The Active Faults of Harris County: A Self-paced Field Guide

By Mustafa Saribudak and Caroline Wachtman

INTRODUCTION

Over 70% of HGS members live in Harris County, and many of those members are interested to learn more about the geology of the area. It is easy to see how geologic processes shape the landscape of Harris County after episodic events such as hurricanes or flooding, but other geologic processes such as faulting and subsidence are subtly at work over geologic timescales. This guide focuses on the surface and subsurface expression of selected well-documented faults in the Houston area to provide geologic context for the processes that shape our community. This reference focuses on four faults in the greater Houston area: 1) Long Point, 2) Eureka-Heights, 3) Hockley, and 4) Willow Creek.

The geophysical data presented in this guide were gathered in the early 2000s by first author, Mustafa Saribudak, and have been published by Saribudak and Nieuwenhuise (2006), Saribudak (2011 and 2012), and Saribudak et al. (2018). Recently, major highway construction projects have obscured or remediated (e.g., asphalt patches) surface expression at some fault locations. But, upon close inspection, subtle fault deformation is visibly expressed as cracks or scarps.

This guide is intended to be a self-paced study, and the locations listed below are intended to be easily accessible, making this an activity to share with small groups. Driving directions and GPS coordinates of each fault are provided. Note that participants should always wear a high-visibility safety vest and only park in designated parking lots. Parking along highways is not a safe choice.

STRUCTURAL SETTING OF HARRIS COUNTY

Sheets (1971) documented faults in Harris County associated with salt tectonic movement and regional-scale growth faults associated with formation of the Gulf of Mexico. Growth faults are characterized by increasing displacement with depth. Because displacement on growth faults occurs contemporaneously with sedimentary deposition, the downthrown side of the fault typically contains a thicker sedimentary package. Growth fault geometries can form hydrocarbon traps (Shelton, 1984, Ewing, 1983).

In the late 1970s, the United States Geological Survey (USGS) launched an extensive study of faults in Houston (Verbeek and Clanton, 1978; Verbeek et al., 1979; O'Neill and Van Siclen, 1984; Clanton and Verbeek, 1981). Based on detailed analysis of well logs and seismic data, Verbeek et al. (1979) documented an extensive fault network along the upper Texas Gulf Coast, including numerous faults in the Houston area at depths of 3,200-13,000 ft. Some of the deep-seated faults in Harris County penetrate depths shallower than 3000 ft (McClelland Engineers (1966), and dozens of faults have surface expressions. Verbeek and Clanton (1978) used aerial photographs to identify and map the surface expressions of faults. More recently, researchers from University of Houston, such as Engelkemeir and Khan (2008) and Khan et al. (2013) have used light detection and ranging (LiDar) to map the surface expression of faults in the greater Houston area. Active faults in this region are typically not discrete ruptures. Rather, they are expressed as zones of intensely sheared ground that is tens of feet wide.

Some of the faults have been recently reactivated by petroleum production (Sheets, 1979) or groundwater withdrawal (Holzer and Gabyrsch, 1984). Fault movement is reported to be 0.2 -0.8 inches per year (Shaw and Lanning-Rush, 2005). Norman (2005) identified some locations where displacement is more than one inch (3 cm) per year. Today, active faults are the source of damage to pavements, utilities, homes, businesses, and other manmade structures (**Figure 1**).

Engelkemeir and Khan (2008) report over 300 active faults in the Houston area, but the most recent USGS mapping project compiled by Shaw and Lanning-Rush (2005) identifies 150 active faults, including approximately 30 named faults (**Figure 2**).

SURFICIAL STRATIGRAPHY IN HARRIS COUNTY

The coastal plain of the Gulf of Mexico is underlain by a thick sequence of largely

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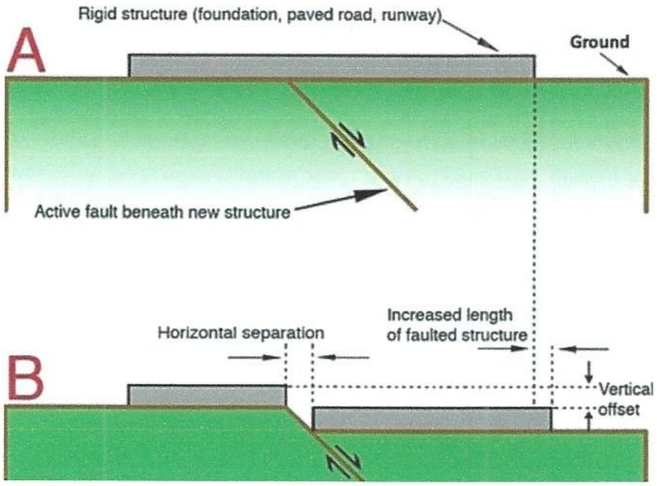

Figure 1. *A) An active growth fault beneath a foundation and B) The fault movement results in horizontal and vertical separations, and is the source of damage to homes, businesses, utilities, and pavements.*

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unconsolidated, lenticular deposits of clays, silts and sands formed in shallow water and marsh-dominated depositional environments. Three Pleistocene-age formations crop out at the surface in Harris County. In ascending order, these are the Willis, Lissie, and Beaumont formations. The Willis is primarily composed of clays with lesser amounts of silts and sands; the Lissie formation contains sands with fewer silts and clays, and the Beaumont contains finer clays with silt (Moore and Wermund, 1993).

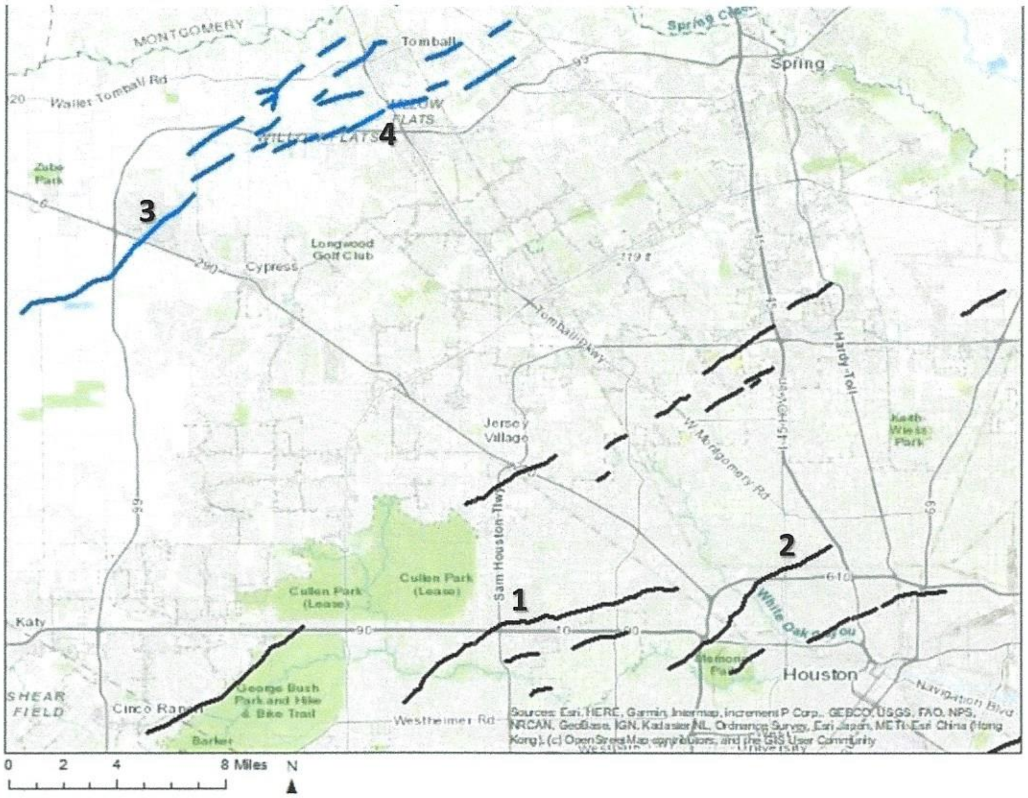

Figure 2. *Map of well-documented faults in Harris County, based on Shaw and Lanning-Rush (2005) and Engelkemeir and Khan (2008). The guidebook focuses on four faults: 1) Long Point, 2) Eureka Heights, 3) Hockley, and 4) Willow Creek.*

HISTORY OF NEAR-SURFACE GEOPHYSICAL WORK ACROSS GROWTH FAULTS

Common methods to identify faults include aerial photographs and field mapping; and subsurface borehole data on both the down and upthrown sides of the faults (Elsbury et al., 1980). In addition, geophysical methods may be used to define faults. A pioneering resistivity study was performed over some of the Houston faults by Kreitler and McKalips in 1978. They used a resistivity meter with four electrodes, and manually crossed several fault locations using a Wenner array. Their results mostly identified anomalous resistivity values that correlated with the locations of the faults.

Building on the work of Krietler and McKalips (1978), Saribudak and Nieuwenhuise (2006) used a multi-electrode resistivity meter and other geophysical methods (conductivity, magnetic, gravity and GPR) to map the Willow Creek fault. Engelkemeir and Khan (2008) published seismic and GPR work over the Long Point fault, which is one of the most active faults of the Houston area. Additional resistivity surveys were conducted over the Long Point, Katy-Hockley, Tomball, and Pearland faults, and results were published in Saribudak (2011). During the following year, integrated geophysical results (resistivity and GPR) were published in Saribudak (2012) for the Hockley fault. Khan et al., (2013) published geophysical results (seismic, gravity and GPR) over the Hockley fault along with airborne LiDar data. More recently. Saribudak et al., (2018) published new geophysical data and discussed the deformation mechanism of the Hockley fault.

STOP 1: LONG POINT FAULT

Location: Coordinates of the fault location are 29° 47.515', 95° 32.064', which falls in the vicinity of the intersection of Moorehead Drive and Westview Drive in the West part of Houston. The fault is located in the northeast part of the intersection of Sam Houston Tollway Road (Beltway 8) and Interstate Highway 10 (I-10). (**Figure 2**)

Driving directions: The easiest way to reach the Long Point fault is to take Westview Road from I-10 and drive to the East until reaching the intersection of Moorehead Drive and Westview Drive. Then, proceed North along Moorehead Drive at the intersection. The fault is located about 140 feet from this intersection. There is a three-foot fault scarp that is highly visible and hard to miss.

Geologic overview: The Long Point Fault extends approximately 11 miles to the West-southwest from US 290, through the Beltway/I-10 Interchange, and close to Eldridge Parkway in West Houston (**Figure 2**). It is a typical Gulf Coast growth fault that slips slowly about 0.25 - 1 inch per year. The fault strikes through many neighborhoods and is responsible for deformation of residential and commercial buildings. The location of the resistivity profile that was collected across the Long Point fault is shown in **Figure 4.**

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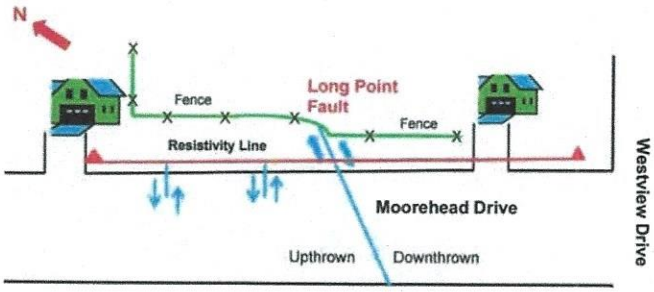

Figure 3. *Schematic map of Long Point fault at Moorehead Drive. The fault location is about 140 feet from the intersection of Moorehead and Westview Drives. Note the deformation on the fence line and the presence of two small faults in the upthrown part of the Long Point fault. The position of a resistivity profile is shown with a red line. There are houses in this neighborhood that have had continuous foundation repairs since 1970s up to now due to the creeping fault movement.*

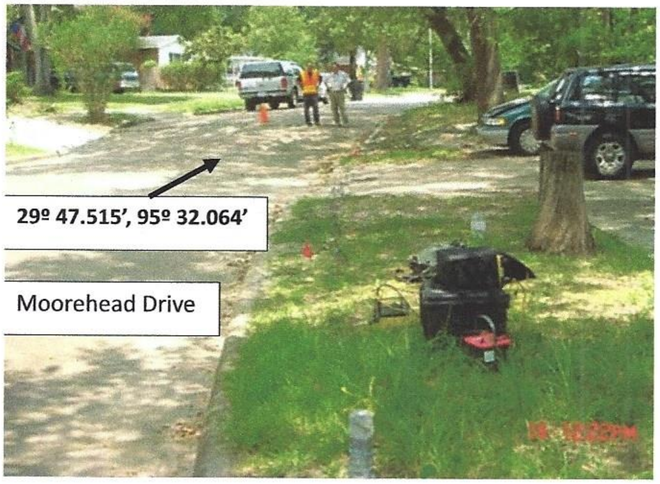

Figure 4.*Picture showing coordinates of the Long Pont fault, the fault scarp on the road and the location of resistivity profile. The view is to the north.*

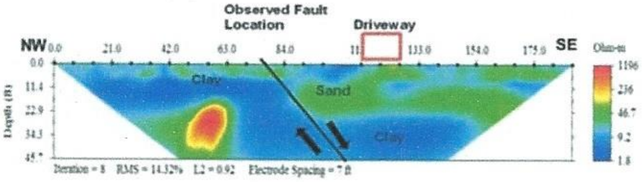

Figure 5. *Resistivity imaging data taken along Moorehead Drive across the Long Point fault. Note the fault offset in the southeast direction which juxtaposes the sand and clay layers.*

The resistivity data collected along Moorehead Drive is shown in **Figure 5**. A fence-line break and the driveway of a nearby house are reference markers. The fault juxtaposes low resistivity soil layers (clay as displayed by the blue) against moderately resistive units (sand as displayed by green color) thus creating an anomaly. 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.

Figure 6. *Resistivity imaging data taken along Moorehead Drive across the Long Point fault. Note the fault offset in the southeast direction which juxtaposes the sand and clay layers.*

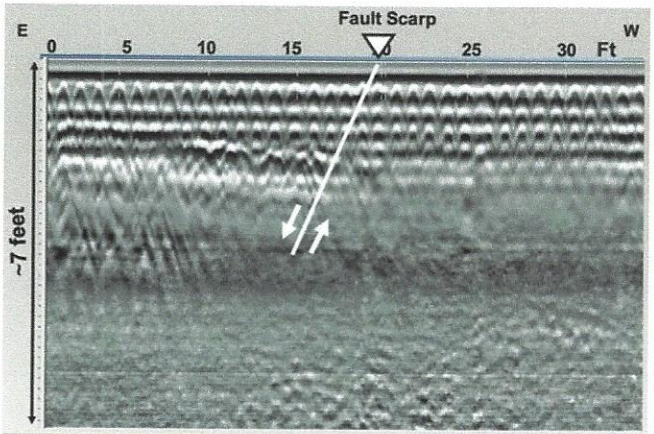

Figure 7. *The GPR data across the Long Point fault. The deformation caused by the fault is visible between 7 and 25 feet. Hyperbolic anomalies are due to rebar reflections.*

The resistivity anomaly can be caused by any change in the soil properties, such as change in moisture, clay content, and porosity ratio across the fault. In general, in the absence of tectonic activity, the soil layers should present horizontal layers. In the case of a growth fault, the different soil layers are juxtaposed across the fault, which creates a visible resistivity anomaly.

Ground Penetrating Radar (GPR) surveys were performed across the fault (**Figure 6**). The 400-MHz antenna was used with a cart system to collect GPR data. The ability of a GPR system to work successfully depends upon two electrical properties of the subsurface, electrical conductivity and relative dielectric constant. The value of dielectric constant ranges between 1 (for air) and 81 (for water). The dielectric constant for sandy soils, depending on its moisture content, varies 6 to 20. However, the dielectric constant of clay is much higher than sandy soil and ranges between 10 and 40. For this reason, the presence of clay absorbs the electromagnetic signals of GPR and limits its exploration depth.

The GPR data is shown in **Figure 7**. The GPR data is displayed in a black-white amplitude format. The high amplitude values are shown by the white color, which are mostly caused by the presence of rebar in the subsurface and the underlying clay. Rebar was likely placed within the pavement to minimize the effect of faulting across the road. Despite the heavy presence of rebar and high conductivity soil

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layer (high dielectric constant) the GPR profile clearly indicates the downthrown section of the fault.

The surface expression of the Long Point fault has generally remained consistent since the photos were taken. The prominent fault scarp is visible despite repairs. Some of the houses in the downthrown side of the fault have been repaired intermittently. Trip takers are encouraged to observe the extension of the fault along Westview Drive, to the East of the intersection of Westview and Moorehead Drives. The fault scarp is also visible at this location.

STOP 2: EUREKA-HEIGHTS FAULT

Location: Coordinates of the fault location are 29° 48.914', 95° 25.036', which is near the intersection of West 31st Street and Dunsmere Road. The fault strikes northeast to southwest and crosses the NW section of N Loop W Freeway, I-10, and Highway 290. The fault tips out before Interstate 45 (**Figure 2**).

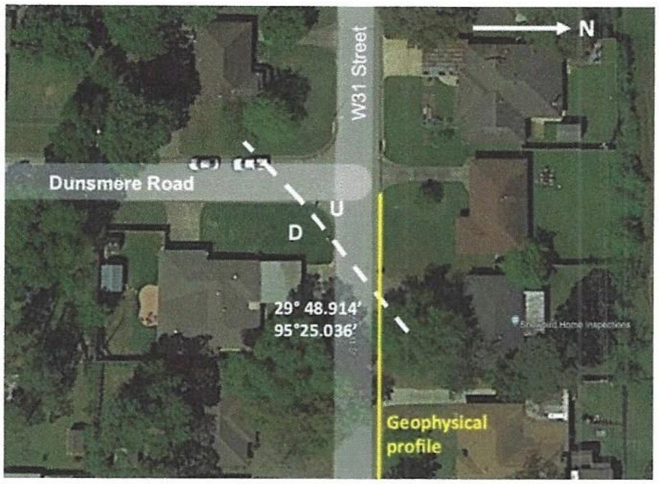

Figure 8. *Site map showing the approximate location of the Eureka fault crossing West 31st Street and Dunsmere Road. Fault deformation is highly visible on the asphaltic pavement of West 31 Street. The yellow line indicates the location of geophysical profiles.*

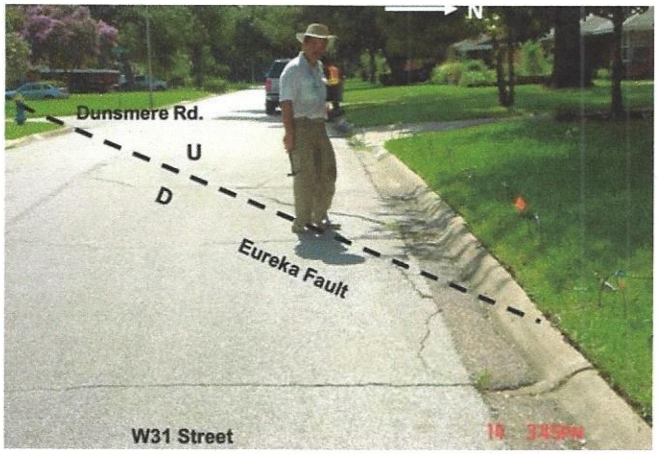

Figure 9. *Picture showing the approximate fault location during the collection of the resistivity data in 2008.*

Driving Direction: The easiest way to reach the fault location is to take the N. Durham exit from N. Loop W Freeway, and drive until reaching West 34th Street. Turn to the West (to your left) on West 34th Street and drive about 400 feet to the West. Then, turn South (left) on Randal Street. After driving about 800 feet, turn West (right) onto West 31st Street. Drive approximately 900 feet on West 31st Street until arriving at the intersection of Dunsmere Road.

Geologic overview: The fault crosses West 31st Street and Dunsmere Road (**Figure 8**). Fault deformation is expressed as cracks on West 31st street that extend 75 feet across the intersection. The fault is about seven miles long. It crossesmany residential places and commercial buildings.

Resistivity and GPR were conducted along the North edge of West 31st Street (**Figures 8** and **9**). Collecting these data were challenging due to the location of utilities, and insufficient contact between electrodes and fill material in driveways (see **Figure 8**). However, the resistivity data indicates a significant fault anomaly (**Figure 10**). In **Figure 10**, the blue color is interpreted to represent clay lithology and the shape of the blue anomaly is interpreted to represent fault offset.

A GPR survey was also conducted across the fault to map the subsurface deformation. The GPR data shown in **Figure 11** is interpreted to represent a fault zone between stations 10 and 37 feet. The fault location marked on the data coincides with the location of fault scarp observed on ground.

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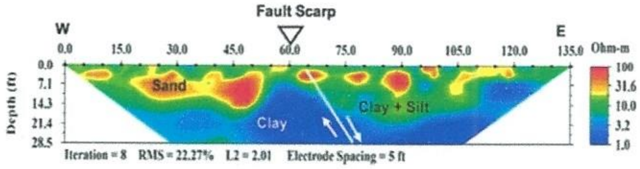

Figure 10. *Resistivity data collected along West 31st Street across the Eureka fault. Note the fault offset in the East direction which juxtaposes the interpreted sand and clay layers.*

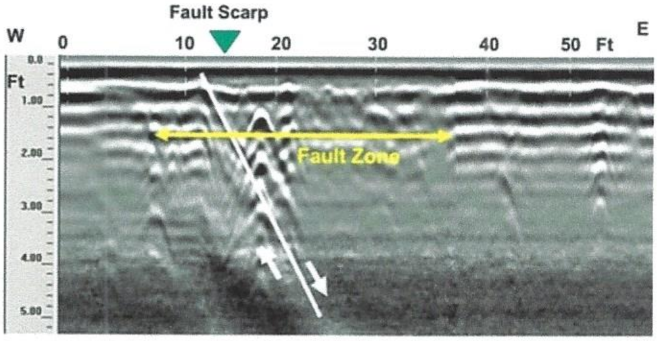

Figure 11. *GPR data across the Eureka fault. The deformation caused by the fault is visible between stations at 10 and 37 feet. Hyperbolic anomalies are due to utility lines.*

STOP 3: HOCKLEY FAULT SYSTEM

Location: There are two fault locations (A and B) to visit at this site. Coordinates of Location A are 29° 56.617', 95°45.241'. Coordinates for Location B are 29° 57.581, 95° 45.283'. The Hockley fault system crosses Highway 290 near the location of the Premium Outlet Shopping Center.

Driving directions: The easiest way to locate the Hockley fault is to drive West on Highway 290 from the Houston area and exit at Fairfield Falls Way. Proceed on the westbound feeder road until you reach Fairfield Falls Way.

Geologic overview: The fault A is evidenced by zones of intensely sheared and cracked ground at this location. The Hockley Fault system continues as a discrete rupture across Highway 290. The uneven highway surface, most obvious in East-bound lanes, is caused by the movement of the fault (**Figures 12** and **13**).

The second fault location (B) is located across from the highway on the East-bound feeder road (**Figure 13**). The Location of B does not align with the strike of Location A; it is shifted approximately 130 feet to the West. There is a discrete rupture of the feeder road. There are smaller cracks in the vicinity of this fault indicating that the deformation is diffusive.

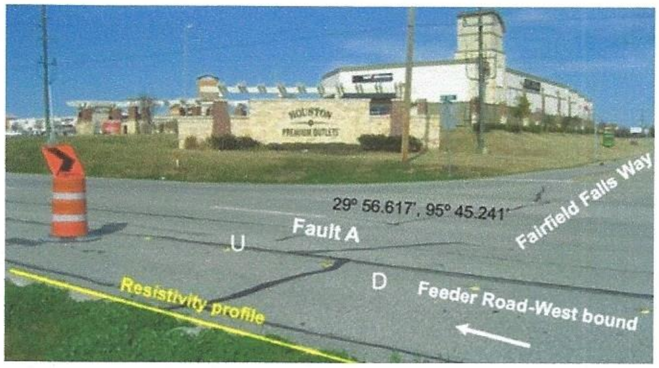

Figure 12. *Photo showing the location of Hockley fault (Location A) at the intersection of westbound feeder road and Fairfield Falls, where the Premium Outlets shopping mall is located. The fault is evidenced by the cracks across the feeder road. These cracks are regularly fixed and are sometimes covered with asphalt patches. Look for deformation to the foundation of the store visible in the background. The fault crosses the West and the East-bound lanes of Highway 290. The yellow line indicates the location of the resistivity profile.*

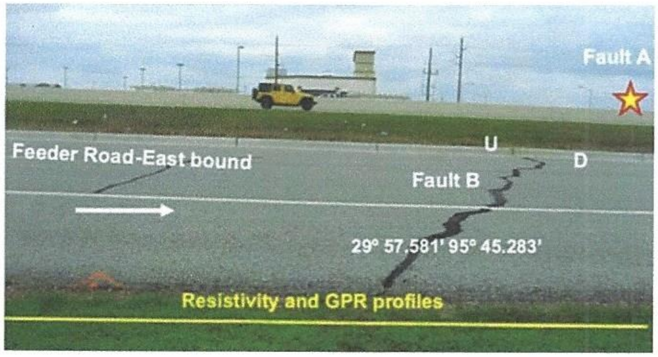

Figure 13. *Photo showing the location of Fault B on the East-bound feeder road. Note that the fault is expressed as a discrete, linear rupture, which has been filled with asphalt. Resistivity and GPR data are collected along the yellow line.*

Visits during April and August 2010 to the Hockley fault site provide additional evidence in the rate of fault deformation (**Figure 14**). Small cracks in the pavement over the main fault trace photographed in April 2010 and had extended and widened significantly by August 2010. Note that the cracks in **Figure 14** have been filled with asphalt. A site visit to the Hockley fault in 2022 showed that cracks were covered with an asphaltic patch.

Fieldwork for geophysical surveys was conducted in 2004 and 2005, before the shopping mall was constructed and before the expansion of Highway 290. There was a grass-covered median between the East- and West-bound lanes of the Highway (**Figure 15**) where more geophysical data was collected. For simplicity, only two geophysical profiles (L1 and L2) are discussed in this work.

The resistivity data collected along L1 is provided in **Figure 16.** A major fault anomaly is located at a station of 440 feet. The fault dips to the southeast but there is no rupture visible in sandy and clayey layers at the surface.

The resistivity data collected along Line 2 (L2) is given in **Figure 17**, which is interpreted to shows a fault anomaly across the discrete rupture

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Figure 14. *Recent pictures of Hockley fault at Highway 290 Frontage and Fairfield Falls Way roads: (a) taken in April 2010 and (b) taken in August 2010. Note the development of the tiny cracks in (a) into significant cracks in (b).*

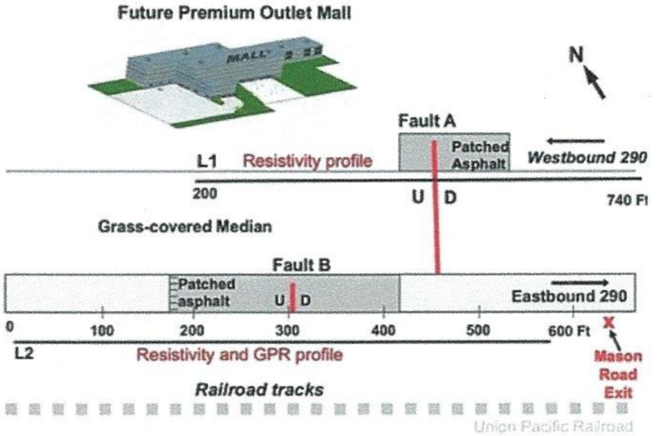

Figure 15. *Schematic map of the Hockley fault at Highway 290 and Fairfield Village during 2004 and 2005. The shopping mall was not yet built, and Highway 290 had a grass-covered median between the East and West bounds. Locations of resistivity profiles (L1 and L2) are shown with a red color. GPR data were also collected along Line 2 (L2) on the feeder road of eastbound. Not to scale.*

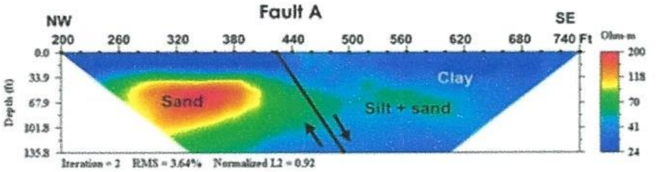

Figure 16. *Resistivity data collected along profile L1 located in the northern section of the grass-covered median in the year 2005.The fault occurs where the scarp is observed on the ground. *

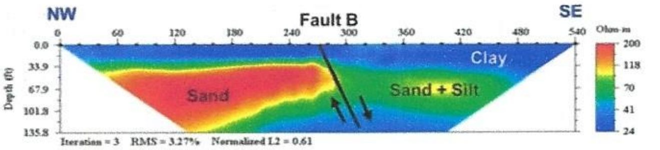

Figure 17. *Resistivity data collected along profile L2 on the southern section of the East-bound feeder road. The fault anomaly is located where the scarp is located and is well-correlated with the resistivity data.*

observed in **Figure 13**. The fault juxtaposes high-resistivity sand and low-resistivity sand and clay layers.

A GPR survey was also conducted along Line 1 (L1) at the southern edge of the East-bound feeder road. The 400-MHz GPR data is displayed in a color-amplitude format, and a color assigned to a specific positive or negative value of the recorded signal. The GPR data shows a significant anomaly at station 302 feet. The data are interpreted to show juxtaposition and offset of sedimentary layers down to the southeast.

STOP 4: WILLOW CREEK FAULT

Location: Coordinates of the Willow Creek fault are 30° 3.857’, 95° 37.282’. It is located on Highway 249 (Tomball Parkway) between Willow Creek and Holderrieth Road (**Figure 19**). The fault location is about 4,800 ft to the North of Grand Parkway (Highway 99). In 2003, a discrete rupture was visible on both bounds of the highway (**Figure 20**).

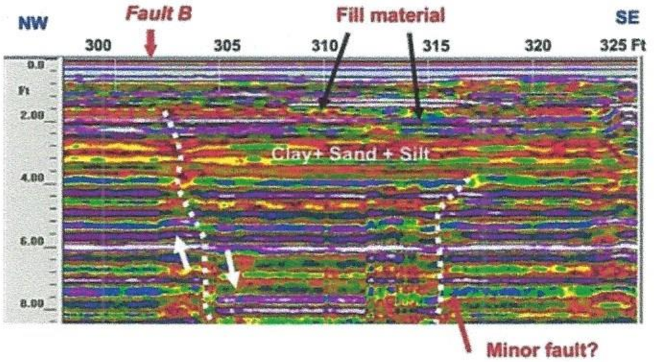

Figure 18. *GPR data along profile L2. A significant GPR anomaly was observed across the fault scarp between stations 300 and 305 feet. Down-to-the-southeast drag is interpreted at depths of 6 and 8 feet below ground level. There is also a minor fault anomaly at station 315 feet. The interpreted offset of sedimentary layers at this location is in the northwest direction.*

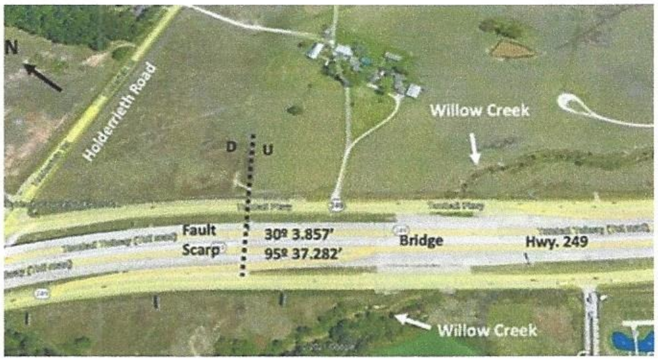

Figure 19. *Site map showing the location of Willow Creek fault, which is located between Willow Creek and Holderrieth Road. Note that willow Creek makes a sharp turn across the interpreted fault location. There were also asphalt patches to the South of the Creek and on the bridge. It is interesting to note that the farmland to the northeast (where the farmhouse islocated) is undeveloped.*

Driving Directions: The easiest way to drive from downtown Houston to the fault location is to take I-10 West until reaching Loop 610. At this intersection, take Loop 610 North to drive about 1.5 miles to get to Highway 290 exit. Take Highway 290 North and drive about 8 miles to reach Sam Houston Parkway (Belt 8). Then take Sam Houston Parkway (SHP) north. SHP bends to the west to meet Highway 249. At this intersection, take Highway 249 North, pass under Grand Parkway (99). Slow down to drive over the Willow Creek bridge. The fault location is about 300 feet to the North of the bridge. Immediately, there is a driveway to a farmhouse to the East, which may be a good parking location.

Geologic Overview: The Willow Creek fault is located about 300 feet north of the Willow Creek Bridge, strikes in a NE-SW direction, and dips to the north (**Figures 3**). This fault is antithetical to the South-dipping regional Tomball fault that is located about 3 km north. A discrete pavement break crossing both South- and North-bounds of Highway 249 clearly marks the presence of the fault (**Figure 20**).

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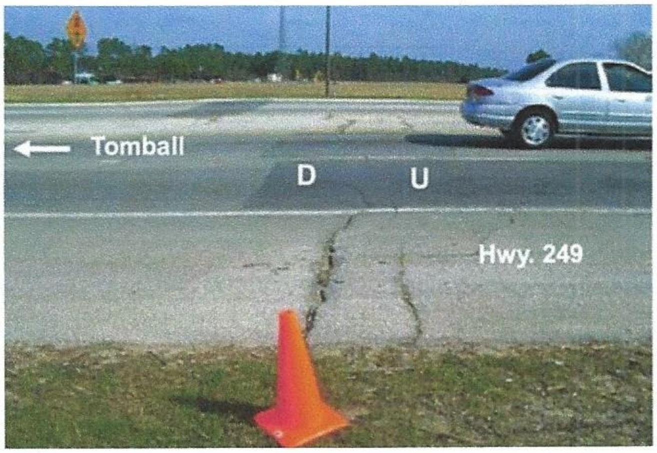

Figure 20. *Picture of Willow Creek fault taken in 2003.*

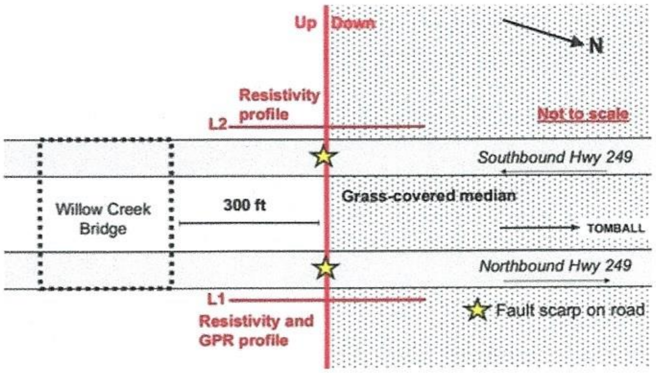

Figure 21. *Schematic map of Willow Creek fault at Highway 249 during the year 2003. Highway 290 had a grass-covered median between the East- and West-bound lanes. Locations of resistivity profiles (L1 and L2) are shown with a red color. GPR data were also collected along Line 1 (L1) on the edge of northbound. Not to scale.*

When the photo in Figure 20 was taken, Highway 249 had a grass-covered median between the East- and West- bound lanes. Multiple geophysical surveys were conducted across the fault (**Figure 21**). Two geophysical profiles will be discussed in this study.

Two resistivity profiles across the fault are provided in **Figure 22**. They both indicate a sharp resistivity contrast over the fault scarp. The resistivity contrast is interpreted to be caused by the juxtaposition of high resistivity sandy and low resistivity clayey sediments.

A GPR survey profile collected across the fault scarp along profile L2 and is provided in **Figure 23**. The GPR data indicates discontinuous layers beneath the scarp at a depth of 2 feet that are interpreted to result from deformation. In addition, the published GPR data (Saribudak and Nieuwenhuise, 2006) detected differential subsidence and a deformation zone between the bridge and the footing of the bridge. The Willow Creek fault movement is a possible cause for this deformation.

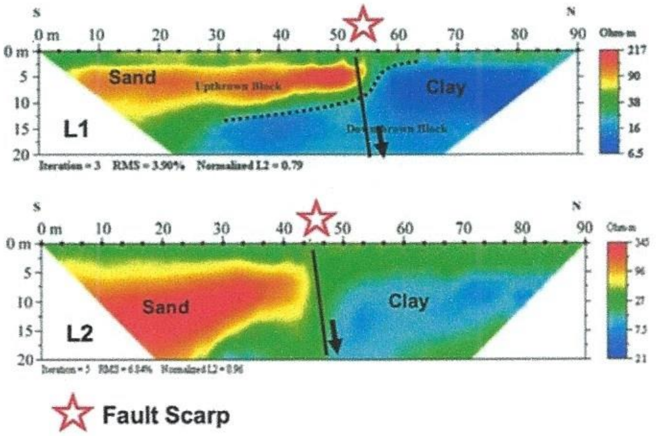

Figure 22. *Resistivity data collected across the fault along profiles L1 and L2. Note that the downthrown side is to the North and juxtaposition of low-resistivity layers along the fault plane is obvious.*

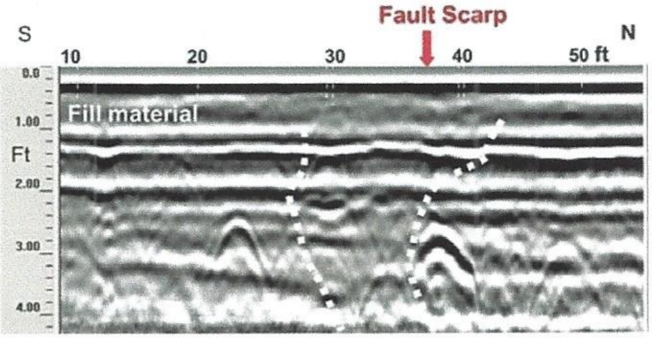

Figure 23. *The GPR data across the scarp of the Willow Creek fault. The data are interpreted to show minor deformation that is less significant than observed at the Long Point, Eureka Heights or Hockley faults. However, the disruption of sedimentary layers is interpreted to be visible. Hyperbolic anomalies could be due to buried pipes.*

CONCLUDING REMARKS

Active faults in Harris County are usually not discrete rupture planes, but zones of sheared ground tens of feet, which are described as fault zones as shown in this study. Geophysical methods discussed here do not provide a fault offset, except with seismic reflection. Common methods used to identify these faults, in addition to geophysical techniques, include analysis of aerial photographs and field mapping and drilling borehole data on both the down- and upthrown sides of the faults. Gamma rays electrical logging used in boreholes give the precise fault offset between the borehole locations.

It is important to know that pavement cracks and offset can be caused by subsidence of ground due to the excess withdrawal of ground water. In addition, the Beaumont Formation, which underlies a significant part of Harris County, contains swelling clays. These clays are also known as "shrink-swell soils." When wet or dry, these clays swell or shrink, respectively, which cause significant fault-like deformation to roads, houses, and utility lines. ■

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QUESTIONS FOR FIELD TRIP PARTICIPANTS:

- Is the surface expression of the fault easy to identify? What do you see?
- Why is the surface expression of the Long Point fault easier to identify than other faults in the area?
- What are indications that this fault is connected to a deeper fault system v. restricted to the shallow surface?
- What do you think is the impact of this fault on surficial processes, e.g. runoff/drainage?
- What are other geologic processes that could have caused the apparent resistivity anomalies?
- Which fault(s) is antithetical? Why do you think this structural orientation is present? Why is it present at this location?

SAFETY TIPS TO KEEP IN MIND WHILE IN THE FIELD

Note that participants should always wear a high-visibility safety vest, and only park in designated parking lots. Parking along highways is not a safe choice. They should be alert by being aware of their surroundings. A sun-protective hat and drinking water would be helpful. It is recommended that participants should be cordial and socialize with the people when they are, especially in neighborhoods.

ACKNOWLEDGMENT

The first author thanks geologist Richard Howe for helping correctly identify some of the fault locations.

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