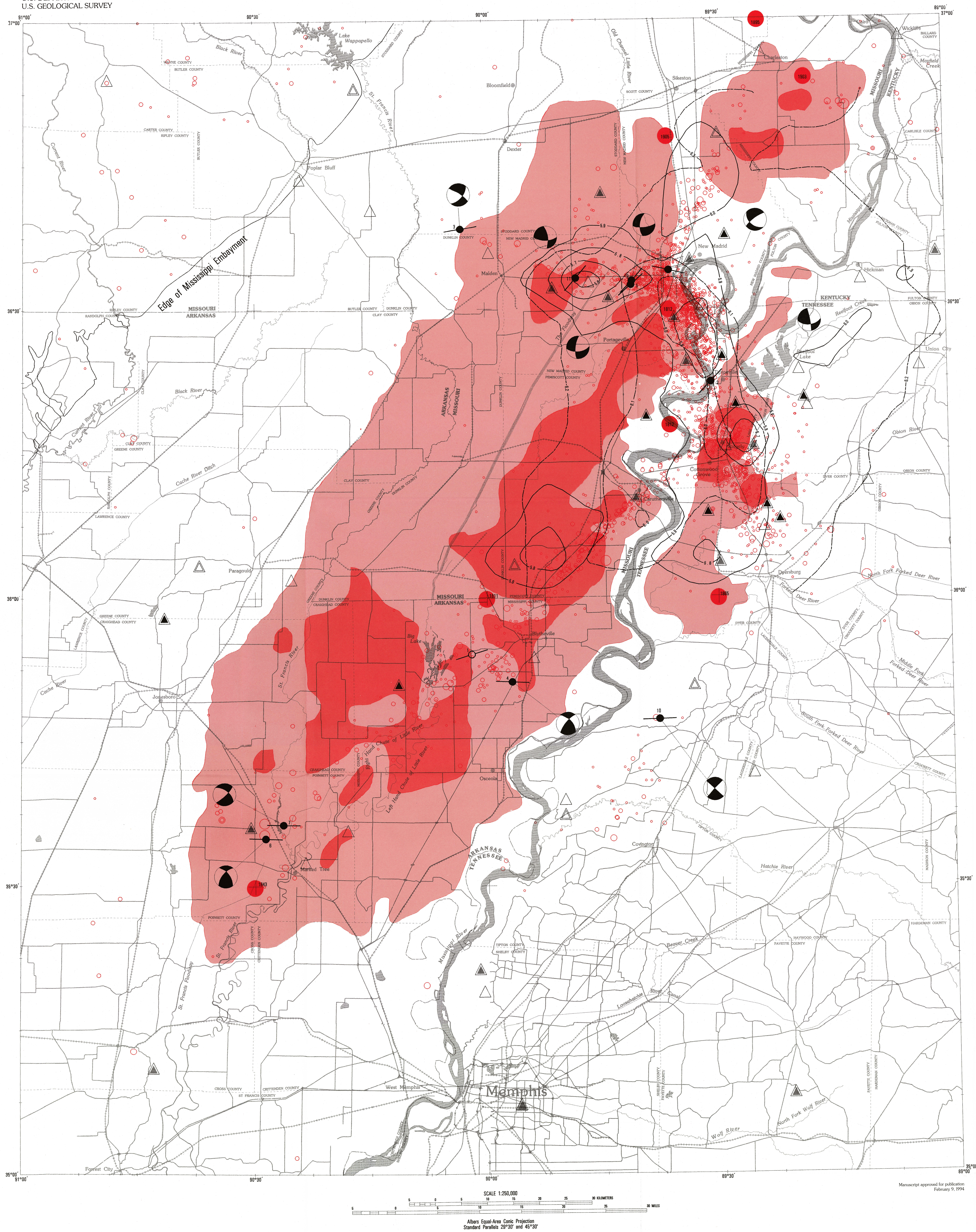

MAP SHOWING SEISMICITY AND SANDBLOWS IN THE VICINITY OF NEW MADRID, MISSOURI

By

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EXPLANATION

Earthquake epicenters, scaled by earthquake magnitude

- **Less than 2.0**
- **Between 2.0 and 2.9**
- **Between 3.0 and 3.9**
- **4.0 or greater**

Historical earthquake with moment magnitude of at least 5.0

Seismometer locations

Seismograph location showing date of installation

- **Oct. 1974 to Dec. 31, 1976**
- **Jan. 1, 1977 to Dec. 31, 1982**
- **Jan. 1, 1983 to Aug. 8, 1989**

Strong-motion accelerograph location

P-wave velocity contours, km/s

- **Depth range 0-5 km**
- **Depth range 5-14 km**

Indicators of trend of greatest horizontal compressive stress

- 1 **From well bore breakouts; circle locates well, number keyed to table 3**
- 2 **Trend of P-axis from earthquake focal mechanism; dot locates epicenter, number keyed to table 3**

Single earthquake focal mechanism; shaded quadrants indicate compressional arrivals

Sand blow deposits from 1811-12

- **Deposits cover 1-24 percent of ground**
- **Deposits cover more than 25 percent of ground**

State boundary

County boundary

Selected city or town if not identified by road intersections

Limited access, primary, or secondary road

Railroad

Selected river, stream, or irrigation ditch

Wide river, selected lake or pond

INTRODUCTION

This is one of a series of five seismotectonic maps of the seismically active New Madrid, Missouri, area (table 1; Wheeler and others, 1992). The map area centers near the sites of three great earthquakes that struck during the winter of 1811-12 (Fuller, 1912; Nuttli, 1973). These earthquakes and continuing subsequent seismicity rank the New Madrid area with Charlevoix, Quebec, as the two most seismically active areas in North America east of the Rocky Mountains. The threat posed by New Madrid seismicity to the central United States makes the area the focus of many investigations (for examples, Heyl and McKeown, 1978; McKeown and Pakiser, 1982; Algermissen and Hopper, 1984; Hamilton and Johnston, 1990; Applied Technology Council, 1991; Johnston and others, 1992). The map area includes the most intense seismic activity in the New Madrid region.

A seismotectonic map shows some of the geologic and geophysical information needed to assess seismic hazard (Hadley and Devine, 1974; Pavoni, 1985). A previous seismotectonic map of the central Mississippi River valley (Heyl and McKeown, 1978) has had wide use for planning field surveys, as a base map for plotting data collected during single investigations, and for compiling a range of information. Since 1978 numerous researchers have greatly advanced our knowledge of the geology and geophysics of the central Mississippi Valley. The New Madrid seismotectonic map folio updates approximately the south-central sixth of the central Mississippi Valley seismotectonic map of Heyl and McKeown (1978).

SEISMOTECTONIC DATA

We used the ARC/INFO geographic information system (GIS) software to compile and edit the maps in this series (table 1). The digital data base that we compiled can be used to produce diverse products in addition to the seismotectonic maps (Rhea and others, 1991). The digital data base is available separately (Tarr, 1991).

BASE MAP

No topographic contours are shown on the base map because most of the Mississippi embayment is flat and people tend to locate themselves on maps and in the field with reference to cultural and hydrologic instead of topographic features. A few topographic landmarks, particularly those likely to have tectonic significance, are shown on the surficial and hydrologic feature map (table 1; Wheeler and Rhea, 1994). The roads, streams, and other linear features are modified from U.S. Geological Survey digital line graph (DLG) data, which in turn had been digitized from standard 1:100,000-scale planimetric and topographic maps (U.S. Geological Survey, 1989). All railroads; state and county boundaries; limited access, primary, and secondary roads; large towns and cities; and named places of any size that scientists commonly use as geographic references are on the base map. Large streams that are identified by Holocene alluvium in the valleys on Saucier and Snead (1989) or by wide flood plains or extensive woodlands in the flood plains on 1:250,000-scale topographic maps and selected large lakes are shown on the base map, although not all drainages appear.

GEOLOGIC SETTING

The map area occupies most of the northern half of the Mississippi embayment, a gentle syncline that plunges south-southwesterly beneath the coastal plain. The syncline is filled with Mesozoic and Cenozoic sediments and sedimentary rocks that overlie the Paleozoic platform rocks of the midcontinent. Accordingly, we show the edge of the embayment within the map area to be the contact between exposed Paleozoic rocks on the northwest and younger strata on the southeast. The contact trends northeast across the northwest quarter of the map area. The contact was digitized from geologic maps published at a scale of 1:500,000 (Haley and others, 1976; Anderson and others, 1979). The digitizing generalized the contact slightly by omitting several small outliers of Cretaceous rocks and small inliers of Ordovician rocks.

SEISMOGRAPH NETWORK

Saint Louis University began the local seismograph network in 1974 and now operates it jointly with Memphis State University. Stations were added in most years until 1989 and the largest number were added in 1980 (S.C. Chiu, Lotte Haas, and Melanie Whittington, written and oral communs., 1992, 1993). The 32 permanent stations that were installed in the map area are shown; of these 26 remained operational in December 1992. Most of the station locations are reported to the nearest 0.0001° (about 10 m), with a few to the nearest 0.01° (about 1 km). Two stations in Memphis are about 150 m apart, so their map symbols are nearly superimposed. Several stations have complex histories of instrument upgrades or additions. Further details are available in the quarterly "Central Mississippi Valley Earthquake Bulletin," distributed by Saint Louis University, and the "Center for Earthquake Research and Information Quarterly Seismological Bulletin," distributed by Memphis State University.

ACCELEROGRAPHS

The number and locations of strong-motion stations in the map area change often. Busby (1990) listed 18 analog and 6 digital accelerographs operated by several agencies and universities. We show the 23 digital stations that were operational in July 1992. Most locations are reported to the nearest 0.001°-0.0001° (about 100-10 m), with a few reported to the nearest 0.01°-0.1° (about 1-10 km). Further details are in the digital database STRONGMO, which is maintained by the National Center for Earthquake Engineering Research (NCEER) Strong Ground Motion Group at the Lamont-Doherty Earth Observatory.

EARTHQUAKE EPICENTERS

Network catalog data are from Saint Louis University (Taylor and others, 1991); epicenters are generally reported to the nearest 0.01° (about 1 km). Ninety-five percent of the epicenters in the map area have calculated precisions (ERH values) of 5 km or less; most of these epicenters have ERH values of 1 km or less. Total locational uncertainty, however, includes inaccuracies and perhaps imprecisions from other sources and probably exceeds the calculated precision. The events shown here occurred between July 1974 and June 1991. The densest cluster of epicenters forms a band trending northwest from near Dyersburg, Tenn., to near New Madrid, Mo. Recently, the area of the band has been monitored by the dense Portable Array for Numerical Data Acquisition (PANDA) of high-resolution seismographs (Chiu and others, 1992). The added precision of the PANDA data improves estimates of depths more than of epicenters, so the two sets of epicenters from the permanent network and PANDA differ little (Taylor and others, 1991; Chiu and others, 1992; J.M. Chiu, oral commun., 1992). Therefore, for consistency we show the epicenters from the permanent network instead of the PANDA epicenters.

Several earthquakes that occurred before the permanent network was in place were larger and caused more damage than any recorded by the network. The 8 historical earthquakes for which Johnston (1994) estimated moment magnitudes (Hanks and Kanamori, 1979) of at least 5.0 (table 2) are identified on the map. Since 1811 all parts of the map area have undergone Modified Mercalli intensity VIII or higher at least once.

P-WAVE VELOCITY

Al-Shukri and Mitchell (1987, 1988) calculated P-wave velocity averaged within large crustal blocks; both reports include contour maps of the calculated velocities. We show the contours from the 1988 report, which used smaller crustal blocks and a more realistic velocity model for analysis. The contours show an area of low velocities both in the upper 5 km of the crust and in the depth range of 5 to 14 km that coincides in map view with the northwest-trending band of epicenters that extends approximately from Dyersburg, Tenn. to New Madrid, Mo.

SAND BLOWS

One of the most dramatic effects of the great earthquakes of 1811-12 was widespread liquefaction, the record of which is preserved in sand blows covering the ground surface. Obermeier (1989, pl. 8) used aerial photographs, field observations, and other information to map the percentage of the land surface covered with sand blows. We simplified his map, following Obermeier and others (1990, fig. 14), to show areas that are 1-24 percent and more than 25 percent covered by sand blows. The sand blow distribution lends support to the estimated epicenters of the 3 great 1811-12 earthquakes, which were located with sparse intensity data. The epicenters are within the overall sand blow area and near or among closely spaced subareas with high sand blow intensity (Obermeier, 1989).

STRESS ORIENTATIONS

Ellis (1994) compiled published estimates of the orientations of greatest horizontal compressive stress for a large region that includes the map area. We updated his compilation for the map area to produce table 3. The focal mechanisms show the recognized pattern of (1) right-lateral strike-slip faulting on northeast-striking surfaces in the epicentral band between Marked Tree, Ark. and Caruthersville, Mo., and (2) strike-slip or reverse faulting in the more complex epicentral bands north and east of Caruthersville. The one stress orientation inferred from well-bore breakouts is consistent with this pattern. Single-event focal mechanisms from the PANDA data are too numerous and complex to show on this map, but most of them are consistent with the stress orientations that we show (J.M. Chiu, oral communs., 1992, 1993; Y.T. Yang and others, written commun., 1993).

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Table 1. *Maps in the U.S. Geological Survey seismotectonic folio of the vicinity of New Madrid, Mo.*

Map	Theme: features shown	Reference
MF-2264-A	Seismicity: earthquake epicenters, focal mechanisms, seismic velocities, instrument locations, and aspects of liquefaction.	This map
MF-2264-B	Crustal structure: epicenters, and large structures inferred from gravity, aeromagnetic, seismic reflection, seismic refraction, and magnetotelluric data.	Rhea and Wheeler (1994a)
MF-2264-C	Geophysical surveys: epicenters, and lines of gravity, aeromagnetic, magnetotelluric, seismic reflection, and seismic refraction surveys and models.	Rhea and Wheeler (1994b)
MF-2264-D	Bedrock geology: epicenters, and geologic and subcrop contacts, structure contours, radon concentrations, selected wells, selected faults, and arches, troughs, and faulted boundaries of the Mississippi Valley graben.	Wheeler and others (1994)
MF-2264-E	Surficial and hydrologic features: epicenters, and aspects of liquefaction, trench sites, earthquake-induced landslides, courses of the Mississippi River since 1765, fluvial and hydrologic anomalies, selected topographic features, Bootheel lineament, and geodetic monuments.	Wheeler and Rhea (1994)

Table 2. *Historical earthquakes in the vicinity of New Madrid, Mo., with moment magnitudes (**M**) of 5.0 or larger*

[Source: Johnston (1994) unless otherwise stated]

Date	**M**	Epicenter[1]		Maximum intensity and reference
		lat N.	long W.	
Dec. 16, 1811	8.2	36°00'	90°00'	XI (Nuttli, 1979)
Jan. 23, 1812	8.1	36°18'	89°36'	X-XI (Nuttli, 1979)
Feb. 7, 1812	8.3	36°30'	89°36'	XI-XII (Nuttli, 1979)
Jan. 5, 1843	6.5	35°30'	90°30'	VII (R.L. Street and R.F. Green, written commun., 1984) or VIII (Hopper, 1985)
Aug. 17, 1865	5.2	36°00'	89°30'	VI-VII (R.L. Street and R.F. Green, written commun., 1984)
Oct. 31, 1895	6.8	37°00'	89°24'	VIII-IX (R.L. Street and R.F. Green, written commun., 1984; Hopper, 1985)
Nov. 4, 1903	5.0	36°54'	89°18'	VII (R.L. Street and R.F. Green, written commun., 1984)
Aug. 22, 1905	5.0	36°48'	89°36'	VI-VII (R.L. Street and R.F. Green, written commun., 1984)

[1] Converted from decimal degrees as given by Johnston (1994) to nearest 0.1° (about 10 km).

Table 3. *Estimates of orientations of greatest horizontal compressive stress in the vicinity of New Madrid, Mo.*

[Data updated from Ellis (1994)]

Well-bore breakouts

Index[1], well	S_{Hmax}[2]	Q[3]	References
1. Dow Chemical Co./B.L. Garrigan No. 1	073	A	Dart (1987, 1992), Dart and Swolfs (1991)

Single-earthquake focal mechanisms

Index[1], date	Magnitude	P axis[4]	Q[3]	References
2. Feb. 2, 1962	m_b4.3	043/19	B-C	Herrmann (1979), Gordon (1988)
3. Mar. 3, 1963	m_b4.8	077/31	B	Herrmann (1979), Herrmann and Nguyen (1993), Gordon (1988), R.B. Herrmann (oral and written communs., 1993)
4. Nov. 17, 1970	m_b4.4	272/09	B-C	Herrmann (1979), Gordon (1988)
5. June 13, 1975	m_b4.2	049/34	B-C	Herrmann (1979), Gordon (1988)
6. Mar. 25, 1976	m_b5.0	272/01	B	Herrmann (1979), Gordon (1988)
7. Mar. 25, 1976	m_b4.5	271/28	B-C	Herrmann (1979), Gordon (1988)
8. Jan. 21, 1986	m_{Lg}(10Hz) 1.7	103/38	D	Mickus (1993), K.L. Mickus (oral and written communs., 1992, 1993)
9. Mar. 23. 1987	m_{Lg}(10Hz) 3.1	143/34	C	Mickus (1993), K.L. Mickus (oral and written communs., 1992, 1993)
10. Aug. 29, 1990	m_{Lg}(10Hz) 3.8	088/03	C	Stauder and others (1990)
11. May 4, 1991	m_{Lg}(10Hz) 4.6	040/02	B	Chiu and others (1991), S.C. Chiu (oral and written communs., 1993), R.B. Herrmann (written communs., 1993)

[1] Index number is keyed to symbol on map.

[2] Stress orientation, taken as the azimuth, in degrees, of greatest horizontal compressive stress, and calculated as the normal to the preferred orientation of breakouts.

[3] Quality, graded from A (best) to D (worst), according to criteria of Zoback and Zoback (1991). A stress orientation calculated from breakouts measured in a well bore is graded according to number and length of breakouts and the standard deviation of their orientations. Orientation inferred from a focal mechanism is graded according to earthquake magnitude, degree of constraint on the mechanism's orientation, and method used to calculate the mechanism.

[4] Azimuth/plunge, in degrees. Stress orientation is taken as the azimuth.

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