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EFFECT OF GEOLOGY ON MASS MOVEMENT IN BUNDU TUHAN AREA, SABAH, MALAYSIA

Rodeano Roslee, Magid M. Faisal, Sanudin Tahir & Shariff A.K. Omang

School of Science and Technology, Universiti Malaysia Sabah
88999, Kota Kinabalu, Sabah, Malaysia

ABSTRACT

ABSTRACT. *This study focused on the effect of geology on mass movement in Bundu Tuhan area, approximately kilometre 84-88 from Kota Kinabalu, which is one of the most vulnerable areas to mass movement in the west coast of Sabah. It is bounded by longitude line E 116° 31.592' to E 116° 31.789' and latitude line N 06° 00.269' to N 05° 59.604'. The area is underlain the Trusmadi Formation (Palaeocene to Eocene age), the Crocker Formation (Late Eocene to Early Miocene age) and the Pinousuk Gravel (Upper Pleistocene to Holocene age). Geological and geotechnical investigations in this study area were conducted to help in solving the problems related to the hazardous geological setting. These hazards will have serious consequences and effects on lives and property if not properly mitigated. Data analysis (52 samples) indicated that the sliding materials mainly consist of clayey loamy soil characterized as low to intermediate plasticity content, medium to very high of degree of swelling (3.76 to 12.67) and low permeability (8.33×10^{-3} to 9.66×10^{-3}). Trixial consolidated isotropically undrained (CIU) results showed that the cohesion value of the soils ranges between from 0.36 to 25.13 and friction angle ranges between from 7.70° to 35.50°. Geological and geotechnical evaluation of the study area indicated that the mass movement took place when slope materials are no longer able to resist the force of gravity. It decreased the shear resistance resulting mass movement, which is due to internal and external factors. Internal factors involve some change in either physical or chemical properties of the rock and soil. External factors involve increase of shear stress on slope, which usually involves a form of disturbance that is induced by man. The triggering mechanism in the study area most likely involves heavy rainfall causing water saturation of the slope material and loss of cohesion along rapture planes. The sheared shale, bedding and fault planes, and opening fractures are all structural weaknesses acting as pathways for water seepage, therefor hastening the weakening and eventual mass movement in the study area. Geological and geotechnical studies will play a vital role in ground stability assessment that is critical to public safety.*

KEYWORDS. Mass Movement Hazard, Geotechnical Investigations, Geological Setting

INTRODUCTION

The study of the earth mass movements has long been regarded as one of the most important and interesting aspect of engineering geology and geotechnical engineering, which the designers and planners from the private and public sectors address when implementing the initial stage of urban and rural development projects. This involves highways and infrastructures construction and land use planning among others. Failure to appreciate the problems relating to mass movements of earth materials can lead to damage of man made structures and even the loss of lives. This study focuses on the mass movement in Bundu Tuhan area approximately 86 km from Kota Kinabalu city, Sabah, one of the most vulnerable to mass movements occurrences in west coast of Sabah. The main objectives of this study are; 1) to map and locate the landslides in the study area; and 2) to study the mechanism and the influence of geological factors causing the mass movement.

LOCATION OF STUDY AREA

The study area is 6 km^2. It is bounded by longitude line E 116° 31.592' to E 116° 31.789' and latitude line N 06° 00.269' to N 05° 59.604' (Fig. 1).

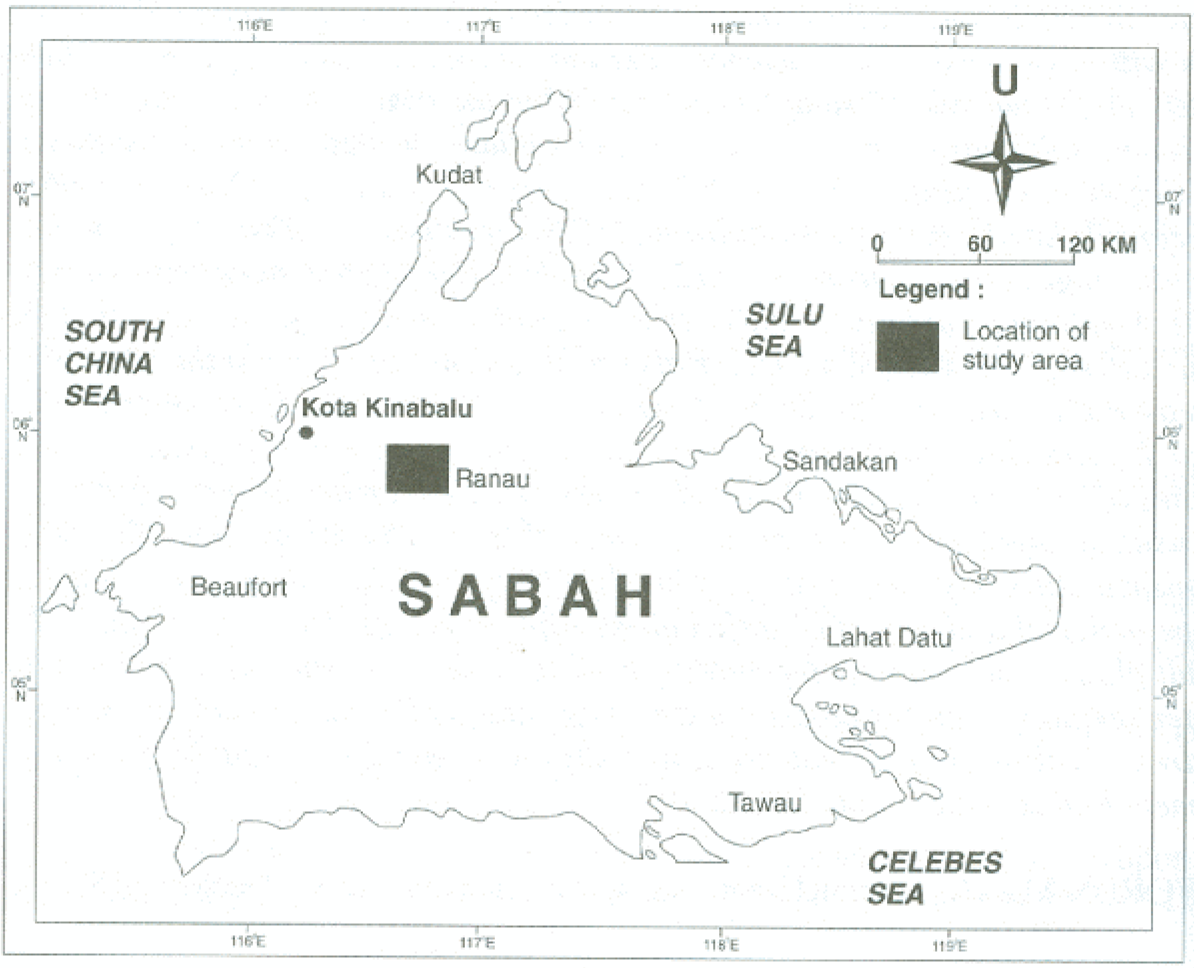

Figure 1. Location of Study Area

METHODOLOGY

Fifty two (52) soil samples from the study area were collected during field mapping for detailed analysis. The laboratory works such as classification tests (grain size, atterberg limit, linear shrinkage and specific gravity), permeability test and consolidated isotropically undrained (CIU) were carried out in compliance and accordance to British Standard Code of Practice BS 5930-1981 and British Standard Code of Practice BS 1377-1990. Sixty (60) boreholes log data were obtained from the J.W. Geotechnical Consultant Sdn Bhd, which were reinterpreted and correlated in order to have clearer idea of the subsurface soil profile and lithological units.

TOPOGRAPHY AND DRAINAGE

The topography of the study area is controlled by the underlying rock. The lowland portions are generally flat while those underlain by the sedimentary rocks are characterized by low rolling topography and steep slopes. The elevation in the study area is ranging between 3500 ft to 7000 ft above sea level (Figure 2 and Figure 3).

The watershed lies within the Early Tertiary sedimentary rock. The study area and its surroundings are controlled by heavy drainage system of different pattern (Trellis, Annular and Parallel) (Figure 4). The general river flow is from north – northwest and drain to the southwards.

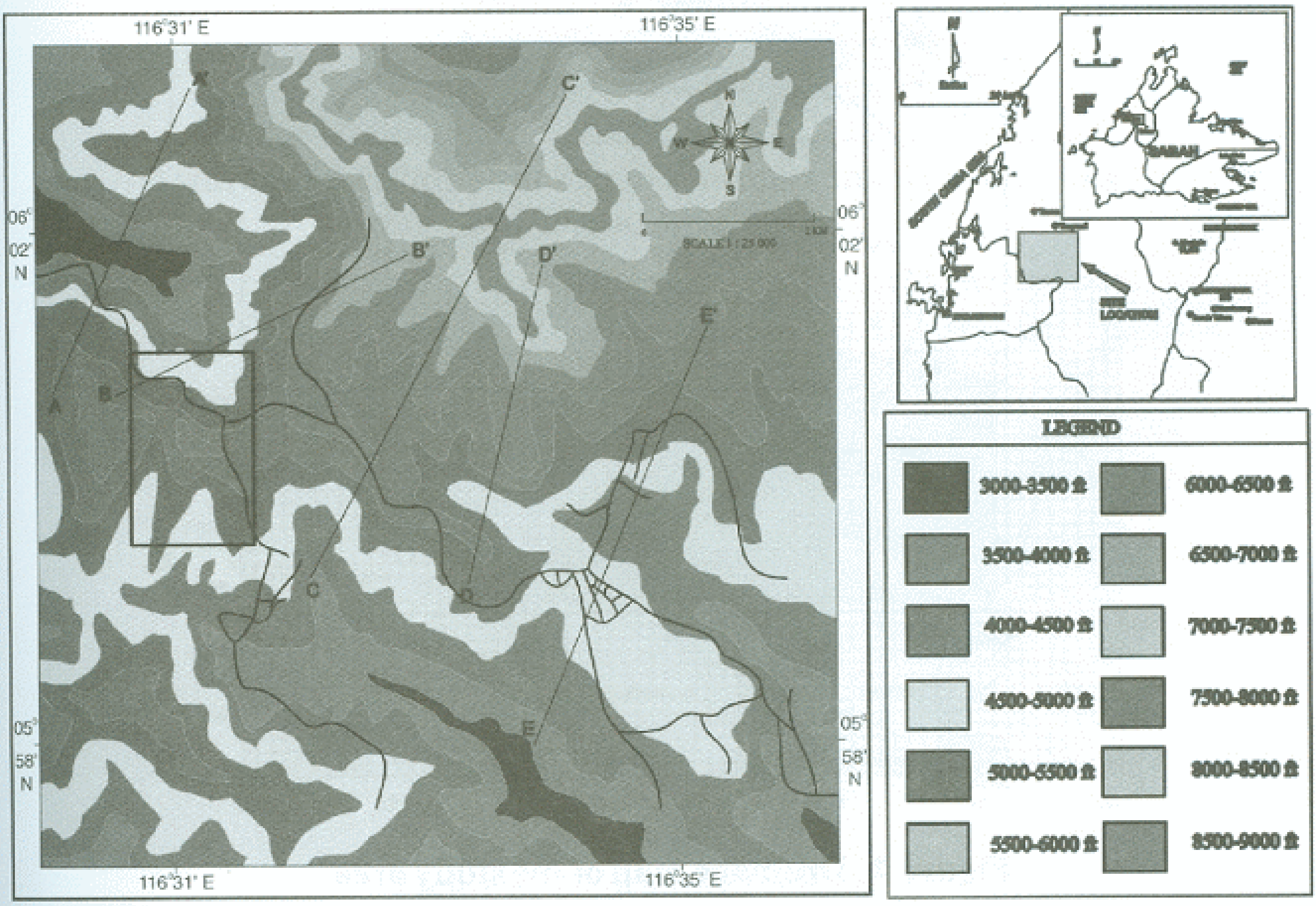

Figure 2. Topographic map of the study area

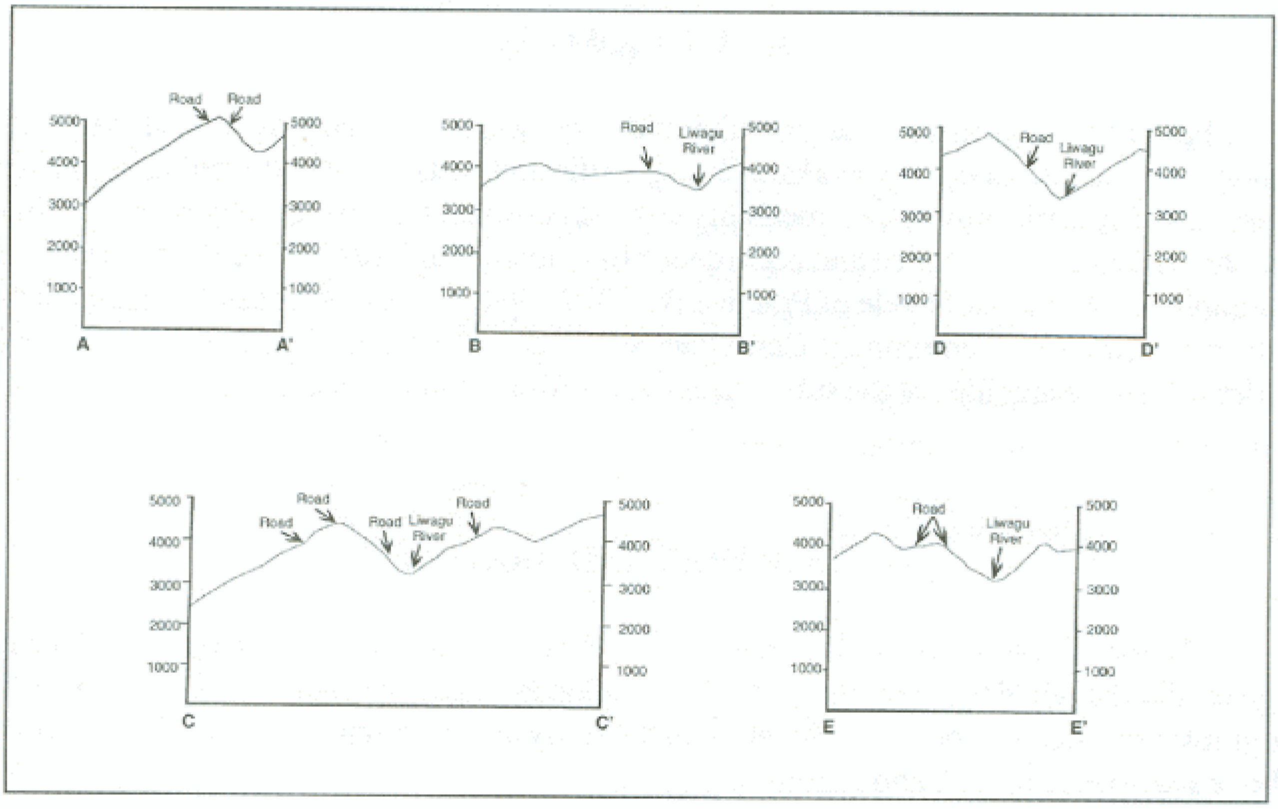

Figure 3. Various cross-sectional of topography map in study area

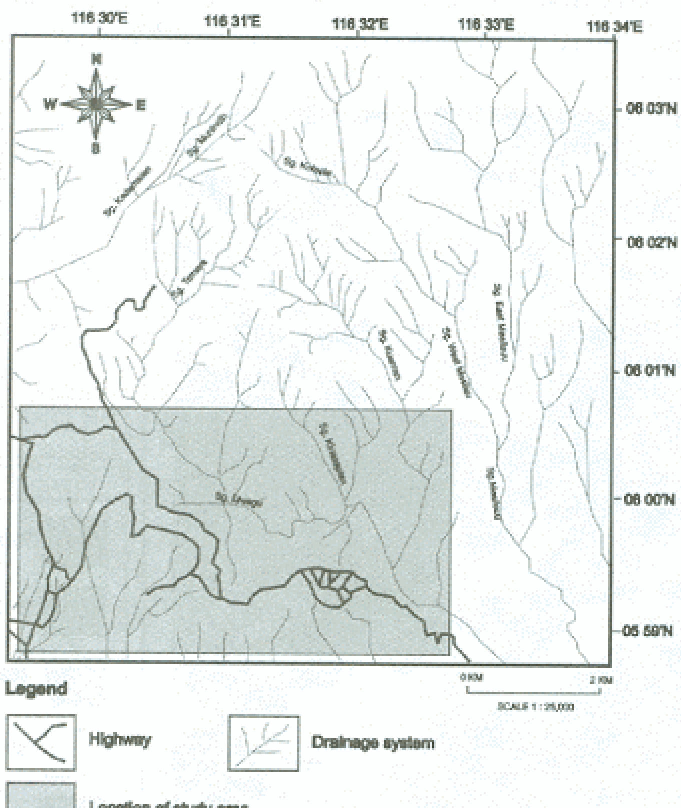

Figure 4. Drainage map of the study area

RAINFALL AND TEMPERATURE

Different regions in Sabah experience variable climatic conditions depending on their geographical location. There are five climatic regions in Sabah based on dry season and wet seasons, which in turn are induced by minimum and maximum rain periods (Figure 5). Regionally, the study area receives annually is between 80 to 160 inch of rainfall. Evaluation of rainfall records in the study area and it's surrounding for the period 1990 to 2001 indicated that the average annual rainfall is ranging 1220.0 mm to 2688.5 mm (Figure 6). The mean annual temperature for the same period is recorded ranges from 30°.9 C to 32.8° C, and the lowest from 23.2° C to 24.1° C.

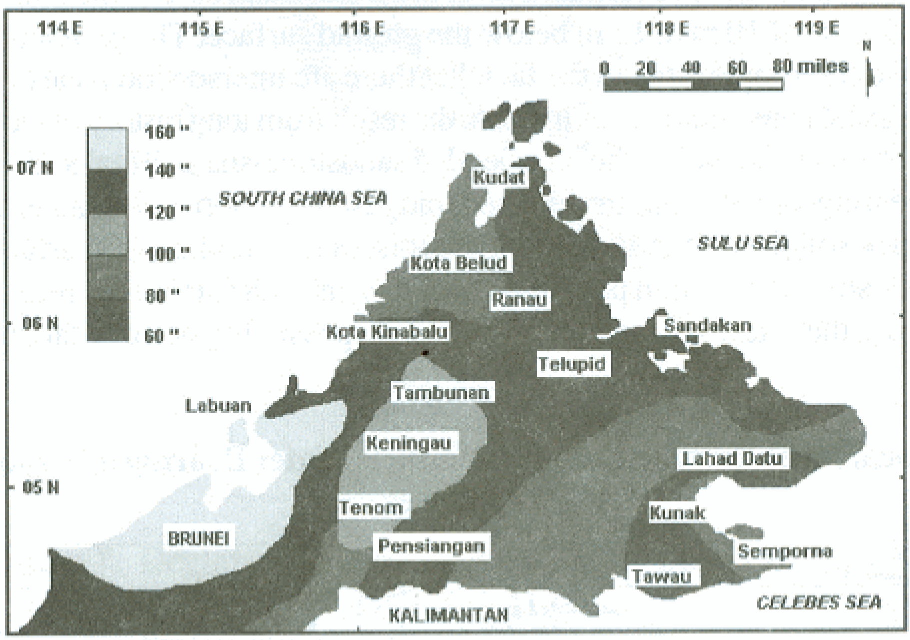

Figure 5. Distribution of Sabah's means annual rainfall data
(Sham, 1997)

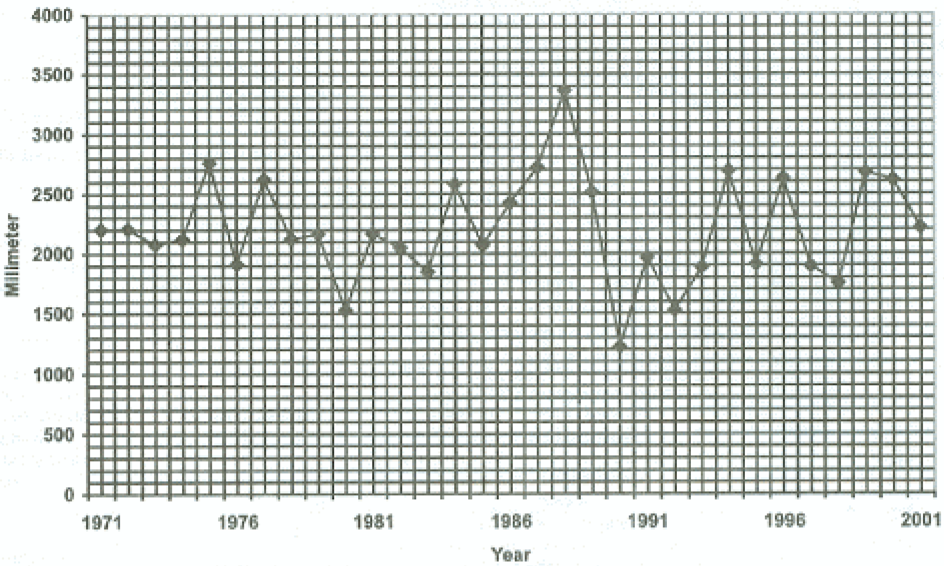

Figure 6. Total annual rainfall
(Source after Metereological Department of Malaysia (Sabah), 2001)

GEOLOGY OF THE STUDY AREA

The geology of the study area is made up of three sedimentary rock formations: the Trusmadi Formation (Palaeocene to Eocene age), the Crocker Formation (Late Eocene age) and the Pinousuk Gravel (Late Pleistocene to Holocene age) (Figure 7). Table 1 shows the stratigraphic column of rock units with their water bearing and engineering properties. The effect of tectonic activity can be observed on the lithologies in the study area (Figure 8). This was confirmed by the existence of transformed fault material consisting of angular to sub angular sandstone fragments, with fine recrystallised quartz along the joint planes, poorly sorted sheared materials and marked by the occurrence of fault gouge with fragments of subphyllite and slickensided surfaces. Transformed faulted material have formed a layer at the slope and base of the faulted scarps in the study area up to depths of 10 m to 15 m below the ground surface. The geometry of these fault lines is expected to be complex due to the fact that there are intersection zone of different type. Highly fractured and sheared sandstones indicate the result from long history of tectonic activities; most of faulting shears exist within the interbedded sandstone-shale. Breaks and fractures were developed by shearing stresses that caused the rapid disintegration and weathering of the rocks into relatively thick soil deposit. As a corollary to this, in rock bodies, the surface roughness of joint are generally smooth to rough planar. A relatively smooth surface decreases the frictional resistance to expose the fractures, therefore effected the possibility of slope failure in study area.

Table 1. Local Stratigraphic Column and their Water Bearing and Engineering Properties

Age	Rock Formation	Unit	General Character	Water-Bearing Properties	Engineering Properties
Quaternary	Alluvium	-	Unconsolidated gravel, sand and silt with minor amounts of clay deposited along the rivers or streams and their tributaries. Includes natural levee and flood plain deposit.	Gravelly and sandy, portions are highly permeable and yield large quantities of water. Important to groundwater development.	Generally poorly consolidated. Hence not suitable for heavy structures and subsidence under heavy load.
Upper Pleistocene to Holocene	Pinousuk Gravel	-	Poorly consolidated tilloid deposits. Unconformable overlie ultrabasic granitic and Tertiary sedimentary rocks.	Good aquifer present in poorly fractured consolidated deposit.	Poorly consolidated. Not suitable for heavy structure. Prone to be heavy sliding.
Late Eocene to Early Miocene	Crocker Formation	Shale	This unit is composed of two types of shale, red and grey. It is a sequence of alteration of shale with siltstone of very fine.	It has no significant to groundwater development due to its impermeable characteristic.	Very dangerous site for heavy structures and the main caused of mass movement.
		Inter bedded Shale-Sandstone	It is a sequence of interlayering of permeable sandstone with impermeable shale. The permeability of this unit is quite variable. Groundwater in this unit tends to be under semi-confined to confined system.	Little importance to groundwater provides some water but not enough for groundwater development.	Dangerous site for heavy structures and high potential for mass movement.
		Sandstone	Light grey to cream colour, medium to coarse -grained and some time pebbly. It is highly folded, faulted, jointed, fractured occasionally cavernous, surfically oxidized and exhibits spheriodal weathering.	Importance to groundwater.	Good site for heavy structures with careful investigation. Stable from mass movement and provide some modification like closing of continuous structure.
Paleocene to Eocene	Trusmadi Formation	Trusmadi Slate and Trusmadi Phylites	Comprise of dark colour argillaceous rock either in thick bedded or interbedded with thin sandstone beds reported along with isolated exposures of volcanic rock is a common feature of this formation.	Fractured sandstone has significant to groundwater.	Dangerous site for heavy structure. Improvement should be conducted before any project.

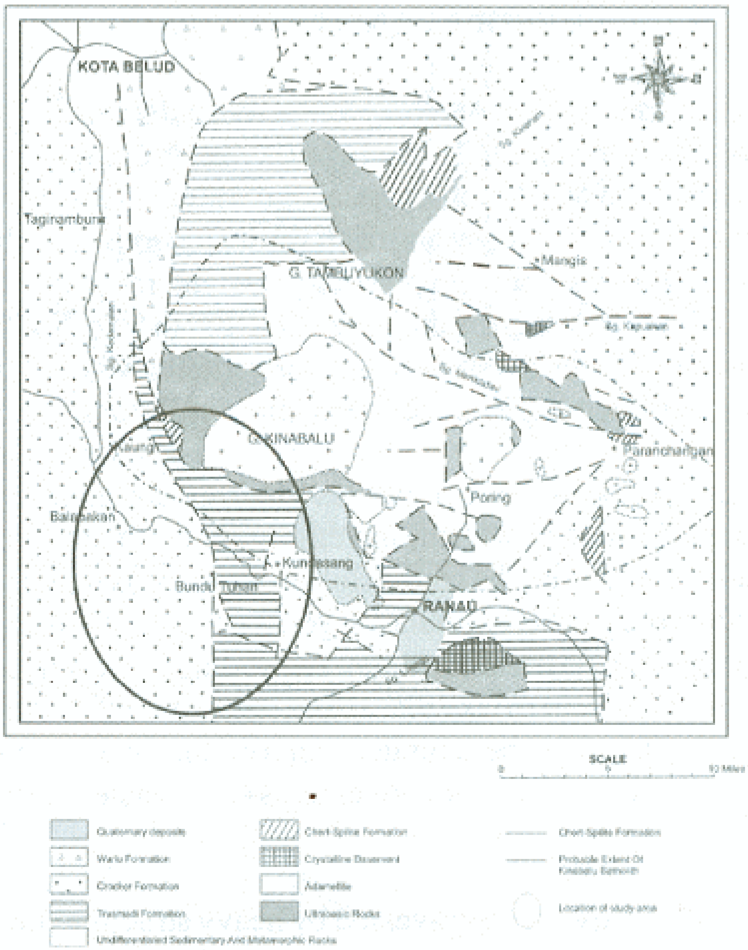

Figure 7. Regional geology map ***(Modified after Jacobson, 1970)***

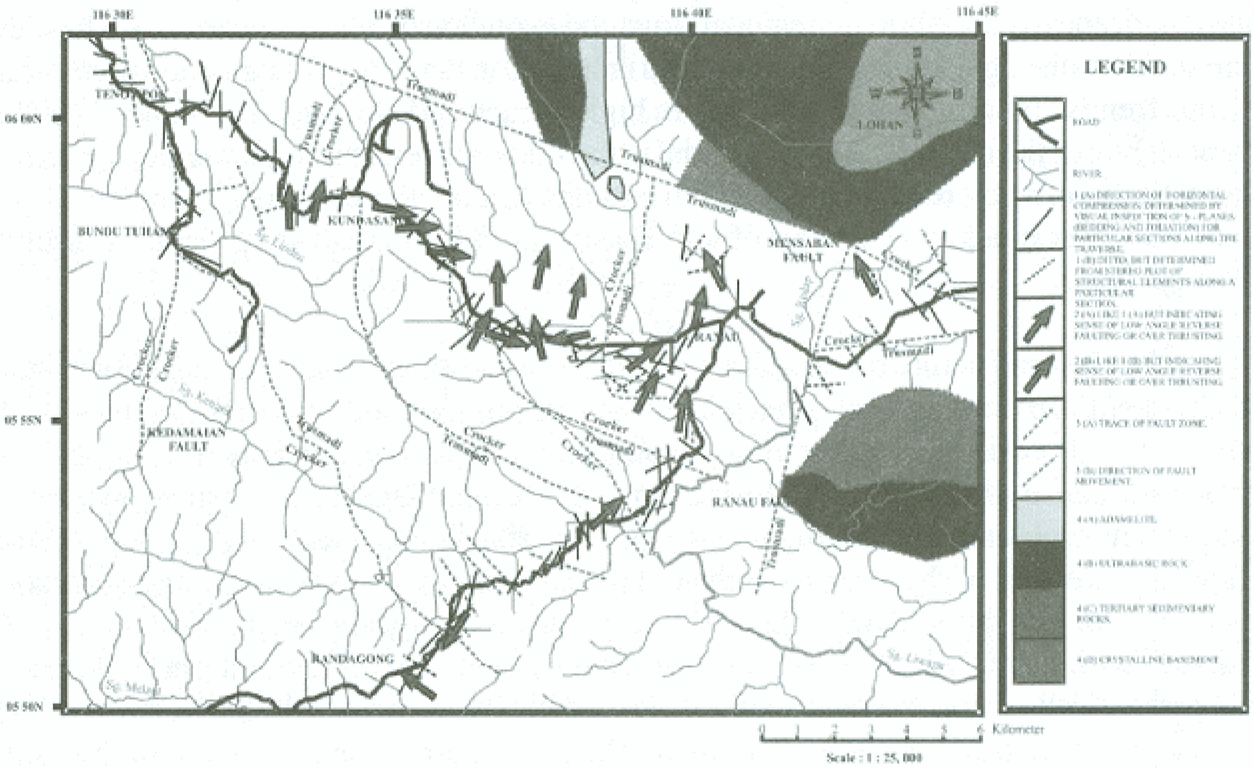

Figure 8. Structural geology map ***(Modified after Tjia, 1974)***

RESULTS AND DISCUSSION

Completed grain size analysis, Atterberg limits, specific gravity, permeability test and triaxial consolidated isotropically undrained (CIU) were conducted to classify and study the physical and engineering characteristics of the sliding material of the area (Figure 9). Data analysis indicated that the sliding materials are mainly consisting of clayey loamy soils. The clayey loamy soils deposit in the study area has low to intermediate plasticity content, medium to very high of degree of swelling (3.76 to 12.67) and low permeability (8.33×10^{-3} to 9.66×10^{-3}). Trixial consolidated isotropically undrained (CIU) results showed that the cohesion value of the soils ranges between from 0.36 to 25.13 and friction angle ranges between from 7.70° to 35.50°.

During the rainy period, water accumulates within the soil grains and this serves to increase the hydrostatic pressure. Therefore, with the increase in water content during the rainy period, the soil cohesion will decrease causing the soil to slide like a viscous liquid. As a corollary to this, in rock bodies, the surface roughness of joints are generally smooth to rough planar. A relatively smooth surface decreases the frictional resistance to sliding at the joints, therefore allowing the possibility of slipping movement to take place. The rainwater infiltrates the soil from the slope areas of the road causing the soil to be saturated, contributing to the decrease in shear resistance of the soil. This consequently allows the movements of the material from the side of the road, further down towards the valley sides.

Geologically, the study area is traversed by heavy structural lineaments produced by a complex tectonic history. An evaluation of the structural lineament distribution shows that the density of structural lineaments in the study area and it's surrounding is high. The geological formations in the study area and it's surrounding have undergone several tectonic events during the Late Oligocene to Late Miocene regional structural evolution of South China basin. These events were shown in the tight folding of interlayered units, and in the serious of thrust and normal fault of various trends and dimension, resulting in highly fractured, deformed, displaced and brittle characteristic of the rocks. The rock material in the study area exhibits high degree of weathering. It may be covered by residual soil, which extends to a depth more than 15 meters. Thus, its engineering properties approach that of soil. These materials are weak and generally cause sliding and subsidence.

The layered nature of the sandstone, siltstone and shale of the Trusmadi Formation and the Crocker Formation in study area may constitute possible sliding surfaces. The sandstone-shale contact is easily accessible by water and such contact seepage may weakened the shale surface and cause slides within the formations. Interbedded sandstone, siltstone and shale may also present problems of settlement and rebound. The magnitude, however, depends on the character and extent of shearing in the shale. The shale units have an adequate strength under dry conditions but lose this strength when it is wet. During the rainy season, the soil becomes highly saturated with water, which increases the water pressure and reduces the shear resistance to sliding specifically within the sandstone – shale contact. This consequently allows the movement of the material from the west side of the road. The upper part of the movement of this slump is downward with common horizontal component. The load of the vehicles and the weight of the

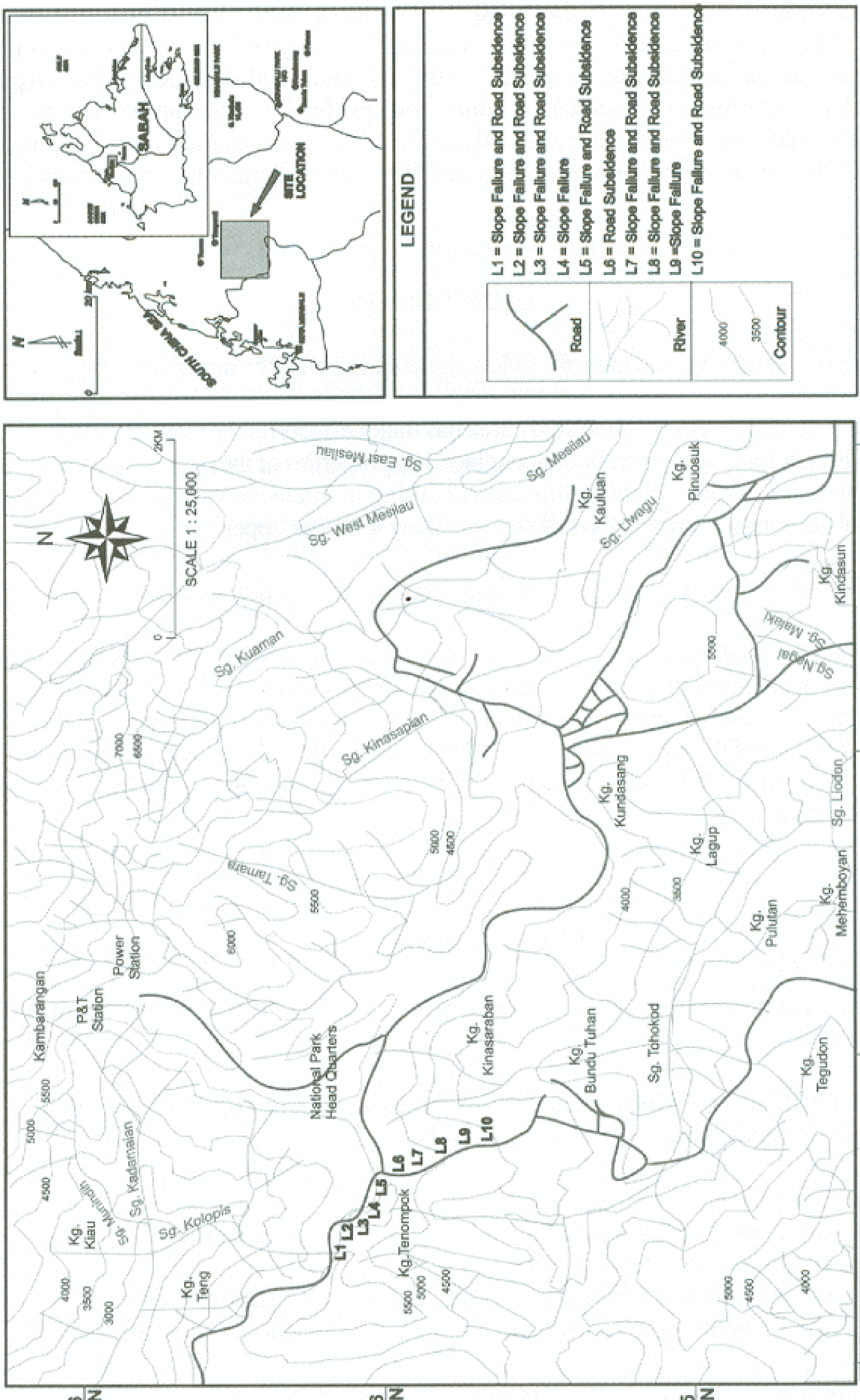

Figure 9. Mass movement location map

back filling material contributed to the driving force. Cracks along the road, and an eastern offset of a part of the road are evidence of quite perceptible downward movement of this portion. Furthermore, along the shear plan (slip surface) the orientation and alignment of the soil particles could take place reducing resistance to sliding, and thus leads to continuity of the movement. Artificial change in the slope gradient, usually due to main structures such as embankment of the road, lead to the increase in steepness of the toe, therefore, rendering the slope unsupported.

CONCLUSION

In light of available information, the following conclusion may be drawn from the present study:

1. The geologic setting of the study area has major effects on the slope stability of the area. This geologic setting reduce the engineering properties of the rock and soil and produces intensive displacement in substrata resulting in intensive weathering processes, and subsequently intensive mass movement along sensitive slopes.

2. The clayey loamy materials in the study area are the specific sites of instability.

3. Landslides take place when slope materials are no longer able to resist the force of gravity. This decrease in shear resistance resulting in mass movements is due either to internal or external causes. Internal causes involve some change in either the physical or the chemical properties of the rock or soil or its water content. External causes that lead to an increase in shear stress on the slope usually involve a form of disturbance that may be either natural or induced.

RECOMMENDATION

To correct or prevent the mass movement in the study area, the following recommendations are proposed:

1. Installation of piezometric and clinometers to monitor seasonal build-ups of pore water pressure and creep movement respectively.

2. Surface drainage, which include:
   a) Sealing off the cracks;
   b) A good vegetation cover;
   c) A good drainage pipe system and gutter system; and
   d) Shotcrete or other means of reducing erosive action of rainwater runoff.

3. Subsurface drainage, i.e. horizontal drainage method.

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