INISEISCEM Resource

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Sent: Saturday, September 04, 2010 2:17 PM
To: INIS_EIS Resource
Subject: DocketID NRC-2010-0143
Attachments: usgs.jpg; hazards.gif; takePride.jpg; usagov.jpg; logo2.jpg; header2.jpg; menu_history.gif; menu_Project.gif; menu_FAQs.gif; menu_home.gif; menu_background.gif; menu_population.gif; menu_diversity.gif; menu_mesa_history.gif; menu_regional_water.gif; menu_ogallala.gif; menu_fast_facts.gif; menu_resources.gif; menu_news_releases.gif; menu_contacts.gif; improve.jpg; header-ogallala.jpg; ogallala.gif; aquifer001.gif; image001.jpg; UTIG PDF.pdf

The federal government thru its (nrc,epa, and doe) employees have been made aware of these earthquake risks in the lea county NM area ; and by their actions chose to ignore them. In my opinion ;by ignoring 2 different government studies on earthquakes, The NRC;EPA;DOE and their employees have done their jobs in less than good faith when locating nuclear facilities and should agree to waive their liability immunity thru the Federal Tort Claims act and be fully liable for any damages, pollution to the water table and loss of livelihood and health to the citizens of Lea county by any future earthquakes that may occur.
I believe any private citizen charged with picking safe nuclear sites and presented with very simple criteria would have passed up lea county for an area with no seismic history and no aquifers under a nuclear site,,

I believe for federal employees to ignore the earthquake history of the area and to allow nuclear facilities over aquifers here is highly irresponsible

Phillip Barr
Hobbs; NM

attached earthquake study done for the state of Texas
PLUS the USGS study below
Tboone pickens map from mesa water.
aquifer map from the Red River Authority of Texas from 2005.

http://earthquake.usgs.gov/earthquakes/states/texas/hazards.php

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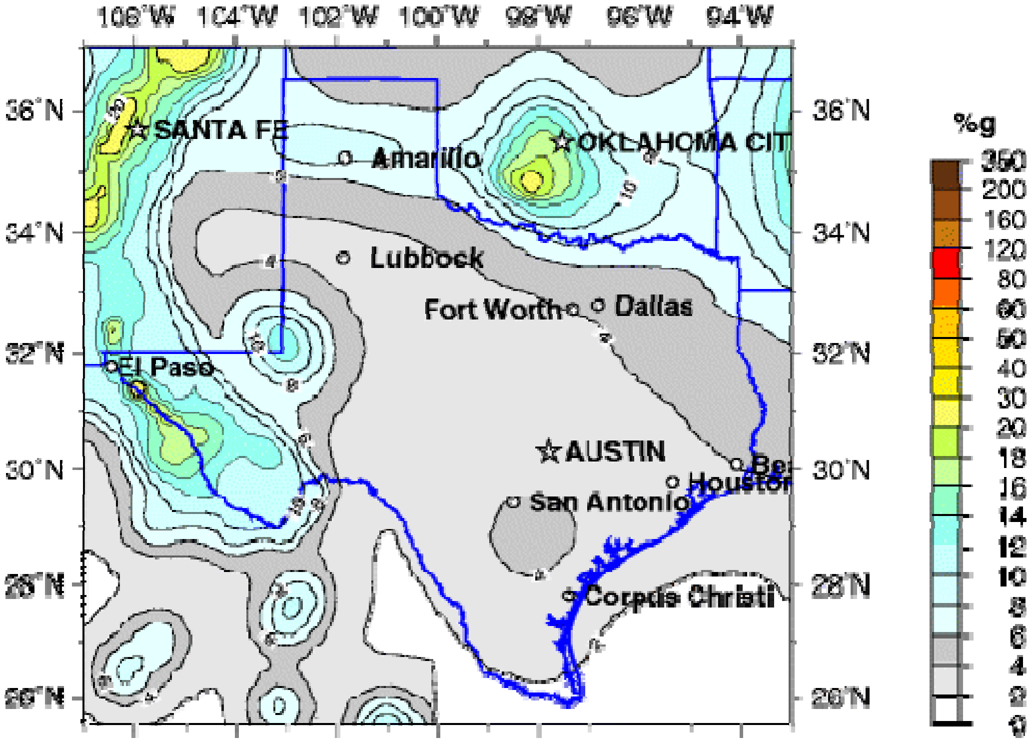
Texas

Seismic Hazard Map



Peak Acceleration (%g) with 2% Probability of Exceedance in 50 Years
site: NEHRP B-C boundary
National Seismic Hazard Mapping Project (2008)

[USGS National Seismic Hazard Maps]

- **Past**
  - Past 8-30 days
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  - About Earthquake Maps
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http://www.mesawater.com/ogallala.asp

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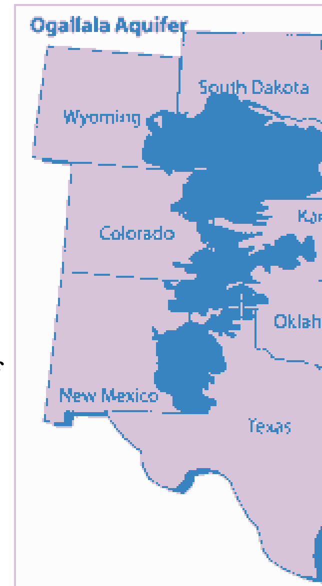
MESA WATER INC.

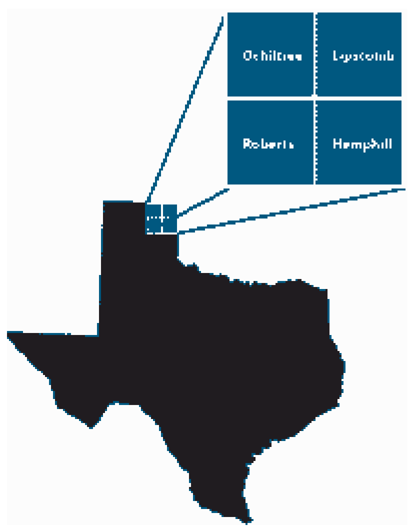
THE OGALLALA AQUIFER

THE OGALLALA AQUIFER

The Ogallala Aquifer is the largest aquifer in North America, extending beneath 174,000 square miles across eight states with more than three billion acre-feet of water.



Beneath the four-county area of Roberts, Hemphill, Lipscomb and Ochiltree, there are approximately 81 million acre-feet of high-quality, terrorist-resistant drought-proof water, with annual recharge estimated at 80,000 acre-feet. Only a very small percentage is used for irrigation because the topography of rolling hills, mesas and canyons is unsuitable for farming. Of 2.5 million acres in these counties, only 4% (about 100,000 acres) is irrigated.



Most of this water can be described as "surplus" because it's not needed in the Panhanc either for agriculture or municipal use.

It is also "stranded" because without production facilities and a delivery infrastructure to other p the state there is no market for it.

The only possible market for this water is sellin areas of the state that need it most, consistent w Texas legislative policy set with Senate Bill On

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Mesa Water is one of the various businesses owned by Mr. Pickens. He is the ch and CEO of BP Capital, which operates energy focused commodity and equity f He is also the largest shareholder in Clean Energy, the largest provider of vehicu natural gas (CNG and LNG) in North America with a broad customer base in th refuse, transit, shuttle, taxi, police, intrastate and interstate trucking, airport and municipal fleet markets.

and one from the rra from 05

http://www.rra.dst.txus/gw/Ogallala_1.cfm

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The Ogallala Aquifer

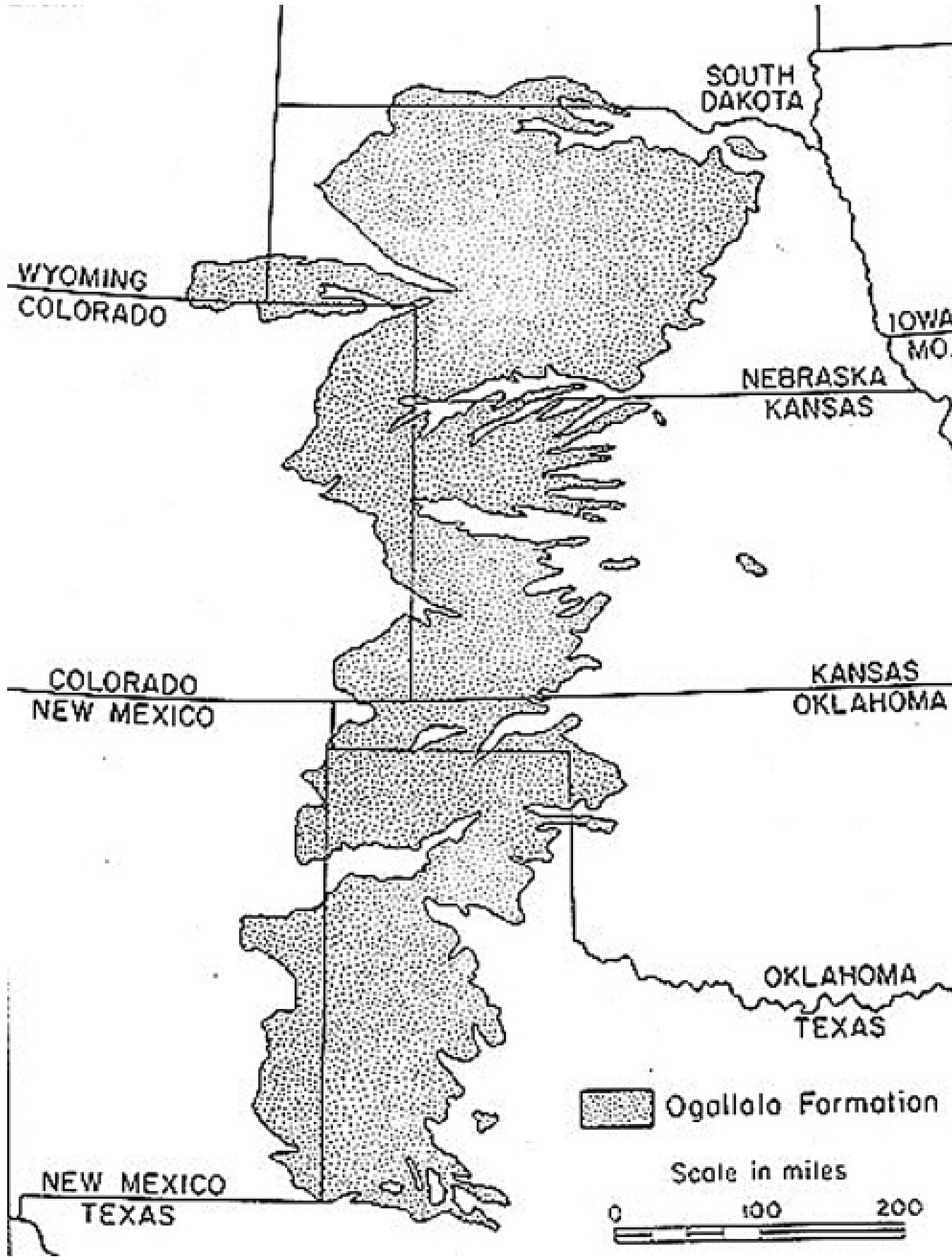

Image by [Texas Tech University]()

The Ogallala aquifer is a huge underground reservoir created millions of ye through geologic action. The underground water supply is west of the Mis River and east of the Rocky Mountains. It includes the following states: South Nebraska, Colorado, Wyoming, Kansas, Oklahoma, Texas, and New Mexi reservoir covers a total area of 800 miles north to south and 400 miles east This region is a part of the Great Plains that is referred to as the [High Plains]().

In order to assess the current problems facing the Ogallala aquifer it w helpful to know a little about its history. The aquifer developed over of years through erosion of the Rocky Mountains depositing ro sediment at the base of the mountain range. Stream beds at the base mountain range were filled and forced the rivers to take on new dir across the nearby countryside. The debris that was left behind by the s

formed the High Plains. This debris was porous and permeable to wat
new landscape formed a "trough" that holds water to depths of 500 fee

The biggest reason for concern is the fact that the aquifer has been
from almost all of its natural recharging sources. The Rocky Mountain
not supplied the aquifer for over a thousand years. The climate of th
Plains today is classified as a semi-arid region receiving 15"-20" of ra
year. When it does rain the evaporation rate is very high due to the
and high winds. Many of the rivers including the Platte, Republican, Ca
and Arkansas actually drain the aquifer because they have water tables
that of the aquifer. Even if a river does act as a source, it only does so
is able to flow. Another reason that rain water is not effective is that ca
found just under the soil surface in many areas. Caliche is a lime-like m
with a very low porosity that prevents infiltration. Playa lakes are also
on the Ogallala aquifer. These lakes are simply depressions in the High
that collect water but do not contribute to infiltration greatly due t
evaporation rates. For these reasons the High Plains were a lifeless
region until the early to mid 1900s.

The problem facing The Ogallala aquifer today is not knowing how lo
water supply will last. The first recorded use of the aquifer for irr
purposes was a hand dug well in 1911. Many of the first wells we
primarily to meet the needs of towns that were forming on the High
These wells were restricted to 50 feet or less. Windmills were the p
mechanism used in drawing water. Through technological advances a
invention of the "horizontal centrifugal" pump, wells were being
depths of 200 feet or more. The newer pumps allowed a flow rate o
gallons per minute (gpm) compared to only a few gpm generated
windmills. Wells were being installed at a rate of approximately 80 per
the 1950s. During this time Colorado became concerned about the fu
the aquifer. The Colorado legislature passed the Colorado Water Manag
Act in 1965. The act established Designated Groundwater
Groundwater Management Districts, and bases for controlling well
Realizing that this act would put restrictions on the number of
permitted, those farmers who had put off drilling wells went ahead w
installations before they could be denied. This surge caused 471 wells
installed in 1967. Situations such as these caused a great deal of strain
aquifer, and researchers today are trying to find ways to help and co
the aquifer's water supply.

A method referred to as "irrigation scheduling" was devised as a way t
better use of the water supply. By monitoring soil moisture and
rainfall along with other important weather conditions, farmers can app
calculated amounts of water to their crops. The key is to make sure the
have adequate water during critical times and short on water at less
times during the growth cycle. Crops with lower water requirement
also been introduced. Even if this method is applied perfectly it wou
eliminate the depletion of water from the aquifer.

Another method is to quit irrigating certain stretches of land. This
greater impact on reducing the water removal rate, but it is unpopul
the farmers who have money invested. Governmental agencies do no
the authority to remove land from irrigation, but due to lower water
the cost of irrigation is rising and at the same time causing land to be re

The truth of the matter is that if the High Plains are to continue to be
agricultural importance new water sources must be found. Potential

supplies could be the collection and storage of natural rainfall before off or evaporates, increasing rainfall through seeding clouds (still researched), and most importantly new sources of water will have to from outside the High Plains region.

Credit : http://www.eos.ncsu.edu/bae/courses/bae472/perspectives/1996/arblanl

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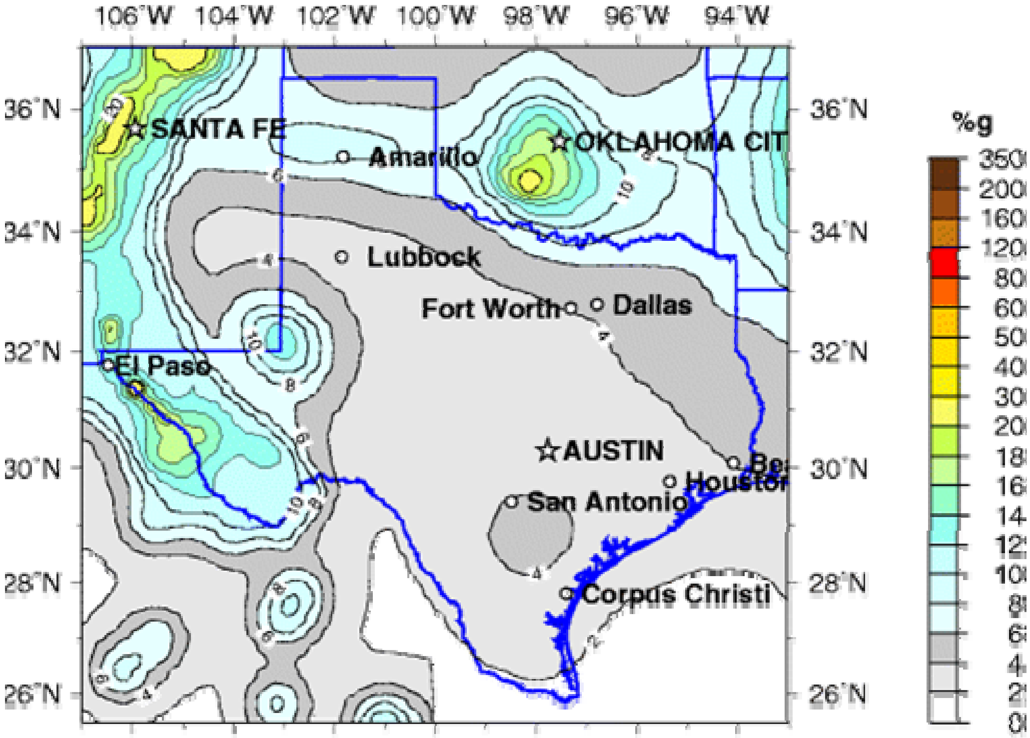

Peak Acceleration (%g) with 2% Probability of Exceedance in 50 Years
site: NEHRP B-C boundary
National Seismic Hazard Mapping Project (2008)

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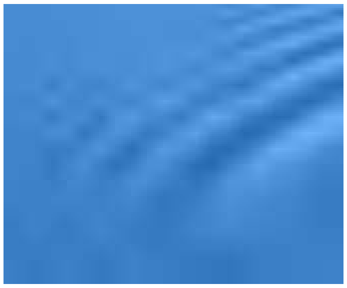

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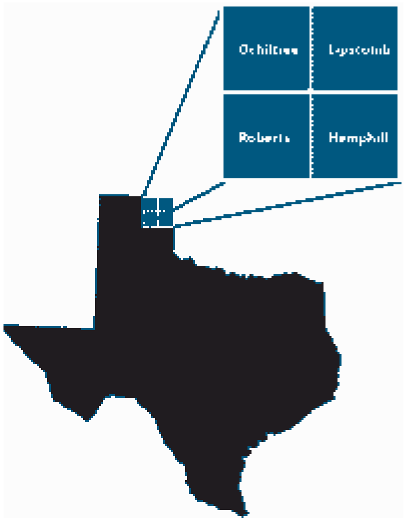
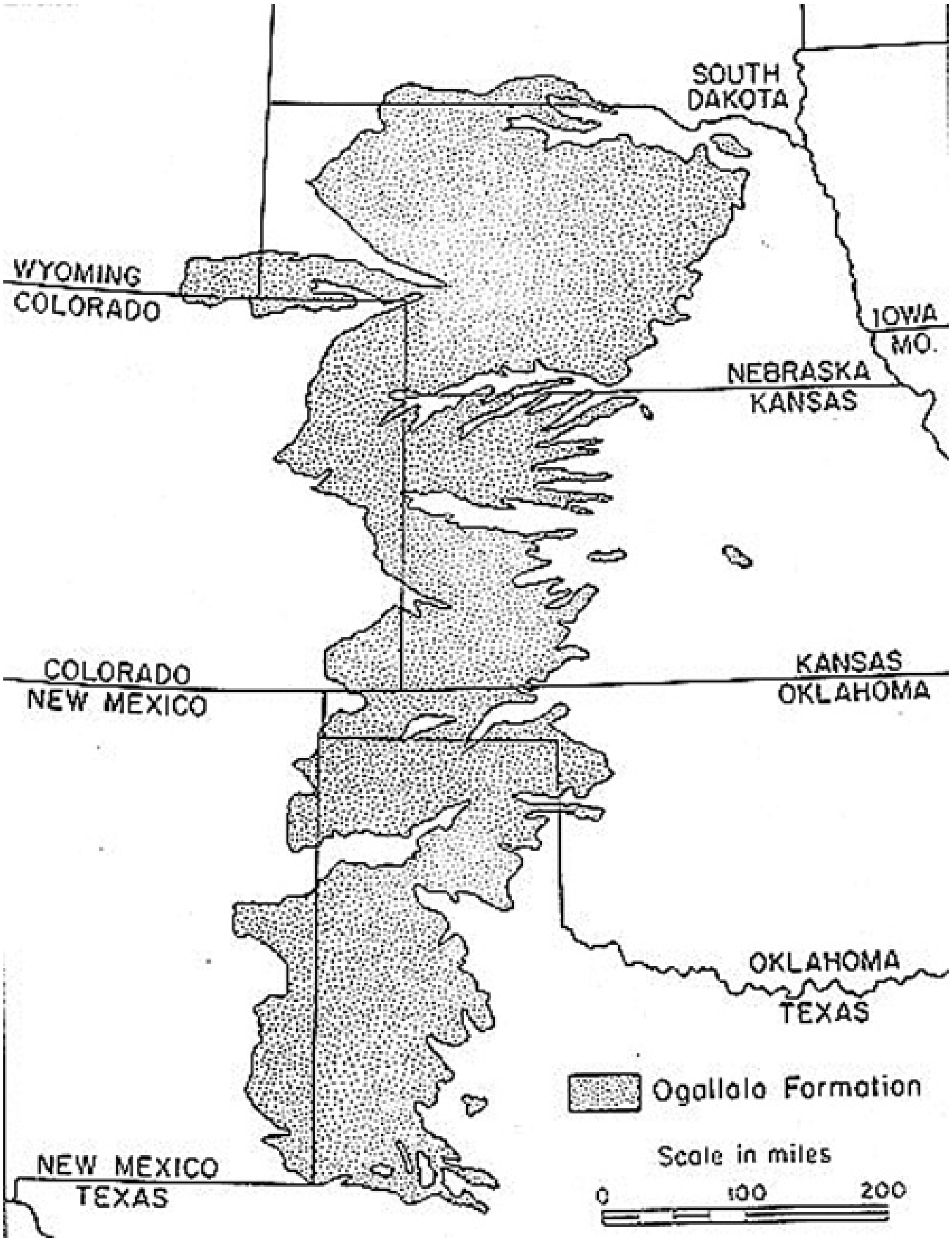
South Dakota
Colorado
Kansas
Oklahoma
New Mexico
Texas


Ochiltree
Lipscomb
Roberts
Hemphill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DAKOTA
WYOMING
COLORADO
IOWA
MO.
NEBRASKA
KANSAS
COLORADO
NEW MEXICO
KANSAS
OKLAHOMA
OKLAHOMA
TEXAS
Ogallala Formation
Scale in miles
0
100
200
NEW MEXICO
TEXAS

EARTHQUAKE SEISMOLOGY

EARTHQUAKES

Chapter 12 of, *State of Texas Hazards Analysis*, by the Governor's Division of Emergency Management, Department of Public Safety, Austin, Texas, 1998.

Introduction: Earthquakes in Texas

An earthquake is a motion or trembling that occurs when there is a sudden breaking or shifting of rock material beneath the earth's surface. This breaking or shifting produces elastic waves which travel at the speed of sound in rock. These waves may be felt or produce damage far away from the epicenter-the point on the earth's surface above where the breaking or shifting actually occurred.

For Texans, three essential facts about earthquakes are important to remember. First, earthquakes do occur in Texas (see Figure 12A). Within the twentieth century there have been more than 100 earthquakes large enough to be felt; their epicenters occur in 40 of Texas's 257 counties. Four of these earthquakes have had magnitudes between 5 and 6, making them large enough to be felt over a wide area and produce significant damage near their epicenters.

Second, in four regions within Texas there have been historical earthquakes which indicate potential earthquake hazard (Figure 12B). Two regions, near El Paso and in the Panhandle, should expect earthquakes with magnitudes of about 5.5-6.0 to occur every 50-100 years, and even larger earthquakes are possible. In northeastern Texas the greatest hazard is from very large earthquakes (magnitude 7 or above) which might occur outside of Texas, particularly in Oklahoma or Missouri-Tennessee. In south-central Texas the hazard is generally low, but residents should be aware that small earthquakes can occur there, including some which are triggered by oil or gas production. Elsewhere in Texas, earthquakes are exceedingly rare. However, the hazard level is not zero anywhere in Texas; small earthquakes are possible almost anywhere, and all regions face possible ill effects from very large, distant earthquakes

Third, while Texas does face some earthquake hazard, this hazard is very small in comparison to that in many other states, including California, Missouri, Montana, South Carolina, and Washington (Figure 12C). In most parts of Texas earthquake hazard is also small compared to the hazard attributable from other natural phenomena, such as hurricanes, tornadoes, and floods. Thus there is no need for Texas to enact sweeping changes in construction practices, or take other drastic measures to mitigate earthquake hazard.

However, Texans need to begin learning about earthquakes. Over the past 70 years Texas has changed from a sparsely populated state with an economy dominated by agriculture to an economically diverse state with various large, technical manufacturing industries centered in a few densely populated urban regions. For reasons of safety, economy, and (in some cases) law, Texans need to consider earthquake hazard when designing or siting various structures which are essential for providing medical or emergency management services, which house sensitive manufacturing processes, or which store hazardous wastes.

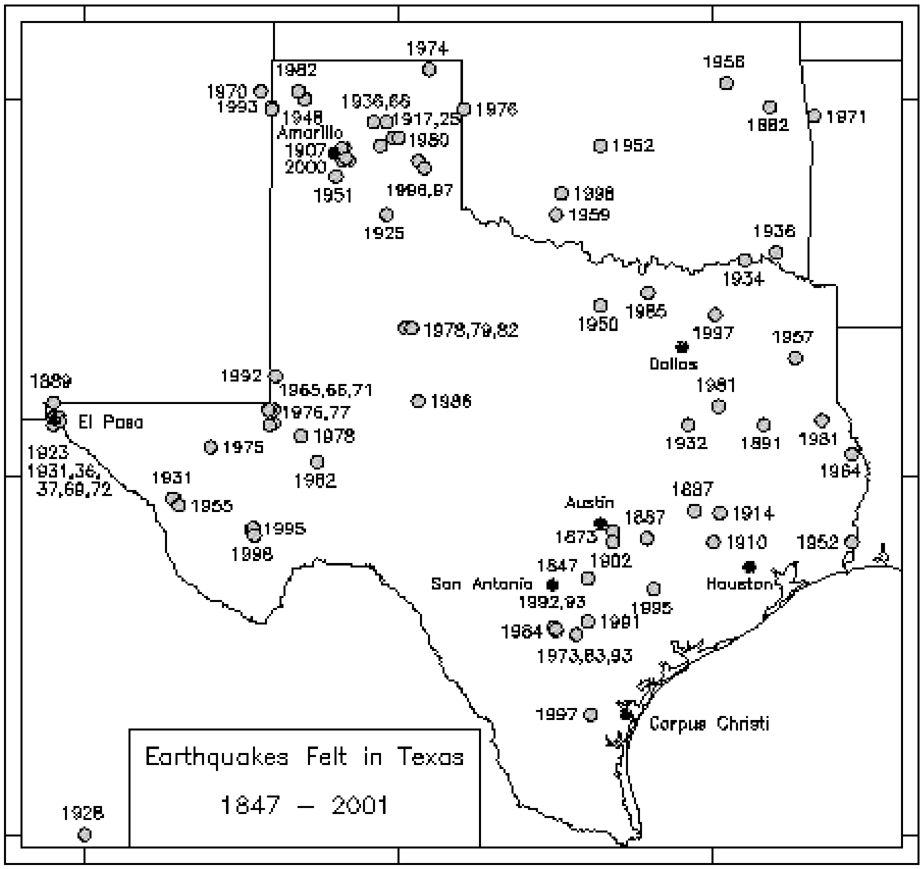


Figure 12A Locations of earthquakes and earthquake sequences that have occurred in Texas, or that were felt by Texas residents. Numbers are the year of occurrence. (See a larger version of this figure.)

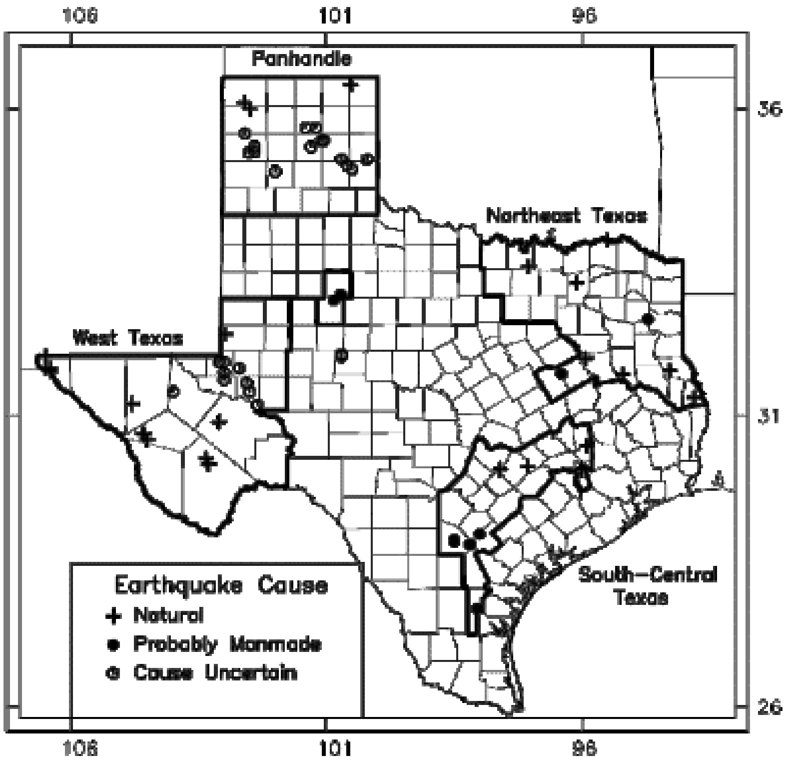


Figure 12B Map indicating probable causes of eartthquakes occurring in Texas. Solid lines show the four regions of Texas where historical earthquake activity indicates there is earthquake hazard. Light lines are county boundaries.

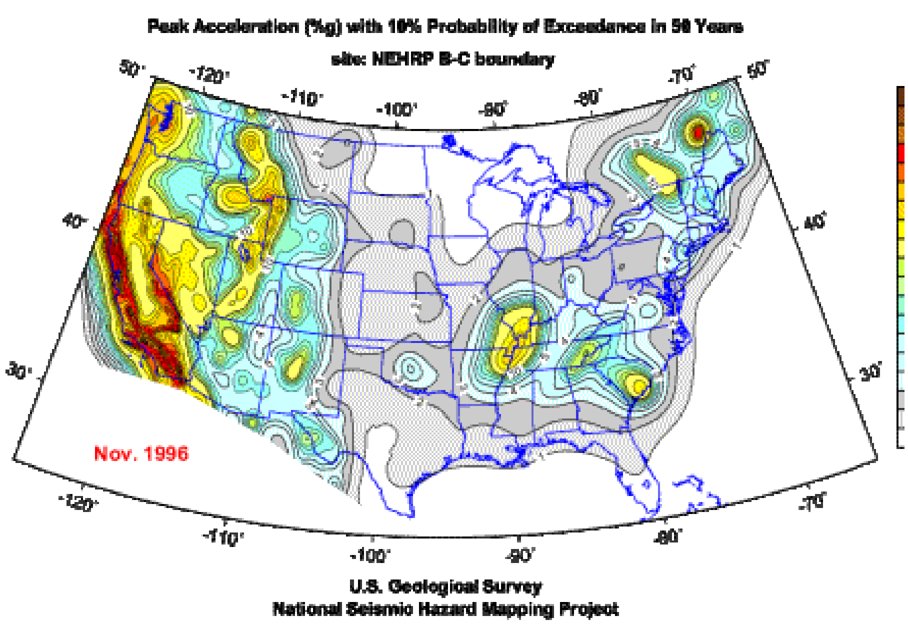


Figure 12C Earthquake hazard map for the continental United States as prepared by the U. S. Geological Survey. In the central and eastern U. S., the regions expecting the highest accelerations all correspond to the sites of known historical earthquakes. These include: Montana, 1959; West Texas, 1931; Oklahoma, 1952; Missouri-Tennessee, 1811-1812; and South Carolina, 1886. In many places such as Texas, the absence of detailed historical information means that earthquake hazard may be higher than indicated in this figure.

Earthquake Magnitude, Intensity, and Damage

The nature and geographical extent of earthquake hazard depends strongly on the quake's size or magnitude. Because earthquakes are rare, people are often confused about how risk depends on magnitude. Imagine that you were about to return from a vacation, and someone told you that animals had infested your property. Naturally, you would ask whether these animal were mice, armadillos, or cattle, because each might cause a different kind and amount of damage. Similarly, if your neighborhood has an earthquake, the kind and amount of damage depends on the earthquake's size. A quake with magnitude 3 may do no more than startle people and rattle dishes within a one-square-mile region. However, a magnitude 7 would be felt by people over the entire state of Texas, and could do significant damage to buildings, bridges, and dams over a considerable region.

Scientists determine an earthquake's magnitude by measuring the amplitude of ground motion as recorded on a seismograph, and then correcting the measurement to account for the effects of distance from the epicenter. The magnitude scale is a 'power of ten' scale; thus if a magnitude 3.8 caused ground motion of 1/10 inch at a particular location, a 4.8 at the same epicenter would cause ground motion of 1 inch, and a 5.8 would cause ground motion of 10 inches. This means that magnitude 3 and magnitude 7 earthquakes are enormously different with respect to their ground motion and the size of and slip on the faults that produce them.

Scientists use the Modified Mercalli intensity (MMI) to describe how strong the motion is at a particular location. The MMI is a number between one and twelve, expressed as a Roman numeral such as MMI IV or MMI IX so that the number won't be confused with magnitude (see Figures 12D and 12E). While each earthquake has only one magnitude, it has many different intensities, since earthquake damage becomes less severe as one moves away from the epicenter. Usually, most of the damage done by an earthquake occurs in the regions nearest the epicenter which have the highest intensities. While intensity depends strongly on factors such as soil properties, in most cases earthquakes with larger magnitudes have higher maximum intensities (see Figure 12F).

Because damaging earthquakes are rare in Texas, it is tempting to ignore them. A more responsible approach is to be selective about mitigation efforts, focusing attention on structures or areas where potential hazard is greatest. The argument for earthquake mitigation is analogous to the argument for having seatbelts and airbags in automobiles-although any one driver is unlikely to have an accident in any given day or year, over a person's lifetime there is a significant chance of having a serious accident. Even in West Texas and the Panhandle, at any particular place damaging earthquakes probably occur only once per century, or less. However, with a little prior planning it is possible to ensure that their damage is minimal.

Earthquake felt intensity - the Modified Mercalli Intensity Scale

MMI	What people feel, or what damage occurs.
I	Not felt except by a very few people under special conditions. Detected mostly by instruments.
II.	Felt by a few people, especially those on the upper floors of buildings. Suspended objects may swing.
III.	Felt noticeably indoors. Standing automobiles may rock slightly.
IV.	Felt by many people indoors, by a few outdoors. At night, some people are awakened. Dishes, windows, and doors rattle.
V.	Felt by nearly everyone. Many people are awakened. Some dishes and windows are broken. Unstable objects are overturned.
VI.	Felt by everyone. Many people become frightened and run outdoors. Some heavy furniture is moved. Some plaster falls.
VII.	Most people are alarmed and run outside. Damage is negligible in buildings of good construction, considerable in buildings of poor construction.
VIII.	Damage is slight in specially designed structures, considerable in ordinary buildings, great in poorly built structures. Heavy furniture is overturned.
IX.	Damage is considerable in specially designed buildings. Buildings shift from their foundations and partly collapse. Underground pipes are broken.
X.	Some well-built wooden structures are destroyed. Most masonry structures are destroyed. The ground is badly cracked. Considerable landslides occur on steep slopes.

XI. Few, if any, masonry structures remain standing. Rails are bent. Broad fissures appear in the ground.

XII. Virtually total destruction. Waves are seen on the ground surface. Objects are thrown into the air.

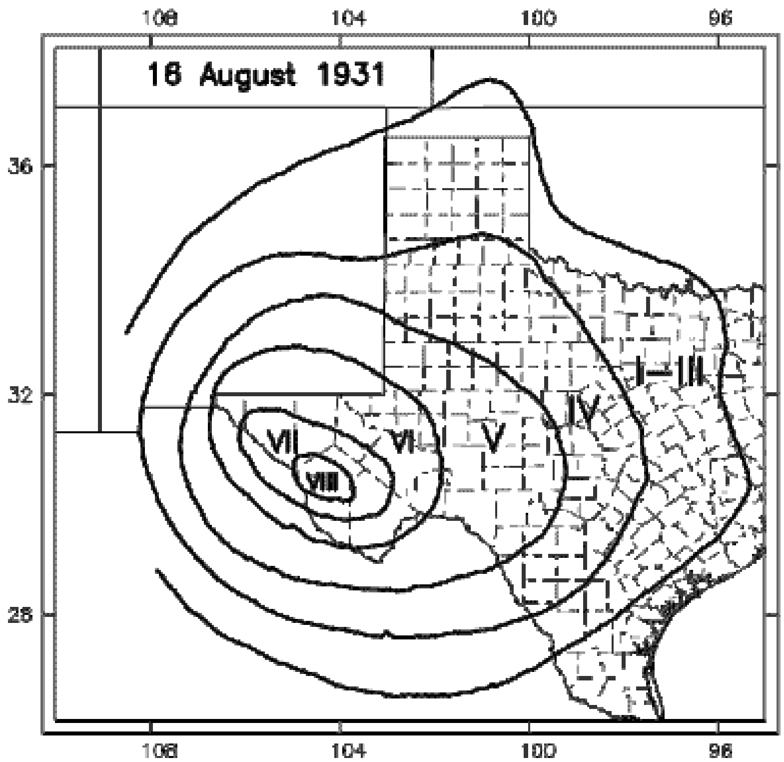


Figure 12D Felt area and Modified Mercalli Intensities experienced by Texans from the magnitude 6.0 Valentine, Texas, earthquake of 16 August, 1931. Dashed lines are county boundaries; small square in south-central Texas indicates region mapped in next figure.

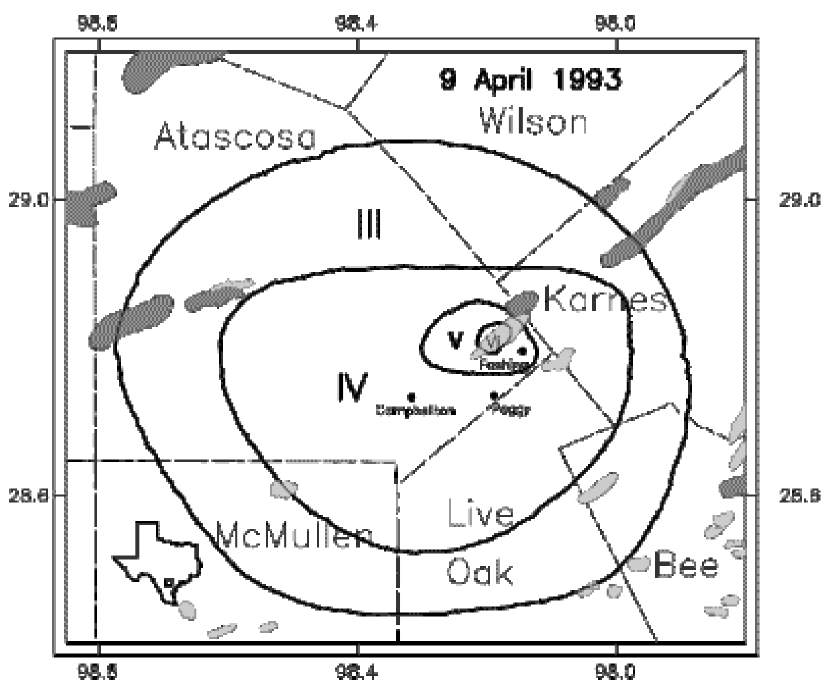


Figure 12E: Felt area and Modified Mercallli Intensities experienced by Texans from the magnitude 4.3 Fashing, Texas, earthquake of 9 April 1993. Dashed lines are county boundaries; shaded regions indicate major oil (dark shading) and gas (light shading) fields. Note how this small earthquake is felt over a much smaller area than the 1931 magnitude 6.0 Valentine earthquake.

Figure 12F

Relationship Between Earthquake Magnitude and Maximum Observed Modified Mercalli Intensity (MMI).

Magnitude	Maximum MMI
3.0	III-IV
3.5	IV-V
4.0	V-VI
4.5	V-VI
5.0	VI
5.5	VI-VII
6.0	VIII

Note that the table values are only approximate, as there is great variation for individual Texas earthquakes.

Approximate Relationship Between Earthquake's Magnitude and the Diameter of and Slip Along the Fault that Produces It.

Magnitude	Fault Diameter	Fault Slip
8	45 miles	20 feet
7	15 miles	7 feet
6	4.5 miles	2 feet
5	1.5 miles	8 inches
4	800 yards	2.5 inches
3	800 feet	1 inch
2	240 feet	.25 inch
1	80 feet	.1 inch

The Cause of Earthquakes

Just as changes in temperature or moisture content can produce cracks in the ground, various ongoing natural processes produce stresses that occasionally cause the underlying rock material to break or shift in an earthquake. Rock material is most likely to break where it is highly stressed or where it has broken before, as along a preexisting fault. Earthquakes are most common along very large, well-developed faults (such as the San Andreas Fault in California) which divide the Earth into huge, country-sized, relatively stable regions, called tectonic plates. The majority of the world's earthquakes, such as most reported in Mexico, California, Alaska, and Japan, occur along plate boundaries.

However, not all earthquakes occur at plate boundaries; in regions like Texas many also occur far away from plate boundary faults. Sometimes these 'plate interior' earthquakes are quite large; for example, in 1811-1812 three earthquakes with magnitude above 8 occurred near the Missouri-Tennessee boundary (see Figure 12G). These quakes were as large as any historic earthquakes that have occurred in California, or anywhere else in the U. S. outside of Alaska. While Texans haven't experienced such large quakes in historic times, smaller quakes do occur naturally along faults in several regions of Texas.

While all earthquakes occur on faults, not all faults have earthquakes. A fault is simply a fracture in rock material accompanied by displacement along the two sides of the fracture. If the displacement occurs slowly enough, no earthquake waves are generated. And, often the displacement may have occurred millions of years ago, so that the fault remains but there is no present earthquake threat. Finally, many faults go undiscovered because they lie far beneath the surface, covered by soil. It is no accident that fault maps show the most faults in regions where bedrock is exposed at the surface (see Figure 12H).

Finally, some human activities are known to cause or trigger earthquakes. These include the injection of fluids into the earth for waste disposal or petroleum production, and the filling of deep lakes or reservoirs. In Texas, there have been earthquakes associated with oil and gas production at a number of fields. These include the Wortham field in Freestone County, the East Texas and Longview fields in Upshur and Gregg Counties, the Cogdell field in Scurry and Kent Counties, and the Fashing and Jourdanton fields in Atascosa County. None of these quakes have been very damaging or very large; the largest had magnitude 4.7. And, usually petroleum production does not cause earthquakes; in Texas there are more than two thousand oil and gas fields but only about five seem to have generated earthquakes. Nevertheless, wherever there is considerable petroleum production, and especially when there is fluid injection to enhance recovery of to dispose of waste, people should be aware that induced earthquakes are possible.

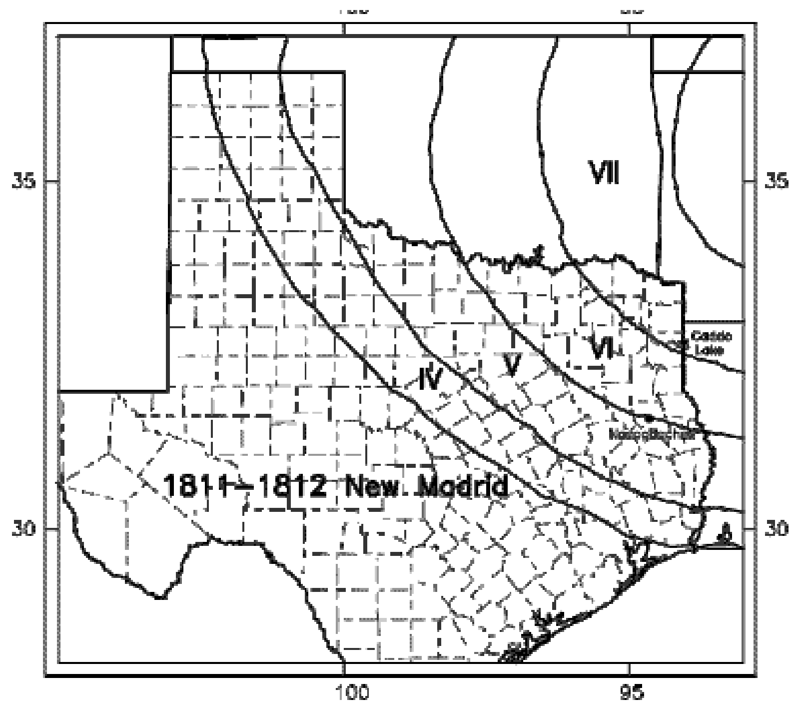


Figure 12G Estimated felt area and Modified Mercalli Intensities for the magnitude 8 Missouri-Tennessee earthquakes of 1811-1812. In much of Texas there is greater earthquake hazard from rare, distant earthquakes such as these than from any quakes with epicenters within Texas.

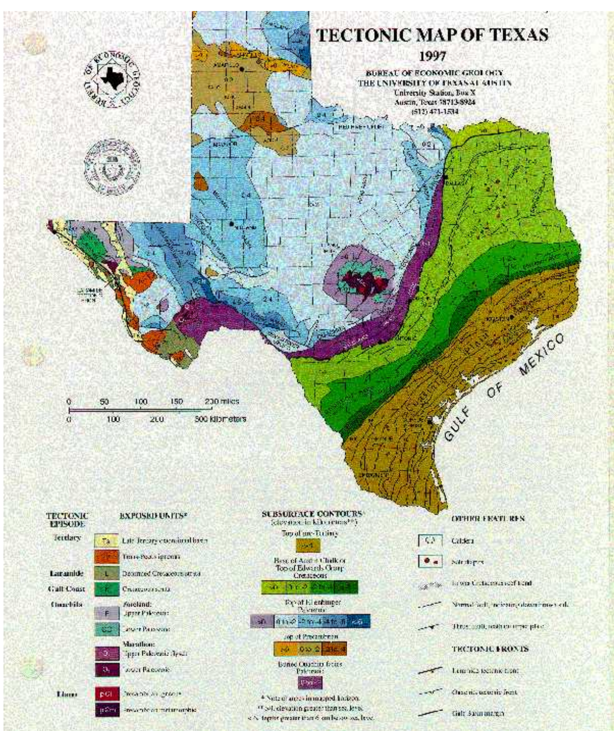


Figure 12H. (Click on image to see full-size version.)

Assessing Earthquake Hazard

In any particular region, the level of earthquake hazard depends on many different factors. These include the size, location, and frequency of earthquakes that may occur, as well as the population density, the topography, and the nature of manmade improvements. In very steep, mountainous areas earthquakes might trigger landslides, for example. And, a nuclear power plant or waste disposal site might pose more potential hazard than a feed lot. For any particular earthquake the expected intensity also depends on the type of construction and the thickness and type of soil.

Nevertheless, for any region the most important factor affecting scientific hazard estimation is the historical record of earthquake activity; regions which have had large earthquakes in the past will probably experience them again. Although hazard estimates also include information about mapped faults, in practice this information isn't very influential since many known faults are not seismically active, and since many damaging earthquakes have occurred on unmapped, unknown faults.

Thus, it is no accident that the regions of highest hazard in United States Geological Survey's (USGS) hazard analysis correspond to the locations of known, large, historical earthquakes. In the central U. S., the USGS assesses the greatest hazard in the Missouri-Tennessee area, where three earthquakes with magnitude of 8 or greater occurred in 1811 and 1812. Unfortunately, the very rarity of large earthquakes makes hazard analysis an inexact science. In the twentieth century, the largest earthquake in the Missouri-Tennessee area only had a magnitude of about 5.5. If quakes like the 1811-1812 events had occurred in Texas a few hundred years ago, would scientists know that such large and damaging earthquakes were possible here? Almost certainly not.

In Texas the regions at greatest risk are in West Texas, where earthquakes of magnitude about 6 occurred in 1931 and 1995, and in the Panhandle, where at least six earthquakes with magnitude above 4 have occurred since 1900. Clearly, such earthquakes will occur again. Unfortunately, what we cannot know is whether larger quakes--like the Missouri-Tennessee quakes of 1811-1812--might possibly occur there. Geologically, some features of the Panhandle are similar to the Missouri-Tennessee area. Fortunately, large continental quakes are extraordinarily rare (occurring less often than once per 500 years in any particular place), so for many Texans there is little reason to make special preparations for them. But, Texans should be aware that they are remotely possible.

Why is there concern about Texas earthquakes, given that historical events have done little damage? One reason is that the frequency of small and large earthquakes are related in a predictable way-a rule of thumb called the Gutenberg-Richter relation states that for every 1000 magnitude 4 earthquakes there will be approximately 100 magnitude 5 events, 10 magnitude 6 event, and one magnitude 7 event. Thus, the occurrence of two earthquakes with magnitude near 6 in the twentieth century suggests that a magnitude 7 may occur every few hundred years or so. Like many other rules of thumb, the predictions of the Gutenberg-Richter relation aren't always correct. For example, transportation experts use rules of thumb to predict the number of auto fatalities during a holiday weekend; these may be incorrect because of the influence of unpredictable factors such as weather, safety campaigns, etc. Similarly, the predictions of the Gutenberg-Richter relation may be incorrect because of factors that scientists don't understand or didn't consider. Yet, the record indicates that magnitude 6 quakes do happen in Texas, and suggests that larger earthquakes are possible. These could be especially serious if they occurred near a major population center.

Finally, there is some risk to Texans from earthquakes that may occur outside of Texas. If the 1811-1812 Missouri-Tennessee earthquakes were to occur today, in the Dallas-Fort Worth area they would probably damage some structures that weren't designed to withstand earthquakes. There is also possible hazard to Texans in the Panhandle from earthquakes which may occur in Oklahoma.

Certain earthquake-related phenomena which affect some parts of the U. S. do not pose a hazard for Texans. These include:

- Liquefaction: For large buildings constructed on certain poorly consolidated soils, strong earthquake tremors can cause the soil to 'liquefy', producing severe damage to large and apparently well-build structures. This is most common for structures built on landfill in lake or ocean regions. In Texas, the regions along the Gulf Coast where this conceivably might occur are not subject to strong earthquake tremors.
- Tsunamis: Tsunamis are tidal waves generated when undersea earthquakes displace the sea surface or when extraordinarily large landslides dump large volumes of material into the ocean. There is no historic record of any such events doing significant damage along the Gulf Coast.
- Volcanoes: Volcanic eruptions may produce ash falls over regions extending hundreds of miles from the eruption site. However, no active or dormant volcanoes occur near Texas, and Mexican volcanoes are too far away to be hazardous to Texans.

Where is the Hazard Greatest?

There is an old saying among seismologists: "Earthquakes don't kill people, buildings kill people." This is because the most serious damage caused by nearby earthquakes often comes when heavy, unreinforced structures collapse. Adobe and unreinforced masonry can be particularly dangerous, even in earthquakes with magnitudes as small as 5 or less. Ordinary wood-frame dwellings are surprisingly earthquake-resistant; in such structures the most serious damage often results from the collapse of chimneys.

In the twentieth century hundreds of man-made lakes and reservoirs have been constructed in Texas; in some cases these pose a special hazard, particularly if there are population centers downstream. Large very distant earthquakes sometimes have surprising low-frequency effects. Seismic waves from the 1964 Alaskan earthquake, with a magnitude of 9.2, caused sloshing in canals and rivers in Texas which damaged boats and docks. Earthen or earth-filled dams are of special concern since intense shaking or sloshing could cause dam failure.

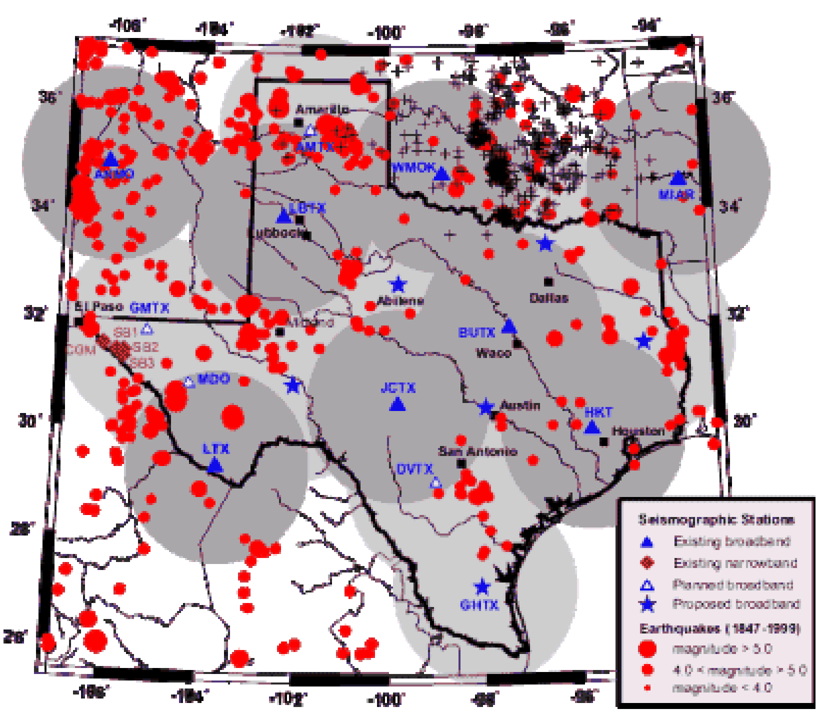
Monitoring Earthquakes as a Mitigation Strategy

It is important to remember that our knowledge of both past and present seismic activity in Texas is incomplete. Unlike states along the east and west coast, much of Texas is sparsely populated and/or was only settled about a century ago. And, even today Texas has only a few continuously recording seismograph stations (see Figure 12-I). This means that we have a much poorer knowledge of the earthquake hazard in Texas than in most other states. With the population of Texas expanding rapidly, the potential for injury to people and damage to structures increases proportionately. To be effective, attempts to assess potential risk must be based on long-term monitoring of seismic activity, so for accurate assessments we must take steps today to ensure that adequate monitoring is performed.

Over the past twenty years, there has been a revolution is the technology to monitor earthquakes. In the past, seismographs recorded on paper or film, and were designed specifically to measure earthquake waves from events of a particular size in a particular, narrow frequency band. The equipment at these 'narrowband' stations had to be selected to be optimum for measuring signals either from small nearby earthquakes (*e.g.*, magnitude 3.5 earthquakes occurring within a few hundred km) or from large distant earthquakes (*e.g.*, a magnitude 7.0 earthquake in Japan). Nowadays, so-called 'broadband' stations record digital information over a broad range of frequencies, and thus obtain information about both nearby and distant earthquakes. These broadband stations are advantageous because the data is useful both for regional hazard analysis as well for research by scientists throughout the world. For a state like Texas, a broadband network is desirable because it is useful for hazard assessment within Texas and for scientific researchers outside of Texas; over the long term this means that part of the support to run the network may come from science organizations outside of Texas.

Presently, Texas has only two modern, broadband seismograph stations, one near Houston, and one in Brewster County in West Texas (see Figure 12I). In addition, there are several narrowband stations in operation near El Paso. To properly monitor Texas earthquakes with magnitude of 3.5 and greater will require about ten additional stations. Currently various organizations within Texas-including university scientists, emergency management personnel, and people concerned with dam safety-have begun to work towards making such a network a reality; however, at present its future is still uncertain.

Figure 12I Nominal monitoring capability for magnitude 3.5 events for for existing stations (dark shading and proposed stations (light shading). Click on map to see full-size figure.



Regional Hazard Assessment

West Texas (Largest City - El Paso)

Counties Affected (22): Andrews, Brewster, Crane, Culberson, Dawson, Ector, El Paso, Gaines, Hudspeth, Jeff Davis, Kent, Loving, Martin, Midland, Pecos, Presidio, Reeves, Scurry, Terrell, Upton, Ward, Winkler.

Hazard Level: Within this region several earthquakes with magnitudes 5 to 6 will probably occur each century. Moreover, the historical earthquake record and regional geology suggest that even larger earthquakes are possible, with a probability of perhaps once per 500 years. In most of this region population density is low and earthquakes only pose a significant hazard for poorly built or very sensitive structures. However, an earthquake with magnitude of 5.5 or greater that occurred close to El Paso would cause personal injury and significant economic losses. Also, people who live, work, or plan to build in hilly or mountainous places should be aware that historical earthquakes have produced landslides in various parts of this region.

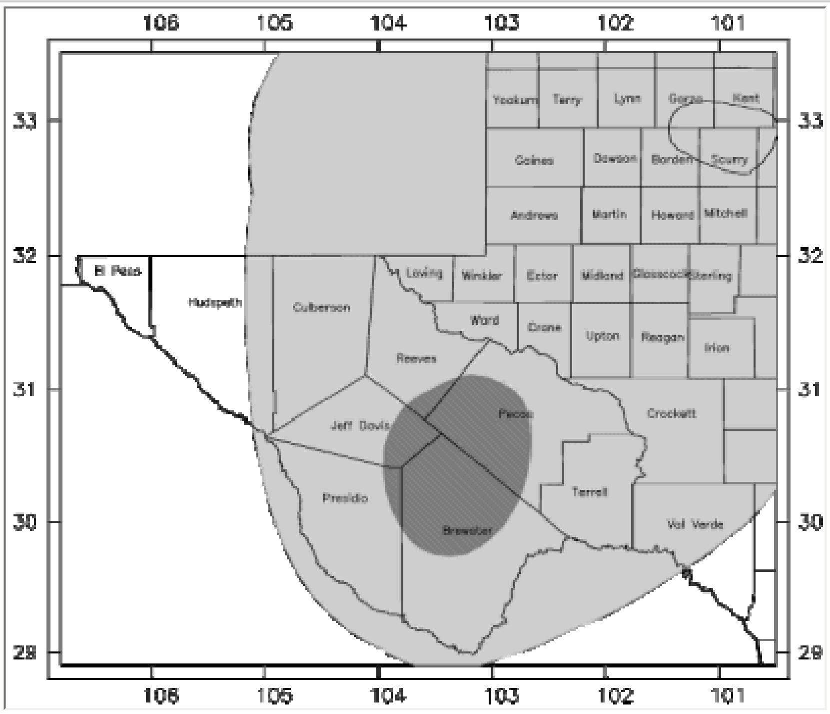
Justification: Historical earthquakes have produced Modified Mercalli Intensities of VI and higher throughout this region.

Significant Historic Earthquakes Affecting West Texas

- There have been three historic earthquakes which have each been felt over all or a significant part of West Texas.
- The first, which occurred on 16 August 1931 and was centered near Valentine, had a magnitude of 6.0. Even though many buildings in Valentine were constructed of adobe and brick and thus damaged severely, few were injured, probably because most people were sleeping outdoors because of the heat.
- The second, which occurred on 2 January 1992 along the Texas-New Mexico border near Andrews and Hobbs, had a magnitude of 4.6 (see Figure 12W-A).
- The third, which occurred on 14 April 1995 near Alpine, had a magnitude of 5.7. Both the 1931 and the 1995 earthquake produced landslides in mountainous areas. The amount of injury and damage from the 1931 and 1995 earthquakes was relatively small, mostly because of the relatively low population density in West Texas.
- In addition, earthquakes with magnitudes between 3 and 4.7 were felt by El Paso residents in 1889, 1923, 1936, 1937, 1969, and 1972. Finally, a magnitude 4.6 earthquake, probably induced by oil production, occurred in Scurry County near Snyder, Texas, in 1978.

Why is there such concern about earthquake hazard in West Texas? The occurrence of two magnitude 6 earthquakes in the twentieth century suggests that a magnitude 7 may occur every few hundred years or so. And, the record indicates that magnitude 6 quakes are likely to happen within the lifetime of ordinary citizens.

Figure 12W-A Areas in West Texas which experienced Modified Mercalli Intensities of IV or V (light gray) and VI (dark gray) during the earthquakes of 16 June 1978 (near Snyder in Scurry County - curved line indicates intensity V region for this quake), 2 January 1992 (near Andrews County - New Mexico border) or 14 April 1995 (near Alpine in Brewster County). Also, almost the entire area shown experienced intensities of VI during the earthquake of 16 August 1931.



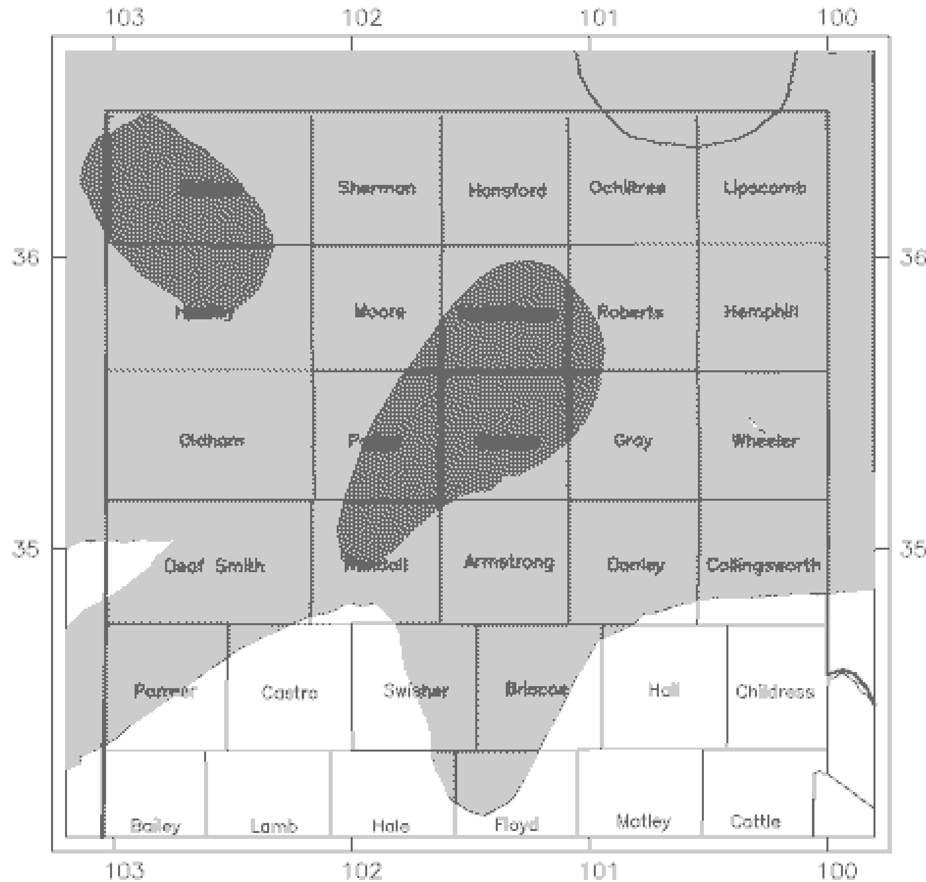


Figure 12P-A Areas in the Panhandle which experienced Modified Mercalli Intensities of V (light gray) and VI (dark gray) during the earthquakes of 1925 and 1936 (near Borger, in Hutchison County), 1948 (near Dalhart, in Dallam County), 1952 (in Oklahoma), or 1974 (near Perryton, in Ochiltree County - curved line indicates intensity V region for this quake).

Mitigation Strategy

- Architects and planners should be informed that damaging earthquakes can affect structures in the Panhandle. Sensitive structures-including dams, towers, very tall buildings, bridges, and highway overpasses-should be constructed with the possibility of earthquakes in mind. Institutions such as hospitals, schools, public meeting places, emergency management organizations, etc. should not be housed in poorly constructed, unreinforced masonry structures.
- Public officials and educators should inform Panhandle residents that earthquakes can and do occur in this region. Citizens should be encouraged to plan for earthquakes; this includes taking steps at home and in the office to mitigate possible injury caused by falling objects such as bookcases or chimneys.
- Citizens should be aware that it is possible that some Panhandle earthquakes are induced by petroleum production.

Table of Texas Panhandle Earthquakes of Magnitude 3 or Greater

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Regional Hazard Assessment

Northeast Texas (Largest Cities - Dallas-Fort Worth)

Counties Affected (41): Anderson, Bowie, Camp, Cass, Cherokee, Collin, Cooke, Dallas, Delta, Denton, Fannin, Franklin, Freestone, Grayson, Gregg, Harrison, Henderson, Hopkins, Hunt, Kaufman, Lamar, Limestone, Marion, Montague, Morris, Nacogdoches, Panola, Rains, Red River, Rockwall, Rusk, Sabine, San Augustine, Shelby, Smith, Tarrant, Titus, Upshur, Van Zandt, Wood, Wise

Hazard Level: This region is at risk from very large, distant earthquakes which might occur in Missouri-Tennessee or Oklahoma; the earthquakes that pose such a hazard are rare, probably occurring only once per 500 years or less. Such distant earthquakes would be most likely to damage large buildings or poorly reinforced masonry structures. Earthquakes with epicenters within this region are rare and small (see **Figure 12N-A**); several earthquakes with magnitudes 3 to 4.5 will probably occur each century. These pose little or no risk unless their epicenters are extremely close to poorly built or very sensitive structures.

Justification: Throughout this region the 1811-1812 Missouri-Tennessee earthquakes, although distant, probably produced

Modified Mercalli Intensities of VI and higher.

Significant Historic Earthquakes Affecting Northeast Texas

Throughout most of this region, the most intense shaking experienced over the past two centuries originated from several earthquakes with magnitude about 8 which occurred in Missouri-Tennessee in 1811-1812, or an earthquake with magnitude 5.6 which occurred in eastern Oklahoma in 1882. Although such distant earthquakes are unlikely to produce severe damage they can cause failure in very large structures, or structures which are designed with absolutely no earthquake-resistant features.

Small earthquakes with epicenters in this region occasionally do occur-some of natural origin and some apparently induced by petroleum production. These include:

- A magnitude 4.0 earthquake with an epicenter near Mexia, probably induced by oil production, that occurred on 9 April 1932.
- A magnitude 4.2 earthquake centered in Lamar County north of Paris that occurred on 12 April 1934.
- A magnitude 3.0 earthquake that occurred in Gregg County near Gladewater on 19 March 1957. This quake may have been induced by petroleum production in the East Texas Field.
- A series of earthquakes in 1964 with magnitudes of 4.0 and higher near Hemphill-Pineland in Sabine County.

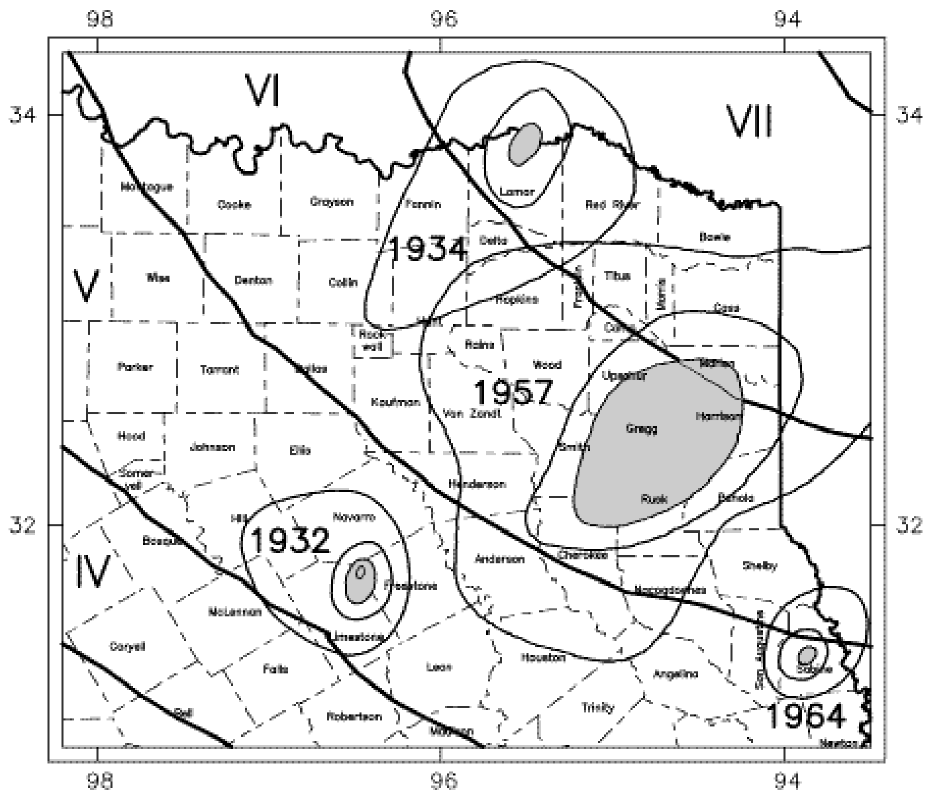

Figure 12N-A: Felt areas of representative historical earthquakes in northeastern Texas. Shaded regions indicate areas of intensity V and above for earthquakes of 1932 (Limestone County), 1934 (northern Lamar County), 1957 (Gregg County), and 1964 (Sabine County). Thick lines indicate estimated boundaries of Modified Mercalli Intensities for the 1811-1812 Missouri-Tennessee earthquakes.

- A magnitude 3.3 earthquake centered near Jacksonville in Cherokee County, which occurred on 6 November 1981.
- A magnitude 3.3 earthquake in Cooke and Denton County near Pilot Point an Valley View; this occurred on 18 September 1985.
- A magnitude 3.4 earthquake centered near Commerce in Hunt County; this occurred on 31 May 1997.

Events of these magnitudes seldom produce damage further than about a few miles from the epicenter.

Mitigation Strategy

- Architects and planners should be informed that distant earthquakes can affect large and sensitive structures in the northeastern Texas. Sensitive structures-including dams, towers, very tall buildings, bridges, and highway overpasses-should be constructed with the possibility of earthquakes in mind.
- Residents should understand that small earthquakes occasionally do occur in this region, including some induced by petroleum production. They should be informed that the principal hazard is from rare, distant, but very large earthquakes occurring outside of Texas.

Table of Northeast Texas Earthquakes of Magnitude 3 or Greater

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Regional Hazard Assessment

South-Central Texas (Largest City - San Antonio)

Counties Included (19): Atascosa, Bastrop, Bexar, Brazos, Burleson, Caldwell, Comal, Gaudelupe, Grimes, Hayes, Jim Wells, Karnes, Lavaca, Lee, Live Oak, Travis, Waller, Washington, Wilson

Hazard Level: Earthquakes with epicenters within this region are rare and small; perhaps 10-20 earthquakes with magnitudes between 3 and 4.5 will occur each century. A significant fraction of these earthquakes are induced by human activities, notably petroleum production. These events pose little or no risk unless their foci are extremely close to poorly built or very sensitive structures.

Justification: Many small earthquakes, some of natural origin and others induced by man's activities, have occurred in these counties.

Significant Historic or Induced Earthquakes Affecting This Region

Small earthquakes with epicenters in this region occasionally do occur-some of natural origin and some apparently induced by petroleum production (see **Figure 12S-A**). These include:

- A magnitude 3.9 earthquake centered in Travis County south of Austin which occurred on 9 October 1902. This earthquake is clearly of natural origin.
- A magnitude 4.2 earthquake near Fashing in Atascosa County on 9 April 1993. This earthquake is one of several in this region which may have been induced by petroleum production.
- A magnitude 3.8 earthquake near Alice in Jim Wells County which occurred on 24 March 1997. This earthquake may have been induced by petroleum production.

Mitigation Strategy

- Residents of this region should understand that small natural earthquakes occasionally do occur in this region. However, the most numerous earthquakes are small events associated with petroleum production in some, but not all fields. These small earthquakes pose a hazard only in the immediate vicinity of their epicenter; the occurrence of significantly larger earthquakes is unlikely.

Figure 12S-A: Felt areas of representative historical earthquakes in South-Central Texas. Shaded regions indicate areas of intensity IV and above for earthquakes of 1887 (Bastrop County), 1902 (Travis County), 1910 (Waller County), 1993 (Atascosa County), and 1997 (Jim Wells County).

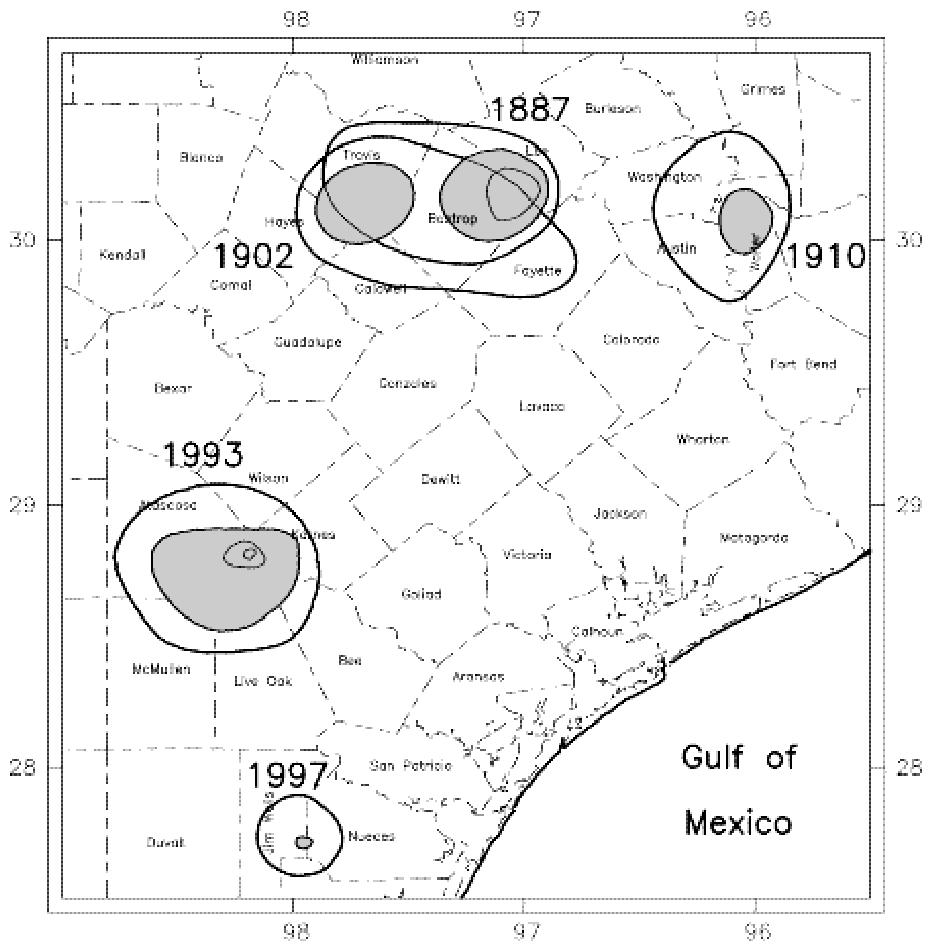

Table of South-Central Texas Earthquakes of Magnitude 3 or Greater

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