MINISTRY OF INTERIOR
PROVINCIAL WATERWORKS AUTHORITY

DEVELOPMENT PLAN AND FEASIBILITY STUDY
ON
PROVINCIAL WATER SUPPLY PROJECTS
IN
THE KINGDOM OF THAILAND

FINAL REPORT
FOR
PHUKET
APPENDICES II

MARCH 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

1. INTRODUCTION

This report describes an engineering geologic assessment as well as geological condition of proposed dam sites inclusive of Khlong Lo Young, Bang Nieo Dam, Khao Che Tra, Khlong Katha and Bang Tho Sung on the basis of a result of boring survey and field reconnaissance. Among above five dam sites, Khlong Lo Young is situated in the Phang Nga area. The other sites are on the Phuket Island as shown in Figure 1-1.

At the Khlong Katha dam site, a previous investigation which consisted of soil boring, test pit and hand auger survey were carried out for a feasibility study of dam construction by Soil & Geology Division, RID in 1981. At the other four sites, any geological study however have not been executed. The previous feasibility study for the Khlong Katha dam site planned small scaled dam in which the crest height from foundation was less than 30 m. Therefore, the scale of investigation was also small such as that the maximum boring depth was 24 m and was not reach to bedrock underlying the weathered rock layer. And the investigation was concluded that there was enough bearing capacity to the planned dam but was not a favorable banking materials.

At two dam site among five proposed sites, the Khlong Lo Young and Bang Tho Sung dam sites, the geological survey was not executed during this time. However, at the remaining three dam sites, the geological investigation was carried out as a stage of feasibility study comprising the field geological reconnaissance, boring survey and in-situ test. Consequently, these test and data also conclude that the construction of dam in each site is technically feasible, although a considerably modification for the dam foundation is required by geological condition simultaneously.

General geology for the study area is explained in Chapter 2; the previous investigation data is reviewed in Chapter 3; and the geological condition revealed by investigation and engineering assessment is dealt with in Chapters 4 and 6.

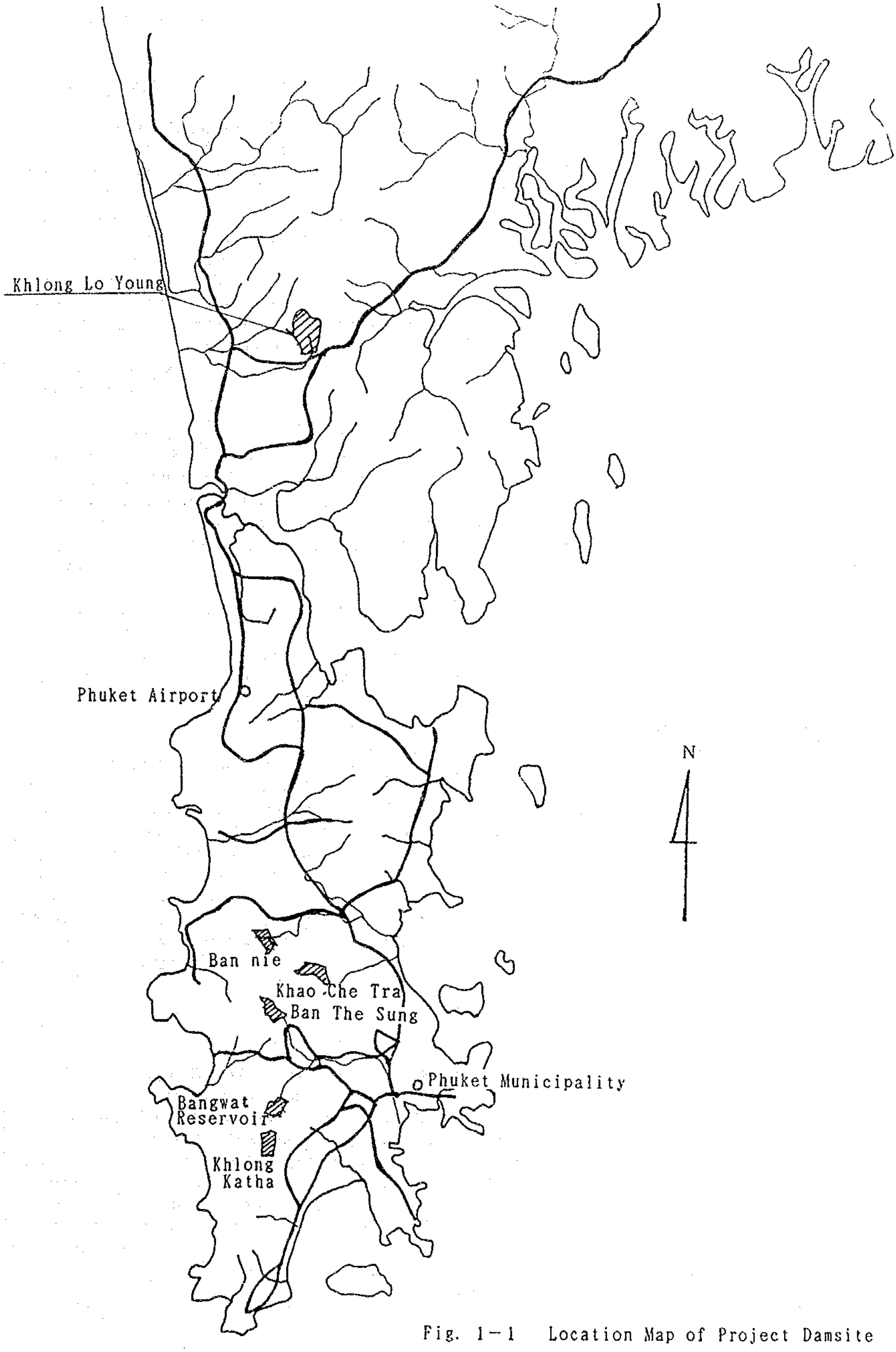


Fig. 1－1　Location Map of Project Damsite

2. GEOLOGY OF SURVEY AREA

2.1 Topography

In the vicinities of Phuket, three main types of land form are classified. They are of highlands with moderate or gentle slopes, steepsided hills and ridges and lowlands.

In general, highland is formed of granites and sediments of Middle-Upper Paleozoic Phuket Group and Mesozoic Ko Yao Noi Formation. Steepsided hills and ridges are formed of Permian limestone, and lowland comprised sediments of Krabi Formation in Tertiary and the post-Pleistocene valleys and plains. Approximately half of the study area is upland. The maximum elevation on the Phuket Island is about 530 m of granite masses trending roughly N-S. The other part of the study area is made of folded and fractured sediments of Phuket Group. Although in some places, the topography looks similar to that of the granite area.

Limestone ridges and monodnocks with steep or vertical sides form spectacular topography shown in the east or north of the study area, particularly in the Phang Nga mainland. Discontinuous ridge extend south into the Phang Nga Bay where they form numerous islands with vertical cliffs. The larger limestone area display a marked karst topography with large sink holes which is formed in the Pleistocene. Most ridges run N or NE in parallel to the main fold axis.

River valley is generally flattened by the post-Pleistocene deposits and are formed coasted plain. In the west of a coastal plain up to 5 km wide borders a granite ridge which is running N-S trend. Mangrove swamp is extensively developed on the stretches of muddy flat up to several kilometers around the western parts of the study area especially at Takua Pa. The widest area is seen at Khlong Phang Nga, Khlong Thung Maphrao and Khlong Takua Pa.

The limestone islands in the Phang Nga Bay which represents the erosion remnant area of gentle slopes can be easily explained by submergence following erosion. Evidence of high sea level is provided by a small patches of marine sediments at various localities above the present sea level around the coast of the Phuket Island and also in the limestone caves in Phang Nga. The erosional surface is commonly covered with abundant recent marine mollusc shells and locally shows mollusc boring. These feature may indicates the eustatic changes in the Pleistocene age. The most of proposed dam sites are also found out these marine terrace on the mountain slope which forms the dam abutment and dam reservoir.

2.2 Geology

Most of the Phuket and Phang Nag area are occupied by granite and a succession of laminated mudstone, turbidite and/or diamictite of presumably Upper Paleozoic age (Carboniferous to Lower-Permian) as shown in Figure 2-2-1. The limestone (Ratburi Limestone) covered with Permian is commonly exposed in Phang Nga and Krabi. The granite and the minor associated intrusive rock in this area belong to the tin province forming an accurate belt of batholithic intrusion stretching over 2,500 km from Indonesia in the south through the Thai-Malay Peninsula into the Shan States of eastern Miyanma and hence into northwestern Thai.

2.2.1 Paleozoic Stratigraphy

The most of the sedimentary rock exposed in the Phuket and Phang Nga area is made of pebbly mudstone facies. Generally, these facies have been recognized as Andaman Group which is classified into two sub-groups of Phuket Formation and Ko Yao Noi Formation. These groups are also lithologically divided into eight litho-facies, namely laminated mudstone, sharp lened sandstone in mudstone, slump units pebbly mudstone, limestone, well sorted sandstone and conglomerate, bryozoan facies and thick bedded sandstone and shale. They however are not able to arrange in stratigraphic order, hence the further stratigraphical study should be needed. Both subjects of these lithological order of facies and the correlation between the Phuket Formation and Ko Yao Noi Formation are still remained as an unsettled geologic question.

(1) Andaman Group

As above mentioned, Andaman Group in this area can be divided into two distinct formations, Phuket Formation and Ko Yao Noi Formation on the basis of lithological ground. Both of them are time-equivalent and lying beneath the Permian area while the facies of sequences are different from place to place.

(a) Phuket Formation

The litho-stratigraphic term of Phuket Formation is derived from the stratigraphical study on the Phuket Island. The facies is well exposed along the eastern coast of the Phuket Island especially at Leam Panwa, Khao Sure, Leam Mai Pai and Khao Sam Leam. The regional distribution of Phuket Formation is extensive, it occupies the central area of the Phang Nga area restricting by Khlong Marui Fault to the Chunporn Province.

The facies of Phuket Formation can be divided into six units as shown in Figure 2-2-1. The aspect of facies is as follows:

- Permian Limestone :

marine limestone and bedded limestone with hard nodules in the lower parts.

- Khao Nang Hong Unit (600-800 m) :

diamictite, laminated mudstone, quartzite, sandstone, fine conglomerate bryozoan beds and alternation of shale and sandstone

- Ko Naka Unit (30-50 m) :

sandstone with mudstone interbedded diamictite, turbidite and slumping structure

- Khao Sam Leam Unit (80-100 m) :

laminated mudstone with stratified diamictite

- Leam Mai Pai Unit (100-150 m) :

laminated mudstone with scattered chert, fossils of brachiopod are found. Boulder of granites in the laminated mudstone.

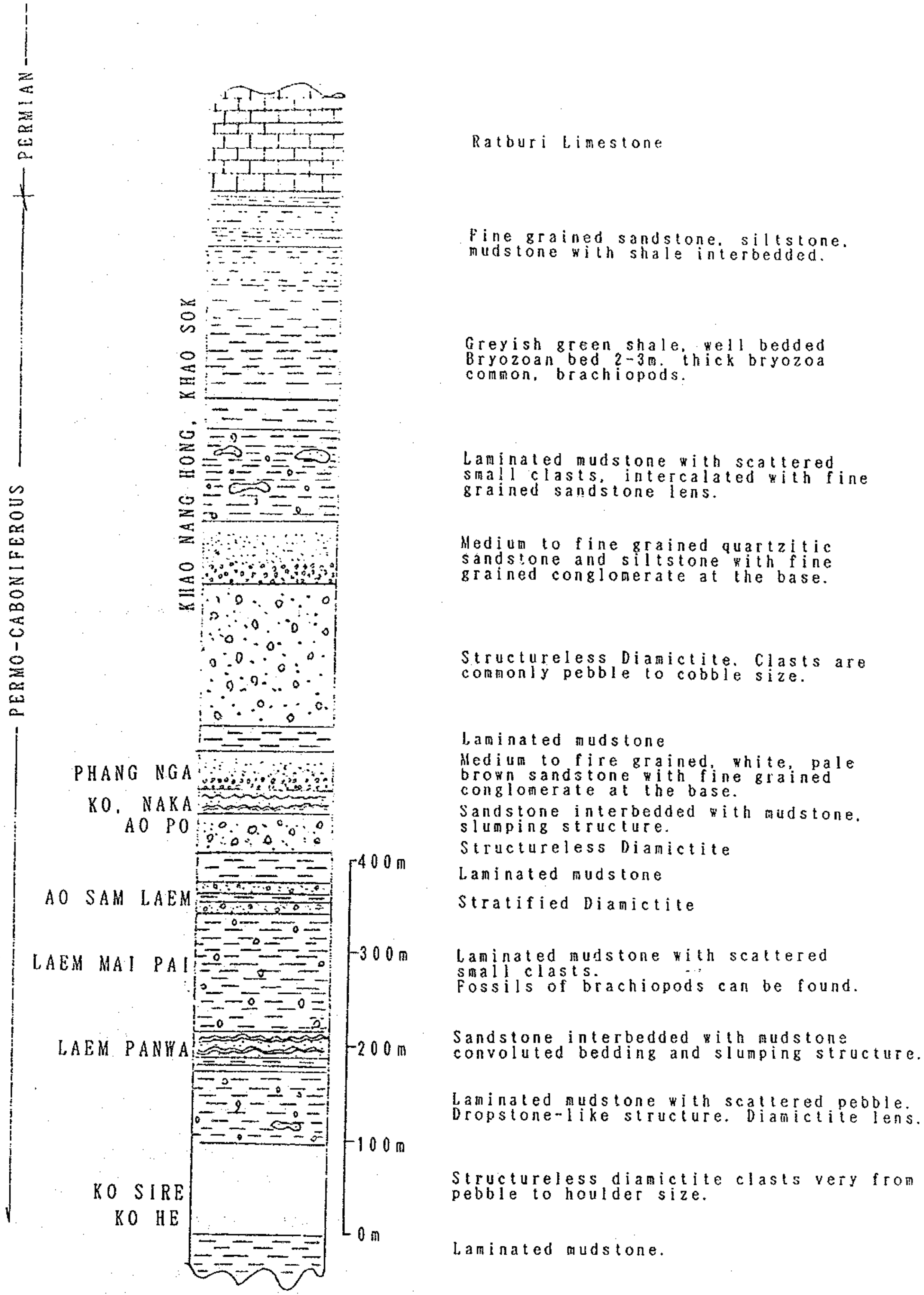


Fig. 2-2-1 Stratigraphical Sequence of Phuket Formation

- Leam Panwa Unit (100-150 m) :

sandstone interbedded with mudstone, turbidite showing convolute bedding and some slumping structure and diamictite with dropstone-like structure. Clasts of diamictite vary from pebble to boulder in size.

- Khao Sure Unit (100-150 m) :

laminated mudstone and diamictite clasts vary from pebble to boulder size.

Among these units, most thick unit is Khao Nang Hong Unit. It mainly consist of the bedded sandstone-turbidite sequence and underlying diamictite. The approximate thickness of Unit is over 600 m and is characterized by abundant fossils in the Bryozoan Bed. In the two proposed dam sites, Khlong Lo Young and Khao Che Tra, sandy facies are crop out. The facies are marked by metamorphosed sandstone and fine alternation of shale and sandstone. Even if its lithologic characteristic is clarified in the above dam sites, the stratigraphic correlation between Paleozoic unit and dam site facies will remain as a still unsolved problem due to the thick vegetation and weathering layer resting on the fresh rock facies.

It however may be inferred that the lithological characteristic of dam site is correlative with that of Khao Nang Hong Unit to Ko Naka Unit.

(b) Ko Yao Noi Formation

The stratigraphy of Ko Yao Noi Formation is recognized on an island approximately 35 km northeast of the Phuket Island. And the formation can be divided into three main units as shown in Figure 2-2-2. The facies of each unit is as follows:

- Permian Limestone :

massive limestone and bedded limestone with chert nodules in the lowest part

- Upper Unit (100-120 m) :

tuffaceous sandstone alternating with thin volcanic tuff, passing upward into bedded chert transitional to Permian limestone with remarkable chert nodules.

- Middle Unit (30-40 m) :

pebbly mudstone in the lowest part, laminated mudstone with scattered pebbles and sandstone interbedded.

- Lower Unit (200-250 m) :

alternation sequence of dark gray laminated mudstone and medium grained sandstone with argillaceous limestone lenses.

The facies of Upper Unit is very different from any strata overlain by Permian limestone in the Phuket and Phang Nga area. It extends mainly from Ko Yao Noi to the Krabi Province and its eastern exposure

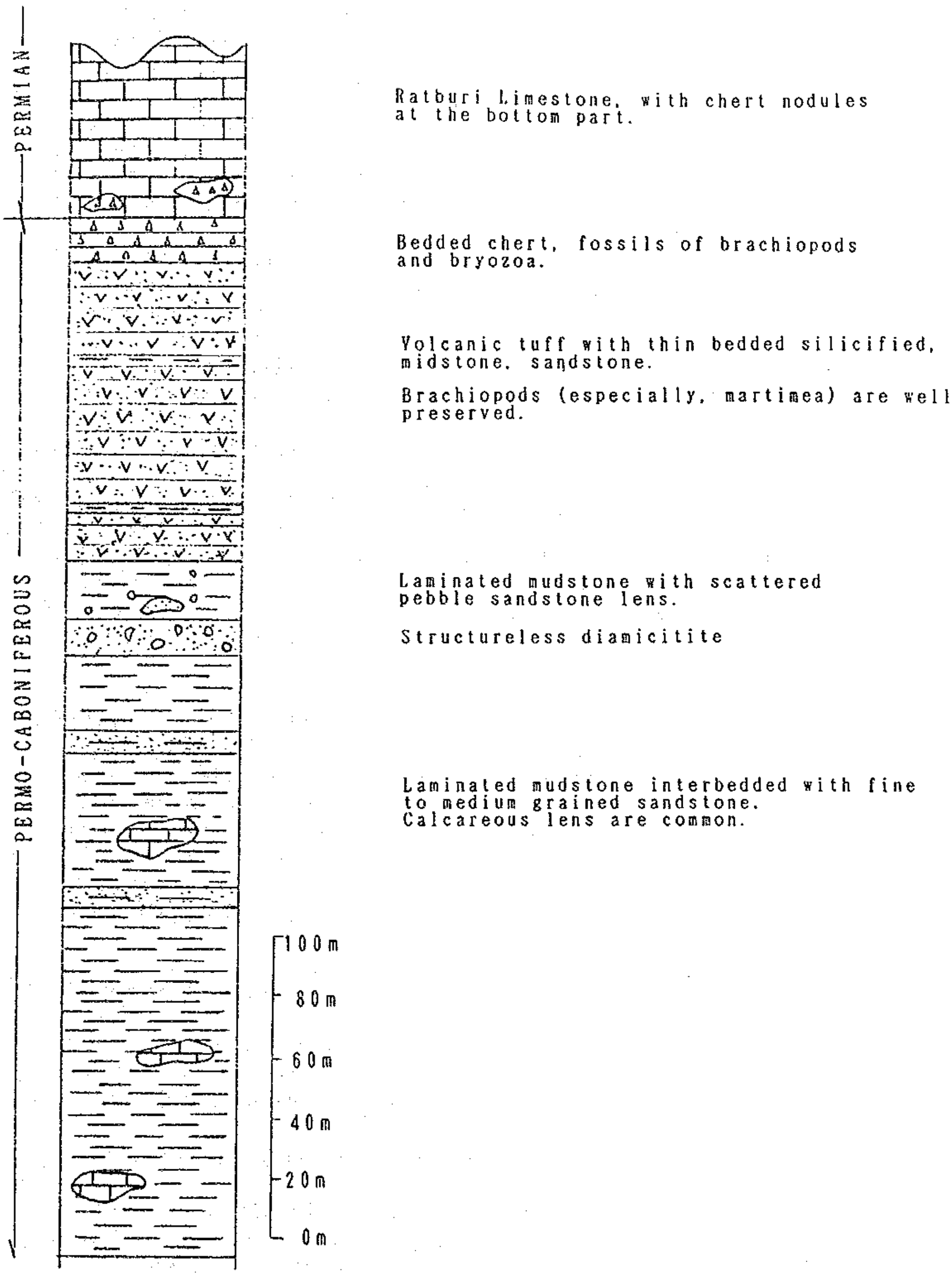


Fig. 2-2-2 Stratigraphical Sequence of Ko Yao Noi Formation

is also defined by the Khlong Marui Fault. Consequently, the Ko Yao Noi Formation can not be looked out in the study area.

(2) Permian Limestone

The distribution of Permian limestone is restricted to the eastern and central part of the Phuket and Phang Nga area, and commonly occupies belts of north and northeasterly trend. This significant feature is highly distinctive appearance in the field, commonly forming hills or ridges with steep or vertical sides several hundreds meters high.

Limestone mountains or hills are inaccessible, but show a well development karst topography with large sink holes and intended drainage. Several terrace partly remains on the steep slope, and is supposed to be suffered several eustatic changes in the Pleistocene age.

The attitude of bedding of Permian limestone indicates that the limestone occupies broad synclinal structure with axes trending north to northeast. Many of synclinal structure are displaced by fault.

From the reconnaissance survey, the Permian limestone however was not observed around the proposed dam sites and its adjacent areas.

2.2.2 Mesozoic Stratigraphy

Mesozoic formation is found out widely in the Ko Yao Noi Island and its locality stretches for the main peninsula area which is along the Khlong Marui Fault running from Khao Hang Nok north of Krabi to the western flank of Khao Phanom Bencha up to Sura Thani. The stratigraphy sequence consisting mainly of white, brown and purple medium to coarse grained sandstone with pebbly horizons, and is unconformably underlain by Permian limestone.

2.2.3 Tertiary Stratigraphy

Tertiary deposits are shown on the several localities near the Krabi area, and have same situation to Mesozoic formation in stratigraphic order in which it rest on the Permian limestone with unconformably relation. The facies are made up of marl, shale, lignite, shell bed, and noncaleareous mudstone in order of the lower horizon. The appearance of Tertiary formation was not observed near proposed dam sites.

2.2.4 Quaternary Deposits

Quaternary Deposits adjacent proposed dam sites area is classified into three type deposits; namely alluvium / estuarine deposits, beach deposits and colluvium. The detailed facies and distribution deposits are as follows :

- Alluvium/Estuarine Deposits :

These superficial deposits inclusive of alluvium, terrace deposit and mangrove mudflats may be grouped together because they are difficult to separate in the map. But estuarine deposits and mangrove mudflats are found extensively around the western coast from Takua Pa down to Krabi. The typical is the presence of dark gray mud or silt. According to the tin mining facies elsewhere in the area, it is found that these sediments are relatively thin,

about 3-7 m overlying gravels and alluvium in which tin are recovered. At the proposed dam site which was surveyed by boring, the grayish marine clay including peat horizon are also observed below 5 m in depth. But in the Phang Nga Bay these estuarine sediments and mangrove mudflats are considerably thicker. Estuarine deposits pass gradually into alluvial deposits which form extensively flat areas flanking the courses of larger streams and rivers. The average depth of these deposits from the surface is 10-15 m in the dam sites, and is consisting of soft clay to granule gravel.

- Beach Deposits :

Beach deposits are strongly developed along the western coasts of the Phuket Island. Most of them are composed of clean quartz rich sand, often with abundant shell and coral fragments. Heavy minerals are often seen. Beach sands and gravels are worked for tin near Takua Pa and Bang Thao. Accumulation of pebbles and cobbles occur locally near the small bay and rocky headlands. Around the proposed dam sites, these sand and conbonate fragment were found out while reconnaissance survey covers the whole reservoir area.

- Colluvium :

The colluvium is used to include the deposits which consist of loose rock debris which has accumulated without river transport. Such deposits usually occur towards the base of slopes where gravity has been more important than running water in transporting the rock debris. In limestone areas, such as Khlong Sok paths of colluvium tend the relatively fine grained silty accumulation of the terra- rossa type. It would be noted that colluvial deposits frequently show lateritization. These deposits are exposed especially along strip which situate between the steep mountain slope and low terrace plane, in the vicinity of the proposed dam sites. The thicker lager noted by lateritization rest on these strip, and it form the gentle slope extending to the low flat consisting of low terrace and alluvial deposits.

2.2.5 Igneous Geology

Granites are the main igneous rocks found in the study area and they apparently belong to a province of tin bearing acidic rocks as shown in Figure 2-2-3. Comprising an arcuate belt of batholithic intrusions stretching over 2,500 km from Indonesia in the south through the Thai-Malay Peninsula into the Shan State of Myanmar. The granitic rocks are intruded along major anticlinal axes and are of various ages. There are several type of granite in the study area which may be lithologically divided into two sub-areas: the Phang Nga and Phuket area which are marked by various kinds of granite compositions. The detailed description for sub-areas is dealt with in the following chapters.

(1) Phuket Area

The granite occupied in Phuket area mainly consists of porphyritic hornblende biotite adamellite, coarse grained biotite porphyritic granite, and fine grained biotite muscovite granite. Distribution and Petrography for each granite are shown below :

(a) Porphyritic Hornblende Biotite Adamellite

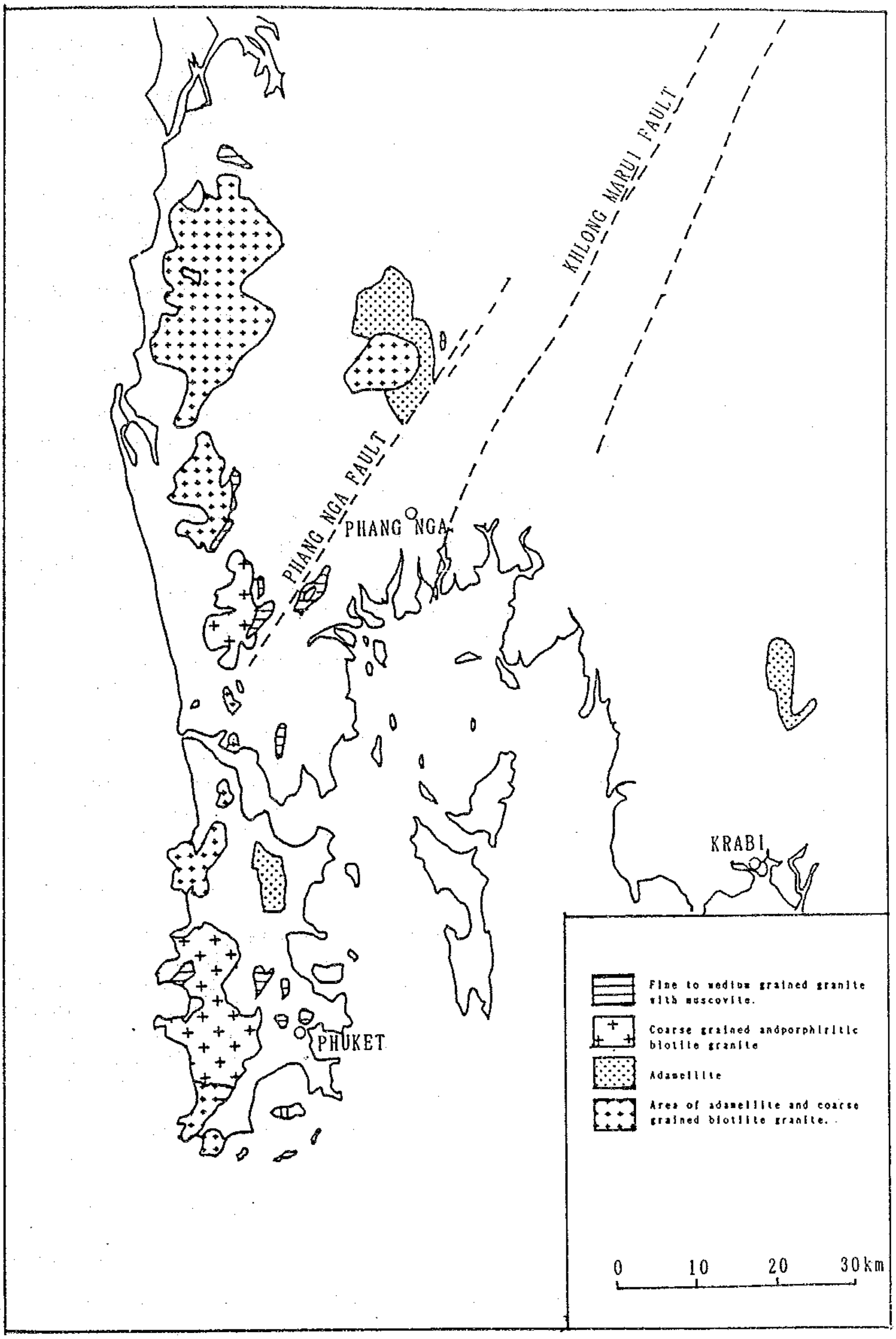


Fig. 2-2-3 Distribution of Granite

The distribution of this kind of granite is at Khao Pathiu, west of the Thalang district in Phuket. It forms an elongated intrusion nearly as large as the Khao Phanom Bencha intrusion. It is composed largely of medium-grained hornblende biotite adamellite while porphyritic texture is partly recognized. The composition is similar to these of Khao Phanom Bencha and Khao Thong, it is hypidiomorphic to allotriomorphic granular texture. Plagioclase is slightly higher than potash feldspar. The overall composition of zoned plagioclase is the common accessory minerals.

As the result of reconnaissance survey near the proposed dam sites, these characteristics of granites are not found out.

(b) Coarse Grained Biotite Porphyritic Granite

In the Phuket Island, this type of granitic rock is found widely exposed along the western part from Khao Muang, Kathu down to the south end of the island. It is marked by the presence of coarse flakes of biotite with minor muscovite. The feldspar phenocrysts are usually up to 3 cm long and often show preferred orientation. The texture is generally allotriomorphic granular. Felsic minerals comprise potash feldspar, oligoclase, myrmekite and quartz. Potash and feldspar are in nearly the same amount. The potash feldspar is either microcline or microperthite. Plagioclase usually shows complex twining and sericitization is commonly present. Biotite forms laths with pleochroism form pale yellow to dark green brown as reddish brown. Apatite and ilmanite are the common accessory minerals.

This type of granite is cropped out in three dam sites which are Bang Nieo Dam, Bang Tho Sung and Khlong Katha in the Phuket area. The reconnaissance survey for above dam sites reveals that not only dam foundation but also the most part of the dam reservoir are made up of coarse grained biotite porphyritic granite.

(C) Fine Grained Biotite Muscovite Granite

The leucocratic granite is found associated with coarse granite biotite porphyritic granite. It is exposed at the north of Ao Surin, north and south of Ao Patong, Ao Karon, Krathu Sapam and Ao To Se. Petrographically, it is characterized by hypiodiomorphic granular to allotriomorphic granular. The felsic minerals are quartz, potash feldspar and albite or oligoclase with microcline. Myrmekitic texture is strongly developed in many localities. Accessory minerals are apatite, zircon, cassiterite, wolframite, monazite and anatase. It is noted that sphene is absent. Tourmaline however is abundant in some localities particularly in the area associated with tin. It therefore would be noted here that tin deposits in Phuket are in good association with this type of granite.

(2) Phang Nga Area

(a) Coarse Grained Biotite Porphyritic Granite

Coarse grained biotite Porphyritic granite is most abundant at the intrusive area throughout the western part of the Phang Nga area and are associated with tin belt. Microscopically, the rock type is similar to those in the Phuket Island and the trend of intrusion is also same which run through the western part of the Phuket Island. The Khlong Lo Young damsite and surrounding area are occupied by

this granite.

(b) Fine Grained Biotite Muscovite Granite

This is in fact composed of fine to medium grained biotite granite and biotite muscovite granite. The latter is regarded as a leucocratic granite and is the dominant rock type in locality. Greisenized rocks are commonly found at the marginal area of these rock mass and are closely associated with cassiterite deposits. In other words, they are actual tin bearing granites. They are also found associated with coarse grained porphyritic biotite granite. In the Phang Nga area, they are well exposed at Nok Hook Mine, Khao Khata Kwan, Khao Lam Ru, Khao Khanim and Khao Khuan Kha. They are usually associated with pegmatites and is shown in the north part of Khlong Lo Young site from the result of the reconnaissance survey.

2.3 Geological Structure

The geologic map for the Phuket Island is shown in Figure 2-2-4, which comprises the above mentioned stratigraphical members including alluvial deposit, colluvium, Permian limestone, Andaman Group and granitic members.

The structural map is shown in Figures 2-2-5 and 2-2-6, which are of both regional structure trend and main structural feature of the Phuket to Phang Nga area. As shown in these figures, the study areas and their vicinity areas are characterized by a complex synclinal structure which is of syncline and anticline involving axes of N-S and NE-SW trends. The foldings accompanied with synclinal structure are commonly observed in the area such as that the folded Permian limestone is found on the top of these syncline. And these foldings have been cut by several faults running in different trends. The faults can be grouped into four sets, Which can be recognized as the dominant strikes of NE-SW, NNE-SSE, NW-SE and horizontal.

The NE-SW trend shows an average attitude of N30°E with 70° to the southeast; the NNE-SSE trend shows the average attitude of N20°W with dipping 50° to the northeast; and NW-SE is N70°W with dipping in vertical. Among sets of strikes of fractures, the major direction is NE-SW, it is concordant with regional structural trend, the minor direction seems in NW-SE and NNE-SSE.

From the viewpoint of relation between each fracture zone, the minor direction of NE-SW is presumably older structure compared to the other directions. The younger fault, especially along NE-SE direction, is supposed to have occurred as strike slip fault and restrict to the recent drainage system. At least, several block faults have been well developed.

The proposed dam site also shows the similar faulting system making up of mainly NE-SW fracture and other accompanied faults such as NW-SE direction. The detailed stratigraphy and structural geology for each sites are discussed in Chapter 5.

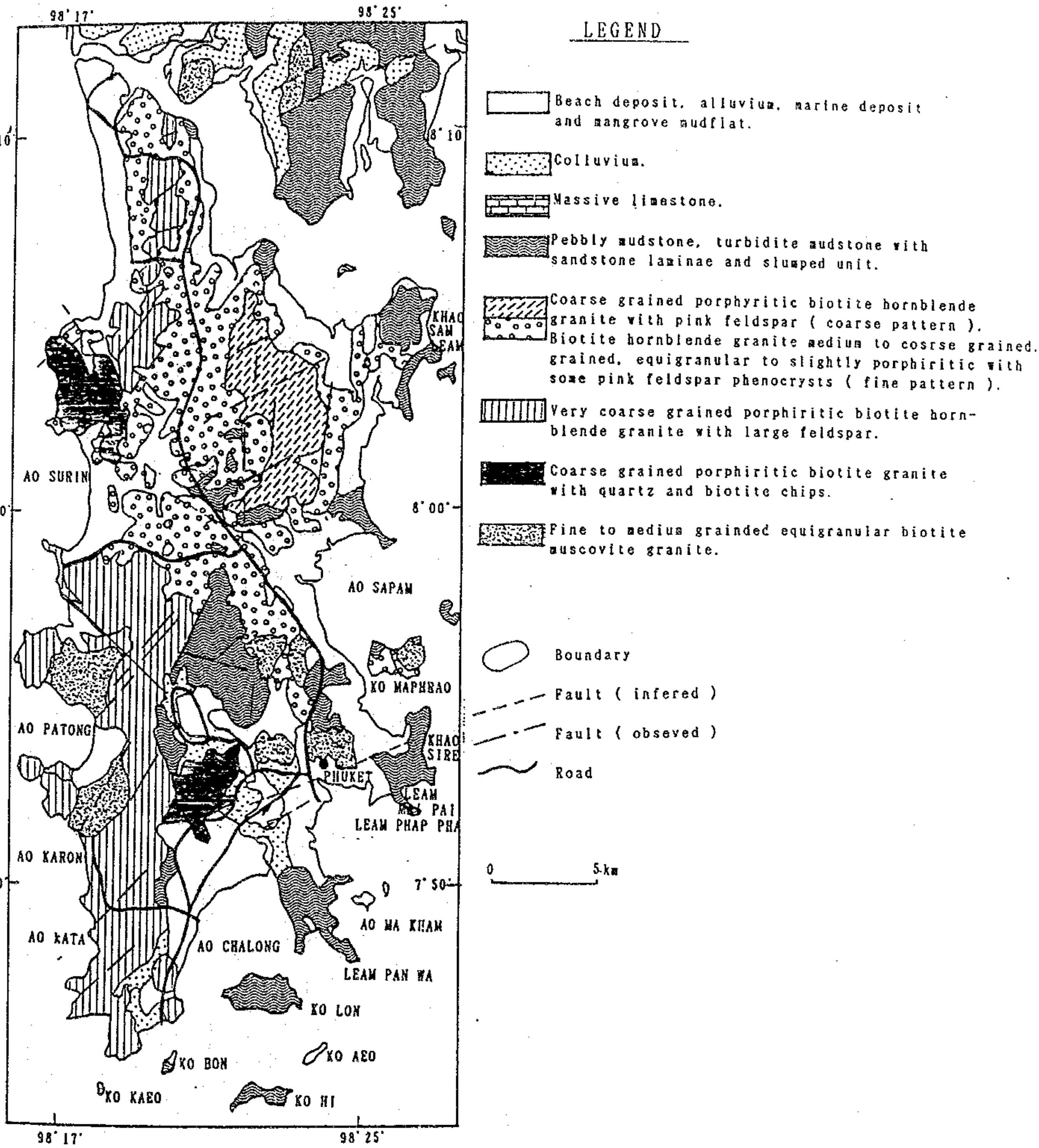


Fig. 2-2-4 Geological Map of Phuket Island

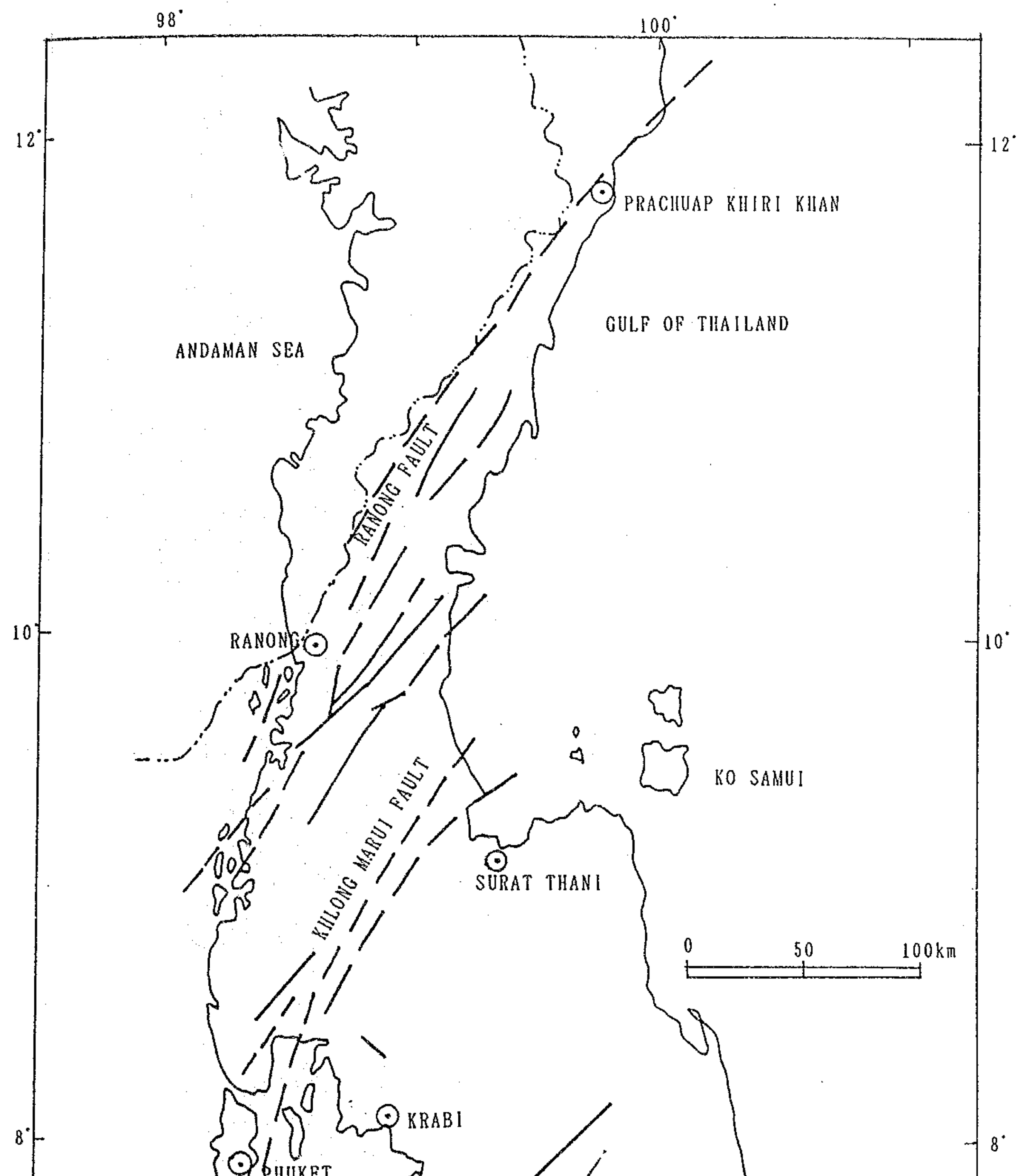


Fig. 2-2-5 Regional Structural Trend in Southern Thailand

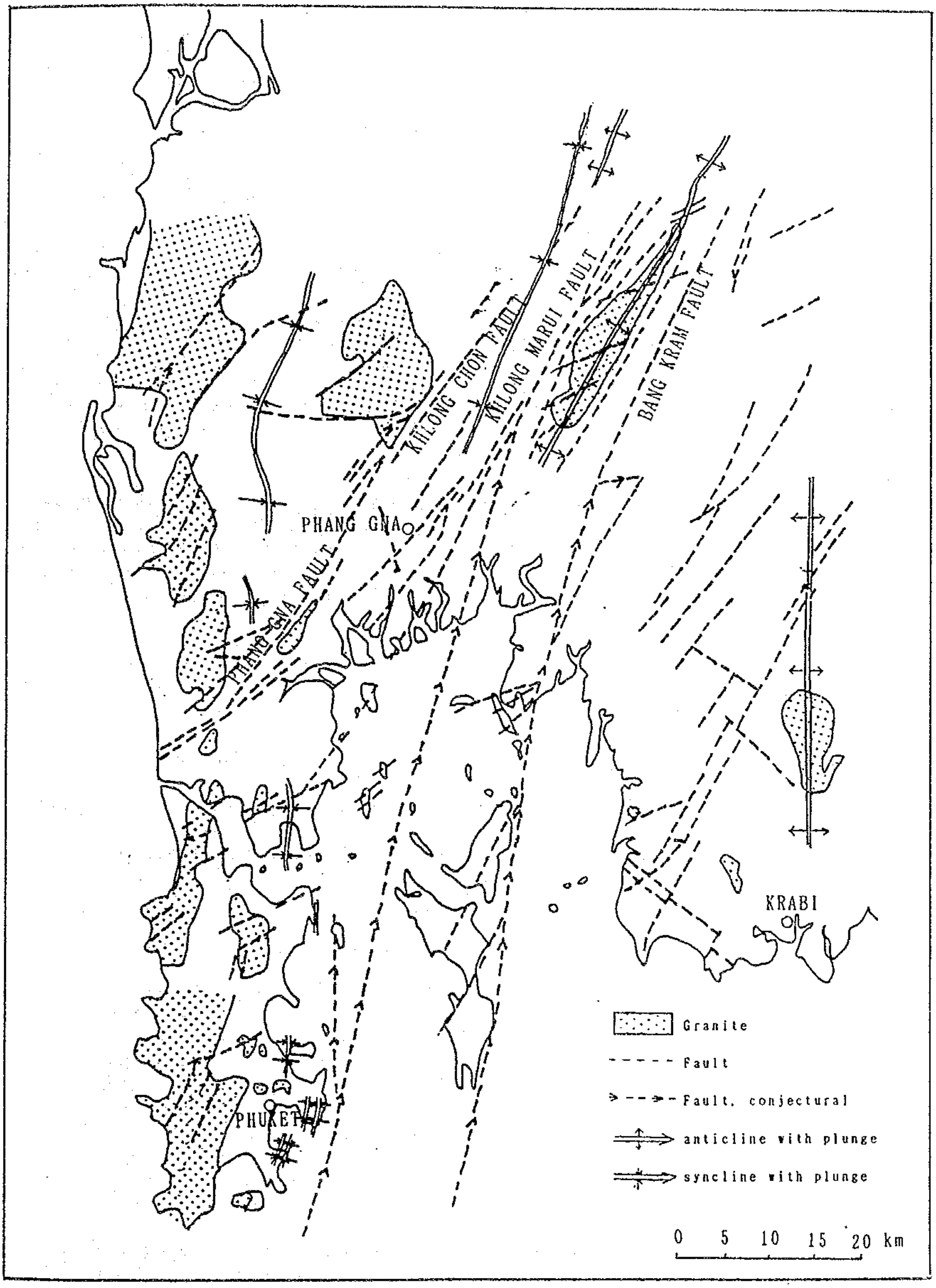


Fig.2-2-6 Main Structural Features of Phuket Island and Phang Nga Area

3. REVIEW OF EXISTING GEOLOGICAL INVESTIGATION DATA

3.1 Introduction

With regard to regional geology in the Phuket Island and Phang Nga area, considerable studies have been conducted since 1950 for mining research or correlative study in Paleozoic stratigraphy.

The primary study area had begun in 1951 as geological reconnaissance for discovering tin resources and diamond. Since 1970 the stratigraphical problem of whether the Phuket Formation contains a strata to be correlative with the surrounding Paleozoic area, thence the several paleontological and stratigraphical studies have been commenced.

However, the stratigraphical problem concerning to order and origin of formations still remains unsolved. The geological investigation data for dam construction is few, whereas fair number of dam sites have been drawn up a plan in this area. Only two sites which are Bangwad and Khlong Katha Reservoir, have been investigated whether the geological condition is feasible for dam construction.

Bangwad Reservoir had shown an acceptable geological condition for building up the small scaled dam, and was constructed in 1983. The Khong Katha site was surveyed in 1981 and was concluded that although the geological condition was feasible for small scaled dam with some modification for foundation, the shortage of available banking materials in the reservoir area was pointed out.

The aspect of investigations for above two dam sites are described in the following section.

3.2 Bangwad Reservoir

Bangwad Reservoir was constructed in 1982 to 1983, by RID. The reservoir, located 3.5 km from the Phuket Municipality, was developed from an old mine. The storage capacity is approximately 700,000 cu.m with a catchment area of 6.75 sq.m. The details for the dam is shown in Table 3-2-1.

Table 3-2-1 Outline of Bangwad Dam

Dam Items	
Type of Dam	: Earth-filled
Crest Length	: 900 m
Crest width	: 8.00 m
Bore Width at Deepest Part	: 200 m
Dam Height	: 25 m
Reservoir Capacity	: 8.5 MCM

The reservoir area is occupied by coarse granite which is made up of same type of rock as the Bang Tho Sung dam site. They are also characterized by mineralization of tin resources; therefore, the tin mines was in operation by several decade ago and mining pits remain in the reservoir area.

The geological investigation for theBangwad Reservoir before construction had commenced in 1977 and 25 borings had conducted for dam foundation which arranged along dam axis, though the most of borings are shallow and average depth is 20 to 25 m, and could not deeply penetrate into hard granite. Consequently, the geological information for hard rock facies has been still unknown. The shallow horizon up to the weathering zone is only revealed clearly. From the result of boring survey, the alluvium, terrace deposit and weathering granite layer which is 20 m thick in average lie on the fresh granite as shown in Table 3-2-2.

Table 3-2-2 Thickenesss of Soil Layer along Dam Axis of Bangwad Reservoir

Location* (m)	Thickness of Soil Layer	Type of Soil Layer
200	22	SC, SM
300	28	SC, SM
400	18	CH, SC
500	15	SP, ML, MH, SM
600	7	SM
700	22	SM
800	20	SM
900	30	SM

* Distance from the right abutment

In accordance with above geological condition and dam scale, the foundation had put on the weathering zone forming of the medium to high dense soil layer. The cut-off trench and grout curtain however were also simultaneously installed along dam axis, the deeper end of the grout curtain is 8 m to 15 m depth from cut-off trench so that the impervious wall can be reached out the hard rock zone.

From the view point of area situation of the site, these geological condition clarified in the Bangwad Reservoir is presumably similar to Bang Tho Sung site. Therefore, the construction record for Bangwad Reservoir may be applied to the plan of the Bang Tho Sung site.

3.3 Khlong Katha Dam Site

The investigation for Khlong Katha dam site was performed by RID. The field survey was carried out on February 1981. The result of survey was reported on September 1989. The purpose of investigation comprised of two, clarifying the geological condition along dam axis and survey for embanking materials on the borrow area, was examined on this report.

Investigation along dam axis consists of 13 soil borings up to 2 m in rock facies, in-situ permeability test by gravity or Packer method and standard penetration test at every 1 m depth in the section of soil layer.

The result of soil boring shows that the overburden made up of soft silty sand to sand layer is 10 to 23 m thick along dam axis. The permeabilily of these layer shows relatively high value which can be estimated about one fourth to one hundred thousandth centimeter per second. The investigation result for classified layer is as follows:

Table 3-3-1 Result of Geological Investigation at Khlong Katha Dam Site

Layer	Average Depth (m)	Facies	Permeability (cm/sec)
Upper Layer	0 - 4	ML, sandy silt partly including very soft layer	$K=10^0 - 10^{-4}$
Middle Layer	4 -	SM, silty sand	-
Lower Layer	-	Very dense sand	$K=10^{-3} - 10^{-4}$
Rock	-	Weathered granite	$K=10^{-4} - 10^{-5}$

On the borrow area, the hand auger borings and test pits with 53 holes totally dig on the upstream of dam axis, were conducted for detecting the quality and quantity of embankment materials.

As the result of these survey, the soil classification system is applied to soil samples for distinguishing the soil type respectively and each quantity of soil type is estimated as follows:

Table 3-3-2 Quantity of Banking Materials in Khlong Katha Reservoir

Soil Classification	Quantity (cu m)
CL	156,000
ML	307,000
SM	46,000

According to the report, the geological condition of the dam site is generally stated that the thickness of overburden, which was of the very loose sandy layer, is over 10 m. The loose sandy layer lies on the medium dense layer and the both layers indicate fairly high permeability, the average is $K = 10^{-3}$ to 10^{-4} cm/sec. On the ground of these geological condition, the report concludes that the very loose layer should be taken away as an unsuitable material for the dam foundation, and high permeable horizon including medium dense layer should need a treatment such as slurry trench method. And banking material from the reservoir area is not available in quantity; therefore, the blanket method is not adaptable for this site.

4. RESULT OF GEOLOGICAL INVESTIGATION

4.1 Introduction

The geological investigation during this time was carried out for obtaining the basic data for design of three dam sites comprising Bang Nieo Dam, Khao Che Tra and Khlong Katha sites. Ten boreholes were made up to 38.5-52.5 m depth with standard penetration test (SPT) in soil layer and in-situ permeability test in soil and rock strata. The boreholes were stopped when rock strata of about 30 m were drilled. Water pressure test, practically called Lugeon test, was performed in rock strata. Quantity of works are as shown in Table 4-1-1.

Table 4-1-1 Summary of Quantity of Boring Survey

Dam Site	Borehole No.	Total Depth	Thickness Soil	Thickness Rock	SPT	Permeability Test
Bang Nieo Dam	BN-1	50.0	20.0	30.0	19	8
	BN-2	52.5	22.5	30.0	21	8
	BN-3	49.8	21.8	28.0	15	8
Khao Che Tra	CT-1	47.5	22.5	25.0	22	7
	CT-2	50.0	30.0	20.0	27	6
	CT-3	48.5	18.5	30.0	18	5
	CT-4	48.0	18.0	30.0	17	5
Khlong Katha	KK-1	47.0	12.0	35.0	11	8
	KK-2	45.5	20.5	25.0	20	7
	KK-3	38.0	8.0	30.0	7	4
Total		476.8	193.8	283.0	177	66

The method applied to investigation is described in the following section. And subsurface condition grasped by investigation in above three sites are summarized respectively in Section 4.3

4.2 Investigation Method

(1) Soil boring

Ten Soil boring of about 10 cm in diameter were made by power augering in clay and sandy clay and by wash boring in sand or clayey sand. steel casing of 9 cm in diameter was embedded in soil layer to prevent collapse of borehole and water loss during working.

(2) Rock Coring

Ten boreholes of about 7.4 cm in diameter were drilled by NMLC and NQ core bits which have the outer diameter of 74 mm and inner diameter of 52 mm respectively. Core bits used are both surface set and impregnated type. Core samples from NMLC and NQ core barrels are cut into 1 m length for putting in a core boxes by arranging from left to right and upper to lower so the lower horizon is at upper left corner

and upper one is lower right corner of boxes. Borehole logs of every hole are shown in chapter 8 and photographs of core is in chapter 9.

(3) In-situ Permeability Test

The test were performed in each borehole at every five meters interval for a stage. Permeability is measured mainly in the pressure injection method which is called water pressure test or Lugeon test. For the unconsolidated or highly weathered layers in each borehole, the falling head or constant head method are adapted. The result summarized in Figures 5-3-9, 5-4-9 and 5-5-9 and Chapter 6.

(4) Standard Penetration Test (SPT)

The standard penetration test was performed conforming to ASTM D 1586-67 specification at every 1 meter interval in overburden made up of unconsolidated and highly weathered facies. The test was performed by driving a split spoon barrel of 2 inches outside in diameter into the soil by a 140 lb. drop hammer free falling through a distance of 30 inches. Number of blows were recorded at every 6 inches of penetration until either 18 inches have been penetrated or 50 blows have applied. The first 6 inches of penetration is considered to be a seating and the sum of blow required for the second and third 6 inches of penetration was termed the standard penetration resistance (SPT N-value). Disturbed soil samples from the standard penetration test were kept closely in plastic bags to prevent a loss of moisture contents.

4.3 Subsurface Condition

Subsurface condition of sites are mentioned below as lithological description of borehole respectively. The permeability and bearing capacity are dealt with in Chapter 5.

(1) Bang Nieo Dam

(a) Borehole No. BN-1

Overburden was found 20.0 m thick in the upper most underlain by granite through the bottom borehole which can be concluded briefly as follow:

Depth (m)	Description
0.00 - 1.50	Stiff clay with gravel.
1.50 - 5.50	Medium dense to dense clayey fine to coarse sand.
5.50 - 8.20	Medium dense to dense silty fine to coarse sand.
8.20 - 9.50	Stiff clay
9.50 - 20.00	Medium dense to dense and very dense silty fine to coarse sand, trace of gravel.
20.00 - 50.00	Granite, phaneritic - non porphyritic texture, grayish white with scattered of biotite and hornblend which is black spot, slightly weathered to fresh rock, hard rock, joint plane about 20 to 30 degrees dipping, some join plane perpendicular, wide spacing and open stained joint, composed of quarts, Na-feldspar, biotite and hornblende.

(b) Borehole No. BN-2

Overburden was found 22.50 meters thick in the upper most underlain by granite through the bottom borehole which can be concluded briefly as follow:

Depth (m)	Description
0.00 - 0.50	Top soil, sand.
0.50 - 1.50	Loose silty fine sand.
1.50 - 9.50	Very loose silty fine to medium sand.
9.50 - 10.50	Very loose clayey sand.
10.50 - 12.50	Very soft to medium clay.
12.50 - 14.50	Very soft to medium sand.
14.50 - 17.50	Medium dense to dense clayey sand.
17.50 - 22.50	Dense to very dense clayey sand.
22.50 - 52.50	Granite, phaneritic - non porphyritic texture, grayish white with scattered of black spot which is biotite and hornblende slightly weathered to fresh rock, hard rock, joint plane about 30 to 70 deg. dipping, moderately close to spacing and open stained jointing, composed of quartz, Na-feldspar, biotite and hornblende.

(c) Borehole No. BN-3

Overburden was found 21.80 meters thick in the upper most underlain by granite through the bottom borehole which can be concluded briefly as follow :

Depth (m)	Description
0.00 - 3.00	Medium to stiff clayey sand.
3.00 - 8.90	Completely weathered granite.
8.90 - 10.50	Granite boulder.
10.50 - 13.50	Completely weathered granite.
13.50 - 14.50	Medium dense silty fine to medium sand.
14.50 - 21.80	Completely weathered granite.
21.80 - 49.80	Granite, grayish white with scattered of black spot, slightly weathered to fresh rock, hard rock, joint plane about 30 to 40 dipping, wide to moderately close jointing, composed of quartz, Na-feldspar, biotite and hornblende.

(2) Khao Che Tra

(a) Borehole No. CT-1

Overburden was found 19.50 meters thick in the upper most underlain by sandstone through the bottom borehole which can be concluded briefly as follow:

Depth (m)	Description
0.00 - 1.00	Clay.
1.00 - 5.50	Loose to medium dense sand.
5.50 - 7.50	Hard clay.
7.50 - 8.50	Very dense gravelly sand.

8.50 - 14.50	Very stiff to hard clay, trace of sand.
14.50 - 15.50	Very dense clayey gravelly sand.
15.50 - 22.50	Hard sandy clay.
22.50 - 47.50	Sandstone, greenish gray to gray, highly metamorphosed, slightly weathered to fresh rock, wide spacing and open stained jointing, hard rock.

(b) Borehole No. CT-2

Overburden was found 30.00 meters thick in the upper most underlain by sandstone through the bottom borehole which can be concluded briefly as follow:

Depth (m)	Description
0.00 - 6.50	Loose to medium dense silty sand.
6.50 - 7.40	Medium clay.
7.40 - 8.60	Loose silty sand.
8.60 - 14.00	Soft clay.
14.00 - 15.00	Stiff clay, trace of fine sand.
15.00 - 26.07	Hard sandy clay.
26.07 - 30.00	Pebble and gravel.
30.00 - 50.00	Sandstone, Greenish gray, slightly metamorphosed slightly weathered to fresh rock, moderately close spacing jointing, open stained jointing, moderately hard rock.

(c) Borehole Nos. CT-3 and CT-4

Overburden was found 18.50 m and 18.00 m thick in the upper most underlain by sandstone through the bottom borehole which can be concluded briefly as follow:

Depth (m)		
CT-3	CT-4	Description
0.00 - 6.00	0.00 - 7.00	Stiff to very stiff sandy clay.
6.00 - 18.50	7.00 - 18.00	Hard sandy clay.
18.50 - 48.50	18.00 - 48.00	Sandstone, greenish gray, slightly metamorphosed, slightly weathered to fresh rock, moderately to extremely close jointing, open stained, soft to moderately hard rock.

(3) Khlong Katha

(a) Borehole No. KK-1

Overburden was found 12.0 meters thick in the upper most underlain by granite and grano-diorite through the bottom of borehole which can be concluded briefly as follows :

Depth (m)	Description
0.00 - 0.50	Sand.
0.50 - 1.50	Medium dense silty fine sand.
1.50 - 6.50	Loose silty fine sand.
6.50 - 11.00	Medium dense to dense silty fine sand.
11.00 - 12.00	Completely weathered granite.
12.00 - 36.00	Granite, porphyritic texture, pink slightly weathered rock, joint plane above 40 to 60 deg. dipping, composed of quartz, K-feldspar, hornblende and biotite.
36.00 - 47.00	Grano-diorite, grayish white with scattered of black spot, fresh rock, joint plane about 40 to 60 deg. dipping wide spacing jointing, composed of quartz, Ca-feldspar, biotite and hornblende.

(b) Borehole No. KK-2

Overburden was found 20.50 meters thick in the upper most underlain by diorite through the bottom of borehole which can be concluded briefly as follows:

Depth (m)	Description
0.00 - 0.50	Sand.
0.50 - 3.50	Medium dense to very silty fine sand.
3.50 - 5.50	Very loose silty fine sand.
5.50 - 9.50	Medium dense silty fine sand.
9.50 - 12.50	Loose silty fine sand.
12.50 - 15.00	Medium dense to dense silty fine sand.
15.00 - 20.50	Completely weathered granite.
20.50 - 45.50	Porphyritic diorite, dark gray, hard rock, joint plane about 40 to 70 deg. dipping, some joint showing slacken side, wide spacing jointing, composed of quartz, Na-feldspar, biotite and hornblende.

(c) Borehole No. KK-3

Overburden was found 8.00 meters thick in the upper most underlain by granite through the bottom of borehole which can be concluded briefly as follow :

Depth (m)	Description
0.00 - 2.50	Very loose to loose silty fine sand.
2.50 - 5.50	Very loose clayey fine sand.
5.50 - 8.00	Completely weathered granite.
8.00 - 9.00	Granite, porphyritic texture, slightly weathered rock, moderately hard rock, composed of quartz, K-feldspar, hornblende and biotite.

9.00 - 38.00 Granite-biotite, porphyritic - phaneritic texture fresh rock, joint plane about 30 to 70 deg. dipping, hard rock, wide spacing jointing and open stained, composed of quartz, Ca-feldspar, biotite and hornblende.

5. GEOLOGY OF DAM SITE

5.1 Introduction

In this chapter, geological condition of each dam site is described and considered on the basis of the investigation result which has been already explained in Chapter 4. The description is orderly involved in (a) topography, (b) overburden, (c) bedrock, (d) geological structure, (e) permeability and bearing capacity.

The attached figures for each site, which are Figures 5-2-1 to 5-6-9 consisting of bird's eye view, topographical map, topographical profile, geological map, boring log and permeability result, are very useful for understanding topographical and geological situation as dam site.

5.2 Khlong Lo Young

(1) Topography

The topography of Khlong Lo Young can be generally recognized as preferable dam site since the reservoir area is extensive as compared with the crest length of proposed dam axis. When the dam axis is planned on a position as shown in Figure 5-2-1, 2, the catchment area can be estimated about 7 km2, furthermore, the reservoir capacity is able to calculated 16 MCM. In case that the dam height will be settled at the 30 m from the river bed, the dam coefficient of reservoir capacity / volume of dam therefore can be estimated around 6. It may be said that the site is most economical site in view of above coefficient among planned dam sites in this Project.

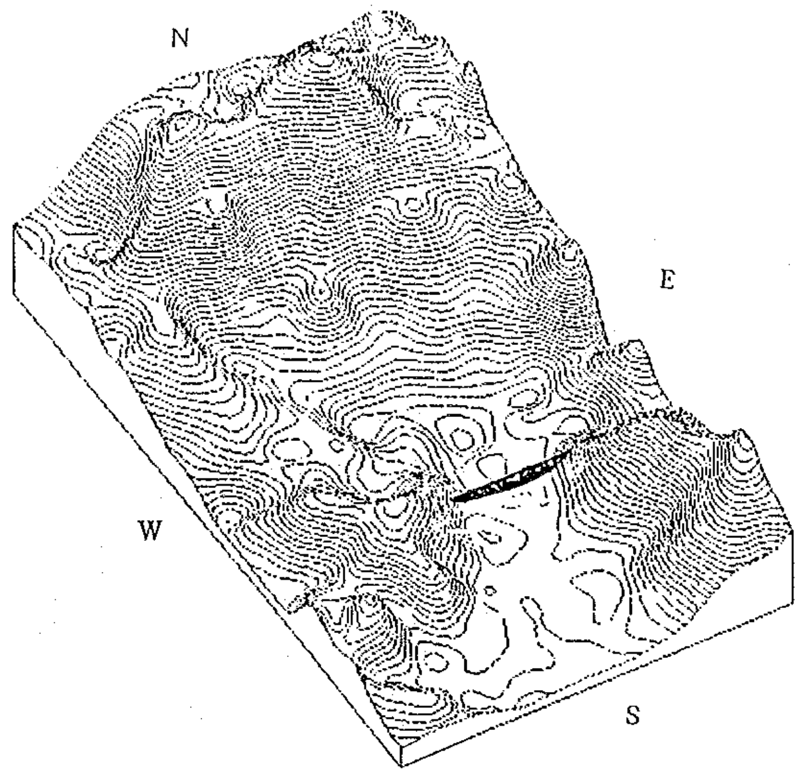
All over the catchment area, the maximum peak in elevation is 575 m while the lowest point near dam axis is about less than 40 m above mean sea level, so that the relative height is over 530 m. And the distance from the divide to dam axis is shown 3 km, consequently, the average gradient in the longitidinal section of reservoir is considerably steep as show in Figure 5-2-6. Especially at the upstream near the top of ridge, the gradient is steepest over 40/100, on the other hand that of the downstream near dam axis shows less than 10/100.

Between higher peaks forming the catchment boundary, the typical col topography are also developed. Nevertheless two deep cols are remarkably on the eastern and western ridges of dam site, their lowest elevation is shown over 100 m which is fairly higher than top of the proposed dam.

(2) Overburden

The thickness of overburden along dam axis is still unknown because any investigation has not been carried out. Due to a circumstance of investigation work in site, the classification and their thickness of overburden have to be inferred from the adjacent geological condition. From the evidence in weathered metalials overlain above the dam axis, the bedrock is presumably composed of the coarse granite and its associated rock types.

The similar type of granite was observed at the other four proposed dam sites which are Bang Nieo Dam, Khao Che Tra, Khlong Katha and



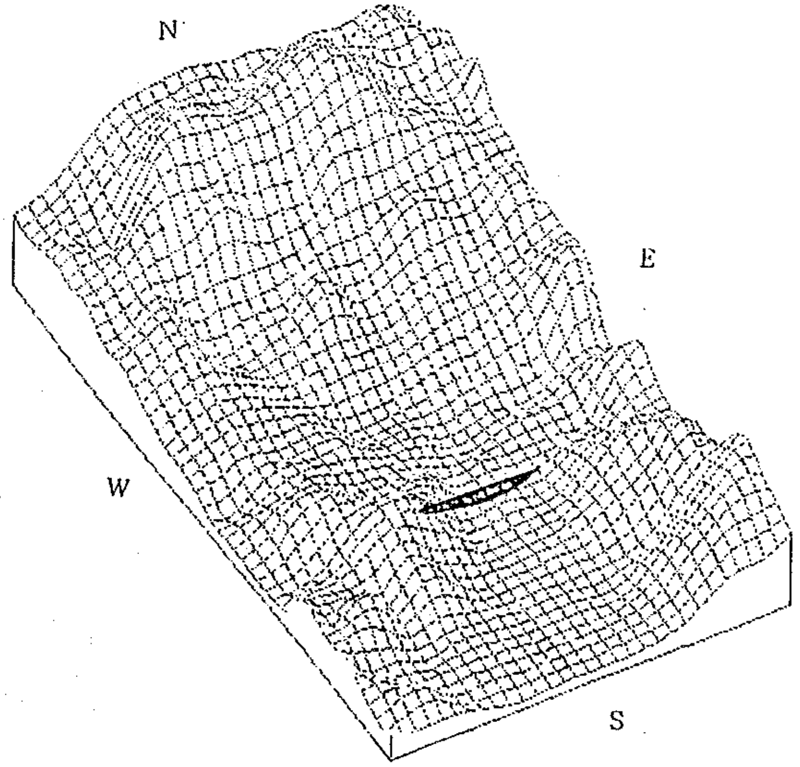
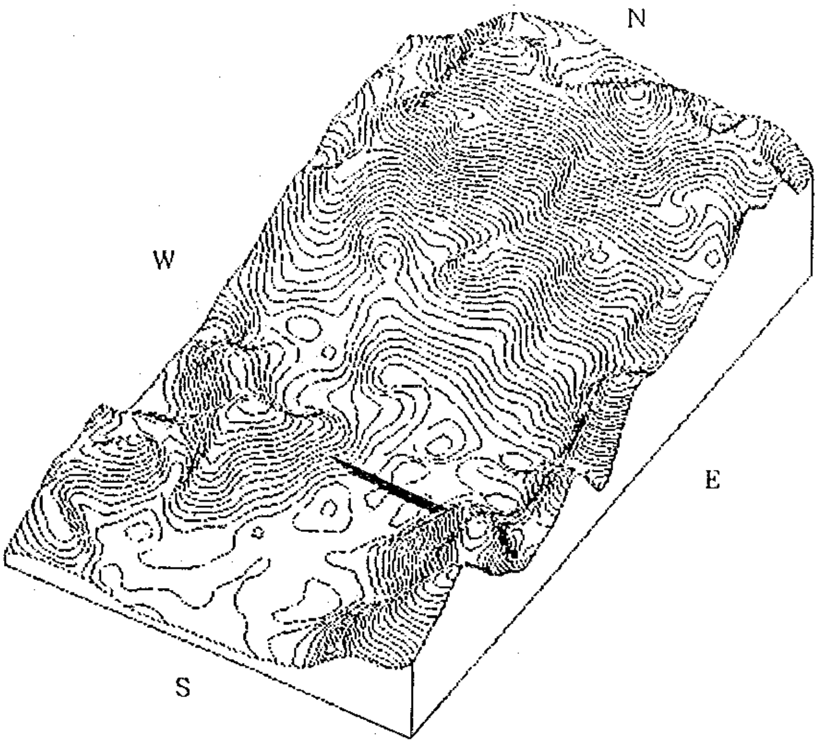


Fig. 5-2-1 Bird's Eye View of Khong Lo Young Dam Site(1)



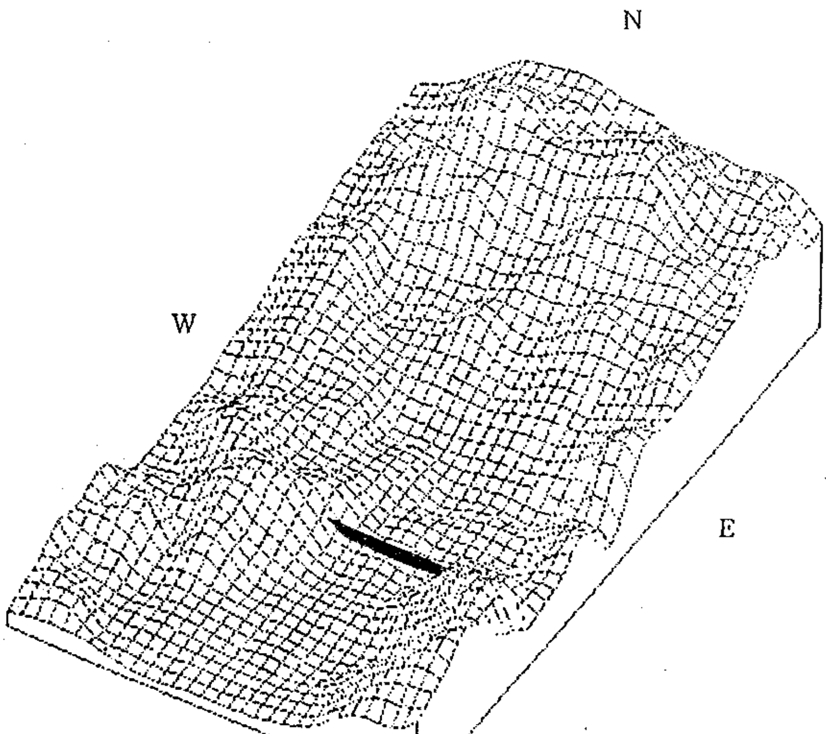


Fig. 5-2-2 Bird's Eye View of Khong Lo Young Dam Site(2)

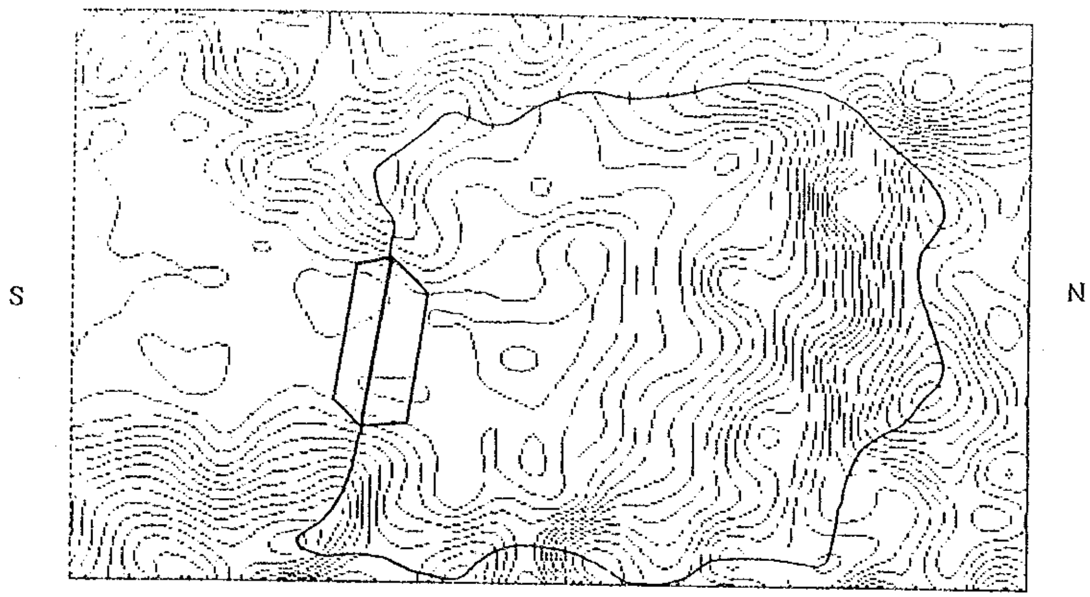


Fig. 5-2-3 Catchment Area of Khlong Lo Young Dam Site

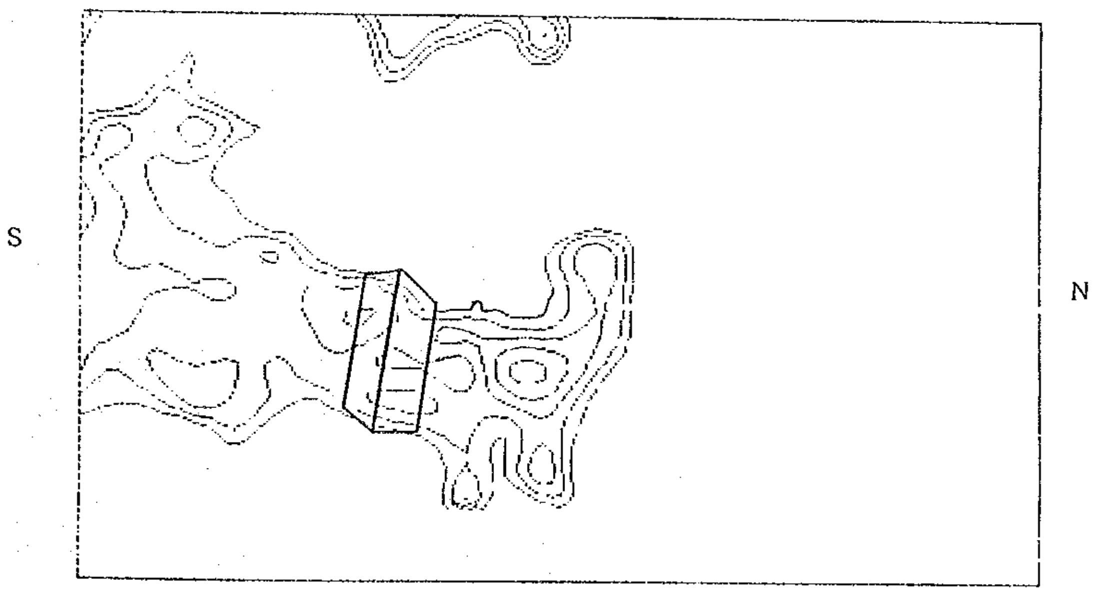


Fig. 5-2-4 Reservoir Area of Khlong Lo Young Dam Site

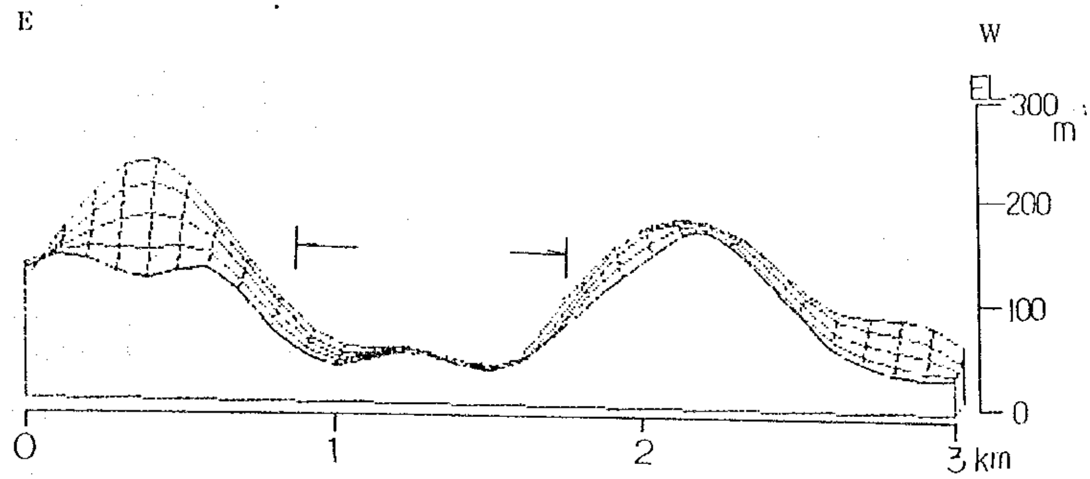


Fig.5-2-5 Cross Section along Dam Axis of Khlong Lo Young Dam Site

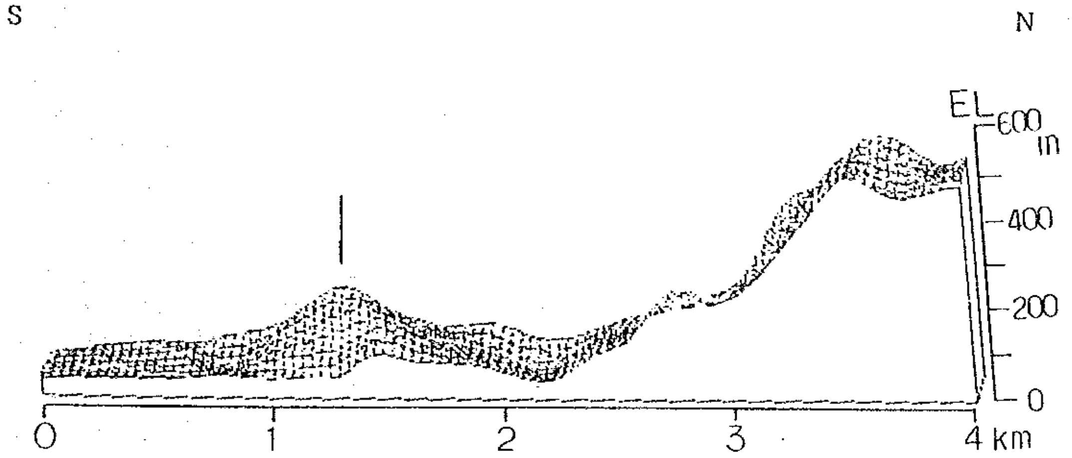


Fig. 5-2-6 Longitidinal Section along River Stream of Khlong Lo Young Dam Site

Bang Tho Sung sites. Among four sites, the most resembling area is pointed out to an area extending from Khao Che Tra to Bang Nieo Dam dam site in view of a geological situation as marginal zone where large intrusion exists beside the Paleozoic rock facies.

In the Bang Nieo Dam dam site, the overburden can be lithologically grouped into three facies and total thickness of soft layer reaches out up to 20 m from the result of boring survey. The same geological situation between Bang Nieo Dam and Khlong Lo Young site to the overburden can be inferred as previously mentioned, so that thick overburden is presumably laid above the bedrock along dam axis of this site.

In general, the overburden is consisting of three facies which are Alluvium, terrace deposit characterized by loose sand to silt, and talus deposit involving much content of clayey materials. The maximum thickness of each layer is about 10 m individually from the result of boring survey at the other sites.

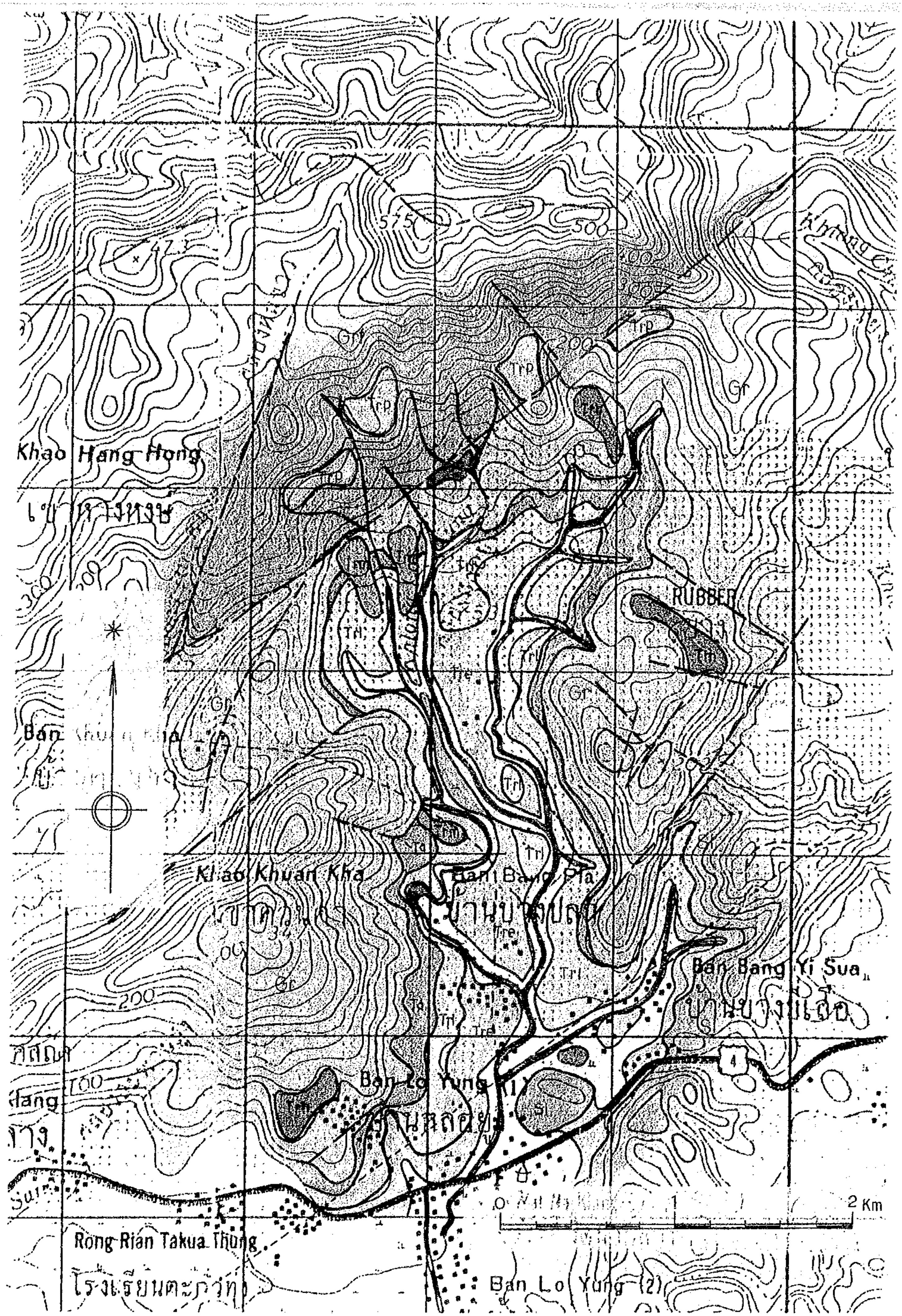
(3) Bedrock

As already stated, the bedrock of Khlong Lo Young dam site is supposed to be mainly composed of coarse grained granite and associated rocks. The bedrock is lithologically characterized by the presence of coarse flakes of feldspar and biotite. Among these minerals, feldspar phenocrysts is remarkably large usually growing up to 3 cm in length. The rock body however is massive and is suffered by deep weathering on the ground of the observation of outcrop exposed on the abutment of dam axis. In accordance with the role of weathering condition for coarse granite at other sites, the weathering zone having the small N value of less than 50 is expected to reach over 10 m thick from the surface.

On the other hand, very soft overburden which is about 5-10 m thick and is made up of Recent to upper terrace deposit lie on the weathering zone of bedrock thickly at the riverbed to flood plain. From these geological condition along dam axis, it may be said that the hard bedrock which have acceptable bearing capacity for large dam foundation lies beneath at least 20 m depth from the ground surface and 15 m to 20 m at abutment.

As shown in Figure 5-2-7, the distribution of coarse granite is de fined by fault systems running trough the upstream in direction of NE to SW. The exposure of coarse granite therefore is restricted to the vicinity of dam axis, alternately fine granite appears in the north of catchment area. Toward the downstream of dam axis, the Paleozoic strata which is mainly composed of slate and metamorphosed sandstone can be traced out.

From the result of boring survey conducted in similar area to Khlong Lo Young which crops out not only granite but also Paleozoic member, the fairly favorable characteristics for dam foundation is expected to this site. In these areas, core recovery percentage is high and R.Q.D. of core can be counted over 50%, so that the Rock classification of bedrock can be generally recognized to the CH to CM class to the Khlong Lo Young site too.



LEGEND

Rd	Alluvium	: Recent river deposite consisting of sand, gravel and silt, Swamp sediment of sand to clay
Tre	Erosional Terrace	: Recent river terrace made up of gravel, sand and silt
Trl	Lower Terrace	: Terrace deposit mainly composed of sand and gravel with thin clay layer
Trm	Middle Terrace	: Flat plain covering thin weathering material and sandy Layer locally
Trh	Higher Terrace I	: Erosional plain on the sideslope at the elevation of 100-150 m
Trp	Higher Terrace II	: Highest erosional plain at the elevation of 200 m
Ta	Talus	: Talus and colluvial deposite consisting of various size materials
Ss	Sandstone	: Palaeozonic sandstone, beded metamorphosed sandstone with chert and slate layer
Sl	Slate	: Slate with metamorphosed sand and chert layer
Gr	Coarse Granite	: Coarse grained biotite-porphyritic granite
Grf	Fine Granite	: Fine grained biotite-muscovite granite

Fig. 5－2－7　Geological Map of Khlong Lo Young Damsite

(4) Geological Structure

As mentioned above, the major geological structure of site is controlled by NE-SW fault. Within the catchment area, NE-SW trending fault can be observed at two localities, one is 1.5 km upstream of dam axis and another is 1 km down of axis, and both can be inferred to be continued from Phang Nga fault which is famous and large fault zone stretching for over 50 km toward NE from site. The geological members of site, such as granitic instruction and Paleozoic succession, are generally arranged in accordance with this structure.

Although the minor faulting structure can be traced out two trends of NW-SE and NNE-SSW, they are interrupted by major fault of NE-SE in a common sence. Consequently, the minor fault is hacked into pieces to be discontinuous. These minor fault makes small scarp and/or depression from place to place.

The terrace plains are also recognized all over the places in the site, furthermore, they can be classified into four planes due to different elevation where they are built up on the slope. The lowest terrace plane develops along river stream widely extending for the lower part of slope up to the elevation of 40-50 m. It has widest distribution as compared with other terrace plains and is usually formed by sandy deposit derived from the weathering granite.

The middle terrace is situated on the foot slope stretching at the elevation of 50-80 m, however, the occupied area is smallest among four terrace in the site and the terrace deposit does not rest on plain but erosional surface. The high terrace on the side slope can be seen as two types which are moreover divided into the lower and higher one depending on their elevation. The lower one is at elevation of 100 m to 140 m, and the higher one is formed at around elevation of 200 m. Both are not remained as the terrace deposit as well as above mentioned middle terrace.

These terraces are seen not only in the Khlong Lo Young site, but at the other dam sites and widely at their surrounding area. Accordingly, the extensive distribution of them may lead to the eustatic changes during the Pleistocene age.

(5) Permeability and Bearing Capacity

Either of permeability or bearing capacity of site is still unknown since the boring survey has not been executed up to the present. On the ground of these situation of site, the physical properties for dam foundation have to be predicted from the result of the other site which is on the same rock type. Considering the geological condition all over the sites, it can be evaluated that the Bang Nieo Dam site is the most similar to this site in geological sense; furthermore its physical condition can be diverted to this site as an available data for dam planning simultaneously.

As data of Bang Nieo Dam site shows the low permeability and high bearing capacity, these preferable properties can be expected to the Khlong Lo Young site.

5.3 Bang Nieo Dam

(1) Topography

It appears that Bang Nieo Dam site is not the best dam site at the thought of topographical advantage. The reservoir capacity is estimated at about 3.1 MCM in the case of dam height of 35 m from foundation and proposed crest length is 830 m. The volume of dam can be calculated roughly at 1.13 MCM so that the dam coefficient divided the reservoir capacity by the volume of dam is expressible to be 2.74. As shown in Figures 5-3-1 and 5-3-2, the reservoir area is relatively small corresponding to other proposed dam site, though the catchment area shows considerably large for which the river stream diverges into several distributaries toward the upstream.

In the catchment area, the lowest elevation is about 15 m and highest peak is about 450 m. Therefore the average gradient of slope is steep over the 15/100 especially at the upper slope over the elevation of 100 m is steeper exceeding 40/100 than the lower slope.

In general, the topographical feature of the site is clearly classified into two sub-areas of the low flat and mountainous area. The low flat area including the most of reservoir area is marked by the moderate relief less than relatively high of 20 m and extends for the alluvial plain near the coast. On the other hand, the mountainous area is characterized by forming various steep slopes partly involving granite cliffs and waterfalls.

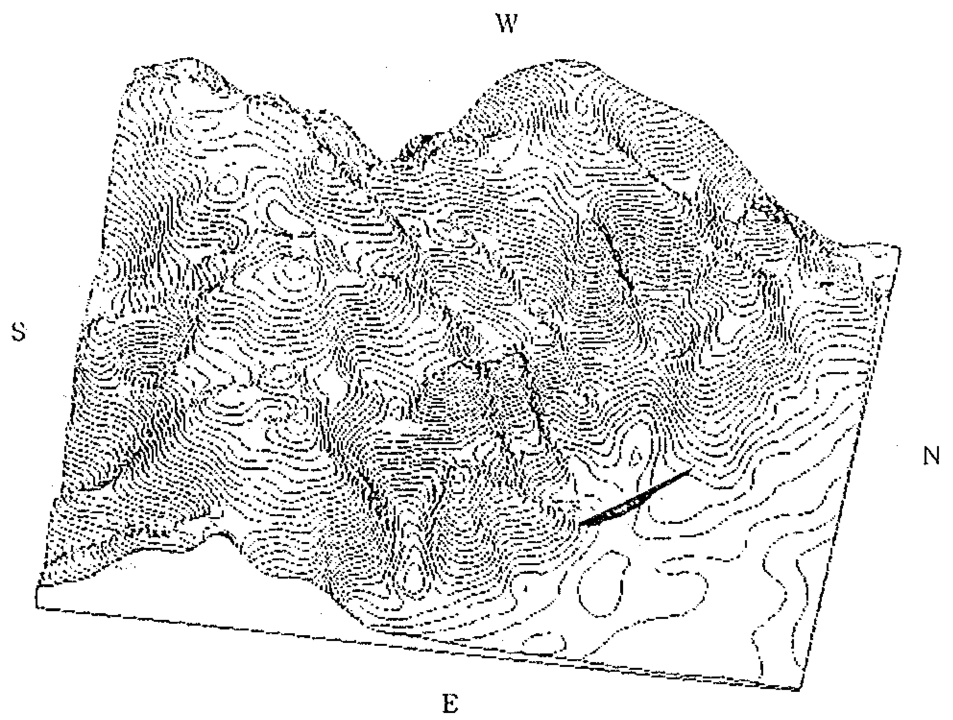
(2) Overburden

The overburden of site has been investigated by boring survey. At the boring points on the riverbed, the bedrock is overlain by the soft layer over 20 m thick which contains the Recent river deposit, terrace deposit and heavily weathered granite as shown in Figure 5-3-7. The thickness of Recent river deposit is gradually decreasing toward the foot slope where the Recent river deposit does not rest on there but the weathering granite is directly exposed on the surface.

The distribution of Recent river deposit is restricted to the strip area along river steam and is made up of various type sediment which contains the much amount of clayey materials at the downstream of dam site, while the dominance of washout sediment at the upstream.

There are three terrace plains located on different elevation respectively. The deposit covered on the terrace plain can be observed on the lowest terrace forming the reservoir area below the elevation of 35 m. Although the deposit appears comprising a facies of medium to coarse sand with thin clay layer, they are also with high content of tin minerals derived from the granite intrusion. The low terrace deposits therefore had been quarried until several decade ago, and mining activity remained the large hollows in the center of reservoir area.

The significant clayey layer is observed in the bottom of these hollows, it shows grey to black color and noted by a very soft facies which is indicated as small N value less than 5 blows by SPT. The facies also show a impervious, so that the sandy layer above it is saturated by ground water. As well as lower clay layer, these saturated upper horizon is also in the very loose condition.



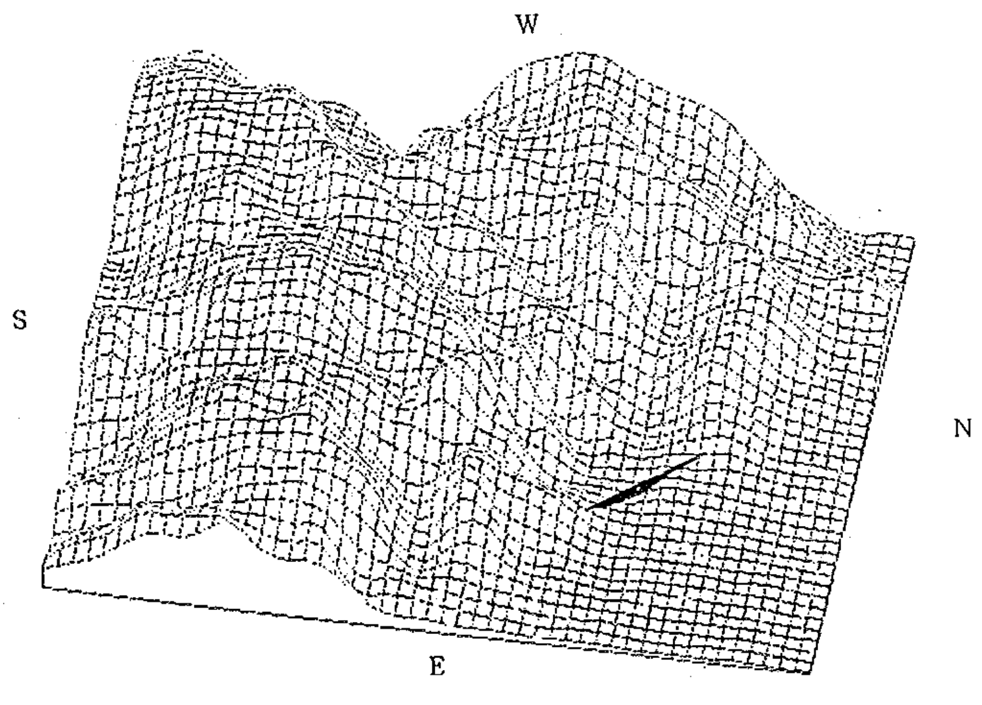
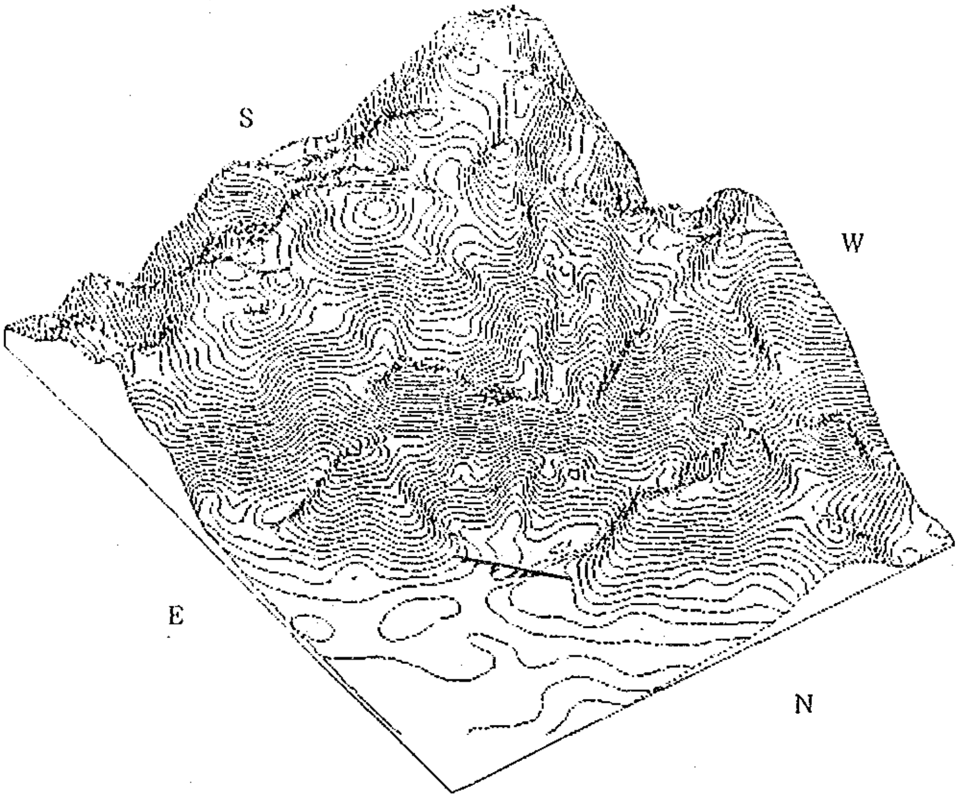


Fig. 5-3-1 Bird's Eye View of Bang Nie Dam Site(1)



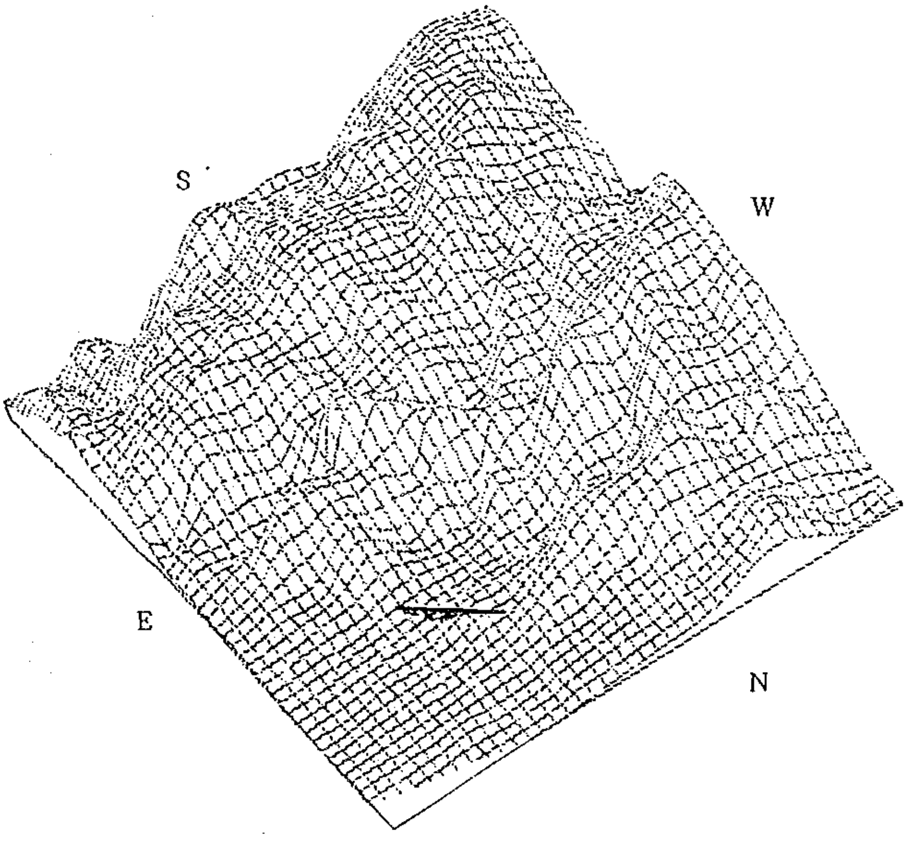


Fig. 5-3-2 Bird's Eye View of Bang Nie Dam Site(2)

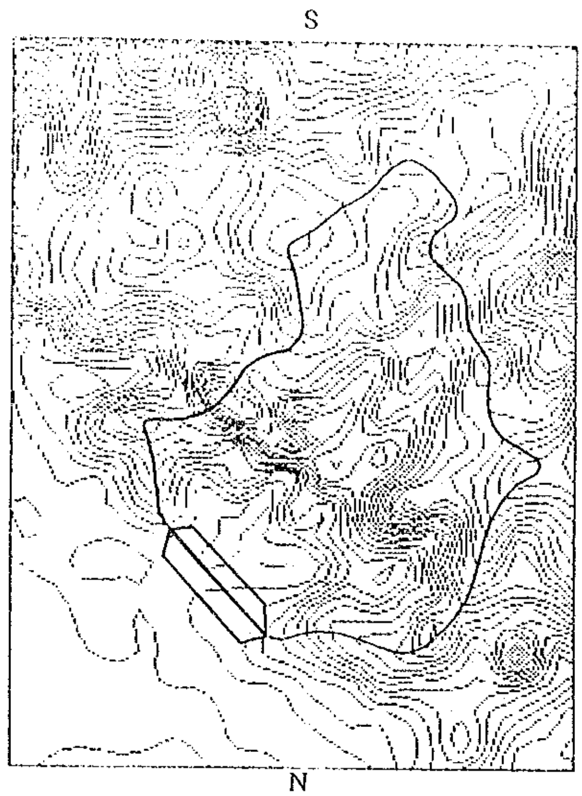


Fig. 5-3-3 Catchment Area of Bang Nie Dam Site

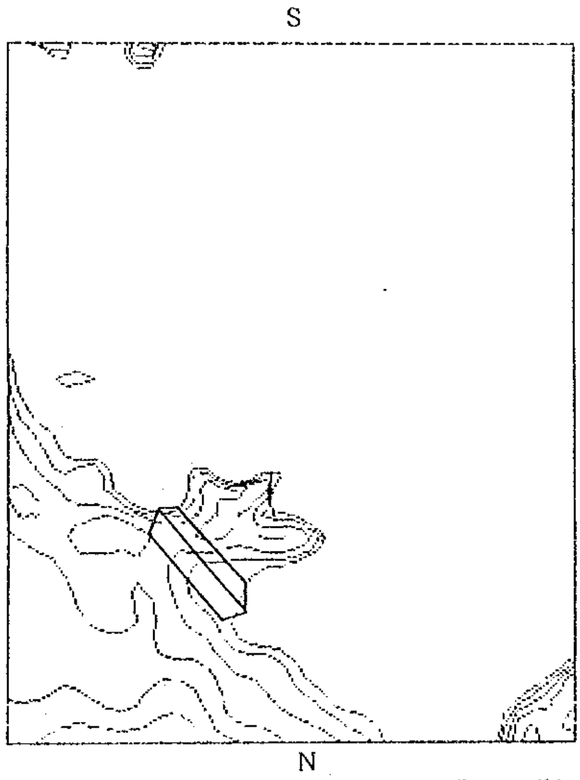


Fig. 5-3-4 Reservoir Area of Bang Nie Dam Site

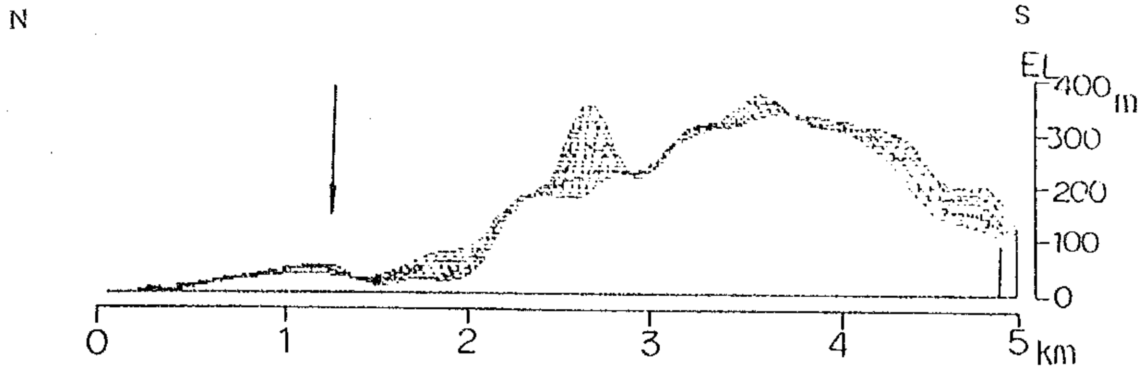


Fig. 5-3-5 Longitudinal Section along River Stream extending for Southern Mountain from Dam Axis

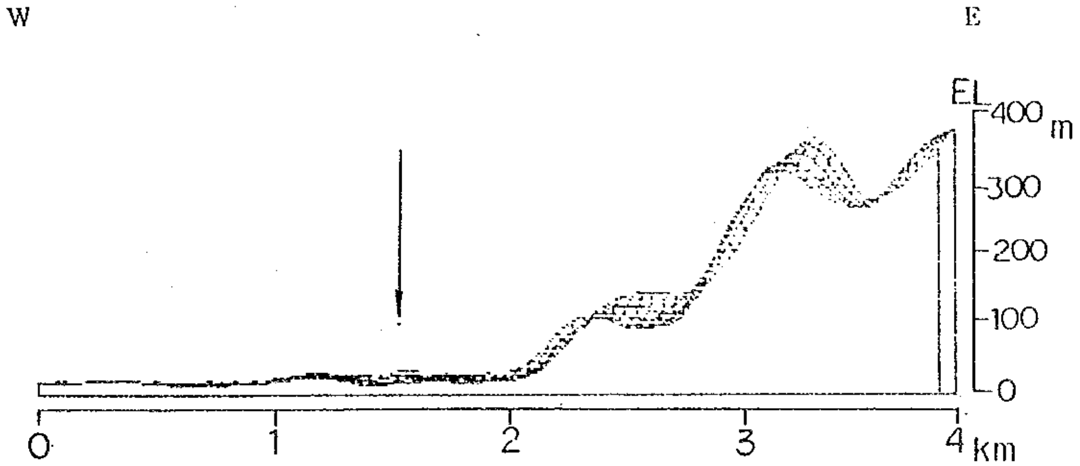


Fig. 5-3-6 Longitidinal Section along River Stream extending for eastern Mountain from Dam Axis

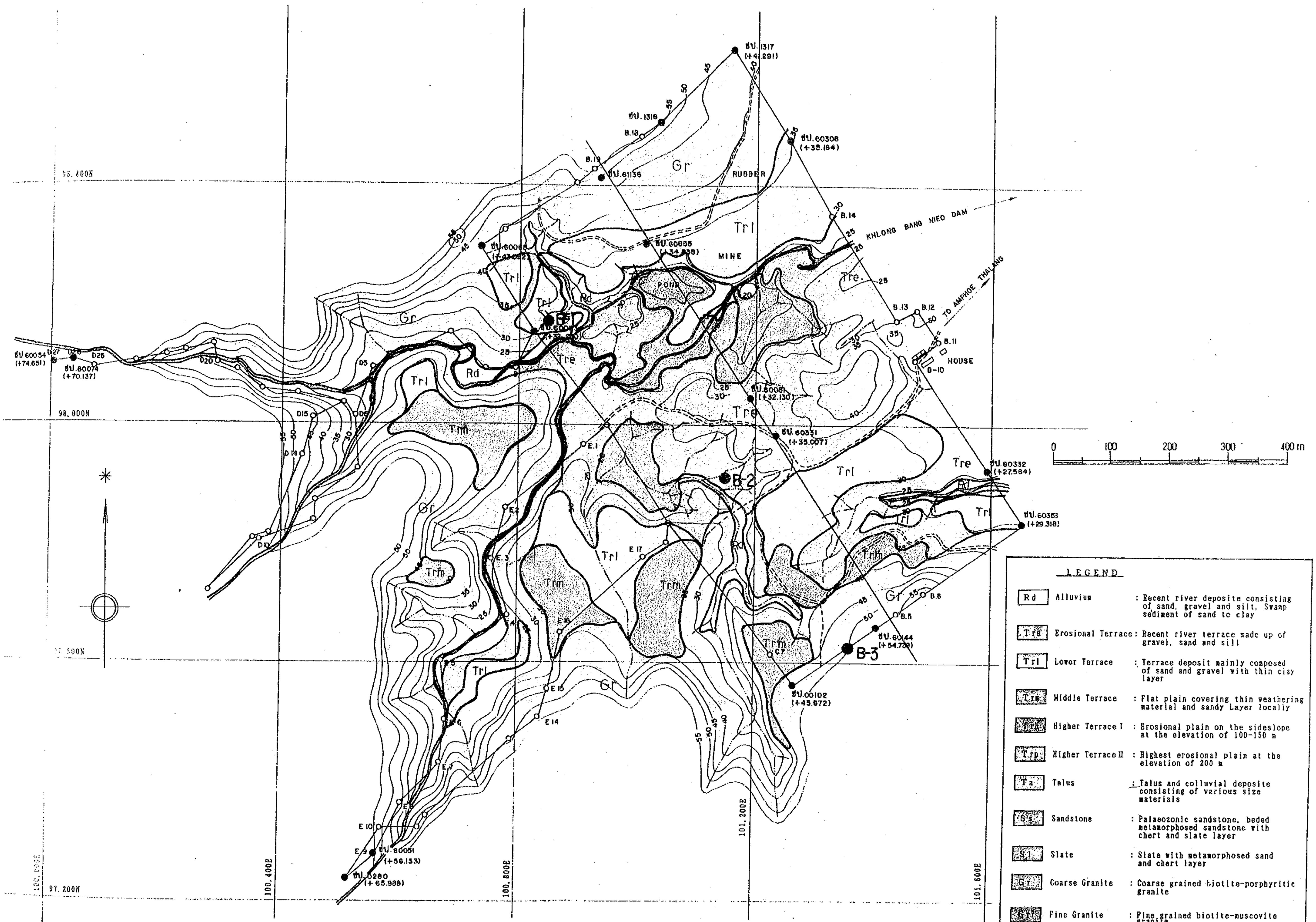


Fig. 5-3-7 Geological Map of Bang Nie Damsite

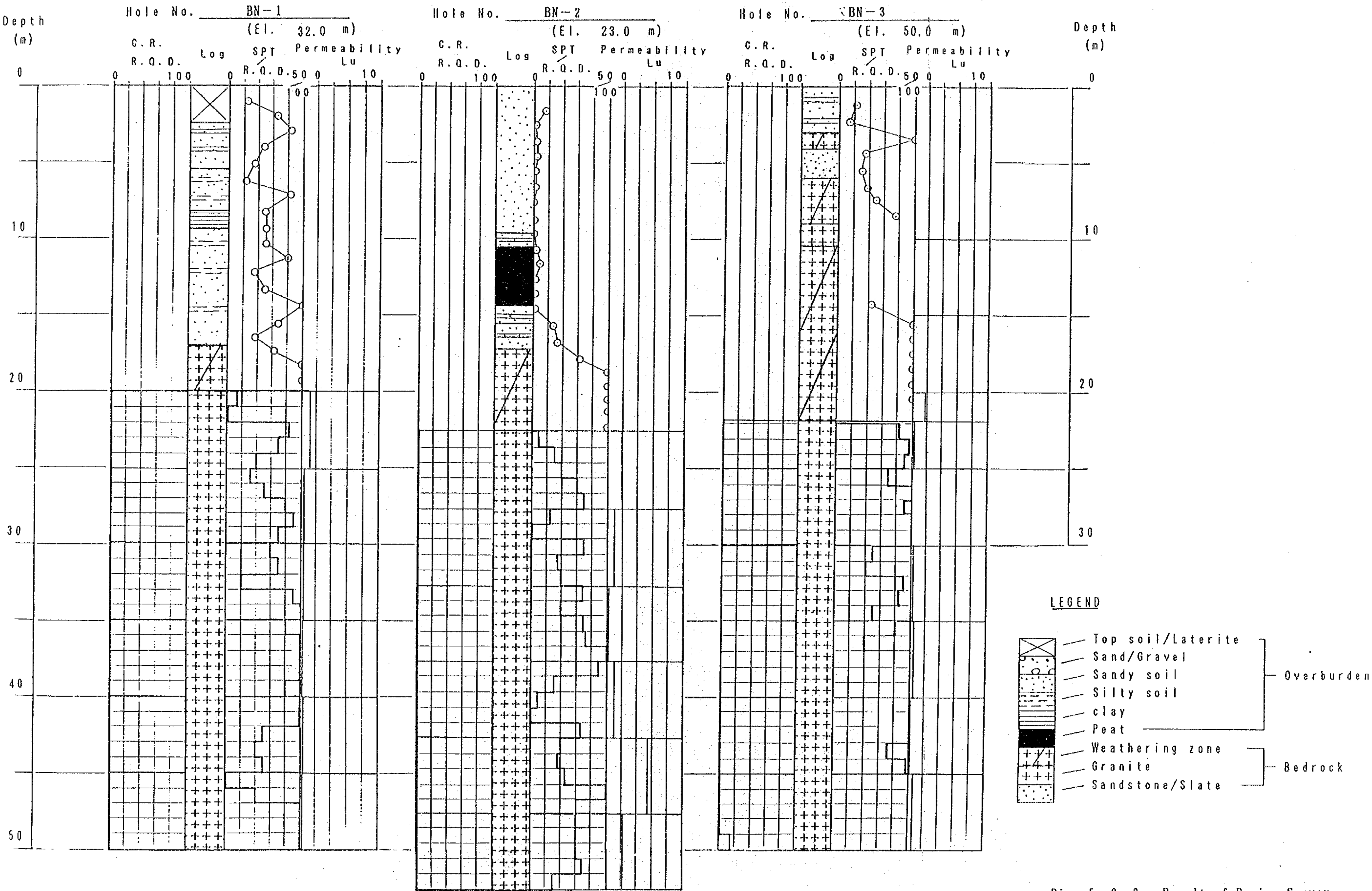


Fig. 5-3-8 Result of Boring Survey

(3) Bedrock

The bedrock of site is composed of granite lithologically grouped as coarse grained biotite porphyritic granite. The hard horizon which shows the over 50 blows by SPT is detected at the various depths depending on the weathering condition of bedrock from place to place. On the side slope of catchment area, the hard granite cliffs can be traced out remarkably at the right abutment of the upstream, the advance of weathering nevertheless can be observed deeply at such exposed slopes.

In the case of BN-3 drilled near the outcrop at right abutment, the hard rock is encountered at about 10 m, but the clayey layer appears at the 2 m deeper repeatedly. Finally, the clay layer continues up to the 21 m depth, while the slight weathering zone in bedrock is reached up to 35 m depth.

The tendency of weathering condition seems to resemble between each sites and the data for weathering in this site can be applied to the surrounding area making up of the similar granite.

(4) Geological Structure

In the site, the major faulting zone can not be found out in contrast to the other sites where several fractures are passing through everywhere. Contrary to these homogeneous structure about the faulting activity, the joint and crack of rock mass are usually developed all over the site and is arranging in direction of NE-SW to ENE-WSW. These joints commonly run with 0.5 to 1 m intervals and it locally open widely with several centimetres gap. Along the trend of these joint, the outcrop of granite is aligned on the side slope of catchment area.

As stated above, a set of terrace plain is seen in the site. It is grouped into three kinds of flatted plain, which are lower, middle and higher terrace, due to each elevation. The lower terrace spreads over an area and occupies the most of reservoir area below the elevation of 35 m. The middle terrace is situated beside the lower one over the elevation of 35 m. The both are seems to have similar properties example for same facies of terrace deposit and close localities.

On the other hand, the higher terrace appears the different characteristic from lower and middle terraces, the elevation of which is as high as of 70 m to 100 m as shown in Figure 5-3-6. The covering sediments is not observed on plane but on the eroded surface. The distribution however is wide and its continuity also seems to be distinctive.

The lower and middle terraces are inferred to be resulted from the Late Pleistocene transgression. The higher terrace may be attributed to a peneplanation in the post Tertiary.

(5) Permeability and Bearing Capacity

The result of investigation shows low permeability in the bedrock along dam axis in which Lugeon value is generally below the 2 Lu. Bearing Capacity of overburden seems to be on various condition which is shown as the N value changing rapidly from place to place.

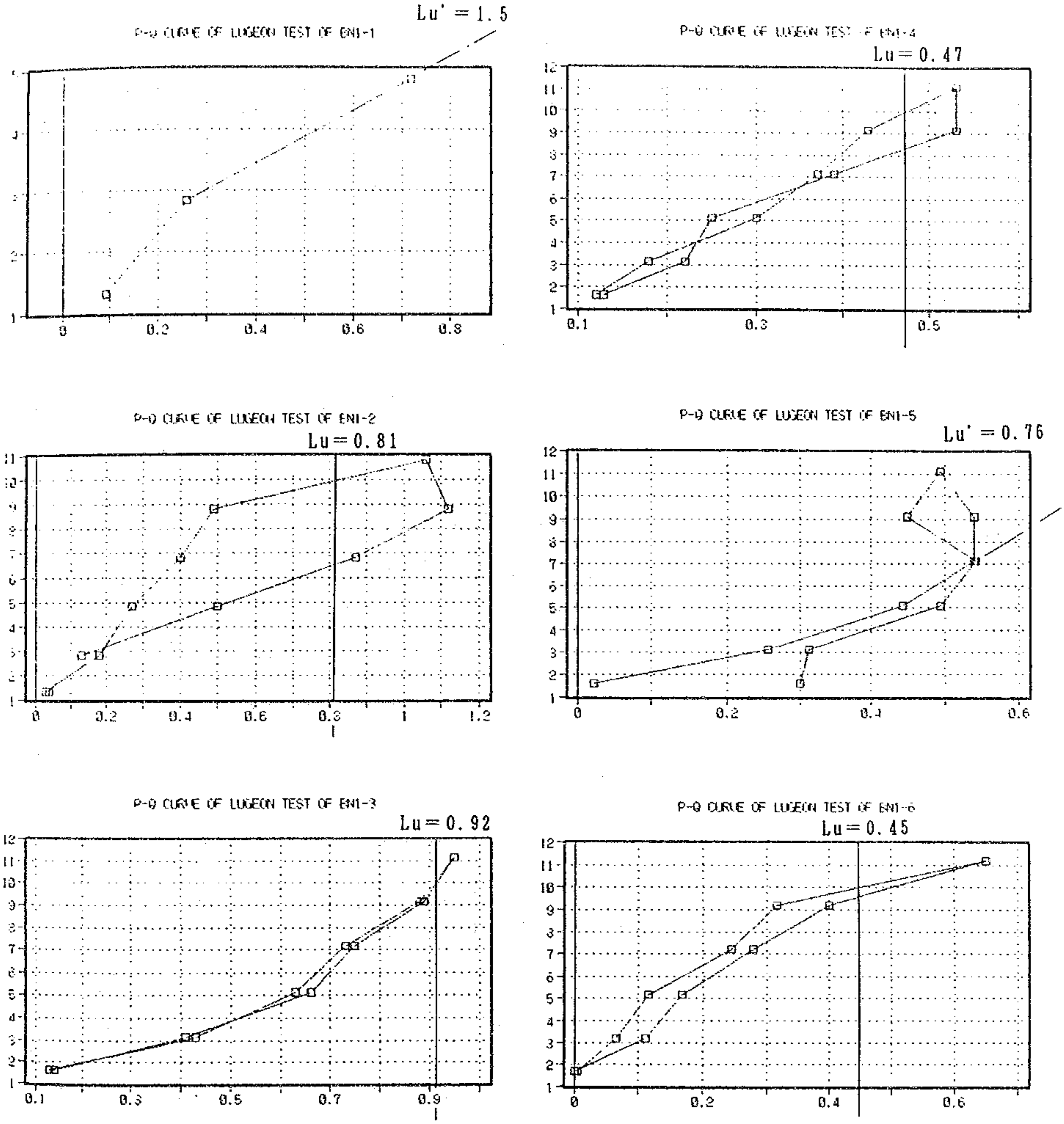


Fig. 5－3－9－1 Result of Lugion Test of BN－1

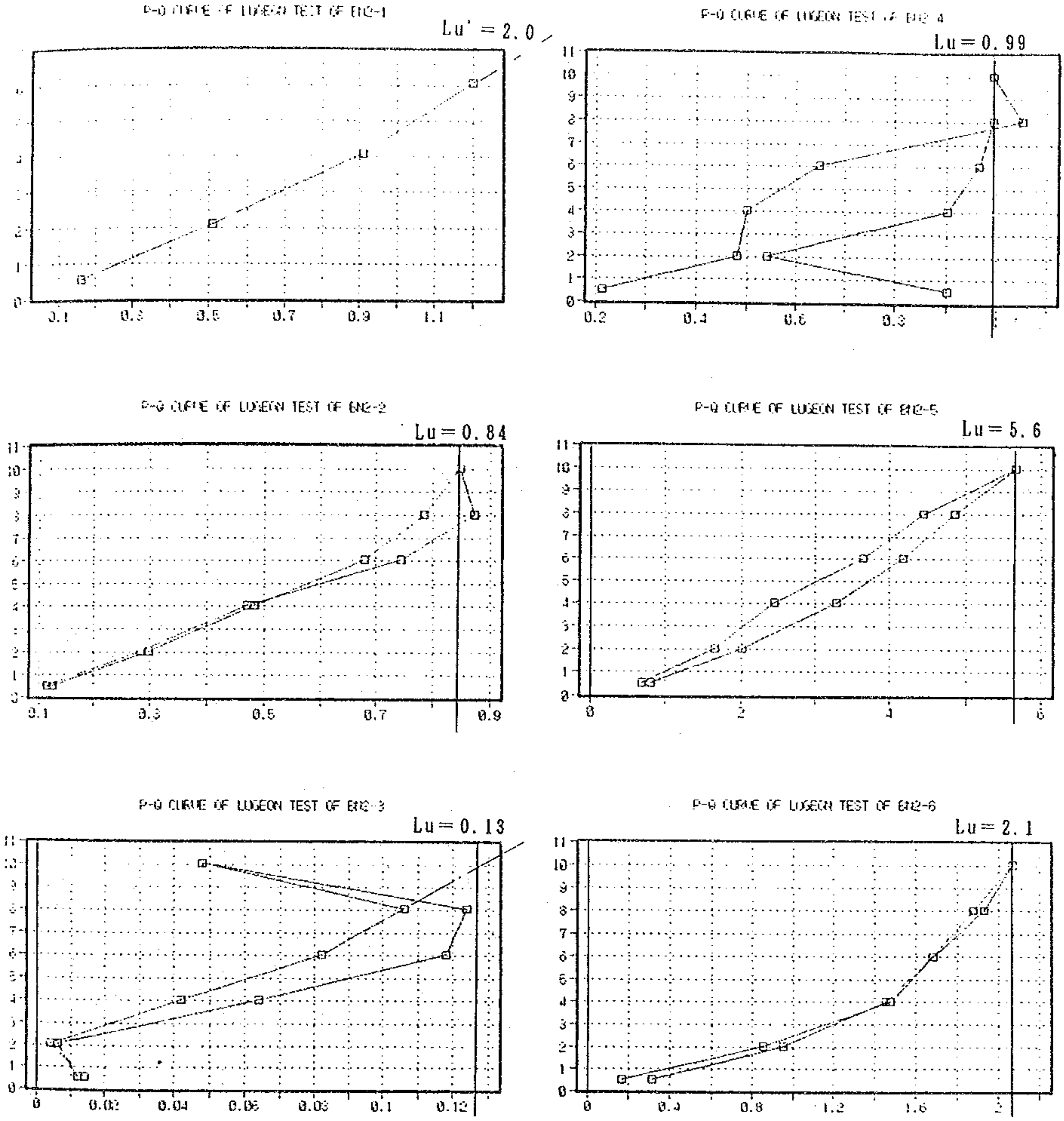


Fig. 5－3－9－2 Result of Lugion Test of BN－2

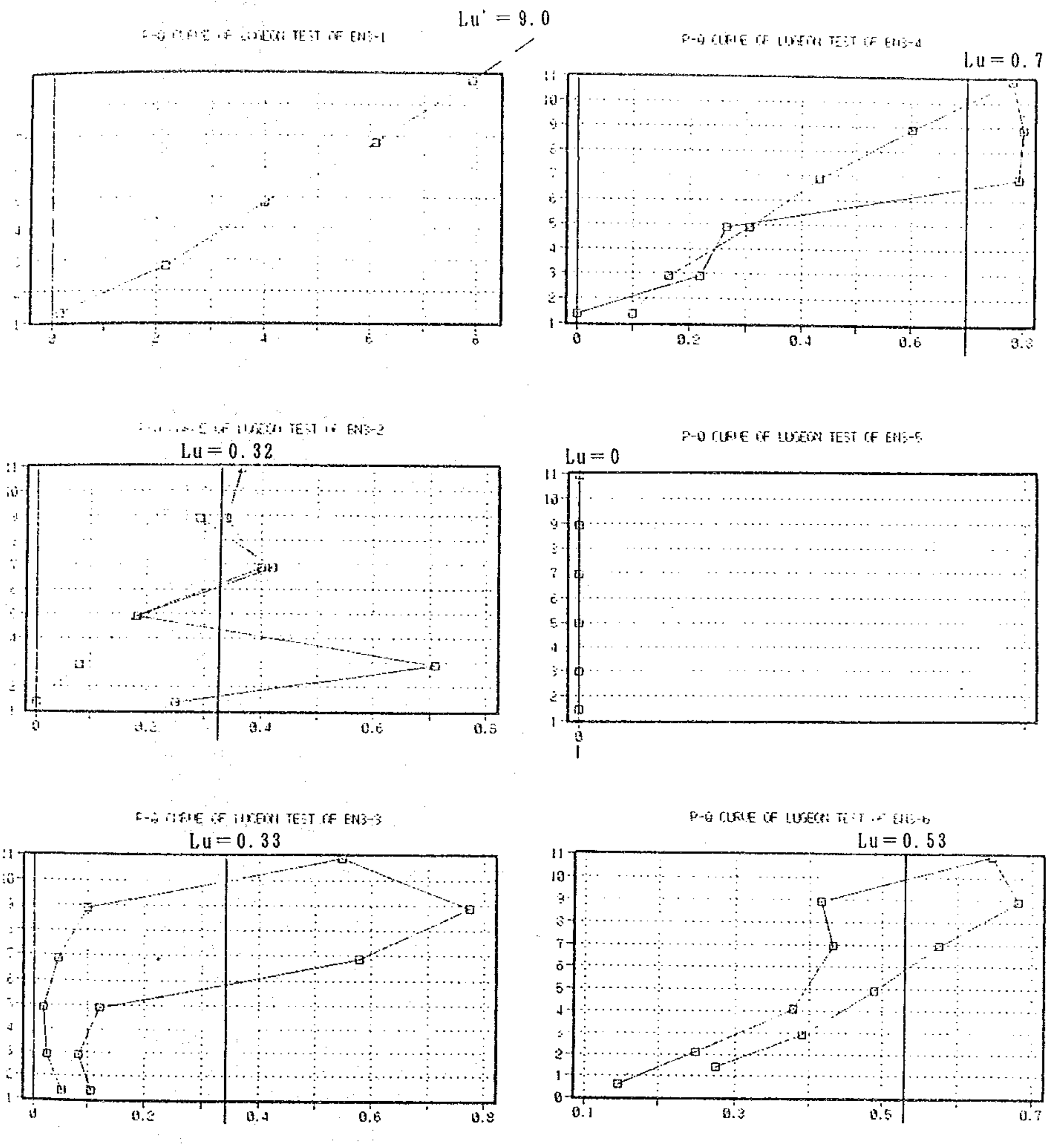


Fig. 5-3-9-3 Result of Lugion Test of BN-3

On the contrary, the overburden behaves like a high permeable zone in consequence of falling head test which is observed less than $k = 10^{-4}$ cm/sec. Bearing capacity of overburden can be presumed with the N value which ranges less than 1 to over the 100 blows. Through the whole horizon, the minimum N value is taken from the clayey layer lying on the weathered facies of bedrock. Toward the upper horizon of clayey layer, the N value increases up to 20 blows. Also toward the lower horizon as well as upper facies, the N value is increasing gradually to over the 50 blows as maximum value at the lower part weathering zone.

5.4 Khao Che Tra

(1) Topography

As shown in bird's eye view of Figures 5-4-1 and 5-4-2, the dam site and its adjacent area can be grouped into three topographical sub-area, which are the low flat, hilly and mountaineous area. The low flat area is made by a peculiar distribution restricted to the lower area below the elevation of 30 m and by having smooth surface covered by alluvium or low terrace deposit. Furthermore, it spreads out widely toward the seaside descending its elevation and continues to the mangrove swamp. From these topographical features, the low flat may causes to imagine that very low and flat topography is formed by a last transgression in Pleistocene age.

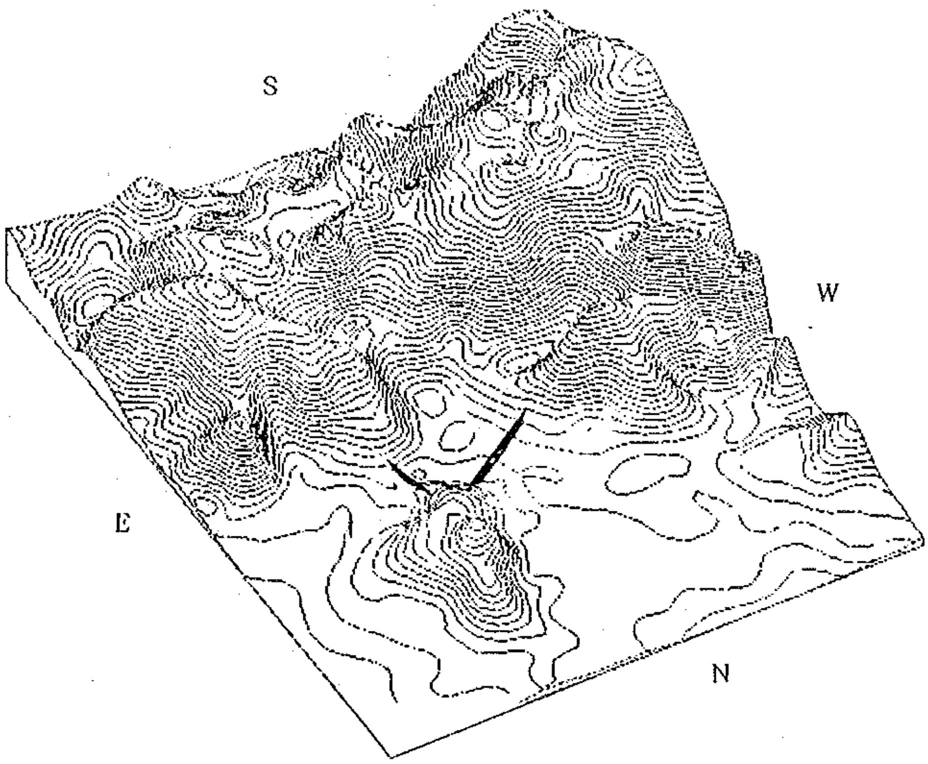
The hilly area is correlative with the right abutment area and is made up of the Paleozoic member. Therefore, the area appears the gentle slope while the left abutment shows the steep slope with bare rocks. Several depression or cols run through the right ridge. They are supposed to be fracture zone extending in NE-SW direction. According to cross section of Figure 5-4-6, the relative height is also lower than that of right abutment and it is only about 50 m higher from the reservoir area to the saddle dam. Contrary to above, the right abutment to the upstream area is characterized by mountaineous aspect having the summit over the elevation of 400 m with steep side slope.

Depending on these topography, the longitudinal section of Figure 5-4-6 shows the clear kick points at the boundary of above mentioned topographical sub-areas, so that the gradient of slope also changes between mountaineous upstream and low flat. At the upstream, the gradient is steeper than 30/100 while down area to dam axis is seen to the less than 2/100.

The profile along dam axis seems to reflect to geological condition as well as the above mentioned topographical features. Accordingly, the site along dam axis can be divided into tree parts comprising of the Paleozoic hilly area at right abutment, Recent to Pleistocene low flat at the river bed and granitic/Paleozoic mountaineous area at the left abutment.

(2) Overburden

The overburden members overlain on the dam site consists of mainly Recent river bed and Pleistocene terrace deposit. The Recent river bed deposit covers along the stream and is noted by a much content of sandy deposit at the upstream, and increases the quantity of clayey



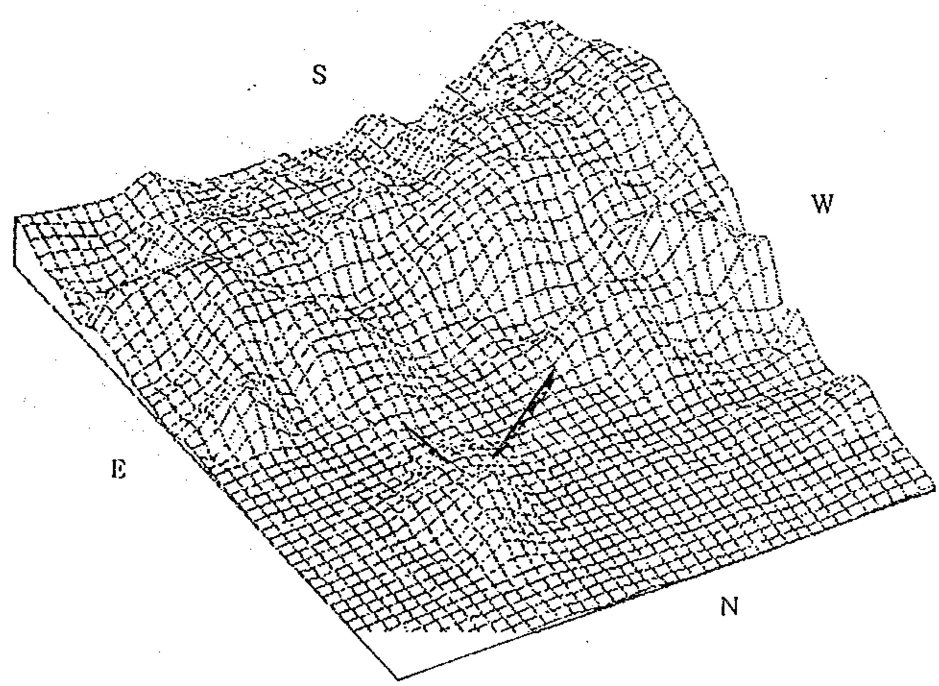
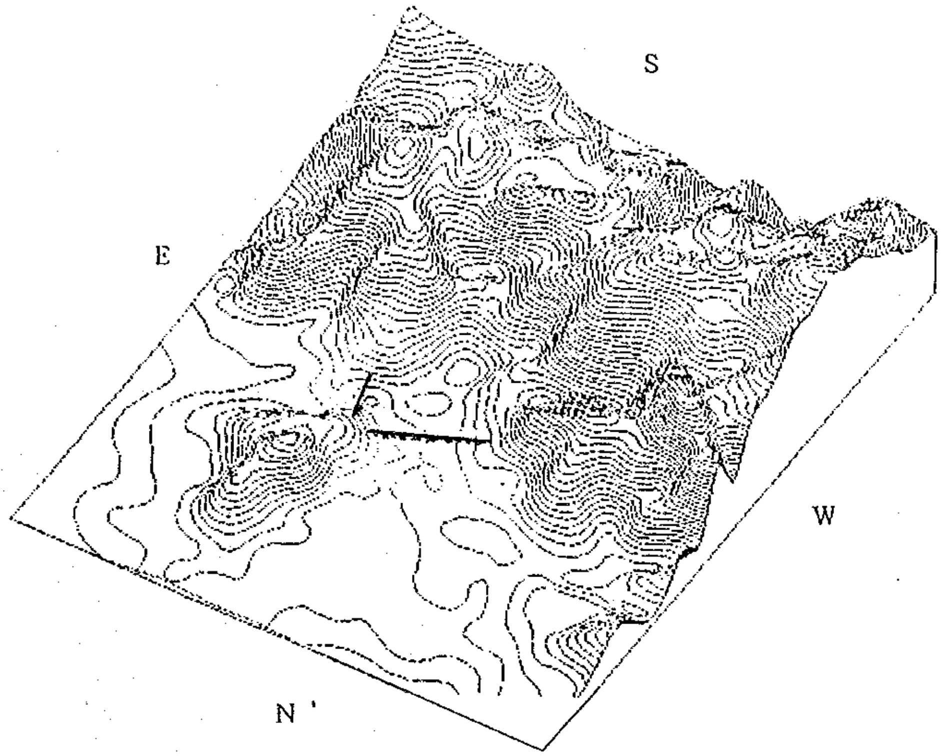


Fig. 5-4-1 Bird's Eye View of Khao Che Tra Dam Site(1)



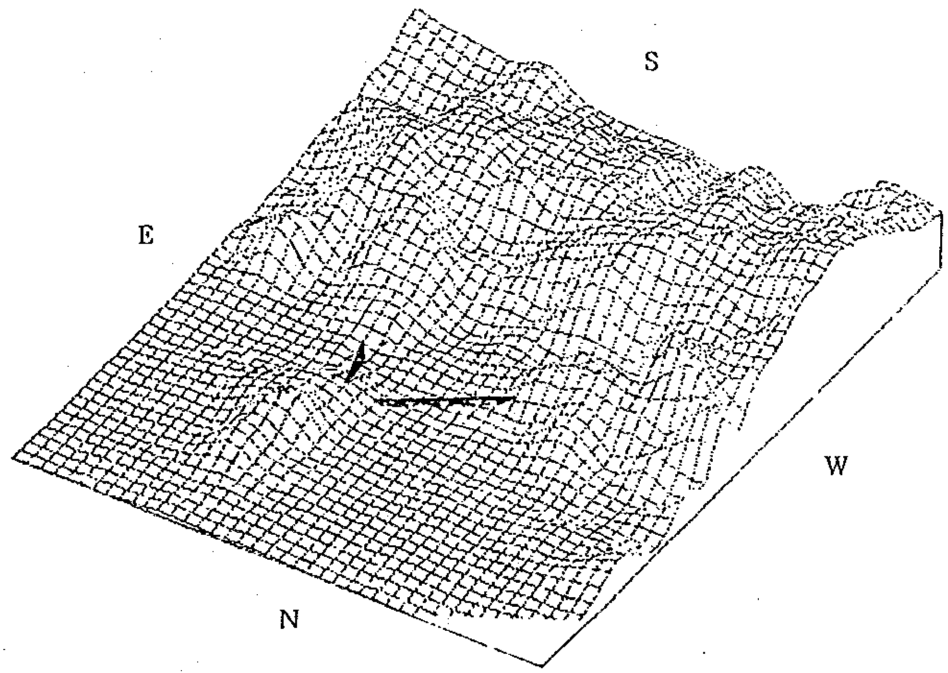


Fig. 5-4-2 Bird's Eye View of Khao Che Tra Dam Site(2)

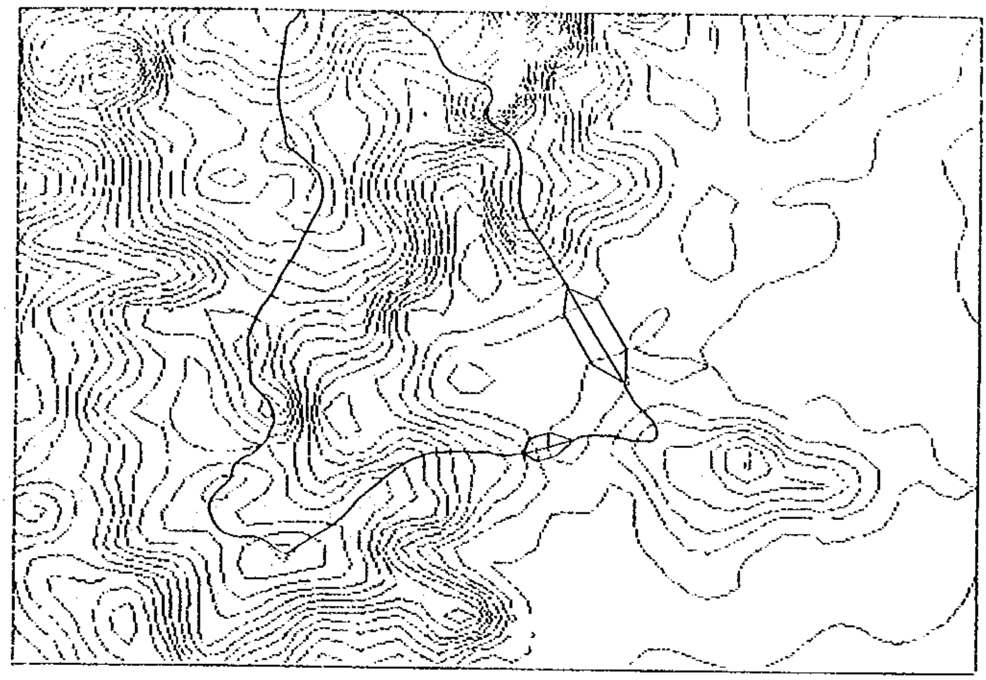


Fig. 5-4-3 Catchment Area of Khao Che Tra Dam Site

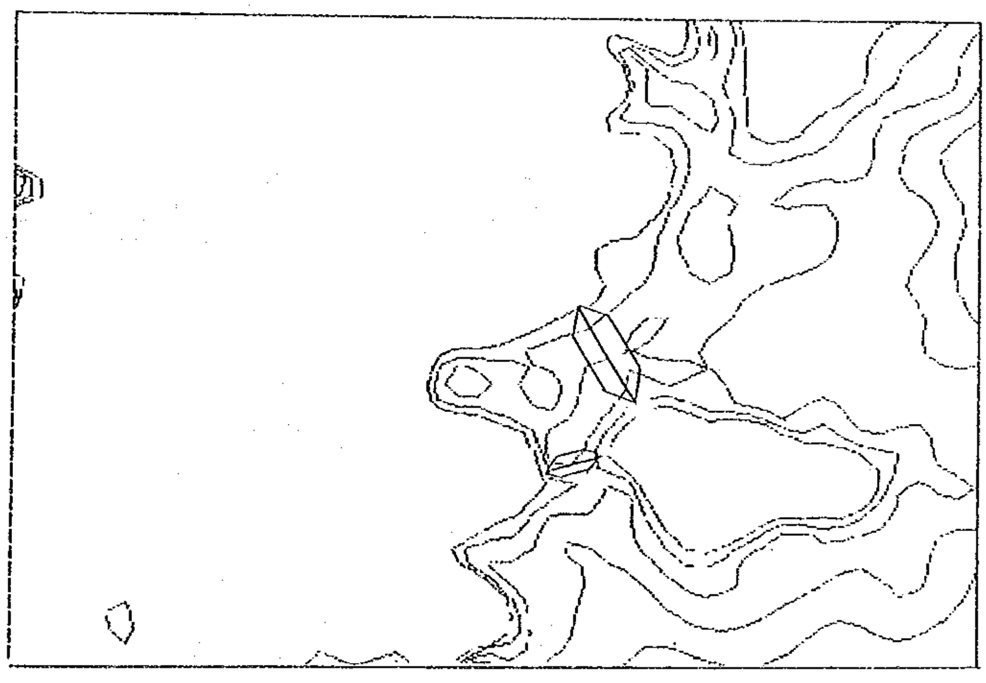


Fig. 5-4-4 Reservoir Area of Khao Che Tra Dam Site

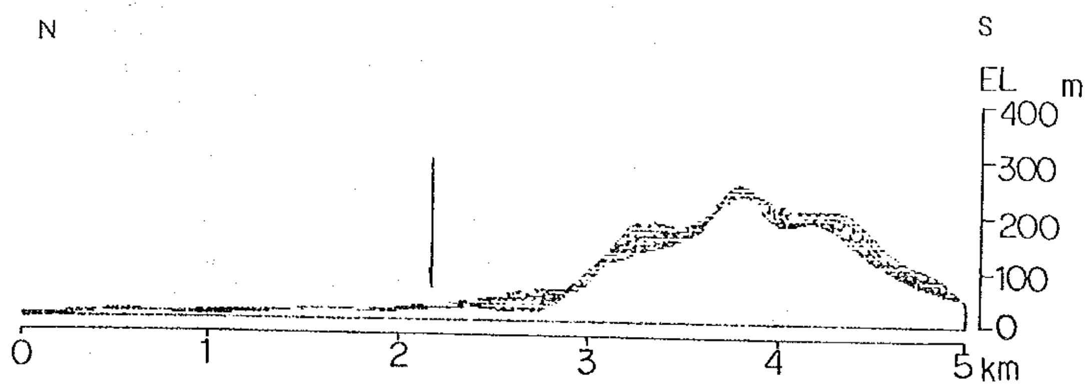


Fig. 5-4-5 Longitudinal Section along River Stream of Khao Che Tra Dam Site

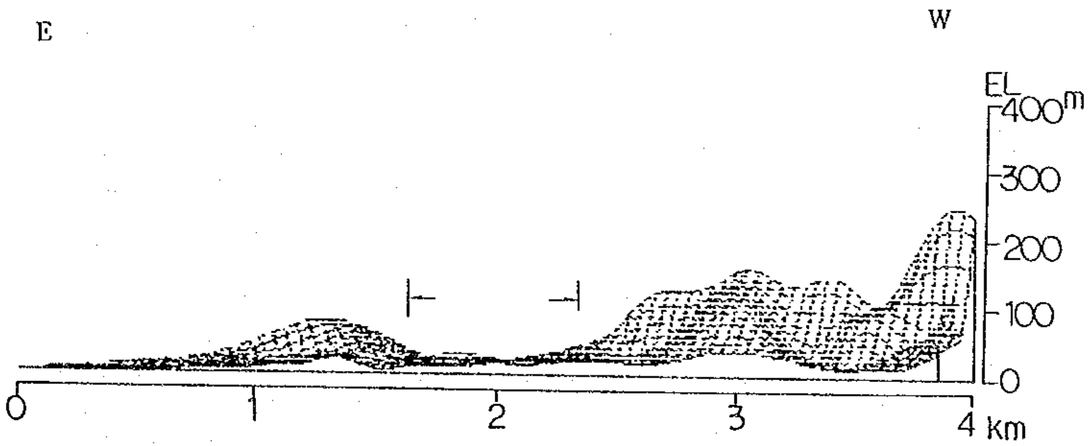


Fig. 5-4-6 Cross Section along Dam Axis of Khao Che Tra Dam Site

materials toward the downstream. In reservoir areas it widely lies in mining pit at 2 m thick.

The Pleistocene deposit is usually seen at the surrounding area of Recent river bed and extends up to the foot slope of mountain. The facies are characterized by the thick sandy layer, thin intercalation of clayey, and gravelly materials. The total thickness, as a result of boring survey, can be measured as about 15 m at the center of dam axis. The clay rich layer locally underlies the sandy horizon and is pronounced by highly lateritization of layer, and insertion of peat and white plastic clay. Its distribution however is restricted to an elevation below 25 m so that the clay rich layer is supposed to be a product of the past transgression age. From the view point of dam foundation, the layer seems not to have a enough bearing capacity since it shows very small N value less than 1 for the any scale of dam.

(2) Bedrock

The bedrock is of granite intrusion and Paleozoic sandstone with apatite vein. The western half of catchment area is occupied by the coarse granite in contrast to the other half which is made of the Paleozoic member of metamorphosed sandstone. The both are supposed to contact not with fault. They rather change by degrees.

The coarse granite is lithologically called as coarse grained biotite porphyritic granite as well as shown at the Bang Nieo Dam dam site. Although the bedded plane or jointing plane remains in places, the rock mass looks like to be a uniform commonly through all localities.

The sandstone usually shows the alternative facies of coarser layer and finer layer with several centimeters intervals, and is partly intercalated by chert and slaty layer.

The weathering condition is different between granite area and sandstone area. The deeper weathering is observed at the sandstone area as that a weathering product can be traced out 20 m depth in the core sample near the saddle dam site.

(3) Geological Structure

The trend of fracture zone in the site is mainly pronounced to be along NNW to SSE which has different direction from the surrounding area. Looking into the surrounding area, NNW to SSE faulting system is minor structure in comparison with the NE to SW trend such as Major fracture zone of Marui fault and Phang Nga fault. The NE to SW faults are traced out up to the vicinity of the site. Their positions lead a possibility that the lineation may continue to along the boundary between the areas of granite and Paleozoic member in the site. The evidence for these correlation however found out in the field reconnaissance while rather concordant contact of both was observed.

In contrast to these, the NNW to SSE fault system well develops in the site. Especially at the upstream of drainage, traceable was the apparent fault topography of waterfall or straight cliff the localities of which are continuous each other in straight position. Owing to the detail observation of outcrop, the faults are considered as a type of normal fault with high angle plane.

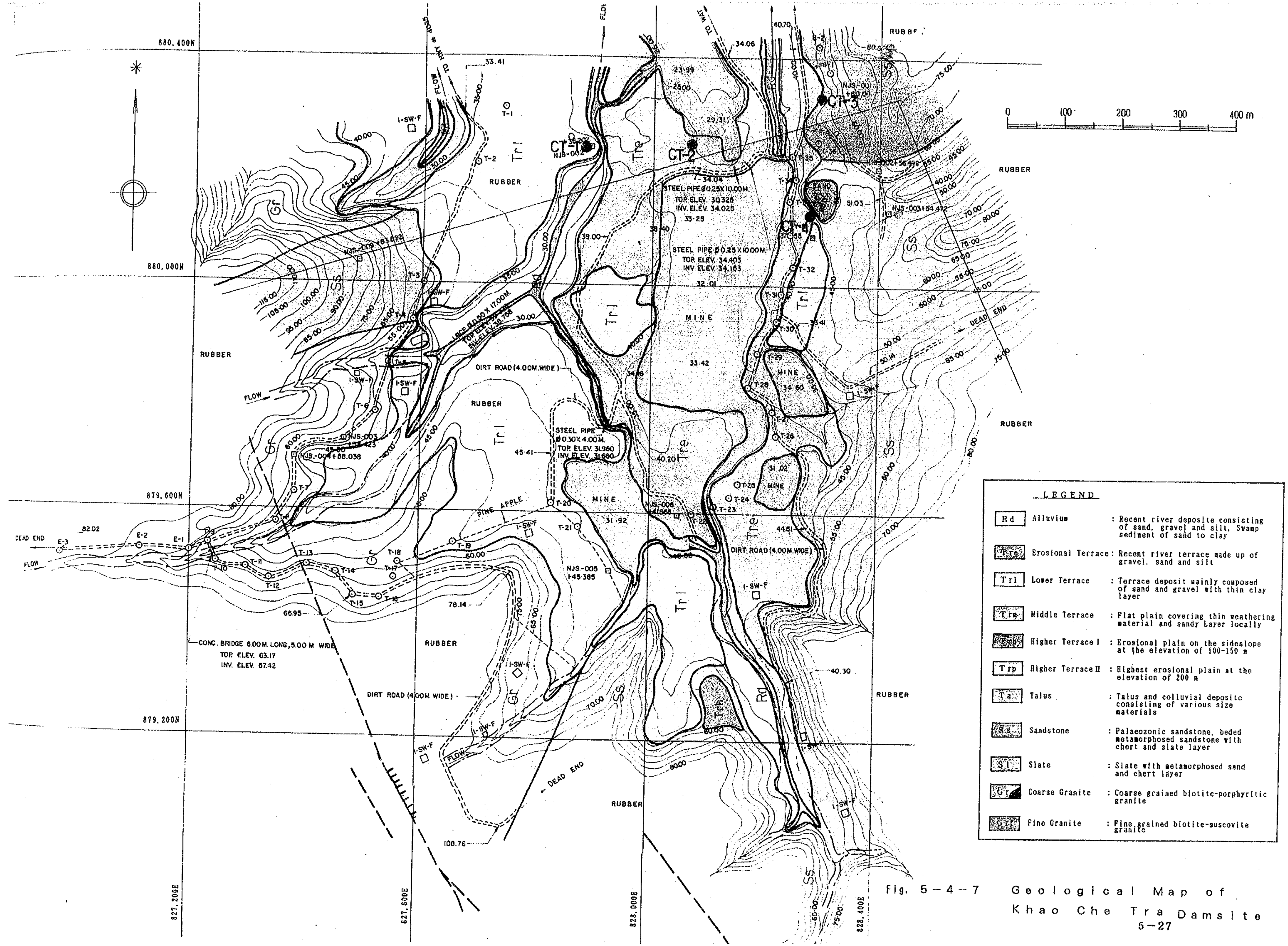


Fig. 5-4-7 Geological Map of Khao Che Tra Damsite

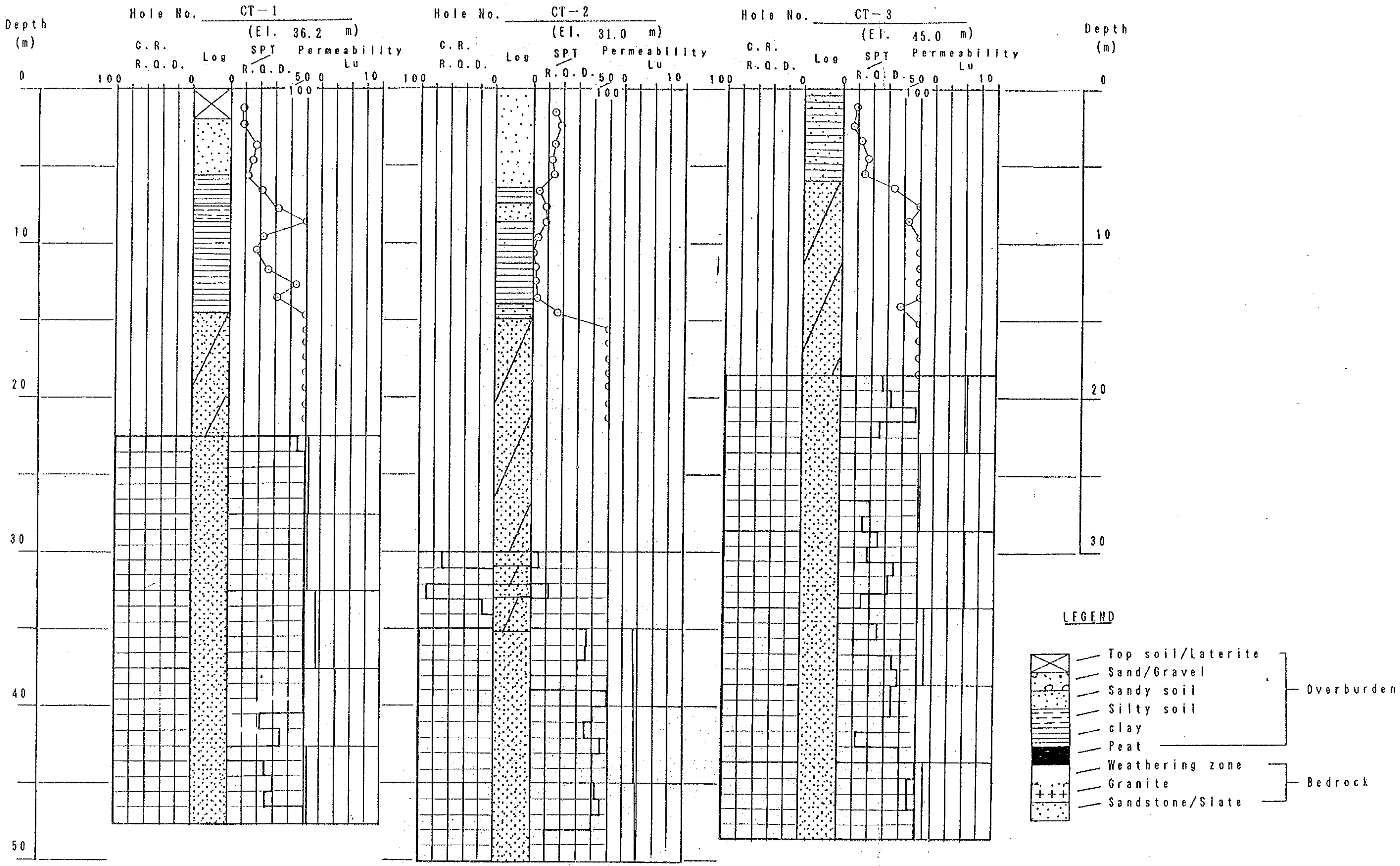


Fig. 5－4－8 (1) Result of Boring Survey

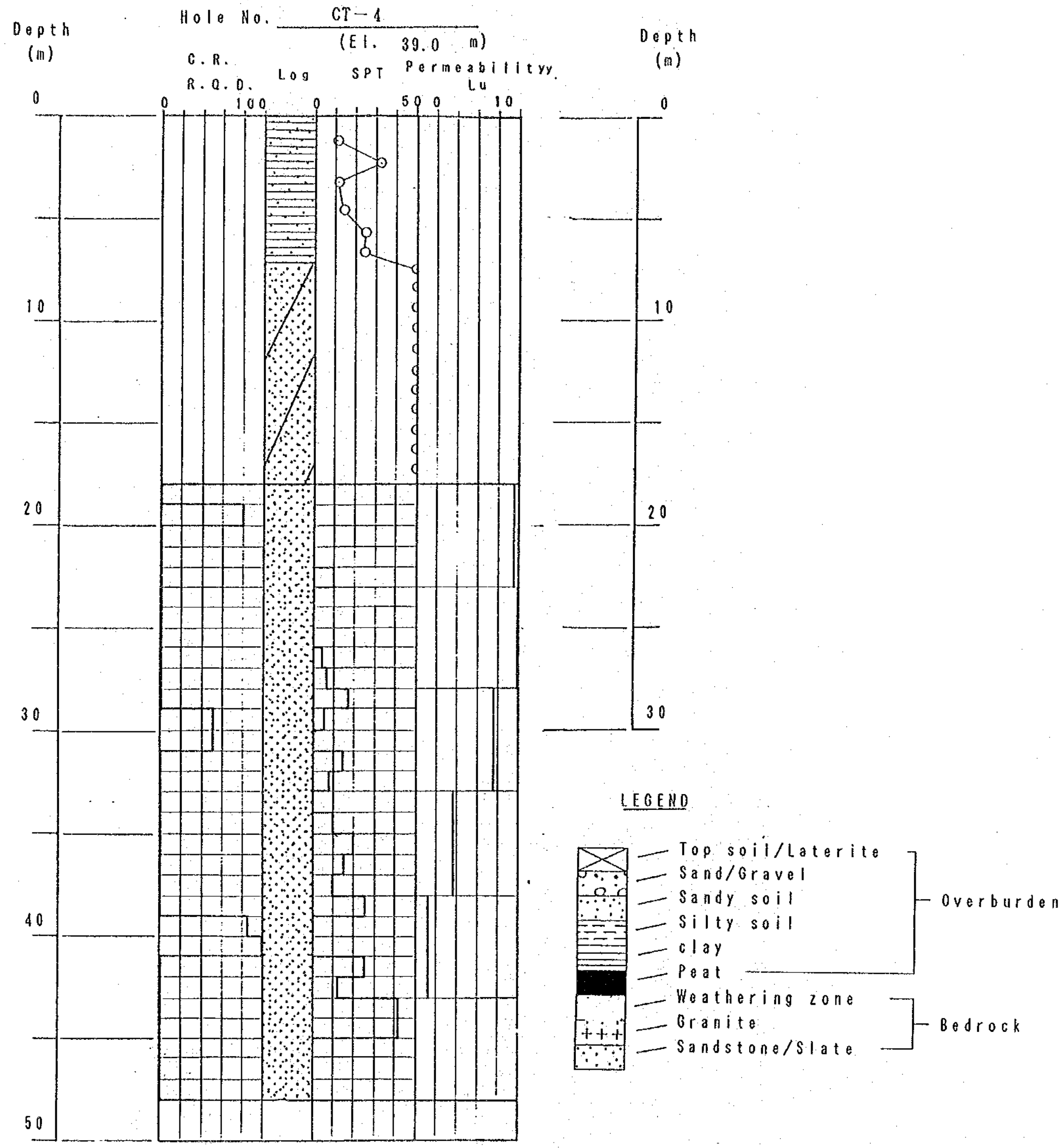


Fig. 5－4－8 (2) Result of Boring Survey