CHAPTER II

GEOLOGY, STRUCTURES, AND MASS-MOVEMENT IN MAE MOH MINE

The general geology of the Mae Moh Basin and of the mine in particular is described below. The detailed field investigation done by the author on the geologic structures and other discontinuities together with the explanation of the down-slope mass movement are also added later.

2.1 Geologic Setting

According to Piyasin (1972), the rock sequences from Permo - Triassic, Triassic, Tertiary to Quaternary ages are found in Mae Moh area. Their distribution have already shown in Figure 3 on Chapter I. In Mae Moh Basin the rocks are essentially of the Tertiary non-marine sedimentary units, deposited in a narrow elongate basin, bounded by the Triassic-rock banks. The rock sequences, like those in many other Tertiary basins in Thailand, are graben-deposited and lignite-bearing. The graben has its trend following the regional strike of the basement stratigraphic layers, i.e. toward the northeast, forming a flat-lying alluvial plain between the ridges.

Longworth - CMPS's report (1981) suggested from the coincidence of the Basin axis and the general trend of the basement sedimentary rocks that the graben orientation was probably controlled by the previously - formed structures, the mechanism is yet to be clarified. If the block - faulting episode is a part of the Cretaceous/Tertiary "orogeny", the previously - formed plastic (?) deformation may be either of the early Upper Triassic or even as old as Lower Carboniferous tectonic event. After the displacement of the fault block, Tertiary sediments started depositing in the Basin.

Piyasin (1972) suggested a younger orogeny superimposing on the Tertiary basin, perhaps as young as Late Pleistocene. The tectonism had resulted as the minor - to major - faulting of the Pliocene sediments in Mae Moh Basin.

2.2 Stratigraphy in the Mine Area

The Tertiary rock units appeared in the mine area have been subdivided according to the work of Longworth - CMPS (1980). These units overlie Triassic basement rocks, usually shales or calcareous rocks. The approximate localities of these rocks are illustrated in Figure 4. The stratigraphic sequence from the lowest to the upper most of the Tertiary rock unit can be described as follows.

2.2.1 Lower Claystone

The Lower Claystone sequence is composed mainly of light gray claystones. The unit is probably the lowest of the Tertiary rocks in Mae Moh Basin, hence lies unconformably on the Triassic - rocks basement. The thickness is from 250 to 470 m. Thin fossiliferous beds are oftenly

Figure 4. View of the mine area, showing the distribution of rock units.

Notations :

1 = Red Beds

2 = Overburden Claystone

3 = Lignite K Seam

4 = Interburden Claystone

5 = Lignite Q Seam

6 = Lower Claystone

found in this unit. The fossils are sometimes pyritized, especially in the beds at the upper part of the Lower Claystone unit. Thin, fairly continuous bands of lignite are also found, mostly concentrated at 40 to 70 m below the upper horizon of this rock unit.

The Lower Claystone unit occupied the southeastern mine-floor area, away from the center of mine activity.

2.2.2 Lignite Q Seam

The Lignite Q Seam is the lower of the two lignite seams of Mae Moh Basin. The unit is infact composed of mostly lignite layers interbedded with a small number of thin beds of gray claystones, lignitic clay, and some siltstones. The Q Seam is 10 to 30 m thick.

The lower lignite seam is being excavated in the southeastern portion of the mine. Elsewhere, to the northwest portion, the seam is still buried at depth.

2.2.3 Interburden Claystone

The Interburden Claystone unit lies between the lower lignite Q Seam and the upper lignite K Seam. Similar to the Lower Claystone unit, the Interburden Claystone sequence consists of light gray claystones and shales with a small number of thin lignite interlayers. Some claystone beds are also fossiliferous.

The unit is 20 to 30 m thick and is found in the middle part of the area of mining activity.

2.2.4 Lignite K Seam

The mine operation at the mine floor close to the toe of the NW flank is at present concentrating on the upper lignite K Seam, from where lignite is fed into the power plants. The lignite unit is 15 to 30 m thick. There are two layers of tuffaceous (?) materials. The layers are 50 to 60 cm thick and are about 30 cm apart. There are also thin layers of shell fragments. The fossils are occasionally silicified. The silification is also noted in a lignite bed at the bottom part of the seam.

2.2.5 Overburden Claystone

The Overburden Claystone sequence retains its similarity to the other two claystone units, the Lower - and Interburden Claystone sequences. Overlying the Lignite K Seam, the Overburden Claystone unit (Figure 5) is composed of weathered to fresh light gray claystones interlayered with beds of lignitic claystones, shales, and lignite, 10 to 50 cm thick. Some of these beds are fossiliferous.

Two beds of hard argillaceous limestone (Figure 6), each about 40 cm thick, are also found in the Overburden Claystone unit.

The uppermost claystone unit is found on the northwestern and the southwestern pit slopes. All slope instability has occurred on this claystone sequence. The unit is also found at the lower part of the southeastern slope.

Figure 5. Lithologic sequences of the northwestern pit slope.

Figure 6. Argillaceous limestone cropped out at Subarea 2 on the northwestern slope (at the hammer).

2.2.6 Red Beds

The uppermost sequence of Tertiary rock found only to the top part of the northwestern slope is called the Red Beds (Figure 5). It is 10 to 15 m thick and consists of thin - to thick layered, reddish-brown, soft to firm clays with highly weathered claystone and some clayey siltstones. A thin zone of abundantly crystallized gypsum (selenite) and some discontinuous thin seams of lignite, 10 to 40 cm thick, are also found.

2.2.7 Mae Taeng Formation

The Red Beds sequence was unconformably overlain by the Quaternary sediments, namely Mae Taeng Formation (Piyasin, 1972). This unit consist of unconsolidated gravel inserted with medium sand, loose and pervious, and is covered by residual soils and mine refuses on the top. The rocks of Mae Taeng Formation are found at the topmost portion of the northwestern slope.

The stratigraphic column which measures along the line N9 of the mine area is illustrated in Figure 7. The distribution of those rock sequences are also shown in Plate I.

2.3 Subareas of Study and their Characteristic

To analyse the stability of slope in the mine, five subareas of different characteristic were chosen for the comparison of the physical characteristic as well as the nature and type of down-slope mass movement which may (or may not) be found in those subareas. The five subareas of

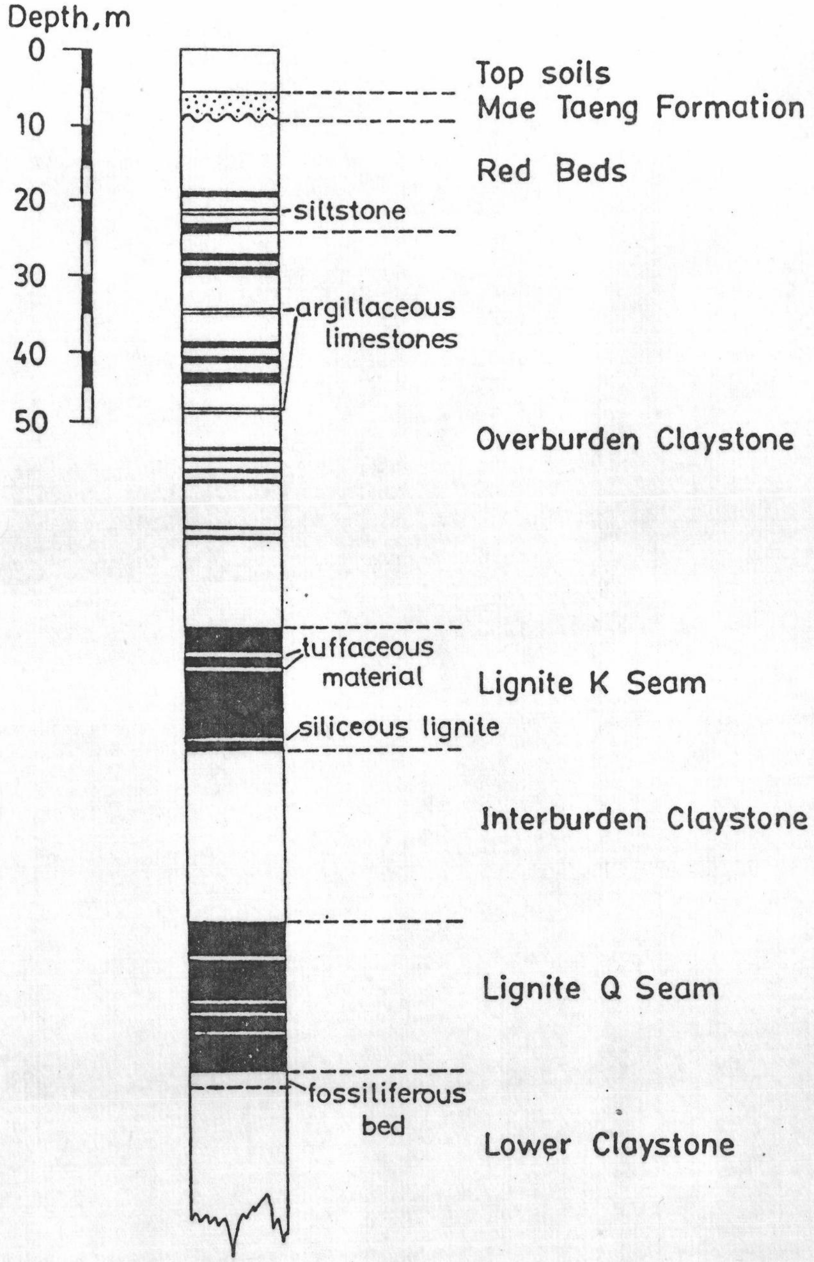

Figure 7. Stratigraphic column at Mae Moh lignite mine. (measured on line N9, mine grid). Black layers are lignite layers, white layers are claystones unless stated otherwise.

study are quite different in the geometry of slope, discontinuities orientations especially the relationship between the orientation of bedding and slope, and stability conditions of the slopes. These differences are directly controlled by the geologic factors including rock types, structures, degree of weathering and geometry of slope design. The size of these subareas is arbitarily. Each of the five subareas of study can be described as follows.

2.3.1 Subarea 1

Subarea 1 was the only subarea on the southwestern flank slope of the mine and represent an area where the bedding strike cuts across the slope face. The slope is composed mainly of 3 to 4 benches of the rocks of Overburden Claystone on the northwestern part, with a few more subordinate benches of the Lignite K Seam on the southeast. The overall slope is 30 to 48 m high with 12° to 16° inclination while the individual bench is 3 to 5 m high, 10 to 15 m wide with 25° to 30° inclination. According to the observed stability condition, the slope is stable.

2.3.2 Subareas 2, 3 and 4

These subareas are on the northwestern flank slope of the mine, from the southwest to the northeast, Subareas 2, 3 and 4 respectively. In this slope, the strikes of the beds and of the slope are approximately parallel, but the dips are in the opposite direction. The rocks of these subareas are of Overburden claystone, Red Beds and residual soils (2 to 8 m thick) on the top.

Subarea 2 is composed of 4 to 5 benches, all trending north. The overall slope is 45 to 50 m high with 25° to 30° inclination while the individual bench is 10 to 11 m high, 8 to 10 m wide with 50° to 54° inclination. The slope is unstable with small scale wedge failures and local rock slumps which regularly within an individual bench.

Subarea 3 is composed generally of 4 benches trending 30° azimuth. The overall slope is 40 to 41 m high with 30° to 32° inclination while the individual bench is 9 to 13 m high, 8 to 10 m wide with 42° to 65° inclination. The subarea is also unstable with the large scale wedge failure and landslide, a scale larger than the size of a single bench.

Subarea 4 is composed generally of 4 benches trending approximately 35° azimuth. The overall slope is 33 to 44 m high with 28° to 35° inclination while the individual bench is 7 to 10 m high, 8 to 12 m wide with 55° to 61° inclination. The slope is unstable with small-scale rock falls recorded.

2.3.3 Subarea 5

Subarea 5 locates on the southeastern pit slope in the area where the mining excavation is threatened by the block slides. The southeastern flank slope in this subarea trending 30° azimuth, is made up of 2 benches and consists of the rocks of Overburden Claystone sequence. The overall slope is 23 to 25 m high with 18° to 25° inclination while the individual bench is generally 8 to 12 m high with 25° to 40° inclination. The lower bench-width is approximately 25 to 30 m. The observed stability condition in this slope is unstable with the planar (bedding-plane) sliding.

2.4 Rock Weathering Classification

The rocks and soils in the five subareas must be reclassified according to their degree of weathering. The engineering rock weathering classification is done according to the work of Fookes and Horswill (1969) (See the comparison of classification done by Saunders and Fookes, 1970, in Appendix I). The classification is essential for the slope stability analysis to follow later on. The geologic materials which are reclassified are as follows.

2.4.1 Residual soils (Rs)

The unconsolidated and permeable materials consist of gravel and sand of Mae Taeng Formation, top soils and mine refuses are grouped under this heading. The materials occupy the top 2 to 8 m of the northwest flank slope. Water seepages were found at the base of the layer of these porous materials where they unconformably overlie the less permeative Red Beds.

2.4.2 Moderately to highly weathered claystones (Mw-Hw)

This group of materials is essentially of the Red Beds sequence. The claystones in this unit are red to reddish-brown, very fine grained, soft to hard, highly plastic and stiff when soaked with water. Traces of original layers were seen by the occurrence of hard, less weathered bed, however.

The weathering process was more significant on the slope face where the water flows over, than just under it (Figure 8).

2.4.3 Slightly to moderately weathered claystones (Sw-Mw)

This type of rocks are from the Overburden Claystone sequence which is light to medium gray, very fine grained, hard and intensively jointed. Weathering process is of a stronger degree on the softer beds which are fissile clays or shales and brittle lignite beds (Figure 9). The weathering process was caused by the surface water flow and groundwater seepage. The two very hard beds of argillaceous limestone which are less weathered and are not included in this group.

2.4.4 Fresh to slightly weathered claystones (Fr-Sw)

These materials are also from the Overburden Claystone sequence which occurred on the pit floor and the lower part of the northwestern and southwestern slopes. The rock is medium to light gray, very fine grained, jointed and relatively unweathered except on the long-exposed surface. Weathering process is sometimes significant along the bedding planes. The processes were controlled by water flow and groundwater seepage which mostly occurred along the bedding planes (Figure 10). Besides, the long-exposed planes are easily cracked to form the weathering chips (Figure 11).

Figure 8. Weathering process in the upper part of northwestern flank slope in Subarea 3.

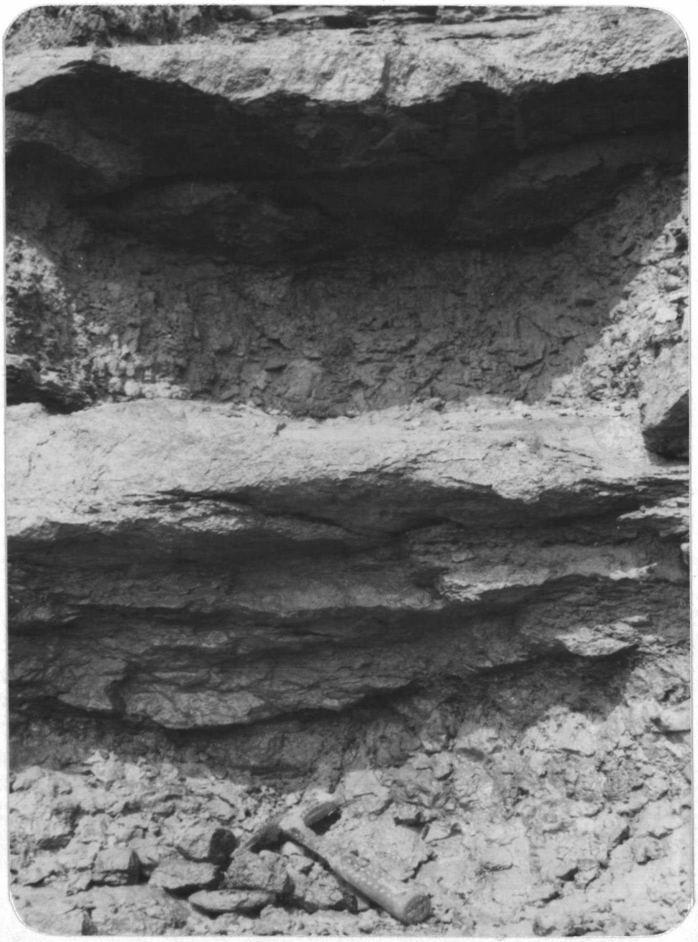

Figure 9. Selective weathering in Overburden Claystone. The materials are classified as slightly to moderately weathered claystone.

Figure 10. Water seepage along bedding in Subarea 5 (at the arrow).

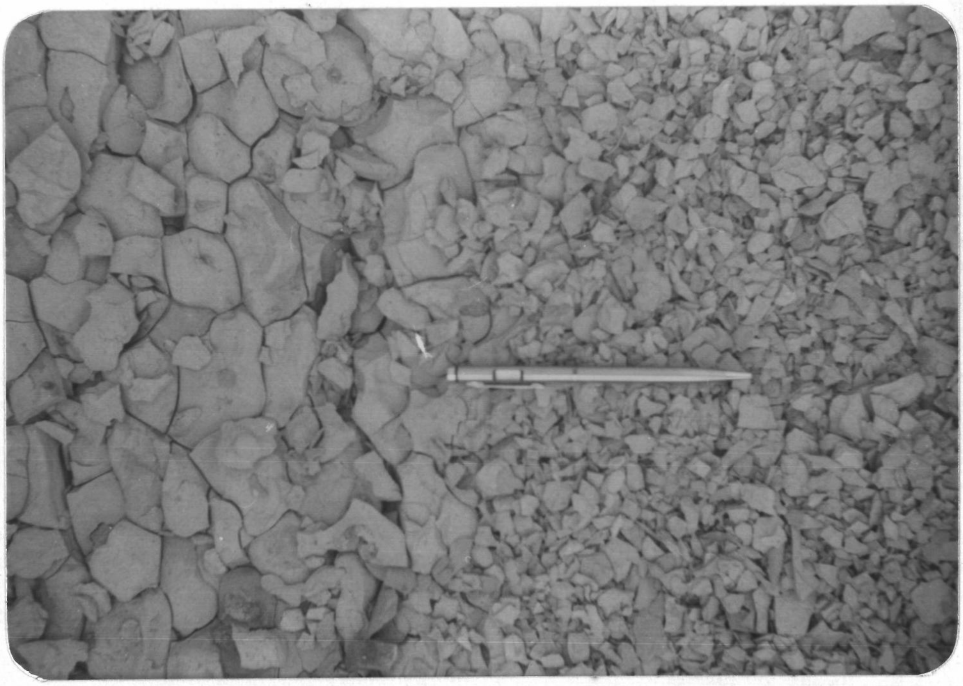

Figure 11. Weathering chips on bedding planes of claystone in Subarea 5.

2.5 Structural Geology

2.5.1 General

The general attitude of the geologic strata of all sequences is strike 195° azimuth and dip 25° W. Two general trends of faults distributed in the mine area are NNW-SSE and NNE-SSW (Figure 12). These faults are mainly en echelon normal faults with moderately - to vertically dipping (45° to 90°) fault planes. The small-scale reverse faults, separation about 30 cm on the slope face, were found occasionally. The approximate attitude of these faults is strike 300 azimuth and dip 70° E. Faults which can be traced for several meters are more important in stability of the slope.

The pervasive joints in the mine area are extension joints of generally 3 sets, trending E-W, N-S, and NE-SW (Figure 13). Shear joints are occasionally found in the area where faults too place. Their attitude (strike/dip) are parallel to sub-parallel to the fault planes.

2.5.2 Detailed discontinuities survey results

Detailed discontinuities survey, all from the rocks of Overburden Claystone sequence, was carried out along the slope of each subarea of study. The discontinuities are composed of the penetrative joint sets and bedding, and a few nonpenetrative faults. The results are illustrated in Table 1 and the stereonet plots of these discontinuities are shown in Plate I.

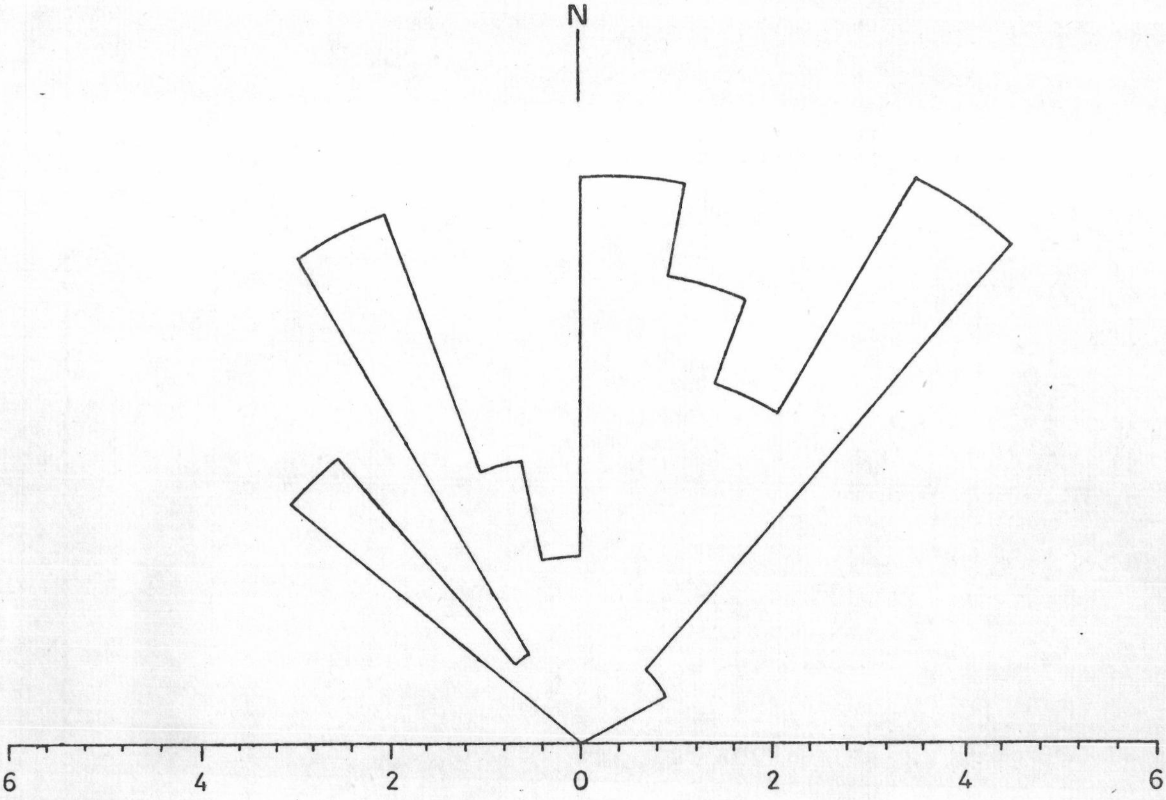

Figure 12. Rose diagram showing strike of 40 faults in the mine area.

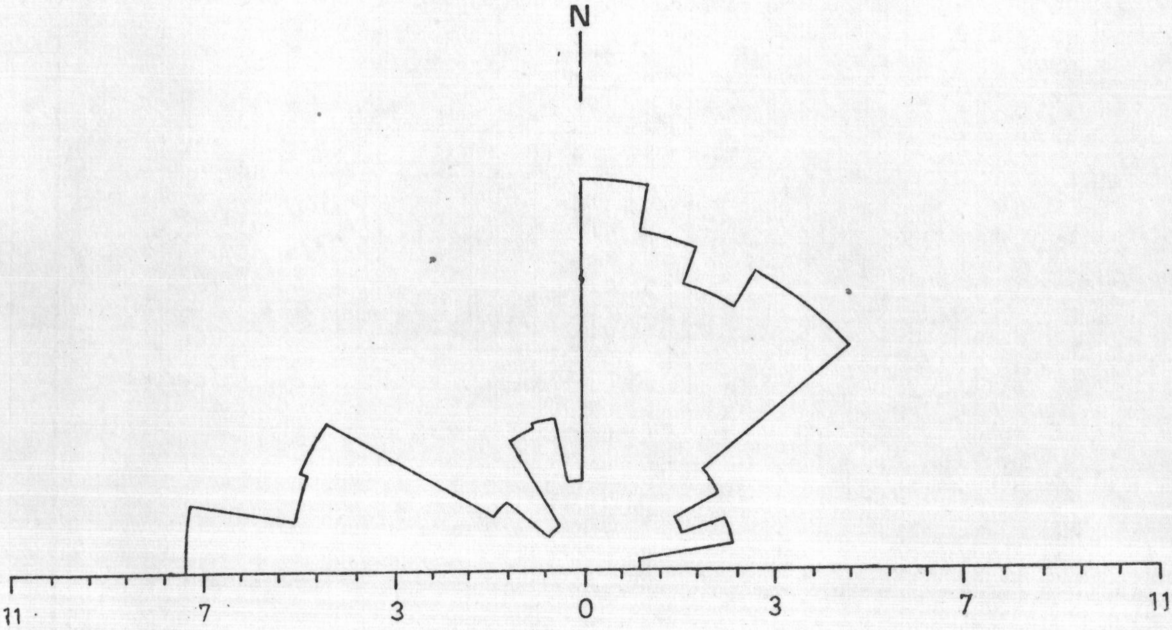

Figure 13. Rose diagram showing strike of 70 joints in the mine area.

Table 1. Results of detailed discontinuities survey.

Subarea	Slope face (strike/dip)	Type of discontinuities	Attitude (strike/dip)	Spacing (m)	Separation (mm)	Length (m)
1	290/16 NE*	Bedding-B	(av)190/30W	0.1-1.0		
	/26 NE**	Joint set J_1	(av)011/68E	0.1-0.3	1 - 3	1.5-2.
		Joint set J_2	(av)189/58W	0.1-0.2	1 - 2	2.0-3.
		Joint set J_3	(av)048/70SE	0.1-0.2	1 - 3	1.5-2.
		Fault-F_{11}	192/58W	Isolated	10 - 20	2.0-5.
		Fault-F_{12}	206/76W	"	10 - 20	2.0-5.
2	358/35 E*	Bedding-B	(av)186/30W	0.1-1.0		
	/50 E**	Joint set J_1	(av)062/68SE	0.2-0.3	1 - 2	1.0-3.
		Joint set J_2	(av)308/75NE	0.1-0.3	1 - 2	1.0-2.
		Joint set J_3	(av)276/84N	0.1-0.4	1 - 4	1.0-2.
		Fault-F_{21}	334/74E	Isolated	10 - 30	>5.0
3	030/33 E*	Bedding-B	(av)194/18W	0.1-1.0		
	/50 E**	Joint set J_1	(av)022/81E	0.2-0.5	1 - 5	2.0-5.
		Joint set J_2	(av)108/88S	0.1-0.3	1 - 2	1.0-2.
		Fault-F_{31}	345/42E	Isolated	10 - 30	>5.0
		Fault-F_{32}	340/52E	"	10 - 30	>5.0
4	034/38 E*	Bedding-B	(av)204/20W	0.1-1.0		
	/55 E**	Joint set J_1	(av)022/70E	0.1-0.5	1 - 5	2.0-5.
		Joint set J_2	(av)054/74SE	0.1-0.2	1 - 2	1.0-2.
		Joint set J_3	(av)355/68E	0.1-0.3	1 - 2	1.0-2.
		Joint set J_4	(av)293/84N	0.1-0.3	1 - 2	1.0-2.
		Fault-F_{41}	340/85E	Isolated	10 - 20	>5.0
		Fault-F_{42}	139/70SW	"	10 - 20	>5.0

* = overall slope

** = individual bench

(av)= average

Table 1. cont.

Subarea	Slope face (strike/dip)	Type of discontinuities	Attitude (strike/dip)	Spacing (m)	Separation (mm)	Length (m)
5	210/24 W* /40 W**	Bedding-B	(av)202/20W	0.1-1.0		
		Joint set J_1	(av)020/74E	0.2-0.5	10 - 15	5.0-10
		Joint set J_2	(av)290/90	0.2-0.3	10 - 15	1.0-2.
		Joint set J_3	(av)096/79S	0.3-0.5	5 - 10	1.0-2.
		Fault-F_{51}	171/64W	Isolated	10 - 20	5.0
		Fault-F_{52}	013/55E	"	10 - 20	3.0-5.
		Fault-F_{53}	006/40E	"	10 - 20	3.0-5.
		Fault-F_{54}	352/63E	"	10 - 20	5.0

* = overall slope

** = individual bench

(av)= average

Table 2. Classification for joint spacing (after Deere, 1966, in Bieniawski, 1978).

Description	Spacing of joints	Rock mass grading
Very wide	> 3 m	Solid
Wide	1 - 3 m	Massive
Moderately close	0.3 - 1 m	Blocky/seamy
Close	50 - 300 mm	Fractured
Very close	< 50 mm	Crushed and shattered.

The results of study can be summarized as follows.

a) Bedding planes in all subareas are generally conformed and dipped to the west.

b) There are generally 3 joint sets distributed in the subareas of study. They are mostly extension joints, mostly with smooth surface. Joint spacing is 10 to 50 cm, thus, the rocks are blocky/seamy to fractured according to Deere's (1966) classification of joint spacing (Table 2).

c) Joint set, J_1, found in Subarea 3, 4 and 5 are longer than other joint sets. These joints are parallel or sub-parallel to the slope face and are steeply dipping to the east.

d) The trace of nonpenetrative faults distributed in Subareas 1 to 4 and on the pit floor are approximately perpendicular to the slope trend. These faults are several meters long with generally 0.5 to 1.5 m displacement. They are the major discontinuities which can be seen clearly on the slope face containing lignite beds (Figure 14).

2.6 Landslides of Subarea 3

The major landslide area is in Subarea 3 at the middle part of the northwestern flank slope. The slope is about 40 m high and 200 to 220 m long and with an overall inclination of 30°. The slides occurred on the first three lower benches which are altogether 35 m high. The geologic map of the landslide area at a scale of 1:500 is shown in Plate III.

Figure 14. The northwestern flank slope of Subarea 4 showing a graben bounded by two normal fault planes.

2.6.1 Nature and type of landslides in Subarea 3

Landslides that occurred in Subarea 3 before and during the investigation were principally of three types : rock slides, topple rotational slumps and debris flows. These types are distinguished by the type of materials and by the kinds of movement of mass. The nomenclature of the landslide used here is of Varnes (1978) (as shown in Table 3).

Table 3. Summary classifications of slope movements (after Varnes, 1978).

Type of movement	Type of material		
	Bedrock	Soils	
		Coarse-grained (debris)	Fine-grained (earth)
Falls	Rock fall	Debris fall	Earth fall
Topples	Rock topple	Debris topple	Earth topple
Slides	Rock-block slide	Debris-block slide	Earth-block slide
Rotational	Rock slump	Debris slump	Earth slump
Translational	Rock slide	Debris slide	Earth slide
Lateral spreads	Rock spread	Debris spread	Earth spread
Flows	Rock flow	Debris flow	Earth flow
Complex	——— Combination of two or more of the above ———		

2.6.2 Cause of landslide

The movement of the landslide in this subarea is mainly controlled by the seeping rain water action which occurred during May to October.

There are two main reasons for failure because of water. They are :

a) seeping water reduces the rock strength in a weathering process and

b) added water increases the weight of the mass, i.e. increases the driving force (gravity), and at the same time acts as lubricant which reduces the resisting force.

Furthermore, the decomposition of rocks because of the self - combustion of the lignite beds may also contribute to the decrease of strength of the slope materials (Figure 15).

All controlling factors mentioned above reduced the factor of safety of the cut slope and eventually the slope failed.

2.6.3 History of the landslides

The northwest flank slope was cut and shaped into a three-bench slope in 1979. In the middle part (Subarea 3), the upper bench is 10 to 15 m high with the slope of 35° to 40°; the middle bench, 15 to 20 m high with the slope of 45° to 50°; the lower bench, 15 to 20 m high with the slope of 45° to 55°. The bench width is about 8 to 10 m each.

The first failure of the cut slope was recorded in the March, 1980 by Pramote Pornrattanapitak (1981, personal communication). The failure was of wedge type and only occurred on the lower bench (Figure 16). The wedge was controlled by the intersection of a fault striking 341° azimuth and dipping 35° NE and an irregular vertical joint striking 108°

Figure 15. The decomposition of rocks caused by the self - combustion of the lignite beds.

Figure 16. Local wedge failure of the northwestern flank slope in March, 1980.

azimuth. The wedge was about 18 m high and 20 m long.

The wedge grew larger in the second failure recorded in March, 1981 by the author. Further sliding was also along the intersection line previously mentioned (Figure 17). This movement is the results of a higher degree of weathering by means of the alternating wet and dry season.

During April 1981, the pit floor infront of the wedge failure was excavated and the slope became a four-bench one. The bench is 8 to 10 m high and the slope is 80° to 85° and the bench width is as narrow as 3 to 5 m. The removal of the claystone at the toe of the slope is the removal of the natural support. Without the retaining force the tension crack occurs.

In early July 1981, two tension cracks, about 55 and 30 m long respectively, were observed. The fractures were sub-parallel to the slope trend. They were probably the result of the stress release and tend to detach the upper part of the slope. When the meteoric water seeped into the slope mass along these cracks, the total weight increased, so was the driving force.

In early August 1981, during the period of heaviest rain, a major landslide took place covering an area of about 200 by 80 square meters (Figure 18). Plate III shows the distribution of landslide materials and the type and course of sliding.

Figure 17. Enlargement of wedge failure of the northwestern flank slope (Figure 16) in March, 1981.

Figure 18. Landslide of Subarea 3 in August, 1981.

2.7 Planar Sliding of Subarea 5

Planar bedding-plane sliding is found in the place where the dip of slope and of bedding plane are in the same direction. The sliding occurred when the blocks of upper strata are loosely bond to the underlying strata. This phenomena is largely effected by water action mentioned in previous section. Such slope movement occurred primarily in Subarea 5 (Figure 19).

Joints which cut perpendicular to bedding plane play an important role by allowing the sliding and at the same time mark the limit of sliding blocks in term of length and width (Figure 20). The joints are of 2 sets, one is approximately parallel to the slope trend and the other cross-cut the slope and is almost perpendicular to the first set. The dip of the two joint sets is very steep to vertical.

Figure 19. Planar sliding in Subarea 5.

Figure 20. Separation of joint due to block slide in Subarea 5.