CHAPTER II

GEOLOGY AND DISCONTINUITY FEATURES OF CHIEW LARN DAM SITE

The geologic condition in the project area is a prime suggestion of the feasibility of the entire project. The geologic investigation must be done in both preliminary and feasibility levels to emphasize the condition of the rock-foundation and over-burden mass at the damsite and other appurtenent construction sites, and of the river channels. The study reveals the answer to the problems of water leakage or foundation stability, hence suggest a suitable treatment. The availability of the construction materials is also known.

2.1 Geologic Setting

2.1.1 Rock Units and Stratigraphic Sequences

Mantajit (1981) reported 3 rock units in the region namely, the Phuket Group, Ratburi Limestone, and Quaternary deposits. Mitchell et al. (1970) had proposed the rock succession of the Phuket Group, the oldest of all 3 units in the vicinity of the Chiew Larn dam project area and the only rock group exposed widely in the study area (Figure 2.1). According to their study, the Carboniferous-to-Lower Permain clastic unit is composed mainly of the laminated mud-stone, turbidites, pebbly mudstones, and quartzitic sandstone. A detailed description of the clastic rocks as studied by the present writer is to be followed.

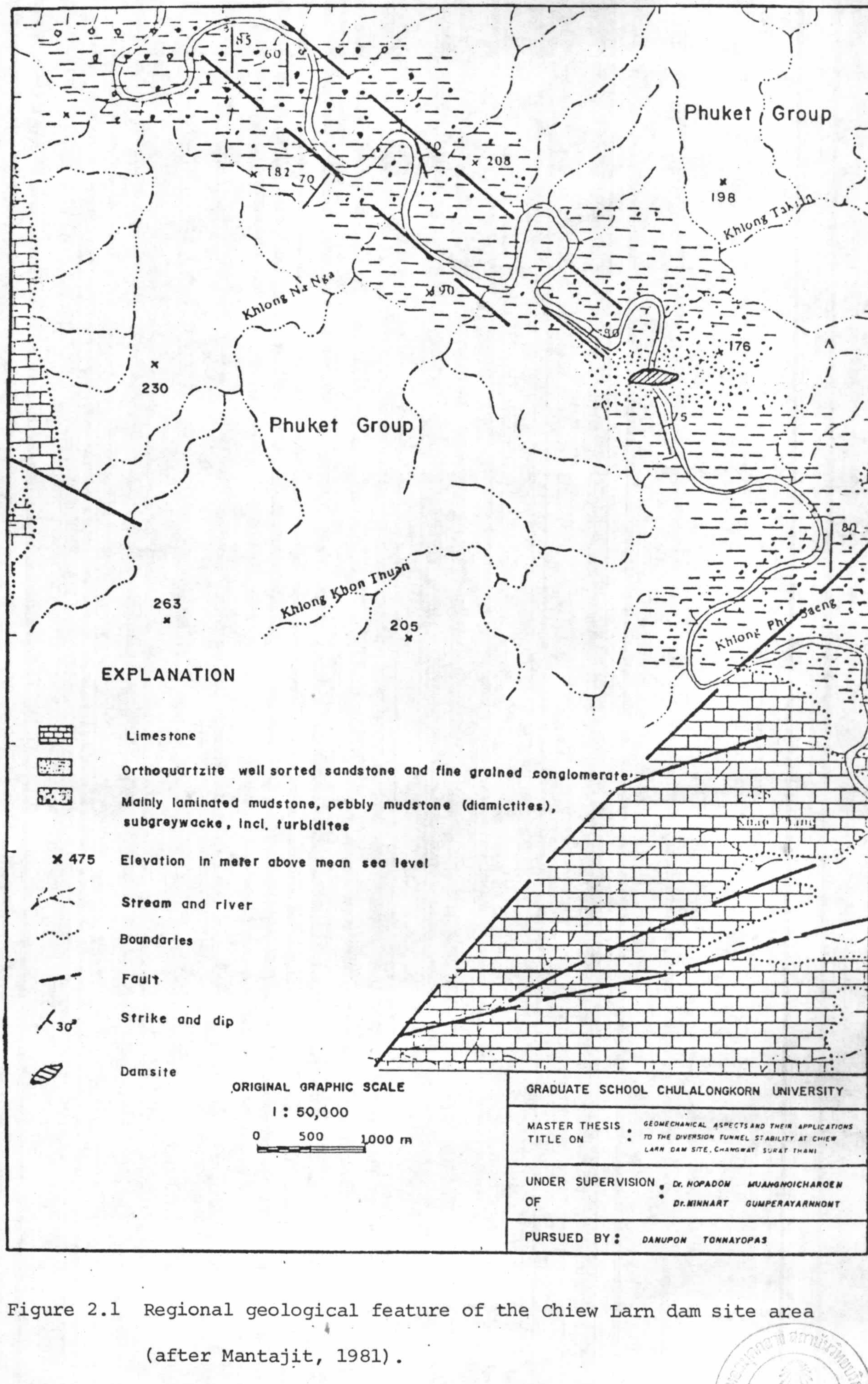


Figure 2.1 Regional geological feature of the Chiew Larn dam site area (after Mantajit, 1981).

Above the Phuket Group conformably lies the Ratburi Limestone of the Permain age (Mantajit, 1981). The latter rock unit consists primarily of cherty clastic, bedded to massive limestones. The exposures are the limestone cliffs found generally around the rim of the proposed reservoir and further south of the damsite (Figure 2.1). The thickness of the entire limestone formation is approximately 800 m.

According to Mantajit (1981), both Phuket Group and Ratburi Limestone had been intruded by the granite of post-Triassic to Early Tertiary age. There are 2 major trends of the granitic batholiths in the region. The first and economically important trend lies from Ranong down south to Takua Pa and Phuket. The other trend occasionally exposes from Chumphon to Surat Thani, passing near the Chiew Larn Dam project area in Amphoe Phanom, and further southward to Krabi. The igneous rock receive no further attention since they do not expose in the project area.

The uppermost sequence comprises of the unconsolidated to semiconsolidated residual soils and the alluvial and colluvial deposits. Their occurrence is fairly widespread, though not of a significant amount.

2.1.2. Structural Framework and Tectonic Movement

The folding has never been clearly understood in the region. However, since the geologic structures that effect the geotechnological project the most are the discontinuities, especially faults and joints, only the discontinuities were further investigated.

In the southern peninsula of Thailand, there are 3 distinctive structural trends (Figure 2.2) which are mostly interpreted as the transcurrent faults.

Most of the structureal trends are in the northeast-southwest direction. They are interpreted as the huge anticlockwise rotational faults. These are Khlong Marui, Ranong, and Bang Khram faults. Judging from the drainage pattern, the smaller-scale structures is Khlong Phra Saeng Fault.

These mentioned structural trends cut across the Permain Ratburi Limestone, thus, giving a lower limit of age of tectonism to be post-Permain. The upper limit has never been noticed, unfortunately. The only information available is that, no recent tectoniam has never been recorded in this region of southern Thailand.

2.2 Local Distribution of Rock Units

In the damsite area and its vicinity, the only rock unit exposed is the Phuket Group. Thus, only the Phuket rocks were studied further to some degree. In general, the group is composed of mostly subgraywacke with subordinate pebbly graywackes, subarkosic to arkosic sandstones and laminated mudstones (Figure 2.3). The following description is done on the rock sequences, from the lowest sub-unit up.

2.2.1 Pebbly Graywackes to Pebbly Mudstones

From the field study these rock types expose in the diversion tunnel (Figure 2.4) and are rather widespread throughout the Chiew Larn project area. In general, the pebbly graywackes to

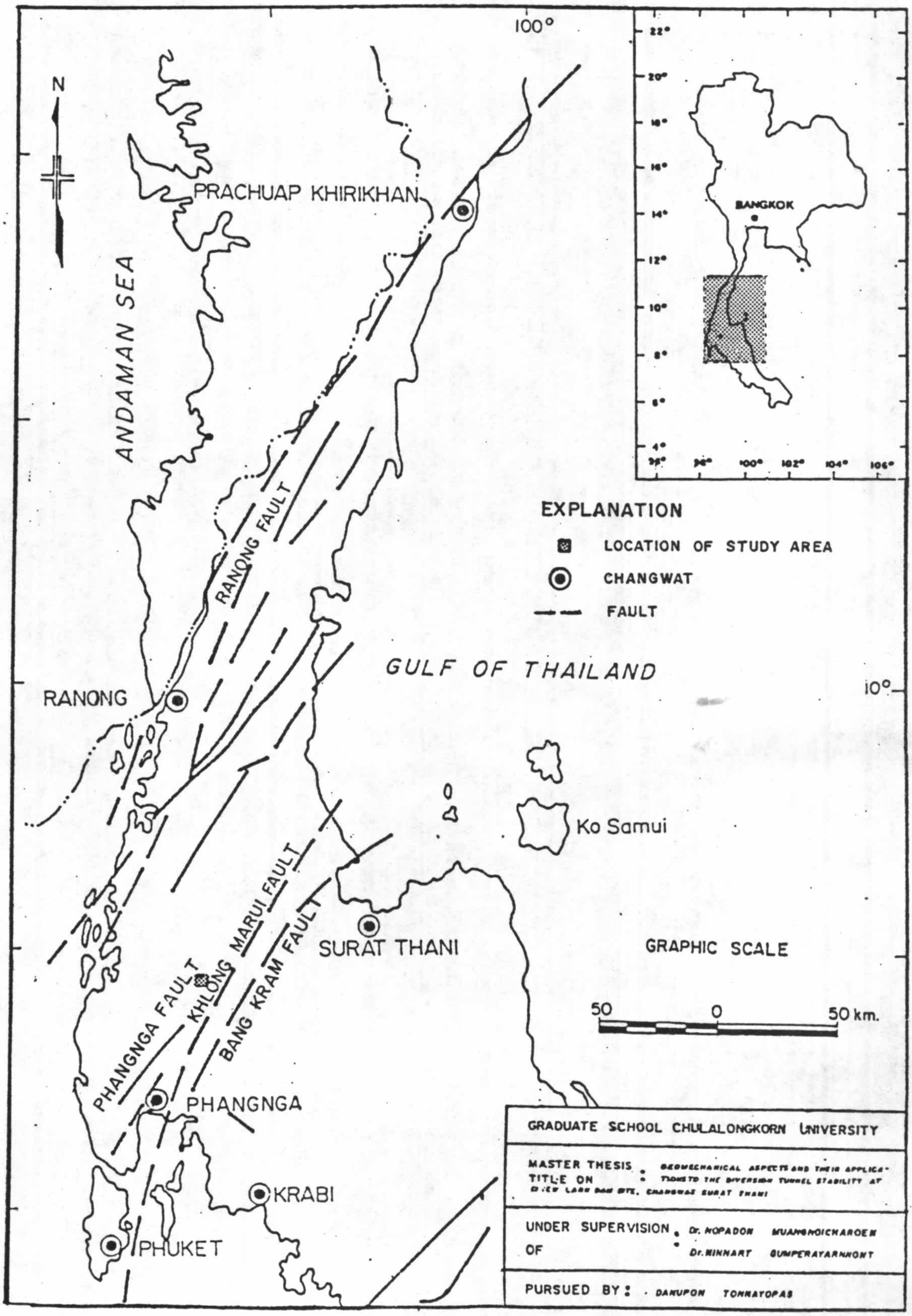


Figure 2.2 Regional geological structural trend in southehrn Thailand (after Mitchell and Carson, 1975).

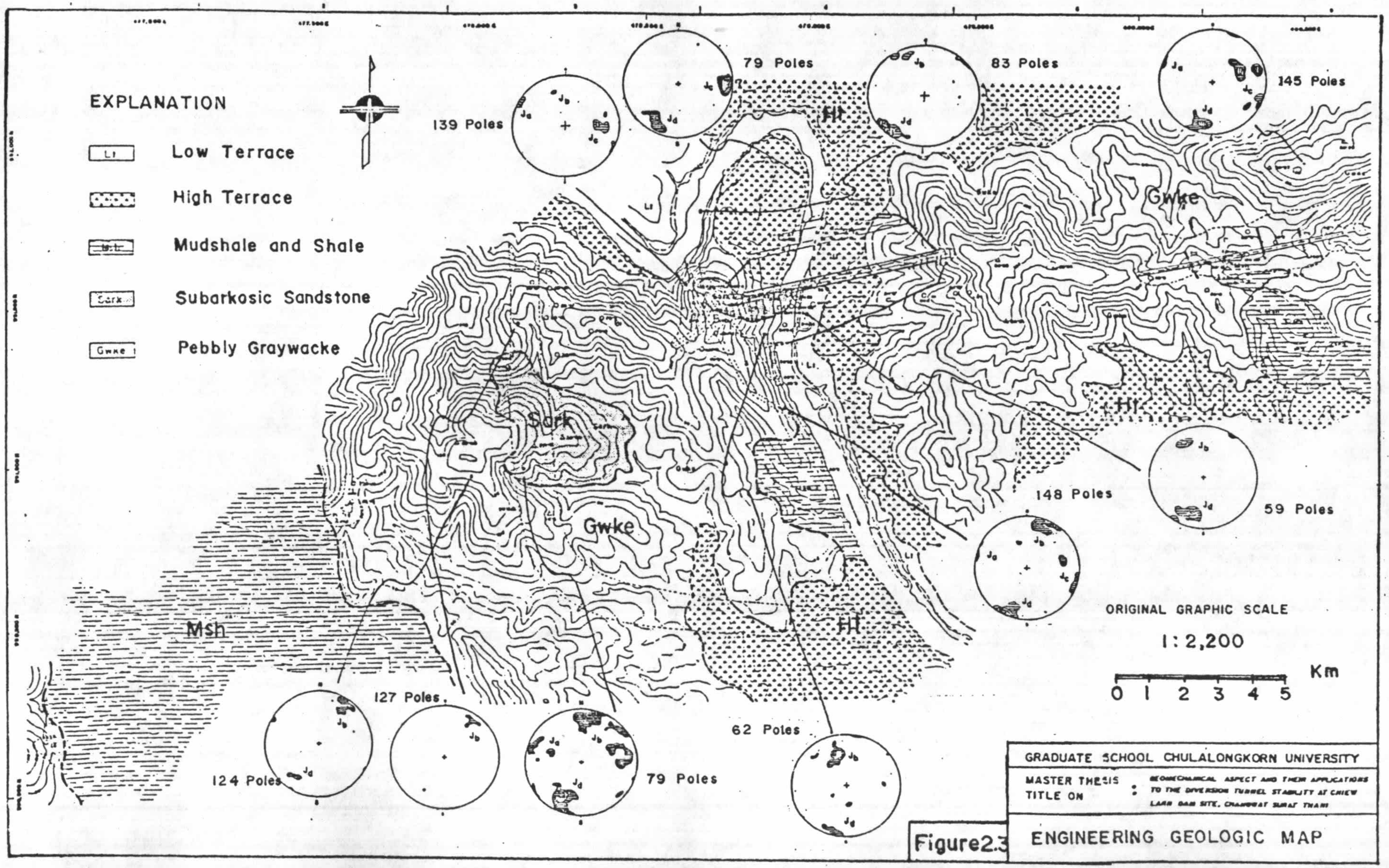


Figure2.3 ENGINEERING GEOLOGIC MAP

pebbly mudstones are poorly bedded, gray to dark gray on fresh surface, fine to medium grained, poorly sorted and containing clasts of (gneissic?) granite, slate, quartzite and limestone. The size of clasts varies from coarse-sand to cobble, and the roundness from subangular to well rounded. The calcite veinlets are common and calcite crystals coated on some pore surfaces. Some fracture-cleavages are usually stained on their surfaces are yellowish-brown to brownish-gray in color and are coated with thin film of iron-oxides.

Petrographically, the rocks comprise of poorly sorted subangular to subround sand size in a fine matrix. The sand-size grains have the diameter varies from 0.2 to 0.6 mm. The phenoclasts are 40 - 60 percent quartz, 5 - 20 percent rock fragment, 5 - 20 percent feldspar, and a little amount of detrital mica and some unidentified minerals which about 0 - 2 percent. The clay matrix occupies approximately 40 - 70 percont of the rock mass. The quartz grains commonly show pronounce undulating extinction. The rock fragments are dominantly calcite, polycrystalline quartz, and fine-grained chert. There are some veinlets of polycrystalline quartz, and limonite cutting across the sandstone. The porosity of the rock is about 1 - 5 percent.

2.2.2 Subarkosic to Arkosic Sandstones and Weathered Pebbly Graywackes to Pebbly Mudstones

Subarkosic sandstones are exposed intervening the weathered pebbly graywackes to pebbly mudstones as layers, lenses or zones which are less than 40 m wide for exposure excavation crop out with slightly abrupt contacts between the two rock types while the stratification is usually absent or indistinct in the pebbly graywackes (Figure 2.5). At the elevation 80.00 m at the diversion tunnel upstream portal (Figure 8.6), a disintegrated mudshale lense about 3 m wide interveing the arkosic sandstones. In general, the subarkosic to arkosic sandstones crop out extensively at the upstream portal at elevation 60.00 m up and below the right abutment of the main dam. The fresh color of these rocks is pale gray to pale brown with dendritic pyrolusite coated on the surface. The unit is massive, fine to medium-grained, well compacted, and very hard. The quartz veinlets are common, approximately 0.1 - 2 cm thick and randomly aligned. Numerous cracks and joints are mottled yellow with brown iron-oxide stained (limonite powder).

Microscopically, the subarkosic sandstone is moderately well sorted, fined-grained sandstone. The sand grains constituent is 85% the rest, the matrix and cementing material for about 15%. The clasts are made up of 60 - 75% quartz grain 10 - 15% feldspar, 1 - 5% rock fragments, and 0 - 5% micas and unidentified minerals. The major content quartz grains form a bimodal pattern of size, the medium grain, of the total quartz 7% is subround, and fine -grained of 93% subangular. The fine-grained feldspars are microcline and orthoclase of equal proportion. These grains are subrounded. The rock fragments are mainly subangular carbonate minerals. The matrix is mostly clay minerals. Two types of cement were recognised, namely, siliceous and ferruginous. The siliceous cement was quantitatively by far the most important, forming on average 80% of the total cement

Figure 2.4 Geological overbreak on left wall at cha. 65.00 - 69.00 m in the diversion tunnel.

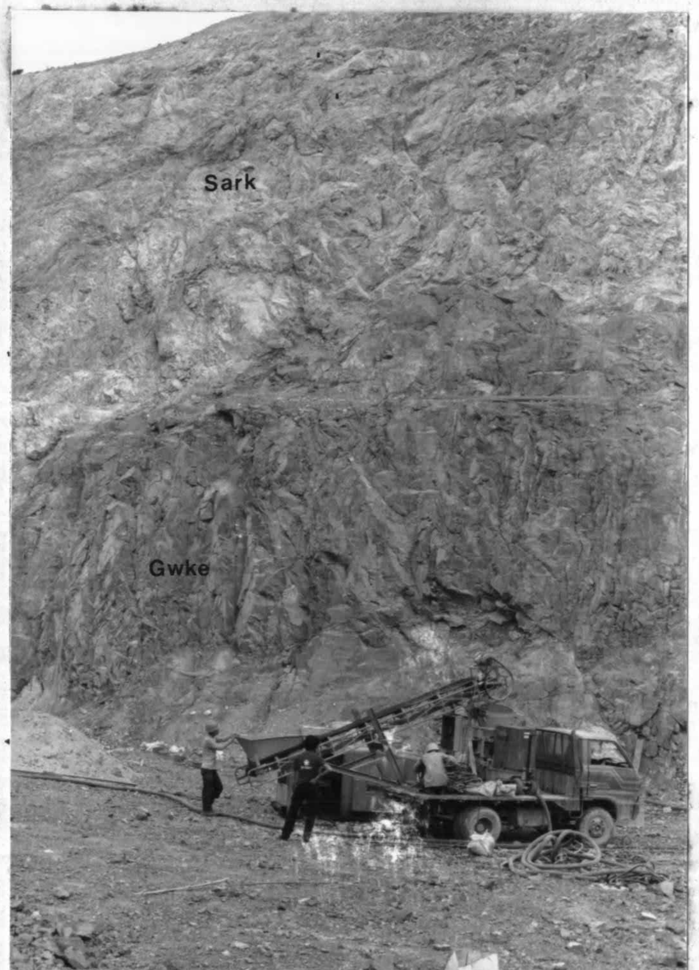


Figure 2.5 Subarkosic sandstones contact with pebbly graywackes at inlet diversion tunnel.

content, as compared with 20% for ferruginous cement. The rock is well cemented and has very low porosity.

The weathered pebbly graywackes to pebbly mudstones are associated with the subarkosic sandstones. The former rocks are light gray to greenish-gray in color. The numerous scattered clasts vary from pebbly to boulder in size and their shape ranges from subangular to well rounded, but mostly subangular. The rock types of the clasts are quartzite, granite, limestones and possible gneissic granite (Figure 2.6). The fossils are rarely found in this rock type, only one core specimen of the designation UD-1 at the depth 3.70 m from surface contains a fragmentary brachiopod (?).

2.2.3 Mudshales

The mudshales overlies the pebbly graywackes and subarkosic sandstones. They mainly expose in the western and southern parts of the studied area (Figure 2.4), i.e. at the housing area of this project, behind the first-aid station, carpenter workshop, and diesel power house. Their contact with the other 2 rock types varies from sharp to graditional, the graditional contact is observed at the borrow pit in front of the EGAT guest house and fuse dike No. 2 and 3. The lithology partly grades from shale to mudstone which tend to dense, massive and poorly fissile. Generally, the color of these rocks are greenish-gray to light gray and brownish-yellow. They are very fine-grained, weak, brittle, and easily disintegrated so that all of them are broken into fragments and pieces. The discontinuity surfaces are stained with dark iron-oxides, brownish-black to black in color.

X-ray diffraction study, it illustrated that the mudshale specimens collected from an outcrop which scarred a wedge shape failure behind the first-aid station is consisted predominantly of chlorite with trace of illite together with fragments of quartz and feldspar (Figure 2.7).

2.2.4 Alluvial Deposits

The alluvial deposits along Khlong Saeng are the river bed gravel and terrace deposits on both banks (Figure 2.3). The sand banks and sand bars are mainly composed of sandy clay with plant rootlets.

2.3 Discontinuities

The study of the discontinuities was performed mostly in the diversion tunnel, portal slopes and main dam foundation. Generally, the geological discontinuities, namely joints and faults in the studied area are uniform with the strike from northwest to northeast and the average dip about 70 degree to the northeast to southeast and northwest to southwest.

The most common defects found along the diversion tunnel and its portal area are joints, faults (crushed and sheared zones) and cleavages. The bedding are rarely observed in the study area. The detailed descriptions of structures are given below.

2.3.1. Joints

The rock mass in the study area is locally extensively jointed. The joint pattern is similar throughout the area, especially

Figure 2.6 The rock types of the clasts, their shapes and sizes of weathered pebbly graywackes

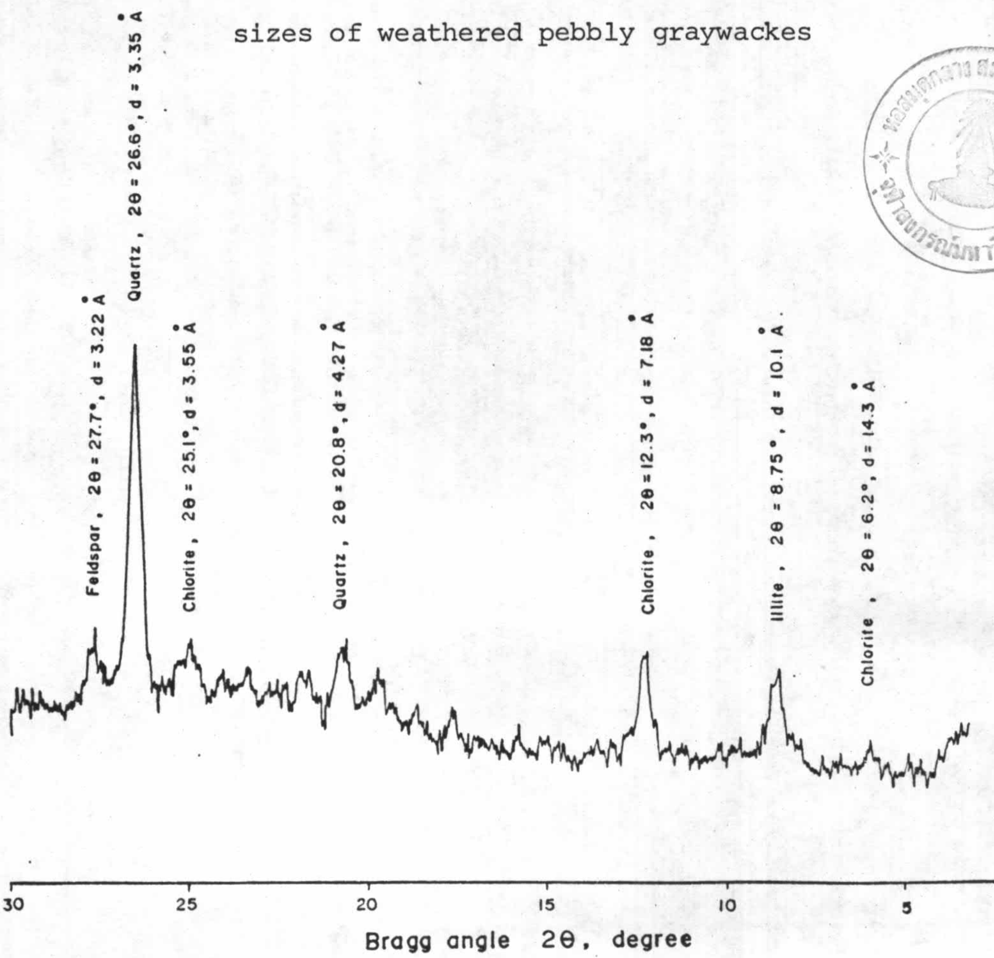


Figure 2.7 X-ray diffractogram of the clayey part of mudshale specimen, CuK_x radiation (λ = 1.5045 Å 35 KV 25 MP) was employed

along the diversion tunnel and in the portals areas, i.e., low to medium persistent, well-developed, moderately to widely spaced. They are both tension and shear joints. The joint pattern is not easy to discern, but the measurements show that these joints may be grouped into four principal sets to be marked A, B, C and D (Table 2.1) although there is a considerable range of strike and dip within each set (Appendix A-1).

2.3.1.1 Joint Set A

The joint set A has the strike N10°W to N38°E and dip 80°E to 85°SE. These joints are moderate to wide spacing, low persistence, tight to moderately open with the smooth to rough surfaces.

2.3.1.2 Joint Set B

The joint set B has the strike N75°E to S65°E and dip 50°SE to 90°SW. Although they are grouped together, there are probably two distinct subsets, one dipping steeply to the southeast and the other dipping almost vertical to the southwest. These joints are moderate to very wide spacing, low to medium persistence, tight to open with smooth to slightly rough surfaces. The strike of these joints is nearly at the right angle to the diversion tunnel axis.

In the pebbly graywackes the spacing of the joints of the sets A and B varies from 0.6 to 6.0 m, though locally of narrower and also wider spacing. The joint surfaces are usually smooth to slightly roughed and are coated with the brownish-yellow limonite.

Table 2.1 Summary of discontinuity orientations in the study area

Rock Type	No. of Subarea	No. of Observation	No. of Discontinuity Orientation of Concentrated Poles (Srike/Dip)			
			A	B	C	D
Gwke	30	3839	17	30	14	29
Sark	2	248	—	—	2	5
Msh	7	764	4	5	7	8

Note: A = 359°/84° - 038°/74°

B = 050°/90° - 135°/90°

C = 140°/69° - 205°/90°

D = 261°/74° - 325°/74°

Gwke = pebbly graywackes to pebbly mudstones

Sark = subarkosic sandstones

Msh = mudshales

The clay coatings are also common. The joints are usually tightly close to moderately open and sometimes curving and oftenly die out in short distances of a few meters.

2.3.1.3 Joint Set C

The joint set C has the strike S20°E to S20°W and dip 70°SW to 50°NW. They are moderate to wide spacing, low to medium persistence with smooth to slightly rough surfaces, and oftenly tight to moderately open. The strike of these joints makes a small acute angle with the length of the diversion tunnel.

2.3.1.4 Joint Set D

The joint set D has the strike N75°W dip 70°NE. The joint spacing varies from 0.2 to 2.0 m. They are commonly low to medium persistence, tight to moderately open with smooth to slightly rough surfaces.

An observation in the tunnel revealed that all important groundwater inflows into the excavation occured along the joint set B, whereas the sets A, C and D were practically dry.

The compactiness or degree of interlocking of the joint blocks is decided by the breaking manner of the rock mass during excavation. In the pebbly graywackes, the surfaces of excavation are composed almost entirely of flat joint faces, indicating that under the effect of blasting the rock mass breaks more readily along the joint planes than across the joint blocks. Contrarily in the subarkosic sandstones, a large proportion of the excavation surfaces are the new fractures where the rock mass had been broken across the joint blocks rather than along the existing joint planes. It was also noticed that the mudshales part along the joint planes as revealed on the cut slope and in the natural outcrops where the rocks were disintegrating under the effect of weathering.

2.3.2 Faults

A large number of sheared and crushed zones were present, varying in the width from 10 mm to 1.5 m, and consisting mainly of varying amount of crushed, angular rock fragments and sandy-clay gouge with iron-oxide stained, but almost without observable displacement since the entire rock mass is rather uniform in composition and consequently lack of any marker bed. These fractures were assumed to be the faults from their characteristics mentioned above. A large fault which lies the closest to the inlet of the diversion tunnel intersects the linear underground excavation at chainage 83.00 m (Figure 2.8). This fault strikes N60°W and dips 40° - 50°NE.

Another wide fault zone intersects the diversion tunnel at chainage 110.00 m. The dip varies rather steeply (from 65° to 85°) to the southwest and the thickness of the fault zone varies from 50 to 150 cm. The very closely jointed and shattered zones were also observed to associate the fault. Though the displacement can not be seen along this fault zone, the crushing evidently occured along the observable length of the discontinuity.

The rock mass along the middle and downstream portions of the diversion tunnel is free from the major faults. The rock mass show much evidence of strain in the from of slickensides along many small joints and by the presence of minor faults perhaps related to the major fault found at the upstream portion of the tunnel.

Three small but persistent minor faults intersect the diversion tunnel. Two were found over the top heading diversion tunnel and were marked No. 1 and No. 2 in Figure 2.8. Their strikes are N45°E and N90°W and dips are approximately 40°SE and 43°NS, respectively. These faults in the pebbly graywackes were found to occur individually or grouped togethers as a cluster of several persistent fracture planes with 10 to 15 cm wide crushed zones filled with a small amount of sandy clay, or as zones of close jointing and in the subarkosic sandstones at the upstream portal, these faults were represented by a zone of close jointing, 1 to 3 m wide, with joint-spacing 5 to 20 cm apart. These joints are usually smooth, coated with white rock flour of calcite and limonite powder, but without clay, and are slickensided and tightly closed.

The third small fault has a strike of N15 E and irregular dip 35 ° - 55°SE. It cuts across the tunnel at chainage 480.00 m and is marked No. 12 in Figure 2.8. It consists of two fracture lines No. 14 and No. 15 with 10 to 30 cm of clay, iron-oxides stained and orushed rock fragments along these fractures. As the fracture approaches the contact between the pebbly graywackes and subarkosic sandstones, it becomes less distinct and splits into several parallel clay coated joints, often without crushed rock, and continues in the subarkose as a group of clay-stained joints.

Major fault is marked No. 5 in Figure 2.8 has the quite-similar attitude to that of the other minor faults and is considered to be contemporaneous with the other fractures. Like the other discontinuities observed here, it is probably a shear fault with a distinguished idsplacement. It is also parallel to the shear joint set D. Thus, the shear joints could have been formed by a stress field with the maximum compression (σ_1) in the NW - SE direction, and the joint set C that is parallel to this direction is interpreted to be a set of tension fractures developed contemporaneously.

Most faults were oriented at a favorable angle (normal or subnormal) to the tunnel alignment in concerning to the tunnel stability. Only in those zones where they are subparallel to the tunnel aris, or where the groundwater flowage was high, was a steel-set required. In general, the faults encountered in the tunnel did not pose any serious restriction on the tunnelling techniques and performance.

2.3.3 Cleavage and Fissility

The bedding are rarely observed in the pebbly graywackes and subarkosic sandstones since the rocks are rather massive but fissility and cleavage can be seen. The fissility and cleavage were to have the same attitude as that of bedding. In mudshales, the fissility can be identified easily in some cutcrops, its strike/dip varies from N to N30°E/40°E - 60°SE.

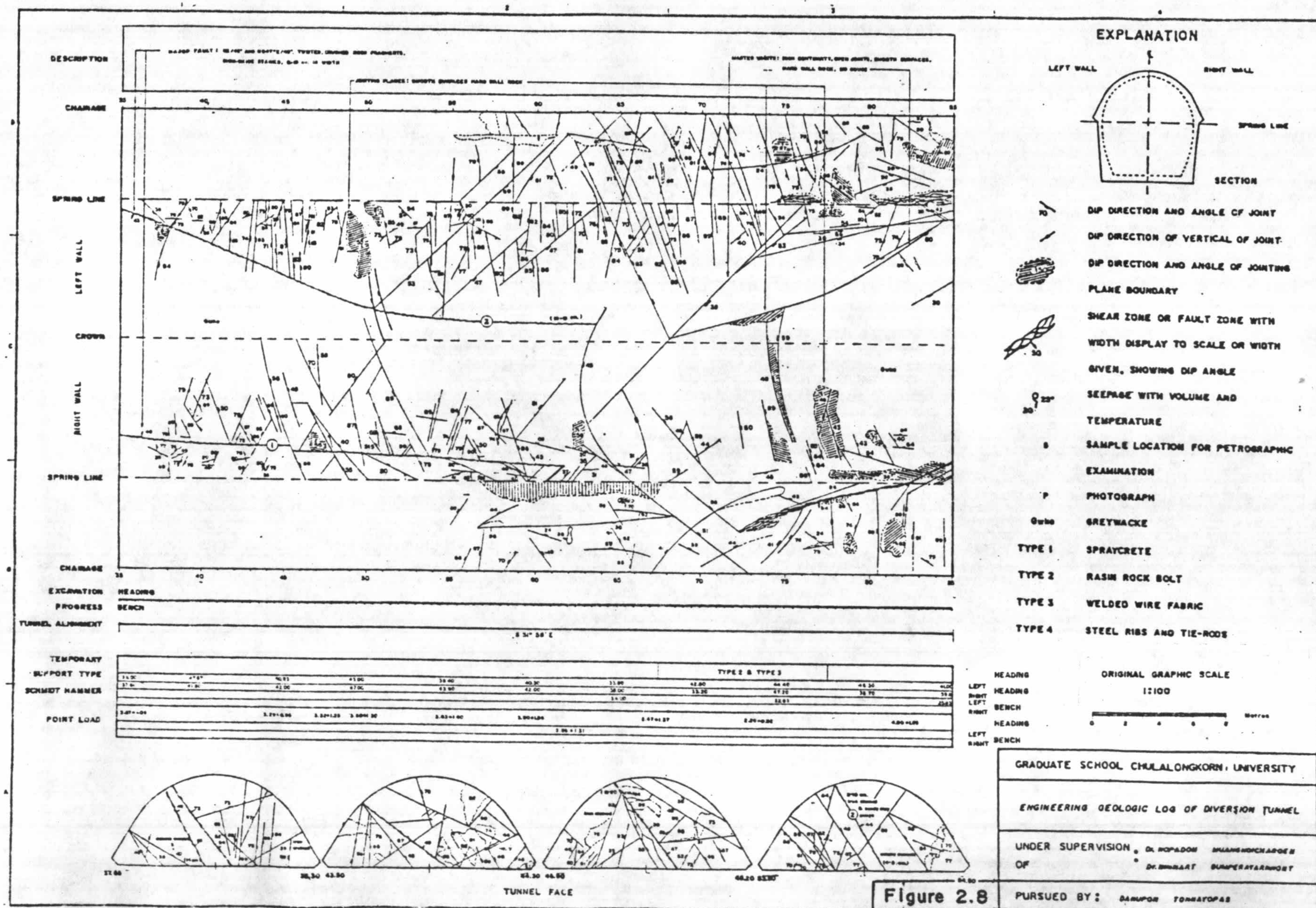
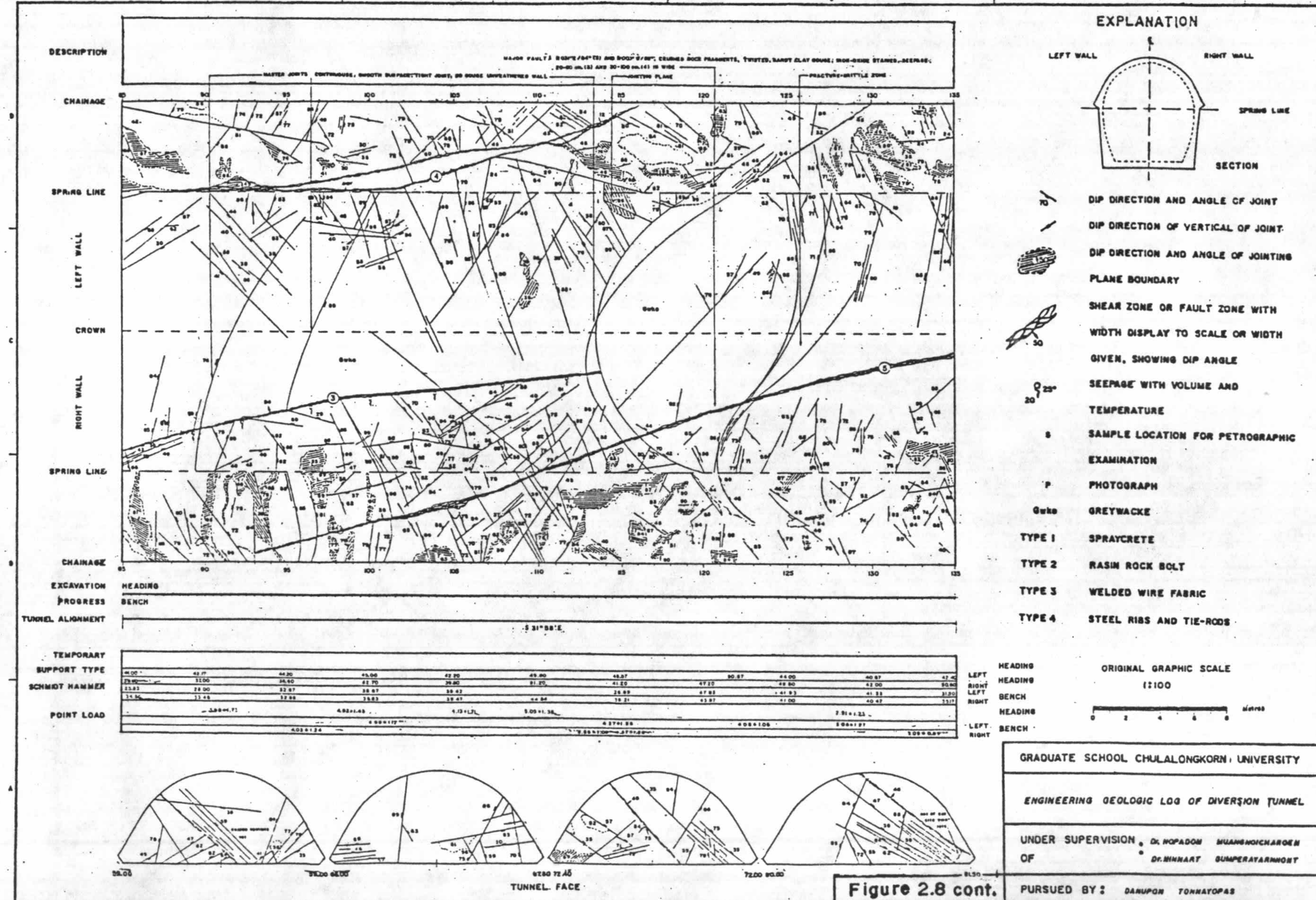

EXPLANATION
LEFT WALL
RIGHT WALL
SPRING LINE
SECTION
DIP DIRECTION AND ANGLE OF JOINT
DIP DIRECTION OF VERTICAL OF JOINT
DIP DIRECTION AND ANGLE OF JOINTING PLANE BOUNDARY
SHEAR ZONE OR FAULT ZONE WITH WIDTH DISPLAY TO SCALE OR WIDTH GIVEN, SHOWING DIP ANGLE
SEEPAGE WITH VOLUME AND TEMPERATURE
SAMPLE LOCATION FOR PETROGRAPHIC EXAMINATION
P PHOTOGRAPH
Gwbe GREYWACKE
TYPE 1 SPRAYCRETE
TYPE 2 RASIN ROCK BOLT
TYPE 3 WELDED WIRE FABRIC
TYPE 4 STEEL RIBS AND TIE-RODS
DESCRIPTION
CHAINAGE
SPRING LINE
LEFT WALL
CROWN
RIGHT WALL
SPRING LINE
CHAINAGE
EXCAVATION PROGRESS
HEADING
BENCH
TUNNEL ALIGNMENT
TEMPORARY SUPPORT TYPE
TYPE 2 & TYPE 3
SCHMIDT HAMMER
POINT LOAD
LEFT HEADING
RIGHT HEADING
LEFT BENCH
RIGHT BENCH
ORIGINAL GRAPHIC SCALE
1:100
Metres
TUNNEL FACE
GRADUATE SCHOOL CHULALONGKORN UNIVERSITY
ENGINEERING GEOLOGIC LOG OF DIVERSION TUNNEL
UNDER SUPERVISION OF
PURSUED BY :

Figure 2.8



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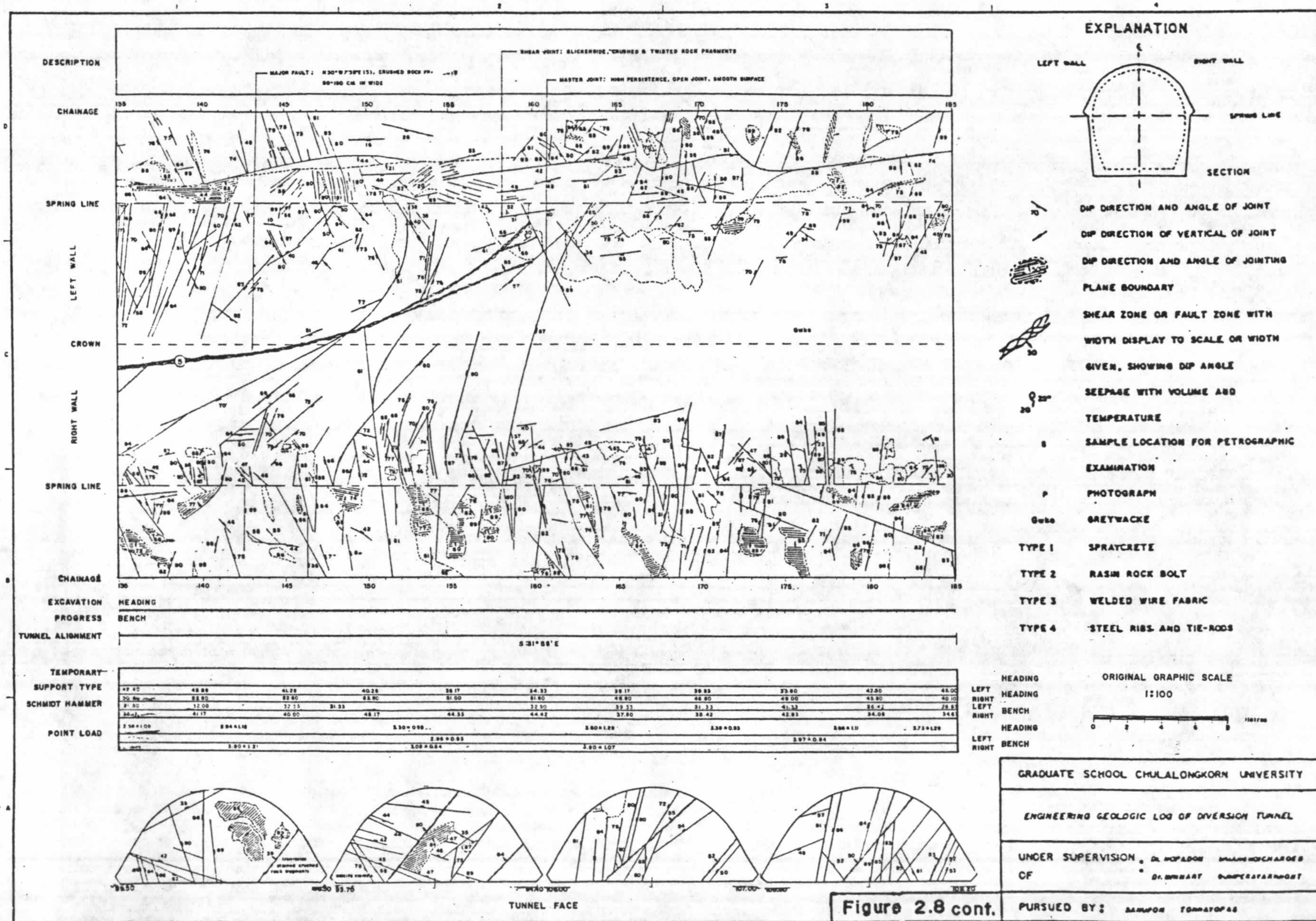

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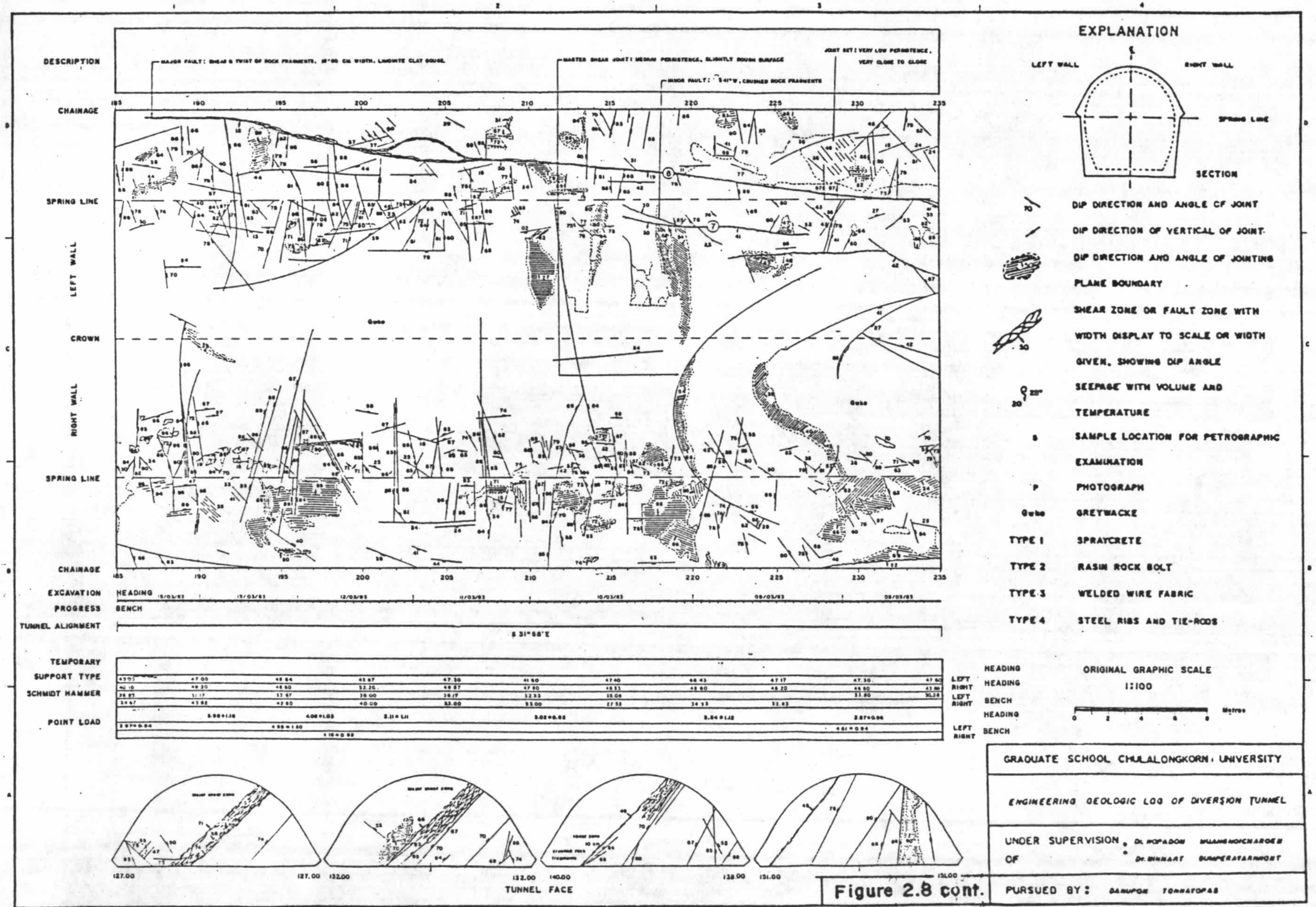

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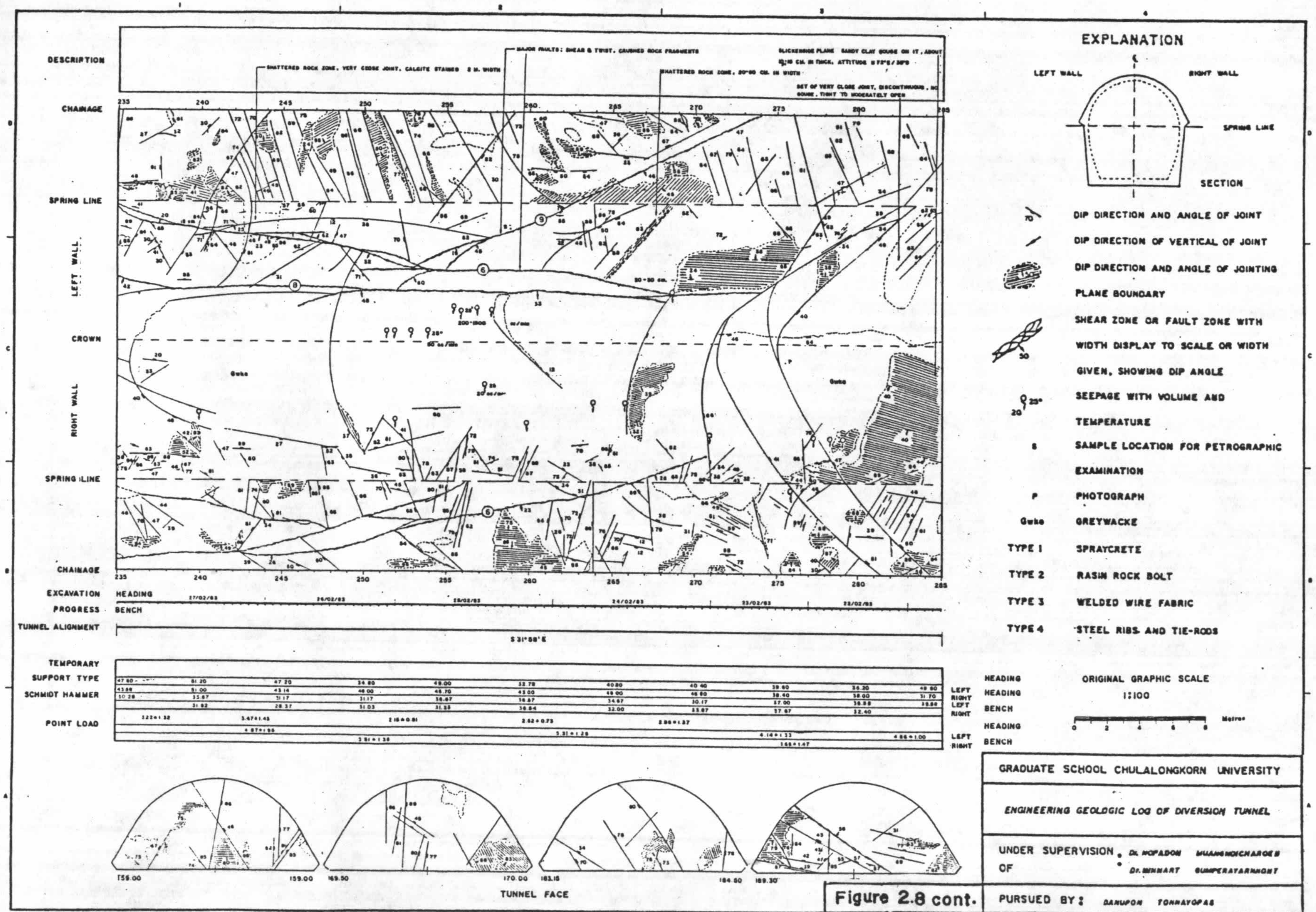

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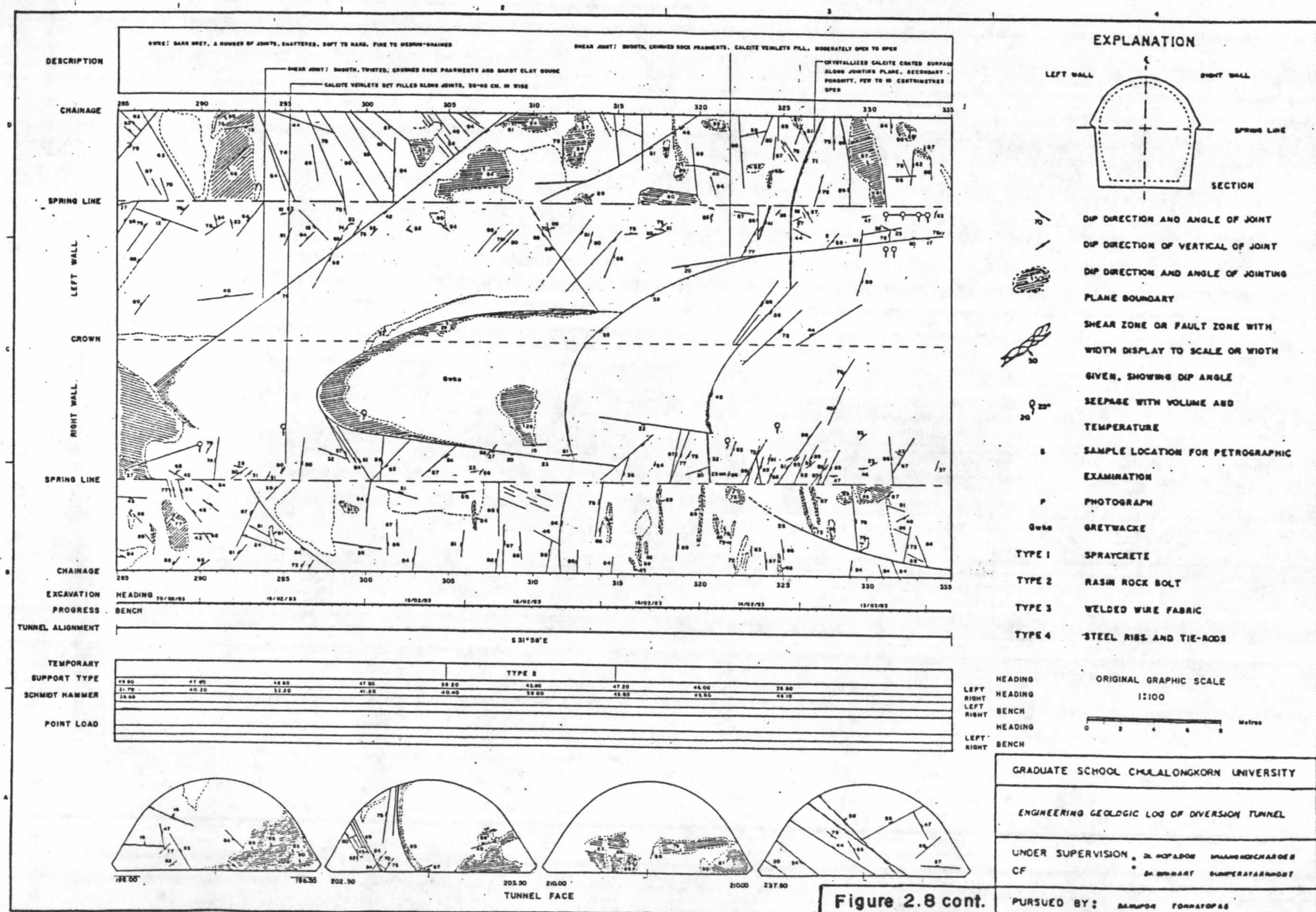

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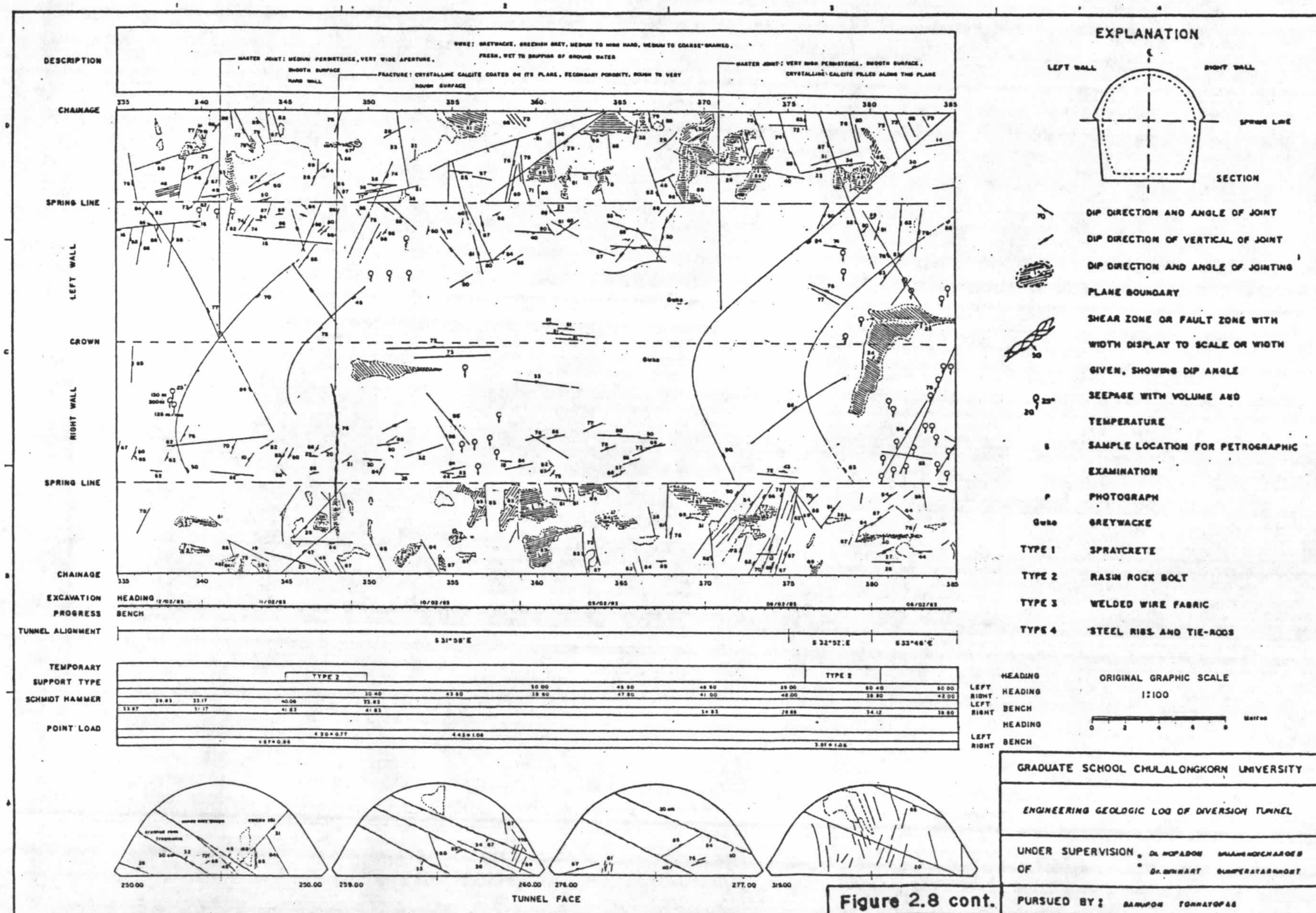

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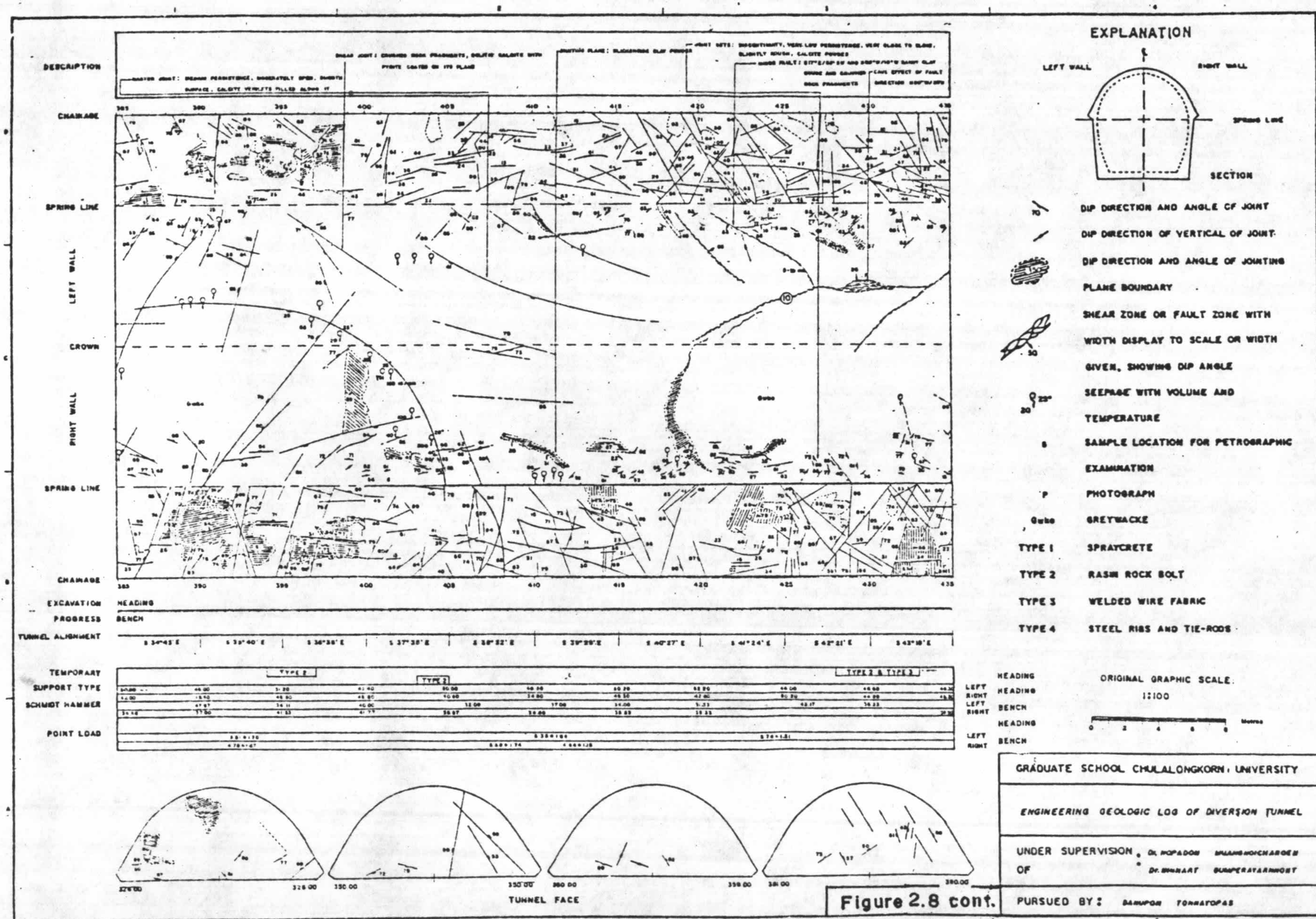

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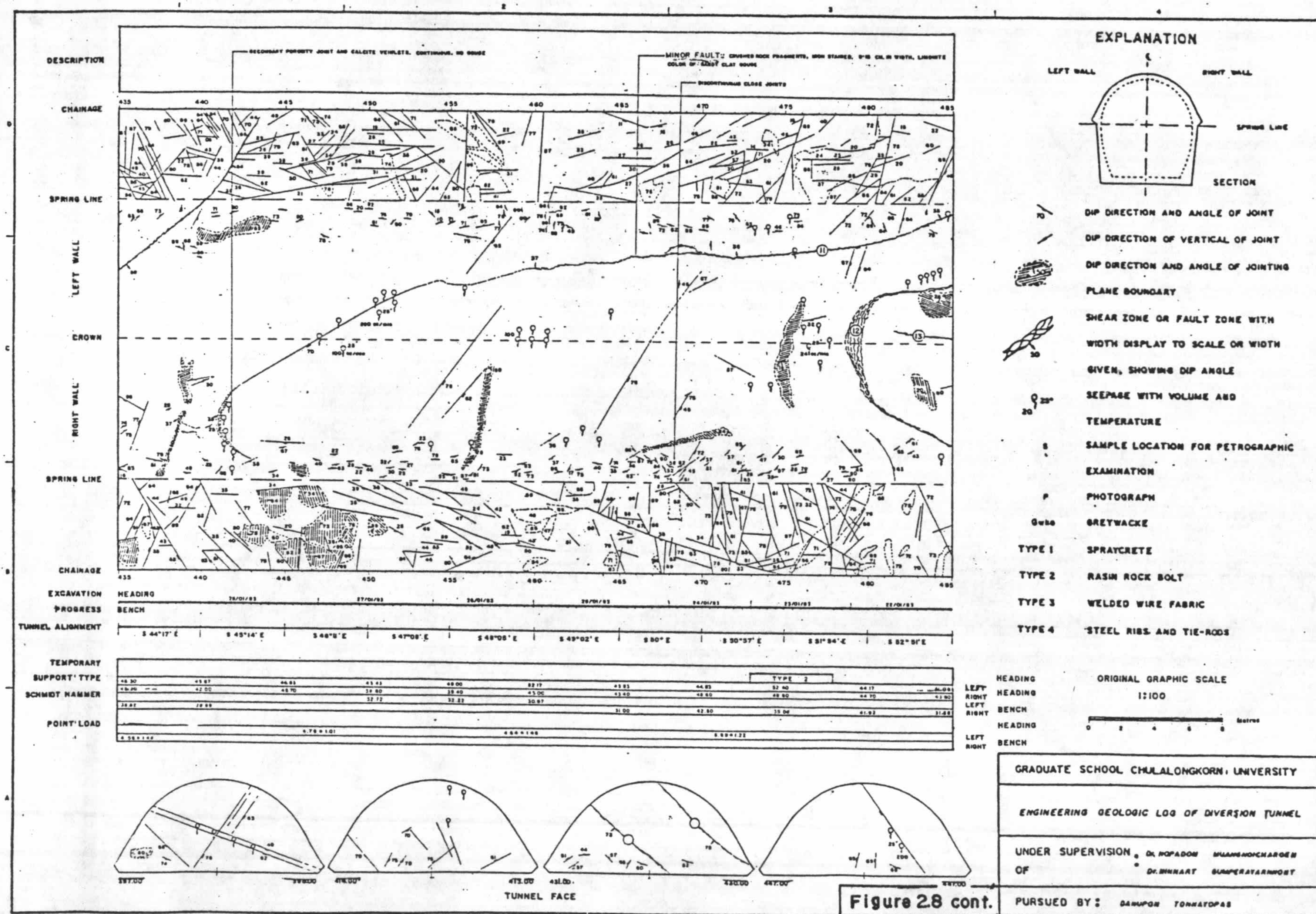

Figure 2.8 cont.

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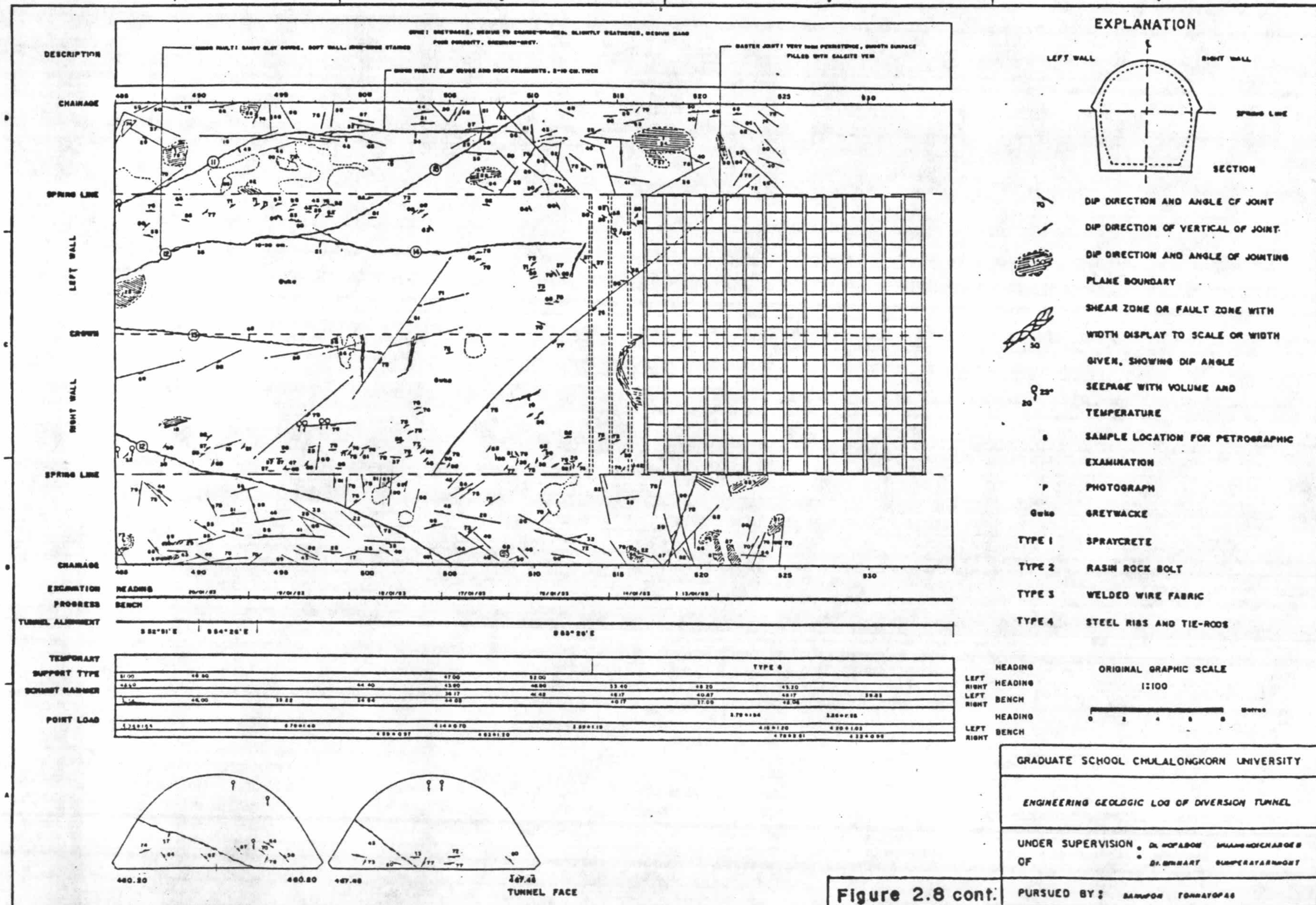

Figure 2.8 cont.

2.4 Degree of Alteration

Due to the mineral composition of pebbly graywackes, the possibility exists that this rock could have suffered the quick alteration processes. This possibility is quite real for the mudshales variety of the pebbly mudstones or pebbly graywackes, whose major mineral constituent is essentially clay minerals, such as chlorite, illite, etc. The disintegration process generally takes place as soon as these rocks are exposed to the atmosphere. Such this field evidence could be clearly observed outcrop at in front of EGAT guest house, where access road cuts across the mudshales which contact with moderately to highly weathered pebbly graywackes. The soft rocks decayed and eventually disintegrated into a lump of small clayey elongated grains. The degree of weathering in rock unit in the study area were classified (Table 6.5) after Bieniawski (1973) and ISRM (1981) which grades from a highly weathered to fresh rock. Generally, the degree of weathering is different depending on the rock types. The pebbly graywackes and subarkosic sandstones usually have a lower degree of alteration than the mudshales. The weathered pebbly graywackes and subarkoses are mostly grayish-green and brownish-yellow in color respectively, mainly with the limonite and white rock flour stains along the fracture surfaces.

The weathered zone in the study area is generally 10 m deep

2.5 Hydrological and Permeability of Rock Mass

An extensive study on the groundwater level were done by EGAT in 1980 to 1982 in some diamond drilling boreholes. The level varies from 10 to 25 m below the topographic surface.

The water-pressure tests or Lugeon tests were performed in the early surface investigation in these diamond drilling boreholes. The test results indicated that the rock mass has a low permeability of 1 x 10^{-7} m/sec to 1 x 10^{-8} m/sec for deep underground (>15 m depth) while some shallow underground of the openly-jointed sandstones were moderately permeable (1 x 10^{-5} m/sec) as would be illustrated in Figure 9.4 .