Growth Faulting, Associated Geologic Hazards, Economic & Regulatory Impact, and Methods of Investigation for the Houston, Texas Area

GSA / AEG-Tx Growth Fault Symposium
Texas A&M University, College Station, Tx
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Rev. 1.0

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Introduction

1) **Summary of a report for the Institute of Environmental Technology (IET)**
(see: http://www.ela-iet.com/sponsoredresearch.htm/)

2) **IET formed in the early 1990's to train out-of-work geologists, geophysicists, and engineers from the depressed oil & gas industry of the late 1980s for working in the environmental industry. Almost 400 graduated from IET Program.**

Introduction (Con't)

3) This investigation originated out of interest in trying a new concept in applying GPR in the Houston area to identify growth faults in the shallow subsurface.

4) Can't interprept growth faults near the surface until their characteristics and likely origins are better known at depth.

5) The technical literature on associated topics is voluminous.

Introduction (Con't)

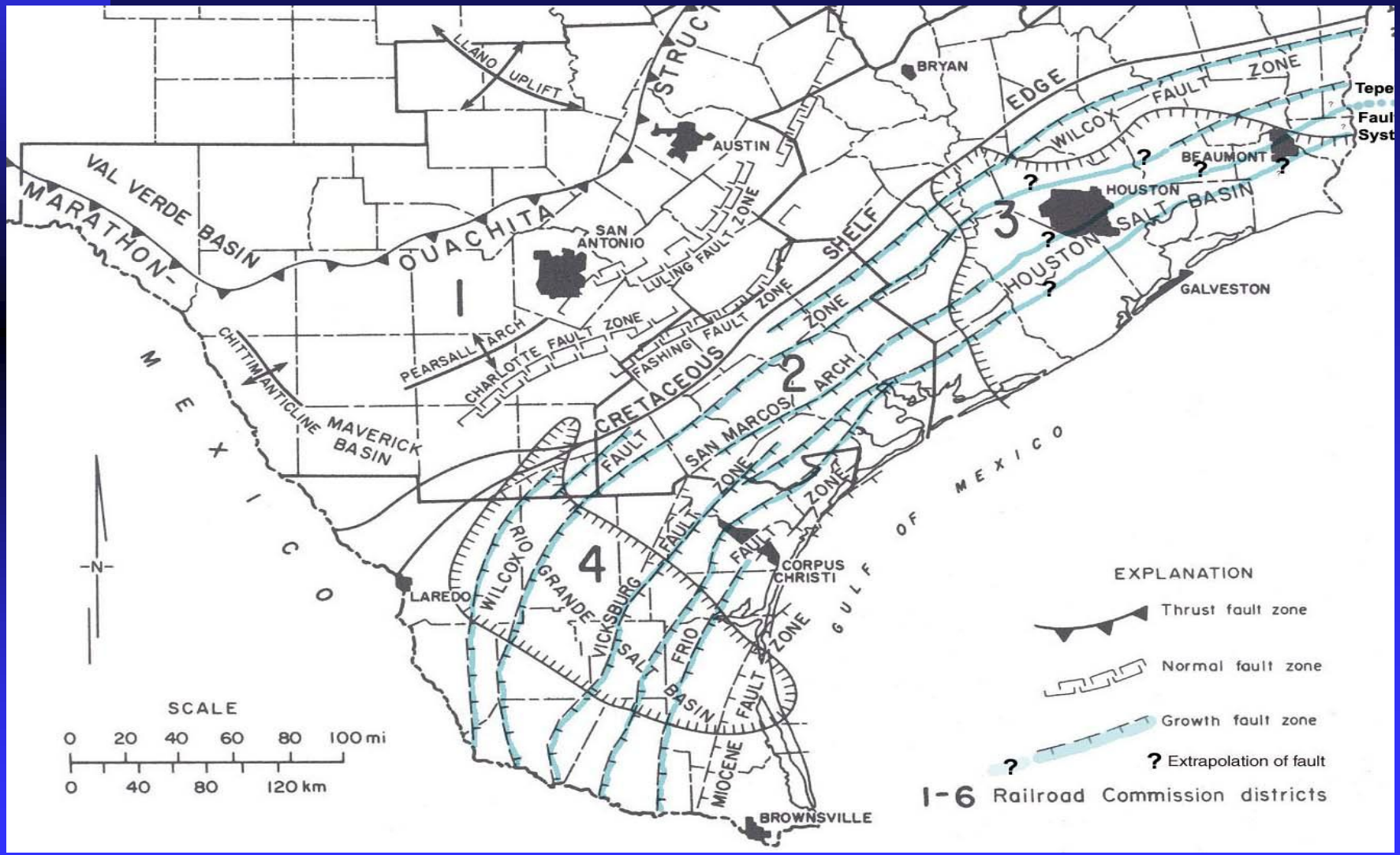
6) What are factors at depth that could affect surface faulting? Our review of the literature suggests:

A. Basin Loading
B. Basement Response and/or
C. Regional Faults
D. Salt Domes, Wedges, & Ridges
E. Surface Subsidence
F. Other Factors

Regional & Local Relationships

The Regional Faults Passing Through the Houston Region…

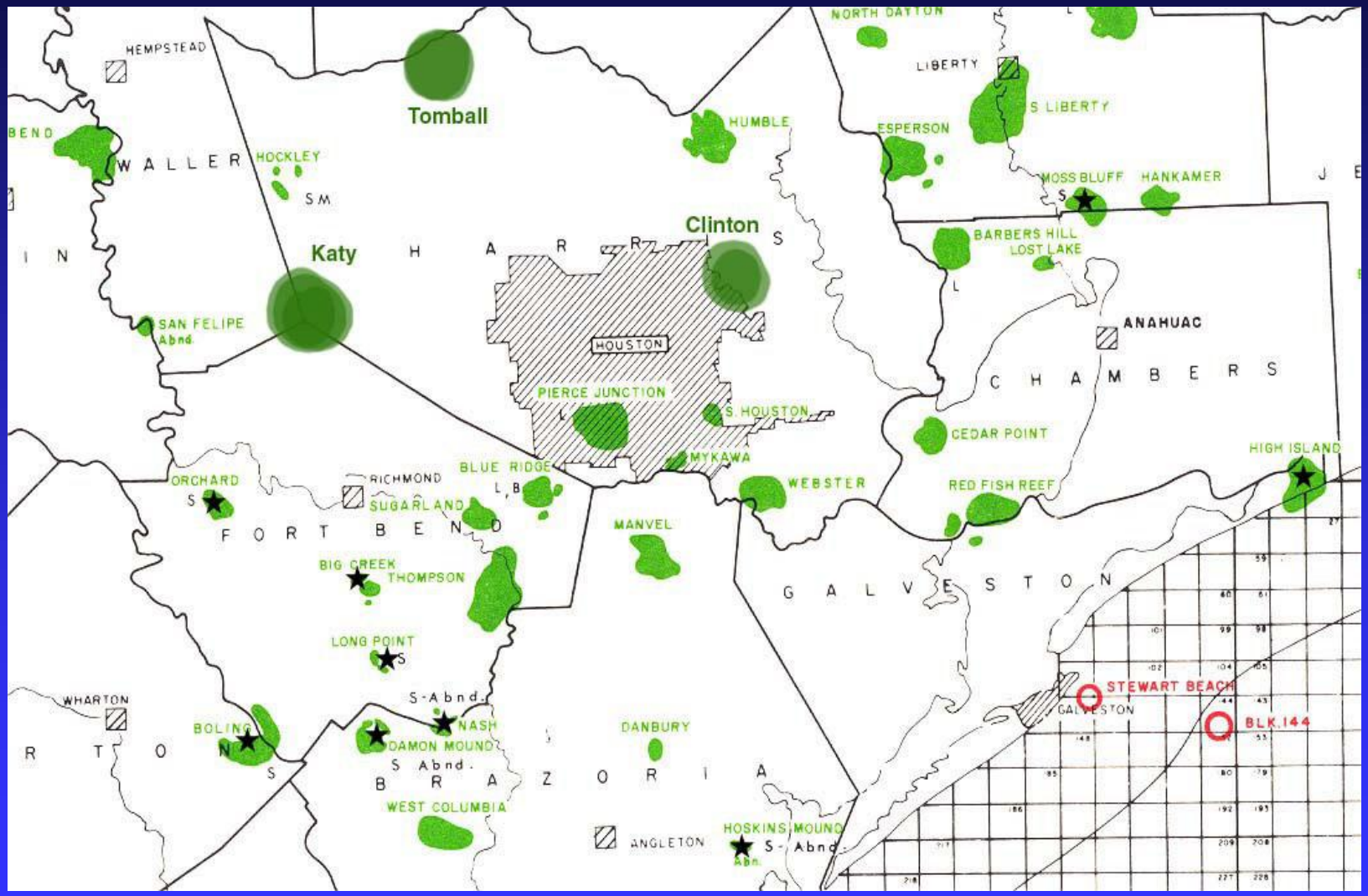
Regional & Local Relationships



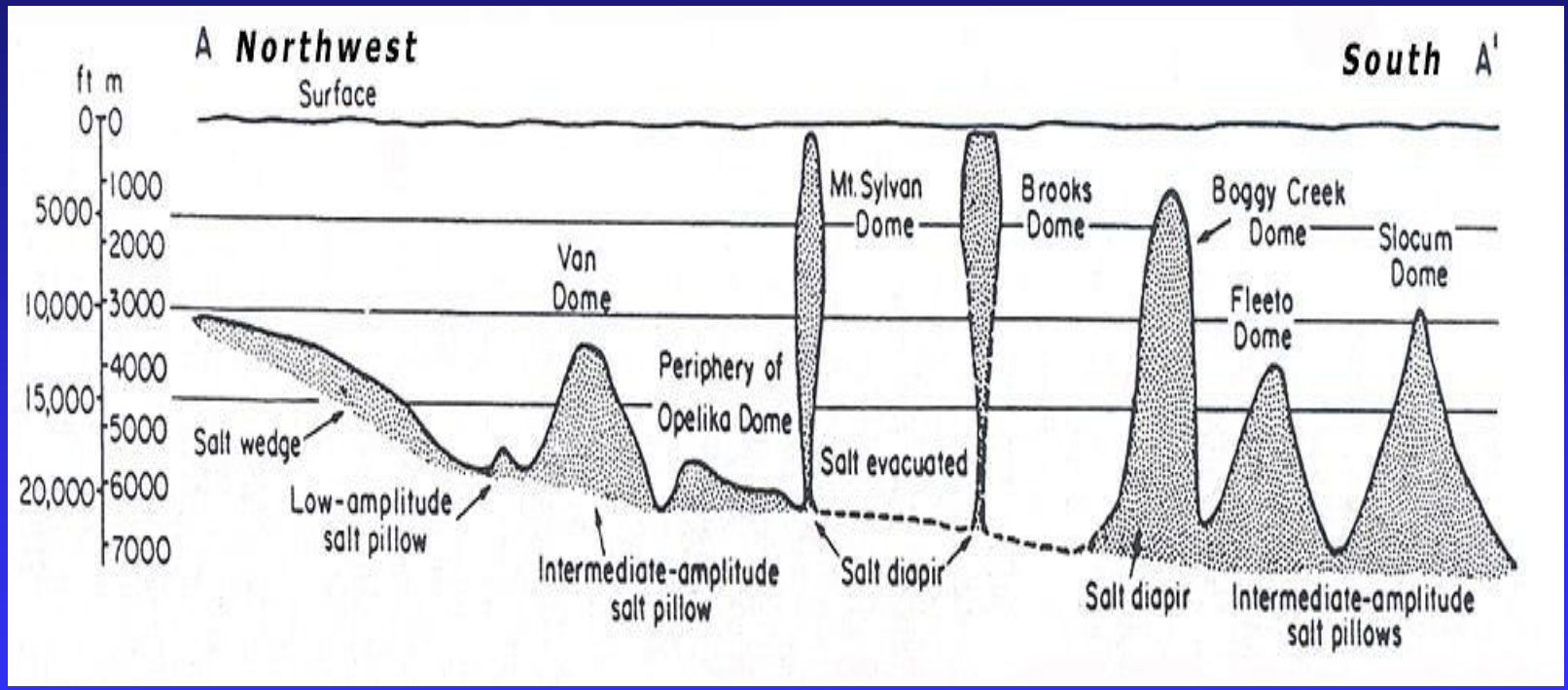
Regional & Local Relationships

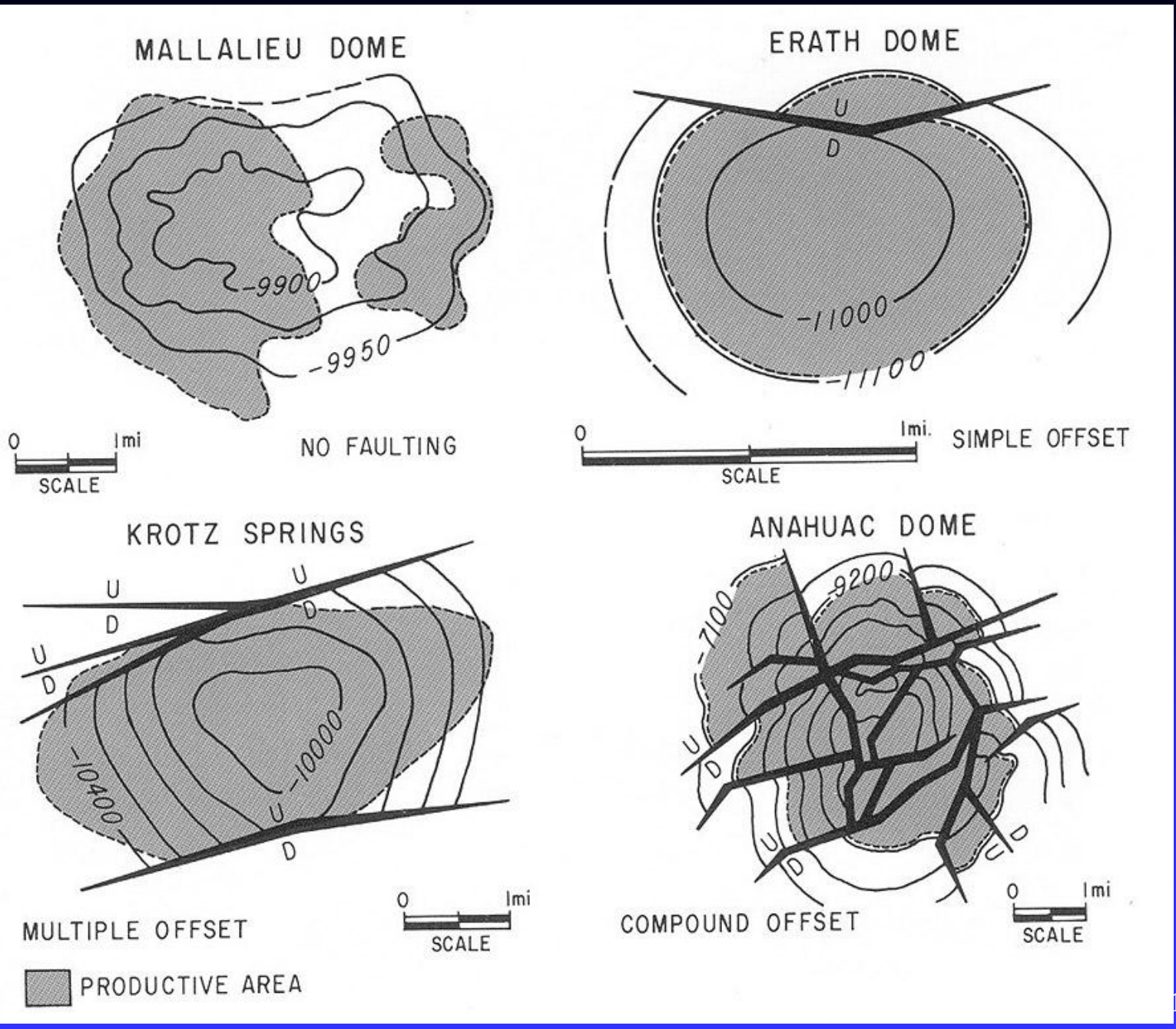
Salt Domes, Wedges, & Ridges…

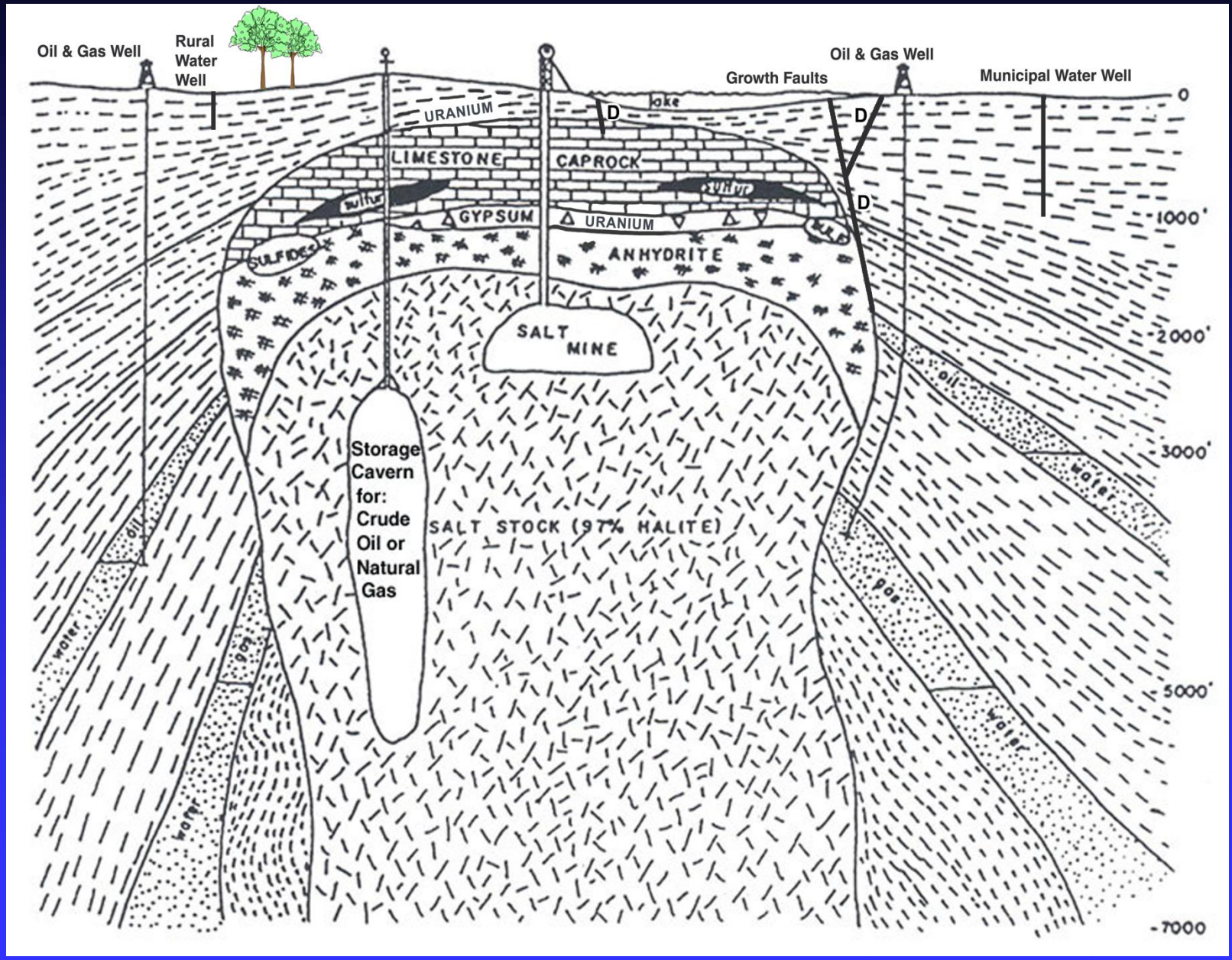
Regional & Local Relationships



Regional & Local Relationships

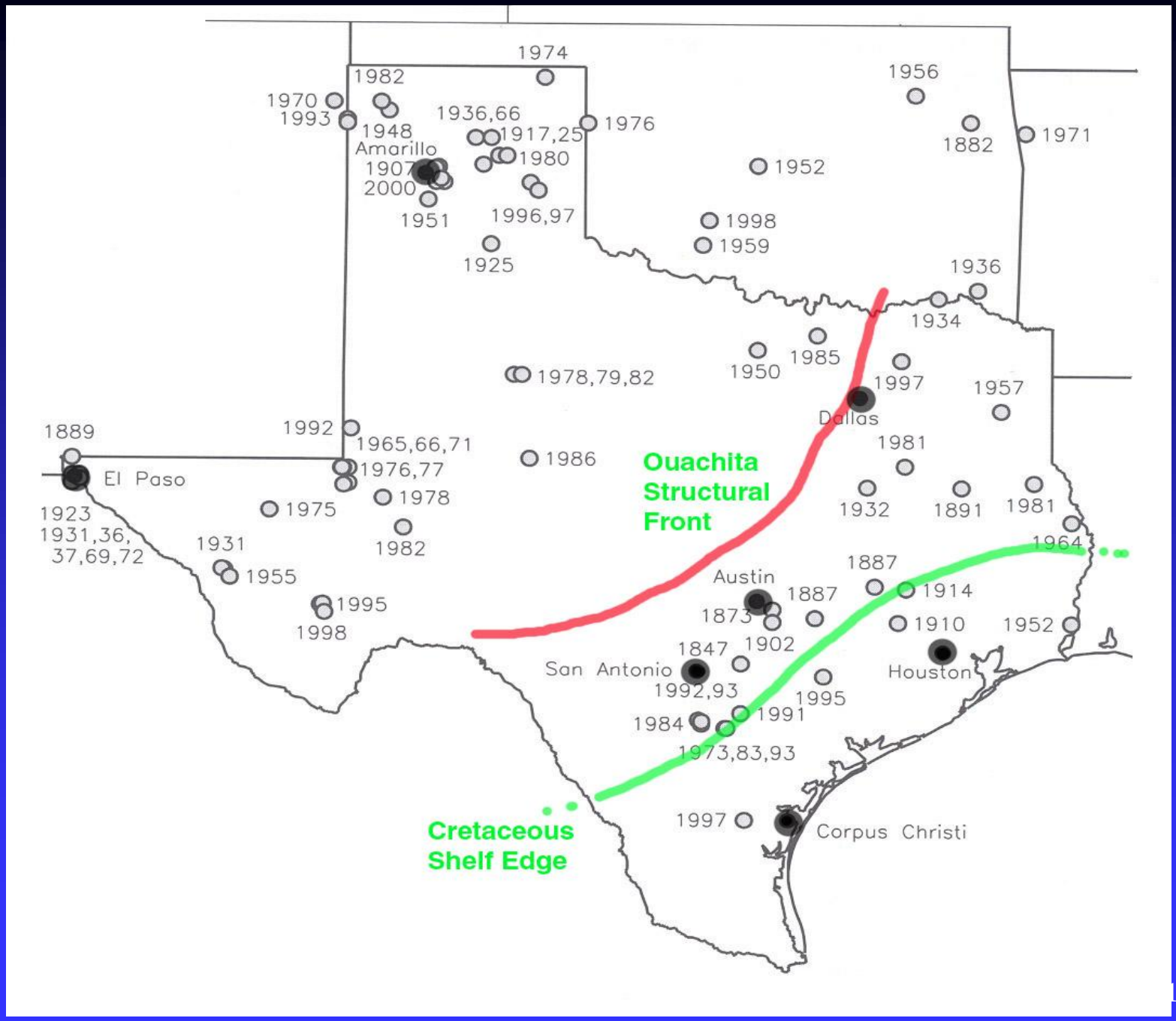



MALLALIEU DOME
-9900
-9950
0
1mi
SCALE
NO FAULTING
ERATH DOME
U
D
-11000
-11100
0
1mi.
SCALE
SIMPLE OFFSET
KROTZ SPRINGS
U
D
U
D
U
D
-10000
-10400
U
D
0
1mi
SCALE
MULTIPLE OFFSET
ANAHUAC DOME
-9200
-7100
U
D
U
D
U
D
U
D
0
1mi
SCALE
COMPOUND OFFSET
PRODUCTIVE AREA


Oil & Gas Well
Rural Water Well
Oil & Gas Well
Growth Faults
Municipal Water Well
URANIUM
LIMESTONE
CAPROCK
D
D
D
lake
sulfur
GYPSUM
URANIUM
SULFIDES
ANHYDRITE
SALT MINE
Storage Cavern for: Crude Oil or Natural Gas
SALT STOCK (97% HALITE)
oil
water
gas
0
1000'
2000'
3000'
5000'
7000

Regional & Local Relationships

Triggers of Houston Area Faulting?


1974
1982
1956
1970
1993
1936,66
1948
1917,25
1976
1882
1971
Amarillo
1907
1980
1952
2000
1951
1996,97
1998
1959
1925
1936
1934
1950
1985
1978,79,82
1997
1957
Dallas
1889
1992
1965,66,71
1986
1981
Ouachita
Structural
Front
El Paso
1976,77
1978
1932
1891
1981
1923
1975
1931,36,
37,69,72
1931
1982
1964
1887
Austin
1955
1914
1887
1873
1995
1910
1952
1998
1847
1902
San Antonio
Houston
1992,93
1995
1991
1984
1973,83,93
1997
Corpus Christi
Cretaceous
Shelf Edge

Surface Faulting Cause and /or Trigger?

Still no general consensus:

1) Load-induced crustal warping below Louann Salt that affect regional faults.

2) Movement of Salt domes, ridges, & associated “soft” structures (troughs) creating deep & shallow faulting.

3) Surface subsidence as a result of fluid extraction within Chicot & Evangeline aquifers & within oil & gas reservoirs at depth.

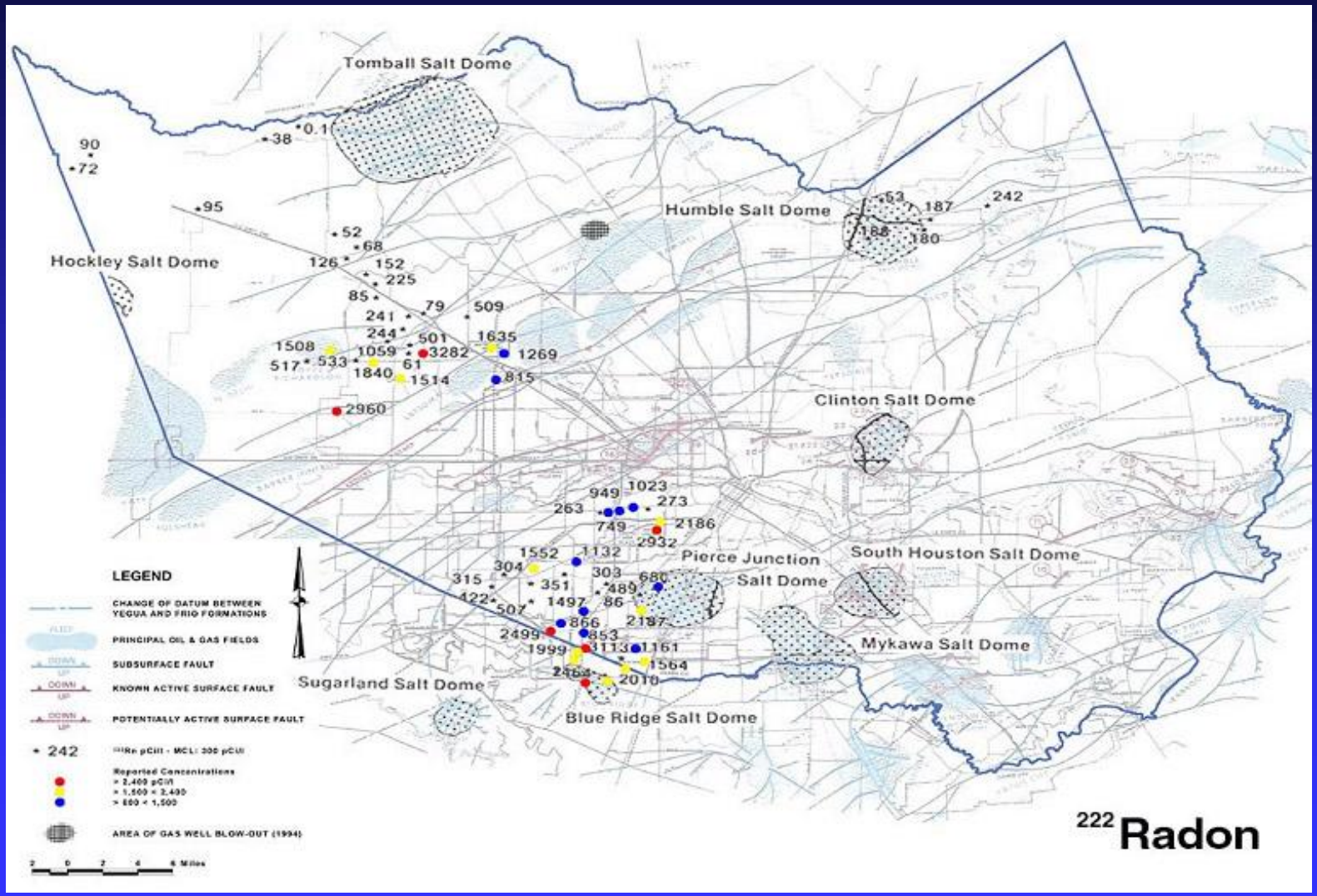
Growth Faults Foster Geologic Hazards?

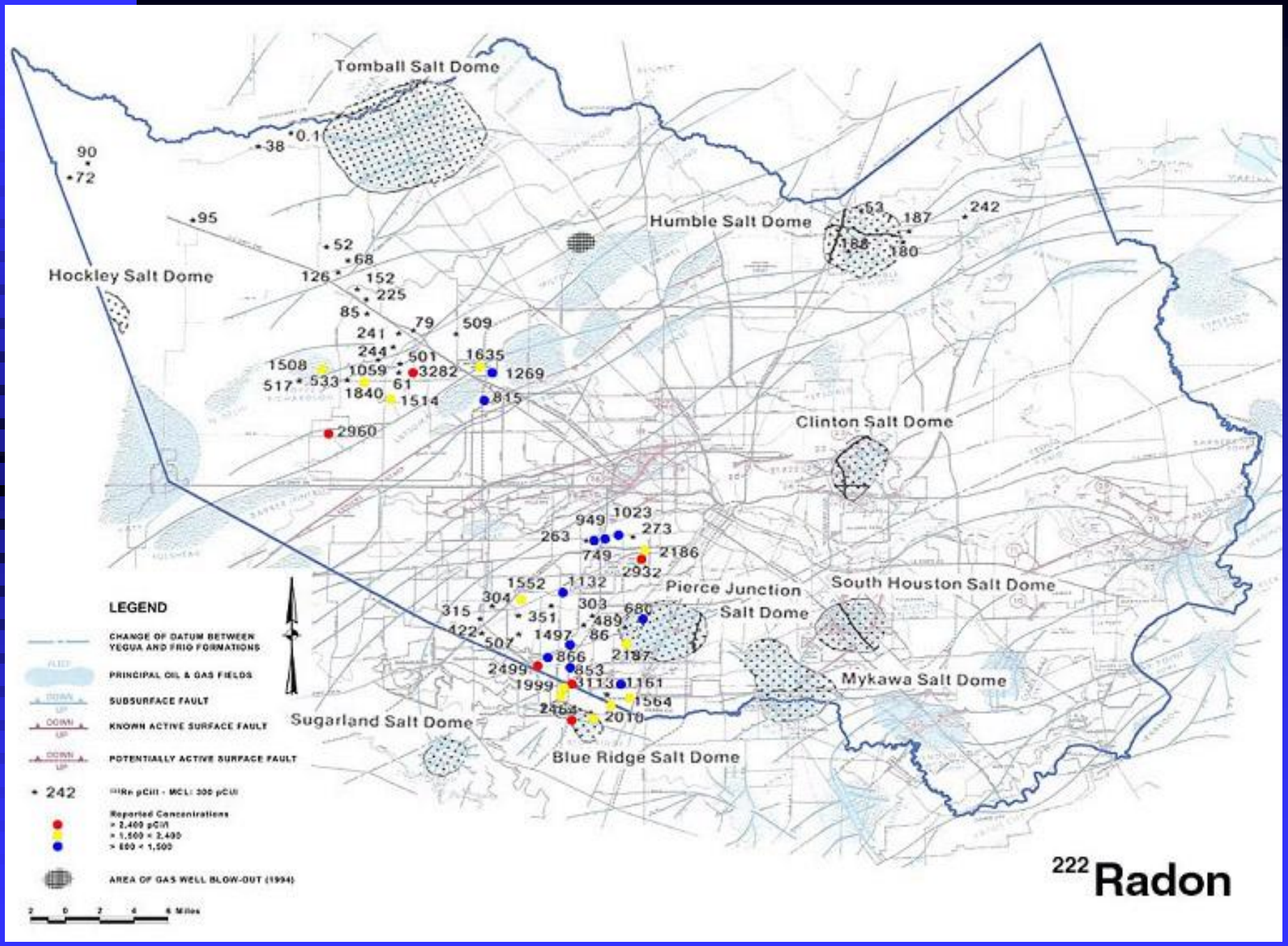
Yes ! In the Gulf Coast, Houston area.

What are the associated GeoHazards?

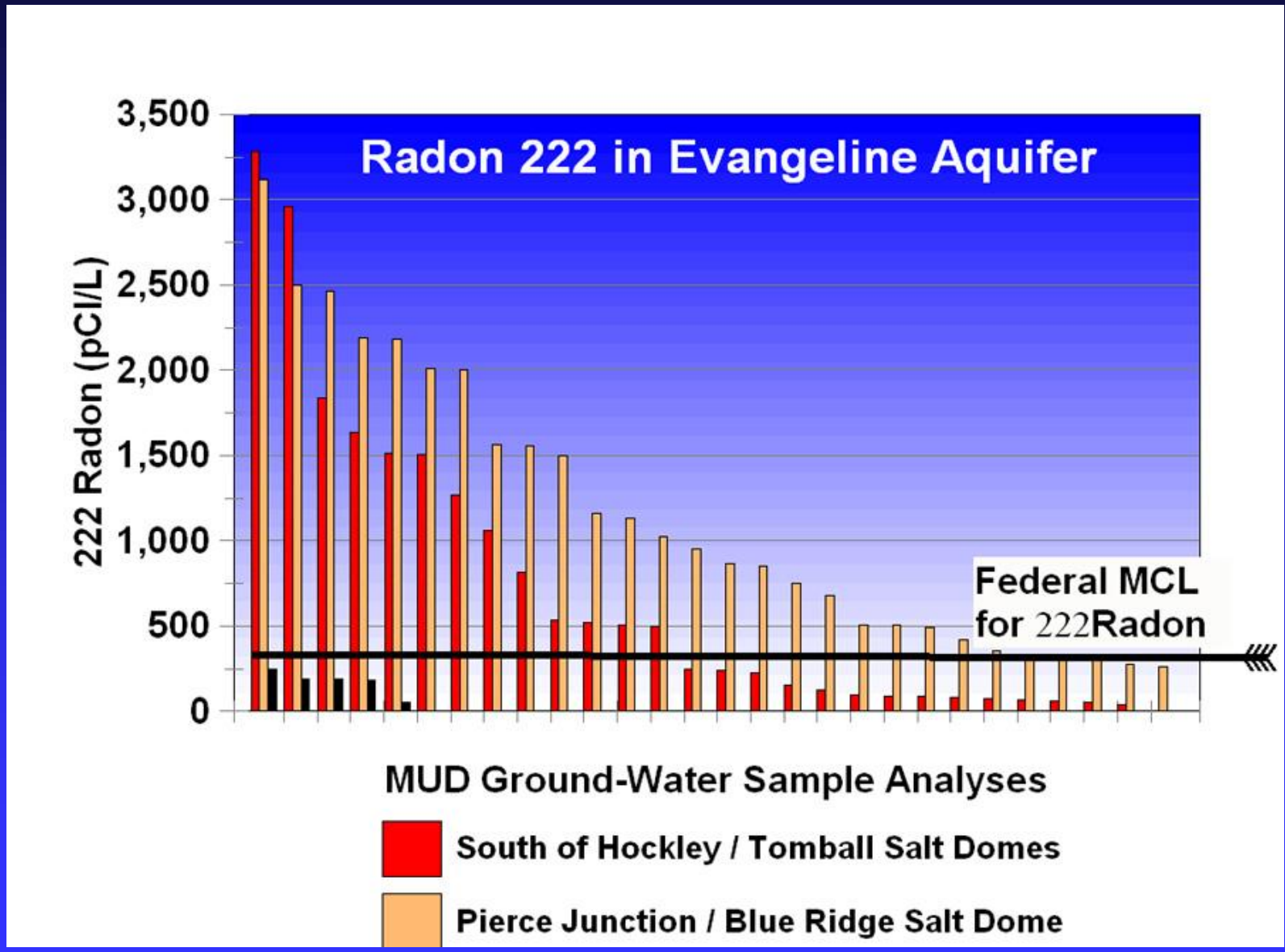
1) Impacts building foundations, roads, bridges, airport runways, etc.
2) Presence of radionuclides in Houston area ground water,

Growth Faults Foster Geologic Hazards?

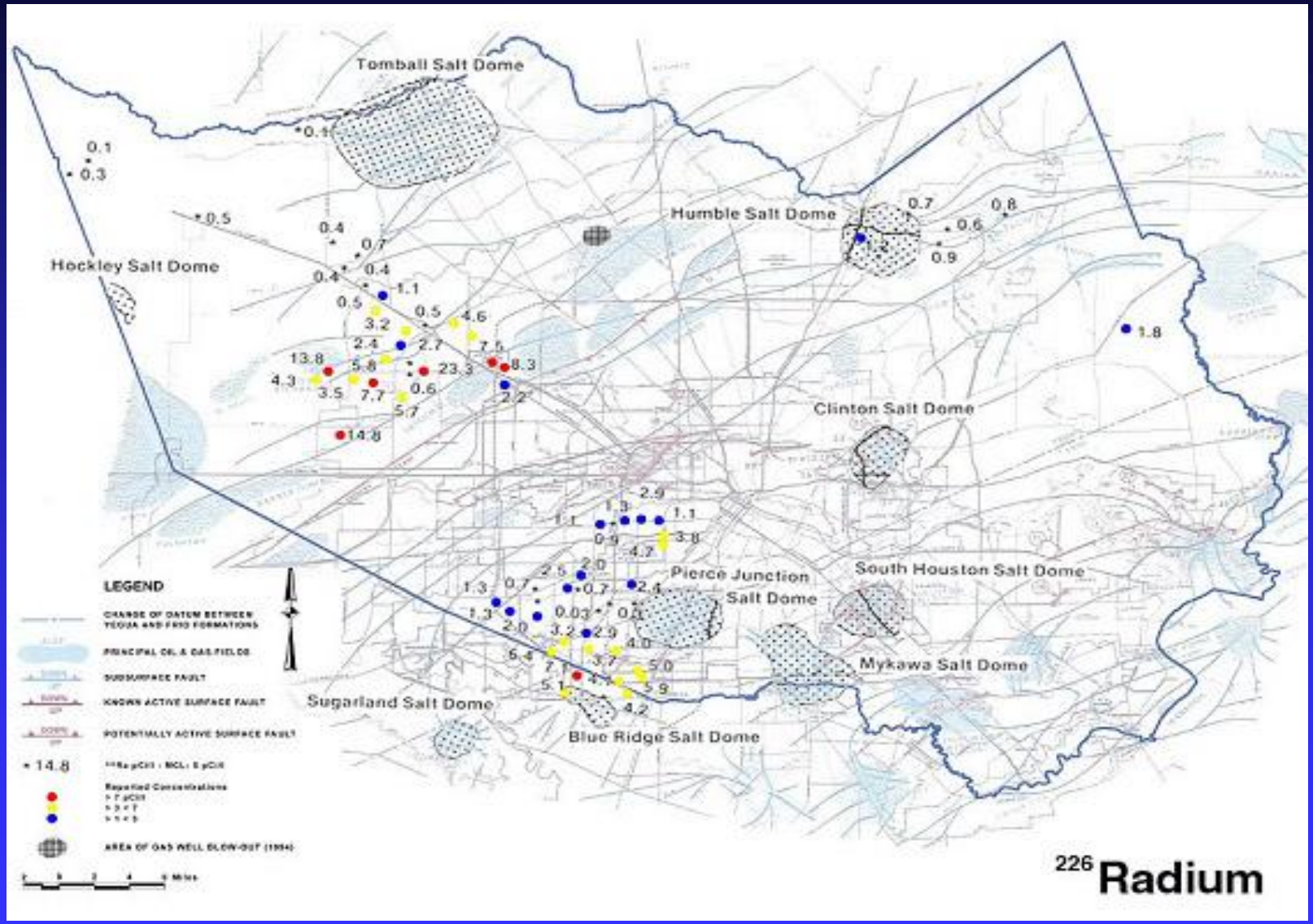


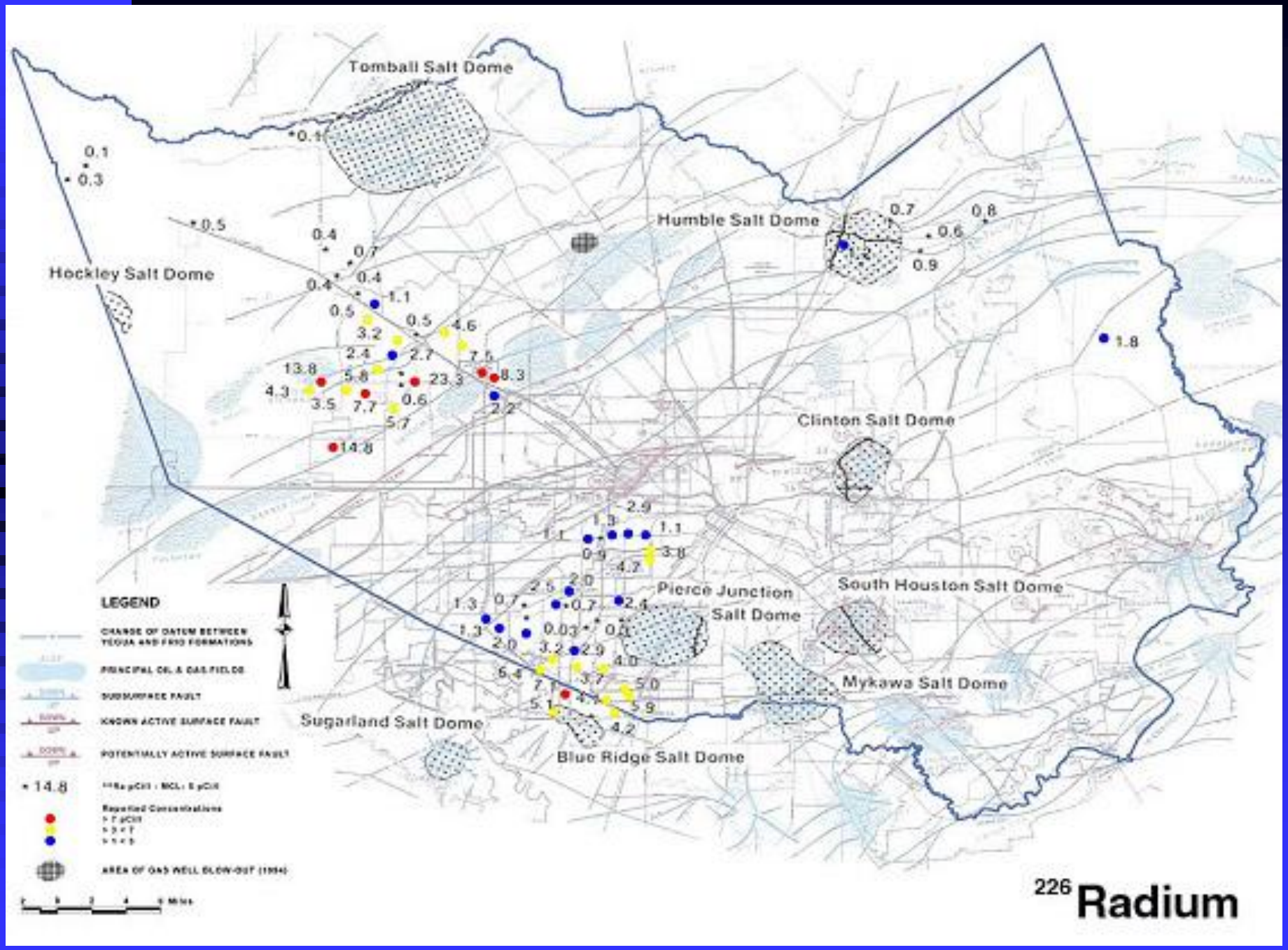

Tomball Salt Dome
Humble Salt Dome
Hockley Salt Dome
Clinton Salt Dome
Pierce Junction Salt Dome
South Houston Salt Dome
Mykawa Salt Dome
Sugarland Salt Dome
Blue Ridge Salt Dome
LEGEND
CHANGE OF DATUM BETWEEN YEGUA AND FRIO FORMATIONS
PRINCIPAL OIL & GAS FIELDS
SUBSURFACE FAULT
KNOWN ACTIVE SURFACE FAULT
POTENTIALLY ACTIVE SURFACE FAULT
Reported Concentrations
> 2,400 pCi/l
> 1,500 < 2,400
> 800 < 1,500
AREA OF GAS WELL BLOW-OUT (1994)
Miles
222 Radon

Growth Faults Foster Geologic Hazards?

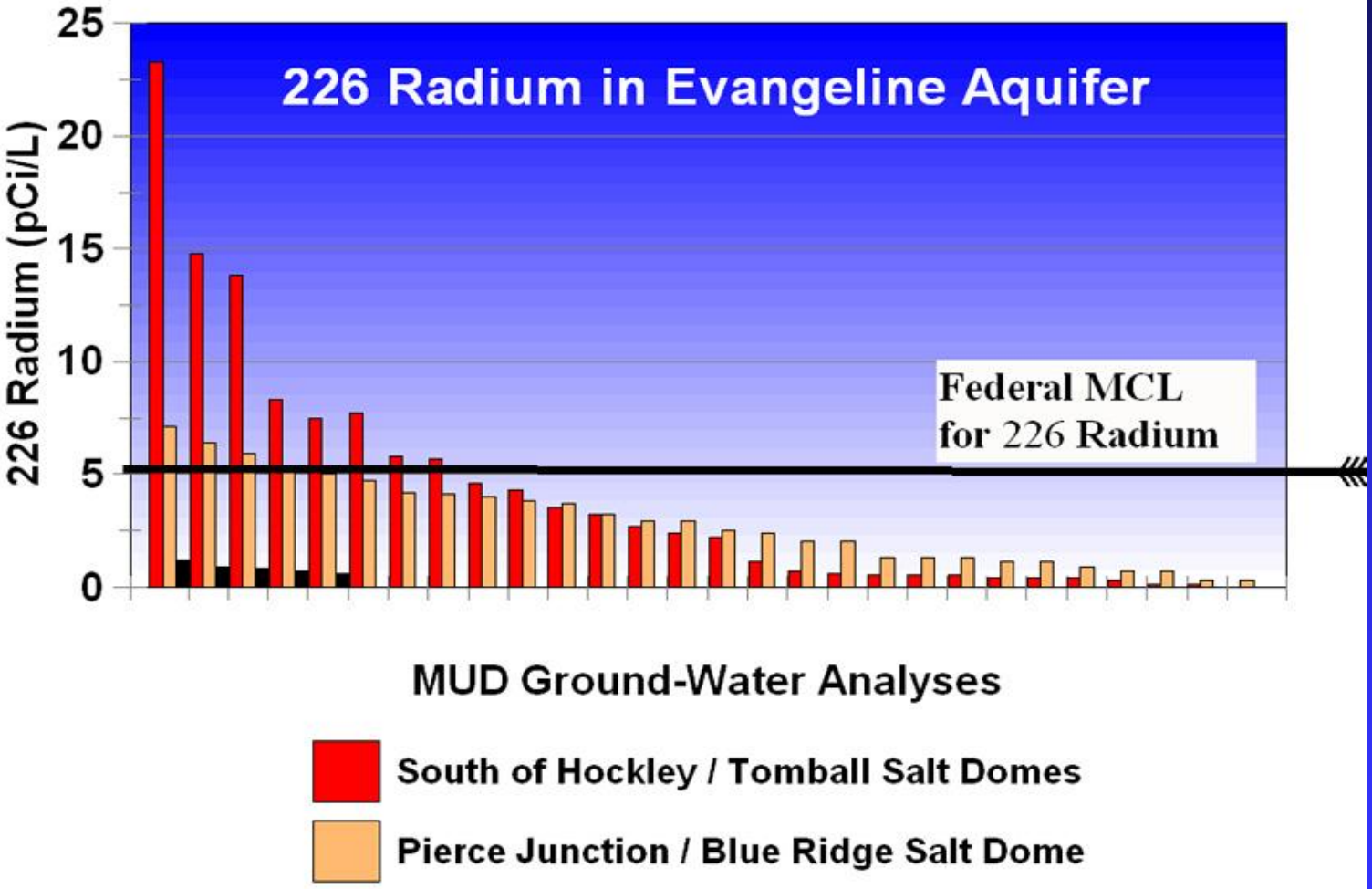


Growth Faults Foster Geologic Hazards?

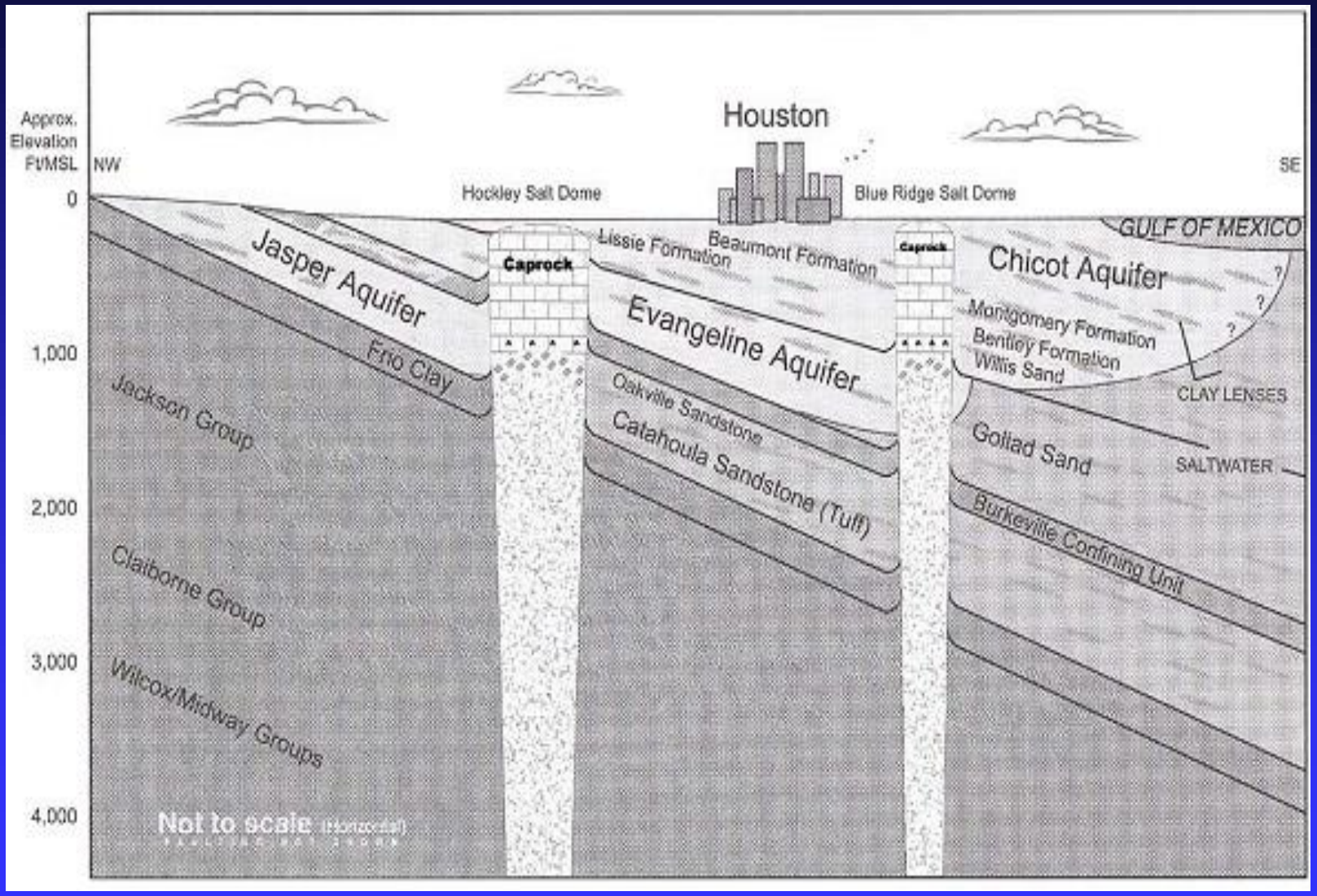


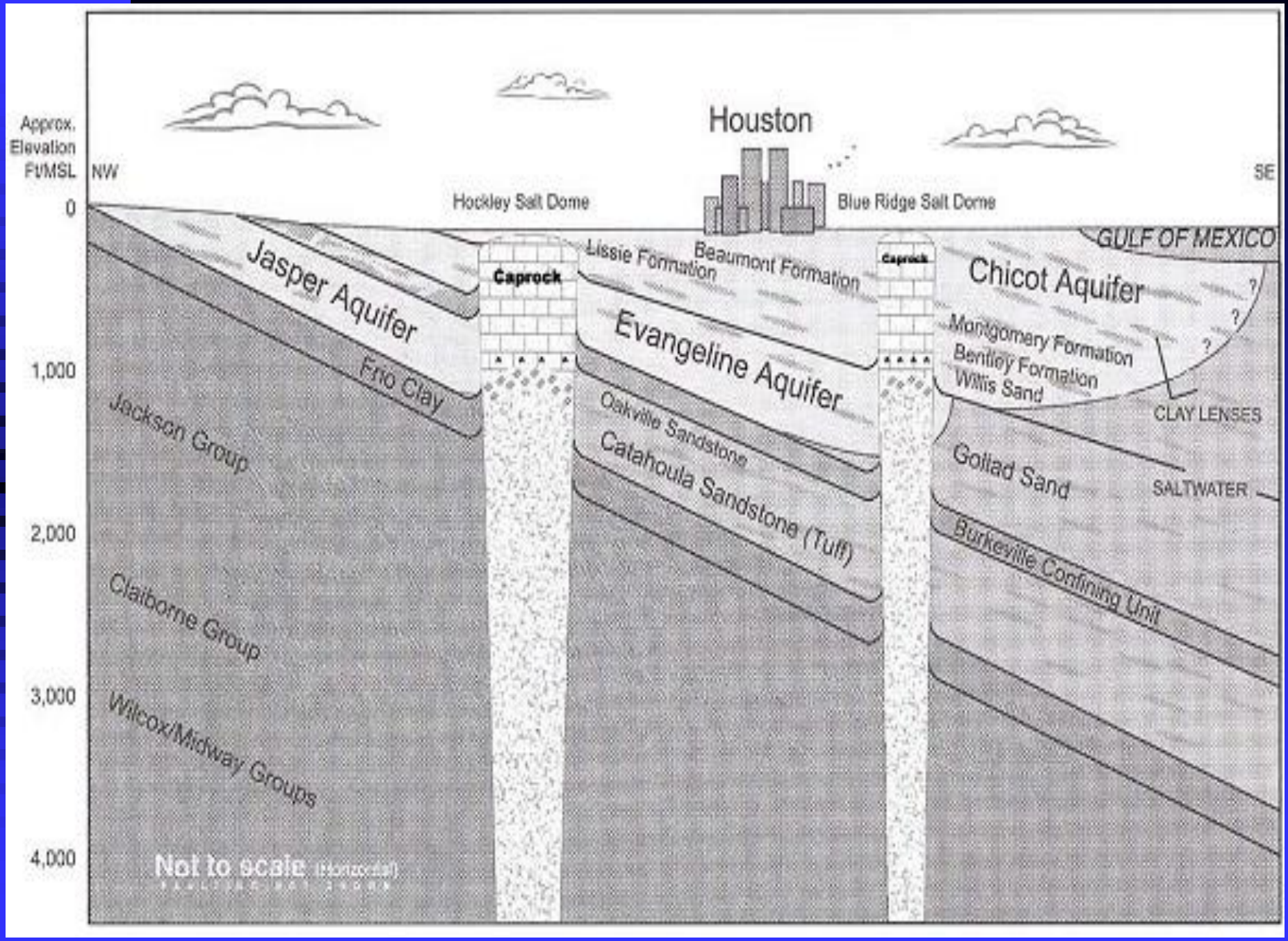

Tomball Salt Dome
Humble Salt Dome
Hockley Salt Dome
Clinton Salt Dome
Pierce Junction Salt Dome
South Houston Salt Dome
Mykawa Salt Dome
Sugarland Salt Dome
Blue Ridge Salt Dome
LEGEND
226 Radium

Growth Faults Foster Geologic Hazards?



Growth Faults Foster Geologic Hazards?

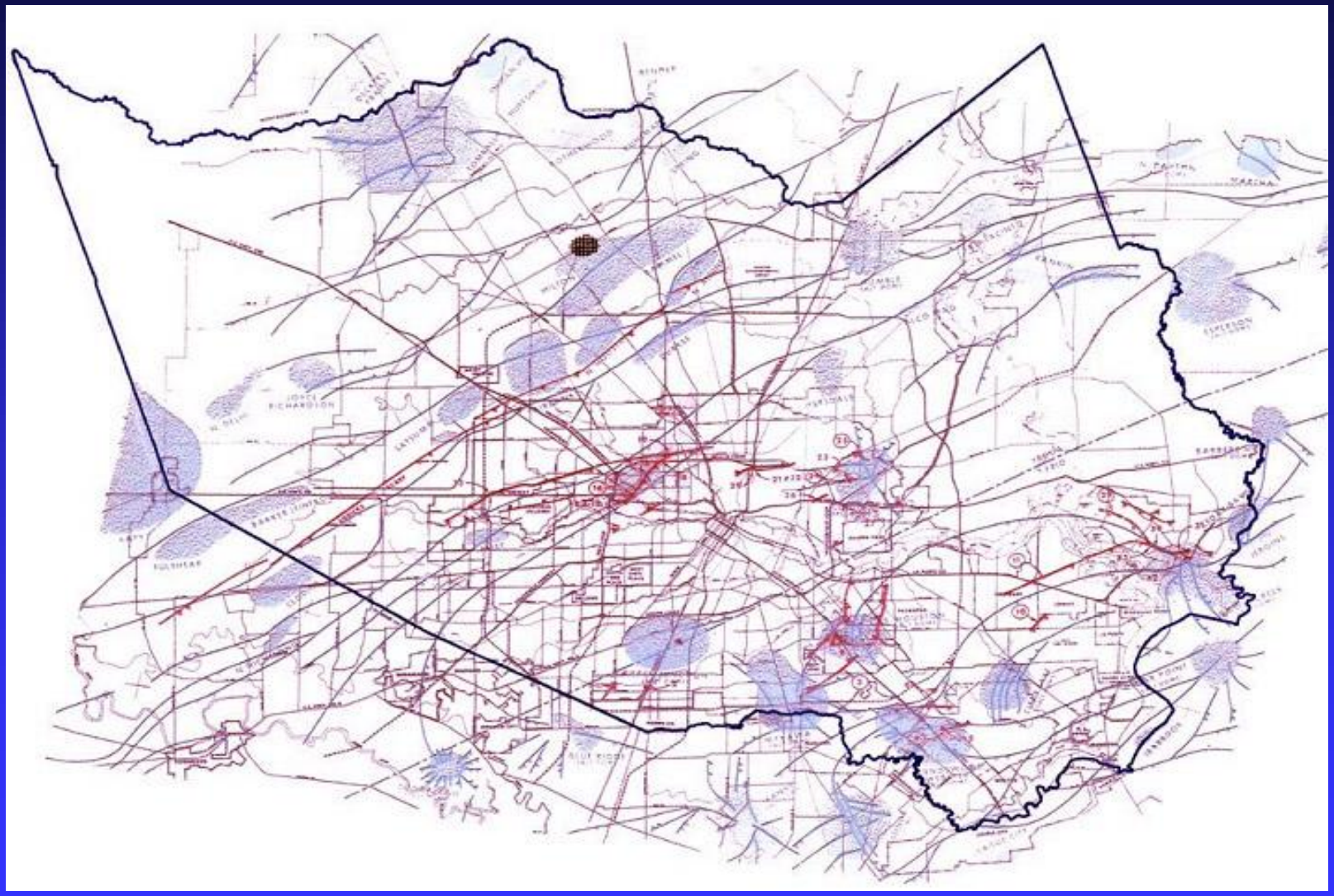


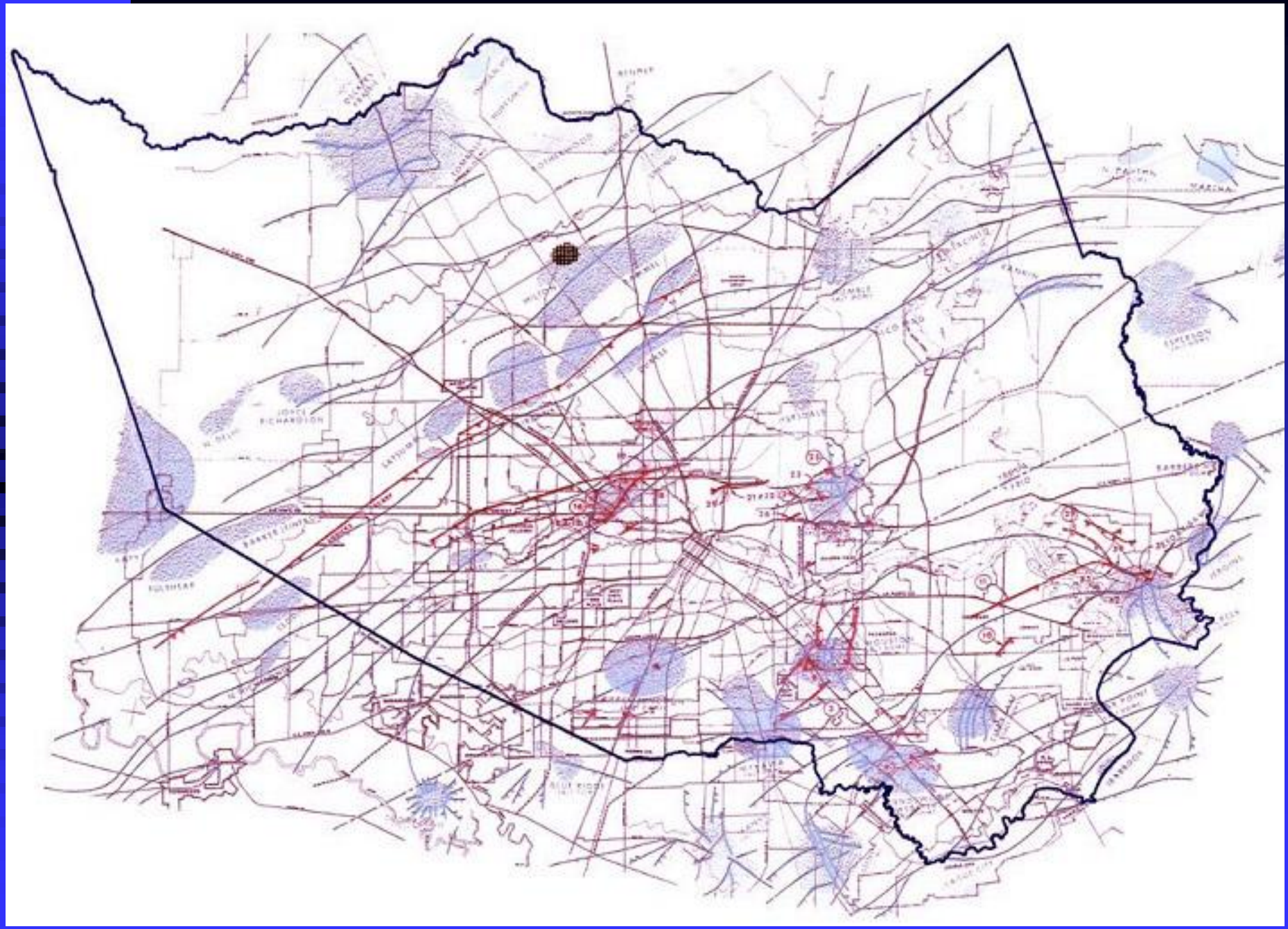

Approx. Elevation Ft/MSL
NW
SE
0
1,000
2,000
3,000
4,000
Houston
Hockley Salt Dome
Blue Ridge Salt Dome
GULF OF MEXICO
Caprock
Caprock
Lissie Formation
Beaumont Formation
Jasper Aquifer
Frio Clay
Evangeline Aquifer
Oakville Sandstone
Catahoula Sandstone (Tuff)
Chicot Aquifer
Montgomery Formation
Bentley Formation
Willis Sand
CLAY LENSES
SALTWATER
Goliad Sand
Burkeville Confining Unit
Jackson Group
Claiborne Group
Wilcox/Midway Groups
Not to scale (Horizontal)

Growth Faults Foster Geologic Hazards?

3) Natural gas in Evangeline aquifer, gas wells, and gas-storage areas,

Gas in Evangeline Aquifer



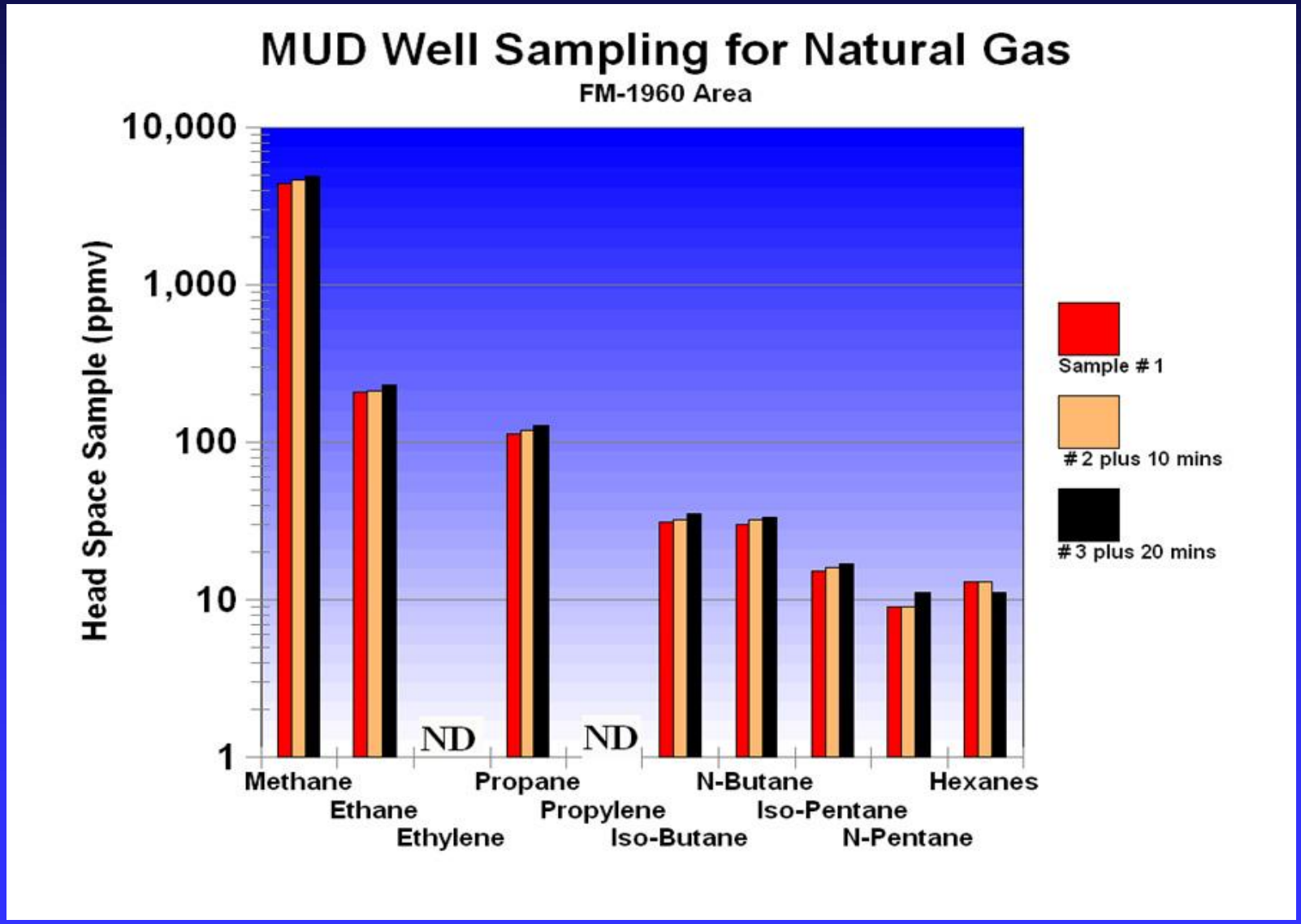


Gas in Evangeline Aquifer

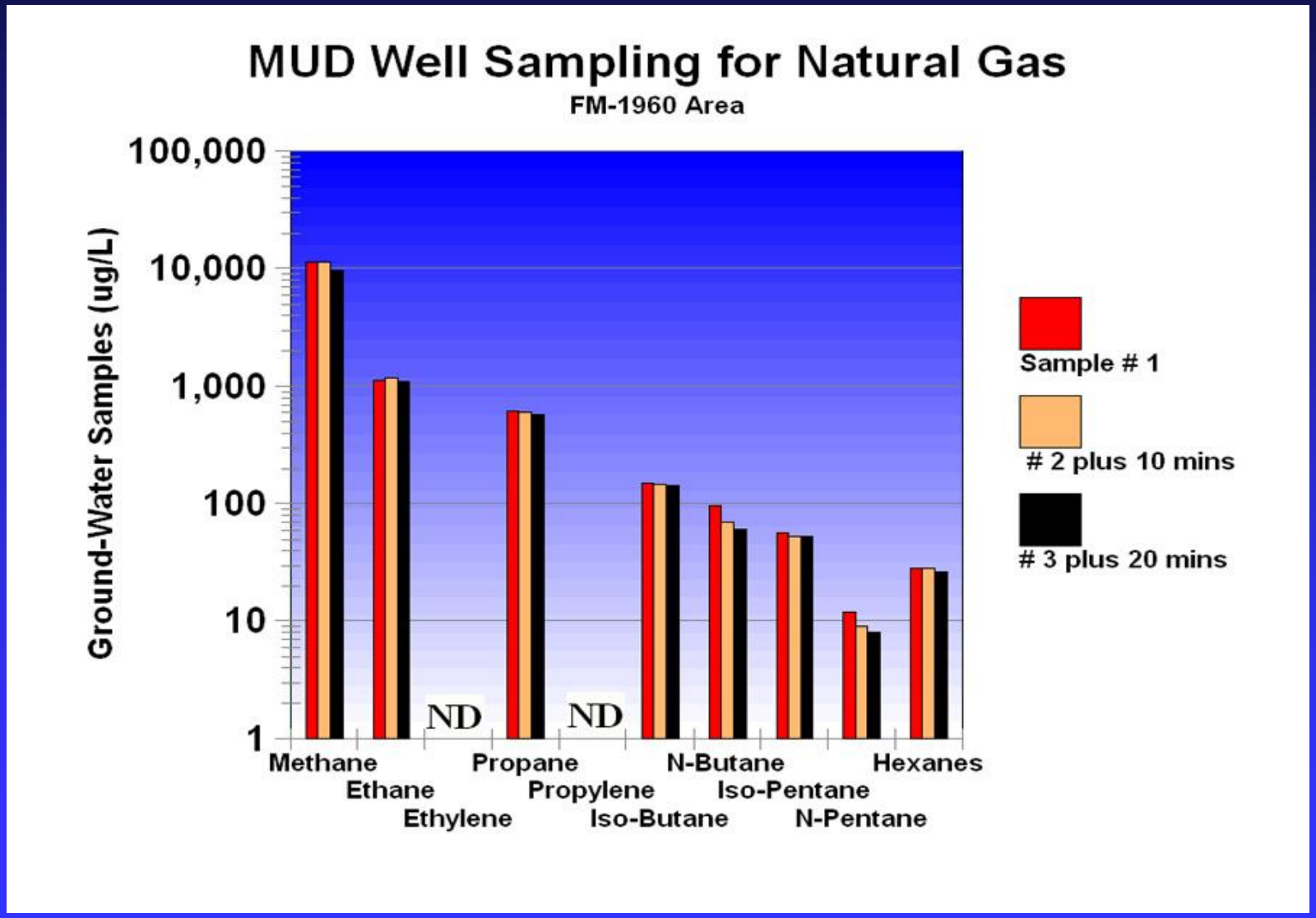
Gas in Evangeline Aquifer Some…

Gas in Evangeline Aquifer Substantial…

Gas in Evangeline Aquifer



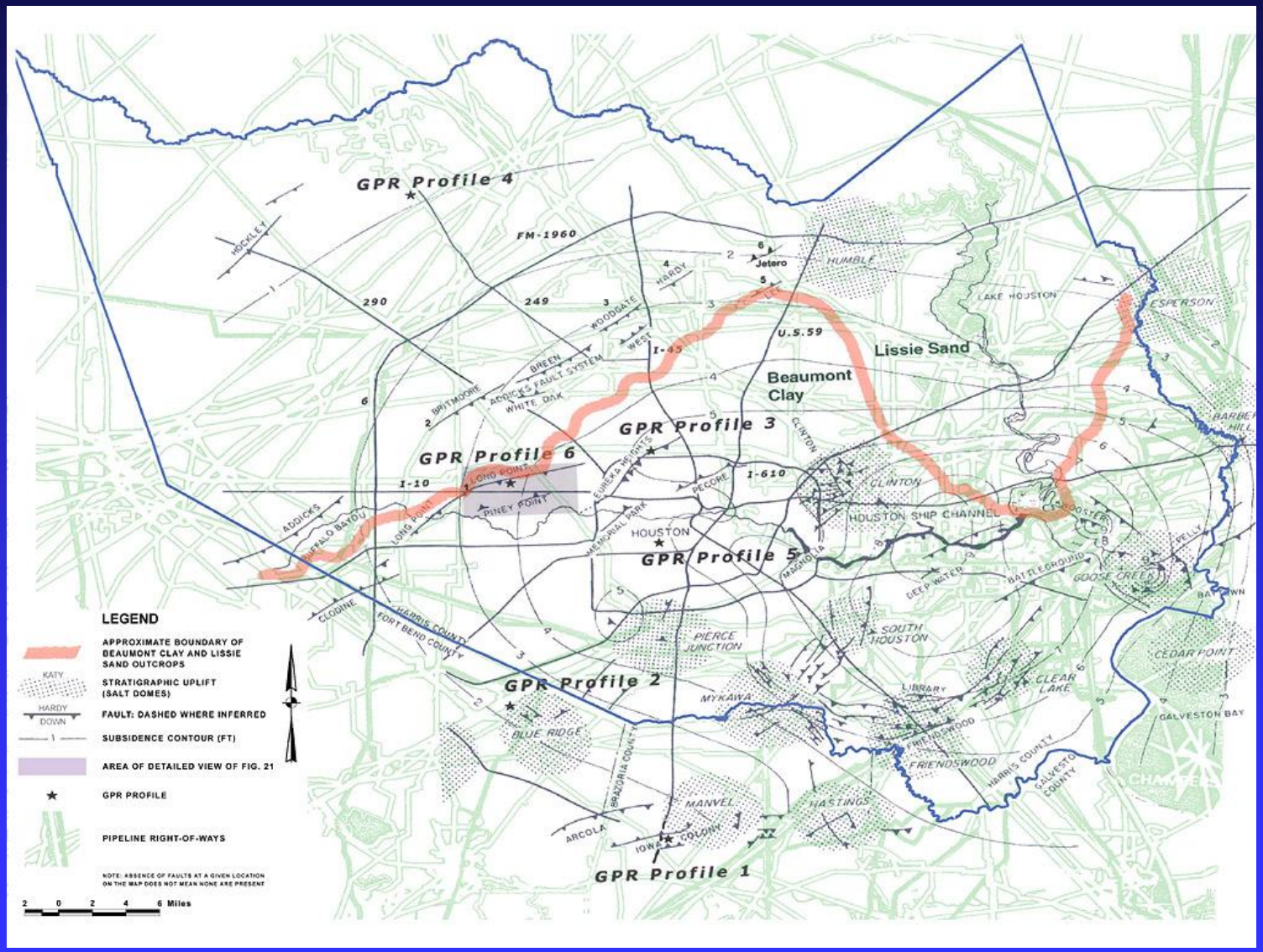
Gas in Evangeline Aquifer

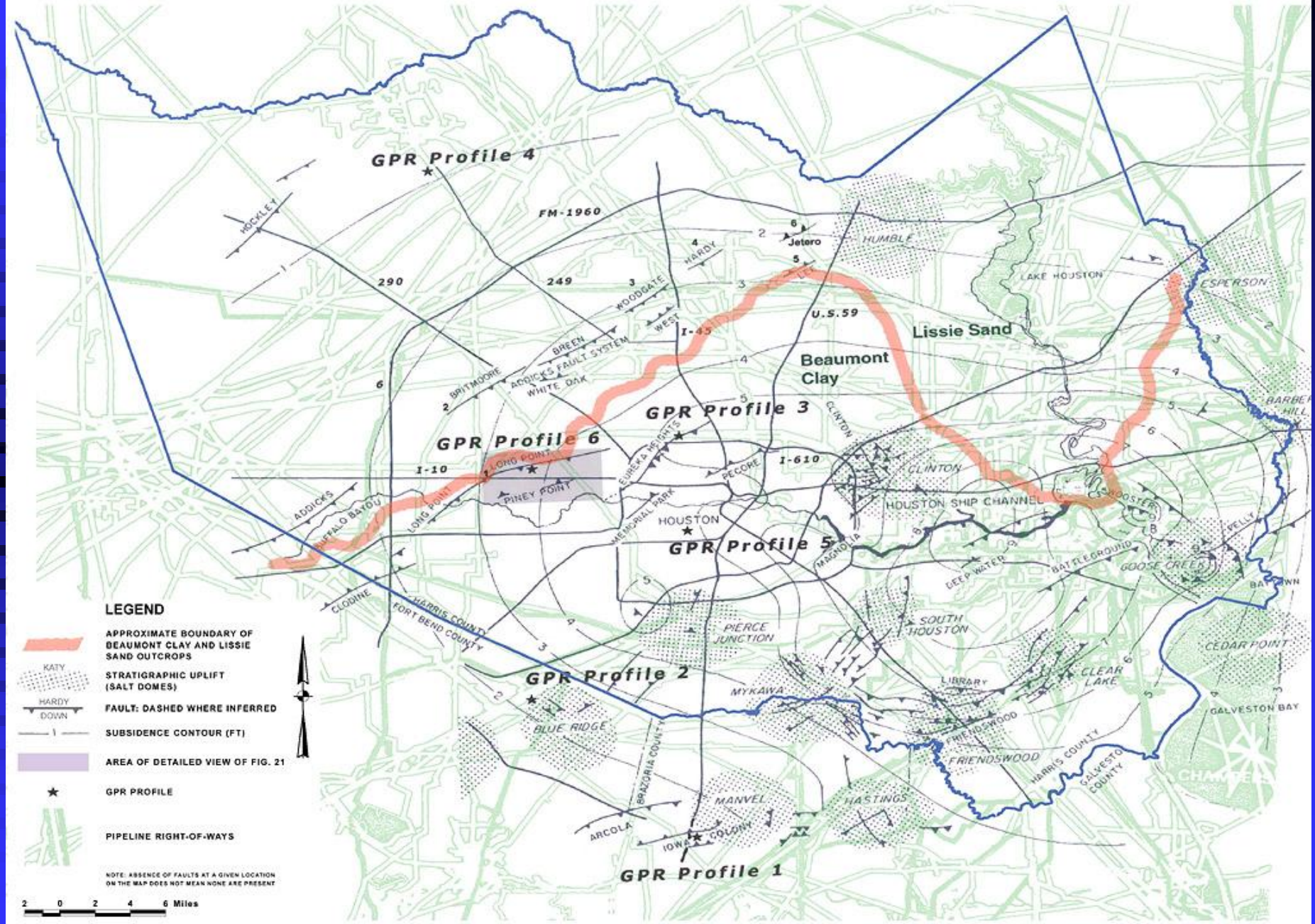


Growth Faults Foster Geologic Hazards?

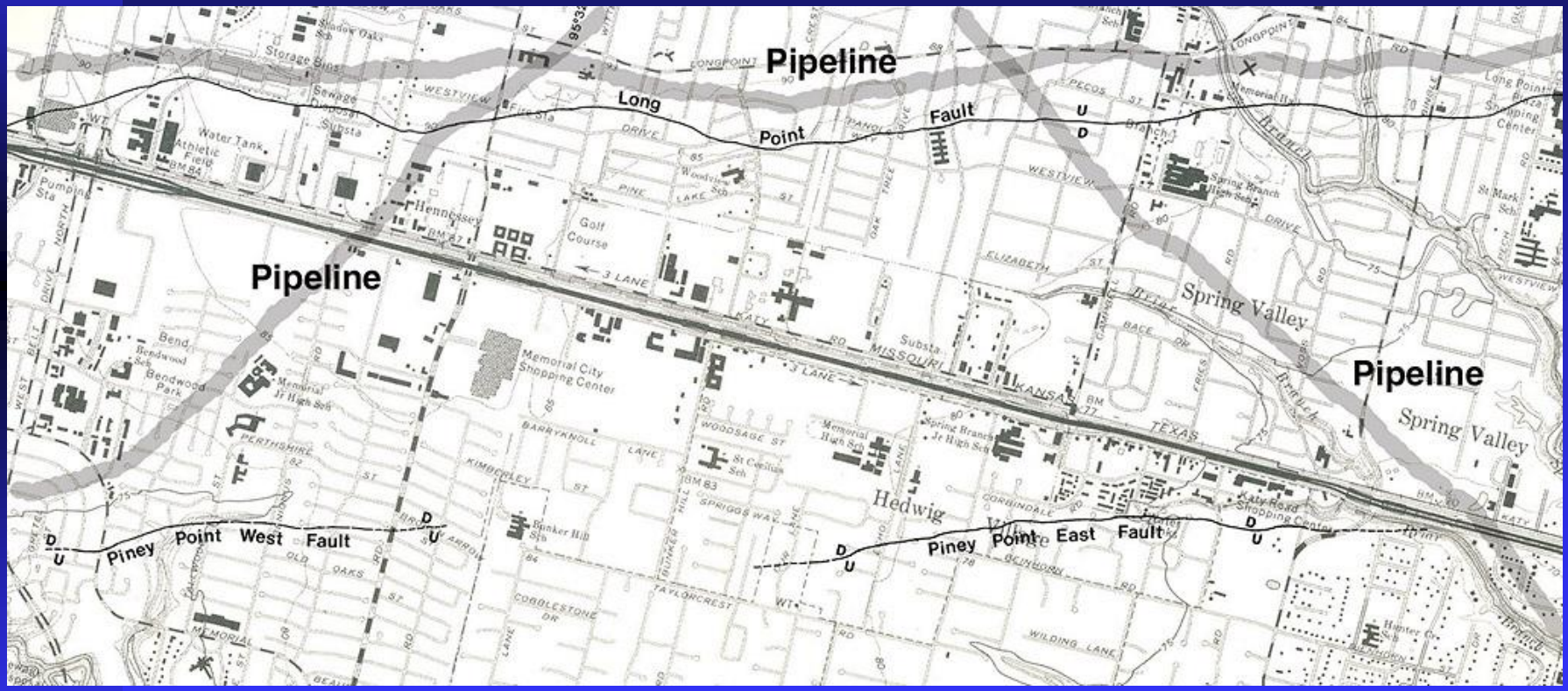
4) Pipeline Integrity: hydrocarbon & drinking-water mainlines,

Growth Faults Foster Geologic Hazards?




GPR Profile 4
GPR Profile 3
GPR Profile 6
GPR Profile 5
GPR Profile 2
GPR Profile 1
Beaumont Clay
Lissie Sand
FM-1960
290
249
I-45
U.S.59
I-10
I-610
HOUSTON
HUMBLE
Jetero
HARDY
WOODGATE
BRITMOORE
WHITE OAK
ADDICKS
BREEN
ADDICKS FAULT SYSTEM
EUREKA HEIGHTS
LONG POINT
PINEY POINT
PECORE
CLINTON
HOUSTON SHIP CHANNEL
MEMORIAL PARK
MAGNOLIA
BUFFALO BAYOU
CLODINE
HARRIS COUNTY
FORT BEND COUNTY
PIERCE JUNCTION
SOUTH HOUSTON
MYKAWA
BLUE RIDGE
BRAZORIA COUNTY
MANVEL
ARCOLA
IOWA COLONY
HASTINGS
LAKE HOUSTON
ESPERSON
BARBER'S HILL
BATTLEGROUND
GOOSE CREEK
DEEP WATER
CEDAR POINT
CLEAR LAKE
LIBRARY
FRIENDSWOOD
GALVESTON BAY
HARRIS COUNTY
GALVESTON COUNTY
CHAMBERS
LEGEND
APPROXIMATE BOUNDARY OF BEAUMONT CLAY AND LISSIE SAND OUTCROPS
KATY
STRATIGRAPHIC UPLIFT (SALT DOMES)
HARDY
DOWN
FAULT: DASHED WHERE INFERRED
SUBSIDENCE CONTOUR (FT)
AREA OF DETAILED VIEW OF FIG. 21
GPR PROFILE
PIPELINE RIGHT-OF-WAYS
NOTE: ABSENCE OF FAULTS AT A GIVEN LOCATION ON THE MAP DOES NOT MEAN NONE ARE PRESENT
2 0 2 4 6 Miles

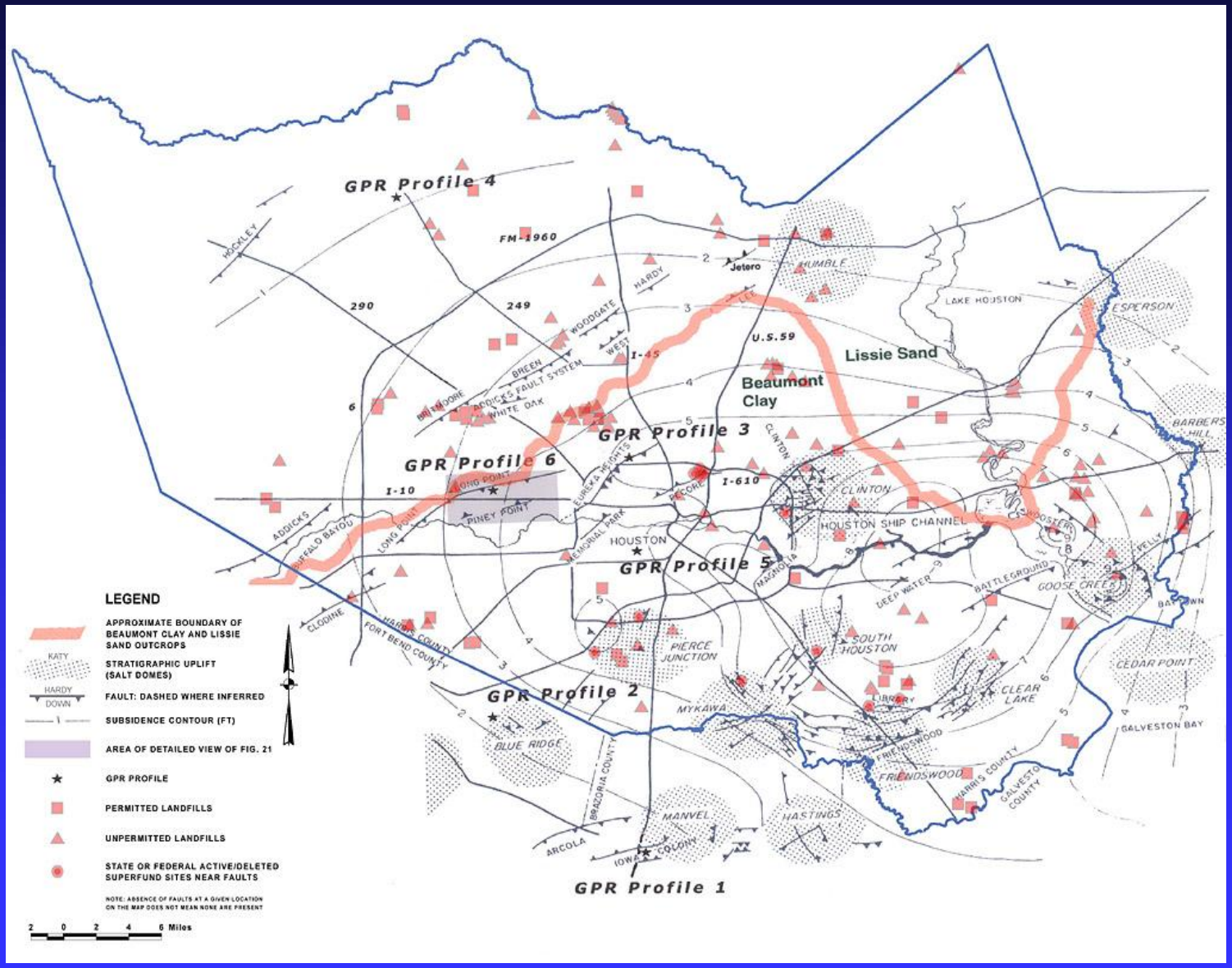
Growth Faults Foster Geologic Hazards?

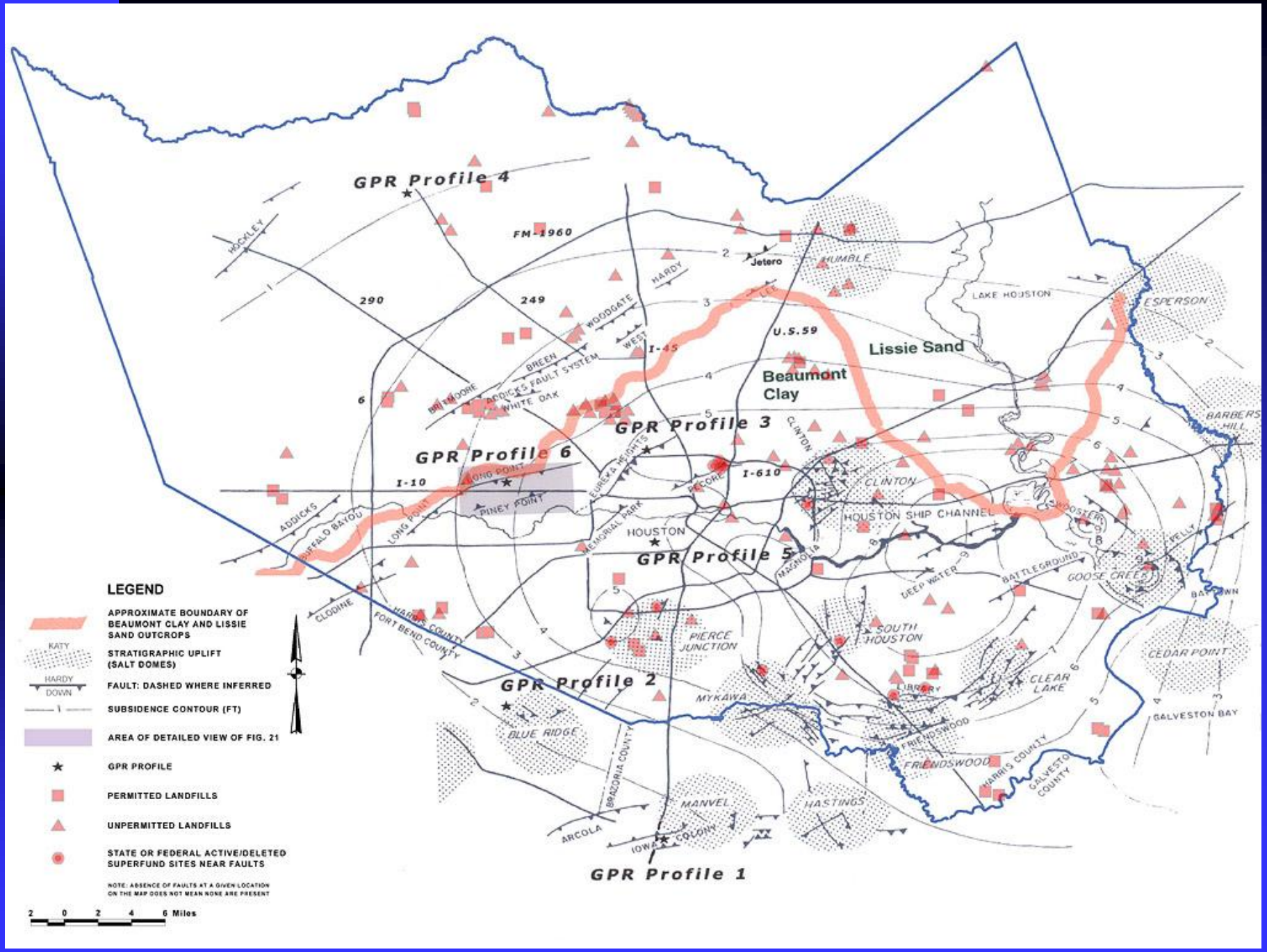


Growth Faults Foster Geologic Hazards?

5) Landfills, permitted & unpermitted, & Superfund sites, active & de-listed.

Growth Faults Foster Geologic Hazards?




GPR Profile 4
GPR Profile 3
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Lissie Sand
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HOUSTON
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APPROXIMATE BOUNDARY OF BEAUMONT CLAY AND LISSIE SAND OUTCROPS
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DOWN
FAULT: DASHED WHERE INFERRED
SUBSIDENCE CONTOUR (FT)
AREA OF DETAILED VIEW OF FIG. 21
GPR PROFILE
PERMITTED LANDFILLS
UNPERMITTED LANDFILLS
STATE OR FEDERAL ACTIVE/DELETED SUPERFUND SITES NEAR FAULTS
NOTE: ABSENCE OF FAULTS AT A GIVEN LOCATION ON THE MAP DOES NOT MEAN NONE ARE PRESENT
2 0 2 4 6 Miles

Economic Impact of Faulting & Subsidence

1) Structural damage to homes along known faults.
2) Foundation repair industry thrives in Houston.
3) Structural damage to public facilities, e.g. freeways, highways, bridges, railroads, storm and sanitary sewers, etc.

In 1973, more than 95 miles of active fault zones in Houston area. Additional faults found since.

Fault damage costs are often lumped in with costs attributed to subsidence damage.

Economic Impact of Faulting & Subsidence

Radionuclides & Hydrocarbons: Health Impact?

1) Extra lab costs for monitoring MCLs
2) Extra vigilance required in monitoring

Other Impacts

1) Contamination lawsuits: real or imagined,
2) Re-leveling drainage to minimize flooding,
3) Real-estate transfers & full disclosure,
4) New TX regulations require investigations to conducted by licensed geoscientists.

Regulatory Impact of Faulting & Subsidence

Texas Administrative Code

Landfills

1) Geological Faults: Part 330.203
2) Soils & Liner Quality: Part 330.205
3) Fault Areas: Part 330.303

Wastewater Treatment Facilities

1) Location Standards: Part 309.11
2) Definitions: Part 309.12

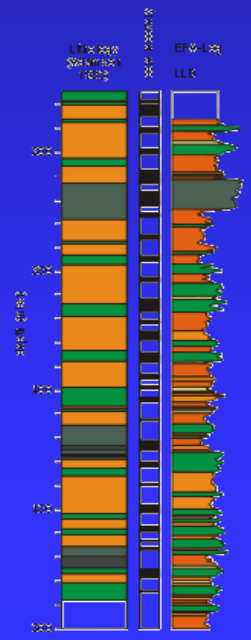
Ground-Water Use

1) Subsidence District Creation
2) Increased Use of Surface Water

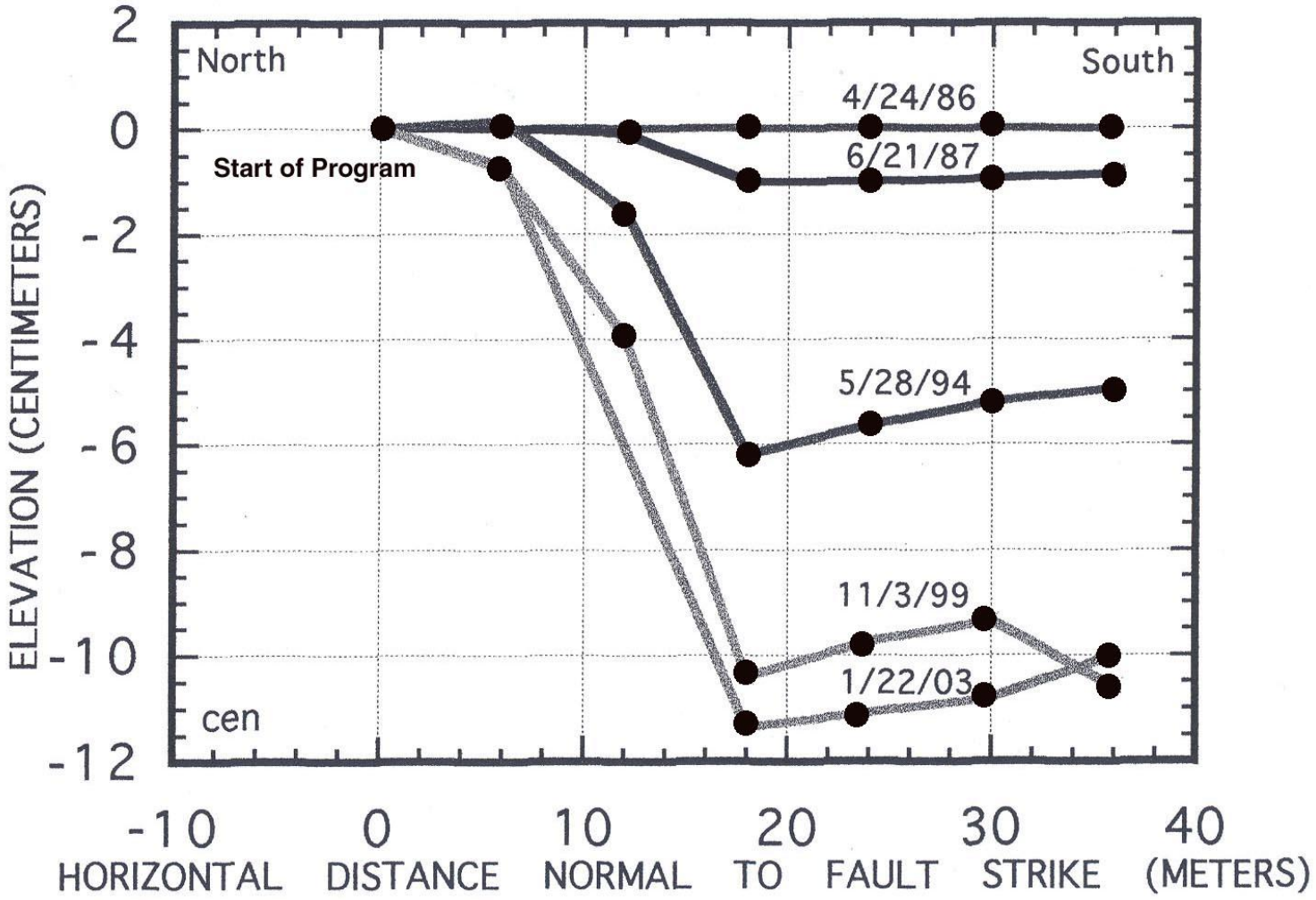
Methods of Shallow Fault Investigation

Methods of Shallow Fault Investigation

EGA



Methods of Surface Fault Investigation



Methods of Surface Fault Investigation

In 1991, Norman and Elsbury provided a summary of their experience over many years of monitoring and investigating growth faults in the Houston area. Here are a few:

1) **Typical fault movement: 0.5 in/yr.**
2) **Rates of movement fairly uniform.**
3) **Faults are normal-slip. No strike slip?**

Methods of Surface Fault Investigation

4) By 1991, no systematic effort had been made to trace most of the known faults to their terminations.

5) Deep faults identified by previous oil & gas exploration may be useful.

6) Near-surface dip is about 70 degrees.

7) Extensional strain may allow vertical movement of fluids.

8) The Long Point, Brittmoore, & Woodgate faults are termed regional contemporaneous growth faults.

Methods of Surface Fault Investigation

9) A 1986 neighborhood survey indicated 243 structures, mostly homes, rested on the zone of disturbance of the Long Point Fault.

10) The Long Point Fault has been active, at least intermittently, for the 1.5 million years since Horizon F in the lower Lissie Formation was deposited.

11) The Conroe Fault is part of a deep regional fault system involved in an oil and gas field with a displacement of about 500 ft at a depth of 5,000 ft.

The Faulting – Subsidence Issue

Many Issues still need to be explored:

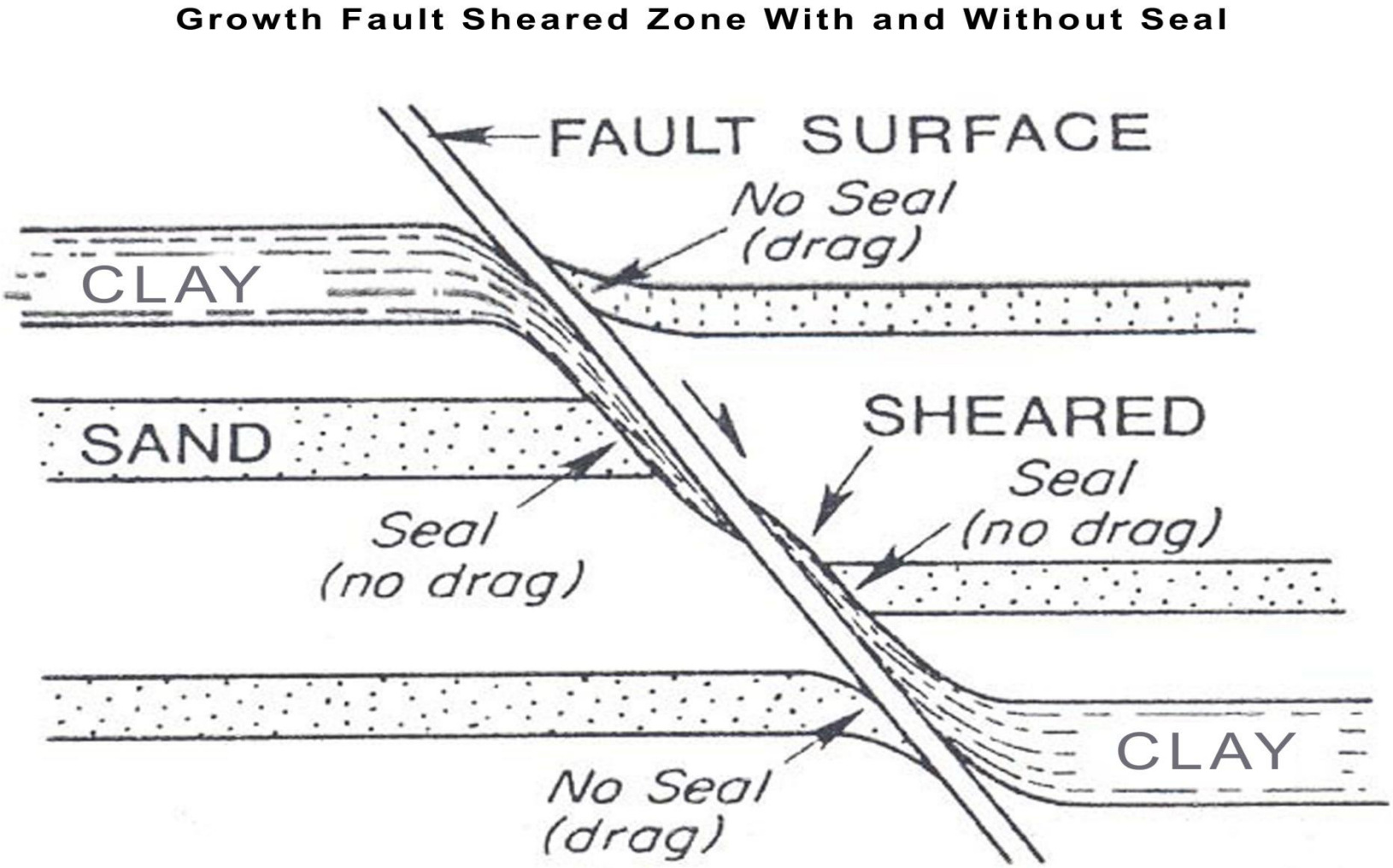
1) **Compartmentalization of faults?**

2) **Persistence of confining pressure?**

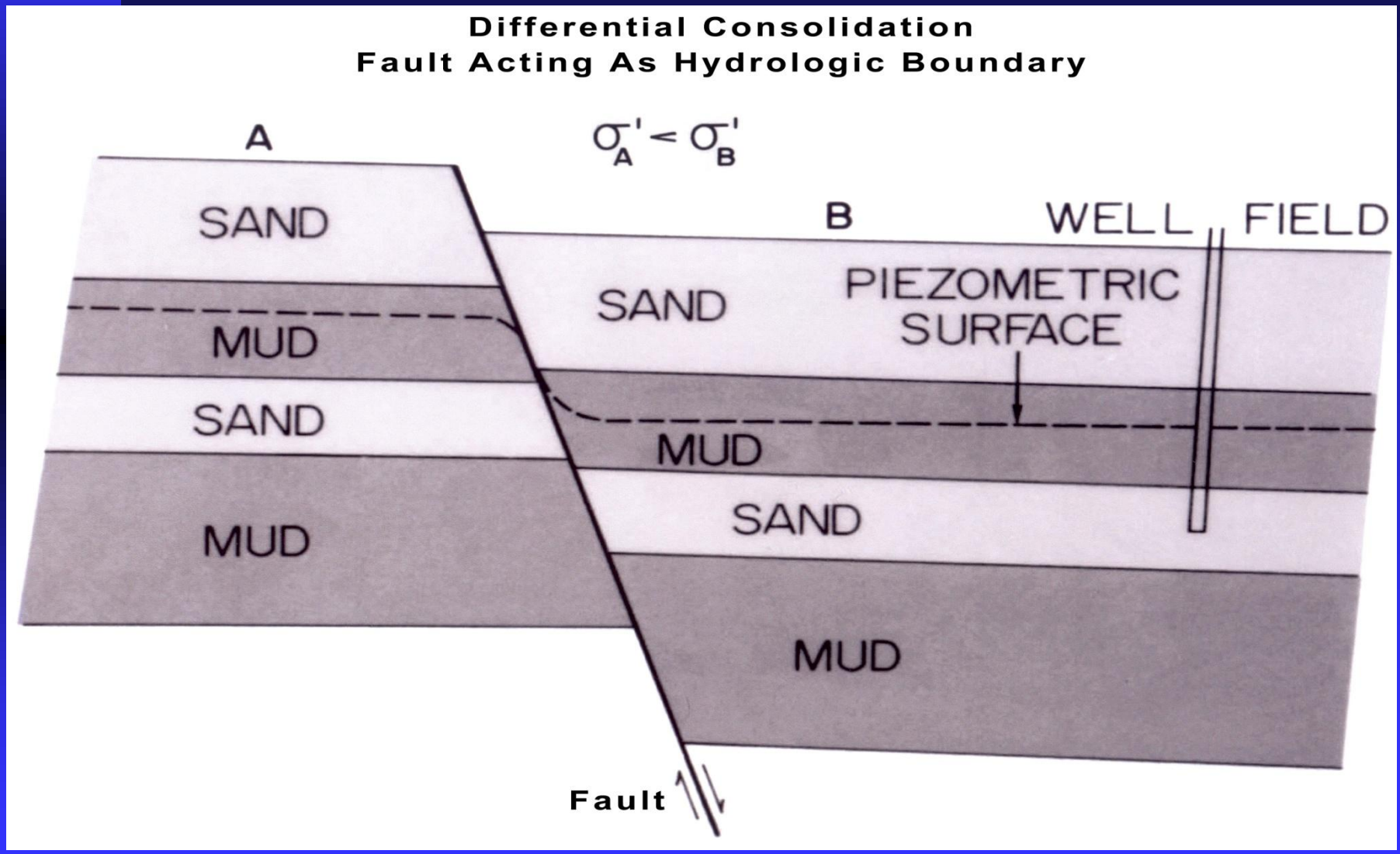
3) **Distribution of stress & strain?**

4) **Relationship between salt domes & deep faults w/ shallow faults?**

The Faulting – Subsidence Issue



The Faulting – Subsidence Issue



The Faulting – Subsidence Issue

Solutions will come from:

1) **Monitoring *in situ* strain gauges at critical locations monitored over extended periods. Also, Hockley Station.**

2) **Monitoring potentiometric surface in selected areas over extended periods.**

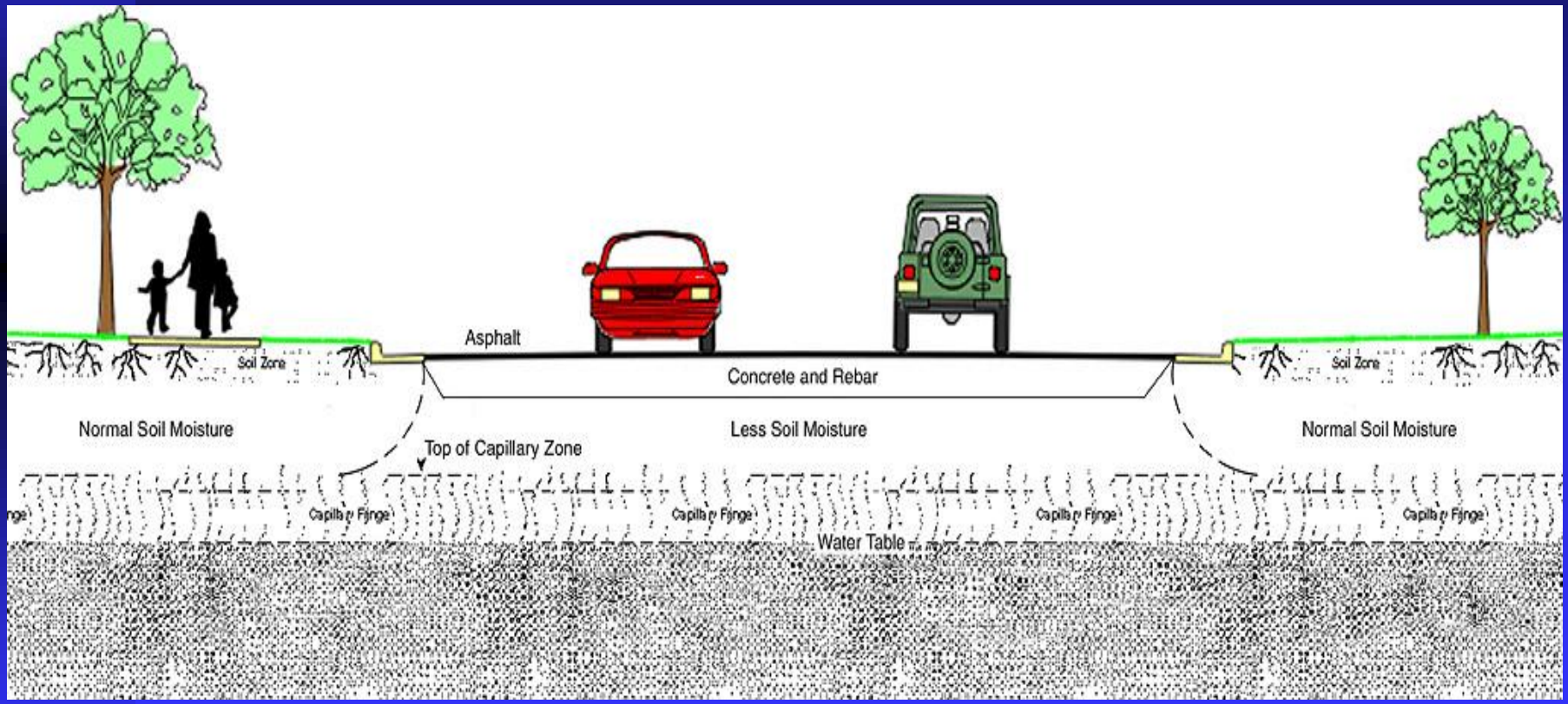
3) **Mapping subsurface (upper 3,000 ft.)**

Who will do the above? Who will use results?

U.S.G.S. providing support & guidance to local university graduate research programs?

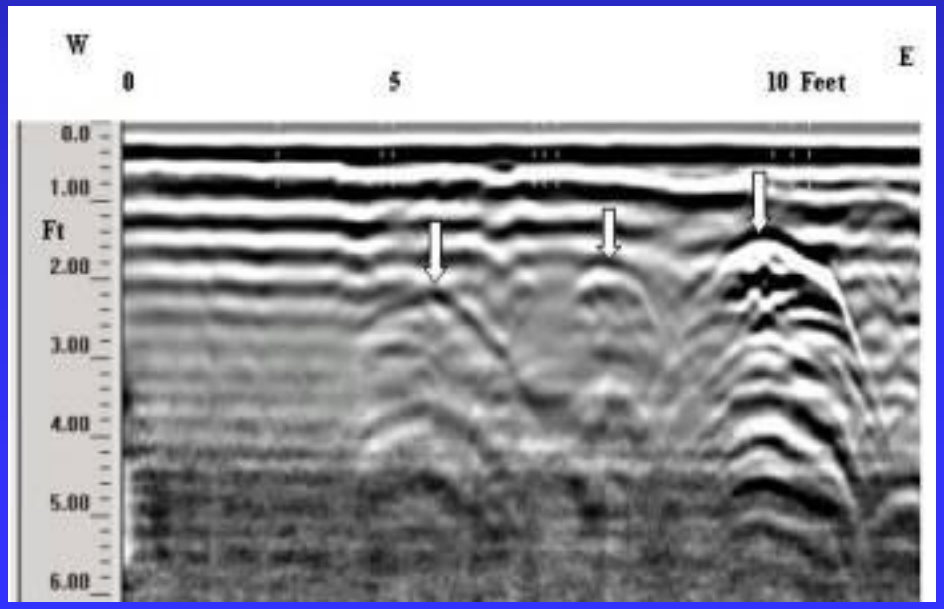
A Tool for Shallow Fault Investigation

The Umbrella Concept ?



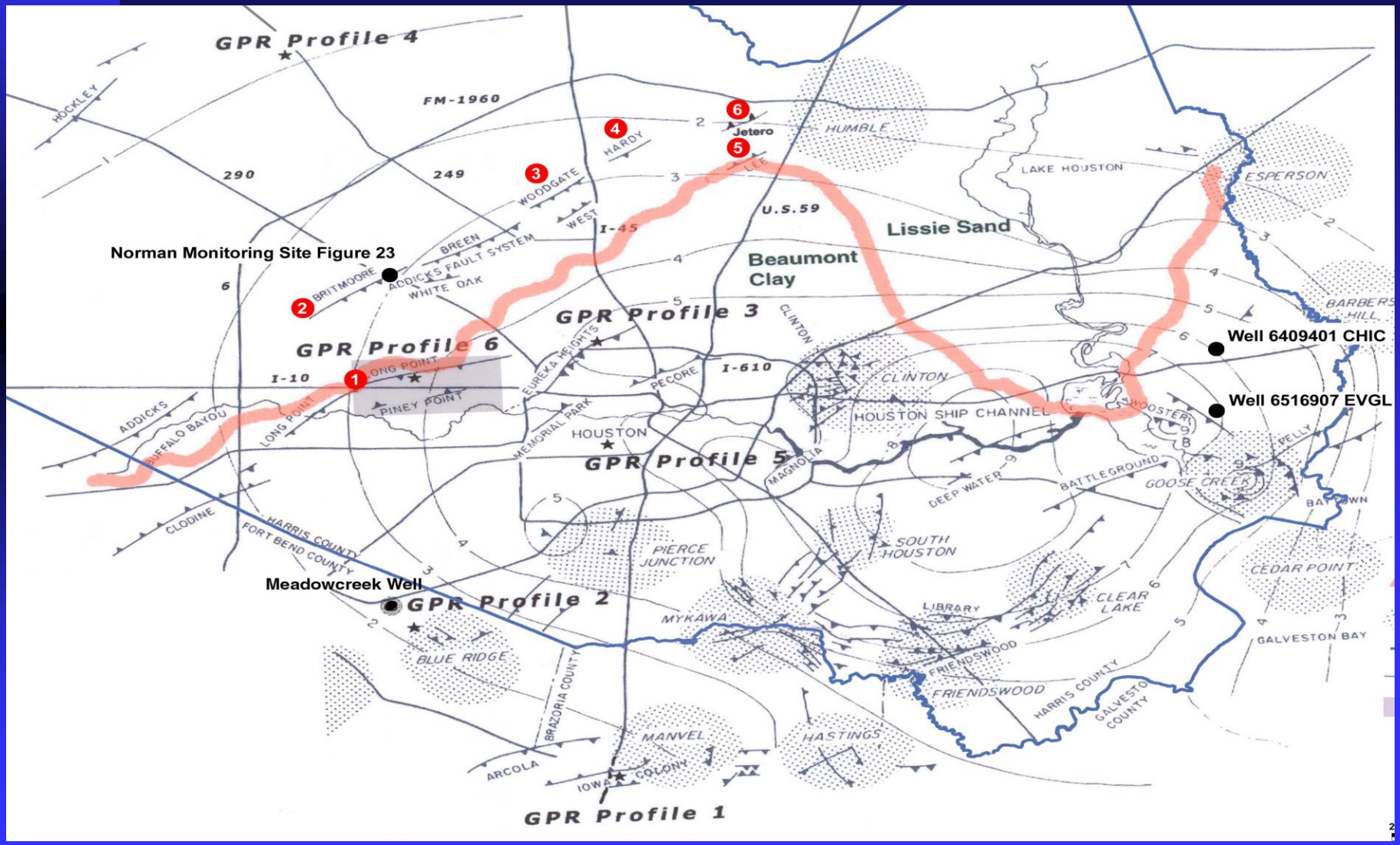
A Tool for Shallow Fault Investigation

But first,
field calibrations !



A Tool for Shallow Fault Investigation

GPR Profile 1: Iowa Colony

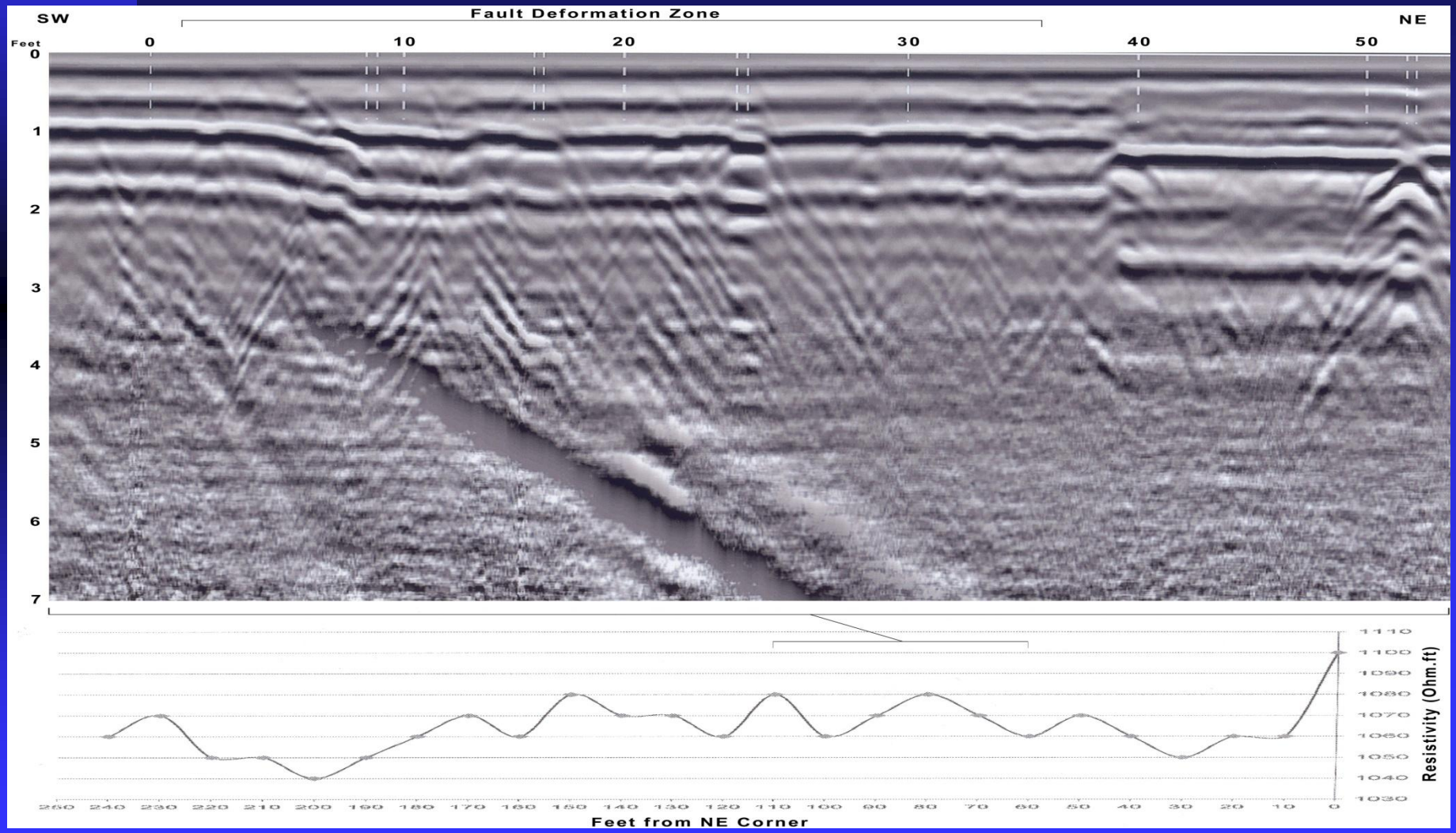


A Tool for Shallow Fault Investigation

GPR Profile 1: Iowa Colony

A Tool for Shallow Fault Investigation

GPR Profile 1: Iowa Colony

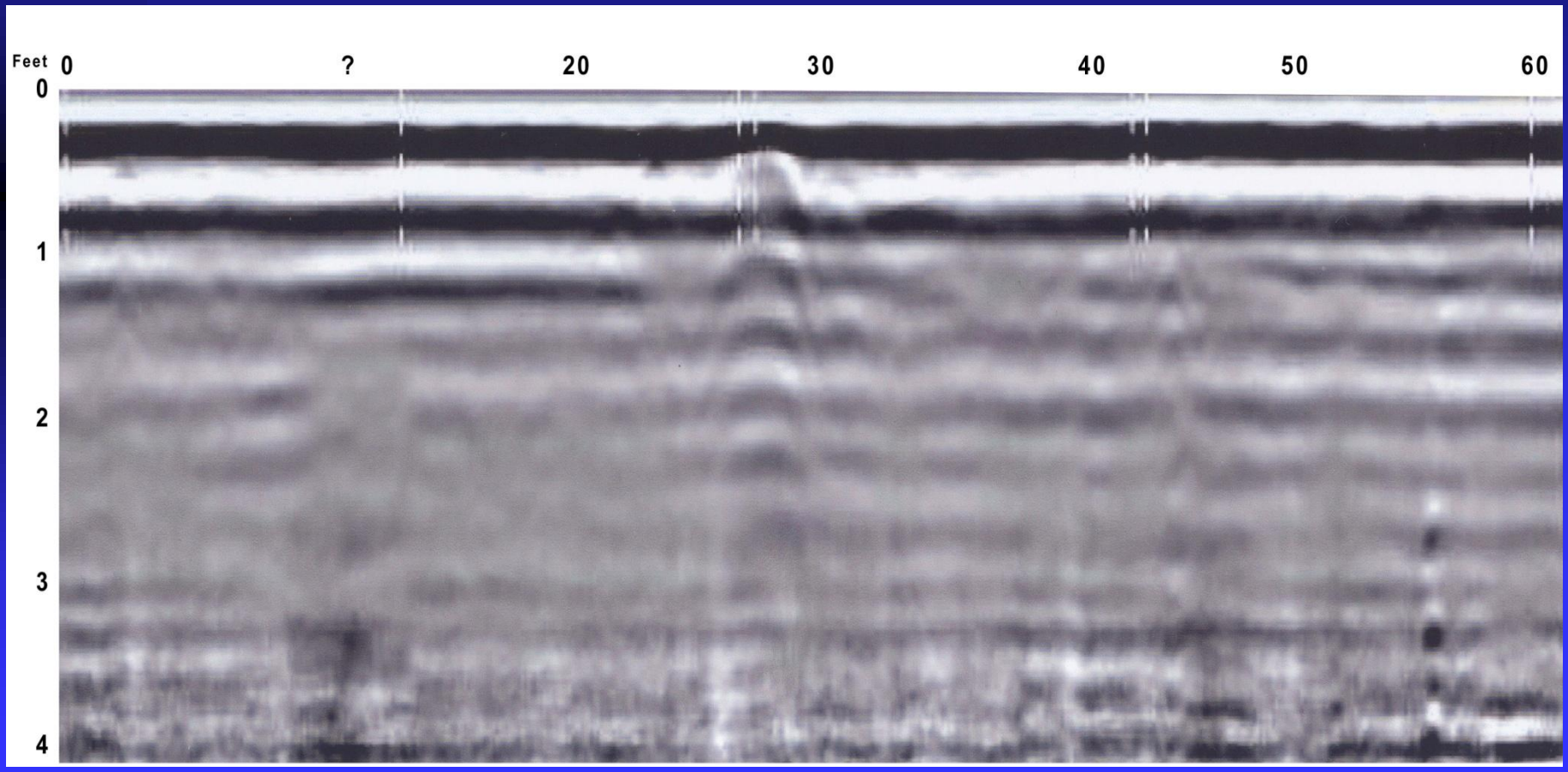


A Tool for Shallow Fault Investigation

GPR Profile 1: Iowa Colony

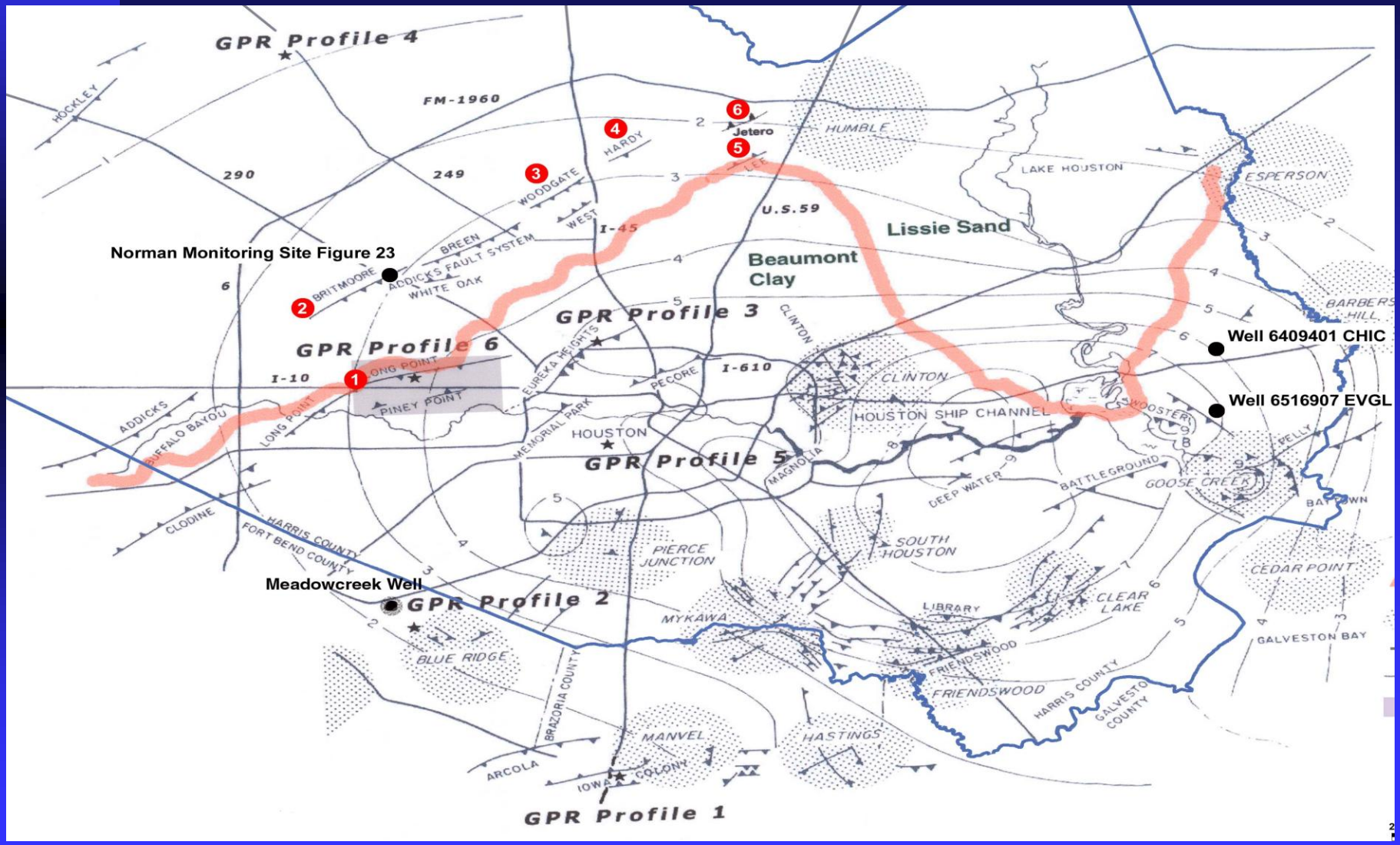
Another Calibration.

A GPR Profile over grassy area next to highway:



A Tool for Shallow Fault Investigation

GPR Profile 2: Quail Valley



A Tool for Shallow Fault Investigation

GPR Profile 2: Quail Valley

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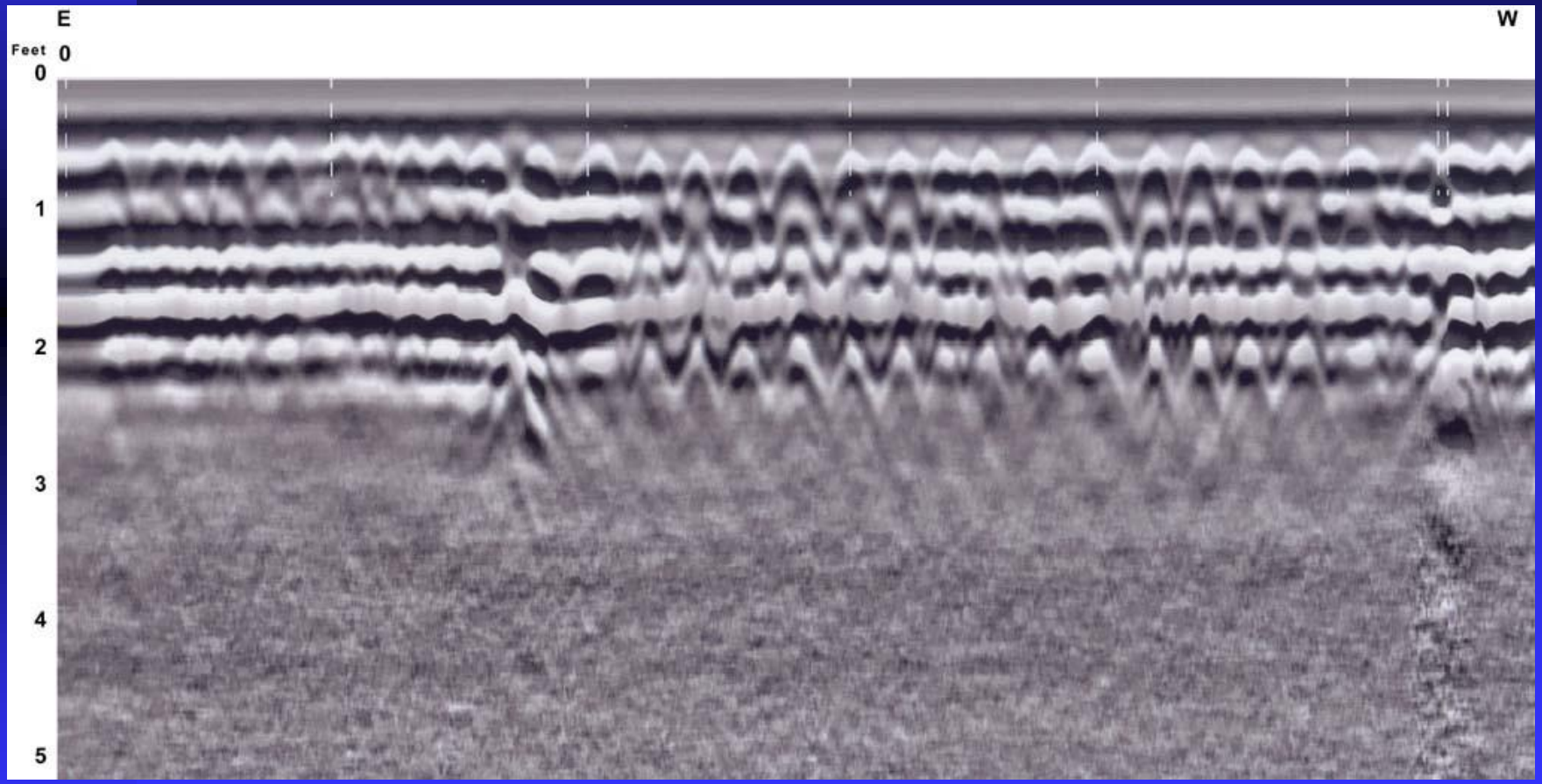
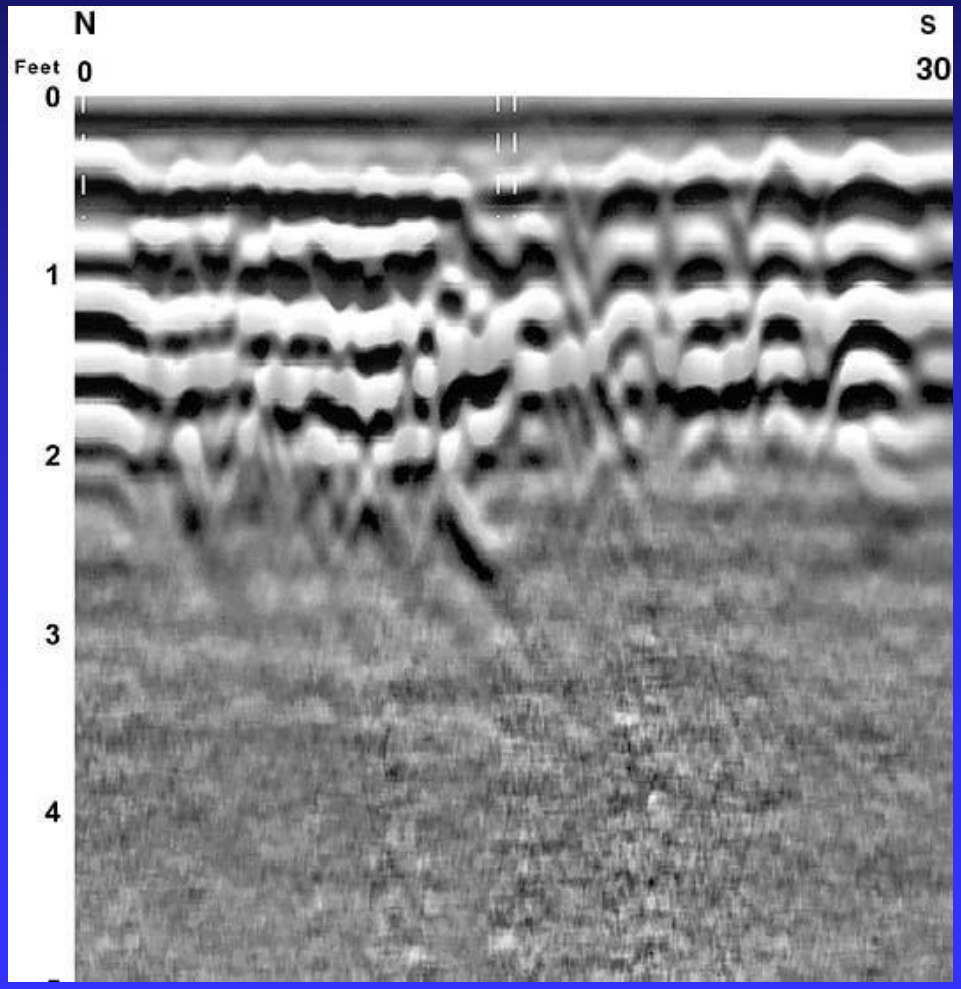


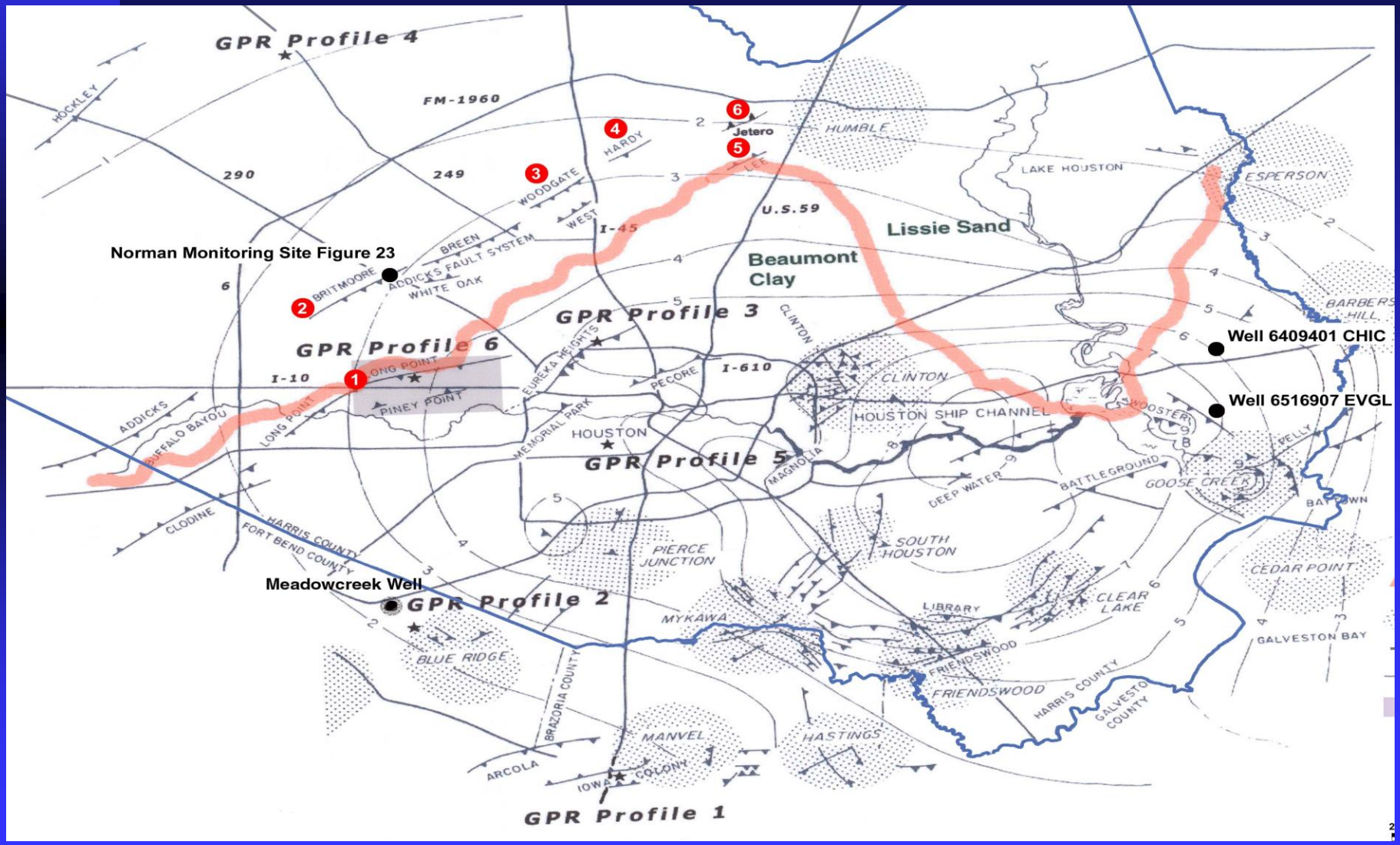
A Tool for Shallow Fault Investigation

GPR Profile 2: Quail Valley



A Tool for Shallow Fault Investigation

GPR Profile 3: Eureka Heights

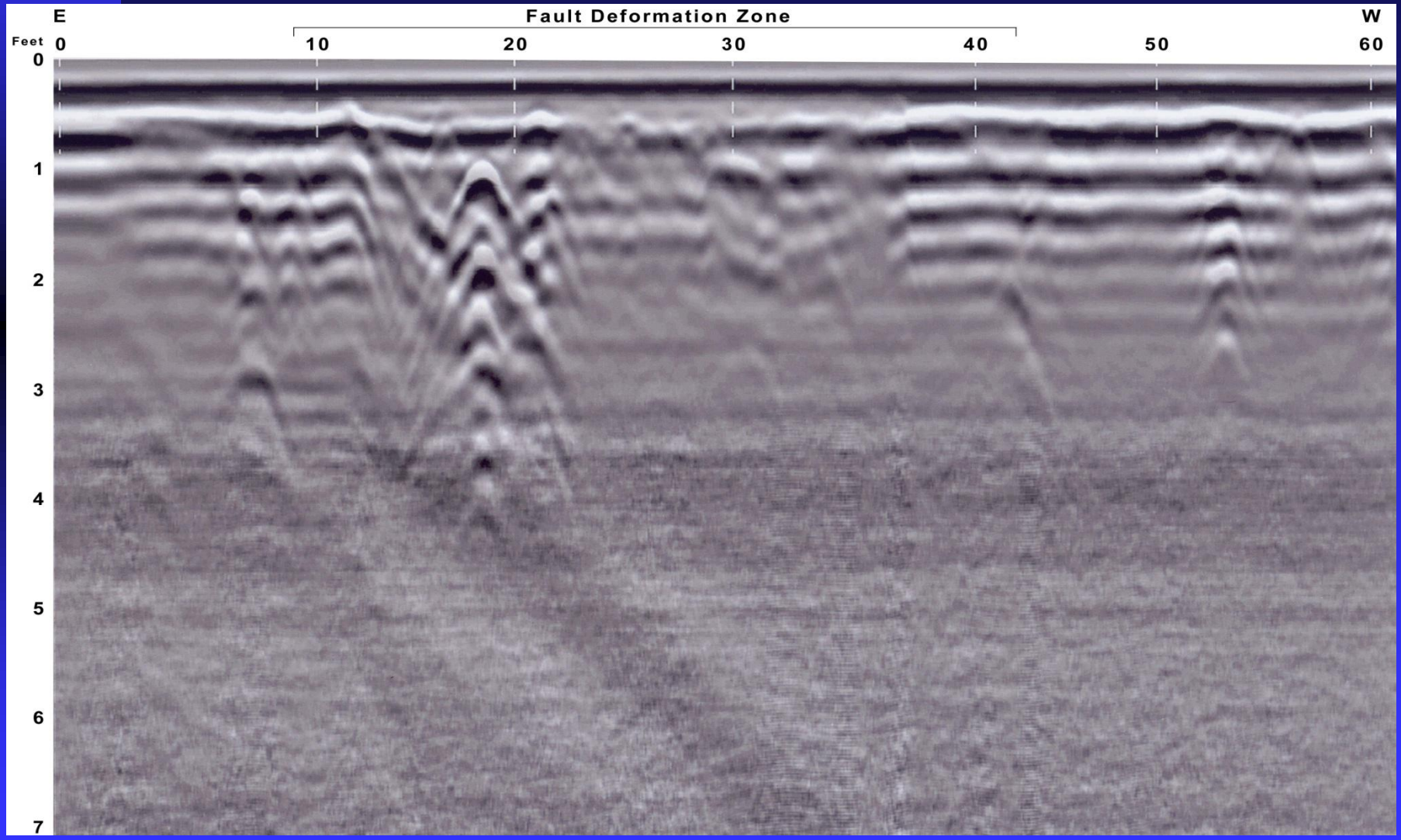


A Tool for Shallow Fault Investigation

GPR Profile 3: Eureka Heights

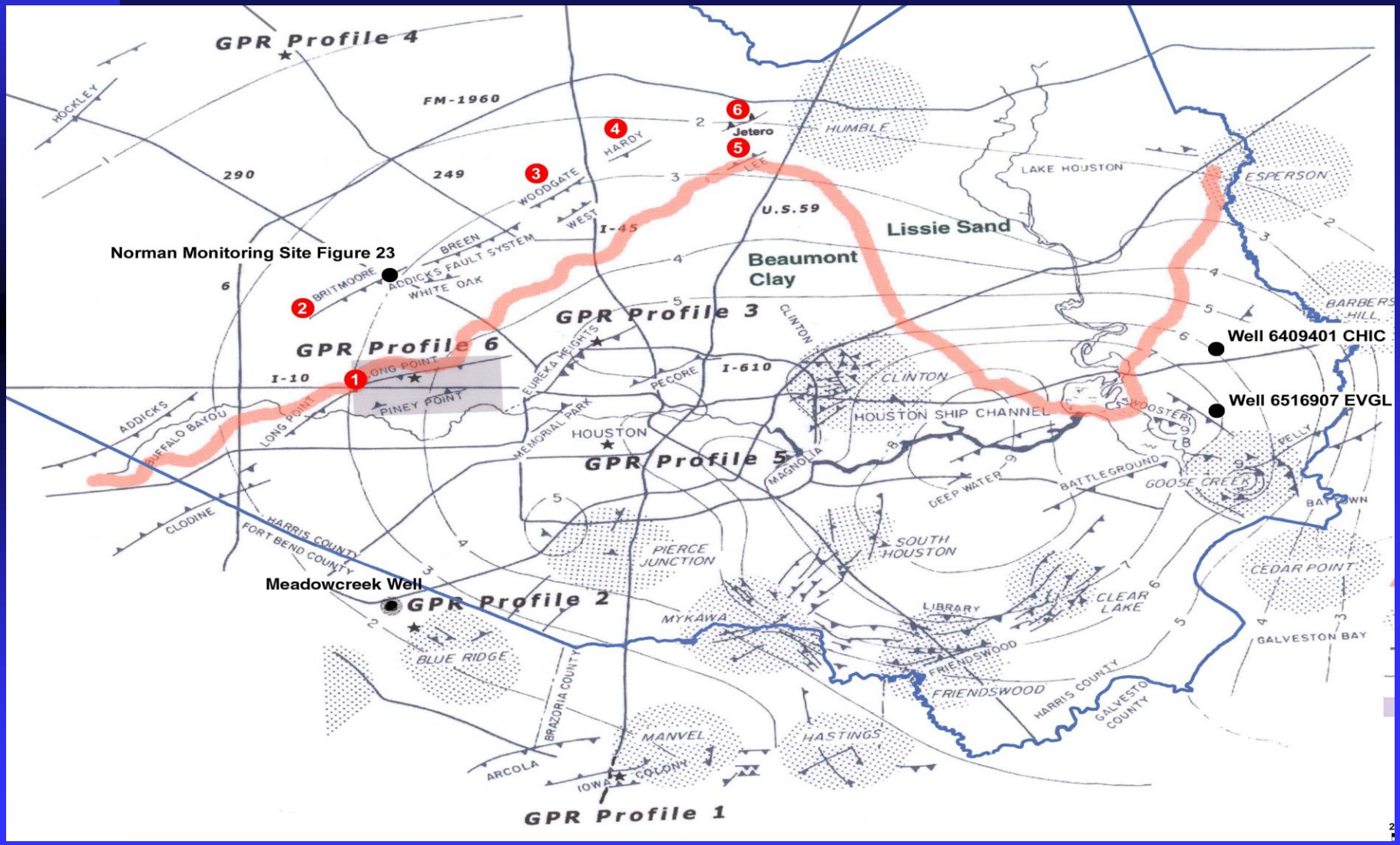
A Tool for Shallow Fault Investigation

GPR Profile 3: Eureka Heights



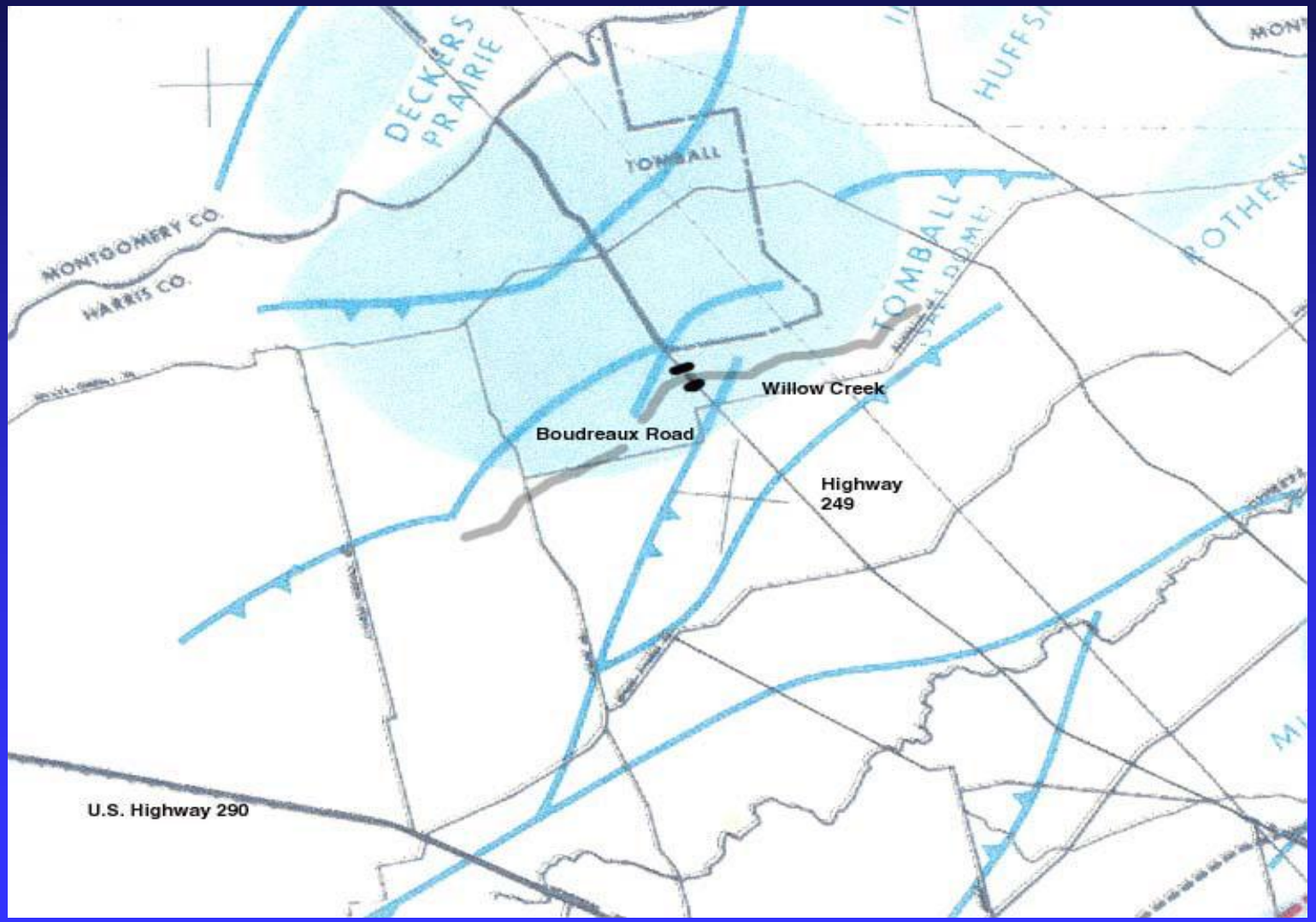
A Tool for Shallow Fault Investigation

GPR Profile 4: Willow Creek



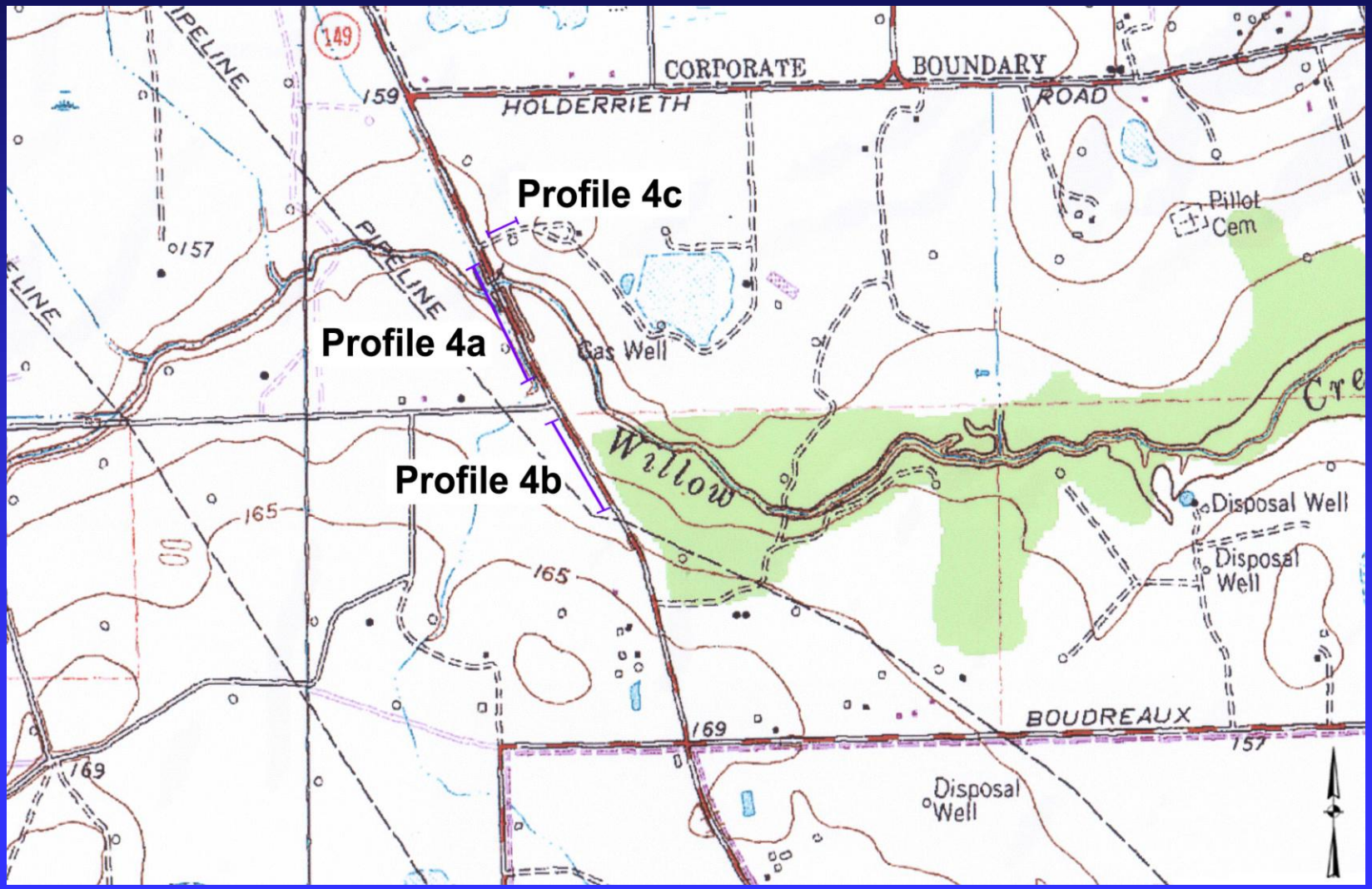
A Tool for Shallow Fault Investigation

GPR Profile 4: Willow Creek



A Tool for Shallow Fault Investigation

GPR Profile 4: Willow Creek



A Tool for Shallow Fault Investigation

GPR Profile 4: Willow Creek

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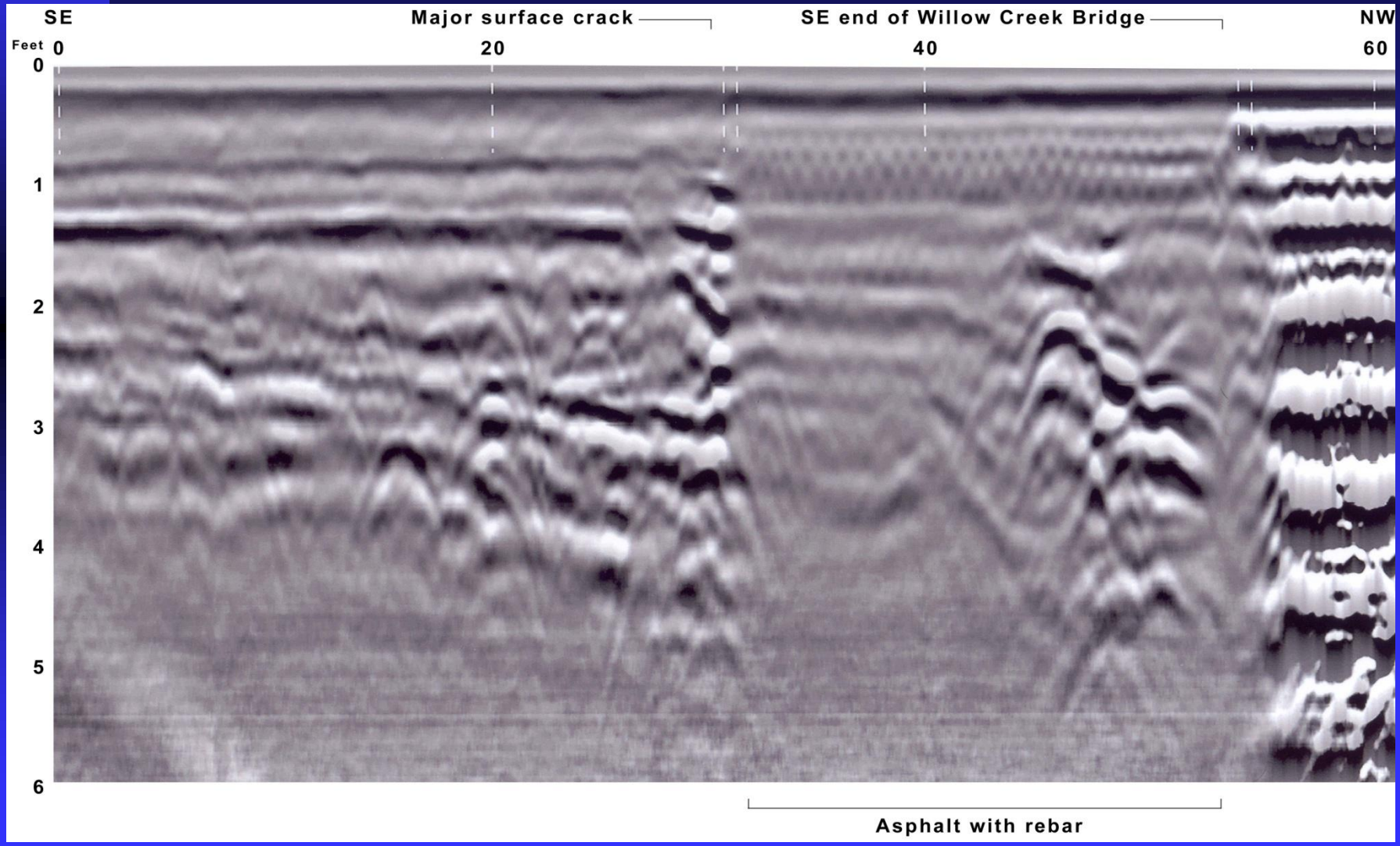
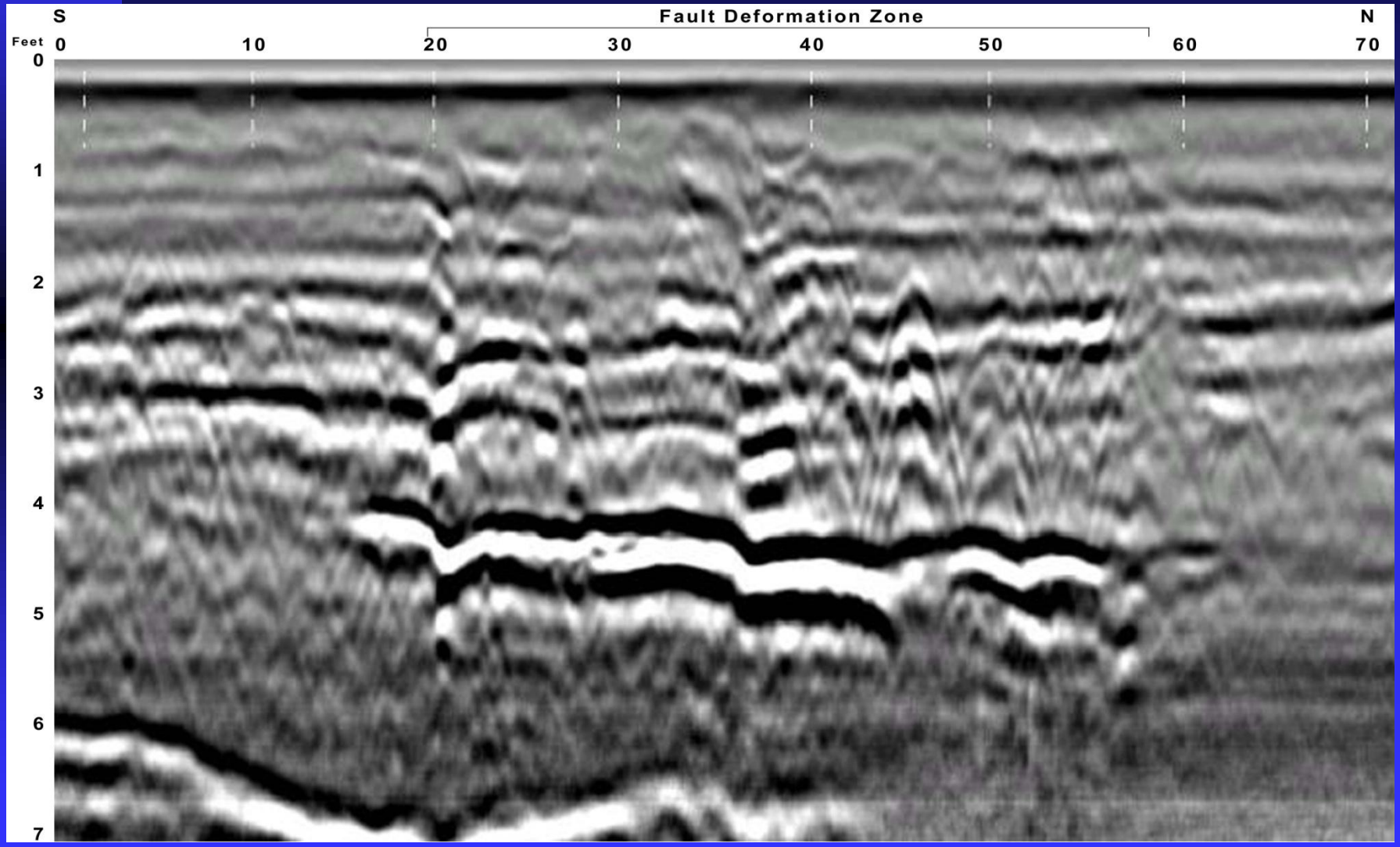


A Tool for Shallow Fault Investigation

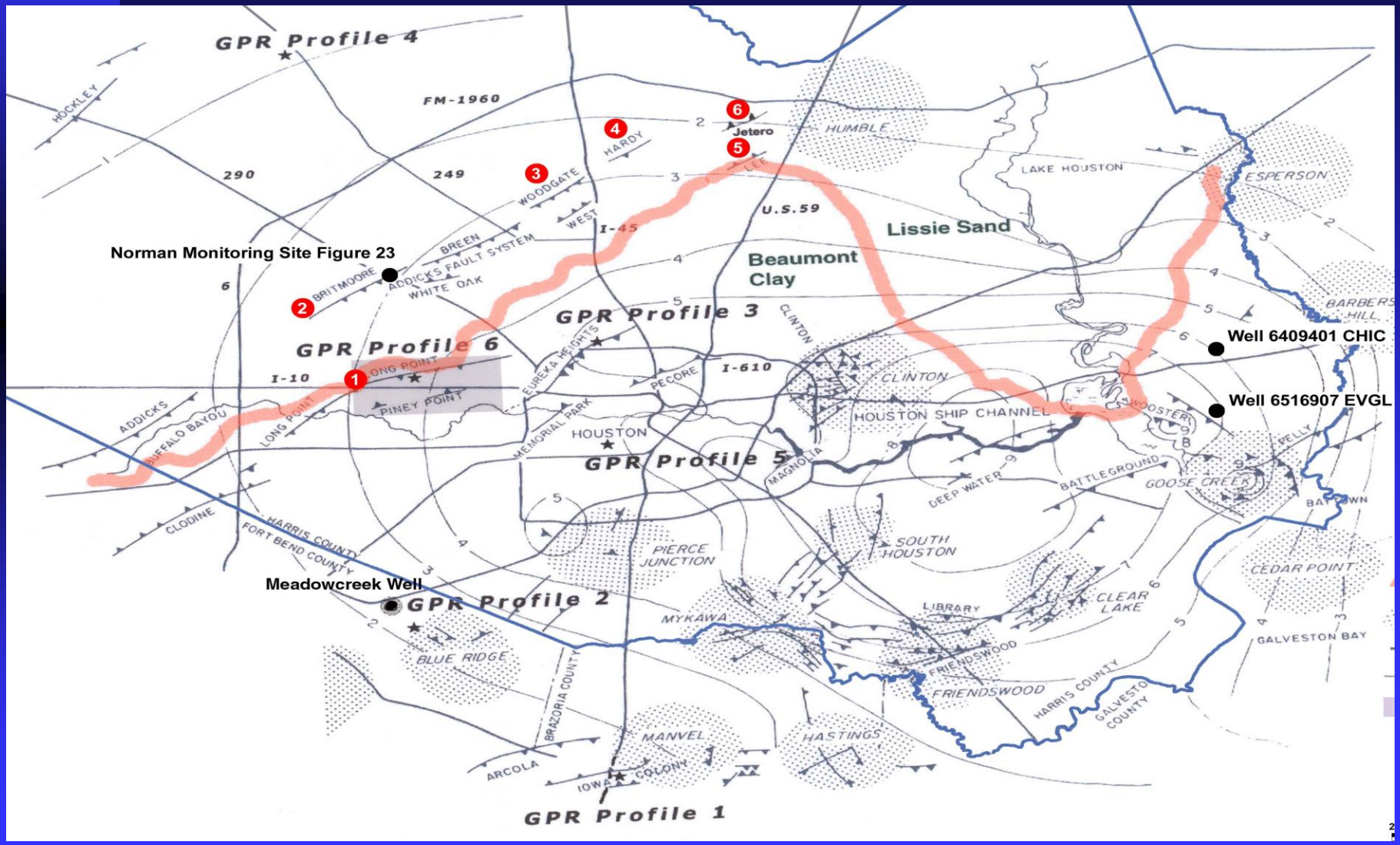
EGA

GPR Profile 4: Willow Creek



A Tool for Shallow Fault Investigation

GPR Profile 5: Hazard Street

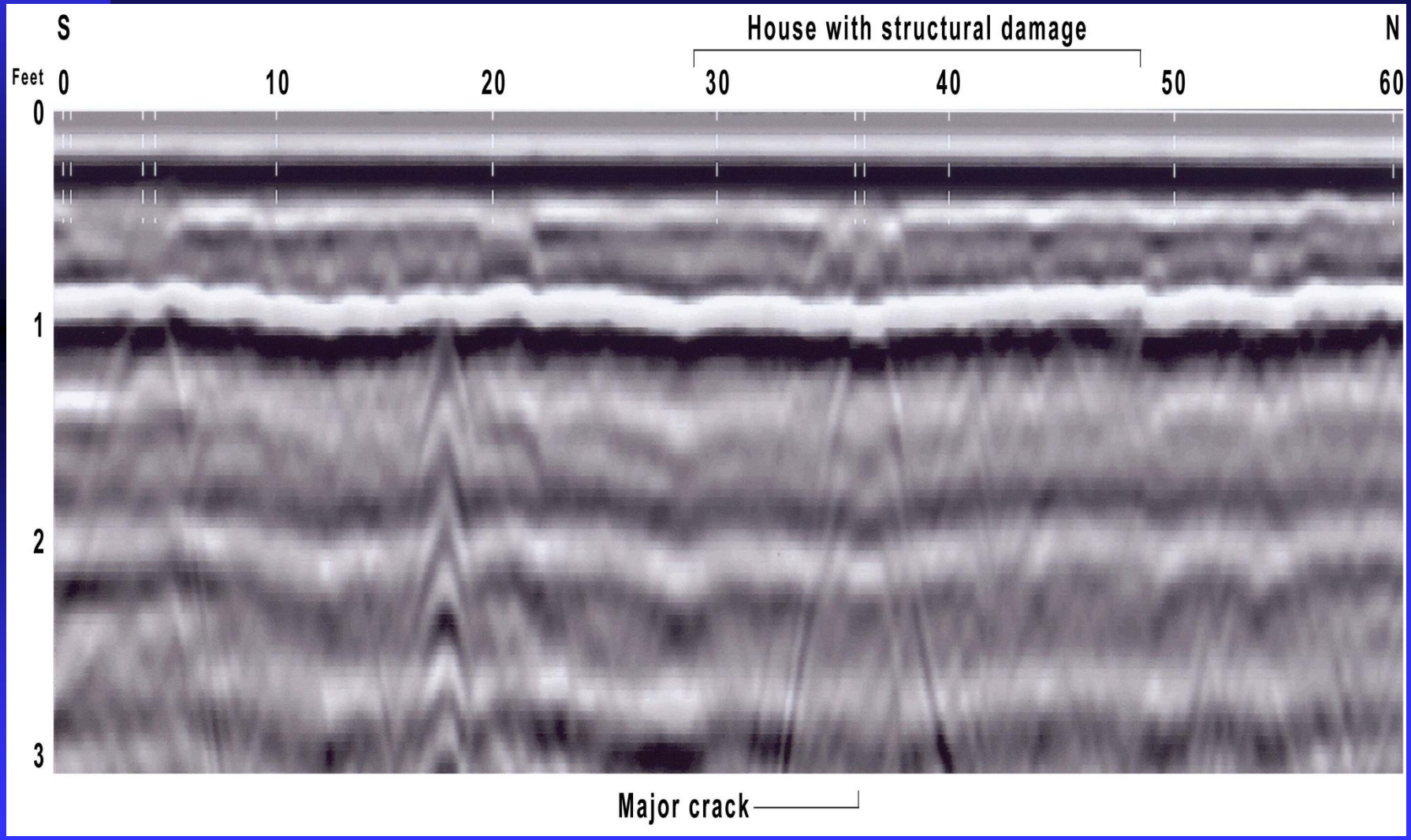


A Tool for Shallow Fault Investigation

GPR Profile 5: Hazard Street

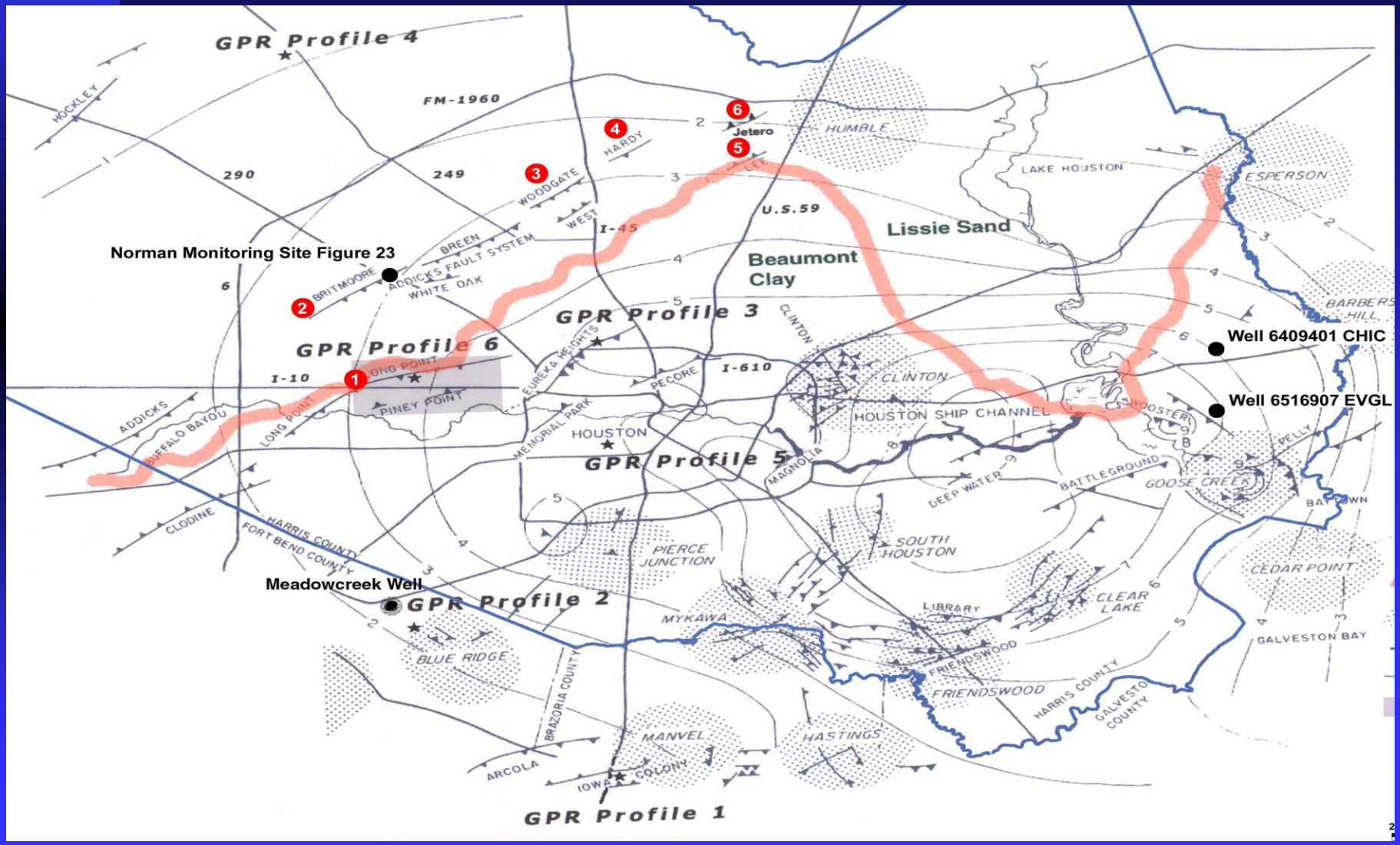
A Tool for Shallow Fault Investigation

GPR Profile 5: Hazard Street



A Tool for Shallow Fault Investigation

GPR Profile 6: Long Point



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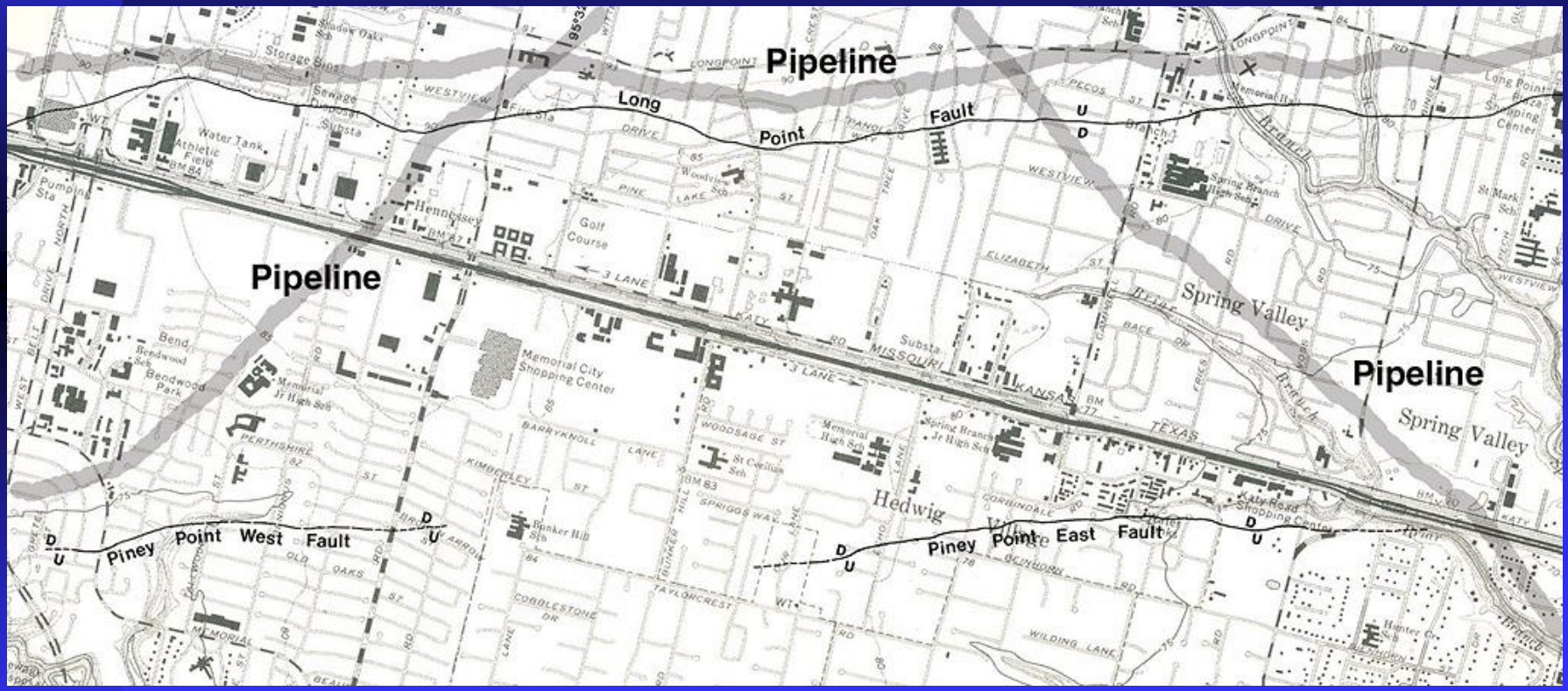
GPR Profile 6: Long Point



A Tool for Shallow Fault Investigation

GPR Profile 6: Long Point

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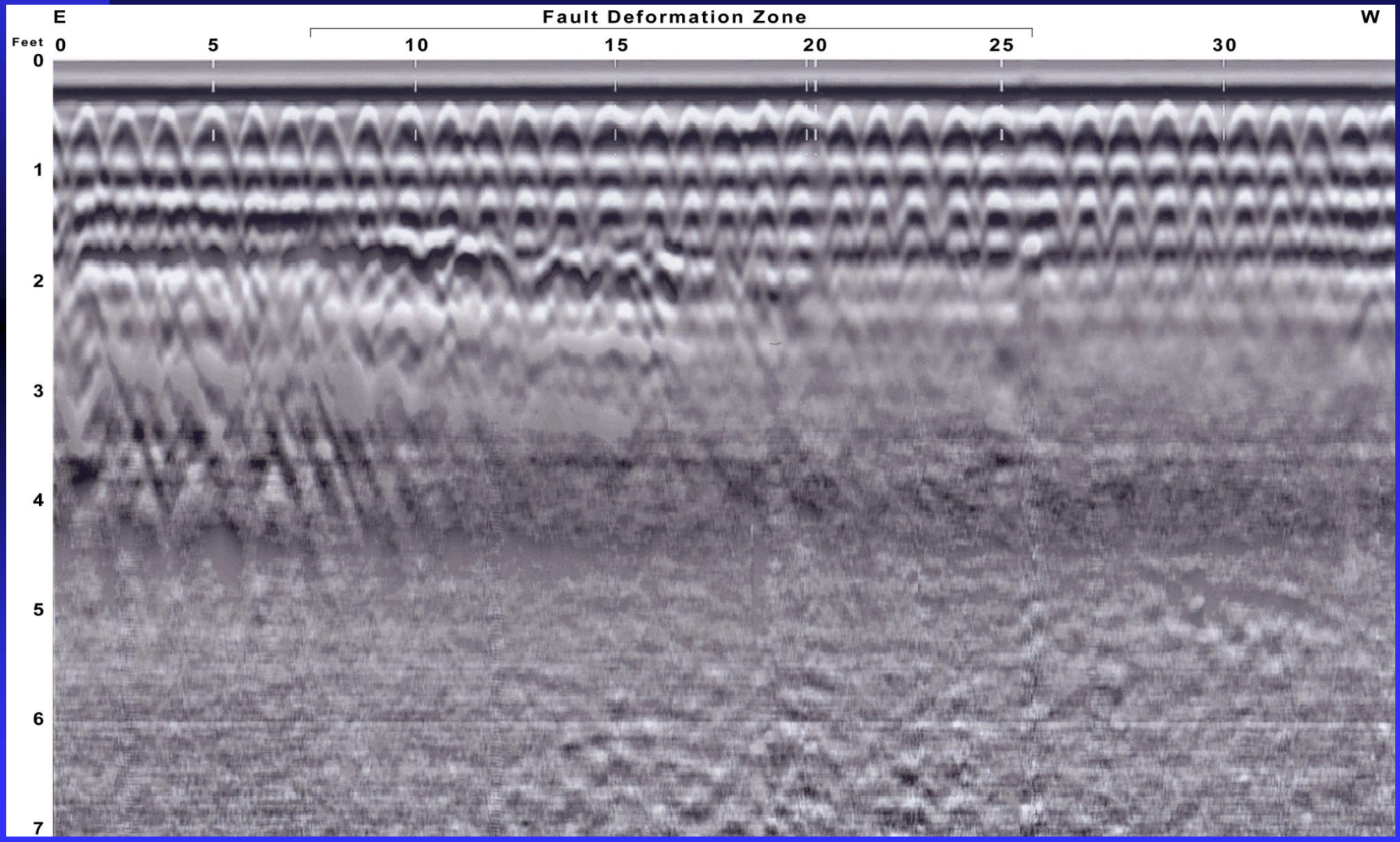
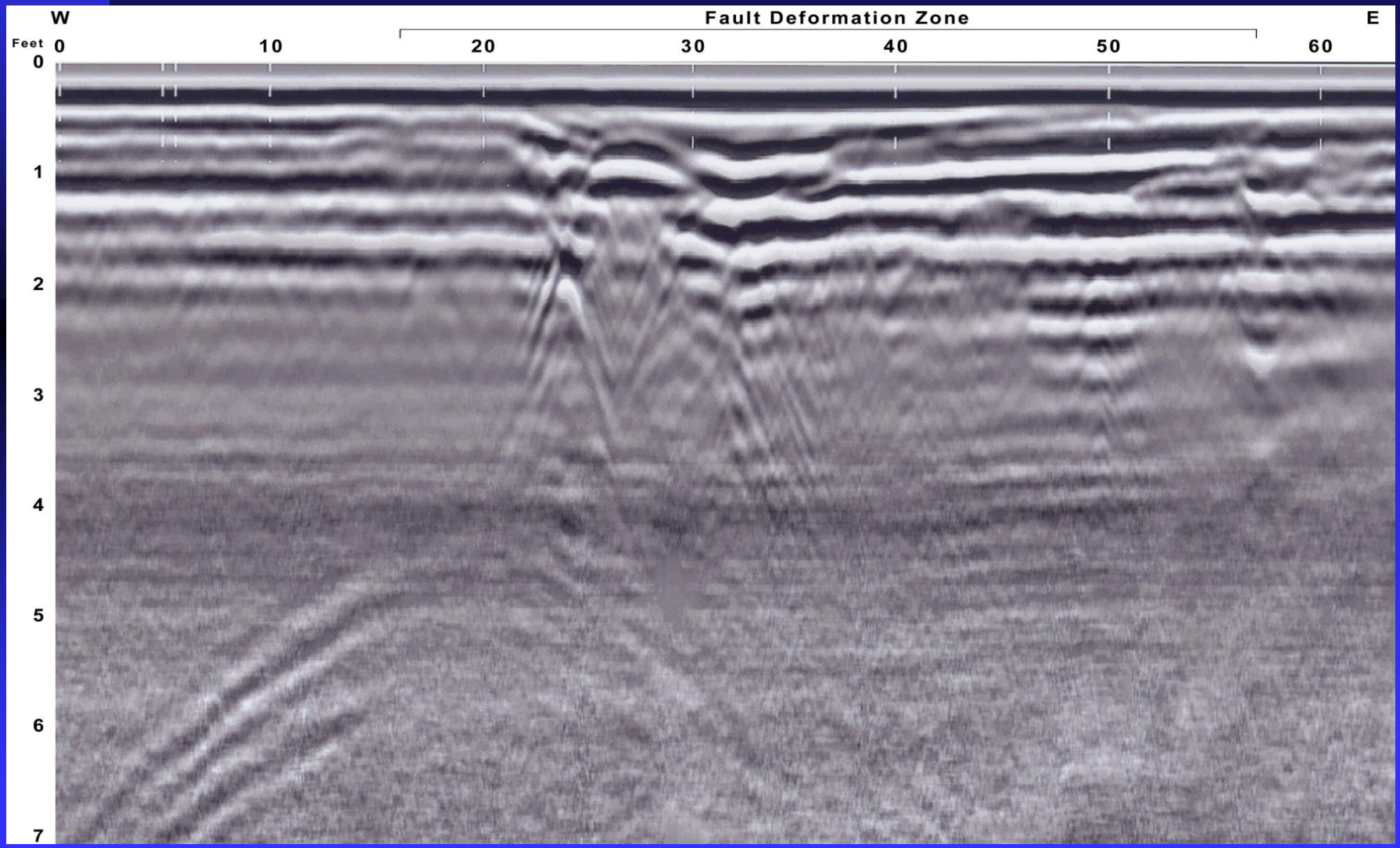


A Tool for Shallow Fault Investigation

EGA

GPR Profile 6: Long Point



Conclusions & Recommendations

1) Field research is needed to determine the presence and impact of growth faults in the urban and suburban areas of Houston, Texas & environs.

2) U.S.G.S. should be tasked to lead the research & to resume the systematic mapping of growth faults in the area.

3) A GeoHazard Rating Scale needs to be developed, defined and implemented by U.S.G.S.

Conclusions & Recommendations

4) Fault maps should become part of county flood plain maps.

5) U.S.G.S. research could guide & support geoscience graduate work within universities.

6) GPR is an effective & inexpensive tool to locate growth faults that cross streets, highways & other areas covered by an umbrella of pavement in the Houston, Texas area.

Report Availability

The interum report on which this presentation was based will be available on the IET Web site. For access to this report, please send us an e-mail requesting the link to:

mdc@mdcampbell.com

The comprehensive bibliography generated by this research is available at:

http://www.ela-iet.com/sponsoredresearch.htm