Active Faults in Southeastern Harris County, Texas

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ABSTRACT / A complex graben southeast of Houston, Texas, extends east-west across the Friendswood–Webster oil field and Interstate Highway 45, through Ellington Air Force Base (EAFB), northeastward through a new residential subdivision, into the Clear Lake oil field, and on to LaPorte, Texas. Some of the faults in this graben system are known to have been active for decades and are represented by scarps several meters high in the deltaic deposits of the Pleistocene Beaumont formation. In the protected environment under two of the buildings at EAFB, one of the faults in this graben occurs as a sinuous fissure 8 to 10 cm wide that is open to a depth of about 35 cm.

Another fault system appears to control the shoreline configuration of Clear Lake and the courses of streams tributary to the lake. Rapid urbanization of the surrounding area began in 1962 and damage to buildings and pavements along certain faults in this system became evident about 1970. Although some of the faults are associated with tectonic movements and the production of oil and gas, many of the faults appears to be related to extensive ground-water withdrawal and the consequent dewatering and compaction of the sands and clays in the aquifer.

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Introduction

Land-surface subsidence and surface faulting are active geological processes that occur throughout the coastal plain of the Gulf of Mexico. Because rates of subsidence, and to some extent faulting, are increased drastically by the production of oil, gas, and especially ground water, the greatest impact of these processes is in the more populated areas (Gabrysch 1969, 1974). Although the entire Gulf Coast shows the effects of subsidence and faulting, the Houston–Galveston area appears to be the most severely affected.

Faulting And Subsidence

The resurvey of the Houston–Galveston area of Texas by the U.S. Department of Commerce, National Ocean Survey (1973) has documented more completely the extent and rate of subsidence. Preliminary studies in southeastern Harris County suggest that some of the losses in elevation are controlled by and concentrated along faults (Clanton and Amsbury 1974). Losses in elevation of some of the bench marks at Ellington Air Force Base (EAFB) document vertical movements in excess of 1.5 m during the interval between 1942 and 1973. Table 1 lists selected bench marks in southeastern Harris County, the dates of survey, and the elevations.* It is significant that the 1936 and 1942 data show movement. Moreover, the 1964 to 1973 data show a definite increase in the rate of movement.

Faulting associated with subsidence caused by the withdrawal of oil and gas can be documented locally. One of the more classic localities is the Goose Creek oil field, Harris County, Texas (Minor 1925, Pratt and Johnson 1926). Major oil production began in 1917 and

*Editor's note: Most data reported in this paper were measured and recorded in the English system, but were converted to the metric system by the editorial staff.

Table 1 Elevations of Selected Bench Marks in Southeastern Harris County

Elevations in feet (meters).*

BM	Location	Dates of survey 1936	1942	1951	1954	1959	1964	1973	Change 1964–73
V 639	North gate EAFB		40.453 (12.333)	39.452 (12.028)	38.921 (11.866)	38.255 (11.663)	37.516 (11.438)	35.381 10.787	2.135 (0.651)
U 639	South gate EAFB		33.209 (10.125)	32.375 (9.870)	31.926 (9.734)	31.293 (9.540)	30.581 (9.323)	28.487 (8.685)	2.094 (0.638)
J 1187	3rd St. JSC and NASA 1						19.144 (5.836)	17.096 (5.212)	2.048 (0.624)
N 646	Ave. B, JSC and NASA 1		4.816 (1.468)		4.278 (1.304)	3.999 (1.219)	3.553 (1.083)	1.450 (0.442)	2.103 (0.641)
Tidal 2	Clear Lake Park	19.593 (5.973)	19.281 (5.878)		18.455 (5.626)	17.890 (5.454)			
Tidal 3		18.701 (5.702)	18.389 (5.606)		17.457 (5.332)	16.883 (5.147)			
Tidal 4							12.549 (3.826)	10.568 (3.222)	1.981 (0.604)
Tidal 5							7.064 (2.154)	5.059 (1.542)	2.005 (0.611)
P 1187	Lake Shore Drive and NASA 1						15.433 (4.705)	13.264 (4.044)	2.169 (0.661)
Q 1187	0.85 miles (0.53 km) west along NASA 1 from junction of State Highway 146						7.999 (2.439)	6.260 (1.908)	1.739 (0.531)

*Measurements were recorded in feet, converted to meters by editor.

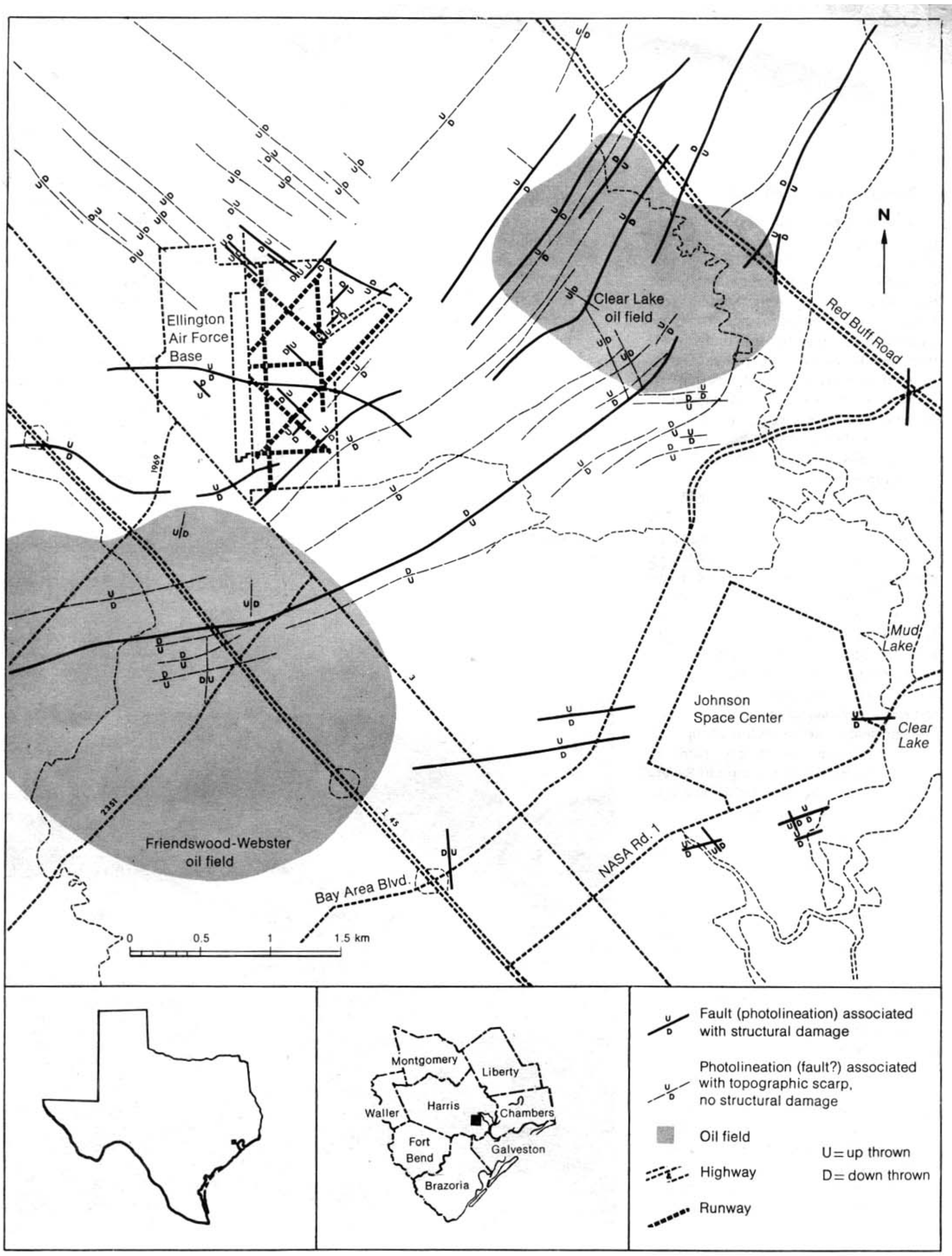
by 1926 subsidence in excess of 1 m had been recorded; fault fissures with up to 241 cm of vertical displacement had occurred in the town of Pelley, Texas (Pratt and Johnson 1926). In addition, some of the faulting was reported to be accompanied by slight earthquakes that shook homes, displaced dishes, spilled water, and disturbed the local inhabitants (Pratt and Johnson 1926). How active some of these faults were before production was initiated and movement was noticed is unknown, but a comparison of maps made before 1850 and the 1917 maps suggests that subsidence was not significant prior to the development of the oil field (Pratt and Johnson 1926). The fact remains, however, that even though some of the faults may be related to the formation of the structure, production may reactivate faults or accelerate the rate of movement.

Kreitler (1975) was able to correlate differences in rate of land-surface subsidence and locations of photolineations. It is possible that much of the general subsidence in the Houston area is localized along pre-existing fracture zones, but because of the wide spacing of bench marks, the data are insufficient to prove it (Gabrysch 1969).

Rate And Zone Of Movement

Limited information is available to document the daily rate of fault movement. Reid (1973) monitored the rate of movement of several faults in the Houston area using extensometers and tilt beams. These data show the movement to be episodic rather than continuous. Periods of movement lasted from one hour to four days and resulted in displacements ranging from 0.09 mm to 3.33 mm. These active periods were separated by periods of inactivity that lasted from four to 60 days. Typically there is a narrow zone that shows an abrupt elevation change; however, precise leveling demonstrates drag deformation up to 45 m to either side of the major break (Reid 1973, Weaver and Sheets 1962).

Figure 1. Faults plotted on a photobase of NASA-JSC near-infrared photo 175/145, roll 69, frame 148. Solid lines mark faults associated with structural damage to roads, buildings, and runways. Dashed lines represent straight-line scarps associated with inactive faults or faults that are active but, because of location, cause no structural damage. Extensive sag ponds occur along both types of faults.


N
Ellington
Air Force
Base
Clear Lake
oil field
Red Buff Road
Friendswood-Webster
oil field
Johnson
Space Center
Mud
Lake
Clear
Lake
Bay Area Blvd.
NASA Rd. 1
1969
2351
3
1 45
0
0.5
1
1.5 km
Montgomery
Liberty
Waller
Harris
Chambers
Fort
Bend
Galveston
Brazoria
Fault (photolineation) associated
with structural damage
Photolineation (fault?) associated
with topographic scarp,
no structural damage
Oil field
Highway
Runway
U = up thrown
D = down thrown

Photolineations and faults

Maps of photolinear features of the Gulf Coast have established a relationship between some linear features and subsurface faults (De Blieux and Shepherd 1941, Miller 1960). Some active faults, whose surface traces can be mapped as topographic, soil, and vegetation boundaries, have been demonstrated to match the upward projections of previously known subsurface faults (Weaver and Sheets 1962). Reid (1973) pointed out the correlation between photolinears observed on color IR aerial photographs and the faulting pattern around the Mykawa oil field near Houston, Texas. Fisher and others (1972) mapped regional photolinear patterns and stated that they represent active or potentially active fracture zones. Kreitler (1975) related some of these photolineations to pavement breaks in the Houston – Galveston area and to projections of subsurface faults whose locations are known from oil- and water-well records. The photolineations also appear to bear a relationship to some salt domes and oil fields, and to abrupt changes in drainage patterns of streams, some as large as the Brazos and Colorado Rivers (Frierson and Amsbury 1974), and others as small as Clear Creek.

Criteria for determining a correlation between certain photolinear features and active faults need to be clearly established, especially because of U.S. Atomic Regulatory Agency regulations regarding siting of nuclear power plants near potentially active fracture zones.[1] The problems are:

1. that many more photolineations are mapped than have been checked by subsurface and seismic techniques, and
2. movement along active faults evidently is episodic (Reid, 1973), and if there is no structure across a fault, recent movement is difficult to document without monitoring by instruments.

We have found that the most useful single tool for mapping potentially active faults is a small-scale, color-infrared photograph. Old aerial photographs, preferably taken prior to urban development, are also useful. Topographic maps with a contour interval of one or two feet (30 – 60 cm) are good sources of data (Van Siclen 1967), but their lack of availability limits their use in many areas. After mapping the linear features, field checking is necessary to verify faulting; the best evidence is damage to pavement or structures.

Examples of faults

Fig. 1 is a map covering about 26 sq km in southeastern Harris County. The information used to prepare the map is from black-and-white aerial photographs taken in 1956, 1965, 1969, 1972, and 1973; color IR aerial photographs taken in 1970, 1972, and 1973; and color aerial photographs taken in 1971 and 1973. In addition, all features have been field checked. The solid lines indicate locations where the photolineations coincide with failures in roads, buildings or runways, and the fault is considered to be active because of the existing structural damage. The broken lines indicate straight-line scarps that represent fault-

[1]Title 10, Code of Federal Regulations, Part 100, Reactor Site Criteria, Appendix A, Seismic and Geologic Site Criteria for Nuclear Power Plants.

Figure 2. Sinuous fault scarp crossing a parking lot near Building No. 743 (EAFB). The variation in height of the fault scarp on the parking lot and in the street and curb reflects different construction dates. The street and curbs have been patched to repair the damage.

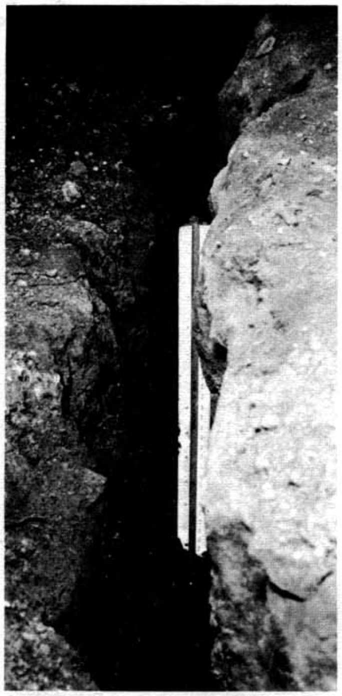


Figure 3. Building No. 732 at EAFB has a pier-and-beam foundation that has protected this fault scarp from erosion since 1942. The fault is a sinuous fissure 8 to 10 cm wide open to a depth of about 35 cm. Below this depth the cavity has been filled.

ing that has not been demonstrated to be presently active by structural failure. The association of sag ponds with some of these scarps suggests that many of these faults are actively moving but, because of the lack of construction, there are no structural failures.

Fig. 2 shows a sinuous fault scarp on a parking lot on EAFB. The difference in height of the scarp on the parking lot and the offset in the street and curbs is the result of a difference in construction dates. This fault has a 1 m scarp in the pastures adjacent to the base but only about 30 to 45 cm on the base. This difference in elevation suggests that the fault was active prior to the construction of the base.

Two buildings at EAFB, with pier and beam foundations, have protected short sections of this fault scarp from erosion since 1942. In this protected environment the fault occurs as an open sinuous fissure (Fig. 3) with not only the usual vertical displacement but also a definite horizontal separation or heave. The fissure is 8 to 10 cm wide and open to a depth of about 35 cm, below this depth the cavity has been filled with rubble from the walls.

The fault shown in Fig. 4 is part of the complex graben that connects the Webster–Friendswood and Clear Lake oil fields. In some areas the fault plane appears to be a zone of high permeability, allowing shallow artesian ground water to reach the surface to form sag ponds. In addition, the differential movement modifies the drainage pattern and surface runoff tends to accumulate on the

Figure 4. A copy of a color IR photograph taken at an altitude of about 300 m. The upthrown side of the fault is typically lighter in color. The more luxuriant vegetation, wet ground, and occasional sag ponds give the downthrown side a darker color. The apparent abrupt termination of the fault at the fence line is an illusion caused by a difference in land use. The scarp can be traced northeastward for another kilometer.

downthrown side. Soils of the downthrown side of the fault are typically darker than those of the upthrown side. This darker color is the result of the higher moisture content of the soil and the difference in vegetation. Bulrush, spike rush, arrowhead, bog rush, and other typically aquatic or wet-land plants tend to dominate the vegetation. In addition, where one fault in the graben crosses a new man-made drainage channel, water flows from a spring in the channel wall.

Faulting adjacent to the shoreline of Clear Lake has caused extensive damage to many buildings and is especially noticeable in two different apartment complexes. Displacement in this newly urbanized area is in excess of 15 cm and may be as much as 30 cm. Open fractures and several generations of patching in the brick walls indicate that failure has been somewhat continuous throughout the six to eight years that these buildings have existed. A swimming pool along one fault has been tilted about 15 cm. Cracks in the pool, sidewalks, and adjacent buildings document the strike and movement of the fault.

Damage by faulting and subsidence

Changes in elevations because of faulting or subsidence have an obvious effect on natural drainage patterns and upon storm and sewer systems. Recognition of the potential problems prior to construction could help limit the damage that would be caused if no action were taken. The southern half of EAFB is a classic example where surface, storm, and sewer drainage has been extensively modified by the 1.5 to 2 m of movement in the area. A television survey of the sewer system has shown sections of shattered pipe, areas of massive infiltration, and some lines with reversed flow. Almost $300,000 has been spent during the last three years on a project to line the existing sewer system with polyvinyl chloride pipe in order to control infiltration. Flooding by surface runoff is now common on the southern part of the base during periods of high rainfall.

Examples of damage to buildings, runways, roads, and utilities occur throughout Harris and Galveston counties. In areas of extreme movement, the land may be used best as a park or recreational area. If construction is required near or across an active fault, proper design, siting, and construction of buildings can do much to reduce damage.

Conclusions

The fault pattern at EAFB indicates that there is an appreciable horizontal component associated with the failure of buildings, streets, and runways in this area. These observations suggest that all new construction, in areas of rapid subsidence and active faulting, should be designed to withstand not only vertical but also horizontal stresses. An even better solution would be to prohibit buildings on the trace of fault ruptures.

Faulting in the Houston–Galveston area is extensive; although no firm figures are available, the resulting damage must involve millions of dollars. Damage by faulting can be expected to increase because of the increasing rate of subsidence.

Most of the people who have buildings breaking apart around them are unaware of the cause. Some agency should take the responsibility for compiling data that can be used in identifying and mitigating geological hazards for developing local ordinances that require geotechnical reports prior to planning and design of structures. Such an agency would require funding to cover the cost of

1. acquiring and storing sequential aerial photographs
2. documenting damage
3. experimenting with techniques such as remote sensing, shallow geophysics, shallow trenching, and shallow drill holes logged by downhole geophysical techniques to locate faults and
4. developing recommendations for coping with active faults.

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