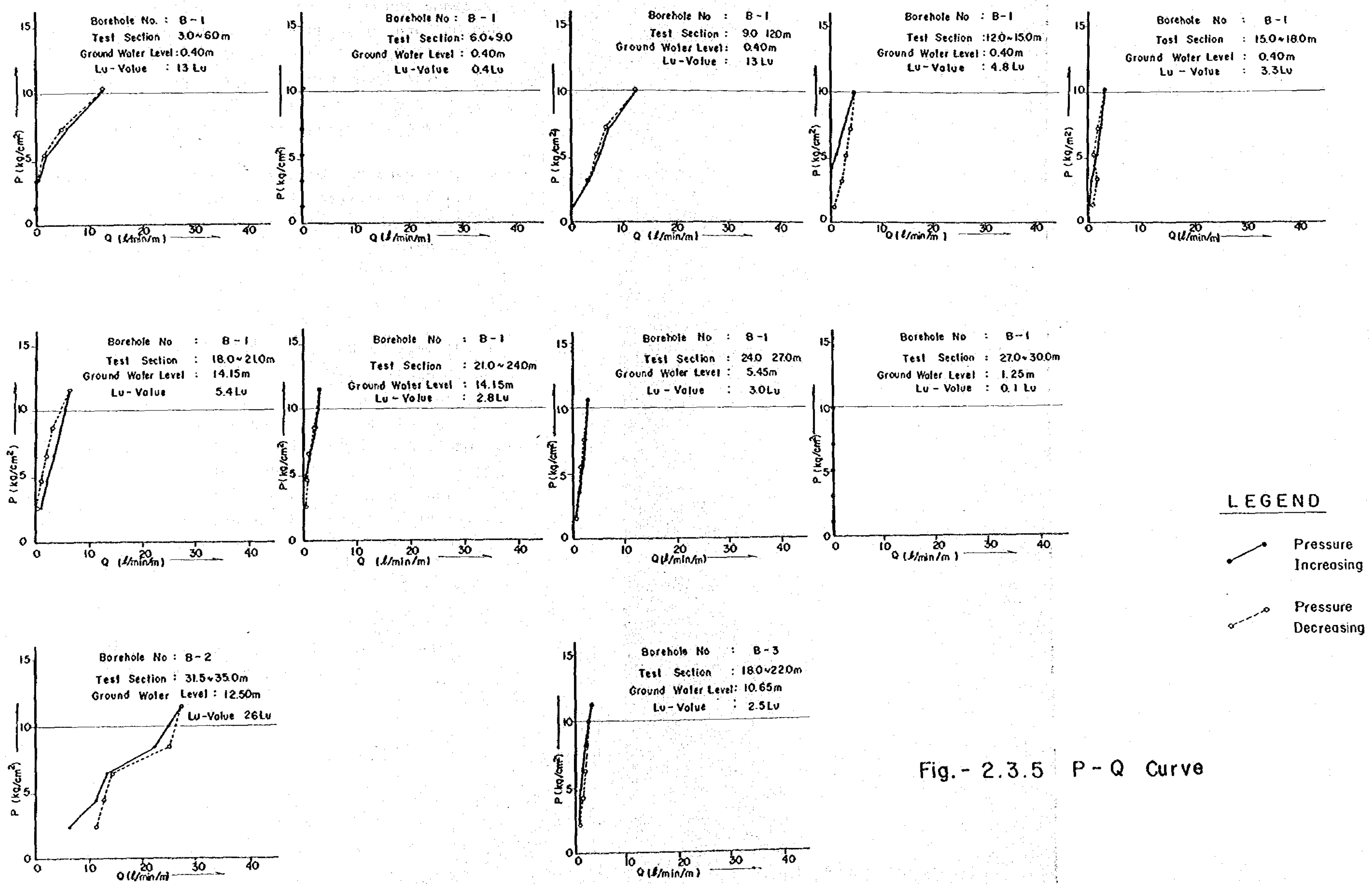


Fig.- 2.3.5 P-Q Curve

material while drilling and/or river sand had entered through the opening of the hole which plugged up the pores of the permeable layer to yield such a low Lu value. Also the rise in the ground water level once dropped during drilling may have been caused by washing out the plugging in the permeable layer.

The foregoing assumptions were made to shed some light on this phenomenon, but if sealing measures were to be required for Pronojiwo dam, more detailed survey will have to be requested to cope with the problem.

-: Permeability

The Lugeon value for B-1 hole is high at over 10 Lu down to the depth of 12 m, but in the portion deeper than 12 m, it is generally less than 5 Lu. The Lugeon value tends to decrease with increasing depth. At depth of -22 to -27 m, it is 3 Lu, and at -27 m or deeper it is less than 1 Lu. It is presumed, however, that there are portions where permeability is very high in the tuff breccia layer at the depth of -18 to -20 m as mentioned in the section of groundwater level.

ii) B-2 Hole

B-2 hole was drilled on the right bank of the damsite as shown in Fig.-2.3.1.

-: Geological Conditions

0 to -2.7 m :	Reddish-brown soft clay containing a large amount of grass roots and tree roots. Highly weathered older Lahar deposits portion used for farming.
-2.7 to -29.5 m :	Older Lahar deposits consisting of greyish-black coarse sand, angular gravels and small amount of silt. Relatively well compacted.
-29.5 to -35.0 m:	Andesite of grey to dark grey color, hard and porous. From -29.5 to -30.5 m section, weathered part of brown pebble-like core shape; (CL) class, from -30.5 to -31.5 m, cracks show brownish color; (CM) class, -31.5 m or deeper, cracks are relatively fresh and rod type core shape; (CH) class.

-: Ground water Level

Ground water level is stable at about -12 m; ground water table is located in older Lahar deposits.

-: Permeability

Lugeon test was carried out in andesite at -31.5 to -35 m, a large value of 25 Lu was obtained. As this was carried out at shallow portion near the bedrock surface, the permeability was high but the crack of the core sample was relatively fresh. The low permeable terrain seems to be located at shallow places.

iii) B-3 Hole

B-3 hole was drilled on the left bank of the damsite as shown in Fig.-2.3.1.

-: Geological Conditions

0 - 1.7 m	:	Ladu deposits consisting of grey very loose volcanic ash, sand and angular gravels.
-1.7 to -8.3 m	:	Consisting of brownish gravels, sandy silt and sand. Considered to be highly weathered older Lahar deposits.
-8.3 to 14.0 m	:	Gray, hard and porous andesite. Cracks show reddish-brown color. From -8.3 to -13 m (CM) class, -13 to -14 m core shape is pebble-like and (CL) class.

-14.0 to -16.0 m:	Reddish-brown and soft. Tuff breccia. Generally pebble-like core, -14.2 to -15.3 m shows slimy condition; (D) to (CL) class. Other section CL class.
-16.0 to -22.0 m:	Grey, hard and compact andesite. From -16.0 to -17.0 m, it is poor core shape and cracks are somewhat weathered, classified as (CL) class. But at -17 m or deeper, rod-like core continues, cracks are fresh; classified as (CH) class.

-: Ground Water Level

The groundwater level is stable at about -11 m; the ground water table is located in andesite.

-: Permeability

Lugeon test was carried out in fresh andesite at a depth of -18 to -22 m; 2.5 Lu was obtained.

2.3.4 EMBANKMENT MATERIAL SURVEY

The embankment material survey was carried out by reconnaissance for aggreagates and soil materials and for laboratory tests. The reconnaissance was carried out by Mr. Uchiseto and Mr. Sasaki of JICA Study Team, and laboratory tests were carried out by ITB. Samples for laboratory tests were collected as shown in Fig.-2.3.1 Geological Map of Damsite and Fig.-2.4.1 Geological Map of K. Lengkong Fan. For the details of the laboratory tests, please refer to the technical reports which were submitted by ITB to Mt. Semeru Project Office.

(1) Soil Material

Judging from the geological conditions of the whole study area, the soil material suitable in quality and quantity for impervious embankment is the weathered layer of the Tertiary formations only. The quantity of highly weathered surface layer (partly Talus-like) of tuff is considered sufficient. On the other hand, from the standpoint of quality, the weathered part of green tuff layer and tuff breccia found in proper grain size distribution, are considered to be better but as they are distributed very thinly on the steep mountainside, borrowing is considered to be difficult. The highly weathered layer of tuff, as mentioned in the section of geology of damsite, is distributed extensively around the damsite, and is the most easily accessible soil material. For the above reasons, in the present study, soil tests were carried out to determine the soil mechanical properties of the highly weathered layer of tuff. The test items and quantities are given in Table-2.3.3.

Table-2.3.3 Items and Quantities of Soil Test

Item	Quantities
Grain size distribution	2
Natural water content	2
Plasticity limit and Liquidity limit tests	2
Compaction test	2
Laboratory permeability test	2

The test methods employed are based on ASTM standards.
Table-2.3.4 shows the test results.

Table-2.3.4 Results of Soil Tests

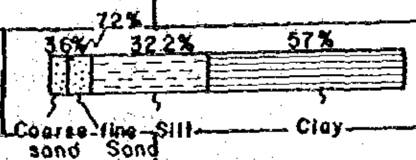
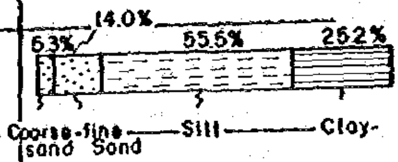
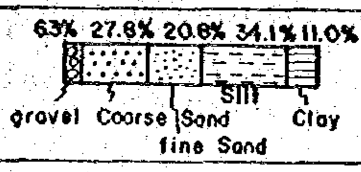
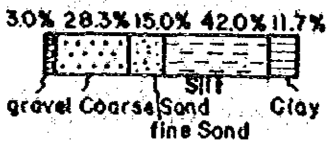
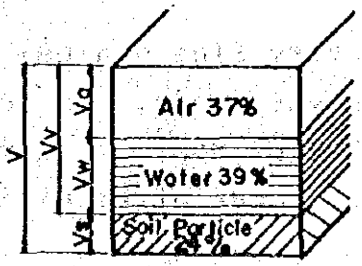
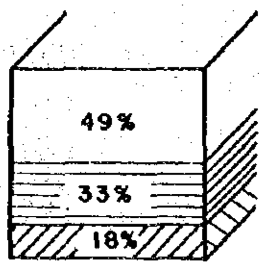
Item \ Name of Sample		Br. Ar. I^A	Br. Ar. I^B
Natural water content (W)		52.45%	104.66%
Specific gravity of soil particle		2.70	2.66
Grain size Analysis			
Consistency	Liquidity limit	78.87%	120.90%
	Plasticity limit	46.44%	84.94%
	Plasticity index	32.43%	35.96%
Compaction test	Max. dry density	1.14 g/cm 2	0.72 g/cm 2
	Optimum water content	49.00%	87.71%
Laboratory permeability		1.76×10^{-7} cm/sec (WC:49.38%)	7.39×10^{-7} cm/s (WC:87.98%)

Table-2.3.5 Results of Soil Test on the Highly Weathered Layer of Tuff in K. Lengkong Fan

Test Pit / Item	P - 1	P - 4
In-situ permeability coefficient (K)	1.4×10^{-2} cm/sec	1.3×10^{-2} cm/sec
Natural water content (W)	59.3%	69.17%
Specific gravity of soil particle (Gs)	2.75	2.71
Field density (γt)	1.06 g/cm^3	0.81 g/cm^3
Grain size distribution		
Volume ratio of each component		
Void ratio ($e = \frac{Vv}{Vs}$)	3.13	4.66
Porosity ($N = \frac{Vv}{V} \times 100$)	75.6%	82.3%
Saturation ratio ($Sr = \frac{Vw}{Vv} \times 100$)	52.1%	40.2%
Air voids ($υa = \frac{Va}{V} \times 100$)	37.0%	49.2%

The results of in-situ permeability and field density tests conducted on the highly weathered layer of tuff in K. Lengkong are summarized in Table-2.3.5.

From the test results as summarized in Table-2.3.4 and Table-2.3.5, the following can be said of the highly weathered layer of tuff.

i) Contains very fine grains; natural water content factor is very high. As core material of a rock-fill type dam, it is very poor in workability; cracks may occur after piling.

ii) Liquidity limit is very high; optimum water content factor is also high. Max. dry density is very small (some part is less than $1.0g/cm^3$).

iii) Field density is very small; and void ratio is very large, in other words very loose.

iv) When compacted at optimum water content factor, the permeability becomes very small at around $K = 10^{-7}$ cm/sec in spite of the very large in-situ permeability coefficient (around $K = 1.3 \times 10^{-2}$ cm/sec).

v) This layer corresponds to volcanic ash clay soil (VH) according to the uniform Soil Classification Standard of Japan; very similar in characteristics to Kanto Loam.

From the foregoing, the highly weathered layer of tuff is found to be unsuitable as core material of a rock-fill type dam. If it is used as such, coarse grain materials must be added.

(2) Aggregates

There are several layers in the study area suitable for aggregates as given below.

a) Younger Lahar deposits

b) Older Lahar deposits

c) Andesite of Tertiary system

d) Andesite of Quarternary system

e) Green tuff of Tertiary system

Among the above 4 layers, the most abundant around the damsite containing fine and coarse aggregates are younger and older Lahar deposit. For the present study, laboratory tests were conducted on only these Lahar deposits. The test items are:

i) grain size distribution, ii) natural water content, iii) specific gravity and iv) water absorption. The sample collection points are given in Fig.-2.3.1 Geological Map of Damsite.

i) Grain Size Distribution

The grain size distribution test on Lahar deposits was conducted at the K.B. Bang Basin, K. Mujur Basin and K.B. Sat Basin, with 6 tests being conducted for each place. Regrettably since the maximum grain size was limited to 4.75 mm for samples taken at the K.B. Bang Basin while for those at both K. Mujur and K.B. Sat Basins the size was 100 mm, the test finding greatly differed between K.B. Bang and K. Mujur, K.B. Sat. For the larger max grain size lends more reliability to test data, the test findings at both K. Mujur and K.B. Sat Basins were used to find grain size distribution of Lahar deposits. These test findings are given in detail in the technical reports submitted by ITB to Mt. Semeru Project Office.

Twelve tests were carried out at both K. Mujur and K.B. Sat Basins and their results are very close as shown in the following grain size distribution.

Gravel	:	70 to 80%
Corarse sand	:	15 to 25%
Fine sand	:	4 to 8%
Silt	:	1 to 2%
Clay	:	0%

ii) Natural Water Content Factor

The natural water content factor of Lahar deposits is roughly about 5%.

iii) Specific Gravity Water Absorption

Specific gravity of sand of Lahar deposits is about 2.7; water absorption rate is 1.5 to 7%, but mostly 1 to 2%.

From the foregoing test results, Lahar deposits, if fine grains such as silt and clay are removed, can be successfully used as aggregates and rock material for a concrete dam and rock-fill type dam in terms of both quality and quantity.

2.3.5 GEOTECHNICAL CONSIDERATION

Geotechnical considerations of Pronojiwo damsite are given below on (1) strength, (2) topography, (3) permeability, (4) embankment material and aggregates and (5) volcanic activities.

(1) Strength

-: Since the strength of andesite in the alternation of andesite/tuff breccia exposed on the riverbed of the damsite is expected to be large (τo = 120 ton/m^2 estimated) with the thickness of about 10 m, the construction of concrete dam of about 30 m in height may be possible. But an additional study must be carried out on the possibility of slipping at the boundary between the tuff breccia layer with less strength (estimated at τo = 30 to 50 ton/m^2) and strong andesite layer.

-: Older Lahar deposits consisting of clay, sand and gravel layers on the left bank of the damsite is relatively thin; thus it would be feasible to excavate these layers allowing a concrete dam body to be placed directly on andesite.

-: Older Lahar deposits distributed on the left bank are well compacted and considered to be usable as foundation of structure of 10 to 15 m in height.

-: From the standpoint of foundation strength and topography of the damsite, construction of concrete dam of about 30 m in height at this site is possible, in spite of some difficulties.

(2) Topography

-: As the left bank forms a small, thin triangle shaped hill, the dam height and its design will be restricted by this topography.

(3) Permeability

-: The permeability of alternation of andesite/tuff breccia is 20 to 30 Lu in weathered part of the surface portion and decreases below 5 Lu at around - 10m or deeper. A highly permeable zone is expected in porous tuff breccia.

-: Older Lahar deposits distributed on the right bank is very compact, however, sand and gravel layer is thin, and permeability is considered to be low. But there might run pipe-like water-veins inside, contributing to a dangerous possibility of water leakage after completion of the dam. Since this may cause piping failure, a further study must be carried out on this point.

:- Ground water level is relatively high. It is expected that the ground water level on both the left and right banks is rising along the ground surface.

(4) Embankment Materials and Aggregates

-: The highly weathered layer of tuff on which the present soil tests were carried out is sufficient in quantity and easy for borrowing, but the test results show it to be inferior in quality. If they should be used as impervious material, it must be properly treated before use.

-: Lahar deposits are regarded as practical source of aggregates both in quality and quantity.

(5) Volcanic Activities

-: Since there are traces of Pyroclastic flow (Nuée Ardente or Ladu) which rushed down to Pronojiwo Damsite in the past, there is a danger of Pyroclastic flow to Pronojiwo Damsite in the future.

3.6 FUTURE STUDY THEMES

The following themes of geological conditions in Pronojiwo Damsite and the related area should be investigated in the future study.

(1) No clear distinction can be observed in the distribution of tuff breccia layer in alternation of andesite/tuff breccia. The thickness of andesite exposed on the riverbed is unknown. These exert great influence on the stability of dam body.

(2) If a dam requires water sealing measures, high permeable layer feared in the tuff breccia layer must be confirmed and its continuation clarified.

(3) Since the geological condition of the tuff layer which is supposed to be distributed above the road on the left bank is not clear at the present stage, question remains whether this can be used or not as dam foundation.

(4) Deformability and bearing capacity of older Lahar deposits on the right bank and its permeability and resistance to piping failure are entirely unknown at present. These exert great influence on the stability of dam body on the right bank.

(5) In constructing a rock-fill type dam, a survey for soil material other than highly weathered tuff is necessary. If there is no other suitable material, more detailed testing and study of highly weathered tuff would be required as well as carrying out a study of the processing and treatment method for weathered tuff.

(6) It is necessary to carry out a more detailed study and testing on Lahar deposits as a source of aggregates (selection of quarry site, detailed testing of aggregates such as stability and Losangels tests).

2.4 K. LENGKONG FAN

2.4.1 CONTENTS

In this section, information gained regarding the layers comprising K. Lengkong Fan, its permeability and geological structure as a result of the present study are discussed here as well as general characteristics of K. Lengkong Fan as ground water basin. These findings are summarized as basic information for the analysis of ground water.

2.4.2 TOPOGRAPHY, GEOLOGY AND GROUND WATER OF K. LENGKONG FAN

K. Lengkong Fan, as shown in Fig.-2.2.1 Location Map of the Investigation Sites, is located at the west end of the study area and is the southern foot of Semeru volcano. The surface of the study area, damaged by Lahar in 1977 and 1978, and covered with sand and gravels of that time, is now waste land with poor vegetation. Before the disaster of 1977, the area was said to have been a rich paddy field.

(1) *Topography*

K. Lengkong Fan, as shown in Fig.-2.4.1 Geological Map of K. Lengkong Fan, is located on the foot of the southern slope of Semeru volcano. The inclination of the slope is about 2°. It is a smooth slope with no large valley cutting in. On the south side of K. Lengkong Fan, the Tertiary mountains composed of tuff and tuff breccia are distributed. Its mountain ridges, running roughly from east to west, have intercepted volcanic products from the crater of Mt. Semeru. K. Lengkong meanders down toward west along the boundary between K. Lengkong Fan and Tertiary mountains.

The inclination of the riverbed of K. Lengkong changes at a certain point near the downstream. On the upper stream of this point, the inclination of the riverbed is very gentle, but on the downstream from there, the riverbed inclination shows tendency of growing steeper. Near this changing point, a sabo dam named Tumpak Nanas is scheduled to be constructed.

(2) Geology

The geological map of K. Lengkong Fan, prepared based on the geological reconnaissance, electric sounding and drilling survey, is given in Fig.-2.4.1; geological profile is given in Fig.-2.4.2, Fig.-2.4.3 and Fig.-2.4.4. Also Fig.-2.4.5 gives schematic geological profile. As shown in these figures, K. Lengkong Fan is comprised of layers summarized in Table-2.4.1 Sequence of Strata of K. Lengkong Fan.

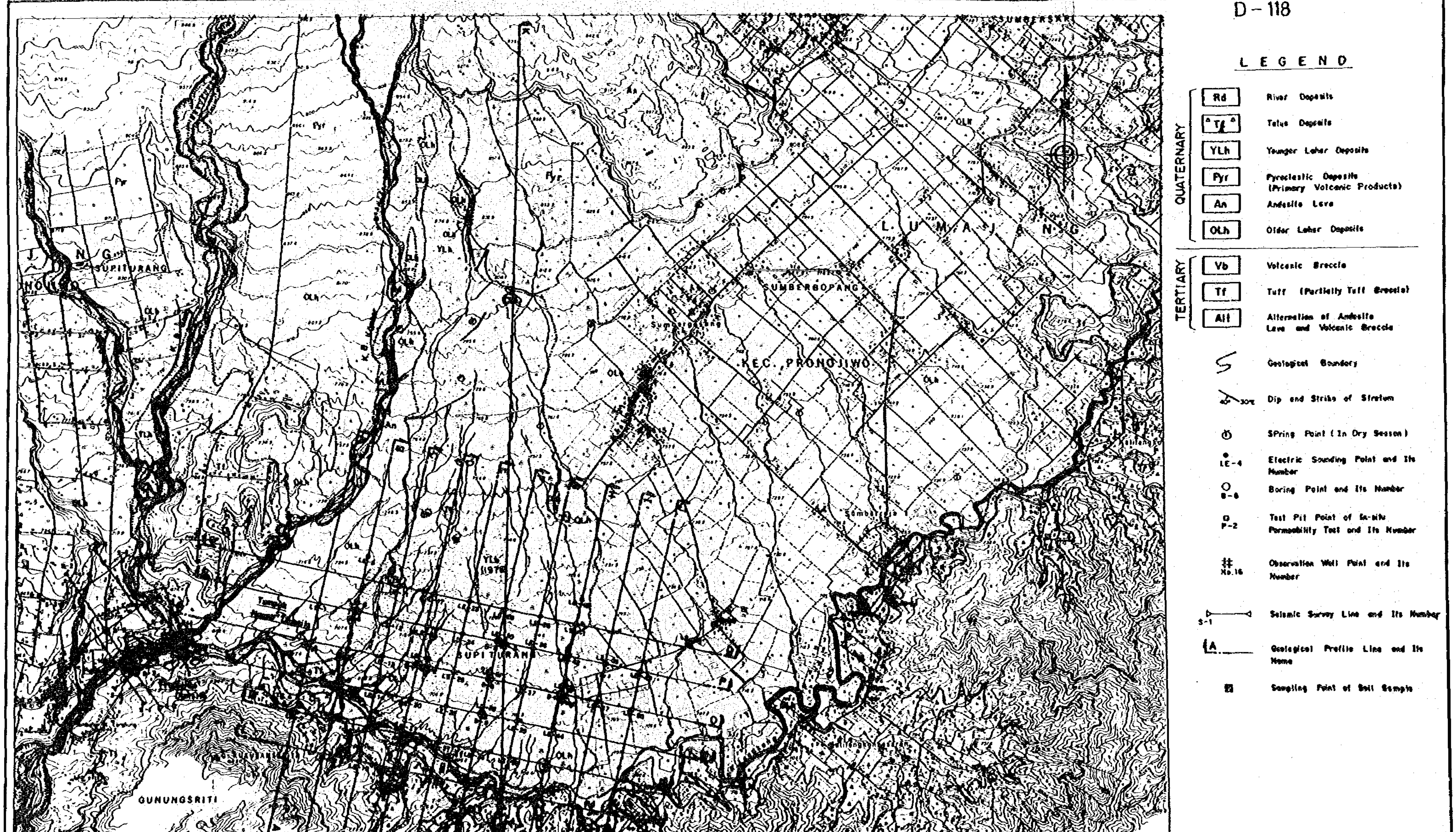
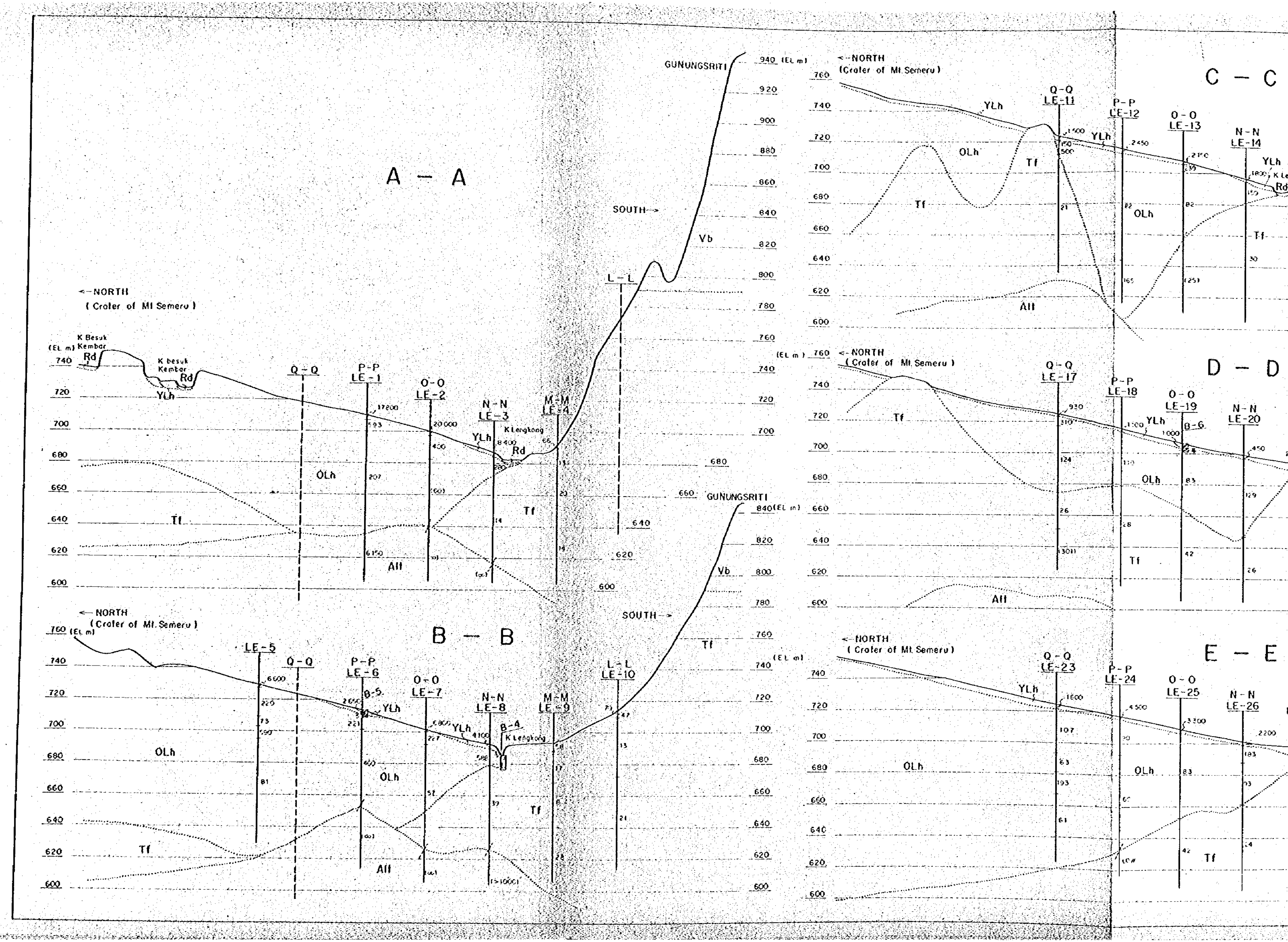


Fig.-2.4.1
Geological Map of K. Leng-Kong Fan



A - A
B - B
C - C
D - D
E - E
← NORTH
(Crater of Mt. Semeru)
SOUTH →
GUNUNGSRITI
(EL m)
K Besuk Kembar
K Lengkong
Q - Q
P - P
O - O
N - N
M - M
L - L
LE-1
LE-2
LE-3
LE-4
LE-5
LE-6
LE-7
LE-8
LE-9
LE-10
LE-11
LE-12
LE-13
LE-14
LE-17
LE-18
LE-19
LE-20
LE-23
LE-24
LE-25
LE-26
B-4
B-5
B-6
YLh
OLh
Tf
Alf
Rd
Vb

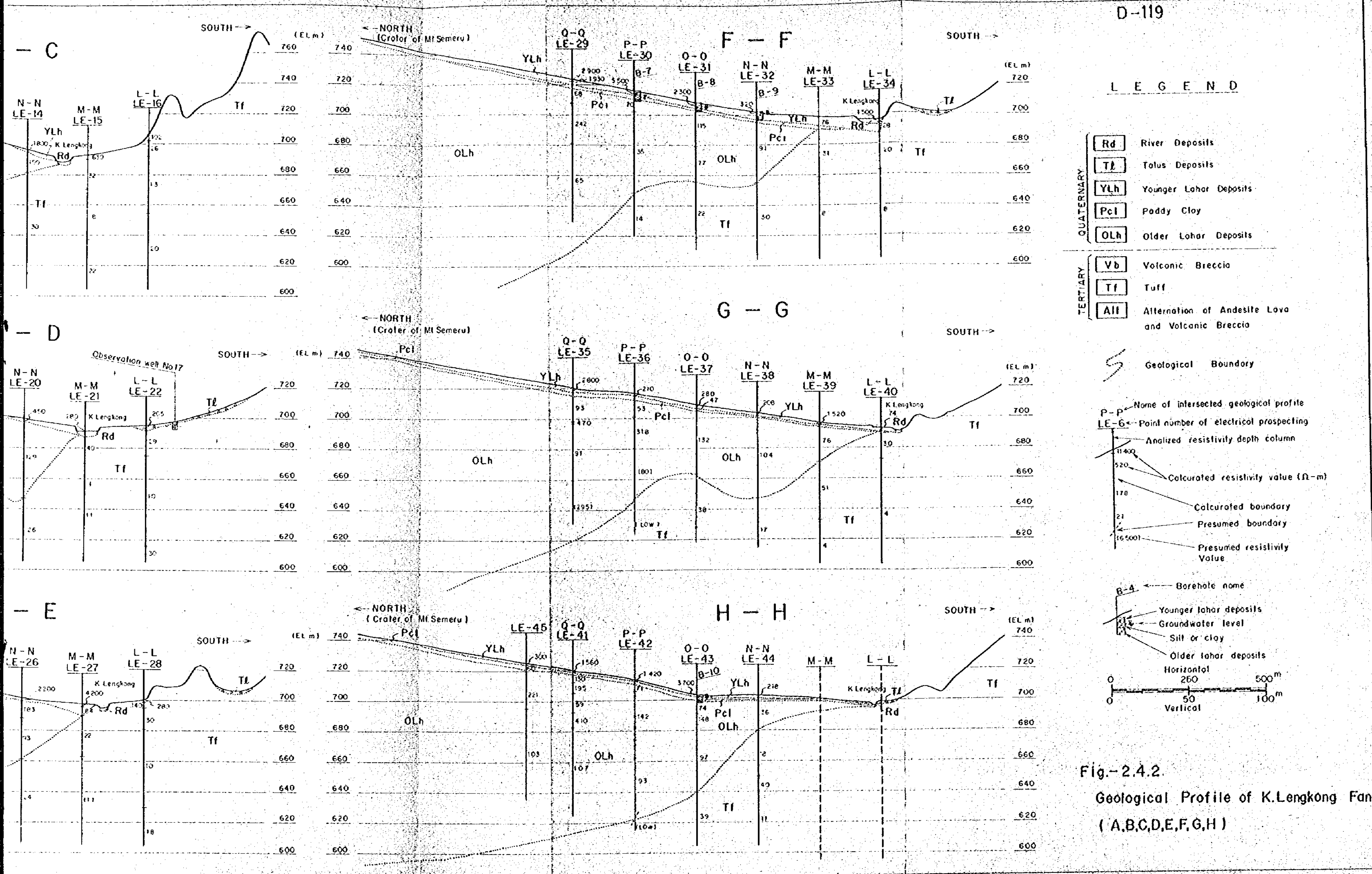
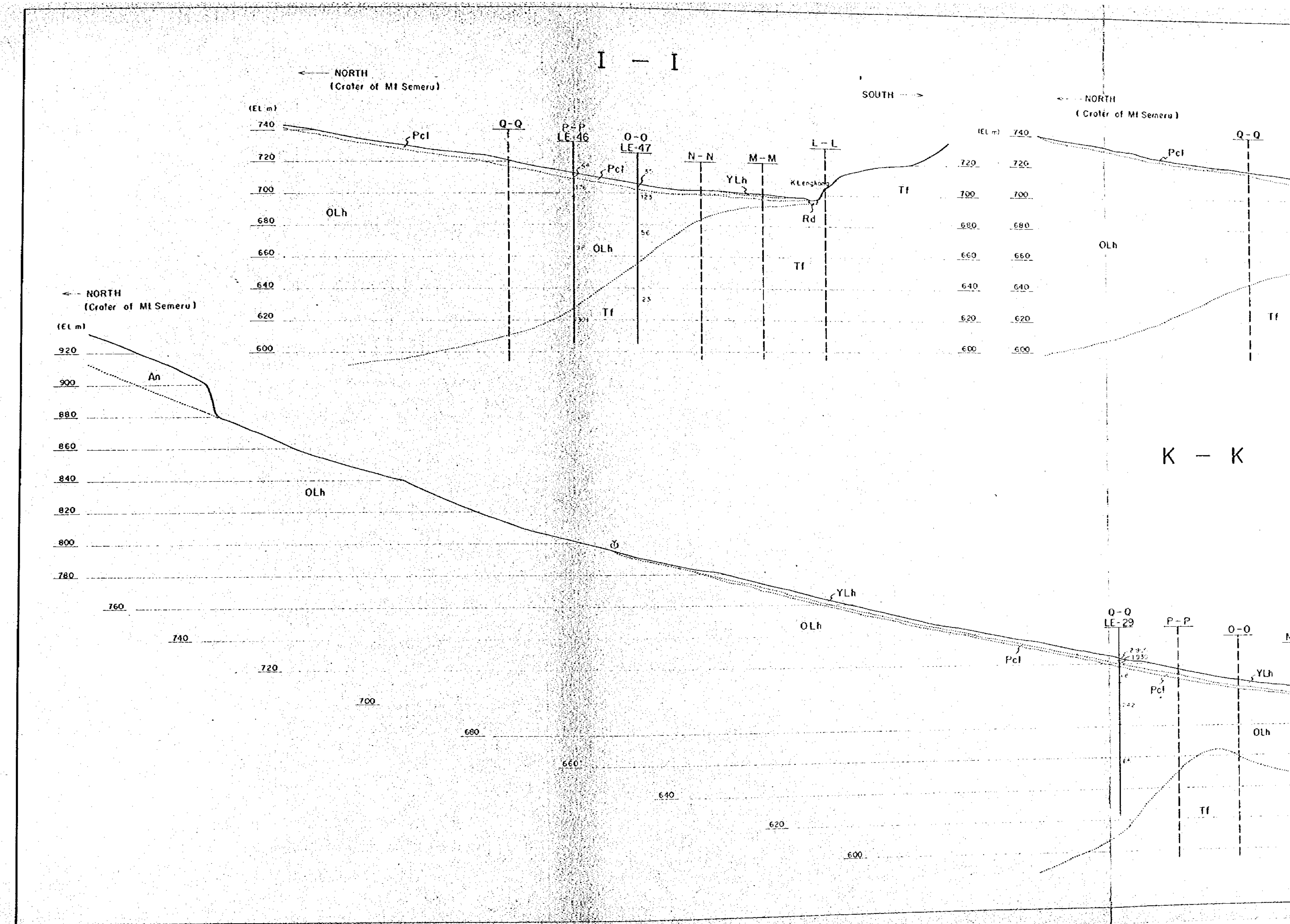


Fig.-2.4.2.

Geological Profile of K.Lengkong Fan (A,B,C,D,E,F,G,H)


I – I
NORTH (Crater of Mt Semeru)
SOUTH
(EL m)
740
720
700
680
660
640
620
600
Pcl
Q-Q
P-P
LE-46
O-O
LE-47
N-N
M-M
L-L
YLh
K.Lengkong
Rd
OLh
Tf
K – K
NORTH (Crater of Mt Semeru)
(EL m)
920
900
880
860
840
820
800
780
760
An
OLh
YLh
Pcl
Q-Q
LE-29
P-P
O-O
Tf

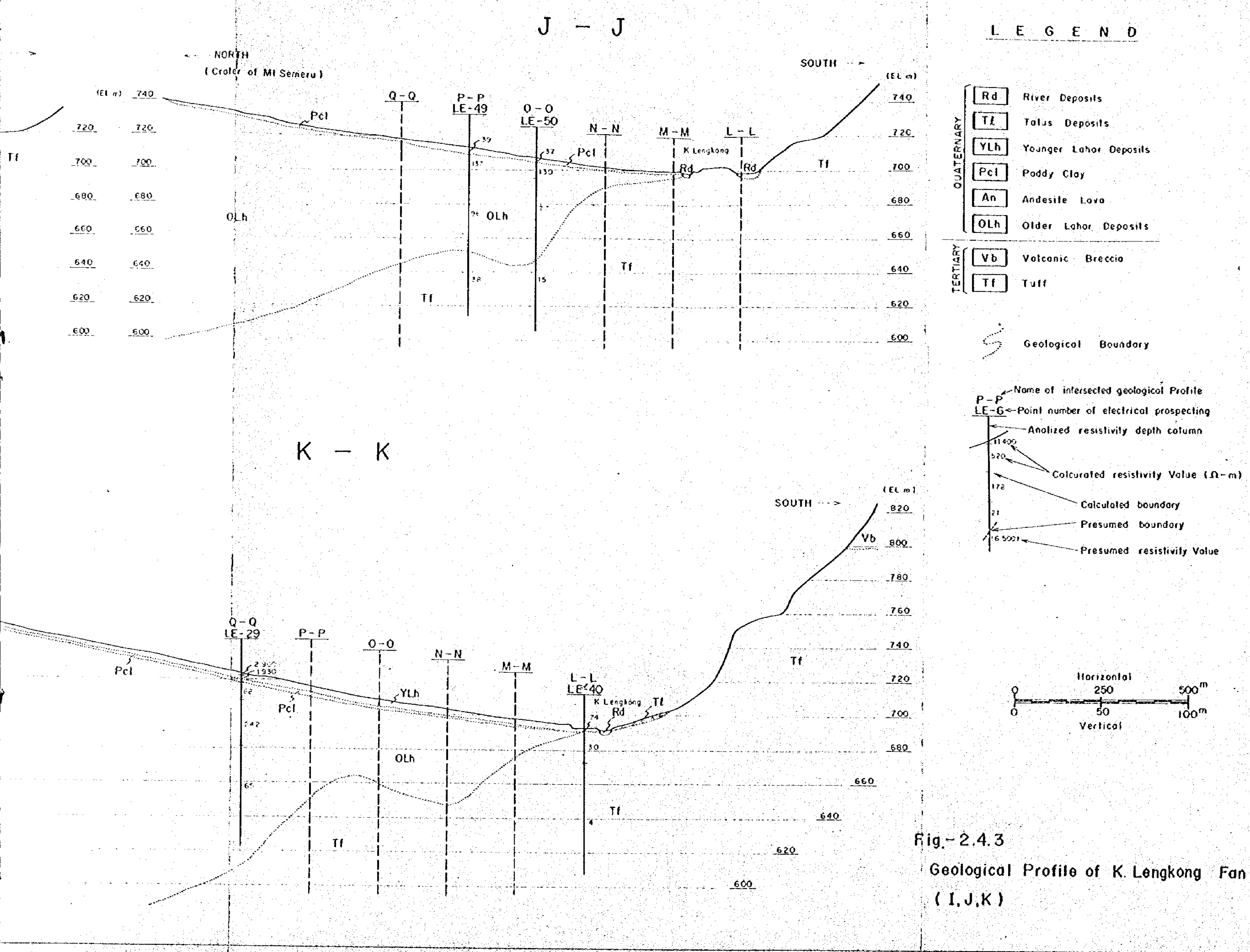
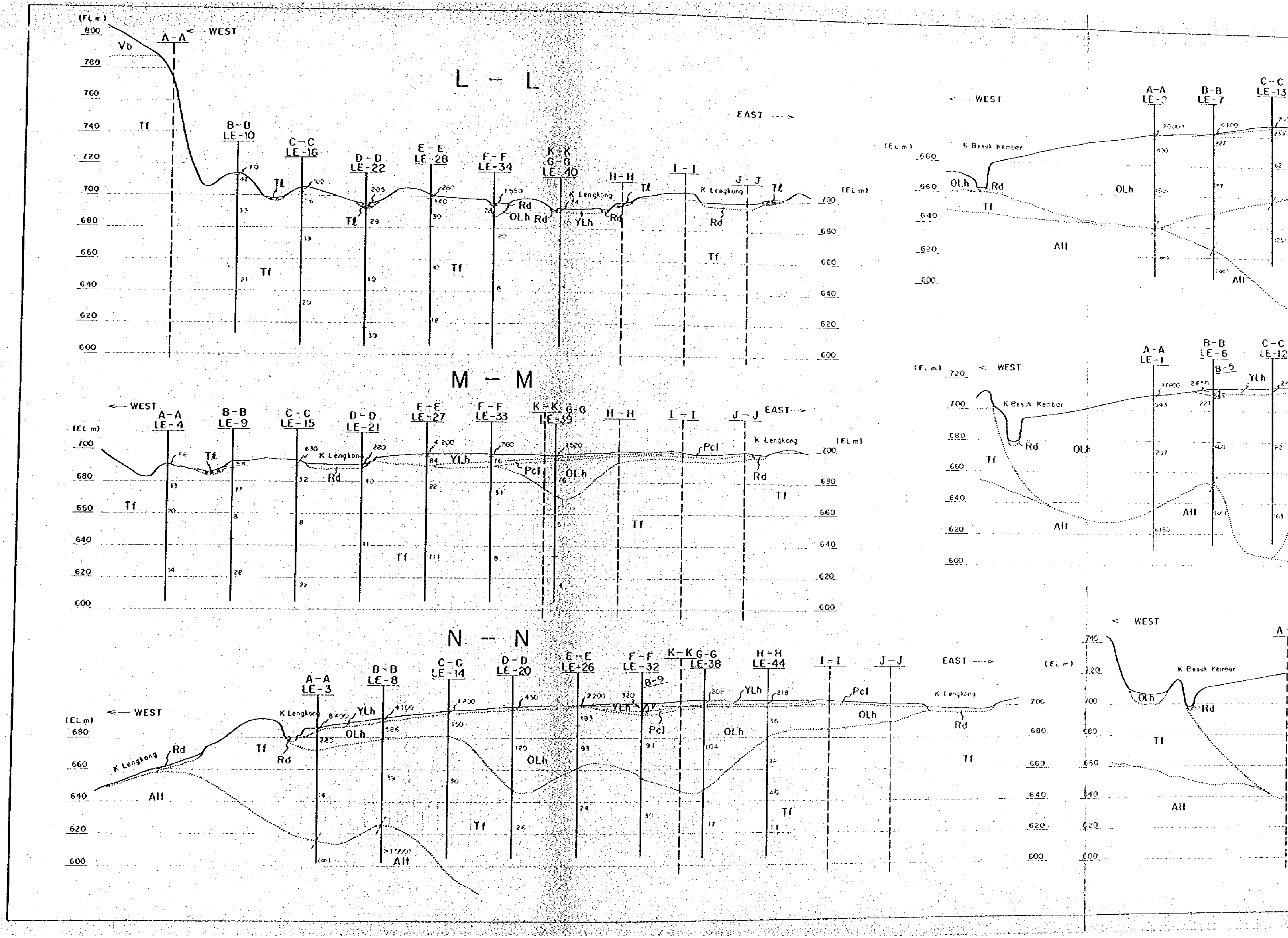


Fig.-2.4.3 Geological Profile of K. Lengkong Fan (I,J,K)



L - L
M - M
N - N
WEST
EAST
(EL m)
A-A
B-B LE-10
C-C LE-16
D-D LE-22
E-E LE-28
F-F LE-34
K-K G-G LE-40
H-H
I-I
J-J
K Lengkong
Vb
Tf
Tl
Rd
OLh
YLh
Pcl
All
A-A LE-4
B-B LE-9
C-C LE-15
D-D LE-21
E-E LE-27
F-F LE-33
K-K G-G LE-39
A-A LE-3
B-B LE-8
C-C LE-14
D-D LE-20
E-E LE-26
F-F LE-32
K-K G-G LE-38
H-H LE-44
B-9
K Besuk Kembar
A-A LE-2
B-B LE-7
C-C LE-13
A-A LE-1
B-B LE-6
B-5
C-C LE-12

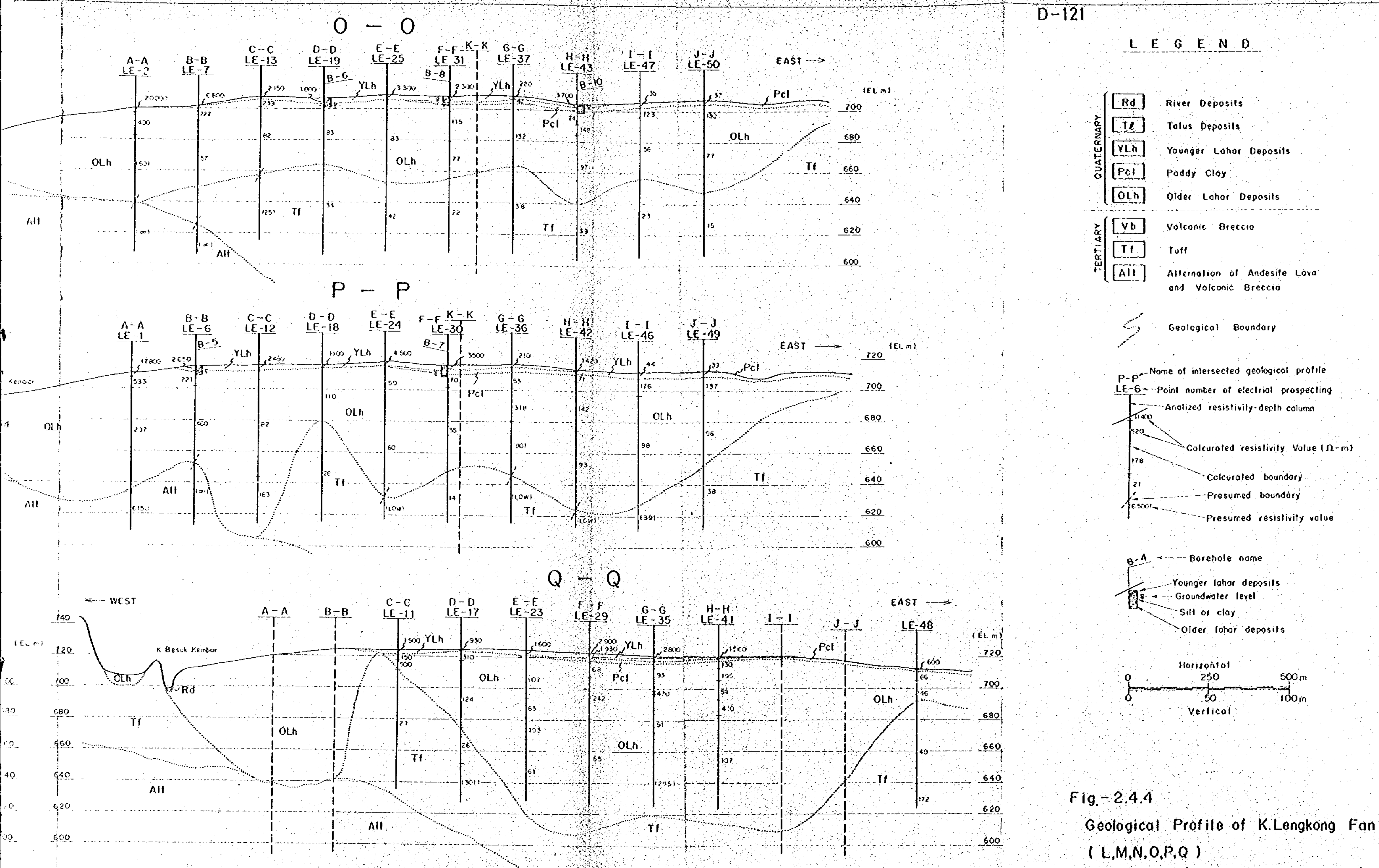


Fig.-2.4.4

Geological Profile of K.Lengkong Fan (L,M,N,O,P,Q)

Fig. - 2.4.5 Schematic Geological Profile of K. Lengkong Fan

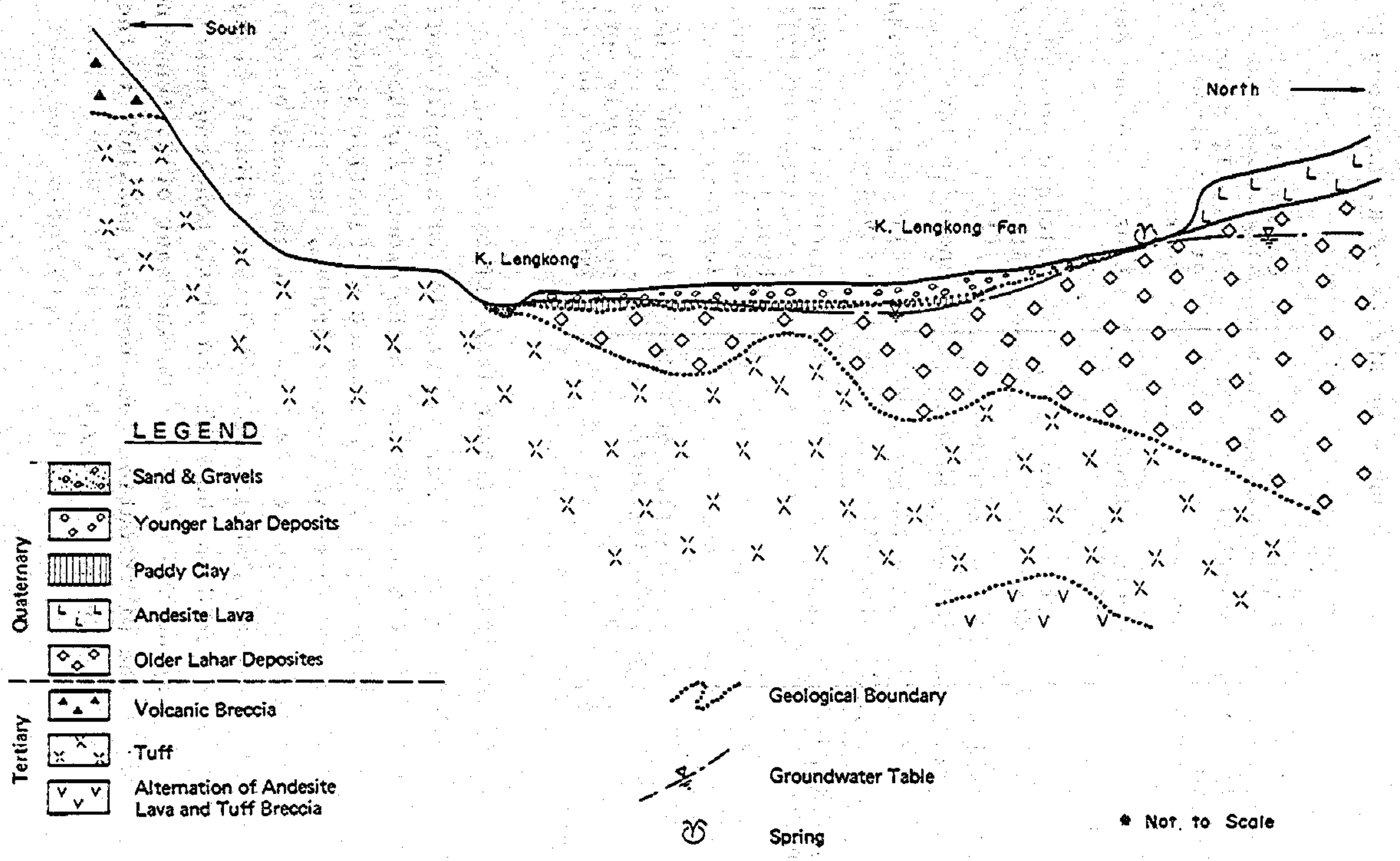


Table-2.4.1 Sequence of Strata of K. Lengkong Fan

Age	Layer	Components
Quarternary Period	Riverbed deposits	Presently moving sand and gravels along river course.
	Younger Lahar deposits	Loose sand and gravels.
	Pyroclastic deposits	Volcanic products directly issued from the crater.
	Andesite lava	Andesite lava.
	Older Lahar deposits	Well compacted sand and gravels.
Tertiary Period	Tuff	Soft tuff, tufficious sandstone and tuff breccia. With thick weathered layer.
	Alternation of Andesite/Tuff Breccia	Alternation of hard, compact andesite and comparatively soft and porous tuff breccia.

i) Alternation of Andesite/Tuff Breccia

The existence of alternation of andesite/tuff breccia not exposed on the ground surface in K. Lengkong Fan is estimated by electric sounding. Its resistivity is over 10,000Ω m, and it is found at around -60 to -80 m depth in the west of K. Lengkong becoming shallower toward west, finally being exposed on the riverbed of K. Lengkong near Pronojiwo Damsite. On the east of K. Lengkong Fan, the distribution goes deeper, possibly to the depth of 100 m or below.

Alternation of andesite/tuff breccia is, according to the Lugeon test results at Pronojiwo Damsite, less than 1 Lu ($K = 1 \times 10^{-5}$ cm/sec) at the deep fresh part which may be considered as an impervious layer but there are some very porous layers in tuff breccia which may let ground water pass easily.

ii) Tuff

Tuff layers distributed at the foot of the Tertiary mountains opposite K. Lengkong Fan and plateau-like hill located west of the fan are composed of these layers. Also they are exposed at two spots in K. Lengkong Fan. The layers show loam-like condition on the ground surface due to weathering, and tufficious sandstone and tuff breccia are intercalated. The resistivity of the layer is very low at 1 to 30 Ω m. This layer overlies the alternation of andesite/tuff breccia; its thickness is greatly varied and is partly missing while the thickness reaches as much as over 80 m on other parts.

Weathered surface part of this layer which is very similar to loam, contains much silt and clay and its rate is about 40 to 50%. Inspite of the existence of fine particles, the permeability coefficient on the surface is very large at 8×10^{-3} cm/sec according to the in-situ permeability test. Because void ratio of the weathered layer near the ground surface is large at 3.1 to 3.7, soil fabric may be considered very porous. B-11 penetrated the surface layer of tuff at 55.2 m deep. According to the core sample of B-11, the surface layer of tuff has turned into soft black clay including some organic contents.

Incidentally the permeability coefficient when the soil layer is compacted under the optimum water content is K = 10^{-7} cm/sec. From this, the permeability coefficient of this layer under great load in underground is estimated to be at about K = 10^{-6} to 10^{-7} cm/sec. From the foregoing, the tuff layer can be regarded as an impervious layer at depth.

Spring water is observed at several points along K. Lengkong where ground water pours out from pipe-like watervein (diameter is 1 - 3 cm) in the weathered layer of tuff. This indicates the existence of ground water moving through the pipe-like watervein in the weathered layer of tuff.

iii) Older Lahar Deposits

Older Lahar deposits consist of relatively well compacted sand and gravels with its resistivity very large at 7,000 to 20,000 Ωm at dry portions above the ground water level, dropping sharply to 50 to 600 Ωm at wet portions below the ground water level. Also because there are many parts where resistivity of less than 100 Ωm is widely observed, it is supposed that older Lahar deposits in K. Lengkong Fan contain mostly much fine materials such as silt. Among older Lahar deposits, several high resistivity layers are observed, but they are not continuous. This indicates that older Lahar deposits are composed of accumulation of very irregular tongue shaped stratum. These strata may consist of various layers from silty to very coarse. Among older Lahar deposits in K. Lengkong Fan, andesite lava may be intercalated in some portions.

Older Lahar deposits bury ancient mountains consisting of Tertiary formations and its thickness is as much as over 100 m within the study area.

Older Lahar deposits are relatively well compacted and their permeability coefficient is assumed to be about $K = 10^{-4}$ cm/sec. As some very coarse layers considered to be autobrecciated lava, coarse and loose Lahar or Pyroclastic deposits, etc. are presumed intercalated in order Lahar deposits, the permeability of older Lahar deposits is considered to vary largely from layer to layer as $K = 10^{-2}$ to 10^{-4} cm/sec. As a matter of fact B-11 hole penetrates some coarse layers and fine layers in Older Lahar deposits.

iv) Paddy Clay

Covering the older Lahar deposits, the distribution of paddy clay is limited to western part of L. Lengkong Fan. Before the disaster of 1977, K. Lengkong Fan was a rich paddy farming area; traces of paddy clay can still be found today.

The maximum thickness of paddy clay is about 3 m with fine grains of silt and clay occupying nearly 80% of it. Its permeability coefficient is small at $K = 8 \times 10^{-5}$ cm/sec. For this reason, paddy clay acts something like a sheet to prevent infiltration of rain water to underground.

v) Younger Lahar Deposit

Younger Lahar deposits distributed over K. Lengkong Fan were derived from Lahar of 1977 and 1978 and consist of sand, silt and gravels of low compaction. The maximum thickness of the layer is 4 to 5 m which is not very thick. The layer contains about 3% fine sand and silt and void ratio is relatively low at 1.1 For this reason, the permeability coefficient is small at about K = 5 to 4×10^{-4} cm/sec.

vi) Pyroclastic Deposit

These are products from the crater of Semeru volcano and parasitic volcanoes which have not moved by precipitation. They consist of very loose volcanic ash, volcanic sand, pumice, lapili, angular boulders, etc. These deposits are distributed over the area 800 m above sea level nearly 2.5 km north of K. Lengkong.

vii) Andesite Lava

Andesite lava is distributed in the area about 3.5 km north of K. Lengkong extending northwest to southeast about 2 km in width and about 6 km in length. According to the observation of outcrops along K.B. Kembar, the thickness of the lava flow is 20 to 30 m and is very hard and compact andesite in the inner part. Clinkers comprised of breccia of several meters is destributed in upper and bottom parts. There are many springs at the tip of this andesite lava. It is supposed that ground water flows down through waterveins in the very porous clinker at the bottom of lava.

iix) Talus Deposits

Talus deposits are observed on the west bank of K. Lengkong where the tuff of the Tertiary formation is widely distributed. Their maximum thickness is estimated to be at about 10 m. The entire surface layer of tuff is highly weathered and the weathered portion seems to have somewhat creeped. But Talus deposit, shown in Fig.-2.4.1 Geological Map of K. Lengkong Fan, represent only those portions apparently moved and re-deposited. Talus deposits consist mostly of reddish-brown clay and often contain large boulders of tuff breccia of 2 to 4 m in diameter.

ix) Riverbed Deposits

These are sand and pebbles presently moving on the riverbed by the flowing water. The thickness is about 1 to 3 m.

(3) Geological Structure

Next, geological structure of K. Lengkong Fan will be discussed.

K. Lengkong Fan was formed by deposits of volcanic products from Semeru volcano over the ancient mountains of Tertiary system. The base Tertiary formations may have small faults but large faults which would substantially affect the ground water movement are considered non-existent because of the surrounding topography and geological structure. Also in the Tertiary formations, the bedding plane is roughly horizontal although there is local undulation but without any anticlinal or synclinal structure of any large size.

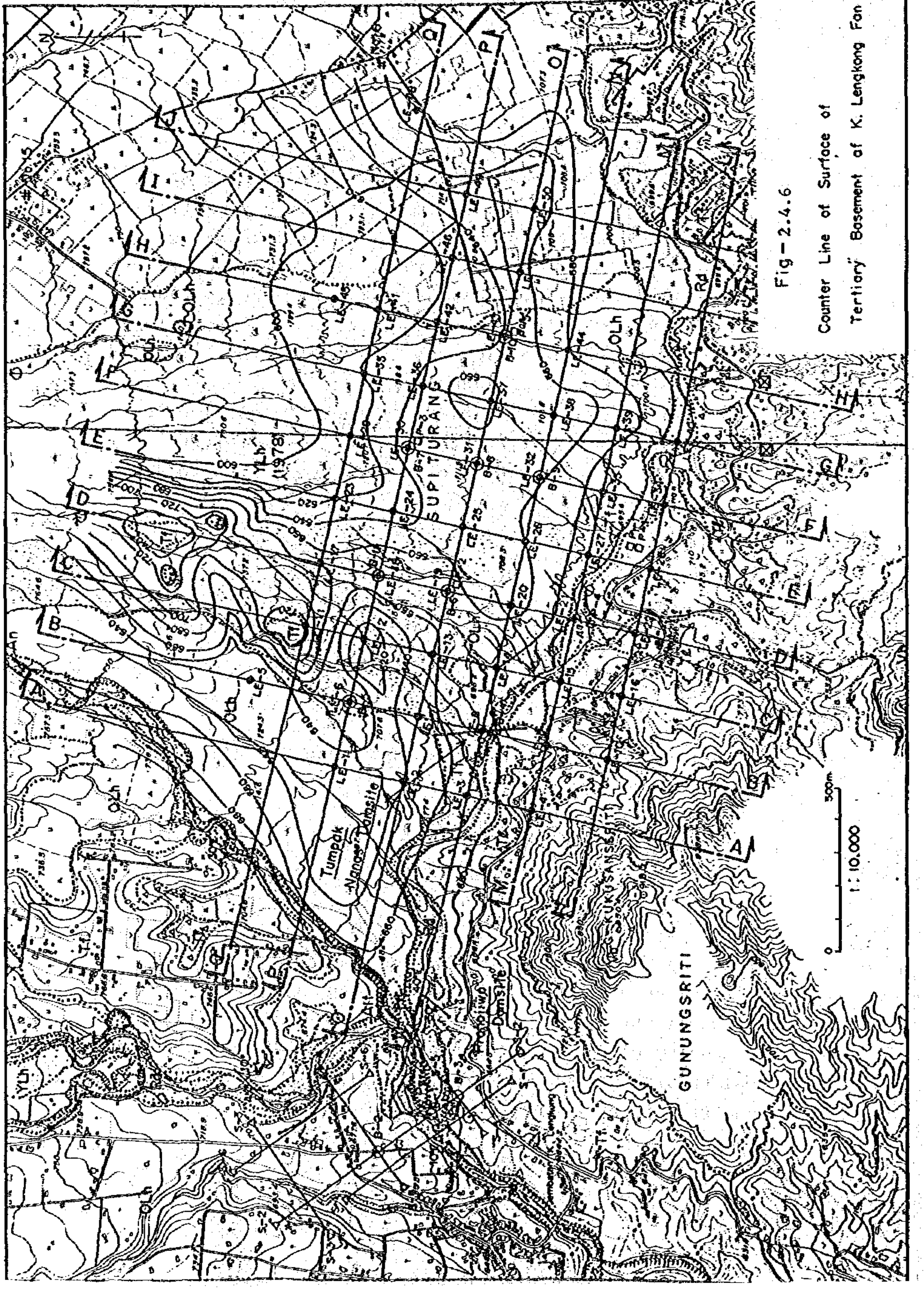


Fig-2.4.6

Counter Line of Surface of Tertiary Basement of K. Lengkong Fan

The plane of unconformity between older Lahar deposits and Tertiary formations, that is, the surface of ancient mountains consisting of Tertiary formations shows a shape of ground water basin of K. Lengkong Fan. This is shown in Fig.-2.4.6. As observed from this, a long narrow ridge of Tertiary formations extends from south to north, and part of the ridge is exposed to the ground surface in K. Lengkong Fan. Thus the ground water basin of K. Lengkong Fan is divided by the ridge.

Older Lahar deposits and younger Lahar deposits consist of sand, gravels and silt, are piled up randomly and continuation of each stratum is very poor. But the structure of deposits is considered inclining from north to south roughly in parallel with the present ground surface of the fan, because volcanic products are being spauted from the crater of Mt. Semeru. No faults and folds are observed due to the tectonic movement in older Lahar deposits around K. Lengkong Fan.

(4) Ground Water

In the dry season of 1982, only small amount of spring water was observed at several spots below 830 m above sea level in K. Lengkong Fan, but none at higher than EL. 830. Also, K.B. Kembar flowing through west of K. Lengkong Fan becomes a dry river at above EL. 820 m but the water was observed flowing at lower than EL. 830 m. This seems to indicate the existence of a changing line of ground water level at around the elevation of 820 m. Spots of spring water are observed distributed in an arc shape along near EL 830 m counter line on the slope of the volcano. One of the reasonsis that the inclination of the slope of Mt. Semeru changes at around EL. 800 m. In other words, above EL. 800 m steep Ladu fan is distributed and relatively slow Lahar fan is distributed below EL. 800 m. This phenomenon cannot be explained by topographical features only, for it may be intimately related to the hydrogeological structure of Semeru volcano.

According to the results of drilling survey, in the area near K. Lengkong, the ground water level is located at a shallow depth of about -1 to -4 m. As the elevation gets higher, the ground water level tends to go deeper. Also similar trend is observed for the ground water level of wells in villages situated in east of K. Lengkong Fan. At wells near 800 m above sea level, the ground water level is shallow at -1 to -0.5 m and many springs are observed around the area. As the elevation decreases, the ground water level goes deeper at EL. 750 to 730 m, the ground water level is located at a depth of -3 to -5 m. As the elevation further drops and gets closer to K. Lengkong, the ground water level rises again and stays at a depth of about -1 m. The ground water level of these wells were measured in the dry season of 1982. According to local inhabitants, the ground water level usually rises about 1 m in the rainy season.

Volcanic products of Semeru volcano including older Lahar deposits are deposited largely in parallel with the slope of the present volcano body. Ground water is believed to be regulated by this stratified structure of strato-volvano. Also in this stratified structure, many water veins are thought to be formed in old valleys, lava, coarse Lahar deposits, etc.

2.4.3 INVESTIGATION WORKS AND TESTS

At K. Lengkong Fan, investigation works and tests were carried out as shown in Table-2.4.2. The location of investigation works and sample collection points are shown in Fig.-2.4.1 Geological Map of K. Lengkong Fan. Investigation works and tests were carried out by ITB, and synthesis was carried out by JICA Study Team members.

Table-2.4.2 Items and Quantities of Geological Investigations and Tests at K. Lengkong Fan

Item	Quantities
Boring	8 boreholes, total 103 m
Electric sounding	a = 200 m, 50 points
In-situ permeability test	5 points
Field density test	5 points
Laboratory soil test	5 samples

(1) Electric Sounding

An outline of the results of analysis of electric sounding is given below. The results of analysis of electric sounding are given in the Geological Profile of Fig.-2.4.2, Fig.-2.4.3, Fig.-2.4.4.

i) The resistivity layer of K. Lengkong Fan is classified into the following 6 layers as shown next.

Table-2.4.3 Resistivity Layers of K. Lengkong Fan

Resistivity Layer	Resistivity (Ωm)	Thickness (m)	Geology
I	35 - 20,000	2 - 5	Younger Lahar deposits or top soil of farm land
II	50 - 600	(> 40)	Older Lahar deposits
III	13 - 50	(> 15)	Highly weathered portion of the Tertiary formations and its deposits
IV	1 - 13	(> 20)	Tertiary basement (clay and mudstone)
V	14 - 30	-	Tertiary base (silt and mudstone)
VI	>1,000	-	Alternation of andesite/tuff breccia

ii) Resistivity Layer I is classified into the areas with over 2000 Ω m and under 100 Ω m. The former is distributed from the center of Kali Lehang Fan to the western area and the latter to the eastern area and the foot of Mt. Kukusanseriti.

iii) Resistivity Layer II is further sub-divided into several thin resistivity layers, but they are untraceable layers, however. Resistivity Layer II is located mostly below the ground water table and is highly permeable.

iv) Resistivity Layer III is limited to the area from the foot of Mt. Kukusanseriti to Kali Lenkong Fan. This layer is considered to be an aquiclulde layer, but this assumption must be confirmed by other geological surveys.

v) Resistivity Layers IV and V were detected at the foot of Mt. Kukusanseriti. Resistivity Layer IV is impermeable and richer in clay mineral than the resistivity Layer III.

vi) Resistivity Layer V is also impermeable.

vii) Resistivity Layer VI having the highest resistivity value is limited to the western area of K. Lengkong Fan. This layer corresponds to alternation of andesite/volcanic breccia.

(2) Drilling Work

The drilling work was carried out by ITB and the observation of core samples was performed by Mr. Sasaki, a member of JICA Study Team, in charge of land conditions. An outline of core observation is given below. The results of observation are summarized in Fig.-2.4.7 Geological Log. For the details of drilling work, please refer to the technical reports submitted to Mt. Semeru Project Office by ITB. These boreholes were completed as observation holes and the groundwater level is now under observation. As for the results of B-11 hole, please refer to Part - C Ground Water.

i) B-4 Hole

B-4 hole was drilled on the riverbed of K. Lengkong as shown in the geological map of K. Lengkong Fan, where construction of a sabo dam of Tumpak Nanas is planned.

-: Geology

0 to - 0.6 m: Dark greyish-black coarse sand and gravels.

-6.0 to -7.8 m:	Light grey sand and gravels and small amount of silt.
-7.8 to -9.0 m:	Dark brown compacted clay mixed with gravels. Highly weathered layer of tuff.
-9.0 to -10 m:	Reddish-brown compacted clay. Highly weathered layer of tuff.

-: Ground Water Level

While drilling B-4 hole, confined ground water sprang up. After completion of the hole the water level rose 30 to 50 cm above the level of surface of river water.

While drilling, when a steel casing was inserted to -5.5 m, about 50 l/min. water sprang out. The similar condition continued down to the depth of -10 m where spring water stopped when the steel casing was pulled out. After that, PVC pipe with strainer was installed in the hole. Then the mouth of the hole was covered with a metal pipe cap. When a concrete slab was placed around the hole, the water level in the metal pipe at the mouth of the hole started to rise stabilizing at 30 to 50 cm above the water surface of the river.

This indicates that confined ground water flowed into K. Lengkong from K. Lengkong Fan consisting of older and younger Lahar deposits.

ii) B-5 Hole

B-5 hole was drilled in K. Lengkong Fan.

-: Geology

0 to -3.5 m:	Light gray, loose silty sand with gravels. Younger Lahar deposits.
-3.5 to -5.0 m:	Dark brown, relatively stilf clay with much organic substances. Paddy clay before disaster.
-5.0 to -6.0 m:	Dark brown, soft sandy clay with much organic substances. Paddy clay before disaster.
-6.0 to 7.0 m:	Dark brown, well compacted, coarse sand with some clay. Older Lahar deposits.

-: Ground Water Level

The ground water level situated at a depth of -4.6 m at the time of hole completion. It is located in paddy clay layer.

iii) B-6 Hole

B-6 hole was drilled in K. Lengkong Fan.

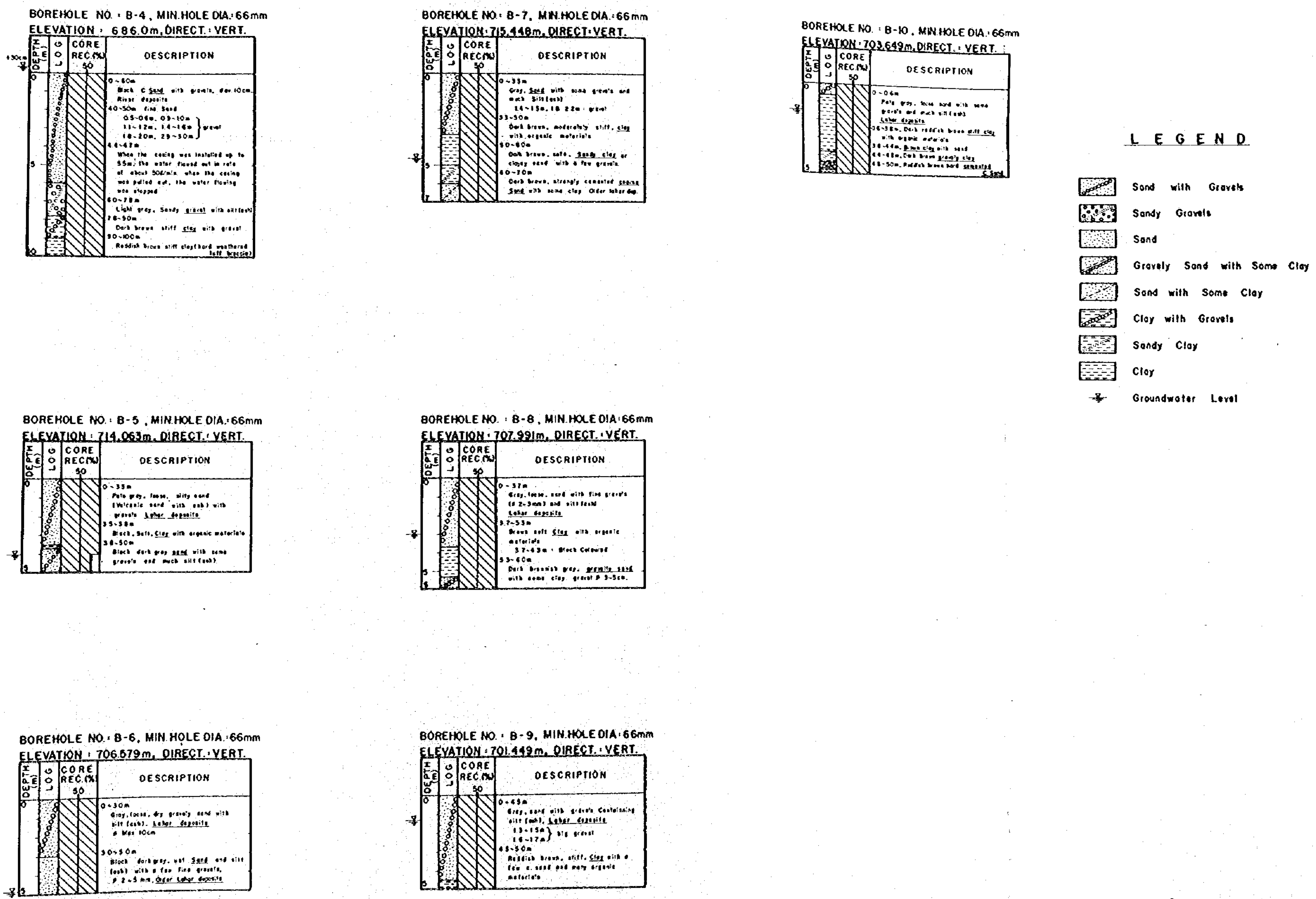


Fig.-2.4.7 Geological Log (B-4 to B-10)

-: Geology

0 to -3.0 m:	Silty sand mixed with grey loose gravels. Younger Lahar deposits.
-3.0 to 5.0 m:	Black to dark grey silty sand mixed with fine gravels. Older Lahar deposits.

-: Ground Water Level

The ground water level was at a depth of -4.8 m at the time of completion. It is located in older Lahar deposits.

iv) B-7 Hole

B-7 hole was drilled in K. Lengkong Fan.

-: Geology

0 to -3.3 m :	Silty sand mixed with grey loose gravels. Younger Lahar deposits.
-3.3 to -5.0 m:	Dark brown, a little compact clay. Contains a large amount of organic substances. Paddy clay before the disaster.
-5.0 to -6.0 m:	Dark brown, soft sandy clay. Contains a large amount of organic matters. Paddy clay before the disaster.
-6.0 to -7.0 m:	Coarse sand containing some dark brown compact clay. Older Lahar deposits.

-: Ground Water Leval

The ground water level was at a depth of -4.6 m at the time of completion. It is located in paddy clay.

v) B-8 Hole

B-8 hole was drilled in K. Lengkong Fan.

-: Geology

0 to -3.7 m :	Sand mixed with grey loose fine gravels. Younger Lahar deposits.
-3.7 to 5.3 m:	Brown soft clay containing a large amount of organic substances. Paddy clay before the disaster.
-5.3 to 6.0 m:	Dark brown sand mixed with gravels. Contains some clay and compact. Older Lahar deposits.

-: Ground Water Level

The ground water level was at a depth of -3.0 m at the time of completion. This is located in younger Lahar deposits.

vi) B-9 Hole

B-9 hole was drilled in K. Lengkong Fan.

-: Geology

0 to -4.5 m : Silty sand mixed with grey loose gravels. Younger Lahar deposits.

-4.5 to-5.0 m: Reddish-brown well compacted clay containing a large amount of organic substances. Paddy clay before the disaster.

-: Ground Water Level

The ground water level was at a depth of -1.3 m at the time of completion. This is located in younger Lahar deposits.

vii) B-10 Hole

B-10 hole was drilled in K. Lengkong Fan.

-: Geology

0 to-0.6 m : Silty sand mixed with light grey loose gravels. Younger Lahar deposits.

-0.6 to -3.8 m: Dark reddish-brown well compacted clay, containing a large amount of organic substances. Paddy clay before the disaster.

-3.8 to-4.4 m: Brown, well compacted sandy clay containing organic substances. Paddy clay before the disaster.

-4.4 to 4.8 m: Dark brown well compacted clay mixed with gravels, containing organic substances. Paddy clay before the disaster.

-4.8 to 5.0 m: Reddish-brown cousdidated coarse sand. Older Lahar deposits.

-: Ground Water Level

The ground water level was at a depth of -1.5 m at the time of completion. This is located in paddy clay.

(3) In-situ Permeability Test and Soil Test

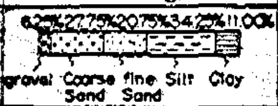
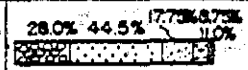
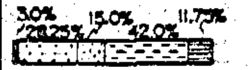
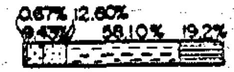
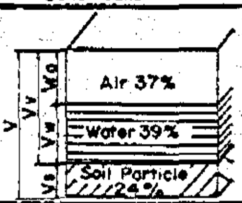
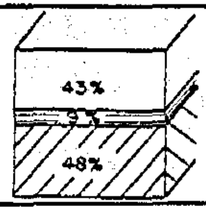
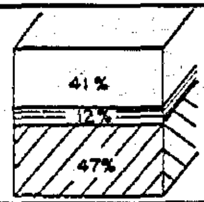
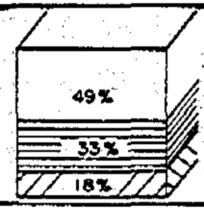
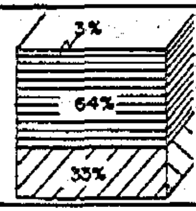
The in-situ permeability test was carried out by ITB and the results of the test used in this report were calculated by members of JICA Study Team. The results of the field density test and laboratory soil test carried out by ITB were used in this report. For details of the tests, please refer to the technical reports submitted to Semeru Volcano Office by ITB.

The results of the in-situ permeability test, field density test and soil test are summarized in Table-2.4.4. The following are obtained from the table.

i) Younger Lahar Deposits

The permeability coefficient is 5 to 4 x 10^{-4} cm/sec., a small figure for sand/gravel layer. This may be due to the fact that 30% of this layer is comprised of fine sand and silt, and void ratio is small at about 1.1, so that pores between coarse grains are filled with fine particles.

Table-2.4.4 Results of In-Situ Permeability Test and Soil Test

Test Item / Pit No.	P-1	P-2	P-3	P-4	P-5
Lithology	Highly Weathered Tuff	Younger Lahar Deposits	Younger Lahar Deposits	Highly Weathered Tuff	Paddy Clay
Permeability Coefficient (k)	14×10^{-2} cm/sec	5×10^{-4} cm/sec	4.2×10^{-4} cm/sec	13×10^{-2} cm/sec	8.0×10^{-5} cm/sec
Natural Water Contents (ω)	59.3%	6.25%	8.6%	69.17%	73.31%
Specific Gravity (Gs)	2.7458	2.7398	2.7562	2.7113	2.6273
Field Density (γt)	1.06 g/cm^3	1.50 g/cm^3	1.42 g/cm^3	0.81 g/cm^3	1.50 g/cm^3
Grain Size Distribution					
Volume Ratio of Each Component					
Void Ratio ($e = \frac{Vv}{Vs}$)	3.13	1.08	1.11	4.66	2.0
Porosity ($n = \frac{Vv}{V} \times 100$)	75.6%	52.0%	52.6%	82.3%	66.7%
Saturation ($Sr = \frac{Vw}{Vv} \times 100$)	52.1%	16.4%	21.4%	40.2%	95.0%
Air Voids ($\upsilon a = \frac{Va}{v} \times 100$)	37.0%	43.5%	41.3%	49.2%	3.3%

ii) Weathered Layer of Tuff (Loam Like)

The permeability coefficient of weathered tuff is about $K = 1 \times 10^{-2}$ cm/sec., a remarkably large figure for the grain size distribution (40 to 50% of silt and clay) and is larger than that measured in younger Lahar deposits. This is due to the fact that void ratio is remarkably large at 3.1 to 4.7 and fabric of soil is very porous. But since it is a portion exposed to the ground surface, it has such high porosity. Where it is compacted in deep underground subjected to heavy load, it is expected to be compact and have a very low permeability coefficient ($K = 10^{-6}$ to 10^{-7} cm/sec. approx.) as mentioned in section 4.2.2. This layer is believed to play a substantial role in impervious layer when it is located below thick Lahar deposits.

iii) Paddy Clay

Paddy clay is distributed on the boundary between older Lahar deposits and younger Lahar deposits. This clay abounds in very fine grains i.e.: 58% silt and 19% clay with the permeability coefficient low at $K = 8 \times 10^{-5}$ cm/sec.

2.2.4 HYDROGEOLOGICAL CONSIDERATION

The ground water level in K. Lengkong Fan is generally shallow, located at a depth of about -1 to -5 m from the ground surface, with a small seasonal variation between the dry and rainy seasons of as little as about 1 m accroding to the local inhabitants. Also there is a place where confined ground water flows into K. Lengkong from K. Lengkong Fan.

From the standpoint of ground water basin, on the west of K. Lengkong Fan, Tertiary basement ridge, an impervious layer, runs from south to north. On the east side of the ridge, a large scale underground basin is assumed to extend extensively. Ground water on the east side of this underground ridge is thought to be blocked by this ridge.

Older Lahar deposits, main body of pervious layer, consist a number of discontinuous layers. Its hydrogeological structure is greatly varied but from an overall point of view, it is believed to be a strafied structure with many ground water veins in many layers.

Although permeability coefficient of Lahar deposits is very small (about $K = 5 \times 10^{-4}$ cm/sec.) according to the in-situ permeability tests, older Lahar deposits may be intercalated with highly pervious layers such as autobrecciated lava, very loose and coarse Lahar or Pyroclastic deposits composed of mainly angular boulders, etc. So that the permeability of older Lahar deposits is assumed to vary largely from layer to layer as $K = 10^{-2}$ to 10^{-4} cm/sec.

The surface layer of Tertiary basement is comprised of highly weathered tuff according to the results of B-11 hole and it is considered to have a small permeability coefficient of $K = 10^{-6}$ to 10^{-7} cm/sec. according to the laboratory soil tests. It plays a major role in impervious basement of K. Lengkong ground water basin. As for the detailed hydrogelogical consideration, please refer to Part-C Ground Water.

2.4.5 FUTURE STUDY THEMES

Through the present study, the general geological condition has been investigated, but it did not fully clarify the hydrogeological structure of K. Lengkong Fan. There are, therefore, many points that should be clarified in the future. The unclarified points are listed below as themes for future studies.

(1) The present study was carried out in a comparatively narrow range along K. Lengkong the regional shape of the ground water basin is not known. Therefore, it is necessary to expand the range of study to include the whole area of the fan and study the geological condition of the whole K. Lengkong Fan.

(2) Because of lack of successive records of ground water levels, it is necessary to carry out the observation of ground water level for a long period of time in the future and collect data. Also it is necessary to arrange ground water observation points in the whole K. Lengkong Fan as well as in the neighboring area.

(3) Also it is necessary to learn hydraulic coefficient (permeability coefficient, transmissibity, storage specific capacity and etc.) of older Lahar deposits which is believed to be a pervious layer and its optimum specific yield. For this purpose, pumping test must be carried out using deep boreholes.

(4) It is necessary to confirm the quality of ground water in great depth, to learn the relationships among ground water, river water, rain water, etc. for studying the source of ground water.

(5) In case ground water of K. Lengkong Fan is developed, it is necessary to clarify its effect upon the wells of the surrounding villages.