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GROUND PENETRATING RADAR SURVEY ACROSS THE BOK BAK FAULT, KEDAH, MALAYSIA

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ABSTRACT

GROUND PENETRATING RADAR SURVEY ACROSS THE BOK BAK FAULT, KEDAH, MALAYSIA. A ground penetrating radar (GPR) survey was done across the Bok Bak Fault zone in Baling, Kedah in order to investigate the shallow subsurface geology of the Bok Bak fault zone, its extension and associated weak zones within the study area. GPR data acquisition was compared with visual inspection on the slope of the outcrop. Ten GPR profiles were acquired using 250 MHz GPR frequency. Basic data processing and filtering to reduce some noise and unwanted signal was done using MALA RAMAC Ground Vision software. The data penetrate around 2 meters in depth for all survey lines. In most lines shows clear images of shallowest Bok Bak Fault (NW trending) as detected at distance of 28 m horizontal marker. It also exhibits several sets of faults as a result of Bok Bak Fault deformation, including the conjugate NE trending fault (Lubok Merbau Fault). Active seismicity encompasses the Malay-Thai Peninsular trigger the changes of Bok Bak Fault dipping direction, steeper dips of conjugate faults and faults or fractures rotational movement.

Keywords: GPR, shallow structure, fault, slope.

ABSTRAK

SURVEI GROUND PENETRATING RADAR DI KAWASAN PATAHAN BOK BAK, KEDAH, MALAYSIA. Survei menggunakan *ground penetrating radar* (GPR) yang dijalankan melalui kawasan patahan Bok Bak di Baling, Kedah adalah bertujuan untuk menyelidiki geologi dangkal zona bawah tanah patahan Bok Bak, kemenerusannya beserta zona-zona lemah di sekitar patahan tersebut. Data pengukuran GPR yang diperoleh kemudian dibandingkan dengan hasil pengamatan langsung pada tebing singkapan. Sepuluh profil GPR telah diperoleh menggunakan frekuensi 250 MHz. Pemrosesan dasar dan penapisan data untuk mengurangi sinyal-sinyal yang tidak dikehendaki berikut gangguan-gangguan suara dilakukan dengan piranti halus *MALA RAMAC Ground Vision*. Data mampu menembus hingga kedalaman 2 meter untuk semua garis survei. Umumnya garis survei menunjukkan gambar yang jelas untuk patahan Bok Bak (ke arah Barat Laut) sebagaimana terdeteksi di jarak 28 m pada penanda horisontal. Beberapa set patahan yang dihasilkan dari deformasi patahan Bok Bak juga dapat dideteksi, termasuk pasangan patahan yang ke arah Timur Laut (patahan Lubok Merbau). Pergerakan aktif seismik di Peninsula Malaya-Thailand turut memicu perubahan arah kemiringan patahan Bok Bak, menjadikan kemiringan pasangan patahan lebih curam, dan pergerakan rotasi patahan dan retakan.

Kata kunci: GPR, struktur dangkal, patahan, tebing.

INTRODUCTION

The ground penetrating radar (GPR) is primarily designed to investigate the shallow subsurface of the earth, material, bridges and building, by using a high resolution electromagnetic waves technique[1,2]. However, the use of GPR for shallow subsurface mapping has just been increasing in the last 30 years because it can properly detect shallow underground discontinuity and heterogeneity[3,4,6]. In Japan, the GPR has been widely used to assess the geological hazards such as earthquake and road-cut collapse associated with shallow ruptures in and near fault zones[5,6]. It is because geological and geophysical studies such as GPR may reveal the buried active faults that potential to be reactivated if there is any earthquake in this area, thus possible future damages can be reduced. Although Peninsular Malaysia lie on the relatively stable Sunda Shelf and to be relatively less seismic, however it does not mean that it is free from the threat of the earthquake damage[7]. The study of the Bok Bak fault zone in Baling can help in considering the safety and environmental precautions of the study area including for road, building and other land uses. Especially the study area is a highway road-cut slope and need further road maintenance by the road investigator.

The present study is aimed to investigate the shallow subsurface geology of the Bok Bak fault zone and its extension and associated weak zones within the study area. Comparison of the GPR record and visual check on the wall surface can be done for the certain lines as applied on the slope part. Previous study shown that the 250 MHz (GPR) antenna give the best results for both penetration depth and resolution quality to be applied in this site[8].

GEOLOGICAL SETTING

The GPR survey was established on an outcrop as part of the Semanggol Formation (Triassic) and across the active Bok Bak fault zone. The Semanggol Formation is characterized by greywacke sandstone showing some graded bedding and containing pebbles of contemporary shale, and also by finely laminated siltstone in which pinching and swelling of the bedding, fine-cross bedding and convolute lamination varying from an inch or two in thickness to several feet can be seen, all these shows the turbidities features[9,10]. It is located in Baling-Kulim Express highway route 67, Baling area in the southeastern part of Kedah State, respectively, Figure 1. This site bounded by latitudes of N 05°35’6.56” and longitudes of E 100°45’33.24” at an approximate elevation of 30 meters.

FIELD SURVEY

The survey area, which is located on top of the rock slope, is more or less in trapezoidal shape which is about 75X12 meters square. The site was divided in 10 lines respectively with the spacing between each line is 1 meter. The direction of the GPR survey lines is towards southwest. GPR data were collected on these lines using 250 MHz frequency. Line 1 and line 2 are reference lines to compare with the visual check on the wall surface as these lines are nearest to the slope. Figure 2(a) shows the front-view of outcrop section (landscape view), while Figure 2(b) shows the survey area from the side view. Inset is Image of the survey area from Google Map. The dense vegetation makes the site is getting narrow to the south. Figure 3 shows the sketch of the 10 survey lines, includes the starting and ending point for acquiring GPR data for each line, with the same spacing distance.

DATA PROCESSING

Basic data processing addresses some of the fundamental was done using (MALA RAMAC Ground Vision) software. Several filters must be applied first to reduce noise and unwanted signal. The initial basic processing step is usually temporal filtering to remove very low frequency components from the data. This step is frequently referred to as 'de-wowing' the data. The next step of basic processing is usually to select a time gain from the data set. Very low frequency components of the data are associated with either inductive phenomena or possible instrumentation dynamic range limitations.

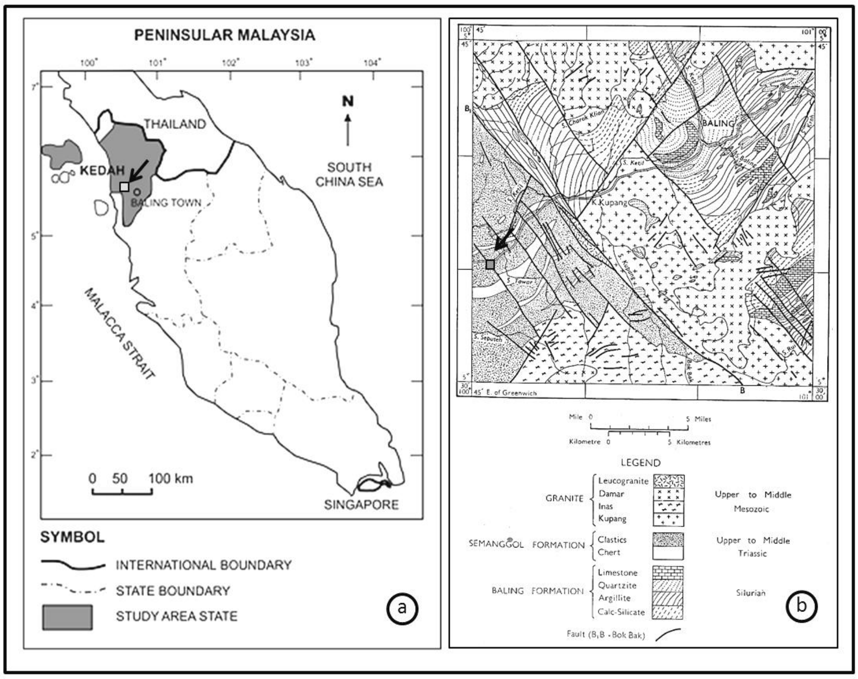

Figure 1. Index map of the Peninsular Malaysia. Pointed area represents the study area (a) and geological context of the study area (b) as part of the Semanggol Formation, modified from[9].

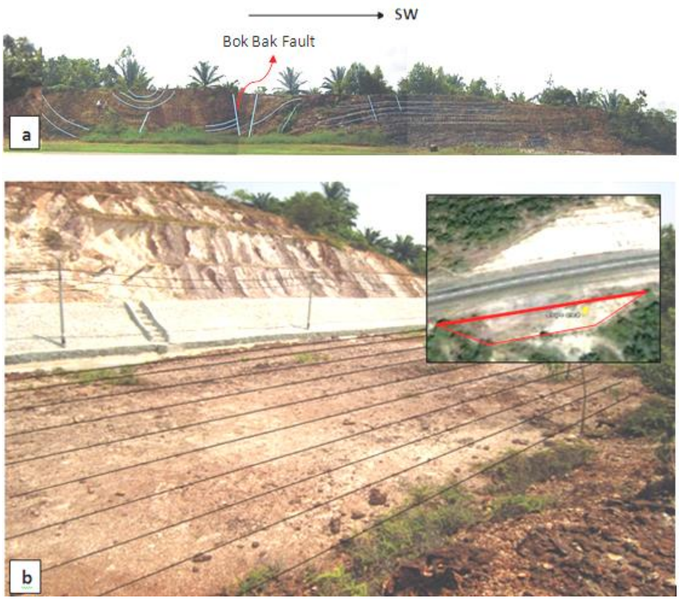

Figure 2. (a) The front-view of outcrop section (landscape view), (b) the survey area from the side view. Inset is Image of the survey area from Google Map.

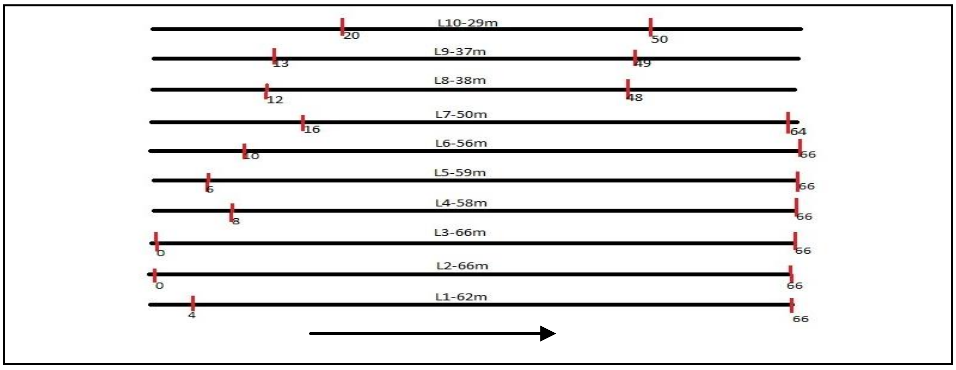

Figure 3. Sketching of the survey line. Starting and ending point for acquiring GPR data for each line (indicated by red mark), with the same spacing distance. Arrow indicates the direction for acquiring GPR data.

Radar signals are very rapidly attenuated as they propagate into the ground. Signals from great depth are very small and display of this information at the same time as signals from a shallower depth is difficult. When the amplitude of display is optimized for shallow depth signals, events from greater depths may be invisible or indiscernible. Equalizing amplitudes by applying some sort of time dependent gain function compensates for the rapid fall off in radar signals from deeper depths. The final filtering process that was applied are Band Pass-Filter. The response is constant over a defined frequency range that does not include origin.

The error in parameter and scale of GPR record is being corrected using CORELDRAW12 software. After the filtering of GPR data have been done, the GPR record is ready for interpretation. All filtered GPR records is observed to find the anomalies that can be captured by GPR system.

DATA INTERPRETATION

In general, 250 MHz antenna frequency can provide the radargram data around 2 meters in depth for all survey lines. The resolution of data is good as the anomaly can be seen clearly. In most lines profile show clear images of shallowest Bok Bak Fault (NW trending) as detected on distance 28 m. It also exhibit several sets of faults as a result of Bok Bak Fault deformation, including the conjugate NE trending fault (Lubok Merbau Fault) as shown by the visual inspection on the rock-slope outcrop (Figure 4).

Line profile 1 to 3

In the first line, many anomalies can be seen clearly, especially at a distance of 12 m, 20 m, 28 m, 32 m, 48 m 52, 64 m as shown in Figure 5(a) below. In Figure 5(b) below, there were about 10 anomalies that had been detected successfully at a distance of, 4 m, 8 m, 12 m, 16 m, 28 m, 36 m, 44 m, 48 m, 52 m and 64 m. Anomalies can be detected more clearly in Figure 5(b) compare to Figure 5(a) as there are many obstacles on the line 1 compared to line 2 due to uneven surfaces. Thus, it might affect the data as the acquiring process can’t be done smoothly. These first two lines were important since it is located near to the outcrop. In the third line, there were about 4 anomalies that can be seen clearly from radargram which were located at a horizontal distance of 12 m, 16 m, 28 m and 36 m as can be seen in Figure 5(c) below.

The anomalies as detected at a distance of 28 m indicates the continuity of the NW trending Bok Bak Fault, while at a distance of 36 m indicates the NE trending conjugate fault. Other anomalies as detected at several points exhibit several sets of faults as a result of Bok Bak Fault deformation. In these three lines profile, there are no significance changes for faults and joints distribution.

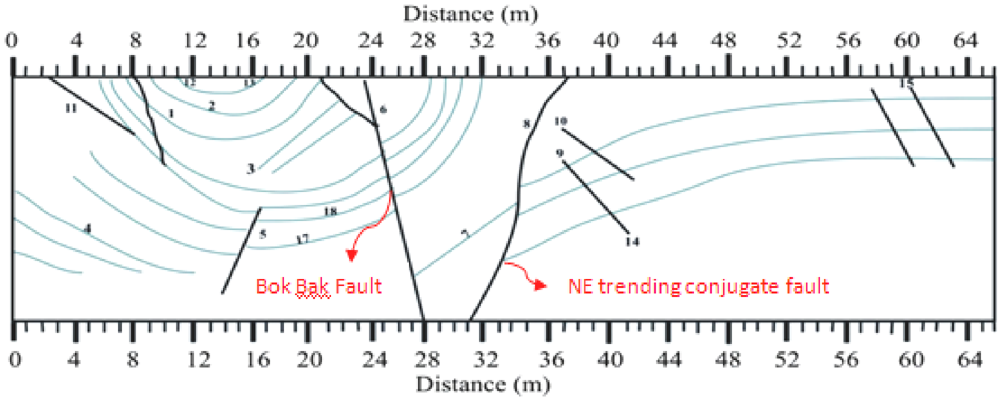

Figure 4. Field sketch for the direct (visual) slope observations on the faults, fold, and joints as a result of Bok Bak Fault deformation.

Line profile 4 to 6

Figure 6(a) below showing the result of line 4 and there were about 7 anomalies that had been detected at a distance of 12 m, 16 m, 20 m, 24 m, 32 m, 40 m and 40 m. While in the survey line 5, there were 10 anomalies that can be recognized as shown in Figure (b) below which were located at a horizontal distance of 12 m, 16 m, 24 m, 32 m, 36 m, 40 m, 54 m and 60 m . Survey line 6 gave about 7 anomalies at distance 16 m, 24 m, 32 m, 36 m, 44 m, 48 m and 56 m as shown in Figure 6(c) below.

In these lines 4 to 6, the Bok Bak Fault cannot be investigated through radargram. Even the anomaly that being captured at around 28 meter horizontal marker has changed its dipping direction from SW towards SE. Some series of faults and joints follow this changing trend. While the anomaly at 36 meter horizontal marker maintain the feature of NE trending conjugate fault. However, it seems the fault planes are dipping steeper compare to at lines 1 to 3.

Line profile 7 to 10

In line 7 that shown in Figure 7(a), there were a lot anomalies that had been detected at a distance of 16 m, 24 m, 28 m, 36 m, 38 m, 40 m, 44, m, 48 m, 52 m and 56 m as well. There were about 8 anomalies on the survey line 8 as shown in Figure 7(b) that was located at a distance of 16 m, 18 m, 24 m, 32 m, 34 m, 36 m and 38 m. While for line 9, there were about only 5 lines at a distance of 20 m, 24 m, 26 m, 32 m and 38 m as shown in Figure 8(a). For the farther survey lines from the outcrop which is line 10, there were 5 anomalies located at a distance of 24 m, 28 m 36 m and 38 m as shown in Figure 8(b).

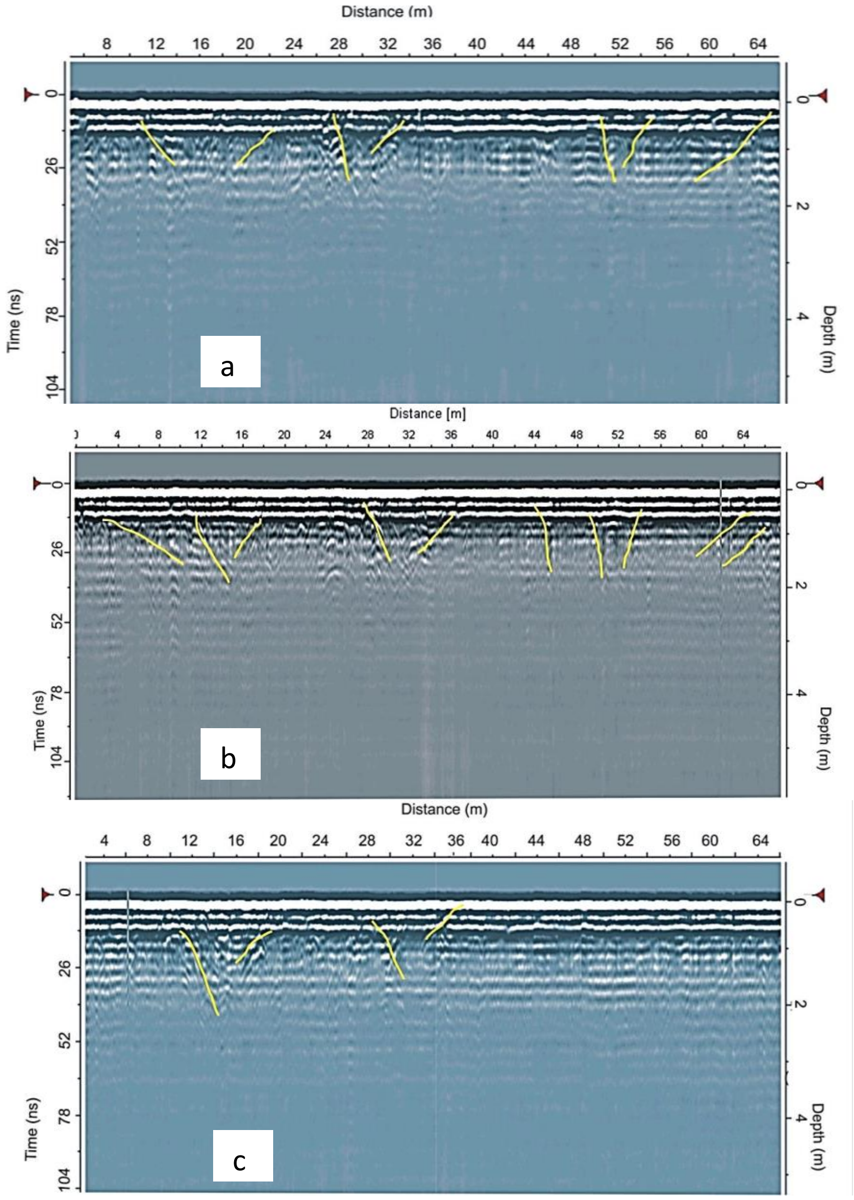

Figure 5. GPR profile (a) line 1, (b) line 2, and (c) line 3. The 28 meter horizontal marker indicate the NW trending fault (Bok Bak Fault) and the 36 meter horizontal marker indicate the NE trending conjugate fault.

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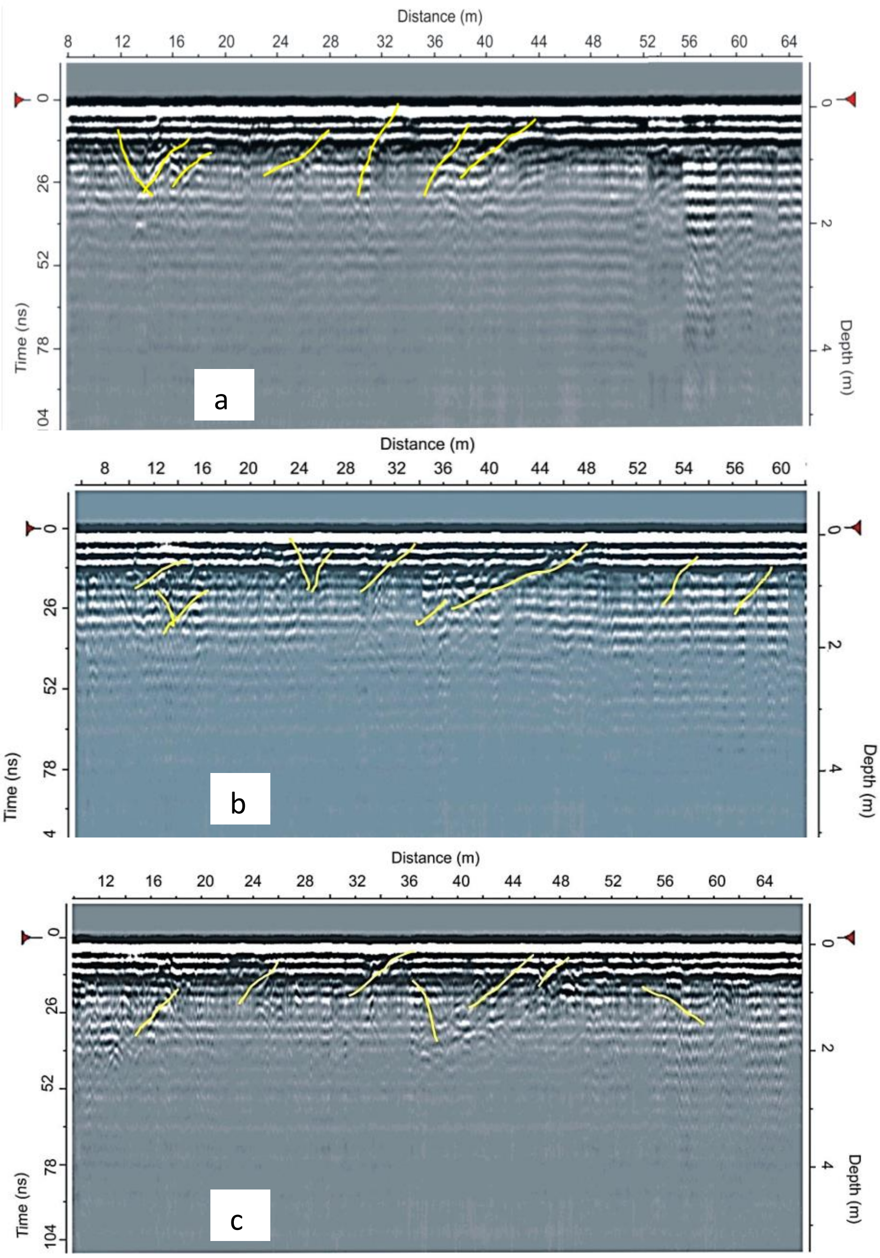

Figure 6. GPR profile (a) line 4, (b) line 5, and (c) line 6. The Bok Bak Fault cannot be seen clearly in these lines, even it has changed its dipping direction towards SE, while the 36 meter horizontal marker still indicate the NE trending conjugate fault.

In contrast with the result in line 6, in line 7 the feature of Bok Bak Fault is re-appear as shown at 28 meter horizontal marker. However, this feature is disappearing again in line 8. While the NE trending conjugate fault can be seen clearly in both line 7 and line 8. In fact, line 7 shows much more complex geological structures if compared to other survey lines. The same case as happened to line 9 and line 10 that the feature of Bok Bak Fault still disappear in line 9 but clearly seen appear as in line 10.

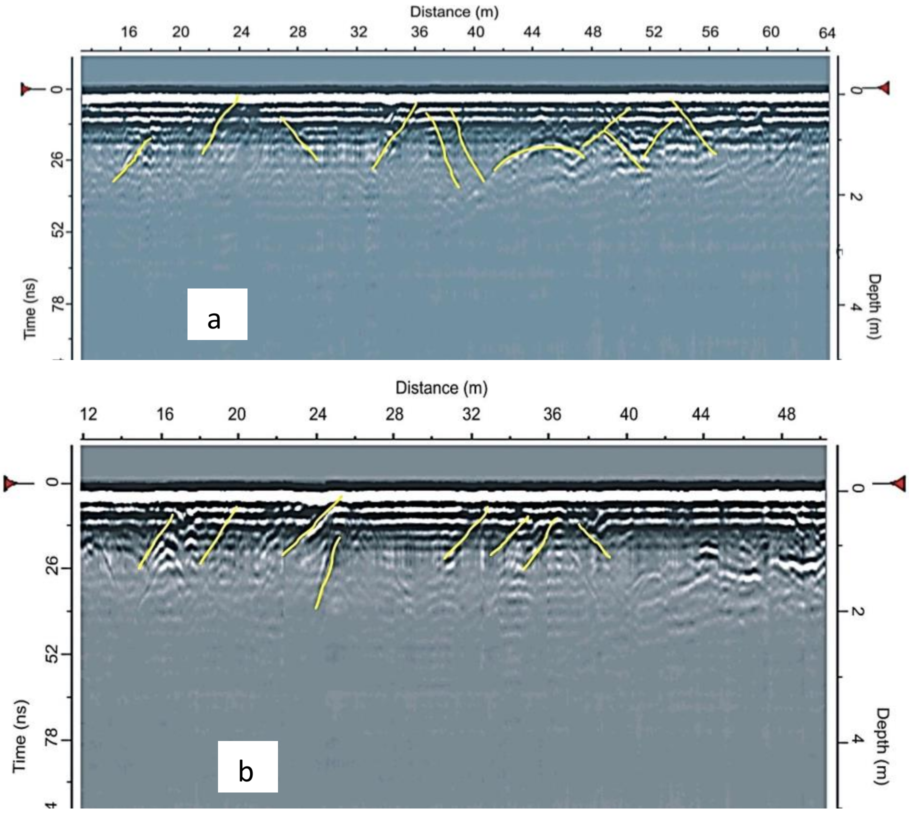

Figure 7. GPR profile (a) line 7 and (b) line 8. The Bok Bak Fault cannot be seen detected clearly in line 7 but it disappear in line 8.

The phenomenon of appear and disappear Bok Bak Fault in this area may have three possible explanations, that: (1) not only first order Bok Bak Faults were detected, but also second or low-order features, (2) the deformation zone is seismically active, thus the distribution of NW trending fault but in different dipping direction (as shown in line 4 and 6, GPR profile) could be the result of the reactivation of the Bok Bak Fault, and (3) the steeper dipping angles of the NE trending conjugate fault as the survey lines move to northeast side are due to the rotational movement created after the second phase N-S or E-W compressive forces.

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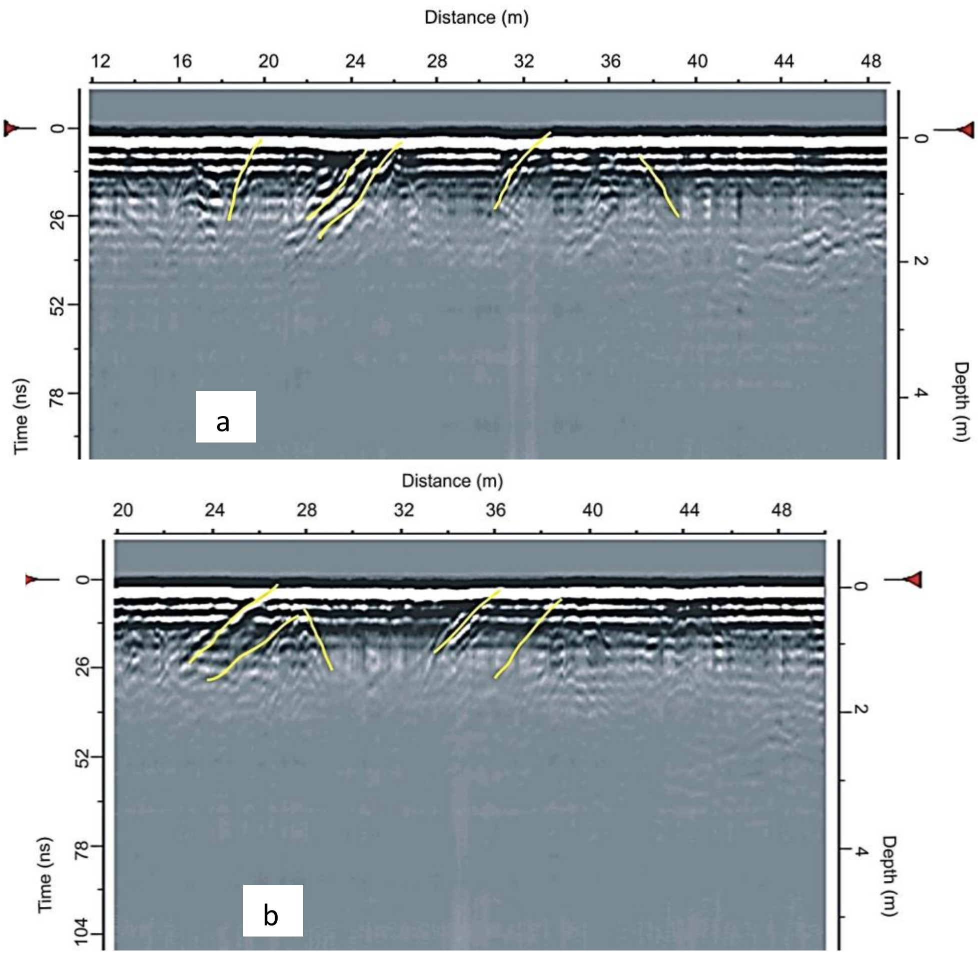

Figure 8. GPR profile (a) line 9 and (b) line 10. After disappear in line 8 and 9, The Bok Bak Fault is re-appear clearly as in line 10.

CONCLUSIONS

GPR study across the Bok Bak Fault in Baling, Kedah using 250 MHz frequency provided good resolution image of the subsurface structure. Many fractures and minor faults and joints accompanied the buried Bok Bak Fault as detected mostly at distance of 28 meter horizontal marker. However, the direction of sinistral or dextral displacement of this fault cannot be observed well, although in most profiles, the signal as captured in the left side of the fault is different as what has been captured in the right side of the fault (refer to figure 5 to 8). The Quaternary to Recent seismicity in the Malay-Thai Peninsular, especially in the NW Peninsular Malaysia (where the Bok Bak Fault lies) were the result of the reactivation of the major Bok Bak Fault. The GPR study conducted in Baling area has led to several recommendations as follows:

(1) Further studies should be done at the present study area by using other geophysics method, to confirm the extension and reactivation movement of Bok Bak Fault in this area.
(2) More field data evidences need to be collected to support the actual displacement of the fault, and so does its reactivation mode.
(3) Due to safety and environmental precautions, this particular road-cut need to be well-maintained, especially since the brittle graded bedding finely laminated sandstone - siltstone and containing pebbles of contemporary shale are in risk of rock collapse by earthquake triggering the active Bok Bak Fault zone.

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