Rangitaiki Plains Hot Pursuit:

Searching for faults in the Whakatane Graben

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26/06/09

Abstract: As one of the most tectonically active areas in the North Island of New Zealand, the Whakatane Graben deserves the attention of researchers. The Taupo Volcanic Zone and the North Island Shear Belt intersect in the Bay of Plenty, between Matata and Whakatane, resulting in an area of land that is actively subsiding and extending. Begg and Mousopoulou (accepted) have attempted to identify new faults in the graben that contribute to an understanding of its environment and its hazards. Through the implementation of ground-penetrating radar, this paper attempts to raise confidence in the existence of the newly found faults. Results were found to be inconclusive due to the interpretation of the collected data, the nature of ground-penetrating radar, and the inaccuracy of the methods used to collect data.

The Rangitaiki Plains is a large area of farmland that blankets the Whakatane Graben: a portion of the Central Volcanic Zone (CVZ) that has been active for about one Ma (Berryman & Beanland, 1989). With a width of 15 km, the Whakatane Graben is formed by the intersection of the Toupo Volcanic Zone (TVZ) and the North Island Sheer Belt (NISB) in the Bay of Plenty area of North Island, New Zealand (Nairn & Beanland, 1989).

The TVZ is a < one Ma old, 250 km zone of faults and volcanoes that acts as a subduction system and extends across the center of North Island (Nairn & Beanland, 1989). The northern end of the TVZ intersects the Bay of Plenty Coast, and is the site of four arc volcanoes: Mt Edgecumbe (active within the Holocene), Manawahe (active 0.4 Ma), Whale Island, and White Island, which are considered active through the present day (Nairn & Beanland, 1989). Part of the TVZ is the Okataina Volcanic Center, which is composed of northeast-trending faults that join into the western boundary of the Whakatane Graben (Nairn & Beanland, 1989). An additional linear fault zone within the TVZ can be extrapolated towards the northeast to join the eastern boarder of the Whakatane Graben (Nairn & Beanland, 1989). Narin and Beanland (1989) suggest that these two linear fault zones are manifestations of significant basement fractures. A 56-

year study by Sissions (1979) suggested that the TVZ is spreading at a rate of 7mm/year. A large portion of the spreading, though, may be condensed within the Whakatane Graben (Nairn & Beanland, 1989).

As the main component of the eastern margin of the Whakatane Graben, the North Island Sheer Belt boasts a north-south trend. Many faults of the NISB are active, with lateral displacement rates of around 16mm/year (Nairn & Beanland, 1989).

The TVZ and the NISB intersect on the eastern margin of the CVZ to form the Whakatane Graben, which boasts tectonic elements such as the Edgecumbe Fault, the Rotoitipakau Fault Zone, the Otakiri Fault, the Omeheu Fault, the Braemar Fault, the Awaiti Fault, and the Matata Fault—all of which contribute to the graben's subsidence (Begg &Mouslopoulou, accepted). The subsidence, which may have begun as early as 0.6 Ma, is estimated to be occurring at a rate of 1-2mm/yr (Narin & Beanland, 1989). Uplift of the western and eastern boarders of the graben began 0.4 Ma and 0.12 Ma, respectively, at rates of 1mm/yr and 0.5mm/yr (Narin & Beanland, 1989).

Faulting in the Rangitaiki Plains is important to understand for two main reasons. Firstly, faults contribute directly to the subsidence rates of the Whakatane Graben. An understanding of present-day faults and their characteristics can be used to postulate the history of the graben's geologic landscape, which can then be used to shed light on its future (Berryman & Beanland, 1989). Secondly, active faults pose a significant seismic hazard to infrastructure and inhabitants of the Whakatane Graben. Berryman and Beanland (1989) declare that events similar to the *M* 6.3 1987 Edgecumbe earthquake, which was characterized by 2 meters of offset, have occurred at least six times in the past 800 years. After evaluating recurrence intervals, however, Berryman and Beanland (1989) estimate that *M* 6-6.5 earthquakes may recur at least once every 100 years in the Whakatane Graben. These events are significant; the 1987 Edgecumbe earthquake strongly shook ground 10-20 km away from the fault itself (Berryman and Beanland, 1989).

Since tectonics in the Rangitaiki Plains is so important to understand, there have been studies that attempt to pinpoint unidentified faults in the area. One such study, by Begg and Mouslopoulou (accepted), used high quality Light Detection and Ranging (LiDAR) data to identify 108 previously undetected fault traces (Figure 1). LiDAR methodology yields high-resolution topographic data that is capable of detecting fault scarps 0.2m in amplitude (Begg and Mouslopoulou, accepted). Although LiDAR is capable of recognizing small topographical changes that are possibly explained by the presence of fault traces, it does not reveal much information about the faults themselves. For example, Begg and Mouslopoulou (accepted) were unable to determine the faults' sense of slip using LiDAR data; instead they inferred slip after considering the slip of all previously identified faults in the area. It is necessary to use supplementary research methods to raise confidence in the presence of faults identified by Begg and Mousopoulou (accepted), understand the nature of the faults, and comprehend their significance within the Rangitaiki Plains.

Ground penetrating radar (GPR) is a technique used to research shallow subsurface geophysical features that has gained popularity within the last 20 years (Neal, 2004). Composed of a transmitting and receiving antenna, it emits high frequency electromagnetic waves that penetrate the ground. As the waves hit materials with varying electrical properties, their velocity is affected and some of their energy is sent back up to the receiver (Neal, 2004). This creates a profile of shallow (<50m) subsurface reflectors that compose geomorphic features beneath the GPR antenna (Neal, 2004).

GPR's ability to reproduce sedimentary structures and depositional environments at greater depth and higher resolution than other subsurface research methods has warranted its experimental use in the identification of faults. Rashed, Kawamura, Nemoto, Miyata, and Nakagawa (2003) used GPR to explore deformational structures near the Uemachi fault in Osaka, Japan. After processing 12 GPR profiles, a subsurface fault scarp was found paralleling the Uemachi fault plane (Rashed et al., 2003). McClymont, Green, Villamor, Horstmeyer, Grass, and Nobes (2008) used GPR to investigate three different deformation styles of active faults in New Zealand, and found that GPR volumes showed evidence of fault geometry that were not discernable from surface mapping. In one particular GPR study, Wyatt and Temples (1996) specified criteria that can be used to identify paleochannels, joints and fractures, and faults in processed GPR profiles. In order to create the criteria, these specific features were observed directly in the field, and compared to their own GPR signature (Wyatt and Temples, 1996).

Considering the tectonic environment of the Rangitaiki Plains and the significance of faulting in the area, it is important to ground truth possible faults identified by Begg and Mouslopoulou (accepted). GPR was used in an attempt to ensure confidence in the presence of possible faults intersecting Angle Road and McClean Road just east of the central region of the Whakatane Graben.

Study Site

Angle Road extends NW-SE 2.1km in the eastern margin of the central region of the Rangitaiki Plains, and intersects McLean Road and SH30. McLean Road extends NWW-SEE 4.9km and intersects Luxton Road and East Bank Road at its eastern and western ends, respectively.

Methods

Two transects were created down the length of Angle and McLean Roads (Figure 2), with marks every 100m. Change in topography was measured at each mark using a Sokkia Electronic Total Station. A GSSI SIR-2000 GPR system with a 200MHz transceiver was dragged at a steady walking pace along each transect, while a marker noted each mark by clicking the red marker button. GPR data was processed using RADAN 6.5 Software in order to normalize distance and correct for topography. A dielectric constant of 6 was used.

Once the data was processed, individual GPR profiles of like transects were stitched together using Microsoft Powerpoint. Charts of total station data were then superimposed onto complete GPR transects, so that references to distance could be made. GoogleEarth was used to measure distances from the beginning of each transect to features of the land that correlated with fault traces, as specified by Begg and Mousopoulou's (accepted) data. Previously published articles discussing the use of GPR to identify faults were used to analyze the GPR profiles of Angle and McLean Roads at the specified distances.

Results

Faults in Begg and Mousopoulou's (accepted) data were correlated to about 550m, 2200m, and 2300m, and 3000m from the beginning of the McLean Rd transect (Figure 3). In the Angle Rd transect, faults were correlated to at least 370m away from the transect's beginning (Figure 4). After extensive analysis following guidelines set forth by previously published papers, it was determined that there was no conclusive evidence of faults at each of the specified locations on the GPR profiles (Figures 5a-d).

Discussion

The GPR profiles of Angle and McLean Roads were interpreted to contradict the evidence put forth by Begg and Mousopoulou's (accepted) LiDAR study of faulting in the Rangitaiki Plains; no faults were found to intersect either road in the locations specified by LiDAR data. These results may be a consequence of the absence of faults intersecting Angle and McLean Roads, or a combination of the nature of GPR profiles and the methods used in this study.

Each priority location (A through E) identified in the GPR transects of Angle and McLean Roads correlates to a location on Begg and Mousopoulou's (accepted) LiDAR map where a fault is meant to intersect one of the two roads. Locations were analyzed and interpreted using criteria adopted by Wyatt and Temples (1996), namely, "(1) abrupt reflector terminations, (2) direct fault plane reflections…[and] (5) correlations of reflectors across a fault plane".[1] None of the priority locations were found to clearly possess any of Wyatt and Temples' criteria (Figures 5a-d). If a hint of any aforementioned criteria were present at any of the priority sites, they were also found to be present in hundreds of other places in each transect. Although the interpretation of the GPR profiles discourages the likelihood that faults intersect the transects, there is evidence that the methods used in the study are inaccurate.

The nature of GPR research is such that gathering data using the GPR antenna does not give you direct results. The GPR profile requires processing and interpretation in order to hold value or significance relative to a research question. As explained by Adrian Neal (2004), there are many different ways to process and interpret a GPR profile, making it very hard to draw conclusions when evidence is not completely and utterly obvious. Additionally, Neal cites that an interpreter must understand "the nature and causes of reflections unrelated to primary sedimentary structure", which was not the case

[1] Wyatt, D. E.; Temples, T. J. 1996 : Ground-penetrating radar detection of small-scale channels, joints and faults, in the unconsolidated sediments of the Atlantic Coastal Plain.*Environmental geology* 27: 219-225. Pg 221.

in this study[2]. Other GPR papers make sure to mention the difficulty of data interpretation and suggest the need for 3-D data with suites of geometric attributes (McClymont el al., 2008).

On the other hand, some studies maintain the ease in interpreting GPR profiles to find faults. Wyatt and Temples (1996) use the word 'obvious' when referring to faulting in Figure 6. In the case of this study, Figure 6 is a testament to the subjectivity of fault identification in GPR profiles.

The methods used to correlate locations of faults in the LiDAR data with locations in the GPR profiles may have also led to inaccuracy in this study. First, as was the case with the fault meant to intersect Angle Rd, some of the faults intersected streets at locations on the LiDAR image with no distinguishable feature (i.e. houses, intersections with other roads, etc.). This made it very difficult to decide what point to measure to on GoogleEarth, when attempting to determine an area of the transect to look for the fault. Second, measuring distances on GoogleEarth is only as accurate as the program's zoom function, the person controlling the mouse, and the amount by which the value is rounded. Third, once a distance value was obtained, it was only meaningful if it happened to fall on one of the 500m markers; otherwise, estimation was used to locate the location of the potential fault. Only one fault chanced to intersect the GPR profile on one of the 500m incremented markers, meaning four out of five were estimated locations. Other inaccuracies in the methods of this study manifested themselves in the inability to match up topographical measurements calculated by the total station with GPR profiles that had been corrected for change in topography.

Conclusion

The Whakatane Graben is one of the most tectonically active areas in New Zealand, and needs to be understood. The identification of faults will help reconstruct the history of the graben's tectonic environment and supplement the prediction of its future activity—not to mention raise awareness of significant hazard.

Due to the nature of GPR profiles and the methods used in this study, it is impossible to strengthen or weaken confidence in the data put forth by Begg and

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[2] Neal, A.; 2004: Ground-penetrating radar and its use in sedimentology: principles, problems, and progress.*Earth-science reviews* 66: 261-330. Pg 1.

Mousopoulou (accepted). Although there were no faults identified in priority areas of the GPR profiles of Angle and McLean Roads, the methods used to determine priority areas can be considered inaccurate.

GPR can be an effective method of exploring shallow subsurface structures, as long as its nature is understood and considered in the experimental design. Future research should aim to positively identify faults through the employment of GPR in conjunction with the latest data processing techniques and expert GPR profile interpreters. In addition, each study should be replicated and researchers should collaborate to standardize GPR interpretation, so as to make the method of data collection a more reliable resource.

Literature Cited

Begg, J. G.; Mousopoulou, V. accepted: LiDAR reveals subtle late Holocene within an active rift, Taupo Rift, New Zealand. 1-51.

Berryman, K.; Beanland, S. 1989: Evaluation of seismic hazard in the Rangitaiki Plains, New Zealand. *New Zealand journal of geology and geophysics* 32: 185-190.

McClymont, A. F.; Green, A. G; Villamor, P.; Horstmeyer, H.; Grass, C.; Nobes, D. C. 2008: Characterization of the shallow structures of active fault zones using 3-D ground-penetrating radar data.*Journal of geophysical research* 113: B10315.

Nairn, I. A.; Beanland, S. 1989: Geological setting of the 1987 Edgecumbe earthquake, New Zealand.*New Zealand journal of geology and geophysics* 32: 1-13.

Neal, A.; 2004: Ground-penetrating radar and its use in sedimentology: principles, problems, and progress.*Earth-science reviews* 66: 261-330.

Rashed, M.; Kawamura, D.; Nemoto, H.; Miyata, T.; Nakagawa, K. 2003: Ground penetrating radar investigations across the Uemachi Fault.*Journal of applied geophysics* 53: 63-75.

Wyatt, D. E.; Temples, T. J. 1996 : Ground-penetrating radar detection of small-scale channels, joints and faults, in the unconsolidated sediments of the Atlantic Coastal Plain.*Environmental geology* 27: 219-225.

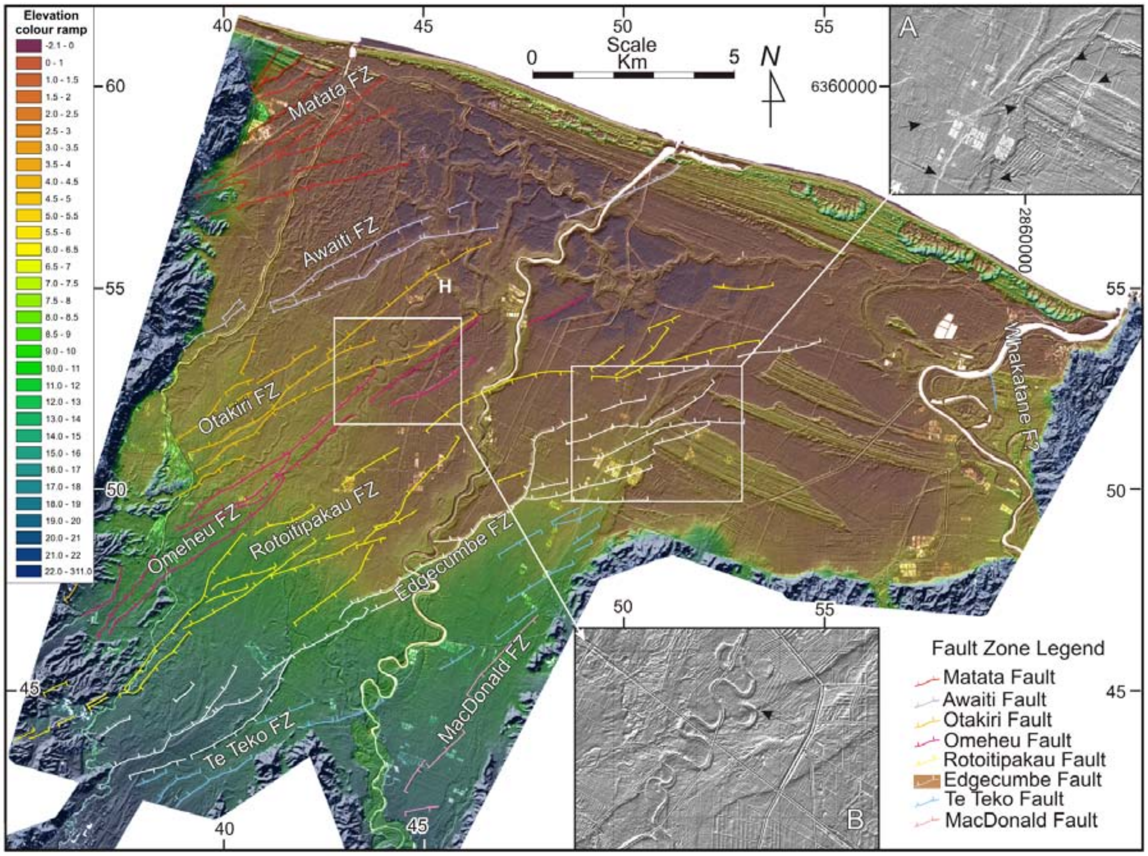

Figure 1. LiDAR data map of newly found faults in the Whakatane Graben. Image is as presented by Begg and Mousopoulou (accepted). The series of faults explored in this study are contained in the white box on the right.

Figure 2. Map of study site; the lengths of McLean and Angle Roads are boxed by dotted bright-yellow lines. Sets of dune ridges can be used to correlate location on Figure 1.

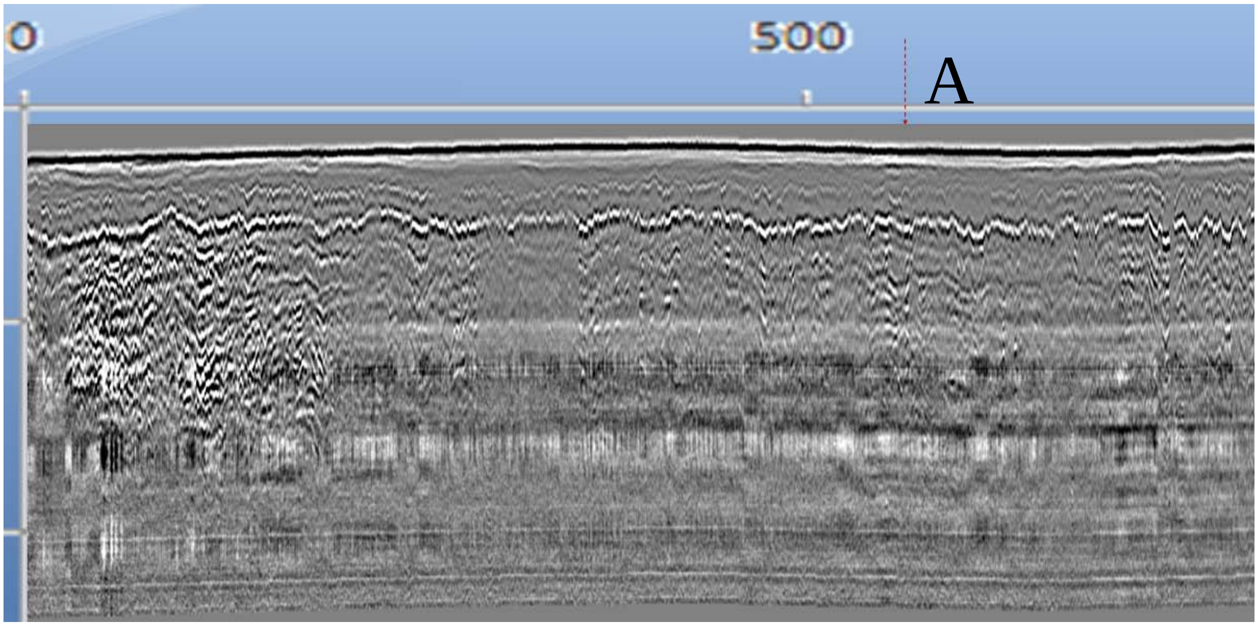

Figure 5a. McLean Rd. priority location A.

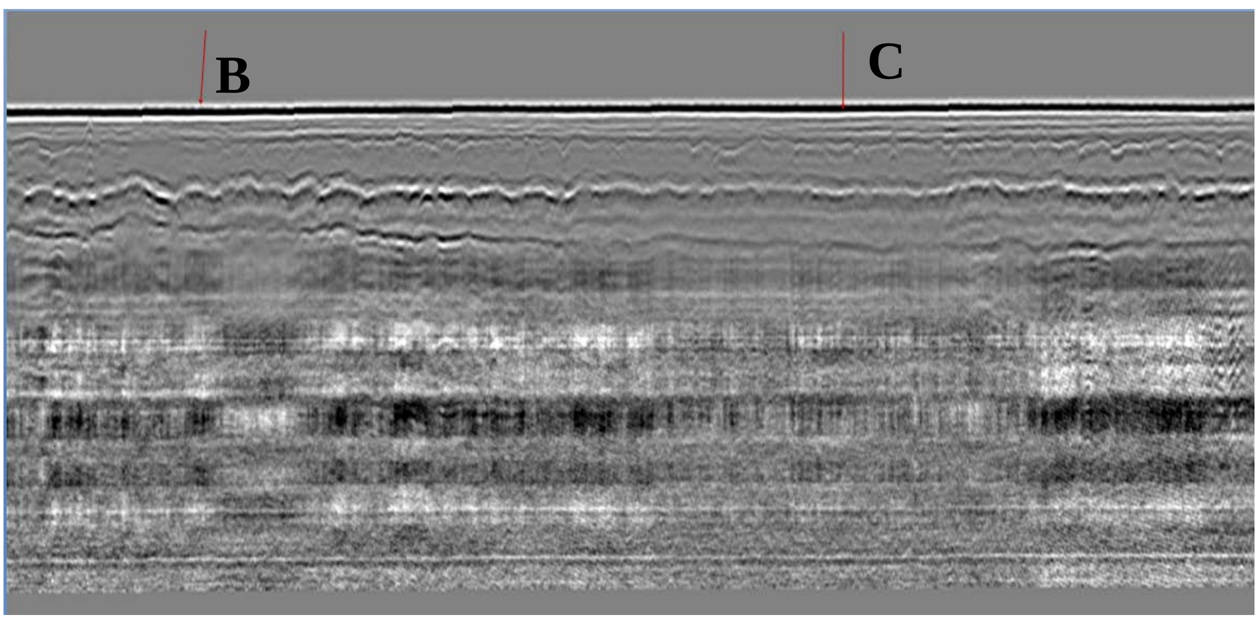

Figure 5b. McLean Rd. priority locations B and C

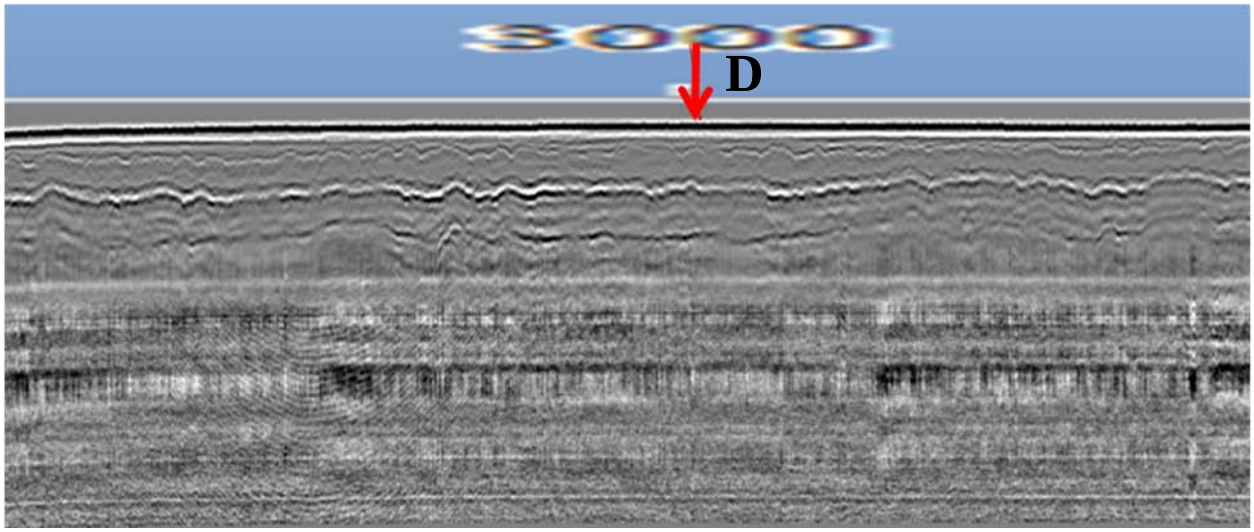

Figure 5c. McLean Rd. priority location D

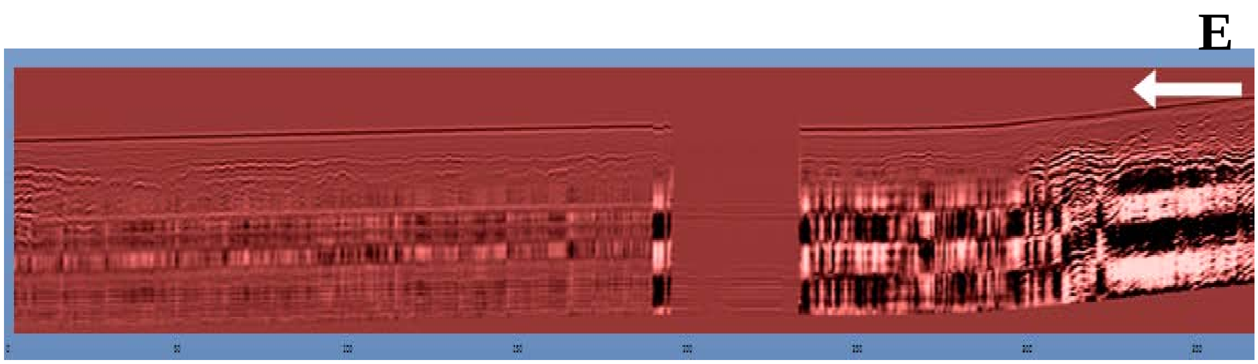

Figure 5d. Angle Rd. priority location E

Figure 5a-d. Specific priority locations that were analyzed for the presence of Begg and Mousopoulou's (accepted) proposed faults. Each priority location was interpreted to contain no faults according to criteria of Wyatt and Temples (1996).

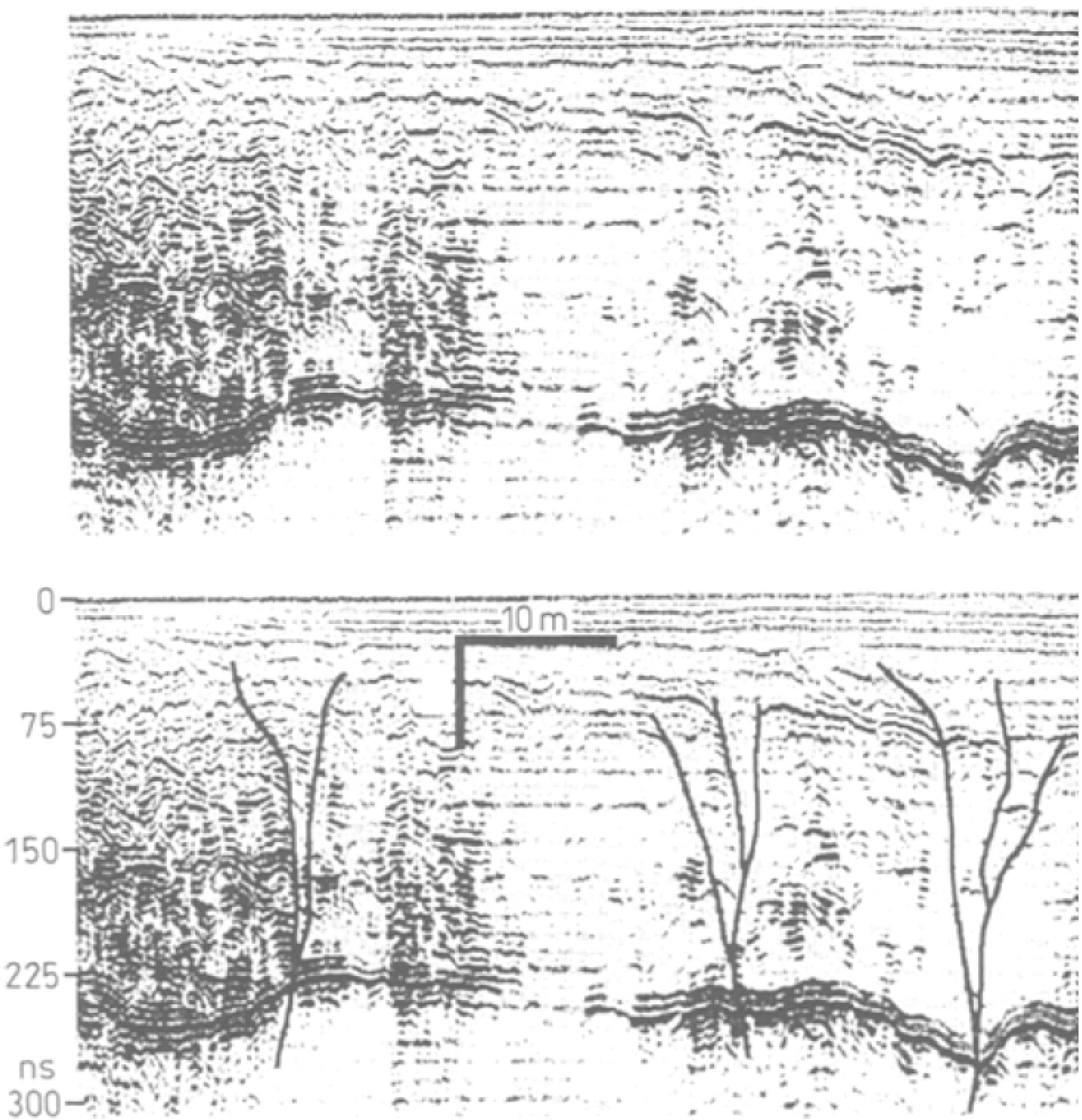

Figure 6. Example of GPR interpretation taken from Wyatt and Temples (1996). This figure showcases the subjectivity of GPR profile interpretation in the presence of broken reflectors. The middle fault structure may be discernible, but the two on the outside could arguably be drawn on different lines.