Urban Geophysics: Geophysical Signature of Mount Bonnell Fault and Its Karstic Features in Austin, TX

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Although most karstic regions are characterized by caves, collapsed features, and sinkholes, such features often do not have surface expressions, and their presence may go unrecorded. Central Texas and the Greater Austin metropolitan area have been built on the karstic limestone Lower Cretaceous Glen Rose Formation and Edwards Aquifer within the Balcones Fault Zone (BFZ). Near-surface karst features in the Austin area have a profound effect on geotechnical engineering studies of structural foundations, residential buildings, shopping malls, utility excavations, tunnels, pavements and cut slopes. Thus the practice of geotechnical engineering is challenging in the Austin area.

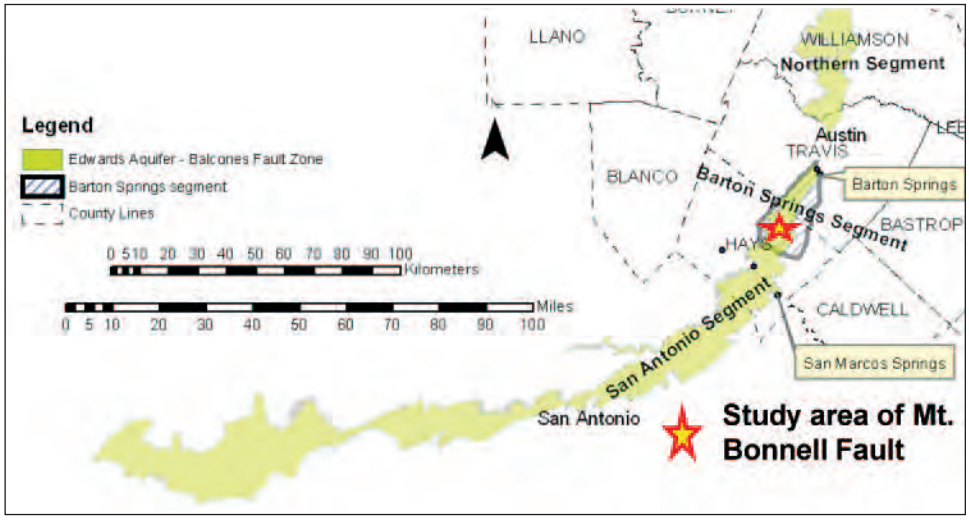

Figure 1: Balcones Fault Zone Portion of the Edwards Aquifer in Central Texas (Hauwert, 2009).

Geophysical methods are sporadically used to estimate the locations and parameters of these karst features prior to any geotechnical studies. Opinions concerning the effectiveness of these geophysical surveys are mixed, and geophysical techniques are not generally recognized as primary tools in engineering-scale studies.

However, remarkable advances in the manufacturing of geophysical instruments over the last ten years have made geophysics a viable tool for geotechnical studies of these karstic features. Data quality has been increased by the advent of continuous data collection. The data are better processed and interpreted by new and improved software packages, which produce improved sub-surface imaging and mapping.

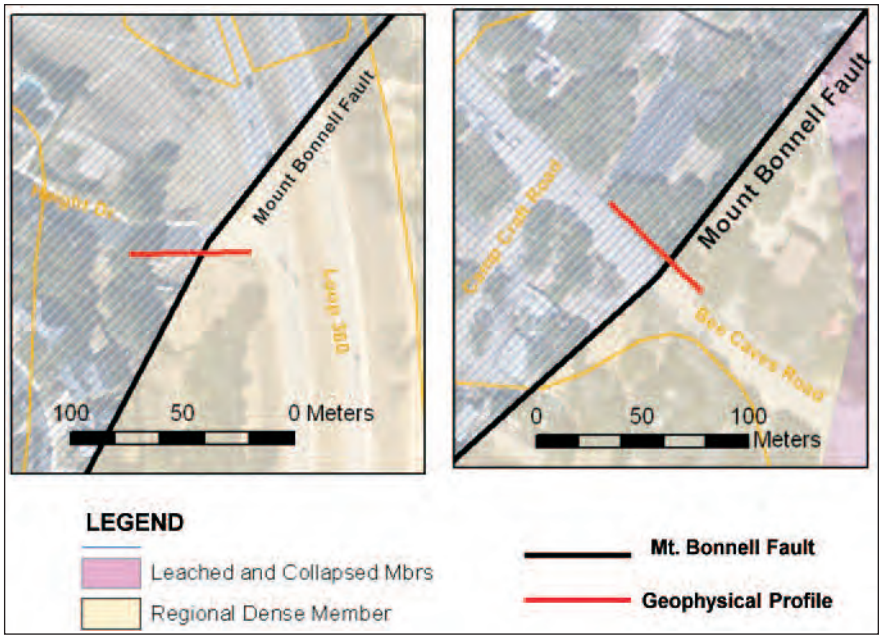

Figure 2: Surface geology of geophysical survey sites. Geologic interpretation modified from Hauwert, 2009 and Rodda et al. (1970) by Nico Hauwert.

Thus integrated geophysical surveys can provide new insight into the near-surface karstic features in the Glen Rose Formation and Edwards Aquifer. I have conducted ground penetrating radar [GPR], resistivity imaging, magnetic [G-858], conductivity [EM-31] and natural potential [NP] geophysical surveys at two locations where the Mount Bonnell fault (MBF) is present, along the northern boundary limit of the BFZ. Results indicate that all methods successfully imaged significant karst anomalies across the known fault locations. Integration of all detected anomalies provides a much better understanding of near-surface geology defined by the caves, voids, collapsed materials, sinkholes and the fault itself.

Introduction

A study of the geologic map of Austin by Garner et., al., (1976) shows that normal faults along the BFZ are some of the main features, if not the primary features, that have shaped the geology and physiography of the city and its environs. At the regional scale,

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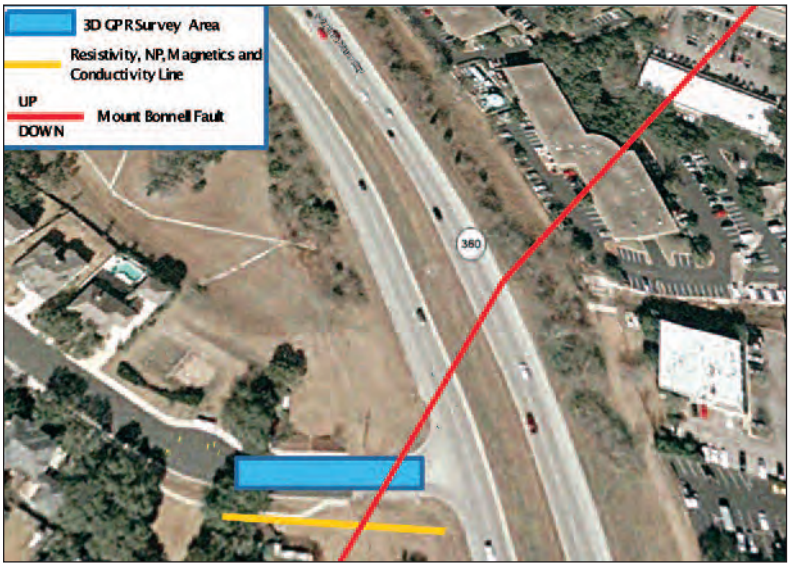

Figure 3: Site map showing the location of geophysical profiles and the Mount Bonnell fault. The fault location is taken from Hauwert, 2009.

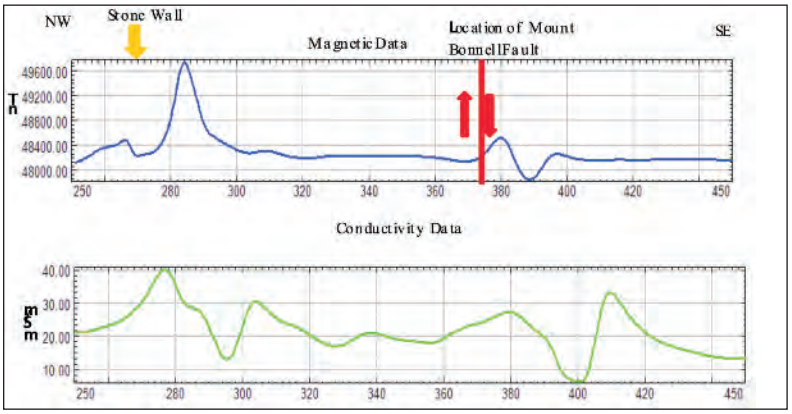

Figure 4: Magnetic and conductivity data across the Mount Bonnell fault. A magnetic high, conductivity high and low anomalies are observed between the stations 270 and 300 feet. Another anomaly on both profiles, caused by a buried pipe, is shown between the stations at 370 and 410 feet. The location of Mount Bonnell is referenced based on the geological data (Hauwert, 2009).

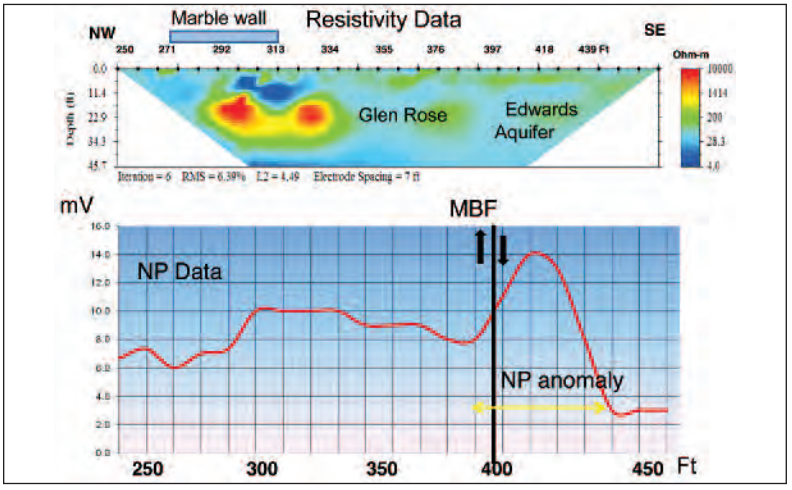

Figure 5. Resistivity imaging (above) and NP (below) data across the Mount Bonnell fault. The resistivity data does not indicate the fault. The location of the fault is based on the geological data (Hauwert, 2009). However, the NP anomaly indicates the fault about 25 feet further SE than its geologically known location.

faults have positioned the geologic units into a framework that juxtapose contrasting rock, soil, and terrain, thereby establishing a major physiographic boundary, the Balcones Escarpment, which extends through west Austin, separates the Edwards Plateau to the west from the Blackland Prairies of the Gulf Coastal Plain to the east (Collins and Woodruff, 2001). The Balcones escarpment, with a topographic relief as great as 300 feet in Austin, is a fault-line scarp, and consists of normal faults, which dip toward the east and southeast. The BFZ's most prominent fault is the Mount Bonnell fault, which comprises the northernmost part of the fault zone with a throw of near 600 feet. The Lower Cretaceous Glen Rose Formation is at the surface to the west of the MBF, while east of the fault zone younger rocks of Edwards Aquifer are at the surface (**Figure 1**).

Geophysical methods have been an important component of effective hydrogeological investigations over the Edwards Aquifer in the San Antonio area. Geophysical surveys that employ a variety of electrical and electromagnetic methods have been used to successfully map stratigraphy, geologic structure, and depth to the water table in major aquifer systems (e.g., Fitterman and Stewart, 1985; Connor and Sandberg, 2001).

In this study, however, I demonstrate the utility of integrated surveys for the near-surface characterization of the MBF in the Austin area (Figure 2). To my knowledge, this is the first application of integrated geophysical techniques to the characterization of karstic features in the metropolitan Austin area. The geophysical surveys were performed at the intersections of Height Drive and Highway 360, and Bee Cave Road and Camp Craft Road (**Figure 2**). Conductivity, magnetic, GPR and NP methods were chosen for their ability to very rapidly map variations in their respective physical attributes such as conductivity, magnetic susceptibility, dielectric contrast and ambient electrical current within the surface. 2D resistivity imaging surveys were conducted to provide information about variation in electrical resistivity as a function of depth. Results of these surveys are described in the following section.

Geophysical Results

Height Drive Site at Highway 360

A site map of the study area including the location of geophysical profiles and the MBF is shown in **Figure**

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3. The magnetic and conductivity data are shown in **Figure 4**. The magnetic data indicate a high anomaly between the stations at 270 and 290 feet, whereas the conductivity data shows a high and low between the stations at 270 and 310 feet. Sources for these anomalies are due to changes in the magnetic and conductivity properties of the Glen Rose Formation. Both data sets also indicate a pipe anomaly between stations 380 and 410 feet. This anomaly is due to a known utility pipe, which is observed at the site.

Figure 5 shows the resistivity imaging and NP data along the same profile as of **Figure 4**. The resistivity data indicates a very significant anomaly consisting of high and low resistivity anomalies between stations 280 and 320 feet. The resistivity profile does not indicate any fault anomaly where it crosses the MBF, however, the NP data shows a typical fault anomaly (sine wave) across the known fault location.

Sixteen GPR profiles were collected along Height Drive perpendicular to the Mt. Bonnell fault (see **Figure 3**), and were used to create 3-D GPR amplitude depth slices. (see **Figure 6**). The trend of the fault is well exposed at depth slices of 2-3 ft, and 3-4 feet.

In summary, NP and the GPR data indicate the location of the MBF, which is consistent with the geological data (Hauwert, 2009). The resistivity, magnetic and conductivity data show cave-like anomalies. GPR, magnetic and conductivity data show location of subsurface pipes across the study area. Findings of geophysical surveys are given in **Table 1**. There is a patched asphalt area on Height Drive where the fault crosses, and the repair on the site may have been necessary because of the near-surface deformation due to the karstic features.

Bee Cave Road Site at Camp Craft Road

A site map of the study area including the locations of geophysical profiles and the

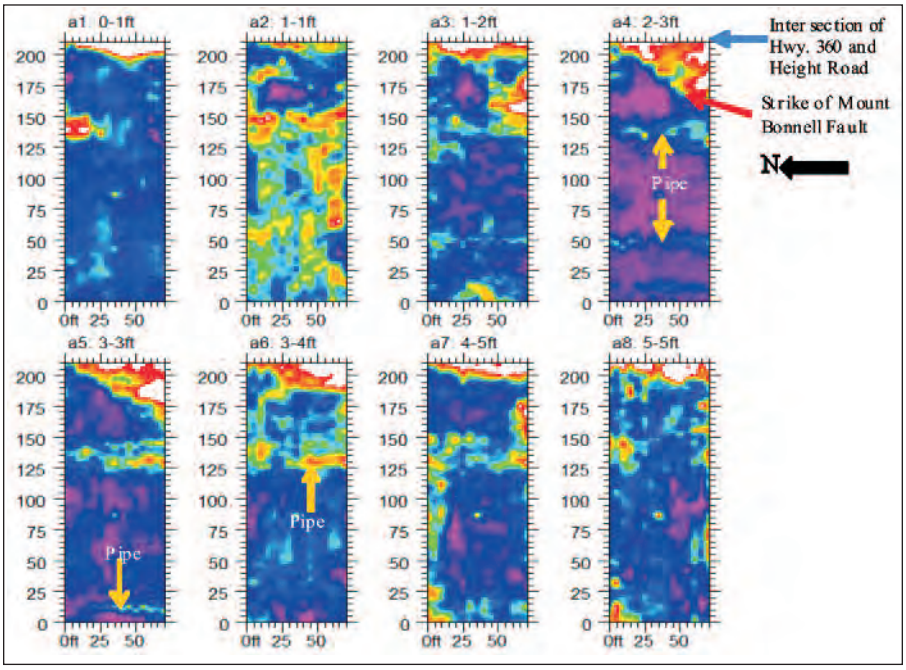

Figure 6: 3-D GPR depth slices showing the strike of Mount Bonnell fault and subsurface pipes. Red color shows the highest amplitude whereas the blue lowest.

Geophysical Methods	Karstic Features			
	Cave	Sinkhole	Collapse Materials	Faults and Fractures
Magnetic	✓			
Conductivity	✓			
Resistivity	✓		✓	
NP	✓			✓
GPR	✓		✓	✓
TOTAL	✓		✓	✓

Table 1: Karstic features located by geophysical surveys at Height Drive.

Figure 7: Site map showing locations of geophysical profiles and the MBF.

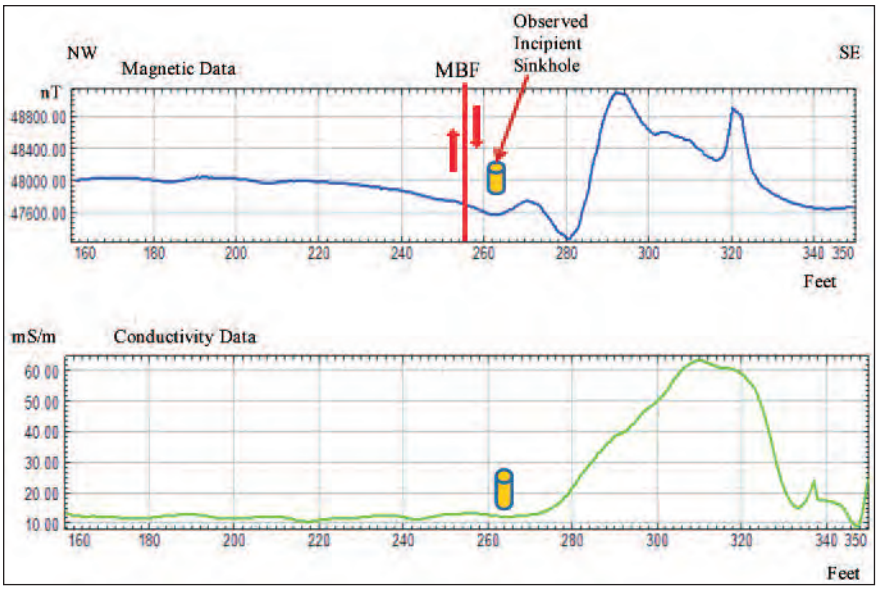

Figure 8: Magnetic and conductivity profile across the MBF. There is a ferrous electrical pole near the station at 250 feet, but observed high magnetic and conductivity anomalies between the stations at 260 and 330 appear to be caused by subsurface sources. MBF stands for Mt. Bonnell Fault and it is location determined by geological field observation (Hauwert, N., Pers. Comm., 2010).

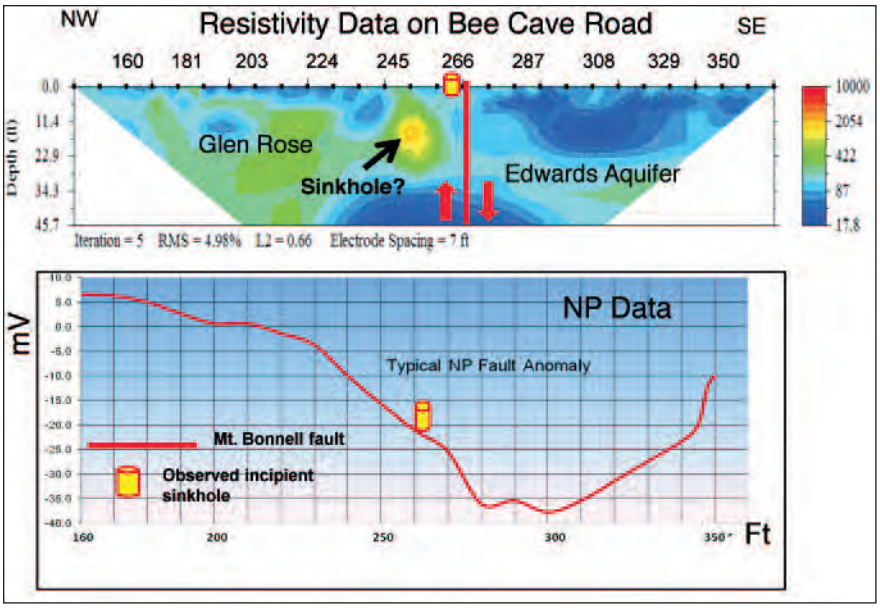

Figure 9. Resistivity and NP data across the Mount Bonnell fault along Bee Cave Road. Location of the fault is placed in the field by examiniation of the outcrops on the either side of the fault (Nico Hauwert, pers. comm., 2010). Note that the NP data indicates a fault anomaly ie. sinusoidal curve and a negative anomaly which may be due to a significant sinkhole in the subsurface. Also note the orange circular high resistivity anomaly between stations 245 and 260 feet, which could be due to a sinkhole.

MBF are shown in **Figure 7**. Geophysical surveys, except the GPR, were all conducted along the grassy area between the two driveways of the West Lake Bible Church and West Lake Animal Hospital. The GPR data was collected along Bee Cave Road adjacent to other profiles . There is an observed incipient sinkhole in the study area.

The magnetic and conductivity data are given in Figure 9 and they show high magnetic and conductivity anomalies between the stations 279 and 330 feet. The source of these anomalies appears to be subsurface. The incipient sinkhole is located at the station at 265 feet. The resistivity and NP data are given in **Figure 9**. The resistivity data show karstic anomalies, cave, sinkhole, collapsed materials, etc., along the entire length. The high magnetic and conductivity anomalies correlate well with the locations low resistivity material (≤ 20 ohm-m). Based on this correlation, the source of the magnetic and conductivity anomalies can be attributed to magnetic soils in the subsurface. The NP data shows an unique "U" type anomaly along the profile. The NP values range between 10 and -38 mV. The NP anomaly appears to be caused by a combination of the fault and a sinkhole. A GPR profile from the site is shown in **Figure 10**, which indicates a sinkhole anomaly between stations 242 and 252 feet.

In summary, (see also **Table 2**) the magnetic and conductivity data show high amplitude anomalies on the downthrown side of the Mt. Bonnell fault. Low resistivity anomalies are also observed across the magnetic and conductivity anomalies. Sources for these anomalies could be collapsed clayey and silty soils. The NP data displays high values on the upthrown side of the fault. There is a significant low NP anomaly where the incipient sinkhole is observed. Overall, the NP anomaly is interpreted to be the combination of the fault and the sinkhole feature.

Discussion of Results/Conclusions

All geophysical data obtained from the two sites across the MBF indicate significant subsurface anomalies. These anomalies appear to be due to caves, voids, collapsed materials, sinkholes, underground pipes, shallow faults and fracture zones. It should be noted that the magnitude of the NP anomaly is much stronger at the Bee Cave Road than the Height Drive site. This may be due to the fact the NP anomaly is caused by the combination of the fault itself and the sinkhole feature observed at the Bee Cave site.

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The GPR data taken along the roads indicate significant near-surface anomalies caused by collapsing soil, sinkholes and caves. It appears that these locations appear to be fixed periodically because of patched, repaired asphalt conditions observed on the roads.

In conclusion, data acquired and used to evaluate the effectiveness of geophysical methods in detecting karstic features and faults/fractures in the Austin area allowed correlation of unique and consistent anomalies with a known fault. It is clear from this study that integrated geophysical methods can be used to map Balcones faults and their associated karstic features quickly and inexpensively. Results of this study show the benefit of multiple geophysical methods to improve fault and karstic characterization of near-surface geology. ■

Acknowledgements

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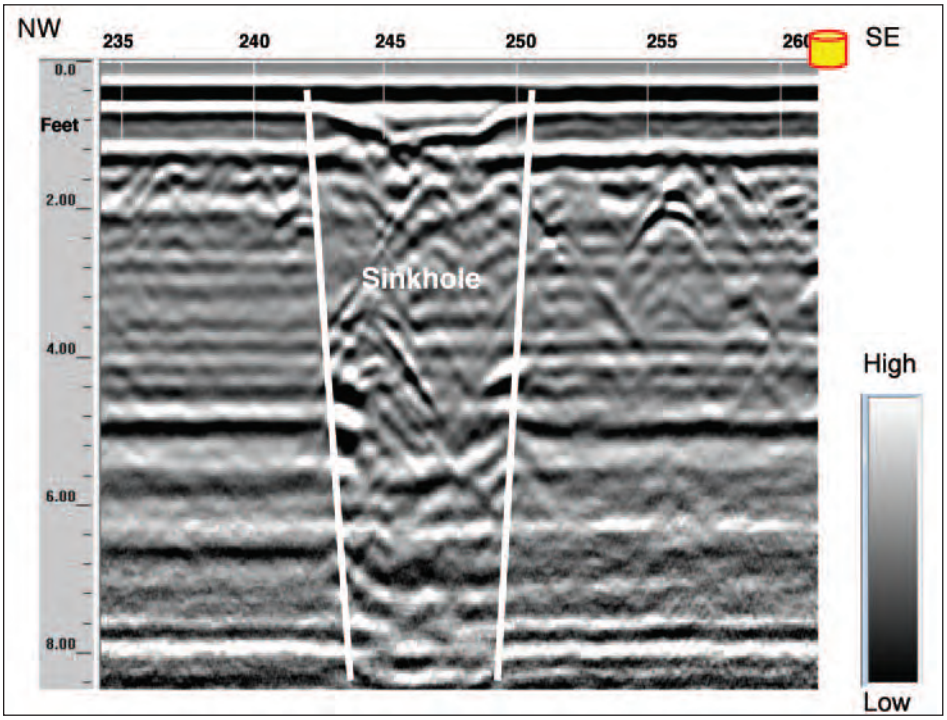

Figure 10. A section of GPR data across the Mt. Bonnell fault. A sinkhole anomaly is located between stations 242 and 252 feet. Note that the sinkhole is very close to the surface at the Bee Cave Road. Location of this sinkhole correlates well with the incipient sinkhole and the orange circular high resistivity anomaly that are observed on the surface and the resistivity data, respectively.

Geophysical Methods	Karstic Features			
	Cave	Sinkhole	Collapse Materials	Faults and Fractures
Magnetic	✓			
Conductivity	✓			
Resistivity	✓	✓	✓	✓
NP	✓			
GPR	✓	✓	✓	✓
TOTAL	✓	✓	✓	✓

Table 2: Karstic features located by geophysical surveys at Bee Cave Road.