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Quaternary Fault and Fold Database of the United States

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Gulf-margin normal faults, Texas (Class B) No. 924

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Compiled in cooperation with the Texas Bureau of Economic Geology

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Synopsis	A belt of mostly seaward-facing normal faults borders the northern Gulf of Mexico in westernmost Florida, southwestern Alabama, southern Mississippi, all of Louisiana and southernmost Arkansas, and eastern and southern Texas (Ewing and Lopez, 1991 #2032). For the purposes of his compilation, the Gulf Coast faults are divided in four large groups because they number in the hundreds. To reflect regional differences in the characteristics of the faults, those in Florida and Alabama are evaluated together in a single group, as are those in Mississippi, those in Louisiana and Arkansas, and those in Texas (described here). Because numerous

	individual faults are combined into a single group for this compilation, it is not possible to provide to provide digital information about the azimuth, length, and dip of each individual fault. The gulf-margin normal faults in Texas are assigned as Class B structures because their low seismicity and because they may be decoupled from underlying crust, making it unclear if they can generate significant seismic ruptures that could cause damaging ground motion.
Name comments	
County(s) and State(s)	ANDERSON COUNTY, TEXAS ARANSAS COUNTY, TEXAS ATASCOSA COUNTY, TEXAS AUSTIN COUNTY, TEXAS BASTROP COUNTY, TEXAS BEE COUNTY, TEXAS BOWIE COUNTY, TEXAS BRAZORIA COUNTY, TEXAS BRAZOS COUNTY, TEXAS BROOKS COUNTY, TEXAS BURLESON COUNTY, TEXAS CALHOUN COUNTY, TEXAS CAMERON COUNTY, TEXAS CAMP COUNTY, TEXAS CASS COUNTY, TEXAS CHAMBERS COUNTY, TEXAS CHEROKEE COUNTY, TEXAS COLORADO COUNTY, TEXAS DE WITT COUNTY, TEXAS DELTA COUNTY, TEXAS DUVAL COUNTY, TEXAS FALLS COUNTY, TEXAS FAYETTE COUNTY, TEXAS FORT BEND COUNTY, TEXAS FRANKLIN COUNTY, TEXAS FREESTONE COUNTY, TEXAS FRIO COUNTY, TEXAS GALVESTON COUNTY, TEXAS GOLIAD COUNTY, TEXAS GONZALES COUNTY, TEXAS GREGG COUNTY, TEXAS GRIMES COUNTY, TEXAS

	HARDIN COUNTY, TEXAS HARRIS COUNTY, TEXAS HARRISON COUNTY, TEXAS HENDERSON COUNTY, TEXAS HILDAGO COUNTY, TEXAS HOPKINS COUNTY, TEXAS HOUSTON COUNTY, TEXAS HUNT COUNTY, TEXAS JACKSON COUNTY, TEXAS JACKSON COUNTY, TEXAS JEFFERSON COUNTY, TEXAS JIM HOGG COUNTY, TEXAS JIM WELLS COUNTY, TEXAS KARNES COUNTY, TEXAS KAUFMAN COUNTY, TEXAS KENEDY COUNTY, TEXAS KLEBERG COUNTY, TEXAS LA SALLE COUNTY, TEXAS LAVACA COUNTY, TEXAS LEE COUNTY, TEXAS LEON COUNTY, TEXAS LIBERTY COUNTY, TEXAS LIMESTONE COUNTY, TEXAS LIVE OAK COUNTY, TEXAS MADISON COUNTY, TEXAS MARION COUNTY, TEXAS MATAGORDA COUNTY, TEXAS MCMULLEN COUNTY, TEXAS MILAM COUNTY, TEXAS MONTOMERY COUNTY, TEXAS MORRIS COUNTY, TEXAS NACAGDOCHES COUNTY, TEXAS NAVARRO COUNTY, TEXAS NEWTON COUNTY, TEXAS NUECES COUNTY, TEXAS ORANGE COUNTY, TEXAS PANOLLA COUNTY, TEXAS POLK COUNTY, TEXAS RAINS COUNTY, TEXAS REFUGIO COUNTY, TEXAS ROBERTSON COUNTY, TEXAS RUSK COUNTY, TEXAS SABINE COUNTY, TEXAS SAN AUGUSTINE COUNTY, TEXAS	

	SAN JACINTO COUNTY, TEXAS SAN PATRICIO COUNTY, TEXAS SHELBY COUNTY, TEXAS SMITH COUNTY, TEXAS STARR COUNTY, TEXAS TITUS COUNTY, TEXAS TRINITY COUNTY, TEXAS TYLER COUNTY, TEXAS UPSHUR COUNTY, TEXAS VAN ZANDT COUNTY, TEXAS VICTORIA COUNTY, TEXAS WALKER COUNTY, TEXAS WALLER COUNTY, TEXAS WASHINGTON COUNTY, TEXAS WEBB COUNTY, TEXAS WHARTON COUNTY, TEXAS WILLACY COUNTY, TEXAS WILSON COUNTY, TEXAS WOOD COUNTY, TEXAS ZAPATA COUNTY, TEXAS
Physiographic province(s)	COASTAL PLAIN
Reliability of location	Poor Compiled at 1:2,500,000 scale. *Comments:* Most of the area was evaluated with regional maps at scales smaller than 1:250,000 because no individual fault has sufficient evidence of seismic slip to justify singling it out for attention here at a larger map scale. Faults in some areas, particularly the Houston metropolitan area, are mapped at scales as large as 1:24,000. Faults in areas having abundant drill-hole data may be better located in the subsurface than at the surface.
Geologic setting	A belt of mostly seaward-facing normal faults borders the northern Gulf of Mexico. These gulf-margin faults face southwest in westernmost Florida, southwestern Alabama, and southern Mississippi; south in Louisiana and southernmost Arkansas; and southeast in eastern and southern Texas (Ewing and Lopez, 1991 #2032). In early to middle Mesozoic time, the opening of the Gulf of Mexico formed a south-facing, rifted, passive margin at the southern edge of North America (DuBar and others, 1991 #2010; Salvador, 1991 #2019; Salvador, 1991 #2020). Subsequently, the rifted margin was buried beneath the thick, Middle Jurassic,

Louann Salt and an overlying, carbonate and clastic, marine sequence that continues to accumulate today. This post-rift sequence thickens seaward (Salvador, 1991 #2020). It is at least 2 km thick everywhere in the belt of gulf-margin normal faults. At the coastline, the sequence is at least 10 km thick west of the Mississippi River and at least 5 km thick farther to the east. Thicknesses exceed 12 km under coastal Texas and southern Louisiana and perhaps 16 km offshore Louisiana.

Rapid deposition and the resulting enormous thickness of the post-rift sediments caused them to collapse and spread seaward. Salt flowed southward and pierced upward, and the overlying sediments extended on listric, normal, growth faults that flatten downward into detachments in the salt and in overpressured shales (Ewing, 1991 #1994; Nelson, 1991 #1995). These listric normal faults, their splays, and their antithetic and transfer faults make up the belt of gulf-margin normal faults described here.

Regional fluctuations in the overall deposition rate divide the belt of gulf-margin faults into two parts with different main ages of faulting and different degrees of Quaternary faulting. (1) The Interior zone of Ewing (1991 #1994) includes the entire belt except southern Louisiana, coastal Texas, and their offshore extensions. Triassic-Jurassic rifting and sedimentation, including deposition of the Louann Salt, led to Mesozoic growth faulting and salt tectonism. A line of large grabens approximates the landward limit of Jurassic salt, and Cenozoic faulting is sparse in the Interior zone (Ewing, 1991 #1994; Salvador, 1991 #2019; Ewing and Lopez, 1991 #2032). The San Marcos arch plunges southeastward from the Llano uplift of central Texas toward the coast. On the arch, the landward limit of the Louann Salt is embayed southeastward to within 60 km of the coast (Ewing, 1990 #3659; Ewing and Lopez, 1991 #2032). Accordingly, on the arch the landward edge of the Interior zone extends southeastward from the line of large grabens just mentioned to the Karnes fault zone (Ewing, 1991 #1994, his Figure 1 and p. 35). Approximately 100 km west of the Karnes fault zone at the western end of the Charlotte-Jourdantown fault zone, the landward limit of the belt of normal faults steps gulfward approximately 40 km to exclude most of the Rio Grande embayment (Ewing, 1990 #3659; Ewing and Lopez, 1991 #2032). The embayment contains some thin salt but lacks the large, southeast-facing, normal faults that indicate gulfward gravitational collapse (Ewing, 1991 #1994, p. 33). (2) The Coastal zone of Ewing (1991 #1994) covers southern

Louisiana, coastal Texas, and their offshore extensions, and is separated from the Interior zone by the Early Cretaceous shelf edge (Ewing, 1991 #1994; Ewing and Lopez, 1991 #2032). Sawyer and others (1991 #3685) summarized total tectonic subsidence (TTS) analyses to infer that the Early Cretaceous shelf edge formed above a crustal boundary that was inherited from the crustal thinning accompanying Triassic-Jurassic rifting. The boundary separates less thinned continental crust on the north from more thinned continental crust on the south. The TTS results indicate that the boundary approximately overlies crust that was thinned to half its original thickness before deposition of the post-rift sequence (Sawyer and others, 1991 #3685, figures 5 and 6). After formation of the Early Cretaceous shelf edge, Late Cretaceous and especially Cenozoic clastic sediments prograded southward, and their load led to abundant Cenozoic and continuing growth faulting and salt tectonism (for example DuBar and others, 1991 #2010, p. 584-585; Salvador, 1991 #2019). The post-rift sequence as a whole is at least 9-11 km thick throughout the Coastal zone (Salvador, 1991 #2020). In addition to causing seaward gravitational collapse of the thick post-rift sequence, the crustal load from rapid Quaternary sedimentation may also aid Quaternary normal faulting and reactivate Tertiary faults of the Coastal zone by imposing extensional bending stresses on the post-rift sequence; older extensional stresses imposed by the Mesozoic sediment load have had time to relax (Nunn, 1985 #2215).

Epicenter maps show only sparse, low-magnitude seismicity within the fault belt (Engdahl, 1988 #1959; Stover and Coffman, 1993 #1986). The only damaging earthquakes reported through 1989 in this huge tract of land are four MMI VI earthquakes in westernmost Florida (1780), southern Louisiana (1930), and eastern Texas (1891, 1932) (Stover and Coffman, 1993 #1986). This level of seismicity is even less than that of sparsely seismic North and South Dakota, which together cover approximately the same area as the belt of gulf-margin faults and which had seven earthquakes of MMI VI since 1909 (Stover and Coffman, 1993 #1986). Furthermore, some of the sparse seismicity in the normal-fault belt may be artificially induced. Earthquakes of m bLg 3.4 and 3.9 and M of 4.0 and 4.7 in southeastern Texas and M 4.9 in southwestern Alabama may have been induced by extraction of oil and gas or injection of fluids for secondary recovery (Pennington and others, 1986 #1876; Chang and others, 1998 #1806; Gomberg and others, 1998 #1828; Gomberg and Wolf,

	1999 #3440). Therefore, the natural seismicity rate in the normal-fault belt might be even less than the recent historical record would indicate. The post-rift sequence and its belt of gulf-margin normal faults may be mechanically decoupled from the underlying crust. The stress field is extensional throughout the post-rift sequence in both the Interior and Coastal zones of the normal-fault belt, as determined mostly from drill-hole data that demonstrate fault slips and well-bore breakouts (Zoback and Zoback, 1991 #2006). The orientations of Shmin are radial to the Gulf of Mexico, in contrast to the east-northeast trends of SHmax that characterize most of North America east of the Rocky Mountains; the stress field in the crust beneath the thick post-rift sequence is unknown (Zoback and Zoback, 1991 #2006). Consistent with the stress field in the post-rift sequence, the normal-faulting focal mechanism of the 1997, M 4.9 earthquake in southwestern Alabama indicated south-southwest extension (Chang and others, 1998 #1806). The presence of the normal faults throughout the post-rift sequence from westernmost Florida to southern Texas (Ewing and Lopez, 1991 #2032) demonstrates that the sequence is sliding and extending seaward on detachments in weak salt and overpressured shales. In summary, the belt of gulf-margin normal faults from Florida through Texas has strikingly low historical seismicity; the stress field and seismogenic potential of the underlying crust are unknown; and, therefore, the ability of the fault belt to generate significant seismic ruptures that could cause damaging ground motion is unclear. Accordingly, the fault belt is assigned to class B.
Length (km)	km.
Average strike	
Sense of movement	Normal *Comments:* In addition to the normal faults, a few strike-slip faults might form trantensional links between the normal faults.
Dip	0° - 90°, SE, NW *Comments:* Dips vary, but faults are generally steeper in their upper parts and flatten downward. Dips are dominantly

	southeastward in the Coastal zone, seaward of the early Cretaceous shelf edge. However, in the Interior zone northwest of the shelf edge, southeastward and northwestward dips are locally paired in grabens (Ewing and Lopez, 1991 #2032).
Paleoseismology studies	
Geomorphic expression	Scarps and drainage, topographic, and tonal lineaments (DuBar and others, 1991 #2010), particularly near the coast.
Age of faulted surficial deposits	Cretaceous to Holocene (Winker, 1990 #3698; Barnes, 1992 #3703).
Historic earthquake	
Most recent prehistoric deformation	latest Quaternary (<15 ka) *Comments:* A belt of mostly seaward-facing normal faults borders the northern Gulf of Mexico (Ewing and Lopez, 1991 #2032). Ewing (1991 #1994) and Ewing and Lopez (1991 #2032) divided the faults into an Interior Zone and a Coastal Zone, which are separated by a boundary that begins in southeastern Louisiana and runs westward across Louisiana and Texas, approximately 100 km inland from the coast in eastern Texas and more than 200 km inland in southwestern Texas. In the Interior Zone, Quaternary slip is rarely reported (figure 3, DuBar and others (1991 #2010)). In contrast, the Coastal zone contains more abundant evidence of Quaternary slip. Widespread Quaternary and historical normal faulting has long been recognized at the surface from Louisiana to Mexico (Groat, 1973 #3665; Verbeek, 1979 #3691; 1979 #3692; Berryhill and Trippet, 1980 #3648; O'Neil and Van Siclen, 1984 #3681; Ewing, 1990 #3659; Ruhl and Norman, 1992 #3684; White and Morton, 1997 #3697). The faulting is generally attributed to regional, late Cenozoic, gravitational collapse of the thick, unlithified to partly lithified, water-saturated sediments of the Coastal zone, locally greatly accelerated by subsidence that is induced by pumping of oil, gas, and water. Historical subsidence and surface normal faulting are particularly pronounced in and around Houston (Pratt and Johnson, 1926 #3682; Verbeek and Clanton, 1978 #3693; Clanton, 1979 #3650; Sheets, 1979 #3686; 1979 #3694; Verbeek and others, 1979 #3695; Holzer and Verbeek, 1980 #3675; Mastroianni and Norman, 1992 #3680).

	The subsidence, faulting, and occasional small earthquakes resemble the effects of withdrawal of subsurface fluids in other urban areas worldwide (Yerkes and Castle, 1976 #3700; Holzer, 1980 #3672). At Houston, reduction in pumping to allow ground water levels to recover was followed by slower subsidence and faulting (Holzer and Gabrysch, 1982 #3673; Holzer and others, 1983 #3674).
Recurrence interval	*Comments:* Estimates of recurrence interval are premature because it is not yet clear whether these faults can generate significant tectonic earthquakes, as explained under "Geologic setting".
Slip-rate category	Less than 0.2 mm/yr *Comments:* The slip rate is unknown. However, a slip rate of 0.2 mm/yr would produce 320 m of slip during the 1,600,000 years of the Quaternary. It is unlikely that any single fault in the gulf-margin belt of normal faults has such a large Quaternary offset. Therefore, probably the long-term rate is less than 0.2 mm/yr.
Date and Compiler(s)	1999 Russell L. Wheeler, U.S. Geological Survey, Emeritus
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