CHAPTER I

INTRODUCTION

General

Granites are one of the most important and abundant rocks in Thailand. They have long been under investigation for many decades because of their enormously associated economic minerals. Consequently, their petrology,mineralogy, and geochemistry are known tremendously (Charusiri,1989 ; Charusiri et al.,1991a, b; Charusiri et al., 1991 ; Charusiri and Pongsapich,1982 ; Mahawat,1983 ; Nakapadungrat, 1983 ; Nakapadungrat and Putthapiban, 1992 ; Puttapiban and Gray, 1983). However, information on engineering properties and weathering grade classification is yet poorly understood.

During the last decade, granitic rocks have become more important in material resources. They have involved and been encountered in numerous civil works, both as foundation of engineering structures and as construction materials and dimension stones. At present, the amount of consumption and production demand of granitic materials is gradually increasing because of the rapid growth of country's industries. Therefore, it is vital to know the granite not only on their standard geological, chemical, and physical properties but also on their engineering properties as well.

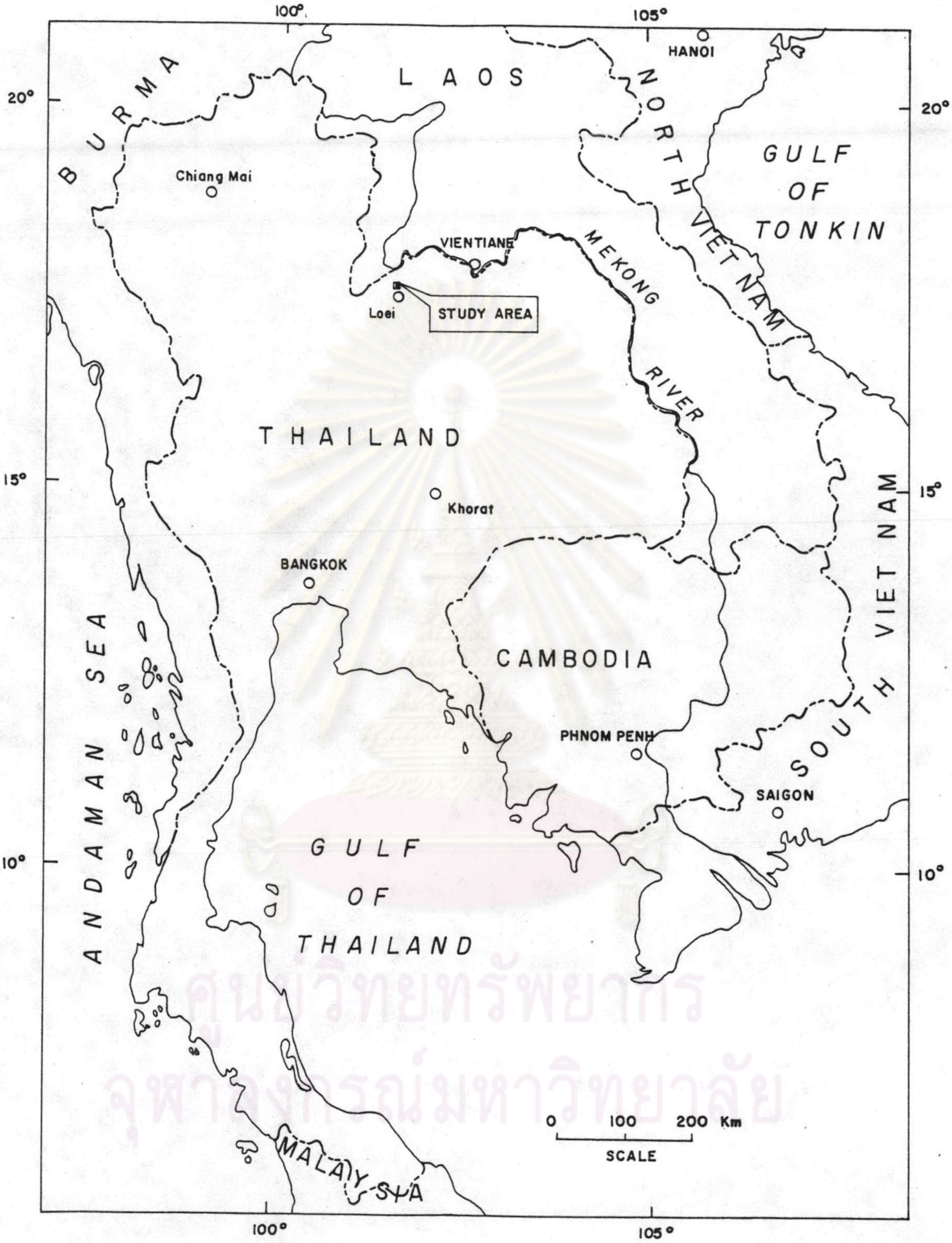


Figure 1-1. Map showing location of the study area.

Objectives.

The main objective of this study is to investigate the engineering properties of the granitic rock at Phu Sa Nao area, Changwat Loei. Detailed petrographic properties of various grades of weathered rocks that strongly influence engineering properties will be precedingly identified. The relationship among these properties will be particularly emphasized. Empirical models of petrographic properties for strength estimation of the rock will be eventually developed. This study is meant to be a case study for any granitic rocks in other areas of Thailand.

Location and Accessibility.

The study area is located at Amphoe Muang,Changwat Loei, a portion of the northwestern fringe of the Khorat Plateau in Northeastern Thailand (Figures 1-1, 1-2). It covers an area of approximately 290 square kilometers, bounded by the geographic longitudes 101° 36′ 12" and 101°45′ 00"" East and the latitudes 17° 35′00" and 17°45′00" North.

The study area can be accessible from several routes (Figure 1-2). The most convenient one is the national highway number 1 from Bangkok to Sara Buri, then take highway number 2 to Sikhiu, tern north to the highway number 201 from Sikhiu via Chaiyaphum, Chum Phae, Wang Saphung to Amphoe Muang, Changwat Loei. From Amphoe Muang the most convenient way to reach the study area that located between the Na O and the Ban That districts is

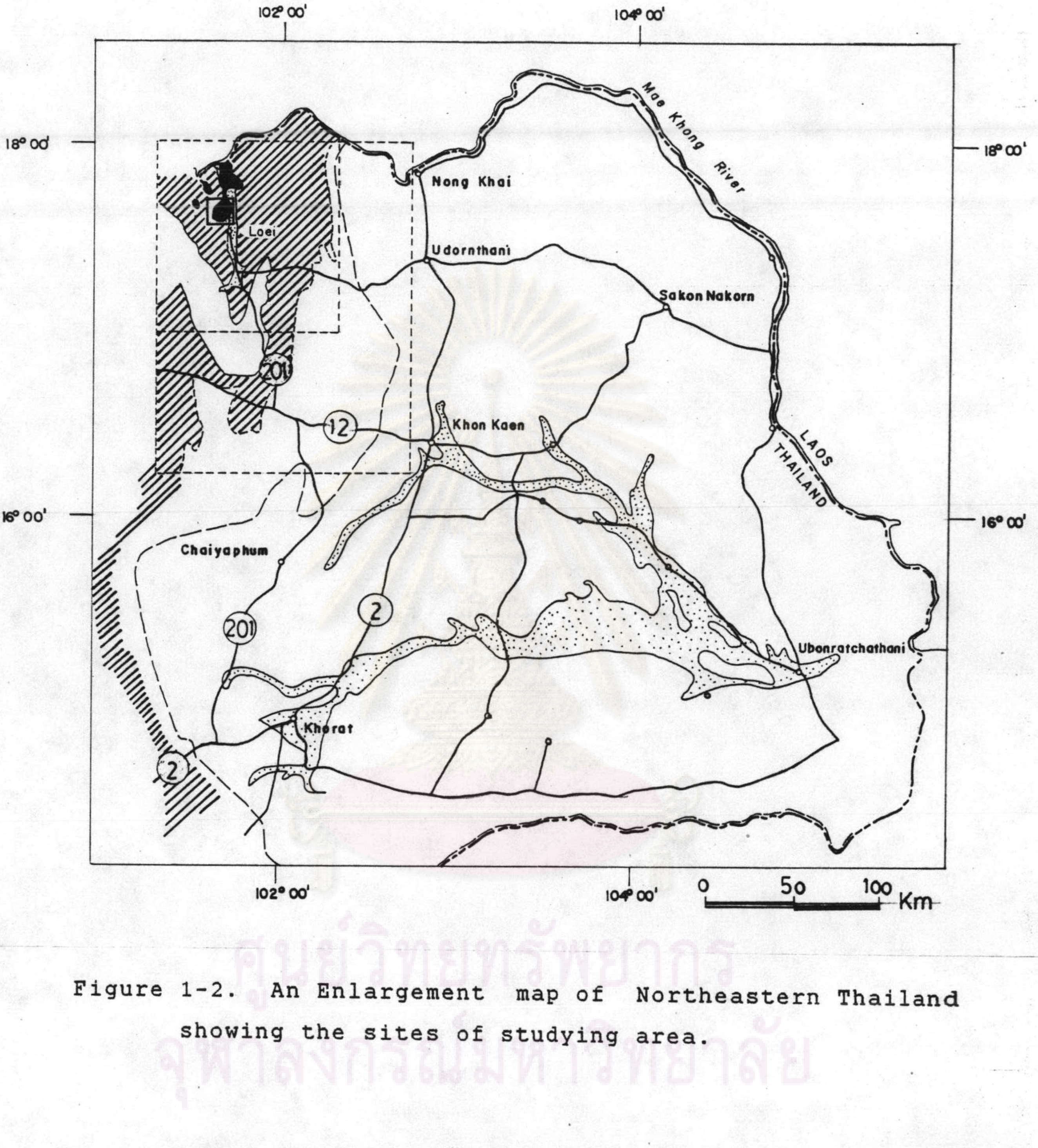


Figure 1-2. An Enlargement map of Northeastern Thailand showing the sites of studying area.

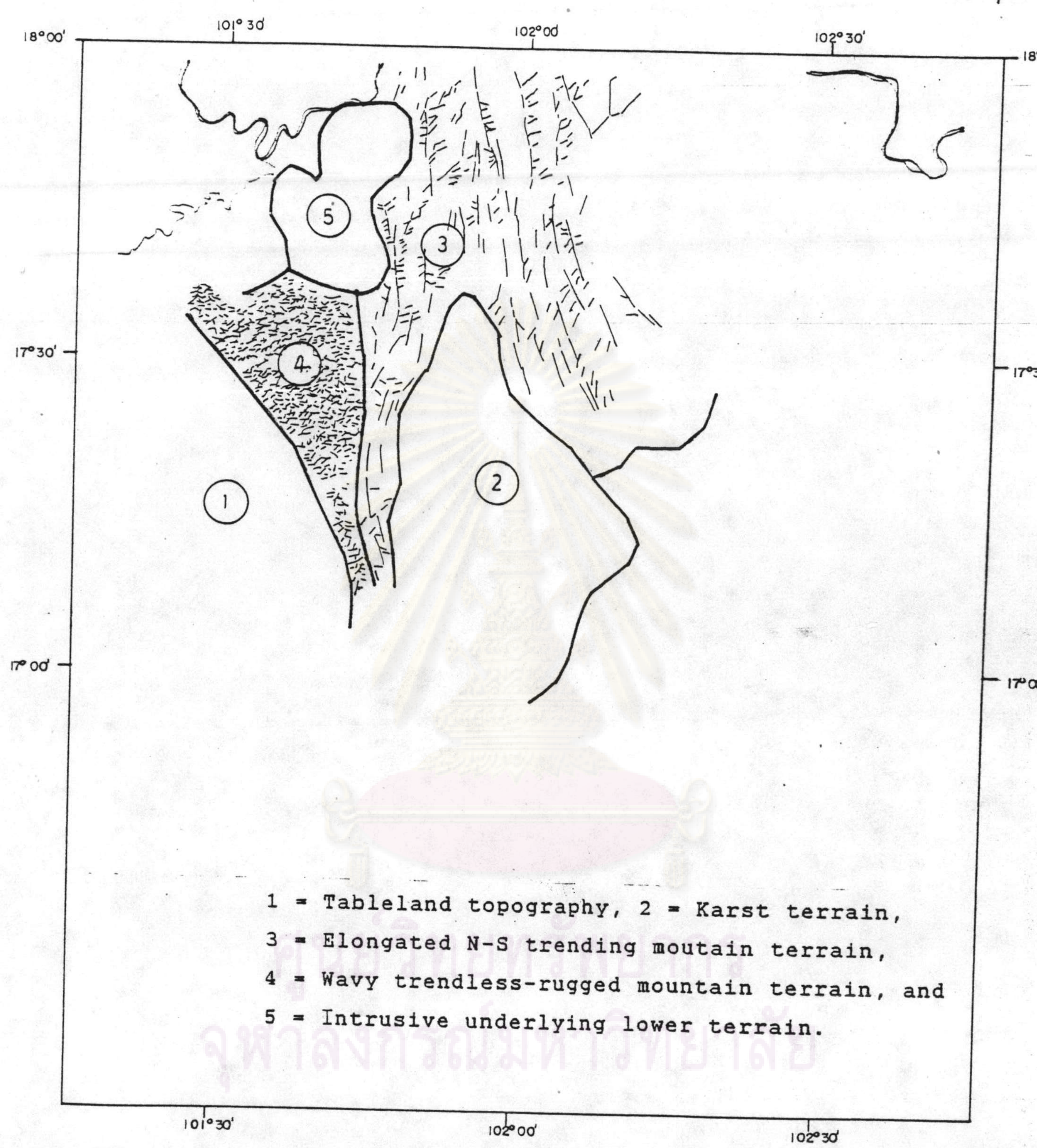
along the Loei-Chiang Khan highway. This is the shortest route which has a distance of 530 Kilometers from Bangkok. The study area may also be reached by longer distances route by starting from Bangkok to Khon Kaen then using the number 12 and 201 highways to Chang Wat Loei respectively.

Physiography.

The Loei area which situated on the northwestern fringe of the Khorat Plateau illustrates one of the important geologic and physiographic features of northeastern Thailand. The general morphology of the area can be simply classified into five topographic terrains, namely ; the tableland terrain; the karst terrain ; the narrow elongated north-south trending mountain terrain ; the wavy trendless-rugged mountain terrain and the intrusive-underlie lower terrain (Figures 1-3 to 1-5). The tableland terrains are situated on the south-western conner of the map and covering approximately a quater of the whole Loei area. They commonly form isolated mesa-butte mountains such as Phu Ho and Phu Kradung as well table-like mountain as Phu Luang which is the highest elevated mountain of the Loei area (1571 meters AMS pointed on its ridge). These mountains are generally high elevation, ranging from less than 300 meters to more than 1,500 meters.

The karst terrains are recognized by the jag-topped, rugged and steep escarpment mountains which covering about 20 percent around the central portion of the area. Other diagnostic features, such as sinkhole and depression topography, are also commonly found. These

Figure 1-3. Physiographic landsat imagery map of Changwat Loei, northeastern Thailand.



1 = Tableland topography, 2 = Karst terrain,
3 = Elongated N-S trending moutain terrain,
4 = Wavy trendless-rugged mountain terrain, and
5 = Intrusive underlying lower terrain.

Figure 1-4. Generalized physiographic map of the Loei area, delineated from Figure 1-3.

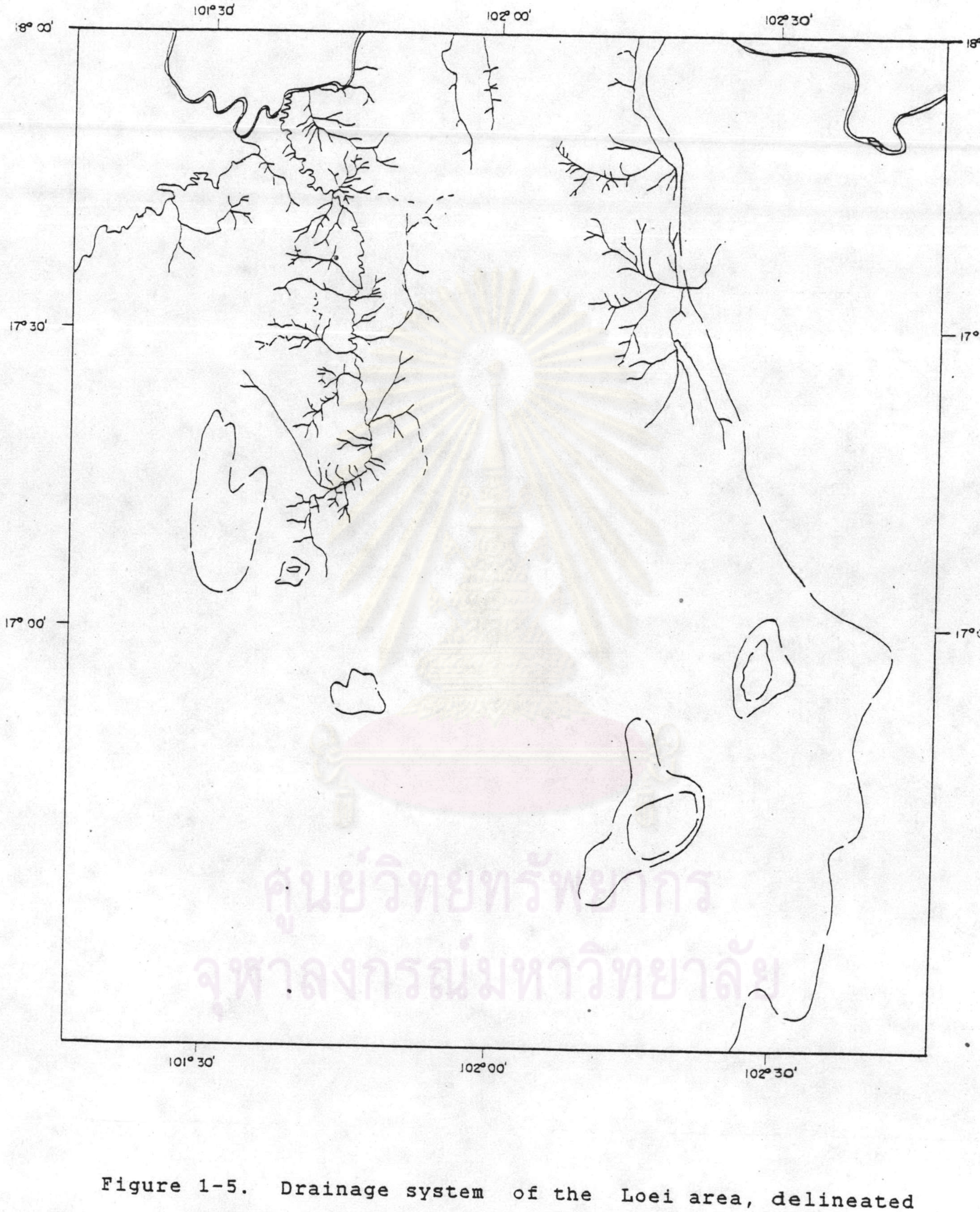


Figure 1-5. Drainage system of the Loei area, delineated from Figure 1-3.

terrains include the most famous geologic units i.e., the Phu Tham Nam Mahoran and Phu Pha Doen limestone, which their elevations are varying between 300 and 750 meters.

The narrow elongated north-south trending mountain terrains, which are the older folded rock belts in this area,cover approximately 40 percent of the total area and extend thoughout the central north and northeastern part of the area. They are dominated by several, north-south trending, narrow-elongated mountain ridges alternated/ separated by narrow elongated strips of undulated lower terrains. These undulated lower terrains stretch with elevations decrease gradually from the south, about 300 meters AMS at the central northern part of the area, northward to about 200 meters AMS at the Mekong valley near Amphoe Pak Chom and Amphoe Chiang Khan.

The wavy trendless rugged mountain terrains occupy an area of the western side of the map and cover about 10percent of the whole area. These terrains form a sharp northwest-southeast contact with the tableland terrain, Phu Luang. The highest elevation of these terrains is 859meters AMS at Phu An Ma, Ban Muang Khai whereas the average elevation is approximately 500 to 600 meters AMS.

The intrusive underlie lower terrains, which show circular features and undulated low land, are concentrically bounded by semi-circular bent mountains which posses steeper slope on inner concave sides. They cover approximately 5 percent of the total area and distribute on the northwestern part, consiting of the Phu Sanao-Phu Khwai Ngoen Batholiths (or Ban That pluton, Nakapadungrat and Putthapiban, 1992) and the Nam Khaem stock. These intrusive bodies appear at Ban Kok Du,Ban Na Khaem, Ban That,Ban Pha Baen, and Ban Nam Khaem respectively.The general elevation of the lower circular part of these terrains is about 260 meters AMS whereas the bounded mountains are 863 and 793 meters AMS at Phu Khwai Ngoen and Phu Sa Nao respectively.

The study area which here called "The Phu Sanao Batholith" is a part of the intrusive underlie lower terrain mentioned above.This area is rather undulated topography of low relief knobs ranging about 100 to 120 meters (Figures 1-6, 1-7). The elevation of the central low land within this terrain is varying between 240 to 340 meters AMS, whereas the eastern,southern and western mountain-bounded ridges have the average altitudes of approximately 400-600 meters AMS. Only the notheastern part of the study area which is opened up but enclosed by the Loei River, contributes long narrow flood plain deposits around Ban That District and being the lowest topographic elevated terrain of the area.

The Mekong River is the main drainage system of the Loei area. It marks the Thai/Loatian boundary and the northern delimitation of the Loei area. It runs from Amphoe Chiang Khan to Amphoe Pak Chom, then off the area northeastward to Changwat Nong Khai. Its important tributaries are Mae Nam Loei, Nam Khan, Huai Chom and Huai Sa Ngao, which all are discharged approxiately north-south trend into the Mekong, at Amphoe Chiang Khan, Amphoe Pak Chom and Amphoe Tha Li. Mea Nam Loei, the major and largest tributary of the area which created central north-

Figure 1-6. Topographic map of the study area.

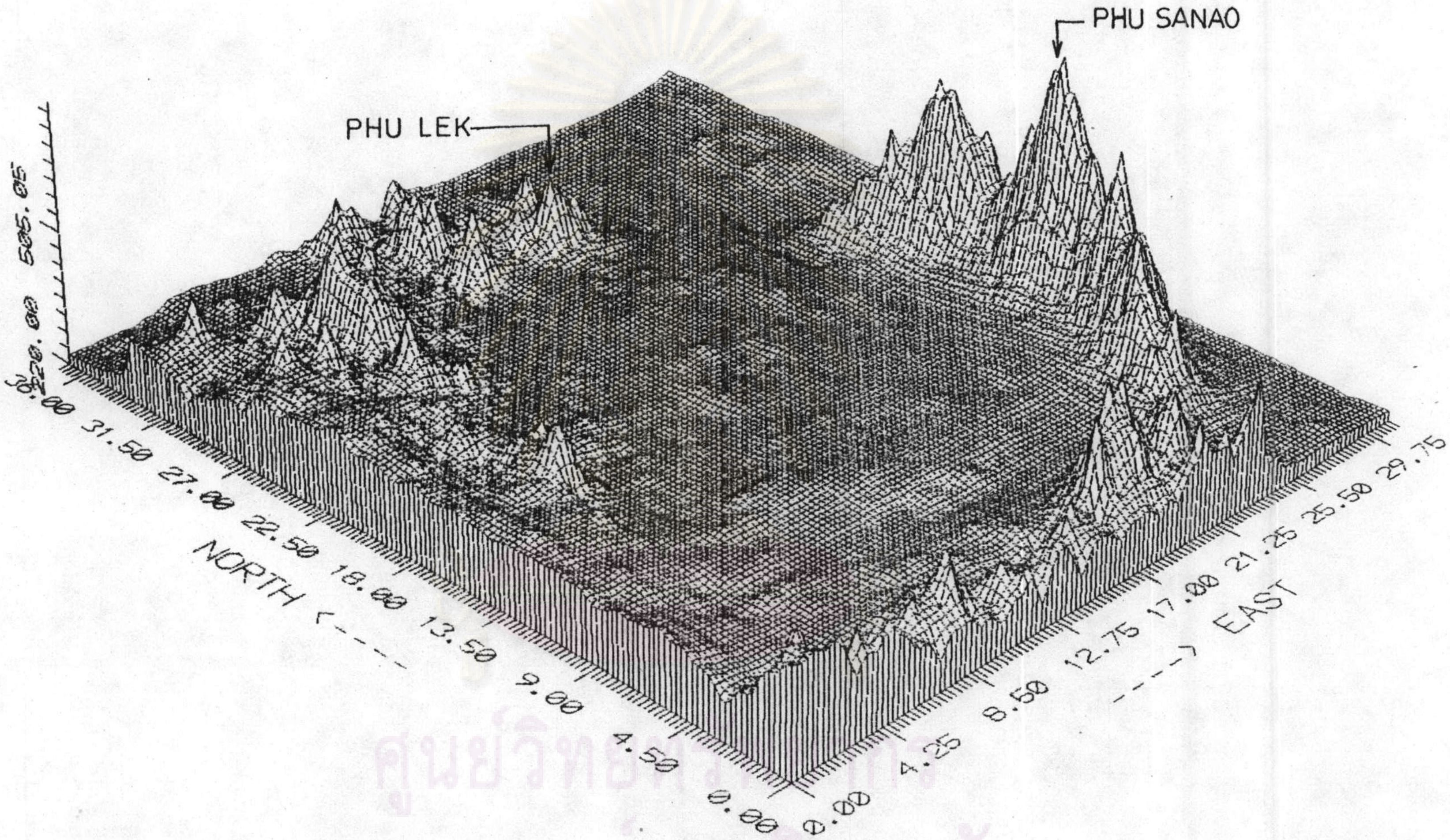


Figure 1-7. 3-dimensional surface of the study area.

trending valley and narrow flood plain, is flanked by mountain topography. Several minor streams such as Huai Nam Lai, Huai Nam Huai and Huai Nam Man are running to join this river at different places.

The Loei area has a tropical climate characterized by an alternating of a rainy season, from May to October, with a dry season, from November to April. The mean annual rainfall of the Khorat Plateau is shown in Figure 1-8. It can be divided into three zones, i) the zone of mean annual rainfall is 1400 mm or greater, ii) the 1200mm to 1400 mm zone and, iii) the zone of mean annual rainfall less than 1200 mm. The Loei area is within the zone of annual rainfall approximately 1200 mm to 1400 mm (total1238.1 mm/year ; Table 1-1). Almost all of the rainfall of the annual rainfall are pouring down exclusively during the rainy season while during the dry season the rainfall is restricted to only minor showers (Table 1-1, monthly mean rainfall).

During the winter months, the temperature is much lower at high altitude mountain at Loei area. At night, temperatures may occasionally drop to the freezing point, while during the day time, temperatures may rise even above 30°C in comparision with above 40°C in the summer days. The mean annual temperature in this area is set to be approximately 25.5°C (Table 1-1).

The climatological diagram for the period 1961-1990 provided from the Royal Thai Ministry of Communication, Meteorological Department at Loei province can be used to construct the diagram of average rainfall,

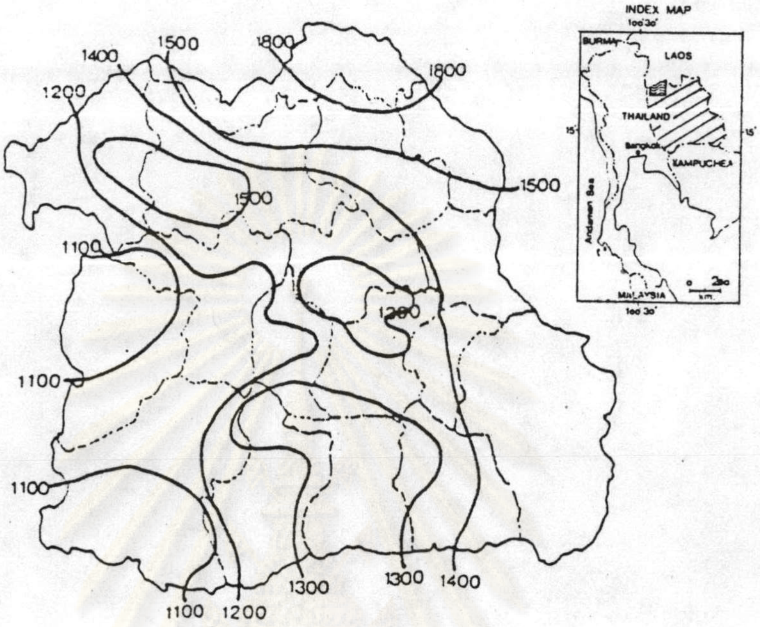


Figure 1-8. The isohytes for mean annual rainfall (mm.) of northeastern Thailand (After Vorasoot and others, 1985).

Table-1 Climatological data for the period 1961-1990 of Changwat Loei.

Station	LOEI	Elevation of station above MSL	253 Meters
Index station	48353	Height of barometer above MSL	254 Meters
Latitude	17 27 N	Height of thermometer above ground	1.25 Meters
Longitude	101 44 E	Height of wind van above ground	11.00 Meters
		Height of raingauge	1.00 Meters

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Pressure (Hectopascal)													
Mean	1014.54	1012.12	1009.90	1008.13	1006.60	1005.10	1005.01	1005.13	1007.63	1011.04	1013.91	1015.48	1009.55
Ext. max.	1028.68	1025.45	1027.05	1022.80	1015.58	1013.75	1013.06	1013.96	1015.94	1020.78	1025.07	1028.38	1028.68
Ext. min.	1002.15	1000.74	998.42	996.57	997.62	994.86	995.45	995.89	997.07	1001.75	1004.31	1003.16	994.86
Mean daily range	6.21	6.61	6.46	5.91	4.99	4.19	4.02	4.13	4.79	5.05	5.24	5.75	5.28
Temperature (Celsius)													
Mean	21.2	23.9	26.7	28.3	27.7	27.7	27.4	27.0	26.3	25.5	23.4	20.9	25.5
Mean max.	29.7	32.4	34.8	35.7	33.6	32.7	32.1	31.8	31.4	30.9	29.9	28.8	32.0
Mean min.	13.4	16.0	19.1	21.9	23.3	23.8	23.6	23.4	22.8	21.4	18.0	14.1	20.1
Ext. max.	36.1	38.9	41.0	42.6	41.1	38.7	37.0	36.2	36.2	35.3	34.8	34.9	42.6
Ext. min.	.1	6.2	7.7	14.4	18.7	19.7	20.5	20.6	16.9	12.8	5.7	2.2	0.1
Relative Humidity (%)													
Mean	67	63	60	66	76	78	78	80	83	80	76	71	73
Mean max.	91	89	86	88	92	92	92	93	95	95	94	93	92
Mean min.	40	36	35	41	56	60	60	63	65	61	52	44	51
Ext. min.	13	11	6	11	24	31	35	40	29	33	25	15	6
Dew Point (Celsius)													
Mean	14.0	15.2	17.0	20.2	22.7	23.1	22.8	22.9	22.9	21.6	18.3	14.7	19.6
Evaporation (MM.)													
Mean-pan	118.6	129.8	161.8	173.0	153.1	138.9	133.5	122.2	109.6	117.3	108.6	110.4	1576.8

Table 1-1. (Cont.)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Cloudiness (0-10)													
Mean	2.9	3.0	3.1	4.4	6.7	7.8	7.9	8.1	7.3	5.6	4.2	3.2	5.4
Sunshine Duration (hr.)													
Mean	256.8	240.3	233.4	236.5	209.4	166.6	159.0	144.7	157.2	202.7	2155.6	244.1	2466.3
Visibility (km.)													
0700 L.S.T.	2.4	2.0	1.7	3.6	6.3	3.0	8.0	7.5	4.8	3.4	2.8	2.4	4.4
Mean	6.7	4.9	3.6	6.1	9.5	10.5	10.6	10.3	9.2	8.7	8.3	7.5	8.0
Wind(Knots)													
Mean wind speed	2.0	2.4	2.6	2.7	2.4	2.4	2.6	2.4	2.0	1.8	1.7	1.8	-
Prevailing wind	E	E	E	E	N	W	W	N	N	N	E	N	-
Max. wind speed	30	40	50	47	43	40	30	34	35	33	21	27	-
Rainfall (mm.)													
Mean	6.4	17.6	37.6	95.9	213.1	164.8	159.5	177.5	226.8	117.4	17.6	3.9	1238.1
Mean fainy day	1.6	3.1	5.2	10.7	18.3	17.4	17.9	19.4	19.7	12.3	3.1	.9	129.6
Daily maximum	19.6	46.0	40.6	101.2	163.8	110.6	125.0	148.2	148.6	102.5	62.5	25.4	163.8
Number of days with													
Haze	23.5	26.1	28.6	22.3	3.5	.5	.2	.1	1.7	5.0	9.2	16.4	137.1
Fog	11.4	6.4	7.1	1.1	1.3	1.3	2.0	2.8	8.4	14.3	15.1	15.7	86.9
Hail	.0	.0	.0	.0	.1	.0	.0	.0	.0	.0	.0	.0	.1
Thunderstorm	.5	2.3	7.4	17.2	23.1	15.3	13.0	12.6	13.8	7.5	1.0	.2	113.7
Squall	.0	.1	.5	.7	1.2	.6	.3	.4	.3	.0	.0	.0	4.1

Data provided from ; Data processing sub-division, Climatology division, Meteorological department, 25-DEC-92 evaporation,temperature and ralative humidity of Changwat Loei as shown in Figure 1-9.

Scope and Approach.

Weathering process is one among many others that will affect the engineering properties of granitic rocks. Degree of rock weathering will undoubtedly determine capability of their usage in engineering works. Therefore, it is almost important to know the weathering process and especially the degree or level of weathering to the rocks.

In order to achieve these requirements, methods of description and classification of weathering of granitic rocks must be formulated initially. Petrographic examination will be conducted on every level of weathered granites. Engineering properties of each grade of these weathered rocks will be tested base in accordance with the British Standard (BS 812,1975) consisting of material properties such as strength,water absorption, porosity, bulk density (saturated) and aggregate abrasiveness. These properties are also used as the criterion of material quality in the study.

Methodology.

During the past few decades, there have been a considerable amount of literatures published on regarding to the characterization of weathered rocks and the engineering properties of weathered materials (Dearman and Irfan, 1978; Deere and Patton, 1971 ; Little, 1969 ; Lee

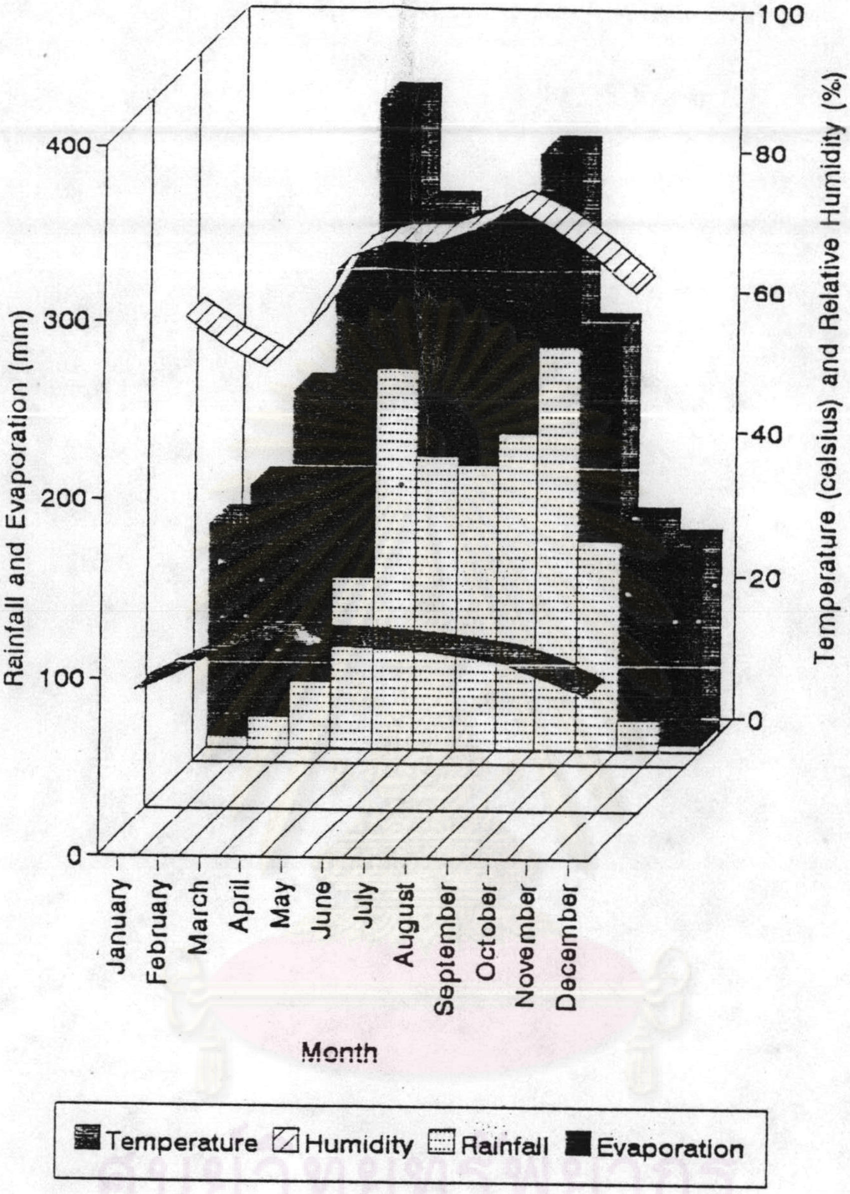


Figure 1-9. Integrated climatological diagram for the period 1961-1990 of Loei province, illustrates average monthly-rainfall, evaporation, and relative humidity (constructed from table 1-1).

and de Freitas, 1989 ; Lumb, 1962, 1965 ; Ruxton and Berry,1957 ;Sunders and Fookes, 1970). In this study, the characterization of weathered rocks has been mainly based on the revision of Lee and de Freitas (1989) that reviewed the commonly occurring difficulties associated with the description and classification of weathered granites. These methods, the diagnostic characters they employ, and the range of their application across the six grades of granite, from fresh (F) to residual soil (RS) have been illustrated in Table 1A-1 (see Appendix A).

Practically, classification for mass weathering grade which has been used here in the field mapping was simplified by Baynes,Dearman and Irfan (1978) (Figure 1A-1,Appendix A). Furthermore details of description and classification for granitic masses have additionally employed method of Lee and de Freitas (1989) (Table 1A-2, Appendix A).

For rock material characterization, simple classifications of weathering state and decomposition grade equivalent have been based on procedure described in BS 5930(BSI, 1981) and GCO manual (1984) (Table 1A-3, Appendix A).Finally, a summarization of description and classification for weathered granitic materials have been based on those proposed by Lee and de Freitas (1989) (Table 1A-4, Appendix A).

For engineering properties of a weathered granite, the BS standard testing schemes in application to roadstone and concrete aggregates are used. The acceptance values for test result are shown in Table 1A-5 (See Appendix A).

The preliminary geological field mapping has been carried out in order to observe general geology and distribution especially of the granitic rocks.Detailed geological mapping and sampling of the fresh and the varieties of weathered granitic rocks in the study area have been undertaken rather scrupulously. Numereous granitic rock samples, ranging from fresh to considerably weathered,are collected in order to be certain that every continuing advance of degree of weathering is not missing for further investigation.

Almost all of the rock samples obtained from the field are prepared for petrographic detemination and for engineering properties testing. The petrographic examination includes macro-analysis and micro-analysis. The macro analysis is a visual examination of rocks ranging from hand specimen to an outcrop scales, including degree of discolouration of rock material, degree of chemical decomposition of biotite and feldspar, degree of physical disintegration, presence of original texture. For rock mass of outcrop scale, weathering profile, degree of discolouration along joint planes, the presence of original structure, rock to soil ratio, degree of weathering along joint planes and angularity of corestone should be noted.For more detailed discussion of these existing description factors of rock material and rock mass see Lee and de Freitas (1989) , Gamon, Fox and Partners (1983) , Irfan and Powell (1985 , Lee and de Freitas (1989).

The micro-petrographic description has followed methods suggested by the ISRM (international Society for

Rock Mechanics) that including the determination of all parameters cannot obtain from a macroscopic examination of rock sample. These parameters such as,mineral content, grain size, and texture, all have influence on the mechanical behavior of the rock or rock mass (ISRM,1977a). To ensure correct petrographic classification the mineral composition and texture of the rock must be ascertained in a very first step.

For engineering properties testing, the rock samples are prepared to be test for those properties that applicable for roadstone and concrete aggregates. All of the standard tests including uniaxial compressive strength test, point load strength index test, Los Angeles abrasion test, Slak-Durability index test, and in conjunction with physical index properties determination, i.e., water content, porosity, void ratio, bulk density, saturated bulk density, absorption and degree of saturation examination, have been carried out.

The general studying program has been shown in Figure 1-10. Detail of specific procedures will be described as the followings.

A. Sample Preparation Methods.

Forty eight large-size granitic samples (~8x10x12 inches) selectively collected from four specific lithologic subunits , are cored by coring machine to the size of NX in laboratory. These samples include the rock weathering grade I, II and III. There are at least 2 to 3 samples representing one different weathering grades in

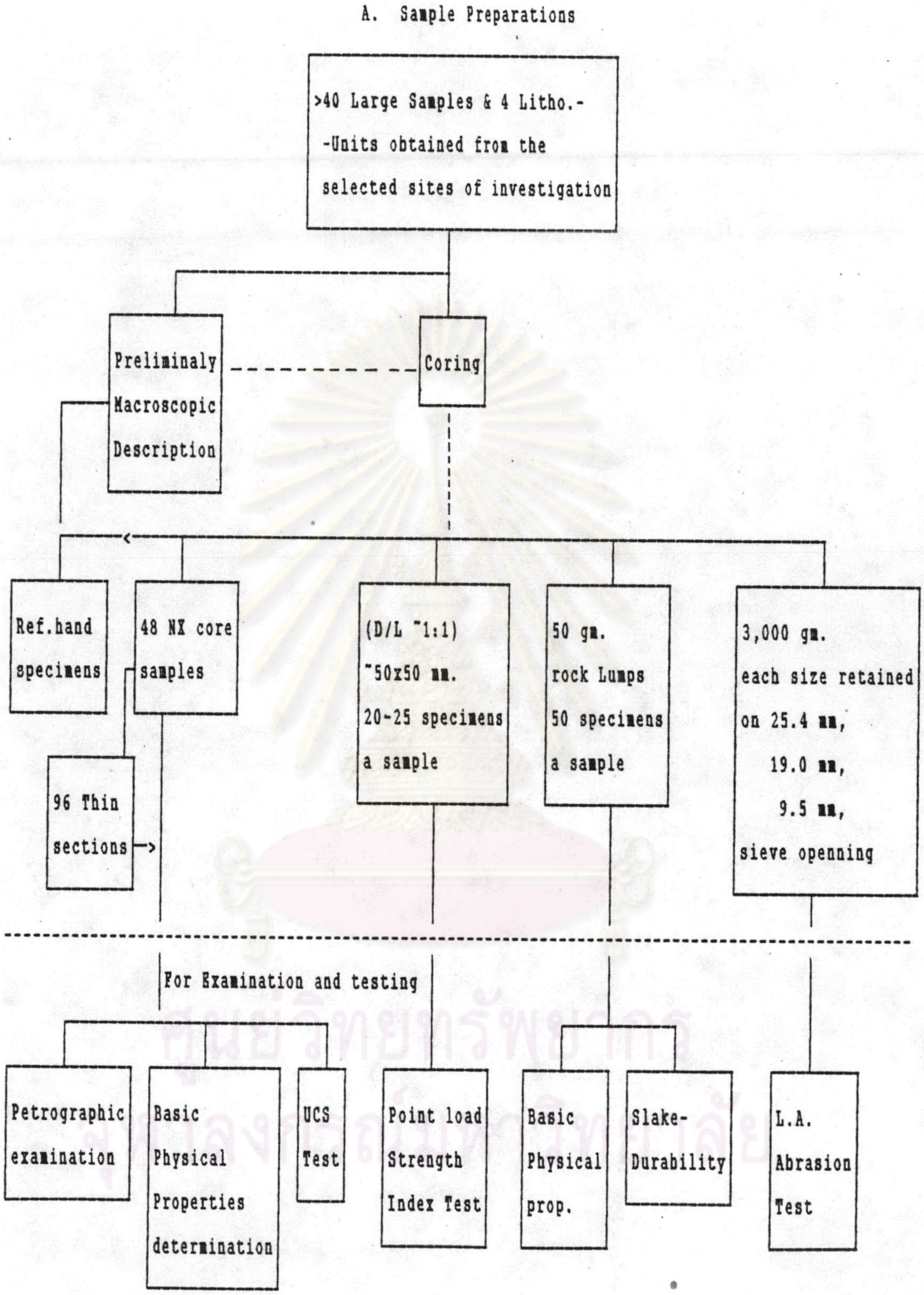


Figure 1-10 Flow-charts illustrating the study methodology and steps of work for the study program.

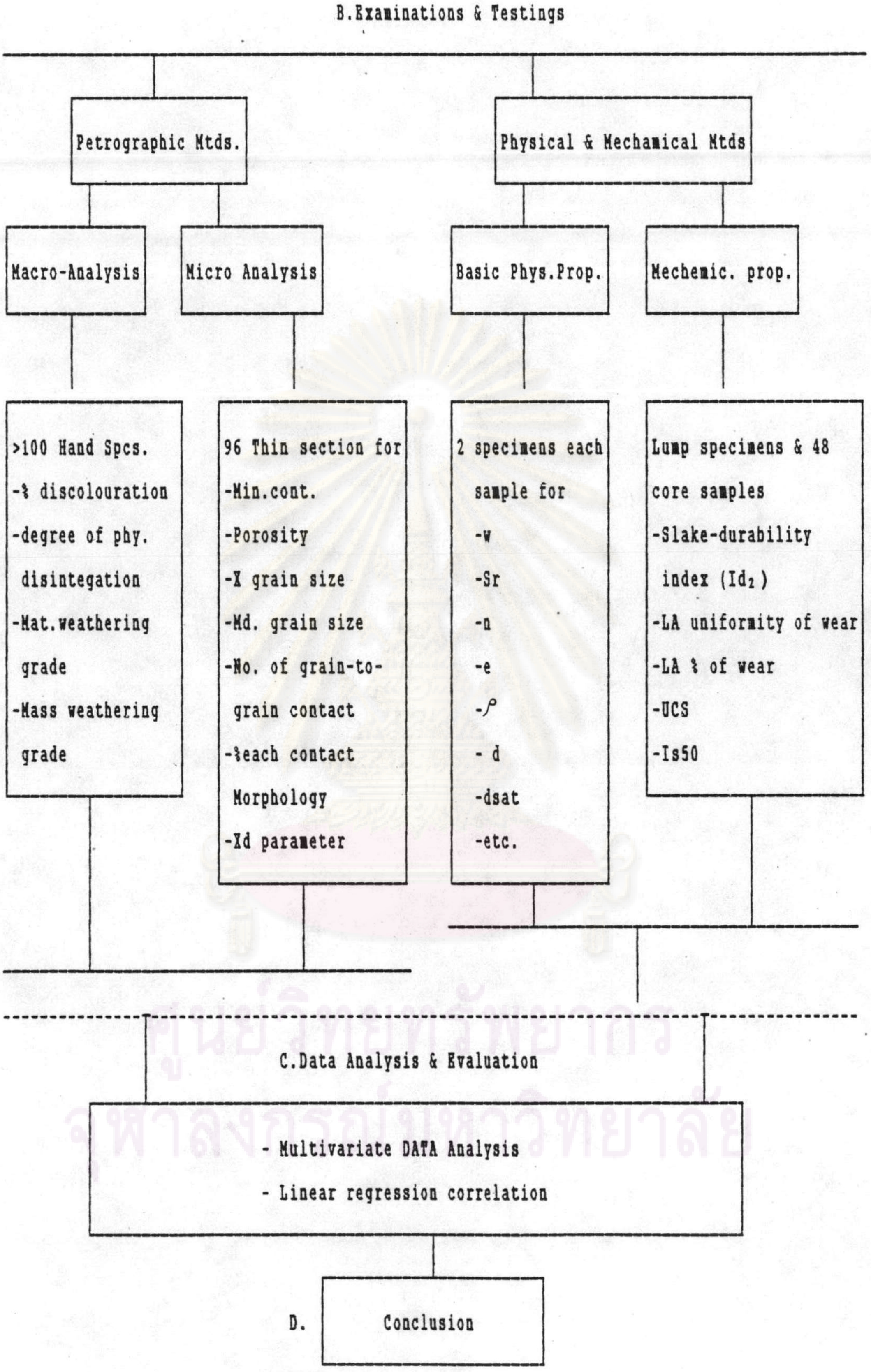


Figure 1-10 (Cont.)

each specific lithologic subunit. In addition to NX-core sample preparation, two standard thin sections have been prepared from each core sample.These thin sections are oriented parallel and perpendicularly to the longitudinal axis of the core.

Samples remained after coring are then broken down to various smaller size by hammer and jaw crusher. 20-25specimens are prepared from the sample with size between30-60 mm(D~50, D/L~1:1)for point load strength index test. 50 lump samples with approximately of 50 gm a lump, are made for basic physical properties and slake-durability test. The grading-size samples of 38.0-25.4 mm, 25.4-19.0 mm, 19.00-13.2 mm and 13.2-9.5 mm, graded by sieve series are prepared approximately 3000 gm of each grading size for Los Angeles abrasion test.

B. Examination and Testing Methods.

1. Petrographic Methods.

The microscopic examination of selected standard thin sections are carried on for many petrographic properties. The methods employed are modified from the method applied to determine the strength estimation of sandstone by using petrographic data (Fahy and Guccione, 1979). 100 randomly selected points are used for counting mineral contents. The maximum diameters of 50 randomly sampled mineral grains are measured in each thin section to determine mean and median grain sizes. The number of grain-to-grain contacts is counted for a total of 30 grains, and the morphology of their mutual contacts is described accordingly to as tangent, straight, concave-convex, or intergrown.

Degree of decomposition, one of the most important petrographic variables of weathered granites, is quantitatively measured by mothods modified from Lumb (1962)and the simplified visual impression statistical model of Baynes and Dearman (1978), as Xd parameter which estimates range from 0.1 to 1.0.

Those of all petrographic methods are assigned to obtain a number petrographic variables, consisting of mean and medial grain size, percent constituent of quartz, mica,feldspars, hornblende, opaque and other accessory minerals,percent tangent, straight, concave-convex and intergrown contacts, and number of contact per grain and Xd parameter, respectively.

2. Physical and Mechanical Methods.

2.1 Basic Physical Properties Determination. The prepared samples from the previously decribed in section-A, are subsequently be tested for basic physical properties.

The grain mass (Ms) is determined by the mass of sample after being dried in oven at temperature 105°C for a period of 24 hours. Both core and rock lump samples are suitable for this test. The bulk volume (V) is obtained by using caliper and buoyancy method for core and irregular lump samples respectively. The sample is saturated by means of vacuum saturation method i.e., immersing sample in water under a vacuum of less than 800 Pa (6 torr) for a period of at least one hour. Thus, volume of voids (Vv ; pore volume) is able to determine from the difference between saturated-surface-dry and oven-dry masses per water density, and also can be obtained grain volume (Vs), porosity (n), water content (w), density (ρ), void ratio (e), saturation and other related properties by using the relationship as the following ;

Water content (w) = $\frac{Mw}{Ms} \times 100$ (%)

Degree of saturation (Sr) = $\frac{Vw}{Vv} \times 100$ (%)

Porosity (n) = $\frac{Vv}{V} \times 100$ (%)

Void ratio (e) = $\frac{Vv}{Vs}$ (-)

Bulk density (ρ) = $\frac{M}{v} = \frac{Ms+Mv}{v}$ (kg/m³)

Relative density (d) = $\frac{\rho}{\rho_w}$ (-)
(specific gravity)

Dry density (ρd) = $\frac{Ms}{V}$ (Kg/m³)

Dry relative density (dd) = $\frac{\rho d}{\rho w}$ (-)
(dry specific gravity)

Saturated density (ρsat) = $\frac{Ms+Vv\rho w}{V}$ (kg/m³)

Satured relative density (dsat) = $\frac{\rho sat}{\rho w}$ (-)
(Saturated specific gravity)

Grain density (ρs) = $\frac{Ms}{Vs}$ (kg/m³)

Grain relative density (ds) = $\frac{\rho s}{\rho w}$ (-)
(grain specific gravity)

Unit weight (γ) = ρg (N/m³)

Where Ms is grain mass, Vs is grain volume, Mw is pore water mass, Vw is pore water volume, Ma is pore air mass ; equal zero, Va is pore air volume, Vv is pore (voids) volume, M is mass bulk sample ; equal Ms+Mw, V is volume bulk sample ; equal Vs+Vv, and ρw is density of water ; equalmass of water per unit volume.

At least two specimens per sample are prepared for each test for these basic properties determination which follow the procedures suggested by ISRM (1977 b).

2.2 Mechanical Properties Testings. The resistance of rock is possible to be determined in two ways, one is the resistance due to wetting and drying effects, and the other resistance due to abrasion of the rock.

The slake-durability index test has been chosen for determination of rock resistance affected from wetting and drying condition. Prepared rock lump specimens, approximately 500 gm in total weight are subjected to two standard cycles of drying and wetting in standard test equipment to obtain slake-durability index (Id2) of the rock. At least 2 specimens per sample are used for each test. The detailed procedure and the standard apparatus used in this method are after Alpan (1957), ASTM (1964) and ISRM (1977 b).

For the determination of resistance of rocks to the abrasion test, a prepared graded sample which is subjected to attrition rock pieces and also to impact forces produced by an abrasive charge of steel sphere. The

Los Angeles abrasion testing machine is used to obtain the L.A. uniformity of wear and L.A. percent of wear respectively.Again the testing apparatus and the detailed procedure are based on the ASTM standare C131-69, C535-69, and C418-68.

Finally, for rock strength testings, the indirect test point load strength index and direct test uniaxial compressive strength are employed. More than 600 irregular specimens from all samples are subjected to point load strength testing while only 48 core samples are selected for the UCS testing in this study. All testing method including apparatus and detailed procedures, follow the national requirements as prescribed in either ASTM Methods E4 : Verification of Testing Machines or British Standard1610, Grade A or Deutsche Normen DIN 51 220, DIN 51 223,Klasse 1 and DIN 51 300, and ISRM Suggested Methods for Determing the Uniaxial Compressive Strength, 1978 b.

Previous Geological Knowledge of Loei Area.

Geological investigations in Loei area began with preliminary investigation by the team led by Bourret Rene'who investigated the Pak Lay area of Loas and parts of the Loei area in Thailand (Bourret, 1925). More than two decades later (during 1951-1965) mineral prospecting in the Loei-Chiang khan area was conducted by Vija Sethaput, Saman Buravas, Amorn Methikul, and several others of the Royal Thai Department of Mineral Resource, and by Louis Gardner and Roscoe Smith of the USGS, under the auspices of the U.S. Agency for International Development and the Government of Thailand. To support these investigations, an aeromagnetic survey was traversed by the Aero Service corporations. A team from the German Krupp Rohstoffe Company examined several iron prospects (Agoes and Curtis, 1959 ; Brown and other, 1951 ; Jacobson et al., 1969 ;Methikul, 1955).

In 1965, Bleackley et al. reported the photogeological interpretation and Stephens compiled map scale 1:125000 covering the area of Loei-Chiang Khan. The Geological Map of Loei-Chiang Khan scale 1:125000 was also compiled by Jacobson in 1965-1966 and published in 1969 as PLATE 1 of the Profressional Paper 618 (Jacobson et al., 1969). Jacobson et al. (1969) also reported the result of geochemistry and geophysical prospecting and drillings for some ore mineral deposits in this area. In addition they gave a potassium-argon age determination of granitoid sample from Phu Kwai Ngoen as 230 Ma which correspond to the Triassic periods.

Adul Charoenpravat et al. (1976) compiled a geological map of the Loei area that was published by the Department of Mineral Resources in 1984 as a part of Geological Map of Thailand scale 1:250000, sheet Changwat Loei NE 47-12. In addition, a Geological Map of Thailand scale 1:500000 of Northeastern sheet had been finished earlier in 1983. The geology shown on both maps is considerably the same. Distribution of rocks in this region as mentioned by Chairangsee, Hinze, Macharoensap, Nakornsri and Silpalit (1988) that a north-south trending strip of lower paleozoic metamorphic rocks runs through the central part of the area. Conglomerate, chert and Limestone occur along the west. Permo-Triassic granodiorite, diorite, and granite are marked in the west and the east of the area.Large occurrences of Permo-Triassic tuff, rhyolite, andesite and conglomerate are in the eastern part of the area.

In 1987, Prinya Putthapiban reported the mineralization potential in this area. Kumarachan (1987) also reported his main investigation in gold deposit in Loei-Nong Khai area.

Surapol Thanaomsap (1987) studied the wrench tectonic in Loei area. He concluded that mineralization within the area has close relationship with the tectonic evolution.

In 1991, Punya Charusiri, Wasant Pongsapich, Wirot Doarerk and Chaiyut Khantaprab reported the data on age determination of granitoid rocks in Thailand(Figure 1-11). They found and showed that the granitoid belt, which the Loei granites are a part of it, has age of about 227-235 and243 Ma by new evidences from $^{40}Ar/^{39}Ar$ geochronological and isotopic investigation. The Loei granite is considered to be I-type granite based on the classification of Chappel and White (1974). Somchai Nakapadungrat and Prinya Putthapiban (1992) reported the granitic rocks and associated mineralization in Thailand. This study includes generalized petrographic characters and geochemistry analysis of Loei granites (Table 1-2, Figure 1-12). They also introduced the name"Ban That Pluton" for the largest intrusive body in the Loei province.

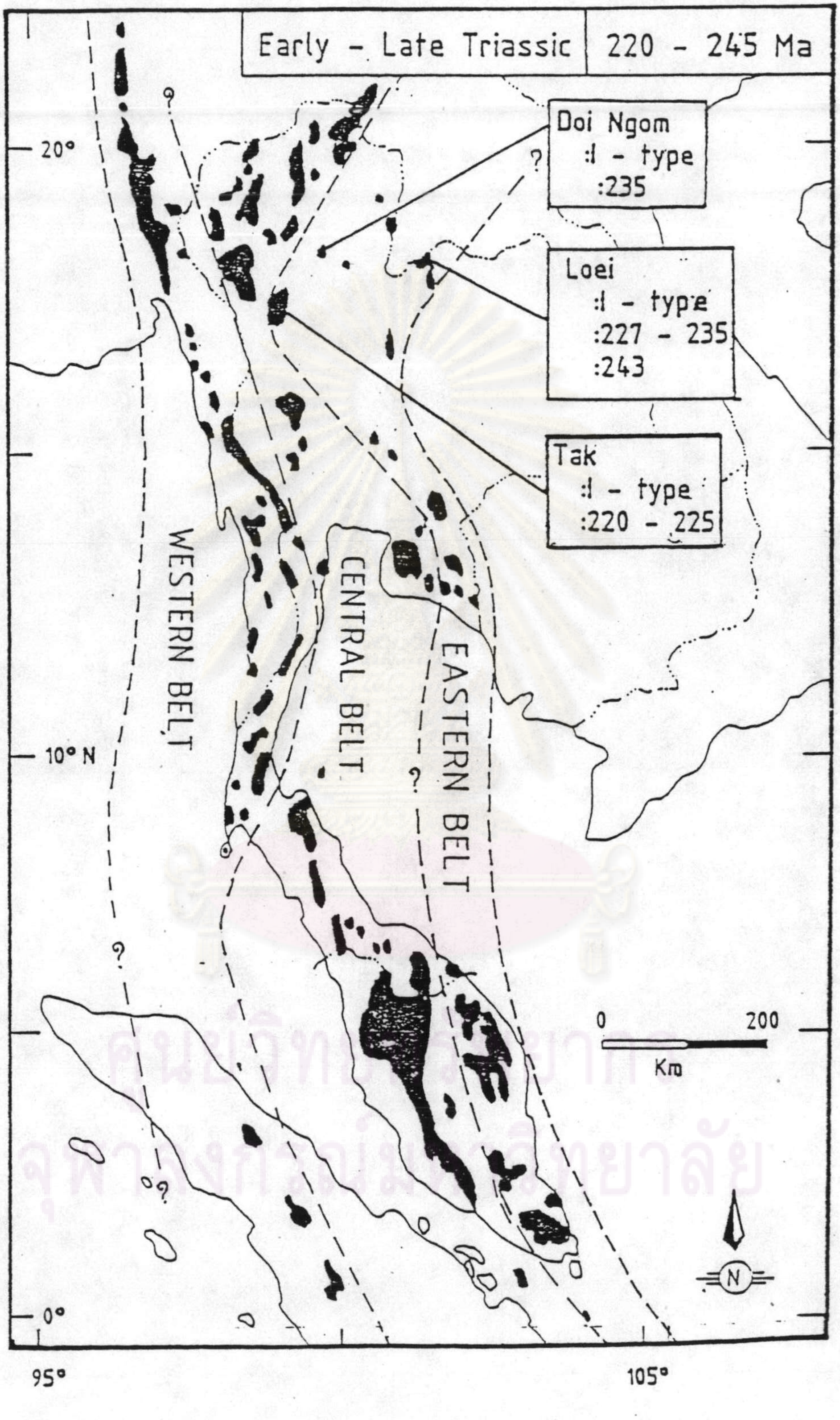


Figure 1-11. Map showing distribution of granitic rocks in Thailand (black patches) and the granitic belt with radiometric age about 220-245 Ma. (from Charusiri et al., 1991).

Table 1-2. Chemical analysis of the Loei Granites (after Putthapiban, 1987 ; unpublished report).

Sample	Si02	Al203	Ti02	Fe203	FeO	MgO	CaO	Na20	K20	MnO	P205	LOI	Total	AI (Ca/2+Na+K)
Triassic														
L-1	65.09	15.85	0.58	1.41	3.61	1.93	4.56	3.06	2.72	0.08	0.20	0.62	99.71	1.83
L-2	66.33	14.81	0.56	1.32	3.22	1.72	3.99	3.30	3.14	0.08	0.17	0.37	99.01	1.54
L-3	66.64	15.11	0.55	1.45	3.29	1.80	4.03	3.02	2.94	0.08	0.18	0.63	99.72	1.69
L-4	67.48	15.09	0.49	1.39	2.74	1.42	3.64	3.30	3.36	0.07	0.16	0.37	99.51	1.52
L-5	69.59	15.03	0.39	1.07	2.50	1.02	2.78	3.85	2.38	0.10	0.14	0.64	99.49	1.64
L-6	73.27	14.06	0.16	0.76	1.20	0.36	1.43	3.65	4.31	0.06	0.06	0.27	99.59	1.18
L-7	74.04	13.69	0.15	0.57	1.43	0.25	1.33	3.40	4.23	0.06	0.07	0.31	99.53	1.20
L-8	75.74	13.05	0.12	0.50	1.30	0.31	1.10	3.40	3.89	0.05	0.04	0.16	99.66	1.20
L-9	76.85	12.16	0.16	0.38	1.15	0.05	0.95	2.98	4.79	0.02	0.01	0.10	99.60	1.00
L-0	77.29	12.11	0.10	0.51	0.96	0.05	0.71	2.94	4.75	0.01	0.01	0.14	99.58	1.04

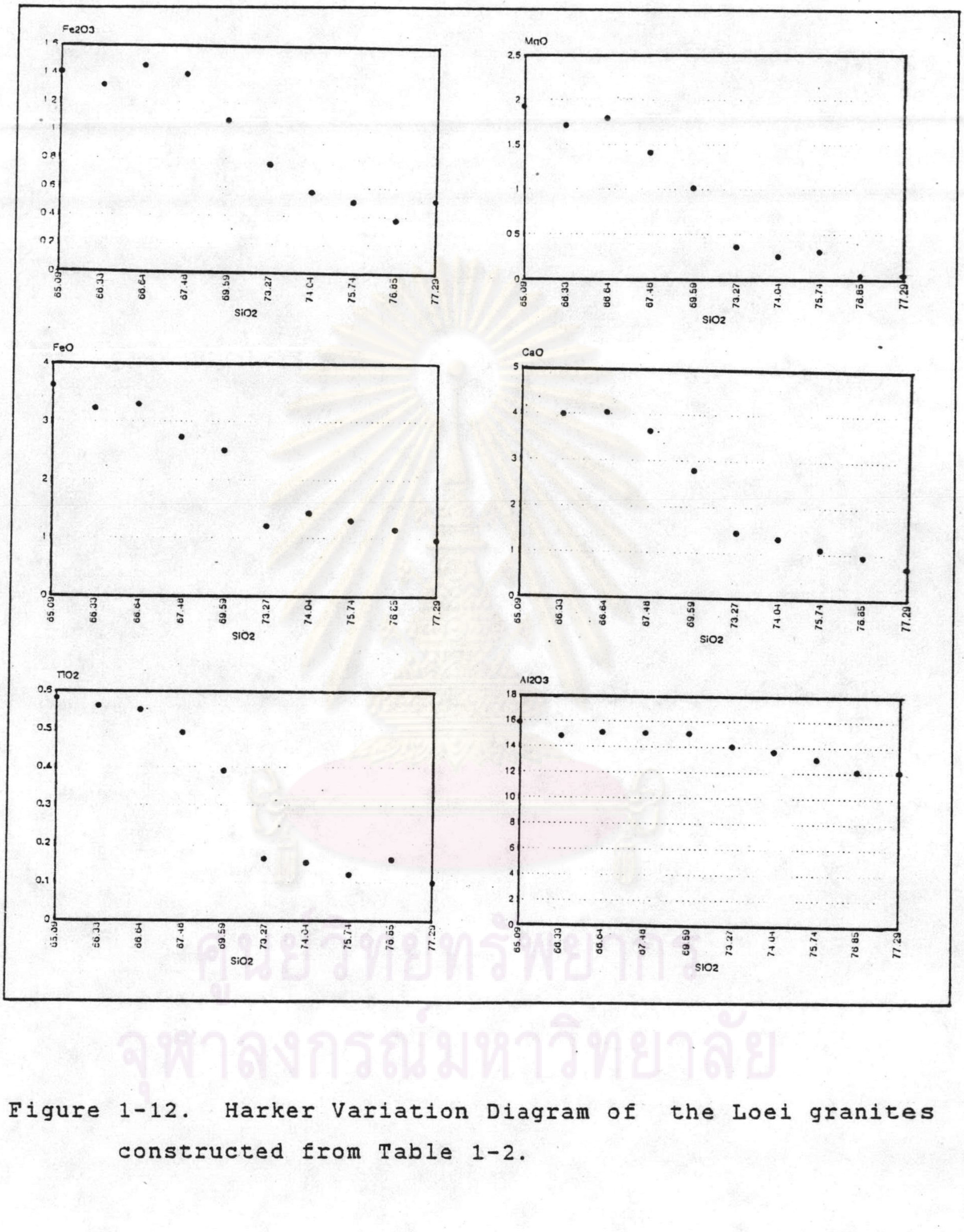


Figure 1-12. Harker Variation Diagram of the Loei granites constructed from Table 1-2.