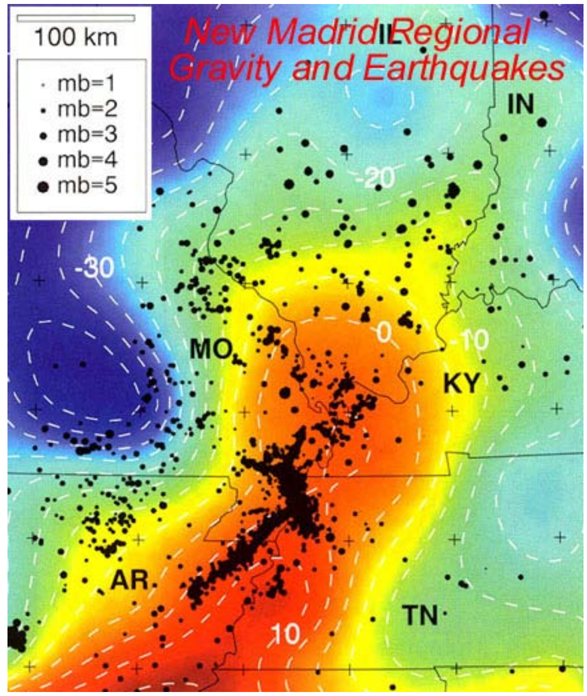
Midwest Earthquakes



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(March, 2004; updated April 15, 2011)

This web page: http://web.ics.purdue.edu/~braile/news/midwest.htm
http://web.ics.purdue.edu/~braile/news/midwest.pdf

During the past three decades, earthquake data recorded by the New Madrid seismograph network (Figure 1) have provided new insight into the seismotectonics of the New Madrid seismic zone (NMSZ). Prior to the establishment of the network, the NNSZ was characterized by the less-than-200-year-duration historical earthquake record (Nuttli, 1973) and by accounts of the great 1811-1812 earthquakes (Johnston, 1982; Johnston and Schweig, 1996). Seismicity and geophysical data analyzed since 1974 have delineated prominent epicentral trends and tectonic features. Earthquake locations correlate with distinct geophysical anomalies (Figures 2 and 3) indicating that the intraplate seismicity of the NMSZ is associated with an ancient, buried rift that is currently being reactivated by the contemporary, nearly east-west compressional plate-tectonic-generated stresses (Zoback and others, 1980; Braile and others, 1982, 1986, 1997).

Positive gravity anomalies in the upper Mississippi embayment (Figures 2 and 3) are interpreted to be caused by high density rocks beneath the embayment that were emplaced during the late Pre-Cambrian to early Paleozoic rifting event or during Mesozoic reactivation of the rift. During the past 150-200 million years, the area has subsided due to the presence of the more dense rocks in the crust resulting in the embayment and the deep burial of the ancient rift structure (Figures 4 and 5). Currently, the buried rift has acted as a “zone of weakness” in the stable continental crust and serves to localize earthquake activity within the Midwest. In addition to the most active portion of the NMSZ that has been the location of large magnitude earthquakes, diffuse seismicity, including events that are generally small than about 5.5 magnitude, is present throughout much of the Midwest. Recent interpretations and discussions of geological and geophysical data in the New Madrid area are contained in papers published in a special issue (Volume 68, Number 4, July/August, 1997) of *Seismological Research Letters.* More information on the NMSZ and Midwest earthquakes is available in the references listed below and the papers published in the special issue.

Recently, GPS measurements have shown that the rate of deformation in the North American continental interior and the New Madrid seismic zone is too slow to explain the earthquakes in the past 5000 years, suggesting the possibility of cycles of deformation and resulting earthquakes (Calais et al., 2005, 2006, Calais and Stein, 2009). Also, Calais et al. (2010) suggest a new model for triggering of New Madrid earthquakes by late-Pleistocene erosion.

New analyses of the intensity of shaking of the New Madrid earthquakes have resulted in new estimates of the magnitudes of these events (Hough and others, 2000; Hough and Martin, 2002). The revised magnitudes range between M7 to M7.5. More recently (Hough and Martin, 2011), present a revised analysis of the 1811-1812 New Madrid events and state that the magnitude of all of the main earthquakes could be in the range of ~M7. Although these estimated magnitudes are smaller than previous estimates, it is clear that these were very significant events as evidenced by the intensity data (Figures 6-9) and their occurrence indicates a significant earthquake hazard for the Central United States (Figures 10 and 11). Shake maps of the two of the New Madrid events (Figures 8 and 12) and of the October 31, 1895 Charleston, Missouri M6.6 earthquake (Figure 13) have been prepared by Hough (http://pasadena.wr.usgs.gov/office/hough/). The shake maps (Figures 8, 12, and 13) provide good estimates of the intensity of shaking that would be expected upon a future repeat of these earthquakes.

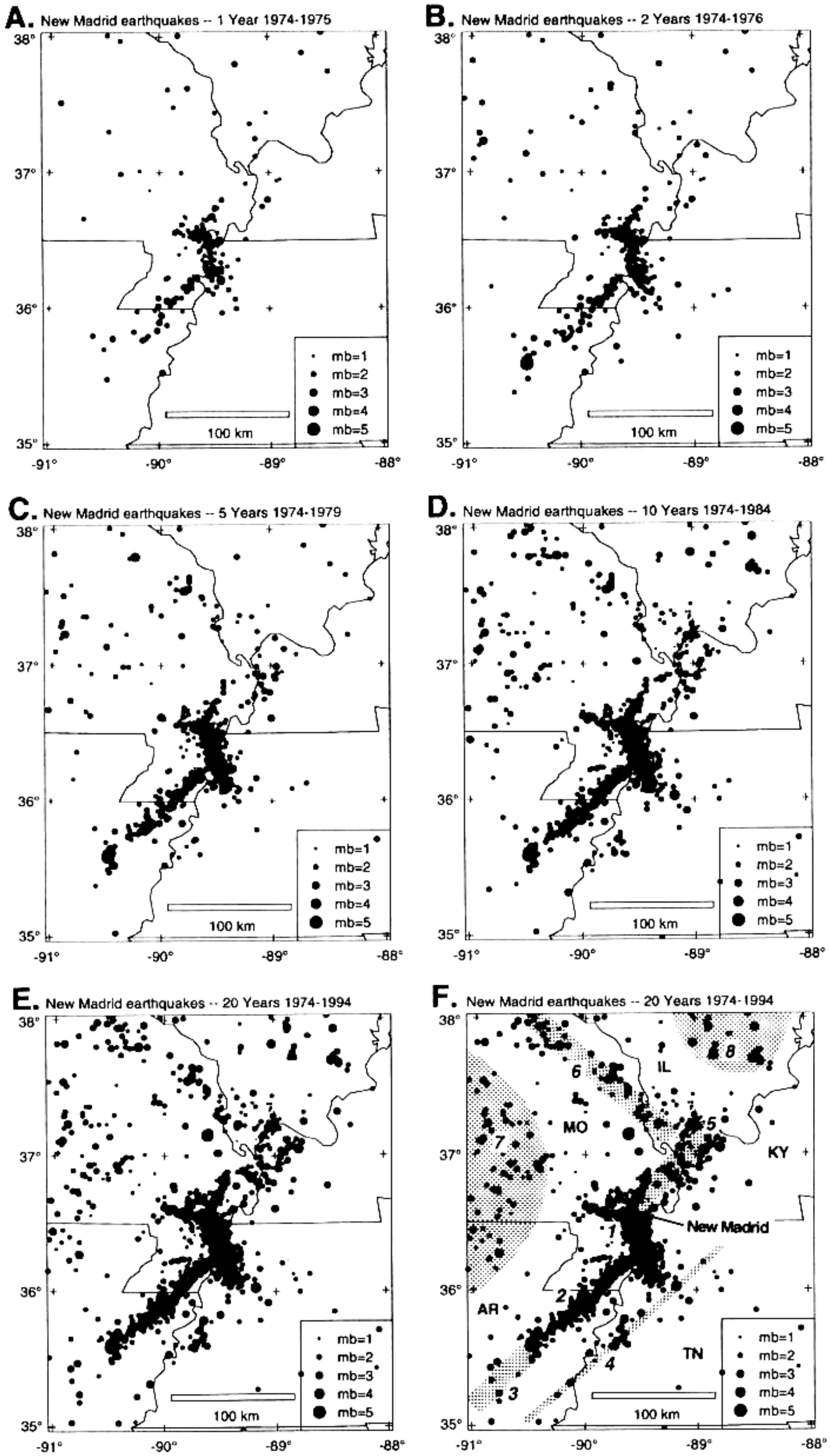


Figure 1. New Madrid area network seismicity through time. Magnitudes (m_b) of the earthquakes are indicated by the size of the dots. A. One year, July, 1974 – June, 1975; B. Two years, July, 1974 – June, 1976; C. Five years, July, 1974 – June, 1979; D. Ten years, July, 1974 – June, 1984; E. Twenty years, July, 1974 – June, 1994; F. Twenty year seismicity map and newly defined trends (shaded areas).

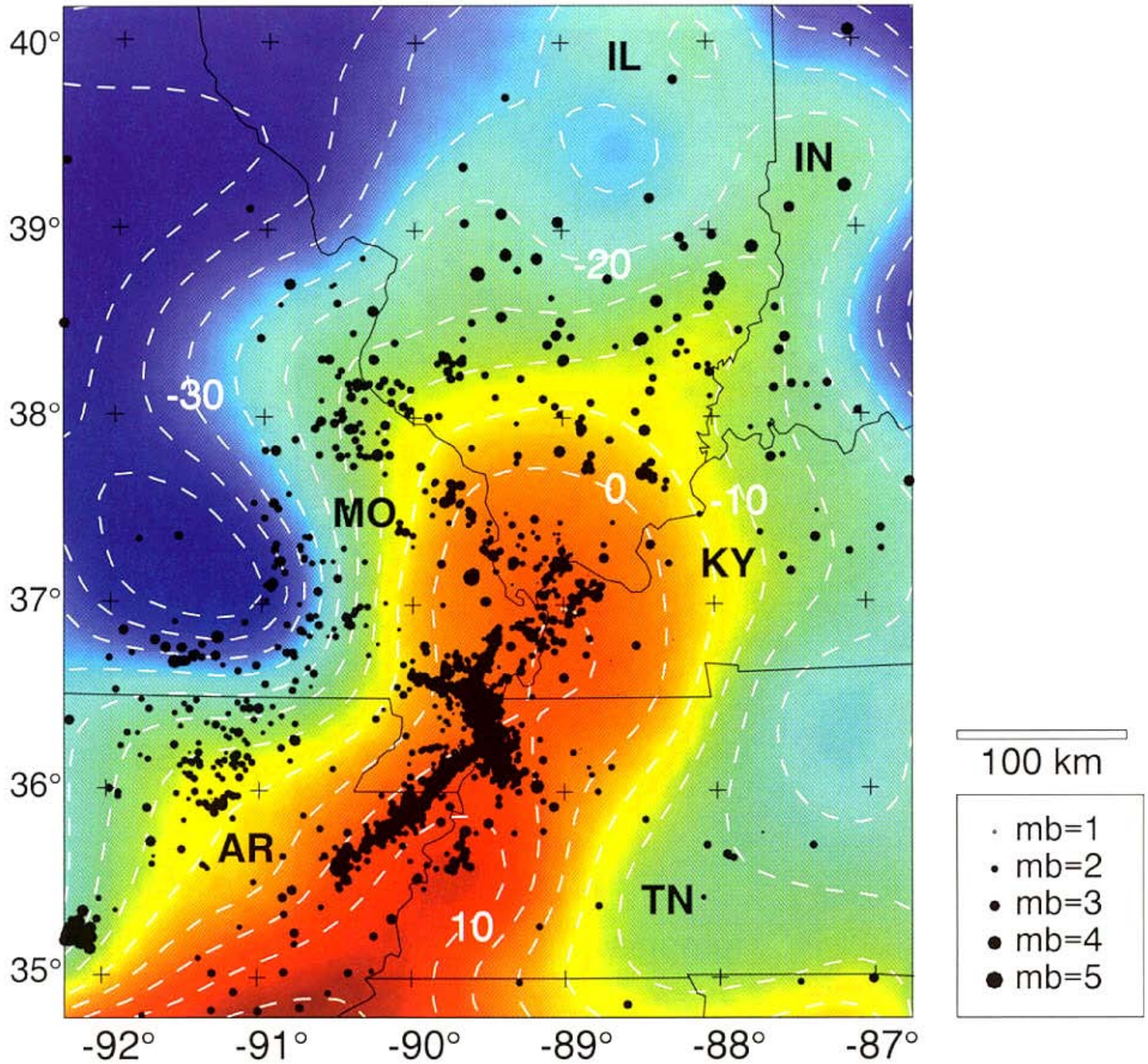


Figure 2. Regional Bouguer gravity anomaly map and 1974 – 94 earthquake epicenters (dot size is proportional to magnitude) in the New Madrid seismic zone. Gravity data have been smoothed and adjusted to correct for the effect of the low-density Mississippi embayment sediments. Contours are in mGal. Gravity data from Cordell(1977).

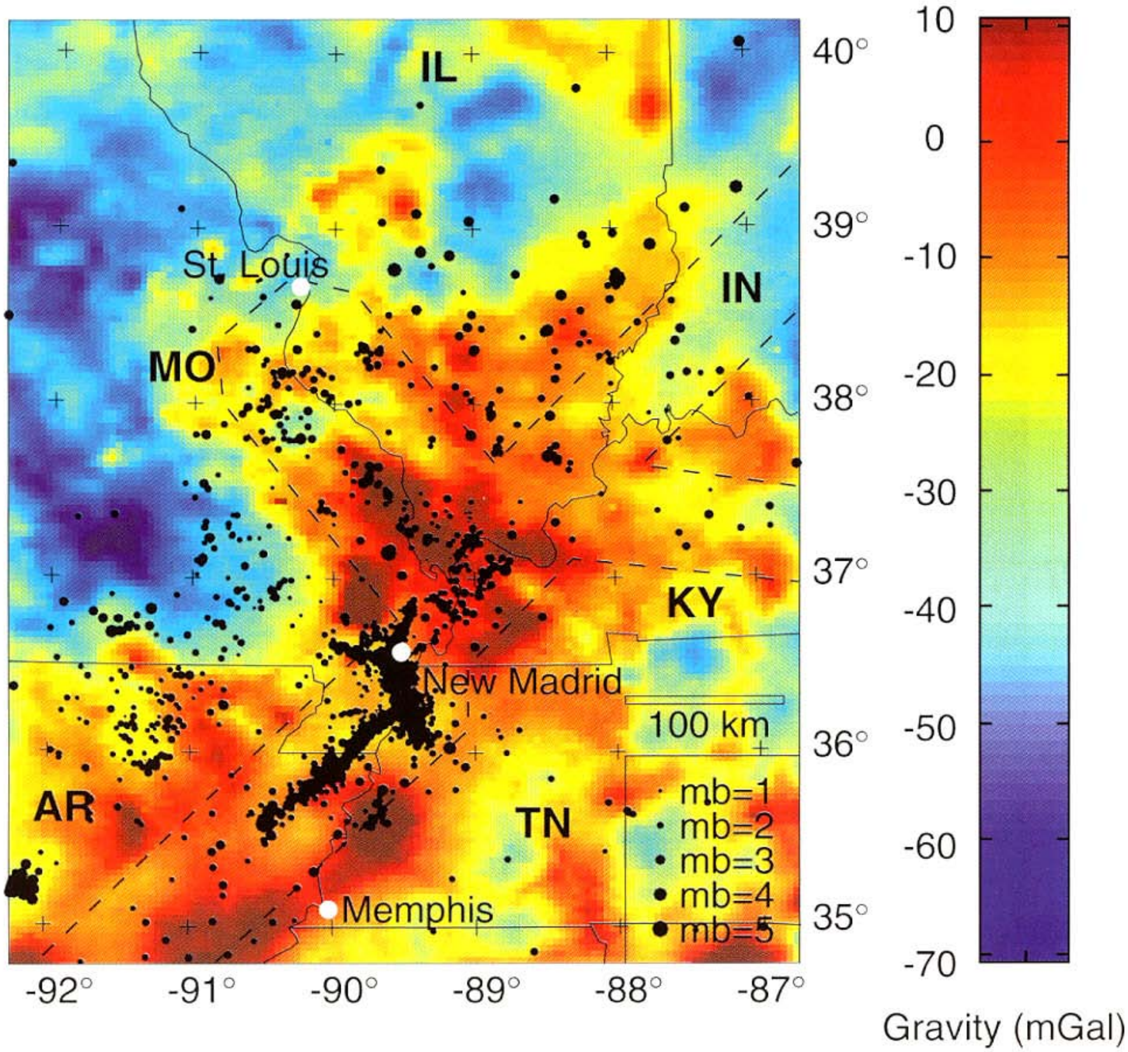


Figure 3. Bouguer gravity anomaly map and 1974 – 94 earthquake epicenters (dot size is proportional to magnitude) in the New Madrid seismic zone. Dashed line shows outline of the interpreted New Madrid Rift Complex. The southernmost portion of this rift complex was recognized in 1975 and named the Reelfoot rift (Ervin and McGinnis, 1975; Hildenbrand, 1985).

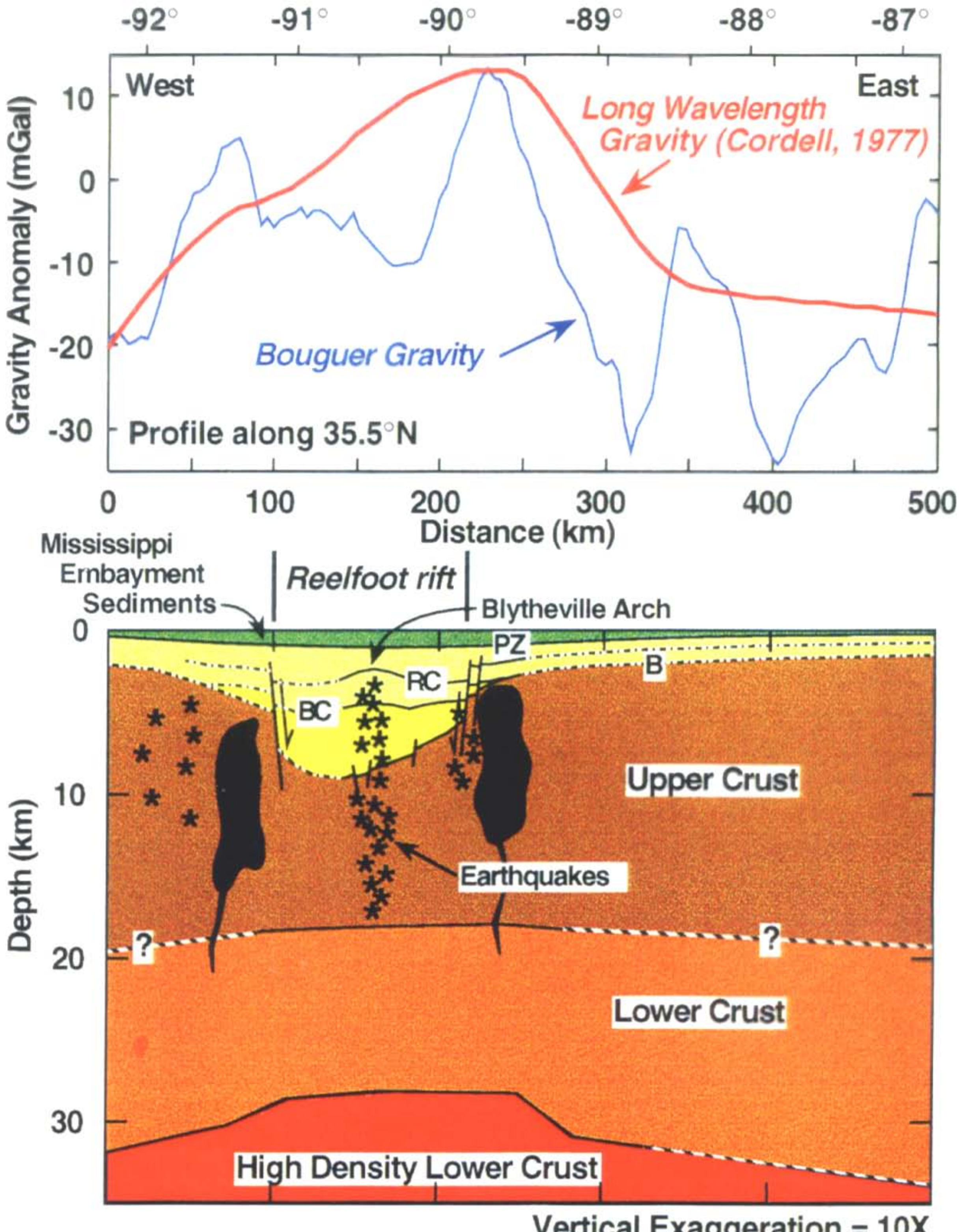


Figure 4. Interpreted crustal model and gravity data along a west-to-east profile at 35.5 degrees North latitude. The high density lower crust and thinning of the upper crust are associated with the development of the ancient rift. Subsequently, the area has undergone substantial subsidence resulting in the deposition of the thick section of sedimentary rocks in the Mississippi embayment. Black areas indicate intrusions into the upper crust along the rift margins. Most of the earthquakes in the rift area show strike-slip or thrust mechanisms.

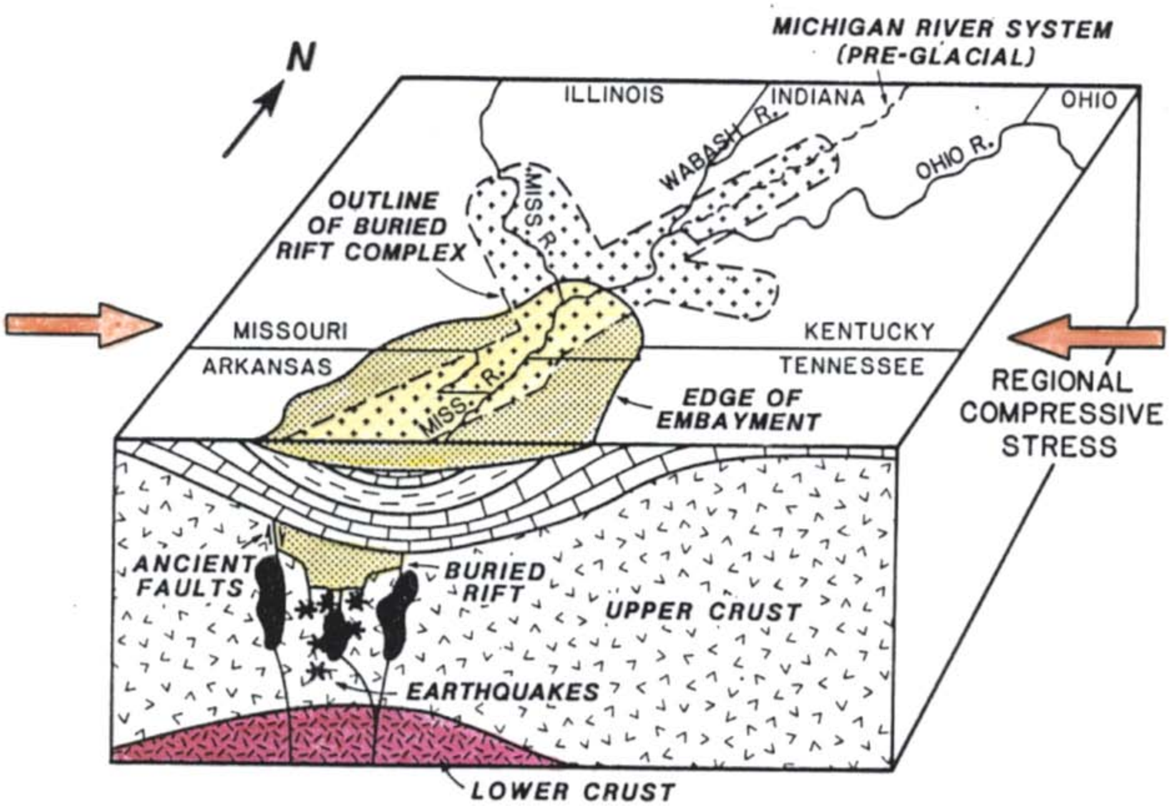


Figure 11. Block diagram illustrating the present configuration of the buried New Madrid Rift Complex. The structurally controlled rivers, Paleozoic rocks in cratonic sedimentary basins, and the Mississippi Embayment, all associated with the buried rift complex, are also shown. Dark areas indicate intrusions near the edge of the buried rift. An uplifted and possibly anomalously dense lower crust is suggested as the cause of the linear positive gravity anomaly associated with the upper Mississippi Embayment.

Figure 5. From Braile and others, 1982.

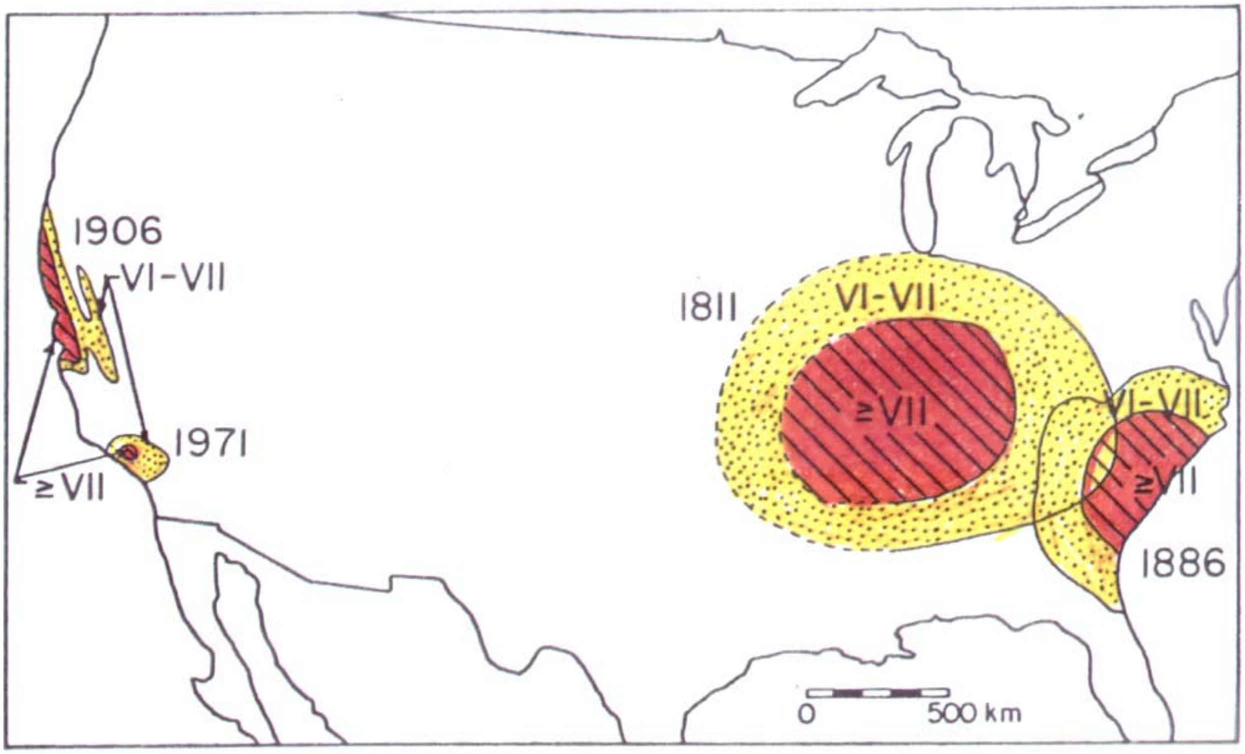


Figure 6. Comparison of areas of minor (I = VI–VII) and major (I > VII) damage for the 1906 San Francisco earthquake ($M_s = 8.3$) and the 1811 New Madrid earthquake ($m_b = 7.2$) and for the 1971 San Fernando earthquake ($m_b = 6.2$) and 1886 Charleston earthquake ($m_b \simeq 7$). The damage area for the western half of the 1811 New Madrid earthquake (outlined by dashed lines) is inferred, because there were no settlements in the area at that time.

Figure 6. Comparison of Intensity observations for Central and Eastern US and California earthquakes.

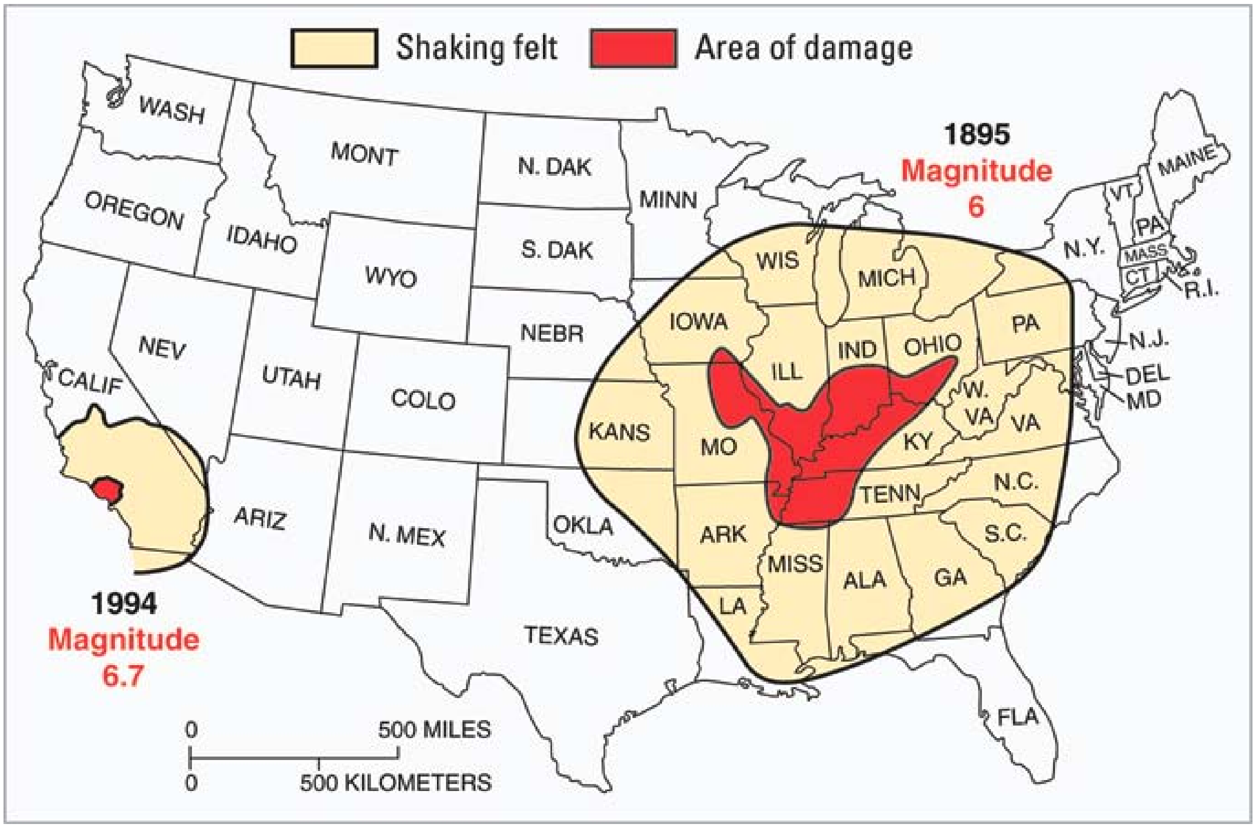
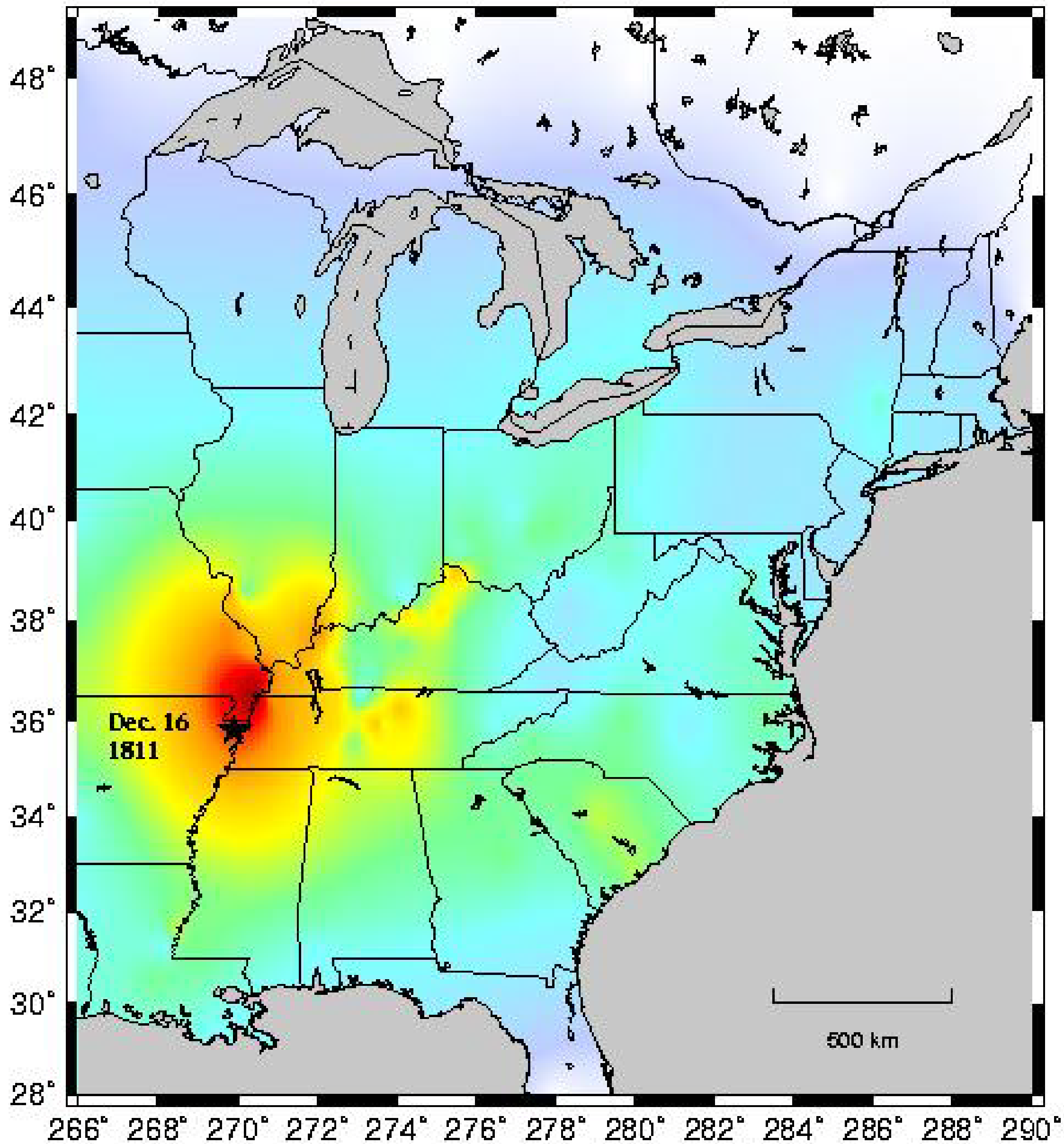
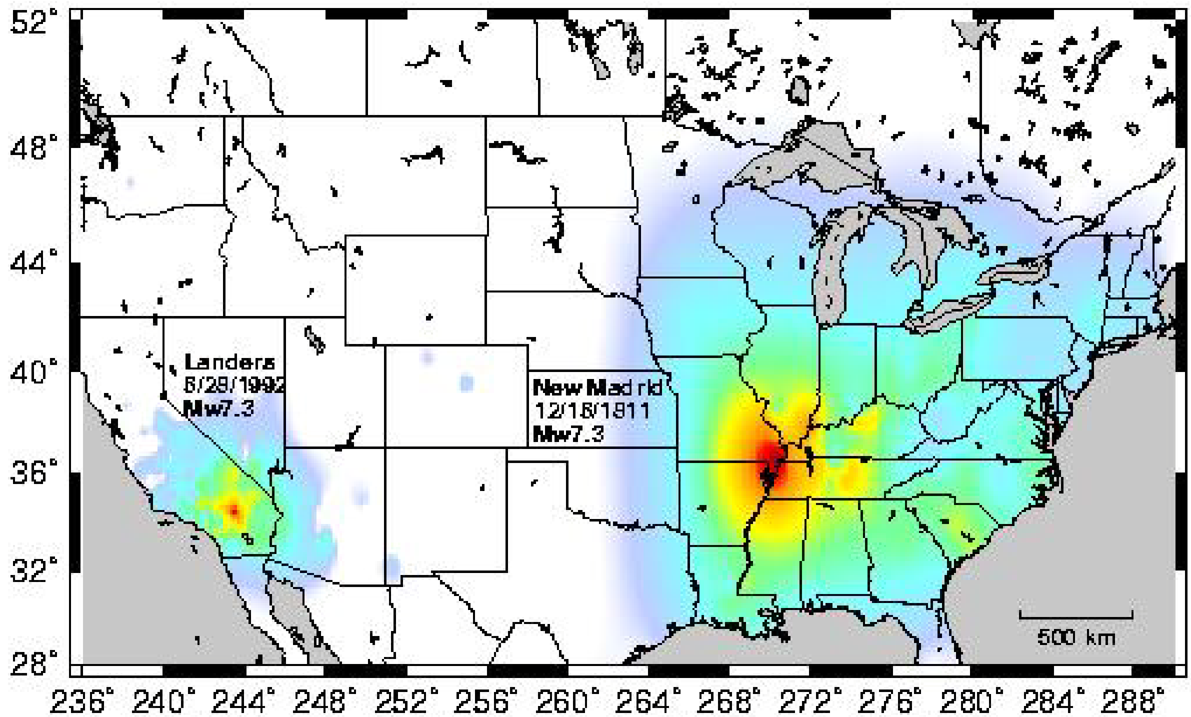


Figure 7. Comparison of Intensity observations for Central US and California earthquakes (http://pubs.usgs.gov/fs/2003/fs017-03/).



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Figure 8. Shake map for the December 16, 1811 New Madrid earthquake (from Susan Hough, http://pasadena.wr.usgs.gov/office/hough/).



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
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INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Figure 9. Shake map comparison of the M7.3 New Madrid and the M7.3 Landers earthquakes earthquake (from Susan Hough, http://pasadena.wr.usgs.gov/office/hough/).

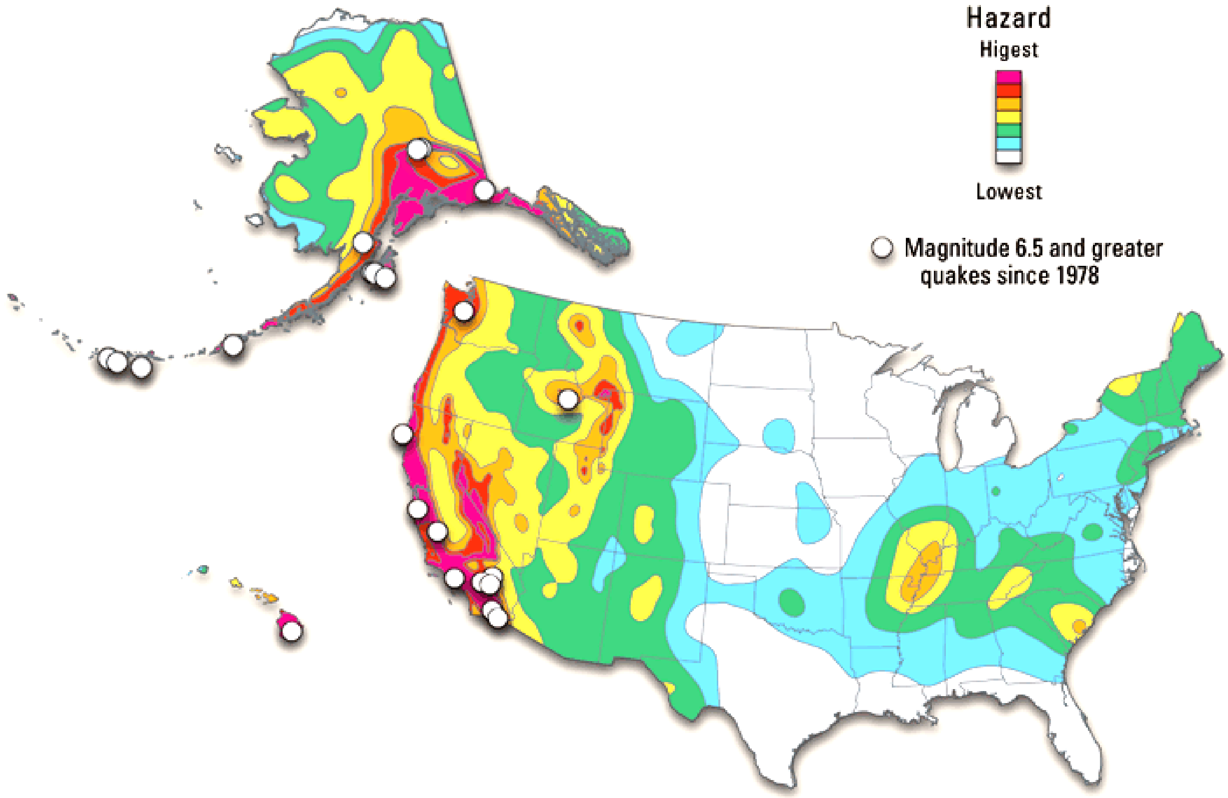


Figure 10. Earthquake hazard map for the U.S. (http://pubs.usgs.gov/fs/2003/fs017-03/).

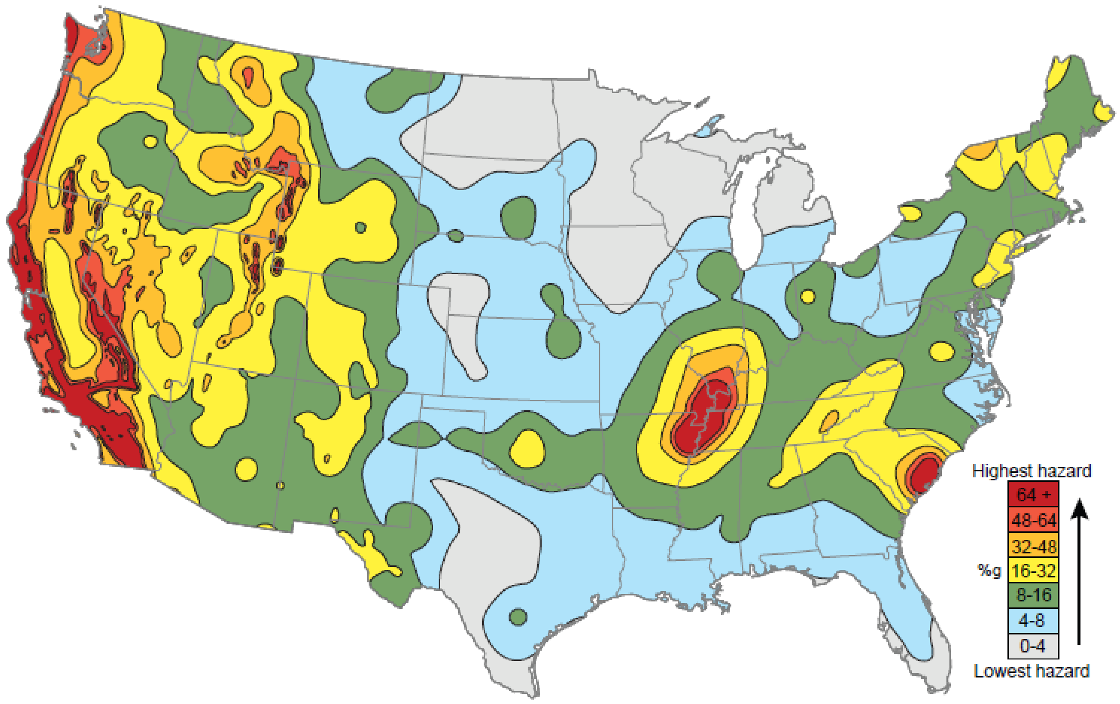
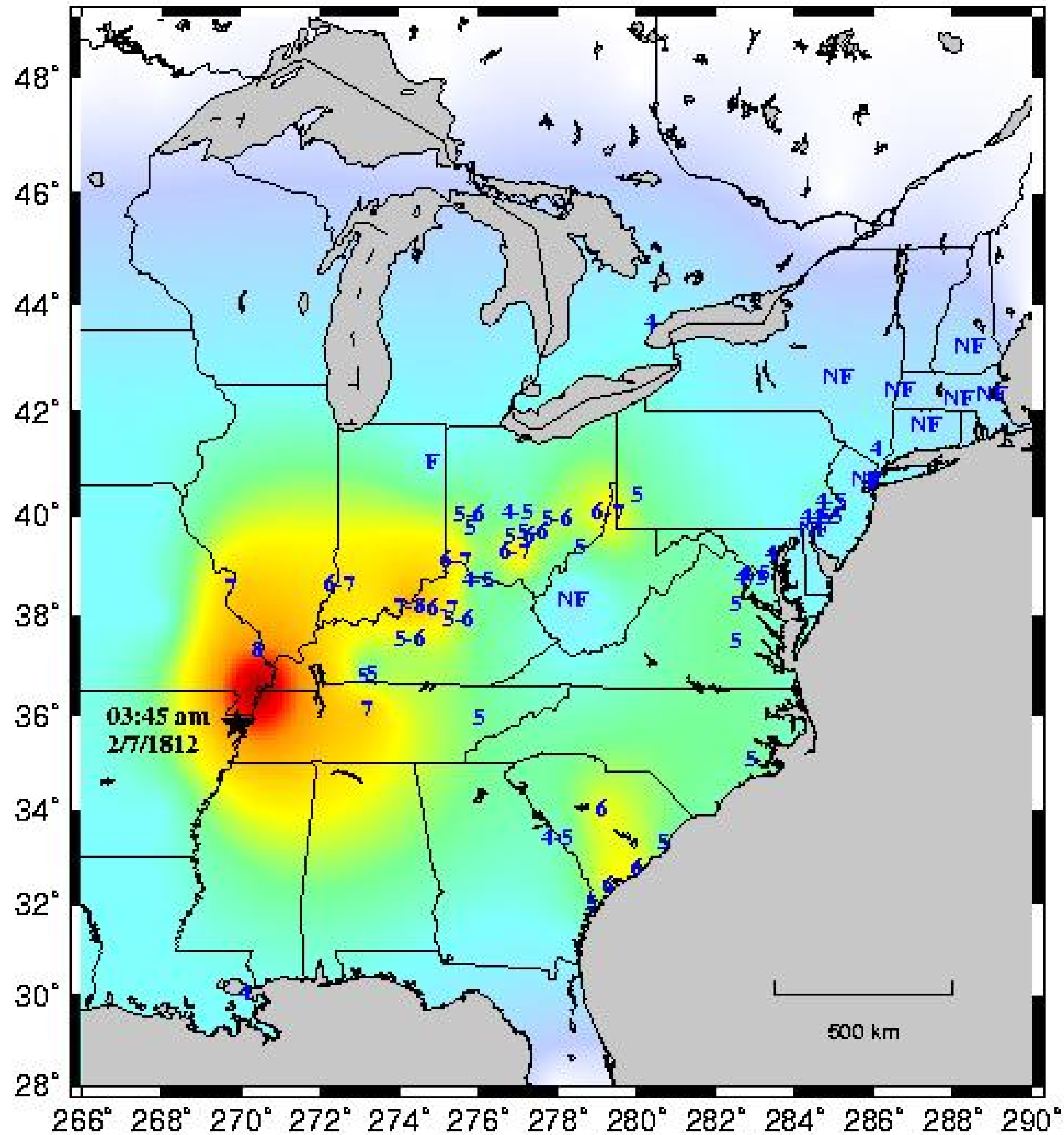


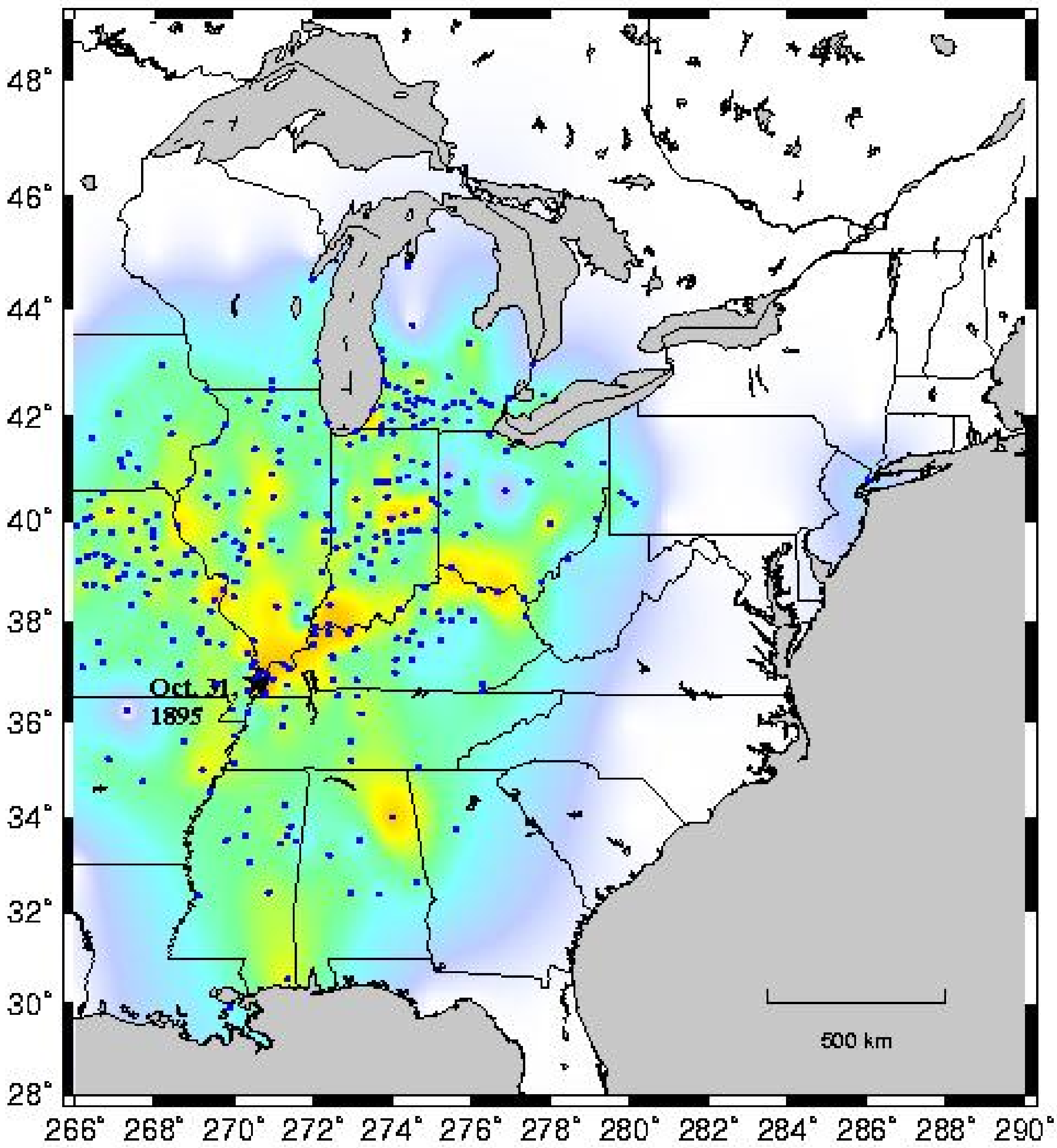
Figure 2. The U.S. Geological Survey shaking-hazard maps for the United States are based on current information about the rate at which earthquakes occur in different areas and on how far strong shaking extends from earthquake sources. Colors on this particular map show the levels of horizontal shaking that have a 1-in-50 chance of being exceeded in a 50-year period. Shaking is expressed as a percentage of g (g is the acceleration of a falling object due to gravity).

Figure 11. Earthquake hazard map for the US (http://pubs.usgs.gov/fs/2006/3125/pdf/FS06-3125_508.pdf).



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Figure 12. Shake map for the February 7, 1812 New Madrid earthquake (from Susan Hough, http://pasadena.wr.usgs.gov/office/hough/)



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
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INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Figure 13. Shake map for the October 31, 1895 M6.6 Charleston, Missouri earthquake (from Susan Hough, http://pasadena.wr.usgs.gov/office/hough/)

References:

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Calais, E., and S. Stein, Time-Variable Deformation in the New Madrid Seismic Zone, Science, 13 MARCH 2009 VOL 323, p. 1442, http://web.ics.purdue.edu/~ecalais/projects/noam/nmsz/sci09/Calais_Stein_Science_2009.pdf.

Calais, E; A. M. Freed; R. Van Arsdale; and S. Stein, Triggering of New Madrid seismicity by late-Pleistocene erosion, *Nature*, Vol 466|29 July 2010| doi:10.1038/nature09258, http://web.ics.purdue.edu/~ecalais/projects/noam/nmsz/nat10/Calais_etal_Nature_2010.pdf.

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http://pasadena.wr.usgs.gov/office/hough/ (Information on recent studies of the New Madrid earthquakes, links to updated intensity maps and contemporary accounts of the New Madrid earthquakes).

A color version of this document is available online at www.eas.purdue.edu/~braile (click on *News*).

Central U.S. Earthquakes Information (L. Braile, April 18, 2011)
Information for the Central U.S. Great Shakeout

Seismic Sleuths (can download pdf): http://www.fema.gov/library/viewRecord.do?id=3558
Tremor Troop (Earthquake) (can download pdf):
http://www.fema.gov/pdf/library/tremortroop.pdf

Get your schools ready and involved in the "Great Shake Out"
http://www.theindychannel.com/news/27449973/detail.html?taf=ind

USGS Earthquake Preparedness Web Page: http://earthquake.usgs.gov/learn/topics/?topicID=25

Central US Putting Down Roots in Earthquake Country (can download pdf):
http://pubs.usgs.gov/gip/119/

Central US Earthquake Guide (can download pdf):
http://www.cusec.org/publications/safety/earthquakeguide_lowres.pdf

Elected Officials Guide to Earthquakes in the Central US (can download pdf):
http://www.cusec.org/publications/planning/electedofficialsguide.pdf

Indiana Great Shakeout Page: http://www.in.gov/dhs/3536.htm

EQ video for kids:
http://www.youtube.com/watch?v=DmYcmpK31wI&feature=youtu.be&safety_mode=true&persist_safety_mode=1

EQ video:
http://www.youtube.com/watch?v=YfaGlzhsxjI&feature=youtu.be&safety_mode=true&persist_safety_mode=1

Central US Great Shakeout: http://www.shakeout.org/centralus/

New Madrid Bicentennial: http://newmadrid2011.org/

Shakeout Video on YouTube:
http://www.youtube.com/watch?v=6Rjyt7XAZrA&feature=player_embedded#at=173

Shakeout Video on Shakeout Page:
http://newmadrid2011.org/index.php?option=com_content&view=article&id=75:new-shakeout-video-available&catid=11&Itemid=25

Central US EQ Map: http://pubs.usgs.gov/imap/i-2812/

Center for Earthquake Research and Information (CERI, University of Memphis):
http://www.ceri.memphis.edu/index.shtml

CERI Great Shakeout Announcement:
http://www.ceri.memphis.edu/awareness/shakeout_ceus.html

CERI How to Survive an Earthquake: http://www.ceri.memphis.edu/awareness/survival.html

Drop, Cover, Hold On: http://dropcoverholdon.org/

Arkansas Earthquake Swarm (Guy Earthquake Swarm) Information:
http://www.ceri.memphis.edu/GUY/press_030411.html

USGS Poster – Guy Earthquake Swarm:
http://earthquake.usgs.gov/earthquakes/eqarchives/poster/2011/20110228.php

USGS Central US Fact Sheets: http://pubs.usgs.gov/fs/2009/3071/;
http://pubs.usgs.gov/fs/2009/3071/pdf/FS09-3071.pdf, http://pubs.usgs.gov/fs/2006/3125/,
http://pubs.usgs.gov/fs/2006/3125/pdf/FS06-3125_508.pdf

USGS Fact Sheets: http://earthquake.usgs.gov/learn/publications/pubs_factsheets.php