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Determination layer of meta-sediment rock using seismic refraction survey at the vicinity of Alor Gajah town, Melaka, Peninsular Malaysia

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ABSTRACT

A geophysical survey using seismic refraction technique was carried out at vicinity of Alor Gajah town, Melaka with the aim to characterize the subsurface materials based on seismic P-wave velocities as well to determine boundary between layer of soil and rock. The geology of study area consists of slate, phyllite to schist and limestone, with minor intercalations of sandstone and volcanics belong to the Ordovician to Silurian age. Seismic surveys were carried out using ABEM Terraloc MK6 24-channel seismic as a recording seismograph, and 24 units of 14Hz-frequency geophones 'to record the incoming seismic waves. The data were processed using SeisOPT software to produce sections of 2D velocity model profiles. Results show three layers of material can be interpreted based on seismic velocity values. The first layer with seismic P-wave velocities less than 1,000 m/s indicates top soil, fill material or heavily weathered and/or decomposed rock, while the second layer with velocities ranges between 1,000 m/s until 2,000 m/s indicate as a rock with varying degrees of weathering and/or fracturing. The third layer with velocities in excess of 2,000 m/s indicates fresh bedrock. The boundary between first and second layer is almost flat pattern and can be observed at around 1 m until 5 m depth, while boundary between second and third layer is obviously in irregular pattern with depth varying from 5 m until 20 m.

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1. Introduction

The seismic refraction method is one geophysical technique which is frequently used to determine the characteristics of soils and rocks (Sjøgren et al., 1979; Hamzah and Samsudin, 2006). It application can be used to determine rock competence for engineering application such as excavation capability, depth to bedrock, groundwater exploration, crustal structure and tectonics (Kilner et al., 2005; Varughese et al., 2011).

This paper presents the result of the seismic refraction survey at the site area near Alor Gajah Town, Melaka. This study was conducted with the ultimate objective to capture the subsurface profile in order to determine boundary between over burden soil and rock layer at few site areas near Alor Gajah Town Melaka. It is anticipate that the result will provide detail information about soil and rock boundary or depth to bedrock.

2. The study area and general geology

The study area is located at Alor Gajah town, Melaka (Fig. 1). There are four area around Alor Gajah Town was proposed to conduct the seismic survey. The first and second areas located at Sekolah Menengah Kebangsaan Dato' Dol Said and Masjid Al Aman Qariah Kelemak.

Fig. 1: The location of the study area at Alor Gajah Melaka

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The study area in Fig. 1, is located about 20 km from Masjid Tanah Melaka, and near to Express North-south Highway.

The third area is along Jalan Kelemak Jaya which is located at Taman Kelemak Jaya, and the fourth area is at the junction of Jalan Perindustrian Alor Gajah and Jalan Dol Said (Fig. 2).

The geology of Alor Gajah area is covered by sedimentary rock that exposed to metamorphic process due to Main Range Granite intrusion. The rocks are varying from slate, phyllite to schist and limestone, with minor intercalations of sandstone and volcanics. But the major rock occurrence is schist which is range from quart mica schist to quartz schist. The country rocks belong to the Ordovician to Silurian age.

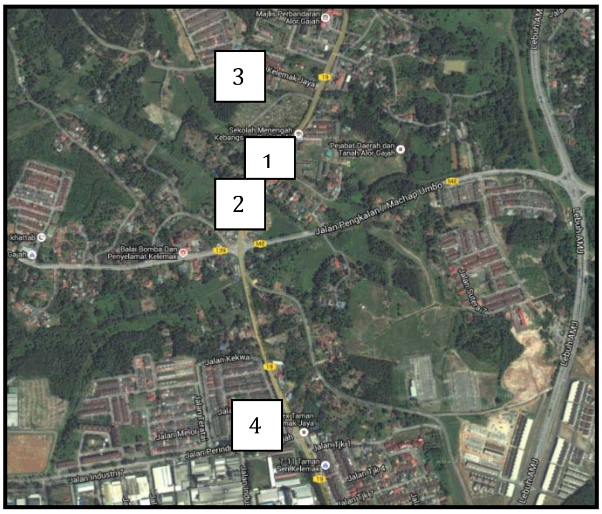


Fig. 2: The satellite image shows the location of site that we conduct the seismic survey

3. Methodology

An extensive review of seismic refraction techniques has been given by Haeni (1986). The review highlights the major use of refraction seismic to map the depth and geometry of bedrock surface underlying unconsolidated (drift) sediment.

3.1. Data acquisition

Seismic methods are commonly used in shallow depth investigations. The seismic refraction method is based on the measurement of the travel time of seismic waves refracted at the interfaces between subsurface layers of different velocity created by hitting a steel plate with a hammer on surface. Energy radiates out from the shot point, either travelling directly through the upper layer (direct arrivals), or travelling down to and then laterally along higher velocity layers (refracted arrivals) before returning to the surface. This energy is detected on surface using a linear array (or spread) of geophones spaced at 5.0 m intervals. Data are recorded on a seismograph and later downloaded to computer for analysis of the first-arrival times to the geophones from each shot position.

3.2. The Equipment

ABEM Terraloc MK6 24-channel seismic recording equipment was used in this survey. Geophone interval was set at 5.0 m. During the survey, the P wave travel times were considered. First arrivals to each geophone are marked and extracted from the data. Commercial package, SeisOPT was used to evaluate the data. The result of 2D inversion for each profile reveals horizontal and vertical velocity variations of subsurface.

3.3. Data processing

The seismic survey was conducted by create 7 individual shots at certain distance along the survey line. Seven shot locations were done at 120 m, 112.5 m, 87.5 m, 57.5m, 27.5m, 2.5m and -5.0m. Each shot locations will produce graph of wiggle traces which is displaying travel time of wave against distance. It means for one seismic survey line, we have seven seismic time-distance graphs. In our study, we have 6 lines of seismic survey which is give the total number of graph need to process is 42 graphs.

We manually picked the first time-arrival from seven seismic time-distance graphs and tabulated it into excel software. By combining seven time-distance graphs and first-arrival reading collected from each graphs, we established the whole view of segmentation of survey line to calculate the velocity for each layer and their thickness. The values of velocities and thickness of every electrode point was inserted into SeisOPT software. It purposed is to generate the pattern of graph and layers of the soil profile. The examples of seismograph, first time arrival, segmentation of first time P-wave arrival and result using SeisOPT software were depicted at Figs. 3, 4, 5 and 6.

4. Line survey distribution

The area at the Masjid Al Aman Qariah Kelemak was representing by line SAG1 and SAG5. The orientation of survey line for line SAG1 and SAG5 both is almost southwest to northeast. The first geophone of line SAG1a is located at the southwest, while last geophone marked as SAG1b is located at the northeast. Differ with line SAG5, the allocation of first geophone SAG5a is on northeast, while last geophone marked as SAG5b is on southwest.

The line seismic in the area of Sekolah Menengah Kebangsaan Dato' Dol Said was marked as SAG3 and SAG4. These two lines is almost perpendicular each other. Line SAG3 is northeast to southwest direction, where the first geophone or point SAG3a is located at the northeast and last geophone which is marked as SAG3b is located at the southwest. The line SAG4 is orientated almost southwest to northeast. The point SAG4a is located at the northwest and point SAG4b is on the southeast (Fig. 7).

The line SAG2 is located along Jalan Kelemak Jaya at Taman Kelemak Jaya. It was aligned almost southeast to northwest. The first geophone or point SAG2a is located at the southeast, while point SAG2b is on the northwest (Fig. 8). The line SAG6 is located at the junction of Jalan Perindustrian Alor Gajah and Jalan Dol Said. It was aligned almost southeast to northwest. Point SAG6a is located at the southeast, while point SAG6B is on the northwest (Fig. 9).

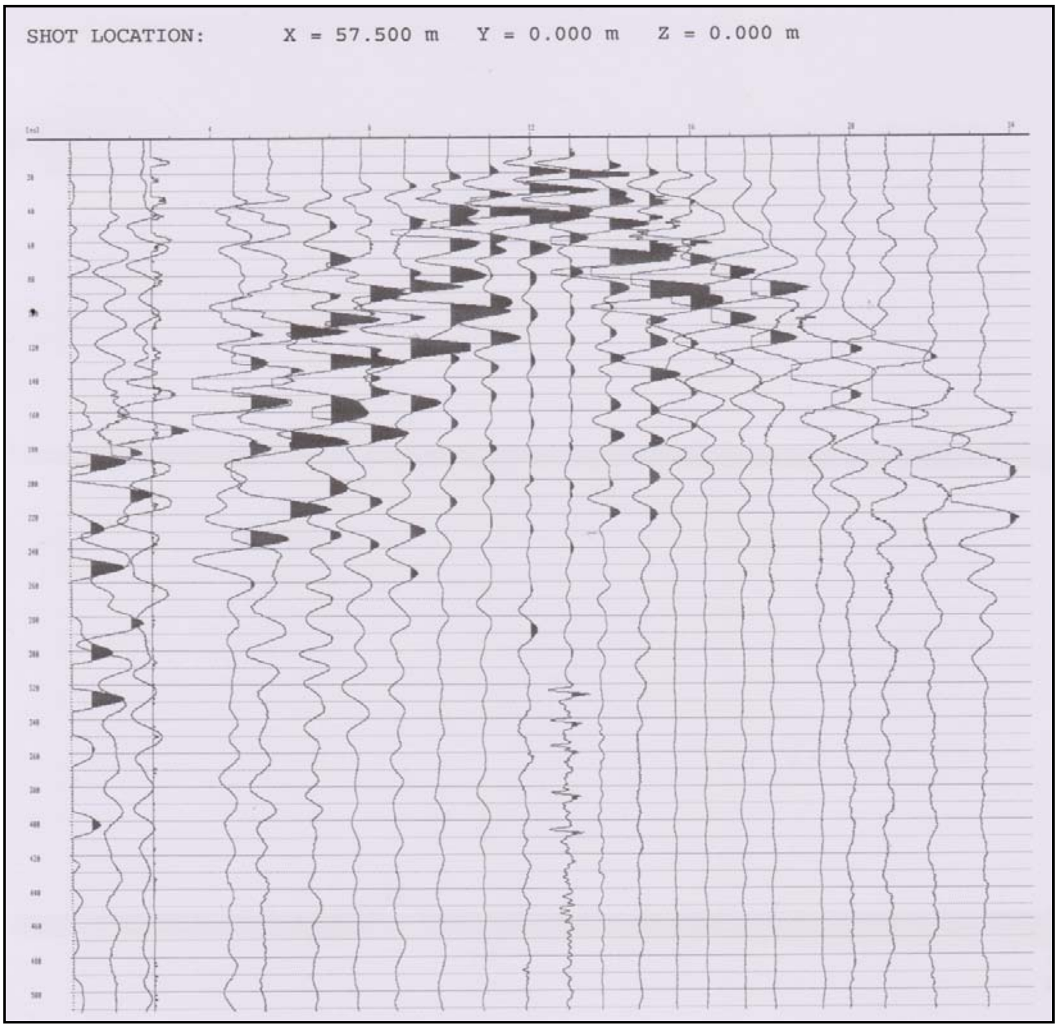


Fig. 3: The seismograph adopted from data acquisition on site

Geophone	Shot Position													
	-0.5 m		2.5 m		27.5 m		57.5 m		87.5 m		112.5 m		120 m	
	X	t	x	t	x	t	x	t	x	t	x	t	x	t
1	0	6	0	6	0	26	0	38	0	50	0	58	0	58
2	5	10	5	4	5	23	5	37	5	49	5	57	5	57
3	10	12	10	6	10	20	10	36	10	47	10	56	10	56
4	15	14	15	8	15	16	15	35	15	46	15	55	15	55
5	20	20	20	16	20	8	20	31	20	44	20	54	20	54
6	25	23	25	22	25	4	25	29	25	42	25	52	25	53
7	30	27	30	26	30	3	30	28	30	40	30	51	30	51
8	35	29	35	30	35	5	35	26	35	38	35	49	35	49
9	40	31	40	32	40	12	40	24	40	35	40	47	40	47
10	45	34	45	34	45	17	45	18	45	33	45	46	45	45
11	50	35	50	35	50	22	50	15	50	30	50	44	50	44
12	55	38	55	36	55	24	55	6	55	26	55	43	55	43
13	60	39	60	37	60	25	60	6	60	24	60	38	60	39
14	65	41	65	38	65	27	65	12	65	21	65	35	65	37
15	70	42	70	39	70	29	70	15	70	17	70	30	70	35
16	75	43	75	40	75	31	75	17	75	14	75	28	75	33
17	80	45	80	41	80	32	80	20	80	8	80	26	80	32
18	85	46	85	42	85	34	85	23	85	5	85	25	85	29
19	90	48	90	43	90	36	90	26	90	4	90	24	90	27
20	95	50	95	44	95	38	95	28	95	8	95	16	95	25
21	100	52	100	46	100	40	100	30	100	13	100	11	100	18
22	105	53	105	47	105	42	105	32	105	18	105	7	105	14
23	110	54	110	49	110	44	110	35	110	21	110	4	110	9
24	115	56	115	51	115	46	115	37	115	25	115	4	115	6

Fig. 4: The first time P-wave arrival pick up from seismograph

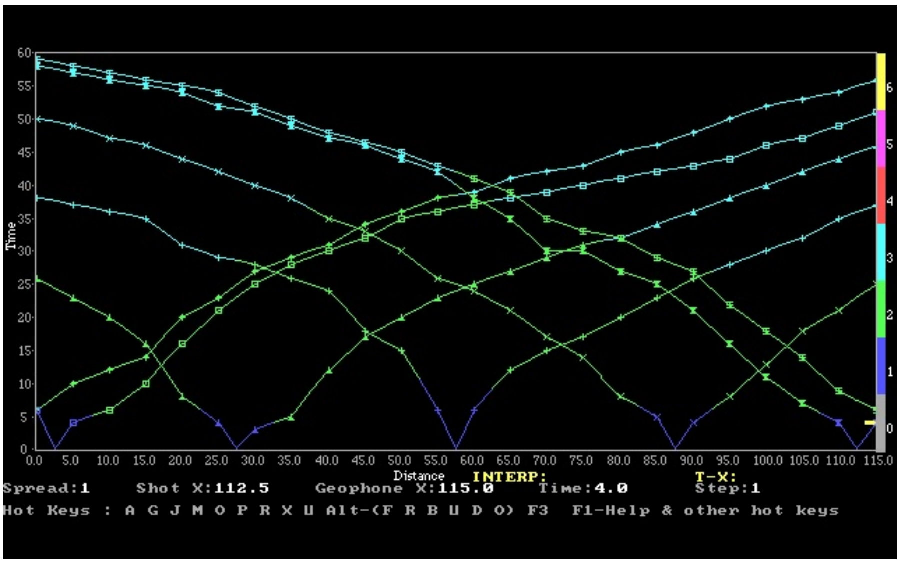
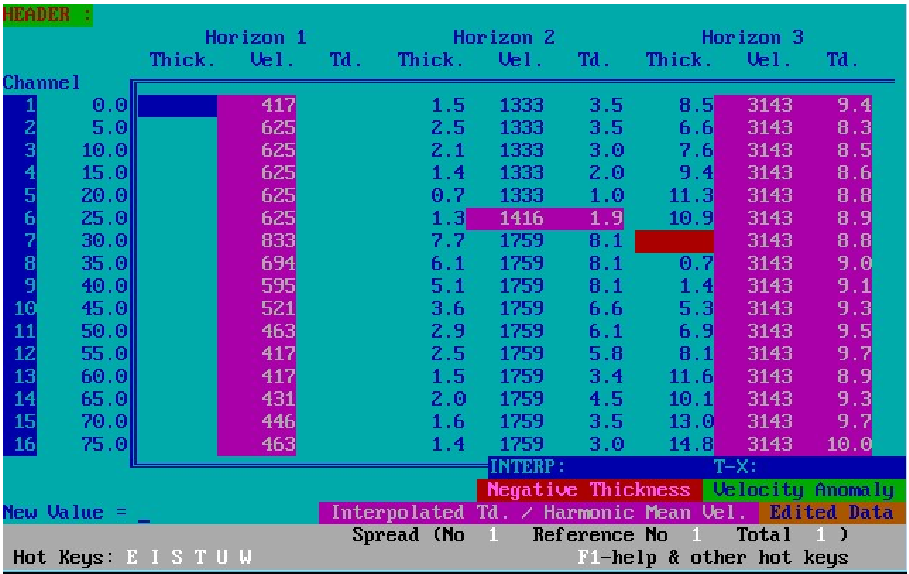


Fig. 5: The whole view of segmentation of survey line to calculate the velocity for each layer and their thickness



HEADER :

Channel		Horizon 1 Thick.	Horizon 1 Vel.	Horizon 1 Td.	Horizon 2 Thick.	Horizon 2 Vel.	Horizon 2 Td.	Horizon 3 Thick.	Horizon 3 Vel.	Horizon 3 Td.
1	0.0		417		1.5	1333	3.5	8.5	3143	9.4
2	5.0		625		2.5	1333	3.5	6.6	3143	8.3
3	10.0		625		2.1	1333	3.0	7.6	3143	8.5
4	15.0		625		1.4	1333	2.0	9.4	3143	8.6
5	20.0		625		0.7	1333	1.0	11.3	3143	8.8
6	25.0		625		1.3	1416	1.9	10.9	3143	8.9
7	30.0		833		7.7	1759	8.1		3143	8.8
8	35.0		694		6.1	1759	8.1	0.7	3143	9.0
9	40.0		595		5.1	1759	8.1	1.4	3143	9.1
10	45.0		521		3.6	1759	6.6	5.3	3143	9.3
11	50.0		463		2.9	1759	6.1	6.9	3143	9.5
12	55.0		417		2.5	1759	5.8	8.1	3143	9.7
13	60.0		417		1.5	1759	3.4	11.6	3143	8.9
14	65.0		431		2.0	1759	4.5	10.1	3143	9.3
15	70.0		446		1.6	1759	3.5	13.0	3143	9.7
16	75.0		463		1.4	1759	3.0	14.8	3143	10.0

INTERP: T-X:
Negative Thickness Velocity Anomaly
New Value = _ Interpolated Td. / Harmonic Mean Vel. Edited Data
Spread (No 1 Reference No 1 Total 1)
Hot Keys: E I S T U W F1-help & other hot keys

Fig. 6: The values of velocities and thickness of every electrode point was inserted into SeisOPT software

Fig. 7: The alignment of line SAG1, SAG3, SAG4 and SAG5 at Masjid Al Aman Kelemak and Sekolah Menengah Kebangsaan Dato' Dol Said

5. Result of seismic survey

In our study, three layer of rock was identified based on seismic velocities value. We considered seismic P-wave velocities less than 1,000 m/s indicates top soil, fill material or heavily weathered and/or decomposed rock, while velocities in excess of 2,000 m/s indicate fresh bedrock (essentially non-weathered of schist but has good foliation) rock (Weaver, 1975). Seismic velocities between these two values indicate as a rock but with varying degrees of weathering and/or fracturing.

Fig. 8: The location and alignment of line SAG2 which is located along Jalan Kelemak Jaya

5.1. Result of seismic line SAG1

Fig. 10 shows a subsurface velocity model and depth of line SAG1. The subsurface profile shows velocity variation in the first layer from as low as 417 m/s until 833 m/s with depth range from 0.7 m until 7.7 m. This velocity is correspond to soft material consists of soil and fill material or heavily weathered rock. The second layer which located at depth range from 0.7 m until 19.5 m with velocity ranging from 1,266 m/s until 1,759 m/s correspond to rock with varying degrees of weathering. The third layer has the velocity value is about 3,143 m/s. This layer is located well beyond 10.0 m upon which the layer 2 is conformably laid. This layer is classified as fresh bedrock with essentially non-weathering.

Fig. 9: The location of line SAG6 which is located at the junction of Jalan Perindustrian Alor Gajah and Jalan Dol Said

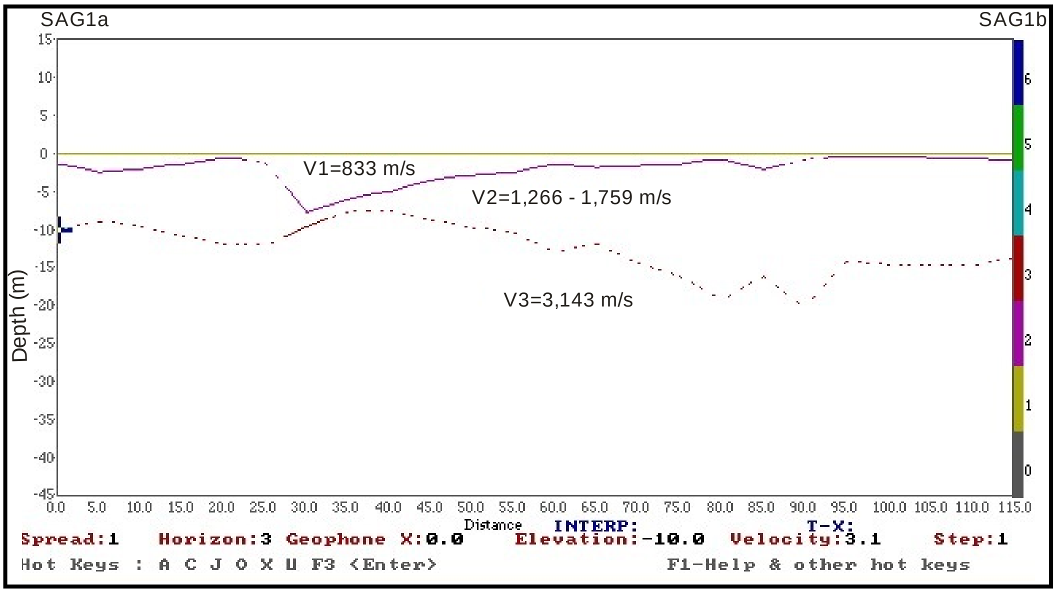


Fig. 10: The subsurface profile for line SAG1 shows velocities of each layer

5.2. Result of seismic line SAG2

The line SAG2 has recorded the maximum velocity of first layer is 833 m/s. It has almost constant depth placed at between 2 m – 6 m. This layer is corresponded to soil and fill material or heavily weathered rock. The velocity of second layer is about 1,850 m/s. This velocity values is detected from 0 m to 95.0 m along survey line SAG2. This layer is very thick about 25 m in average. It could be class as a less weathered rock. The third layer has the velocity value is about 2,057 m/s. This layer is located well beyond 30.0 m upon which the second layer is conformably laid. This layer is corresponding to fresh schist (Fig. 11).

5.3. Result of seismic line SAG3

The range of velocity for first layer of line SAG3 is between 417 m/s until 625 m/s. The layer modelled thickness is placed at between 0.3 – 3.0 m. This layer is corresponded to topsoil or fill material or highly weathered rock. This is grossly loose but stable. The second layer has the velocities range between 1,351 m/s until 1,574m/s. The velocity is 1,351 m/s was detected from 0 m to 20.0 m of survey line. The velocity of material started from 20.0 m until 90.0 m is 1,574 m/s, while from 90.0 until 115.0 m of survey line it has velocity value at 1,307 m/s. This values is correspond to highly weathered rock. The velocity of third layer is about 2,263 m/s. This layer is located well beyond 10.0 to 15 m upon which the layer 2 is conformably laid. This layer is corresponding to fresh schist as bedrock (Fig. 12).

5.4. Result of seismic line SAG4

The result of seismic survey of line SAG4 revealed a subsurface structure consists of three layers; the first layer is topsoil or decomposed rock with seismic velocity ranges from 417 m/s until 833 m/s and maximum thickness reach 3.7 m only. The seismic velocity in the second layer is recorded constant at 1,912 m/s. The velocity show the same value started from first geophone (0 meter) until 115 m, indicating as a less weathered rock of schist. It was observed has an irregular boundary with third layer with depth ranges from 10.0 m until 25.0 m.

The fresh bedrock of schist as third layer is observed below second layer with seismic velocity constant at 2,558 m/s (Fig. 13).

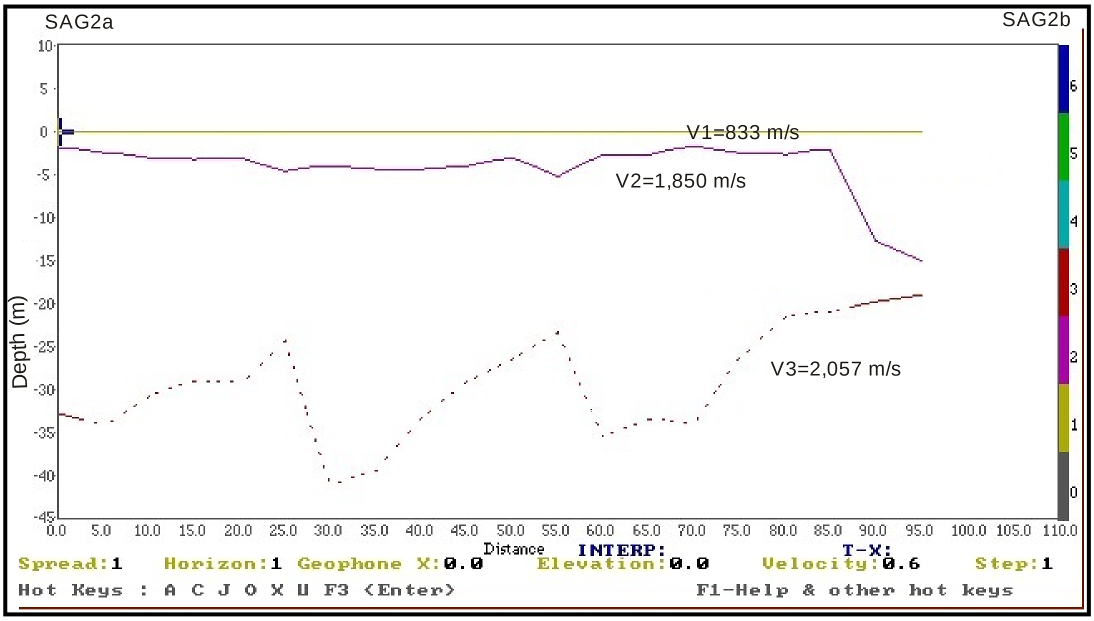


Fig. 11: The subsurface profile for line SAG2 shows velocities of each layer

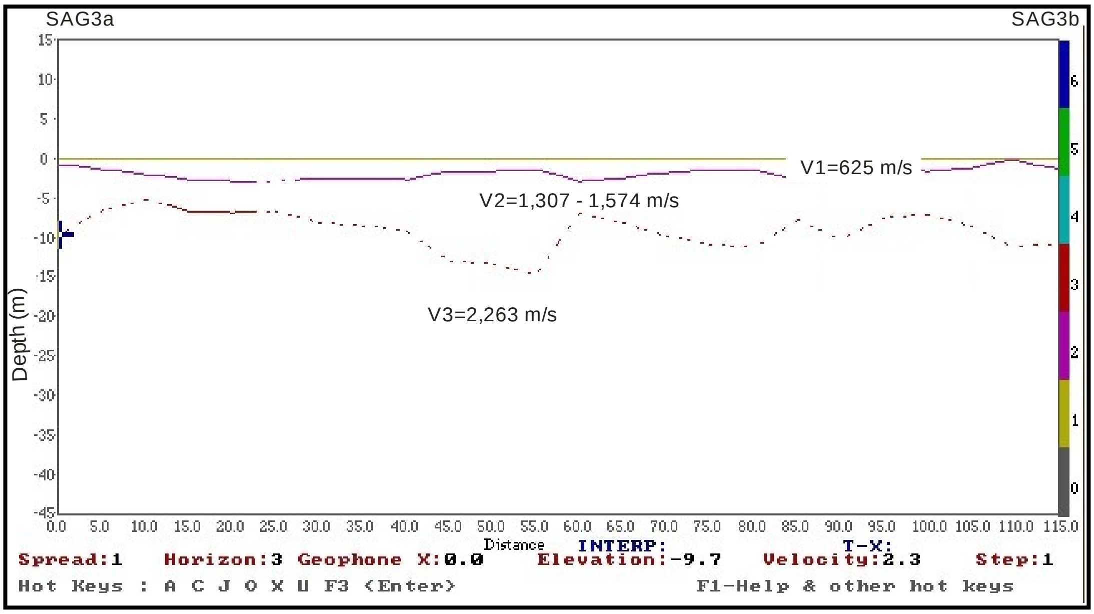


Fig. 12: The subsurface profile for line SAG3 shows velocities of each layer

5.5. Result of seismic line SAG5

The result of subsurface profile for line SAG5 was show in Fig. 14. The range of velocity for first layer is between 417 m/s until 833 m/s. The layer modelled thickness is placed at between 0.3 – 2.8 m. This layer is corresponded to topsoil or fill material or highly weathered rock.

The seismic velocity in the second layer is recorded constant at 1,880 m/s. This layer is corresponding to less weathered rock of schist. It was observed has an irregular boundary with third layer with depth ranges from 5.0 m until 10.0 m. The fresh bedrock of schist as third layer is observed below second layer with seismic velocity constant at 2,097 m/s.

5.6. Seismic line SAG6

The range of velocity for first layer of line SAG6 is between 417 m/s until 1,250 m/s. The first layer is corresponding to topsoil or decomposed rock with average thickness about 2.0 m only. The seismic velocity in the second layer is ranges from 1,316 m/s until 1,809 m/s indicating as a less weathered rock of schist. The layer modelled thickness is placed at between 4.0 m until 20.0 m.

It was consists of less weathered rock. The third layer has velocity value about 2,366 m/s. This layer is located well beyond 4.0 to 20 m upon which the second layer is conformably laid. This layer was found at 0 m until 20 m of survey line at 9 m depth. It was found again at 55 m until 75 m of survey line at 9 m depth. This layer is corresponding to fresh bedrock of schist (Fig. 15).

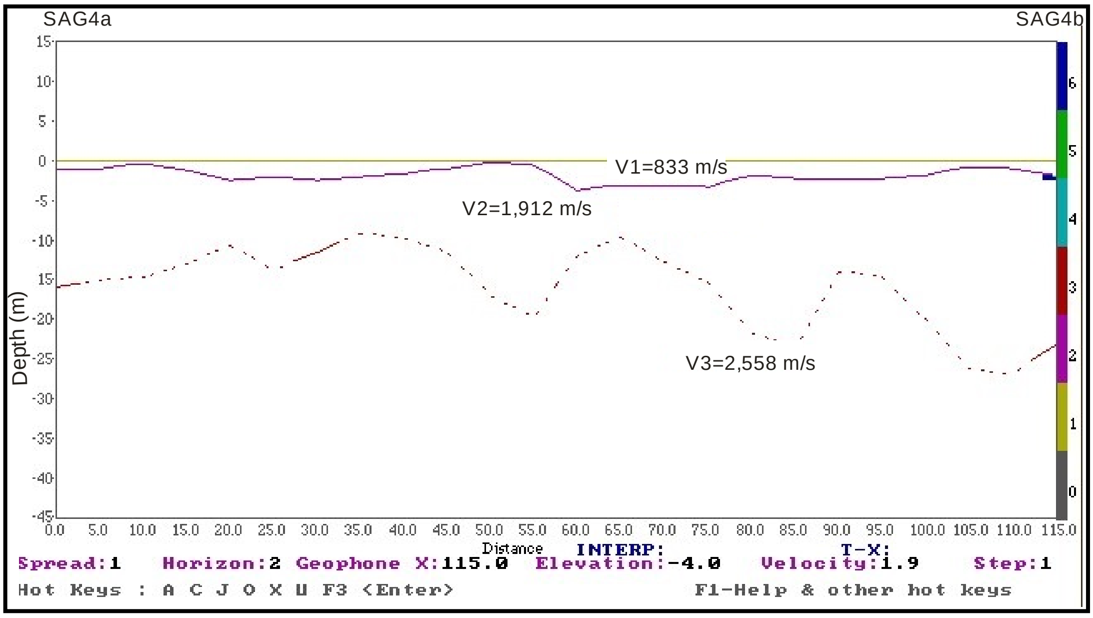


Fig. 13: The subsurface profile for line SAG4 shows velocities of each layer

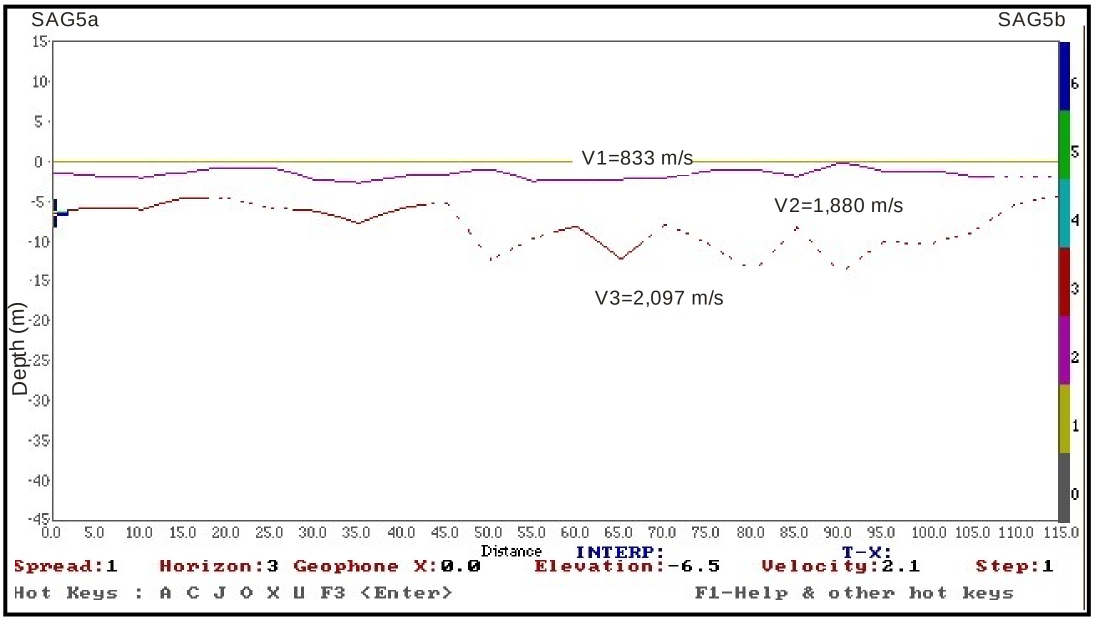


Fig. 14: The subsurface profile for line SAG5 shows velocities of each layer

6. Conclusion

The seismic survey at vicinity of Alor Gajah, Melaka has been analysed and the following conclusions can be drawn;

There are three layers of material can be interpreted based on seismic velocity values from the result of six line of seismic subsurface profiles. There is an increase in seismic velocity with depth which obeys the natural concept, and average velocities of each layer have been obtained. First layer is 676.9 m/s, second layer is 1,675.3 m/s and third layer is 2,414 m/s, all average values.

The first layer with seismic P-wave velocities less than 1,000 m/s indicates top soil, fill material or heavily weathered and/or decomposed rock, while the second layer with velocities ranges between 1,000 m/s until 2,000 m/s indicate as a rock with varying degrees of weathering and/or fracturing. The third layer with velocities in excess of 2,000 m/s indicate fresh bedrock (essentially non-weathered of schist but has good foliation) rock.

The thickness of each layer has also been presented with layer 1 is around 1 m until 5.0 m in general and the second layer is varies from 5.0 m until 25 m.

The boundary between first and second layer is almost flat pattern and can be observed at around 1 m until 5 m depth. It is different compared with boundary between second and third layer which is very obviously in irregular pattern with depth varying from 5 m until 10 m as observed in line SAG1, SAG3 and SAG5, and ranges from 10 m until 25 m in depth as observed at line SAG2, SAG4 and SAG6.

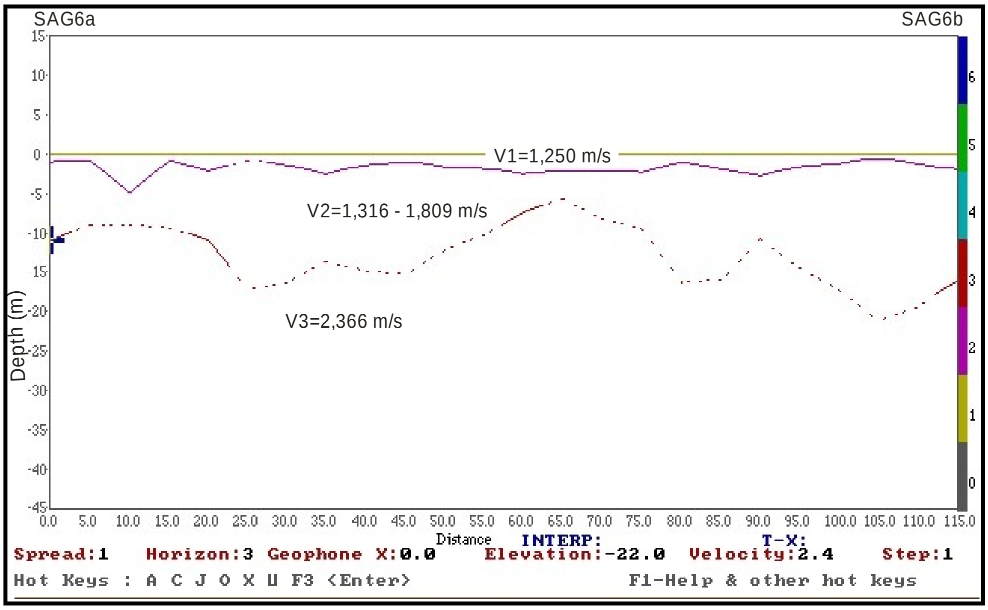


Fig. 15: The subsurface profile for line SAG6 shows velocities of each layer

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