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# Geotechnical and Rock Mass Characterization Using Seismic Refraction Method at Kajang Rock Quarry, Semenyih, Selangor Darul Ehsan

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## ABSTRACT

Rock mass characterization study at the Kajang Rock quarry wasper formed with the use of refraction seismic method. Rock Quality Designation (RQD) can be measured in the field. Discontinuity survey and processing of seismic data determined from 4 locations have been examined in this site. Based on refraction seismic method, velocity of P waves (Vp) can be obtained, and the weathering grade of rock mass has been determined. Location 1 consist of 5 weathering zone with the range of Vp of 200-5400 m/s. Location 2 consist of 4 weathering zone with the Vp range of 600-5600 m/s. Location 3 consist of 4weathering zone with range of Vp of 800-5250 m/s. Location 4consist of 5 weathering grade with the range of Vp of 250-5000m/s. Rock Quality Designation (RQD) Location 1 shows the rock is excellent (98.63%), in Location 2, RQD shows the rock is good(98.38%), in Location 3 RQD shows the rock is excellent(99.03%), in Location 4 RQD shows the rock is excellent(96.43%).

**KEY WORDS:** *Kajang Rock Quarry; Seismic Refraction, RQD.*

## NOMENCLATURE

| | |
|---|---|
| *RQD* | Rock Quality Designation |
| $Vp$ | Velocity of P Wave |
| $Vs$ | Velocity of S Wave |

## 1.0 INTRODUCTION

This study is based on research conducted at the quarry area which located in Kajang Rock quarry, Semenyih (Figure 1) where the quarry is a granite rocks quarry (Figure 2). Kajang Rock Quarry is located in the Semenyih district, Selangor. Kajang Rock quarry position on the map is located at Longitude 02º55,261’ and Latitude 101°50,376'. The quarry is under the auspices of the Rock Kajang Sdn. Bhd. is located in the north of Semenyih district, where the town is a developing area. Semenyih have many parishes quarry, it is visible from many former quarries in the area in the outskirts of town and also in the hill areas of this district.

Lithology in the quarry is granitic type. The study focused on the fresh rock and weathered granite only. Position of the study area is located in the middle line of the granite pluton body then there is only one type of lithology in this area.

Locations surveyed are slopes of a quarry outcrop which are Terrace 2 (SG1 (Location 1) and SG2 (location 2)), Terrace 5 (SG 3 (Location 3)) and terrace 8 (SG4 (Location 4)) (Figure 3). Studies were conducted on the quarry outcrop at the inactivity, which is not operational in the short term.

Geographical condition near the quarry is oil palm plantation. However, a highway was built near the quarry, the road linking the highway Reko, Kajang, Semenyih, Kuala Lumpur and Sungai Long. This highway called Kajang Silk Highway.

### 1.1 Literature Review

Ng ThamFatt (1992a) studied of granite Schleroscope Shore

hardness in the eastern part of Kuala Lumpur, said the hardness (Hs) of the Kuala Lumpur granite is between of values among 85 and 100. Ahya (2007) stated that the granite of Km 14.6 of SILK highway is composed by grade I and I-II and have coarse to medium texture. Ahya also find Rock Quality Designation (RQD) is 87.73%. SerAik Kong (2007) states the granite in Kajang Rock quarry consist of five types of granite, which are medium-coarse-grained porphyry granite, moderately coarse-grained granite, biotite granite, fine grain sheared white granite, clorite sheared granite. Ser centralize analysis of rock mass characterization and rock quality that found this area is starting from very low (V) to very good (I), but most are concentrated in low quality (IV) to moderate (III). Ser also stated that the rock mass classification system based on RMR Bieniawski 1979 found 44% of the rock mass is good quality (class II) and 56% of average quality (Class III).

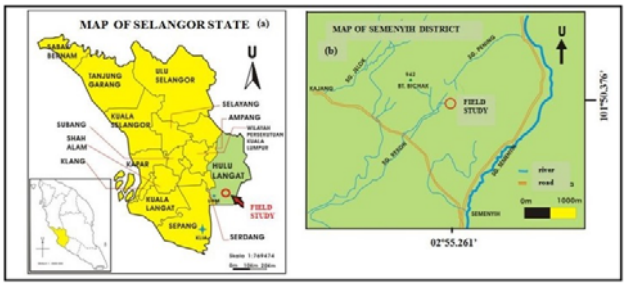


Figure 1: (a) Map of Selangor State shows the field study at Semenyih District, (b) Semenyih District Map; the Field Study.

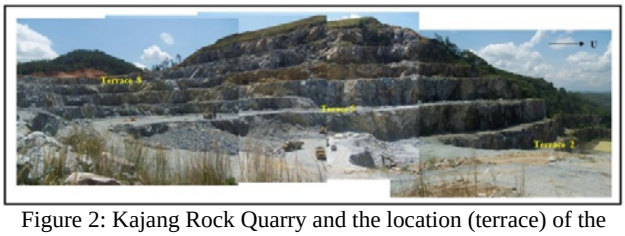

Figure 2: Kajang Rock Quarry and the location (terrace) of the field study.

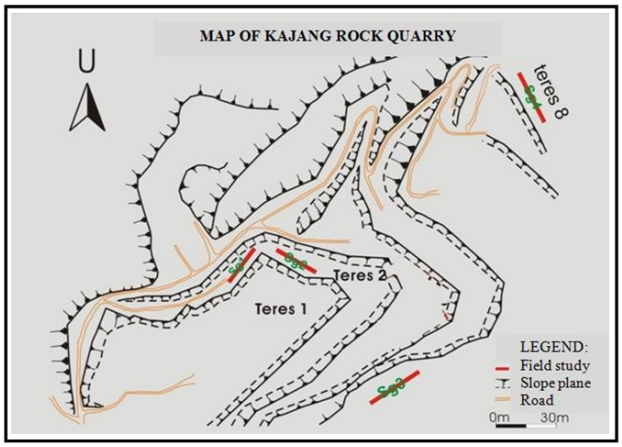


Figure 3: Plan view of field study location (Sg1, Sg2, Sg 3, Sg4), Kajang Rock Quarry, Semenyih (Modified from Ser, 2007).

## 2.0 OBJECTIVE

The main purpose of this study was to determine the effectiveness of refraction seismic methods in the characterization of igneous rock mass. The main objective of this study is:

1. Characterizes the granitic rocks in Kajang Rock quarry using geophysical methods of seismic refraction.
2. Determine the Rock Quality Designation (RQD) for granitic rocks using geophysical methods used in the study area.

Determine the Rock Quality Designation (RQD) on the discontinuity of the granite rock and rock quality indicator to compare the value (RQD) derived from the geophysical method used.

## 3.0 METHODOLOGY

### 3.1Principal of Seismic Method

Method that has been used during the study was determined by seismic refraction methods. The basis of seismic refraction method is based on the wave characterization of optical properties of physics that comply with Snell's Law. In the study of seismic refraction, waves generated by the stress or energy resources as either an explosion or impact hammer is applied to the surface of the earth. Generated waves are then detected by a geophone line on the surface of the earth. Subsequently, the received wave as a signal is sent to the seismograph to be displayed as seismic signals or seismic waves. Seismic method is using artificial seismic wave through the earth to obtain certain information which identify the nature of the earth with the ability to send a wave nature. This method is commonly used to identify the depth of bedrock, slope of the bedrock, the depth of groundwater levels, in certain circumstances, the general lithology. The use of seismology has been rapid in the petroleum and natural gas, where use of the seismic refraction method almost exclusively.

The tools that are used for seismic studies in the area is: Equipment Terraloc ABEM Mark 6, 24 geophone, two connection cables 12 button, hammer, HITACHI Battery HG44-12 (12V, 44Ah) and battery charger, steel plates, compass for measure the direction of survey lines.

A total of four line survey was carried out with long range is 69 meters each. A total of 24 geophone arranged in a straight line profile with the distance between the geophone is 3m. Battery will be used to supply current and operate the equipment, the ABEM Terraloc Mark 6. Each line profile has carried out seven times the emission wavelength on the relative distances specified (Table 1). The source wave generated from the hammer on a piece of steel plate with a vertical shock.

Table 1: Configuration of shock causes from the first geophone.

| No. of Shock | Distance (Meter) |
|---|---|
| 1 | -10 |
| 2 | 1.5 |
| 3 | 6.5 |
| 4 | 34.5 |

### 3.2 Rock Quality Designation (RQD)

Calculation of RQD values in the field can be obtained by the discontinuity survey techniques because these techniques more systematically. Based on this technique, the scanning line is made on outcrop horizontally and vertically. Vertical scan line is made in the intervening at several meters and perpendicular to the horizontal scan lines. Interval width depends on the density of the discontinuity sets to obtain the required data as shown in Figure 4.

Figure 4: Line of discontinuity in vertical scanning survey.

## 4.0 RESULT AND DISCUSSION

### 4.1 Thickness Profile

Vp and Vs velocity and thickness profiles obtained from the testing method of seismic refraction (Vp) expressed for each layer of rock in all study areas. Vp velocity granitic rocks can show their level of weathering of the rock layer in the table of weathered granite rock mass in peninsular Malaysia by Rafiqul Islam @ Zaw Win, 2005 (Table 2). Seismic surveys started with the line located on the second terrace closest to the quarry floor. Results obtained have shown there are five zones of weathered granite, which is divided by the range of refractive wave velocity (Vp).

Table 2: Weathered granite rock mass classification in peninsular Malaysia. (Source: Extracted and adapted from Islamic Rofiqul @ Zaw Win 2005).

| Weathered Grade | P Wave Velocity ($ms^{-1}$) | Explanation |
|---|---|---|
| VI and V | 300-900 | Residual soil and overall weathered |
| IV | 900-1500 | Highlyweathered |
| III | 1500-2500 | Moderatelyweathered |
| II | 2500-4000 | Slightlyweathered |
| I | 4000-6000 | Freshrock |

### 4.2 Profile of Location 1

Study of seismic refraction survey for location1 found the Zone 5 as the closest zone to the surface. From recorded Vp velocity, the range of Vp is from 200-800 m/s consisting of residual soils and completely weathered granite. This zone is classified as a zone of weathering grade VI to V and the thickness was varied from 2 to 7 meters from the surface. Zone 4 is beneath of zone 5. Consist of weathered granitic rocks high, Grade IV. Vp velocities recorded ranged from 800-1500 m/s. This zone begins at a depth of 2-7 meters from the surface and the thickness range from 2-4 meters. The third zone consists of weathered granitic rocks of medium-grade III with a Vp velocity 1500-2500 m/s. The second zone beneath of slightly weathered granite rocks which have a Vp velocity 2500-4000 m/s and has a thickness of 2-3 meters. Which is the bedrock of the first zone is detected at a depth of Location 5 meters to 8 meters (maximum depth that can be detected), which has a Vp velocity range of 4000-5400 m/s and grade I. (Figure 5 and Figure 6).

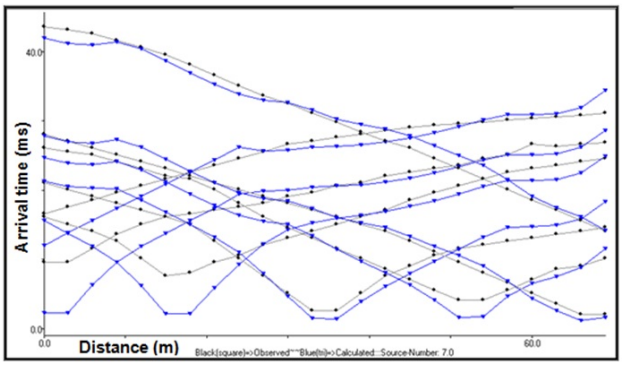


Figure 5: First arrival time graphic at Location 1 (blue is the point used and black point thought by SeisOpt2D).

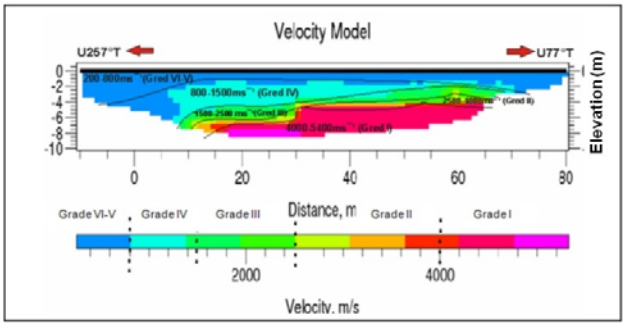


Figure 6: 2D of Vp model from refraction seismic with rock weathering grade and layer depth at Location 1.

### 4.3 Profile of Location 2

Study of seismic refraction survey for location 2 was also conducted on the same terrace with Location 1 and the position is N274ºE – N94ºE. According to Figure 7 there are four zones of the granite weathering can be observed.

Top zone of the four recorded velocity zone Vp ranges from 600-1100 m/s consists of completely weathered granite to highly weathered (grade V-IV). This zone has a thickness range from 1 to 10 meters. The third zone consist of moderately weathered to

slightly weathered based on the record of velocity Vp range from1100-1700 m/s. This zone thickness is 2 to 5 meters. Zone beneath isthe zone consist of two materials with Vp velocity range from 1700-4000 m/s of the weathered rock grade III to II (moderate to slight). Fresh granite rock zone grade I was detected starting at a depth of 5 meters with a velocity Vp range from 4000-5600 m/s which is in zone one (Figure 7 and Figure 8).

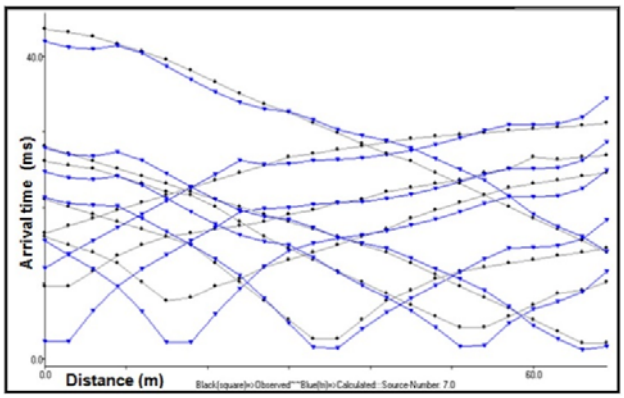


Figure 7: First arrival time graphic at Location 2 (blue is the point used and black point thought by SeisOpt2D).

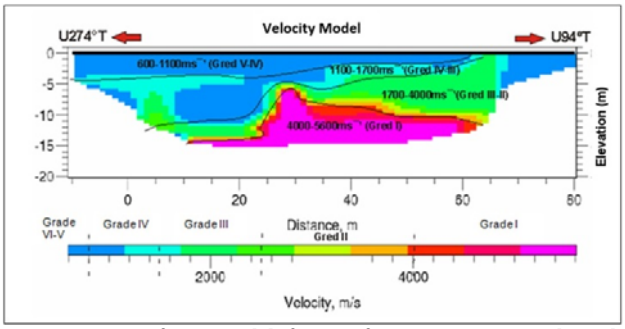


Figure 8: 2D of Vp model from refraction seismic with rock weathering grade and layer depth at Location 2.

**4.4 Profile of Location 3**

Seismic refraction survey line for Location 3 is on the N465ºE-N226ºE. Seismic 2D profile (Figure 9 and Figure 10) shows that there are four zones of weathered granite.

Zone at the top of Location 3 has a Vp velocity range 800-1500 m/s, it can be interpreted as a zone of weathered granite at grade IV. The thickness of this zone is about 2 meters. Layer underneath has three zones of granitic rocks as the moderate weathered (grade III) with velocity Vp range 1500-2500 m/s and this zone was also detected at a depth of 10 meters below the zone of higher velocity. The thickness of this zone about 3-7 meters. The second zone consists of slightly weathered granite or grade II. Recorded velocity Vp range is 2500-4000 m/s and the thickness about 2-10 meters. Zone beneath which is the most basic zone is a zone consisting of fresh granite rock that can be detected starting at the depth of 8 meters and recorded Vp velocity range at 4000-5250 m/s.

**4.5 Profile of Location 4**

The fourth seismic survey line (Figure 11 and Figure 12) was conducted on the highest terrace, the terrace8 N291ºE – N111ºE

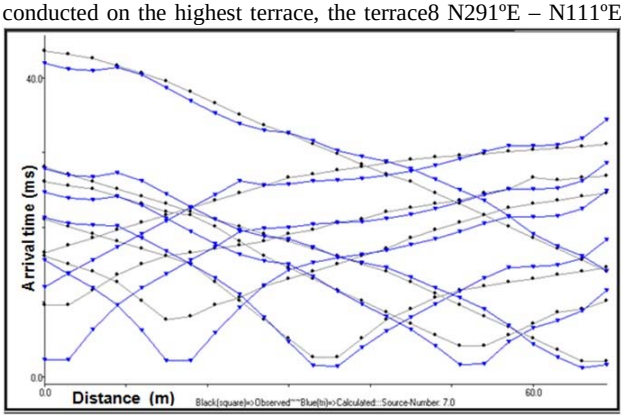


Figure 9: First arrival time graphic at Location 3 (blue is the point used and black point thought by SeisOpt2D).

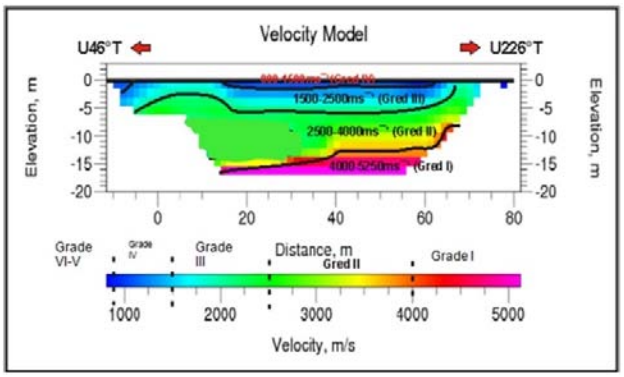


Figure 10: 2D of Vp model from refraction seismic with rock weathering grade and layer depth at Location 3.

directional. 2D seismic section of the five zones of the weathering of granite can be classified.

Top zone is the residual soil grade VI to the overall weathered grade V. This zone has the thickness ranging from 2 to 7 meters and the velocity Vp ranges from 250-800 m/s. At the bottom layer of the fourth zone is a zone of thin granite (1-3meters), which suffered severe weathering of granite grade IV. Vp velocity recorded was 800-1500 m/s. Underneath, there are three zones of weathered granite zone with grade III at 2-4 meters average thickness. Vp velocity range 1500-2500 m/s were recorded. Zone consist of two slightly weathered granite and relatively thick (4-12 meters) recorded Vp velocity range from 2500-4000 m/s. Zone of fresh granite (Grade I) was detected at the depth of 7 meters which looks like a large block with 15 meters thick and this zone is marked as zone one. Vp velocity recorded in this zone is 4000 to 5000 m/s.

**4.6 Profile of Rock Quality Designation (RQD)**

To obtain more effective RQD discontinuity a total of four discontinuity survey conducted in the study area. RQD discontinuity value obtained 98.63%, 98.38%, 99.03% and 96.43% and has very good rock mass quality standard in accordance with Deere (1968). During the survey, the discontinuity is the existence of very hard soil and weathered rock on the depth of 0.0-0.1 m. At the depth of 0.1-7.4 m, it is

composed of fresh and a few weathered granite rocks.

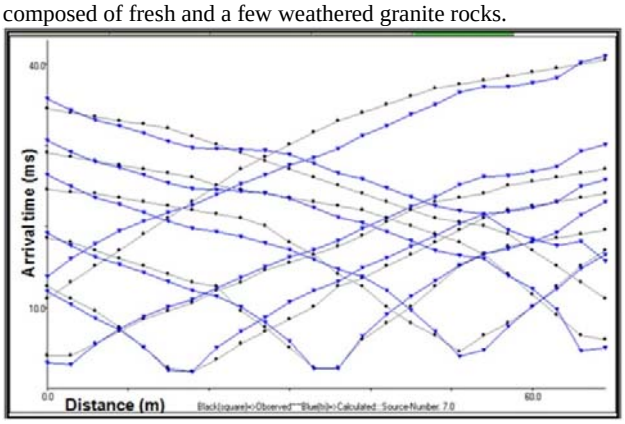


Figure 11: First arrival time graphic at Location 4 (blue is the point used and black point thought by SeisOpt2D).

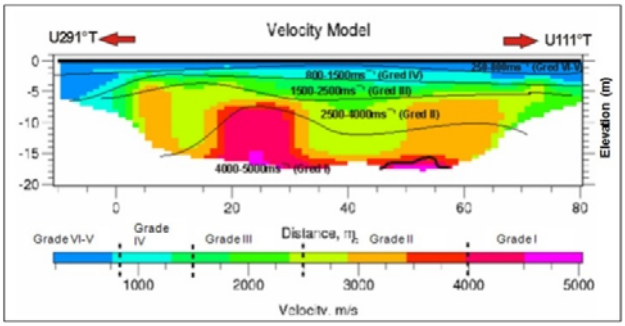


Figure 12: 2D of Vp model from refraction seismic with rock weathering grade and layer depth at Location 4.

**4.7 Layer Formation and Weathering Zone Interpretation**

Based on P-wave velocity (Vp), which was obtained from Kajang Rock Quarry, most layer or zone recorded a non-uniform velocity along the survey lines. Vp has a certain range of velocities for each layer or zone in rock mass while at the same depth. This shown the layer of rock is not homogeneous due to the distribution and mineral content of rocks is not uniform even consists of a kind and is at the same depth. Vp velocity in the rock mass in the field is also heavily influenced by other factors such as the existence of cracks and squat (particularly in granitic rocks), porosity and ground water conditions.

Many of weathered zones layer and recorded for each line based on the velocity Vp survey showed decreasing weathering grade of rock depth although incomplete grade sequence. Since the process occurs with the active chemical weathering in the study area, located in hot and humid climates, the surface exposed to moisture and air will have a significant effect and this effect is decreasing in the deeper parts. Thus, with reference to the results obtained, grade VI residual soil and weathered rock are severe grade V at the very top or surface layer exposed. Grade VI residual soil has a velocity Vp less than 300 m/s while the Vp velocity of grade V ranged from 300-800 m/s. In term of applications in engineering and construction as the geotechnical and rock mass information, this section is the easiest to use tractor-dug D-9 (Caterpillar Tractor Company, 1988) and can also be broken using shovels, tractor, scraper, shovel and dredge loading without having first blown up (Atkinson, 1971).

Base on the observation the thickness of the weathered zone layer range from 2 to 15 meters (excluding fresh rock or grade I). The thickness of this layer is important to determine whether the type of weathering suffered or not, and erosion rate can also be determined. Therefore, the weathered layer thickness range as specified above, it can be interpreted that three study areas did not suffer because of weathering and erosion rate are high. This erosion rate is closely related to the slope of the topography and climate condition at the area. A steeper slope will increase the rate of erosion and transport of weathered material. Therefore, the formation does not occur because of weathering in the weathered material is transported rapidly to other areas. No specific classification to assess whether this study area have weathered or not but this interpretation is based on a comparison relative to other areas.

In summary, the relationship between Vp values obtained with the grade of weathering in each area of study can be summarized as in Table 3.

Table 3: Relationship between P wave velocity and rock weathering grade obtained in Kajang Rock Quarry, Semenyih.

| Velocity of P waves ($ms^{-1}$) | Rock Weathered Grade |
|---|---|
| 200-800 | VI-V |
| 800-1500 | IV |
| 1500-2500 | III |
| 2500-4000 | II |
| 4000-5600 | I |

**5.0 CONLUSION**

Based on seismic refraction method Location 1 has 5 weathered granite zones which consist of grades VI-V, the fourth zone is grade IV. The third zone consists of moderate weathered granite rocks (grade III).The second zone of weathered granite rocksis a few and has a thickness of 2-3 meters. The last zone is found at a depth of 5-8 meters and grade I. On average, the value of fresh granitic rocks RQD survey line is 98.63%.

Location 2 has 4 weathered granite zones which consists of grades VI-V (1-10) meters from the surface, the third zone is weathered granite rocks of the medium to low and the thickness is 2-5 meters. The second zone consists of weathered rock grade III to II, the first zone was detected starting at a depth of 5 meters which consists of slightly weathered granitic rocks and has a thickness of 2-3 meters. The last zone is found at a depth of 5-8 meters and grade I. On average, the value of fresh granitic rocks RQD survey line is 98.38%.

Location 3 has 4 zones of weathered granite. The fourth zone consists of grade IV and thickness of 2 meters. Zone three consists of granite rocks that have moderate weathering (grade III) and detected at the depth of 10 meters. The second zone consists of slightly weathered granite (grade II) and the thickness is 2-10 meters. Zone one consists of a fresh granite rocks that can be detected starting at a depth of 8 meters. On average, the value of fresh granitic rocks PMB survey line is 99.03%.

Location 4 has 5 zones weathered granite. Zone 4 consists of grade VI residual soils and overall weathered or grade V. This zone has a thickness range from 2 to 7 meters. Zone 4 has thin granite (1-3 meters) which suffered severe weathering of grade IV.

Zone 3 is the zone of grade III at 2-4 meter average thickness. Zone 2 consists of slightly weathered granite and relatively thick (4-12 meters). Zone of fresh granite (Grade I) was first detected at the depth of 7 meters which looks like a large block along about 15 meters and this zone is marked as zone one. On average, the value of fresh granitic rocks PMB survey line is 96.43%.

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