2D Resistivity Imaging Investigation of Long Point, Katy-Hockley, Tomball and Pearland Faults, Houston, Texas

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Abstract

Active growth faults cutting the land surface in the Gulf Coast area may represent a serious geo-hazard. Although the average movement of these faults is only a few inches per decade, the potential exists for structural damage to highways, industrial buildings, residential houses and railroads that cross these features. We have conducted 2D resistivity imaging surveys at two sites over two known locations of Long Point fault (Moorehead at Westview, and NW section of east Beltway 8 and I-10 intersections) in the southwest part of Houston, Texas; Katy-Hockley and Tomball faults are located in the northwest part, and the Pearland fault in the southeast part of the Houston area. Results of 2D resistivity surveys on four faults in the Houston area have identified resistivity anomalies that can be used to locate the faults, determine the extent of near-surface deformation, and provide geological information.

Introduction

The Houston area has a very active shallow fault system as evidenced by active surface movement and measurable localized subsidence (Verbeek, R., E. & Clanton S. U., 1981). Evidence of faulting is visible from structural damage such as fractures and/or displacement. Faults are listric growth faults with dominantly dip-slip (normal) displacement to the south, although antithetic faults are present that dip to the north. In the near surface, fault dip is usually 60 to 75 degrees. Some active faults are clearly evident in surface damage such as scarps across lots, fields and streets. Vertical offset is commonly the most visible aspect of fault movement. Because the near-surface dip of the faults is usually 60 to 75 degrees, horizontal extension equivalent to one-half to one-fourth of vertical component of movement takes place. This movement tends to pull the subsurface material apart (Elsbury et al., 1980). Today, active faults are the source of heavy damage to pavements, utilities, homes businesses, and other man-made structures in the Gulf Coast region. In the Houston area alone (Harris County), there are more than 300 active or potentially active faults totaling over 300 miles in length. These active faults are not discrete ruptures. Rather, they are zones of intensely sheared ground tens of meters wide (Clanton, S. U., and Verbeek, R.E., 1981).

One of the most significant faults of the Houston area is the Long Point Fault, which runs from near US 290, west-southwest through the Beltway/I-10 Interchange to near Eldridge Parkway in west Houston, a distance of about 11 miles (Figure 1). It is a typical Gulf Coast growth fault that moves (creeps) slowly about 1/4 to 1 inch per year crossing through many neighborhoods and deforming many residential and commercial buildings. The fault plane dips about 70-degrees from the horizontal toward the coast (southeast).

This paper presents the resistivity imaging data along with observations made on the surface deformation of the Long Point Fault at Moorehead and Westview, and Beltway 8 and I-10 intersections, Katy-Hockley and Tomball Faults in the northwestern part of the Harris County, and Pearland Fault in the southeast of metropolitan Houston area (Figure 1).

Resistivity Technique

Resistivity imaging is a surface geophysical technique, which is used to build define the electrical properties of the subsurface by passing an electrical current along electrodes and measuring the associated voltages. This technique has been used widely in determining plumes, karst features, such as voids, and subsurface structures, such as faults and fractures (Dahlin, 1996, Seaton and Dean, 2004, Saribudak, 2010). For this study, we used the Advanced Geoscience Inc's (AGI) Super R1 Sting/Swift resistivity meter with dipole-dipole resistivity technique, which is sensitive to horizontal changes in the subsurface, and provides a 2-D electrical image of the near-surface geology..

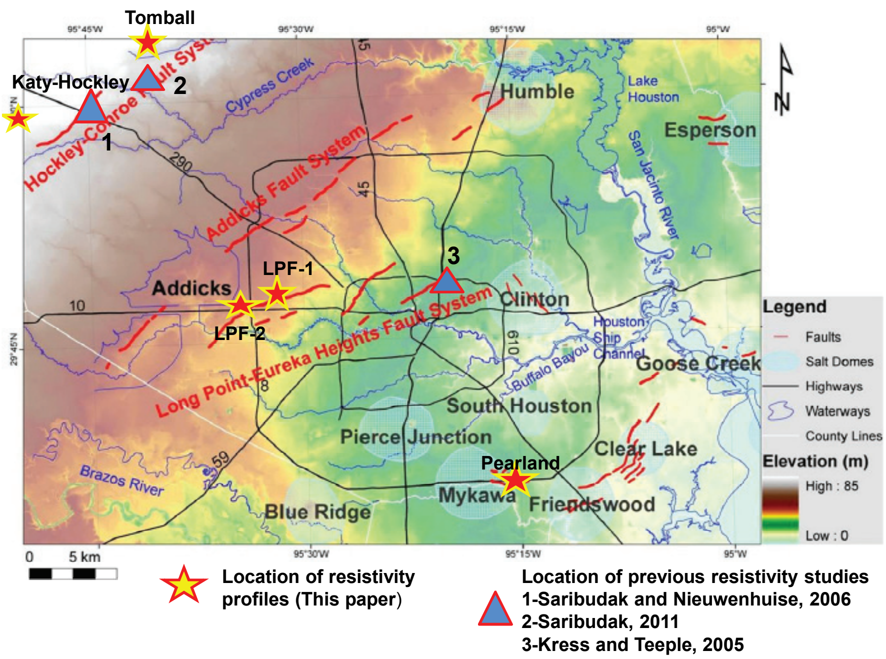

Figure 1.
Lidar elevation map of Houston showing NE-SW trending faults and resistivity survey locations (revised from Engelkemeir and Khan, 2008). LPF-1 and LPF-2 abbreviations indicate Long Point fault locations.

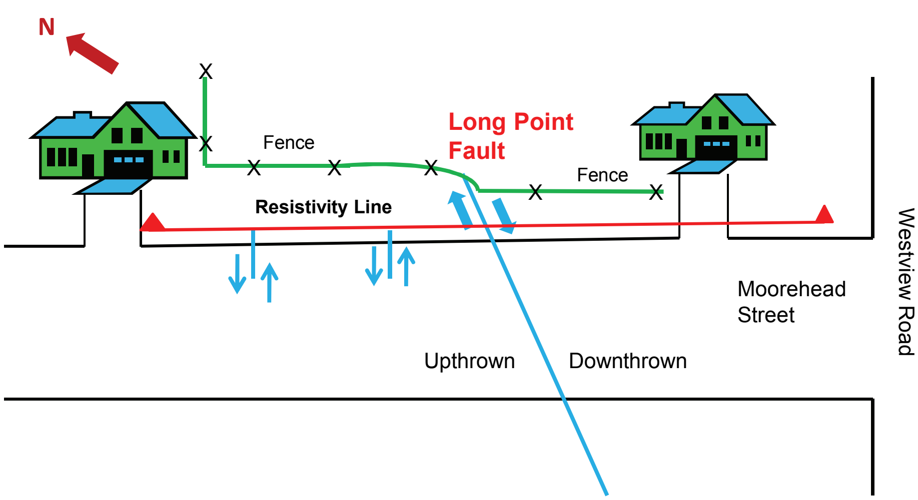

Figure 2.
Schematic map of Long Point fault at Moorehead Street. Note the presence of two small faults in the upthrown side of the fault, and the deformation on the fence line. Resistivity line is shown with a red line.

Field Data Collection and Processing

We collected resistivity data over Long Point fault at two locations: along Moorehead street near Westview Road, and at a location near Beltway 8 and I-10 intersection (see Figure 1). During the field survey at the first location, we sketched the cracks and patched pavement locations and/or fences deformed by the fault (Figures

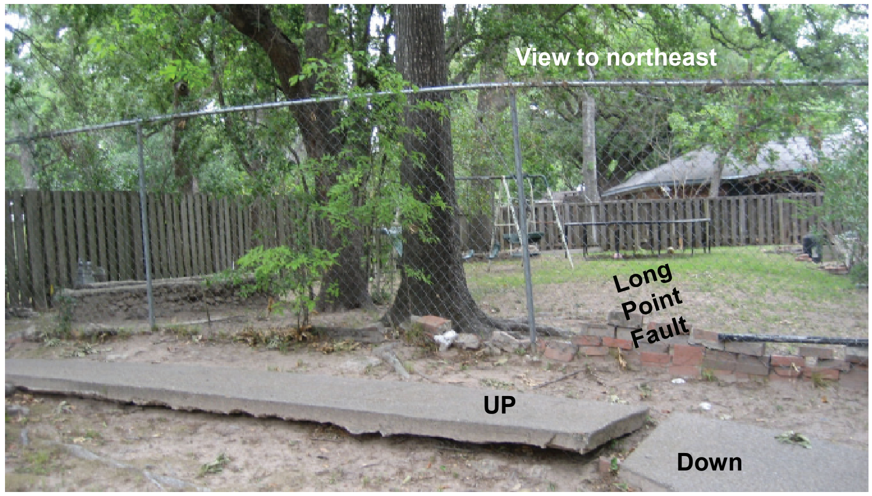

Figure 3.
Long Point fault scarp across Moorehead Street. Note the fault related deformation on the concrete path for pedestrians.

2). At the Moorehead Street location a discrete fault scarp deforms the road, curbs and sidewalks (Figure 3). Figure 4a shows the approximate location of the Beltway 8 and I-10 study area, where the fault clearly deforms the fence, respectively (Figure 4b and Figure 5).

We conducted resistivity surveys over Katy-Hockley fault in the year 2005. For the Tomball fault, we were hired in the year of 2006, and for the Pearland fault in 2007.

We inverted the resistivity data into geo-electric sections using AGI's Earth Imager software. The resistivity values obtained in this study varied between 2 and 2000 Ω-m. Resistivity values, in general, between 1 and 10 Ω-m corresponds to clay; resistivity values between 10 and 25 Ω-m represent clayey sand, silty clay, sandy clay; and 25 Ω-m and above fine sand deposits (Kress and Teeple, 2005). Following color scales for 2D resistivity sections were used: high resistivity (low conductivity) is displayed in red color whereas low resistivity (high conductivity) is represented by blue color. The background resistivity values are shown with the green color.

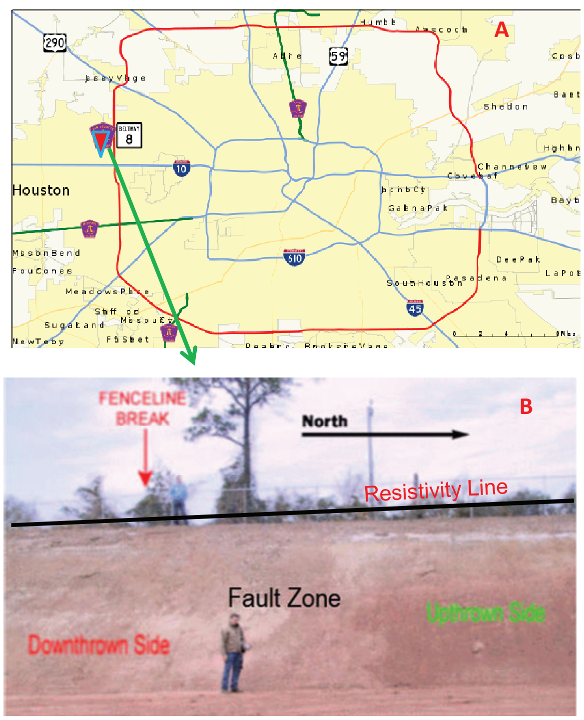

Figure 4.
a) Location of Beltway 8 and I-10 resistivity profile; b) a photo taking in 2006 shows the west wall of the excavated pit for the development of the water detention pond (picture is revised from Britt, P. 2006). Note the location of the resistivity line.

Definition of Resistivity Anomaly

Definition of a geophysical anomaly is defined as a deviation from uniformity in physical properties (Sheriff, 1994; p.10). The resistivity method is used to detect changes in the electrical properties of the subsurface. The electrical properties of soils and rocks are determined by water content, mineralogical clay content, salt content, porosity, and the presence of metallic materials. Thus the resistivity anomaly can also be defined as any changes in the soil properties mentioned above. In general, in the absence of tectonic activity, the soil layers should present horizontal layers in the Gulf Coast region. In the case of a growth fault, the different soil layers are juxtaposed within the fault zone .We attempted to model such a growth fault. Figure 6A indicates the synthetic model showing the silt, sand and clay layers displaced along the fault with a 30 feet vertical offset. Figure 6B and C show the inverted resistivity and synthetic apparent resistivity section, respectively. Figure 6B displays the fault movement and the thickening the soil layers on the downthrown side.

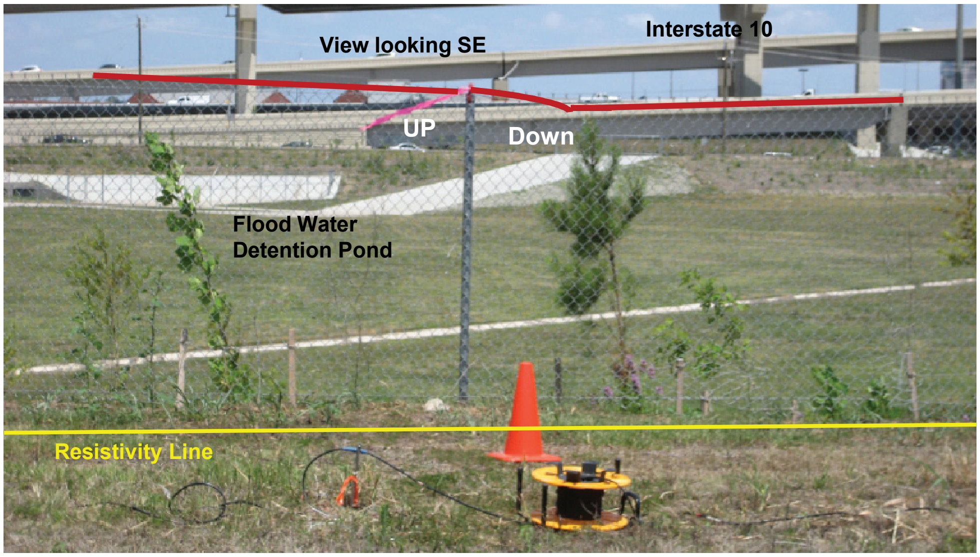

Figure 5.
A picture taken in 2011 shows the resistivity line with respect to the west wall of the detention pond, which is fenced, and the fence break-line indicates the fault location.

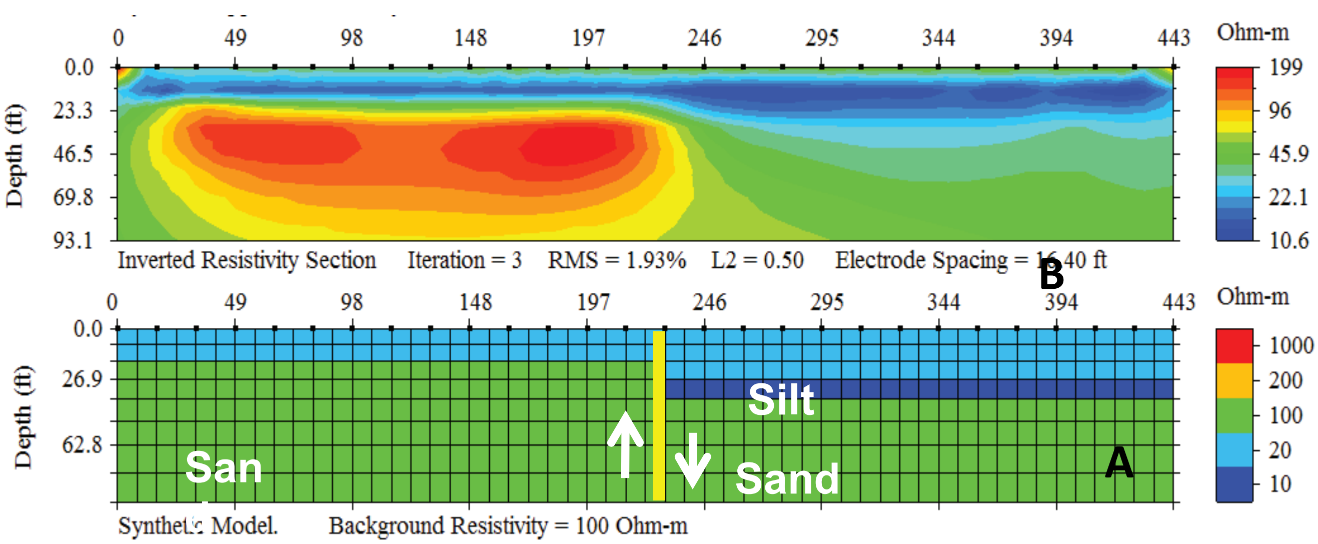

Figure 6. Sections showing (A) a synthetic fault model, and (B) resistivity inversion result of fault model within sand and clayey soils.

Resistivity Imaging of Long Point Fault

1) At Moorehead Street and Westview Road

The resistivity data collected along the Moorehead Street is shown in Figure 7. A fence-line break and the driveway of a nearby house are given for references. The fault juxtaposes low resistivity soil layers (clay as displayed by the blue) against moderately resistive units (sand as displayed by green color). The Long Point fault location observed at the site is superimposed on the resistivity imaging data, which shows south-dipping clay layers on the south part of the fault trace. The northwest part of this anomaly is limited by a high resistivity layer shown by the red color.

2) At East Beltway 8 and Interstate I-10

Resistivity data collected over the fault show south-dipping clay layers in the south part of the Long Point fault (Figure 8), which juxtaposes low resistivity soil (clay as displayed by the blue color) against moderately resistive units (sand as displayed by the green color).

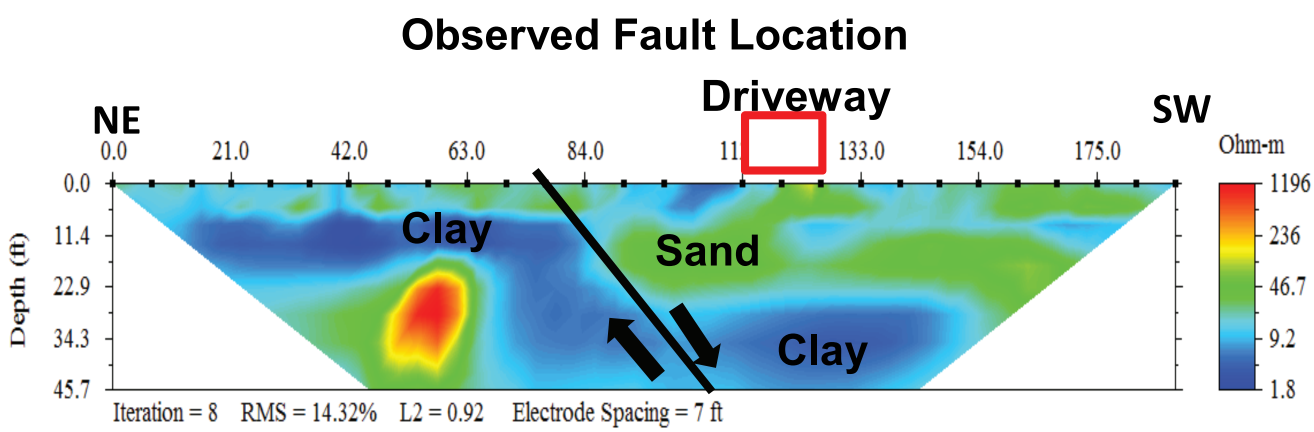

Figure 7. Resistivity imaging data taken along Moorehead Street across the Long Point fault.

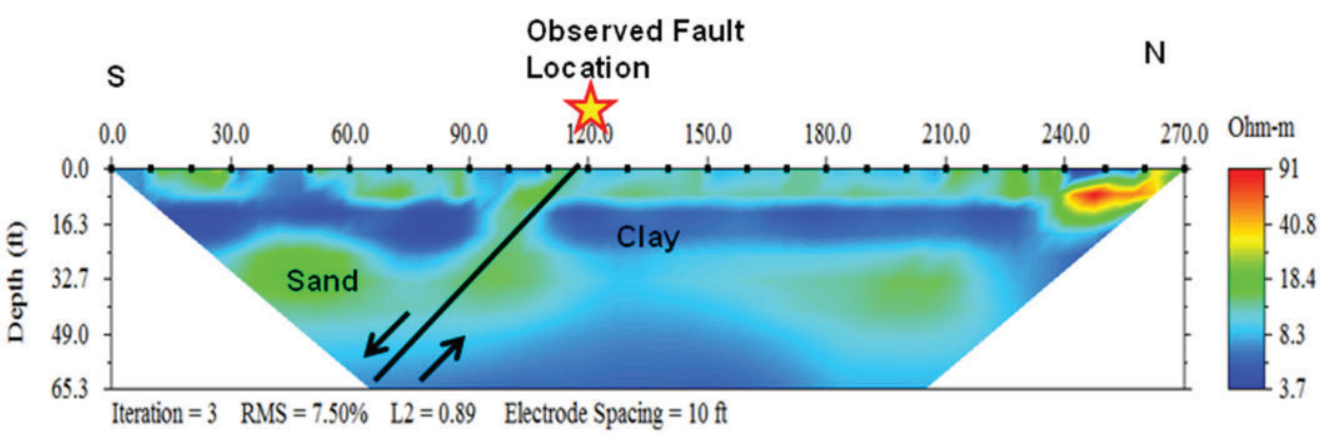

Figure 8. Resistivity imaging across Long Point fault. Note the south-dipping clay layers in the downthrown side.

Katy-Hockley Fault

The E-W striking and south-dipping Katy-Hockley fault crosses Katy-Hockley Road 2235 feet to the north of the intersection of Jack and Katy-Hockley Roads. There was no deformation observed on the road because the road was built newly prior to the resistivity survey. The resistivity data collected across the fault (Figure 9) indicate a thickening of the clay and sand units on the downthrown side of this growth fault.

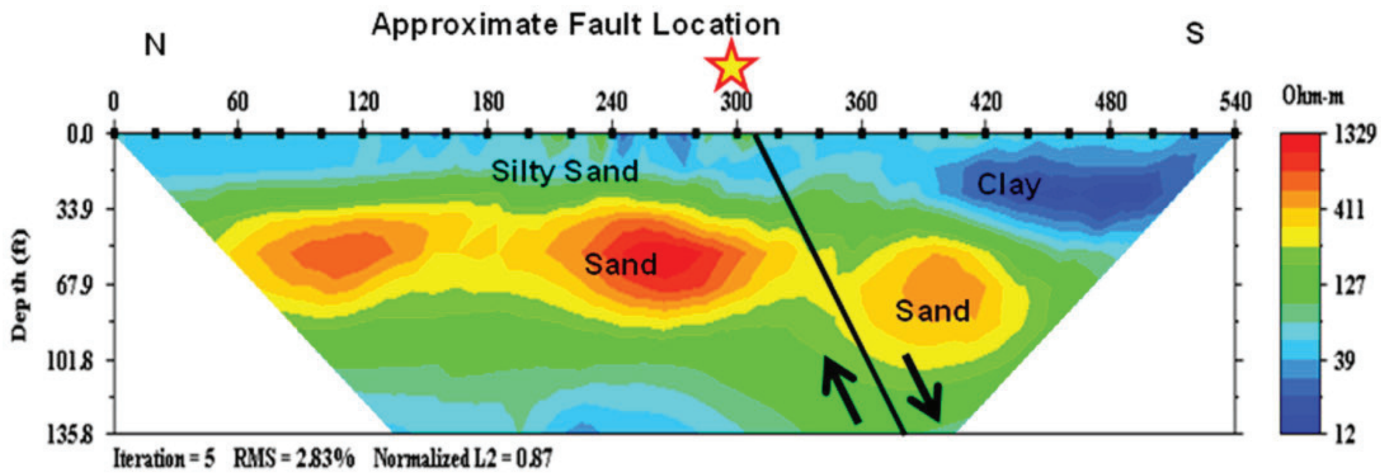

Figure 9. Resistivity imaging data taken across the Katy-Hockley fault. Note the south-dipping sand layers and thickening clay layers in the downthrown side.

Tomball Fault

The Tomball fault is one of the major regional faults of the Houston area, and is located in Tomball City. The fault strikes in the east-west and crosses SH 249. Further east, it runs through Beckendorf Middle School, which is located between Sandy Lane and Quinn Road (Figure 10). The fault deformed and damaged the west entrance of the school extensively. Because of the destruction of the property, the school was closed permanently in 2009.

A line of resistivity data (Figure 11) was collected across the fault in the western part of the school area. The resistivity data is shown in Figure 11, which also shows the sketches of the school and deformation zone schematically. Available borehole data from the site indicates caliche. The resistivity data indicates a significant deformation

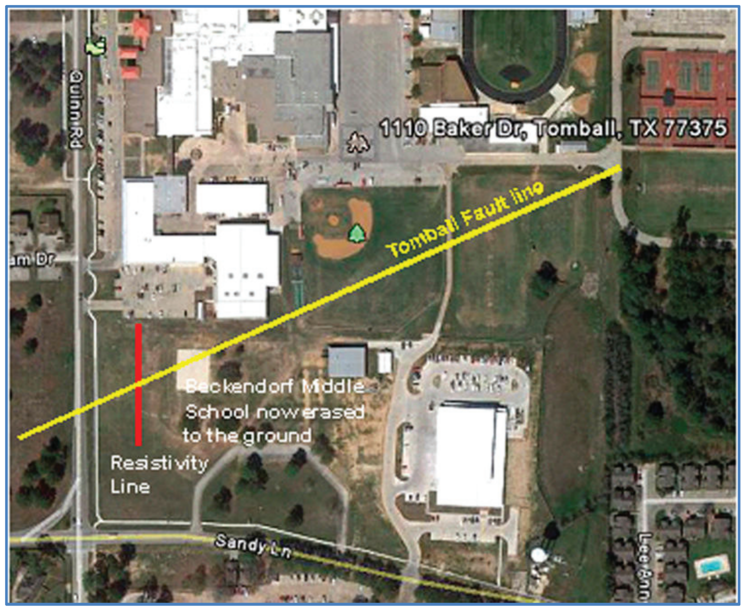

Figure 10. Beckondorf Middle School site map showing the Tomball fault line and location of the resistivity profile.

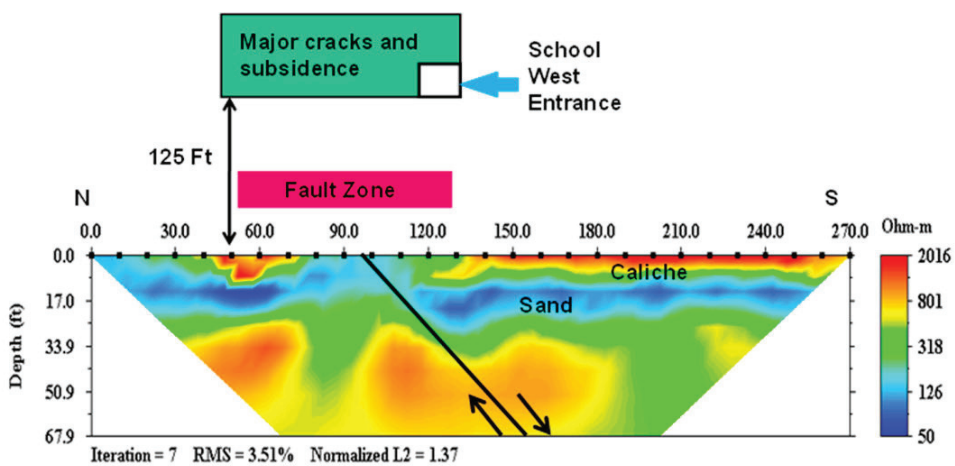

Figure 11.
Resistivity imaging data taken across the Tomball fault at the western side of the Beckendorf Middle School. Note the significant deformation within the fault zone defined by the resistivity data, and thickening sand layers in the downthrown side of the fault.

zone between stations 50 and 130 feet, in which sand layers are displaced upwards and downwards. Away from the fault zone, the sand layers are horizontal. We observed major cracks on the wall of the school corresponding to the resistivity anomalies.

Pearland Fault

A blind test of the technique was conducted in the winter of 2007; we were asked us to perform a resistivity survey over the Pearland fault. Two resistivity profiles 10 feet apart were run across the fault for data redundancy (Figure 12).

Figure 12. A picture, looking SW, showing the location of resistivity line 1 across Pearland fault.

Results of both profiles are shown in Figure 13. Data from the 4 boreholes were used to project the surface location of the fault (at about 260 ft) along the profiles; the fault dips about 70° to the SW. Both resistivity profiles indicate a low resistivity area between stations at 220 and 320 feet. The resistivity for this anomaly varies between 5 and 10 Ω-m, which is indicative of clay. This low resistivity zone was interpreted to be a fault zone anomaly prior to any knowledge on the exact location of the fault. Note the approximate correlation of the fault location based on the borehole data (station 260 feet) and the resistivity data (between stations 220 and 320 feet).

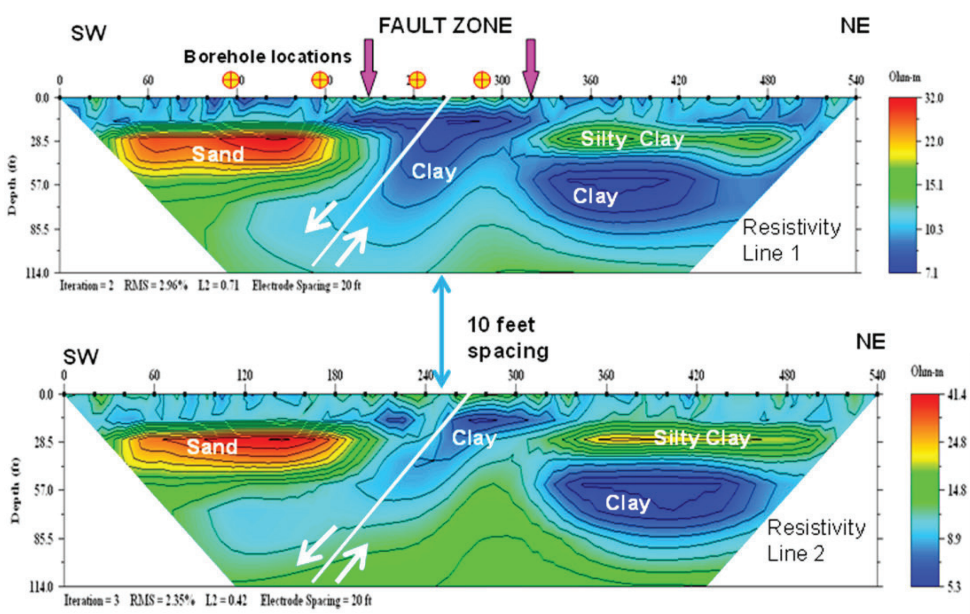

Figure 13.
Two resistivity imaging data sets taken across the Pearland fault. The fault location was not known prior to the resistivity surveys. Location of the fault is based on the four borehole data, and is projected onto the resistivity data.

Discussion

Three of these faults discussed in this paper (Long Point, Tomball and Katy-Hockley) are well known in terms of their locations and their extent. Resistivity anomalies across these faults appear to manifest themselves as south-dipping clay and/or sand layers, and significantly deformed sand and/or clay layers. It is important to point out that these anomalies are only restricted where the resistivity profiles cross the faults. Away from the faults, the resistivity data indicate, more and less, horizontal strata without any significant deformation.

The resistivity data in the Pearland area was obtained without knowing the exact location of the fault. We interpreted the abrupt termination of horizontal continuous sand and silty sand layers and the south-dipping clay layers between them along the two separate resistivity sections as anomalous and related to the location of the Pearland fault.

Previous resistivity results of by Saribudak and van Nieuwenhuise (2006), and Saribudak (2011) indicated similar anomalies across the Willow Creek and Hockley faults, respectively. In a similar study, Kress and Teeple (2005) obtained resistivity profiles coupled with borehole data across the Pecore fault in Houston (Figure 1). Their results (Figure 14) indicate discontinuous sand pockets and normally-displaced clay layers across the fault.

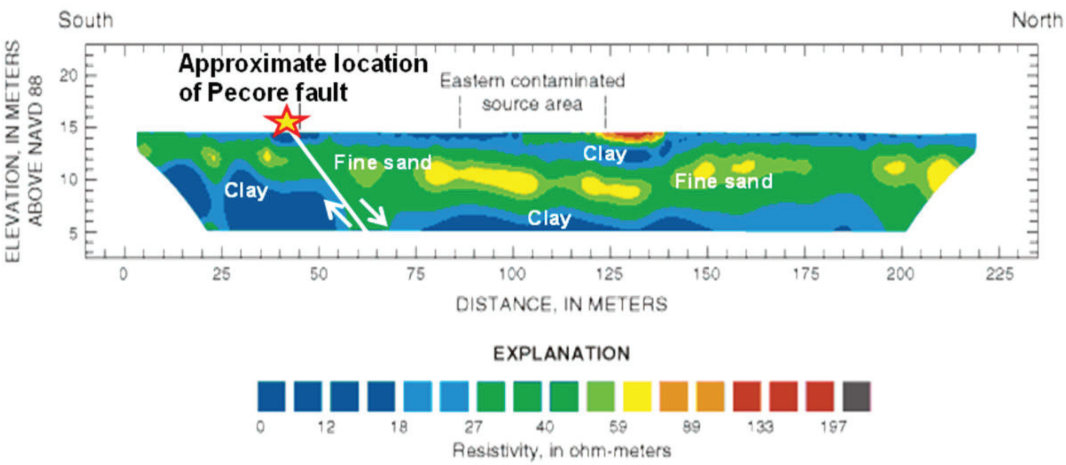

Figure 14. Resistivity profile showing the resistivity data across the Pecore fault (modified from Kress and Teeple, 2005).

In conclusion, data acquired across the known growth faults in the Houston area indicate a variety of anomalies associated with the faulting. These and previously published results indicate that the resistivity technique offer a viable method for detecting and mapping growth faults in the Houston area.

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