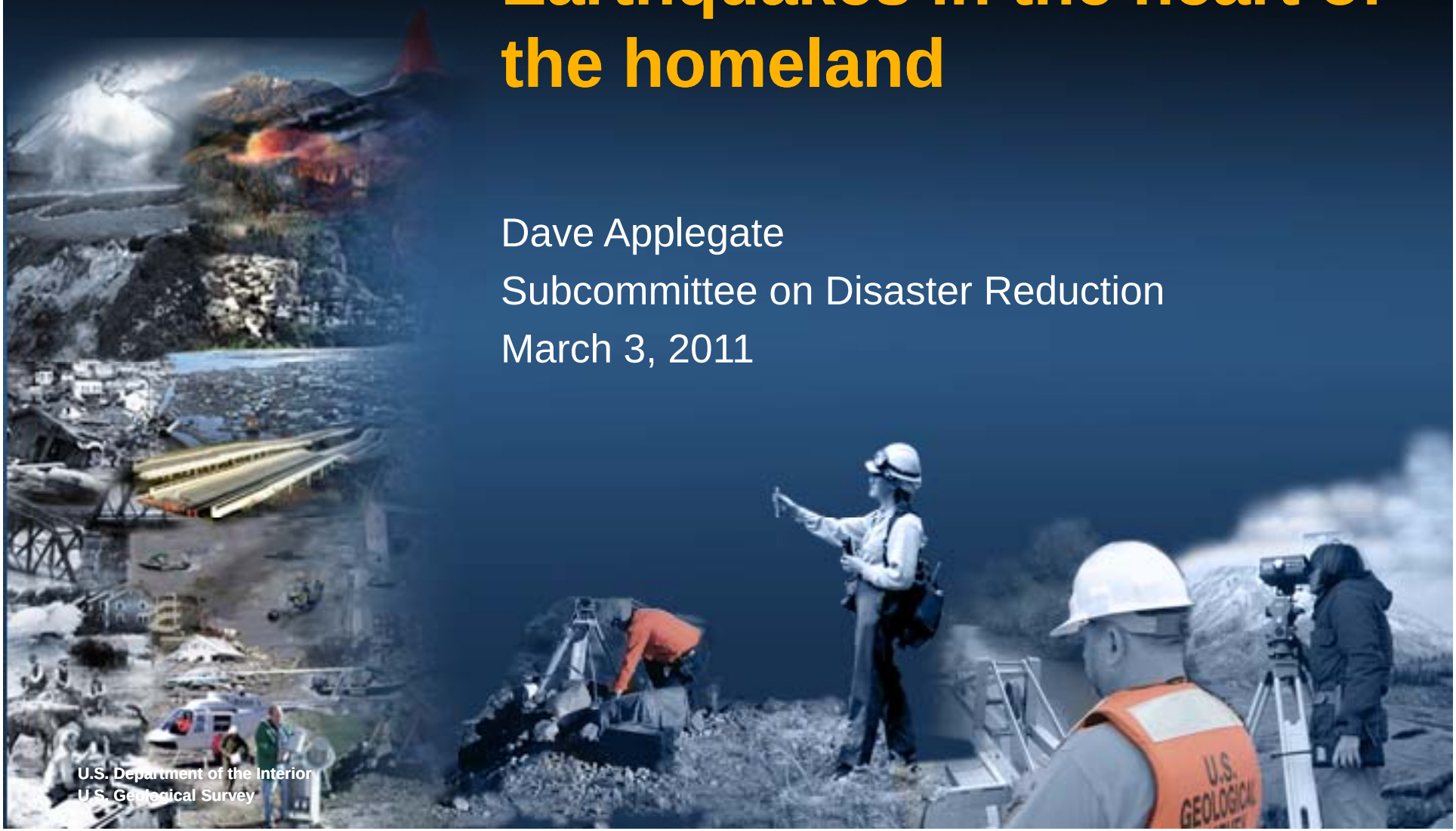
USGS
science for a changing world

Earthquakes in the heart of the homeland

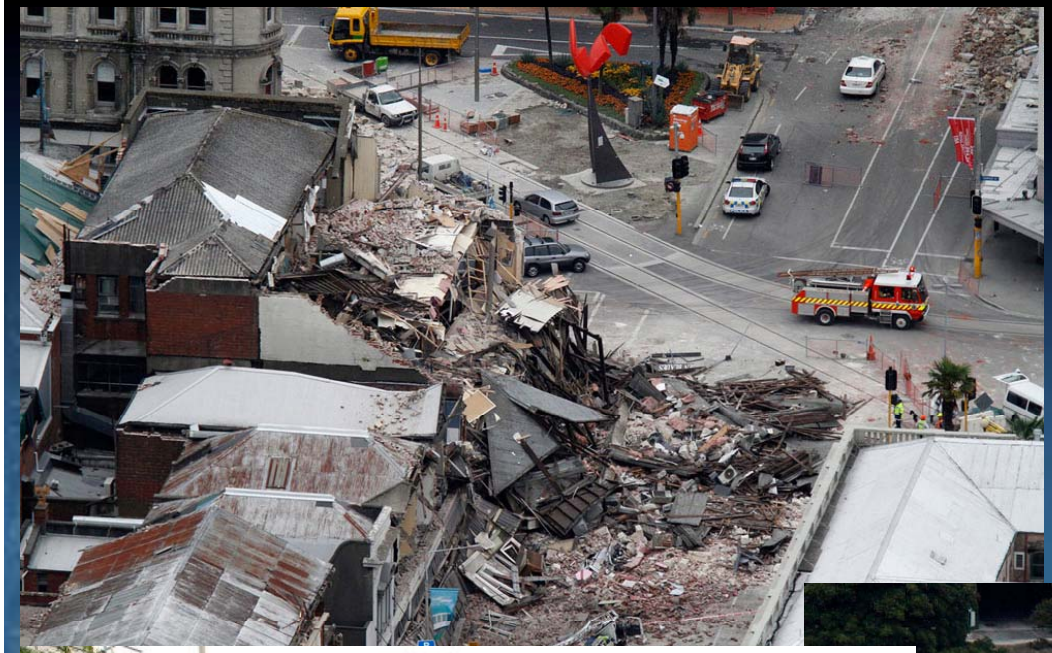
Dave Applegate

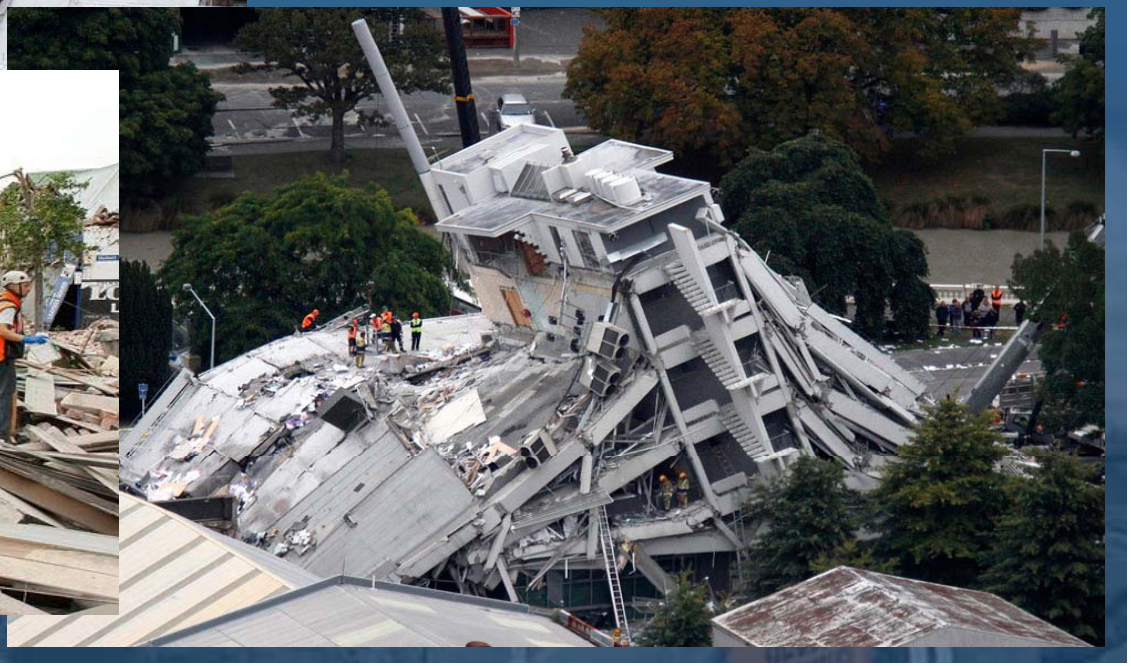
Subcommittee on Disaster Reduction

March 3, 2011



Christchurch earthquake





Christchurch earthquake liquefaction

Many of these abandoned houses are where "sand volcanoes" spurted a mix of sand and water up from the earth at what residents say was an alarming speed, raining down sludge and flooding homes.

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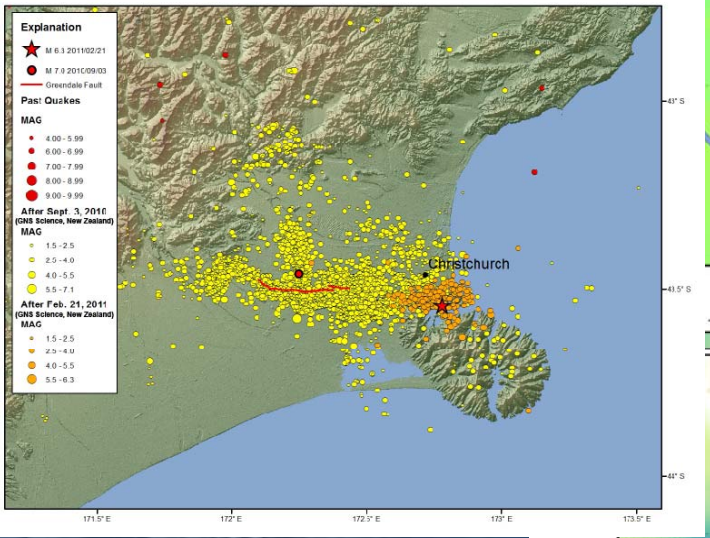
Comparing ShakeMap from the Darfield and Christchurch earthquakes



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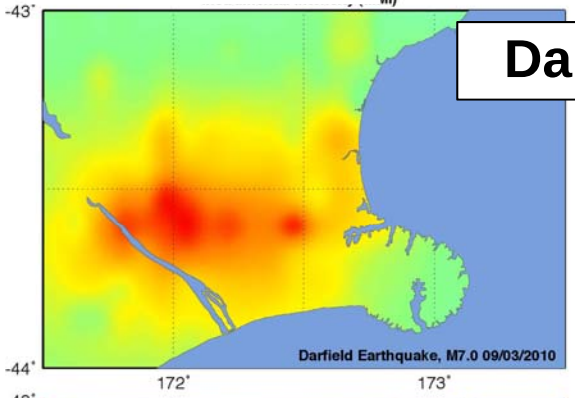
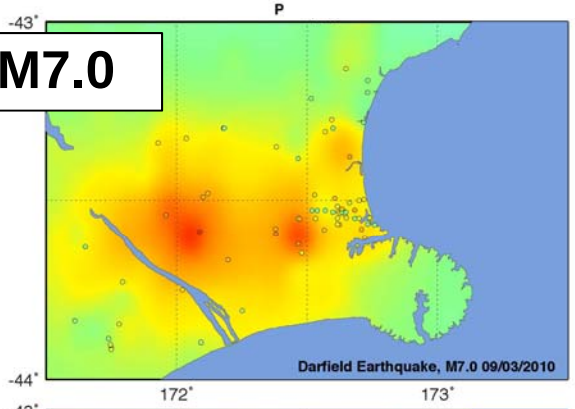
Shaking intensity

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+

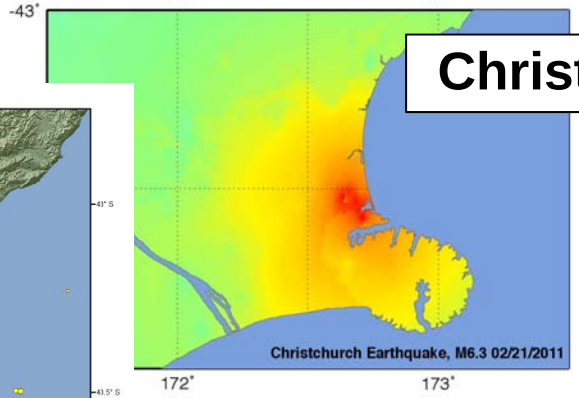
Peak ground acceleration

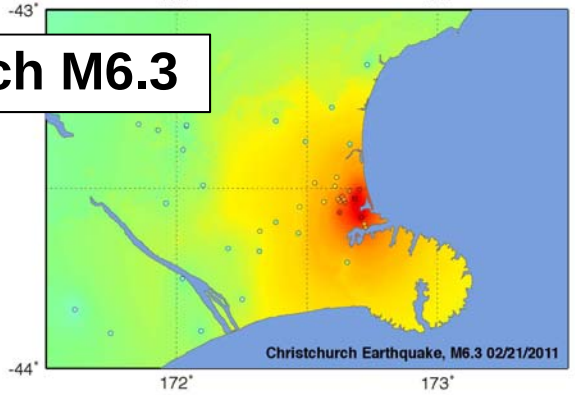
Darfield M7.0



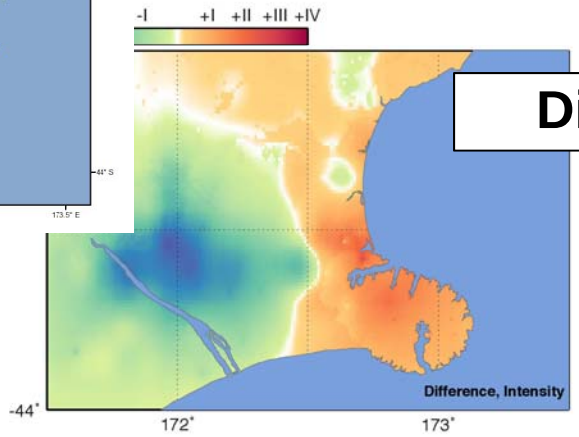


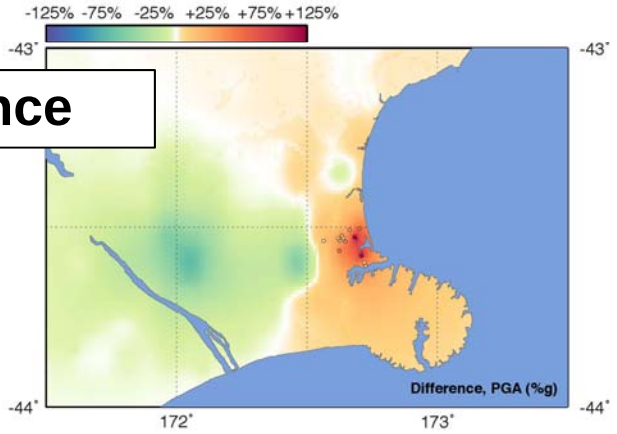
Christchurch M6.3



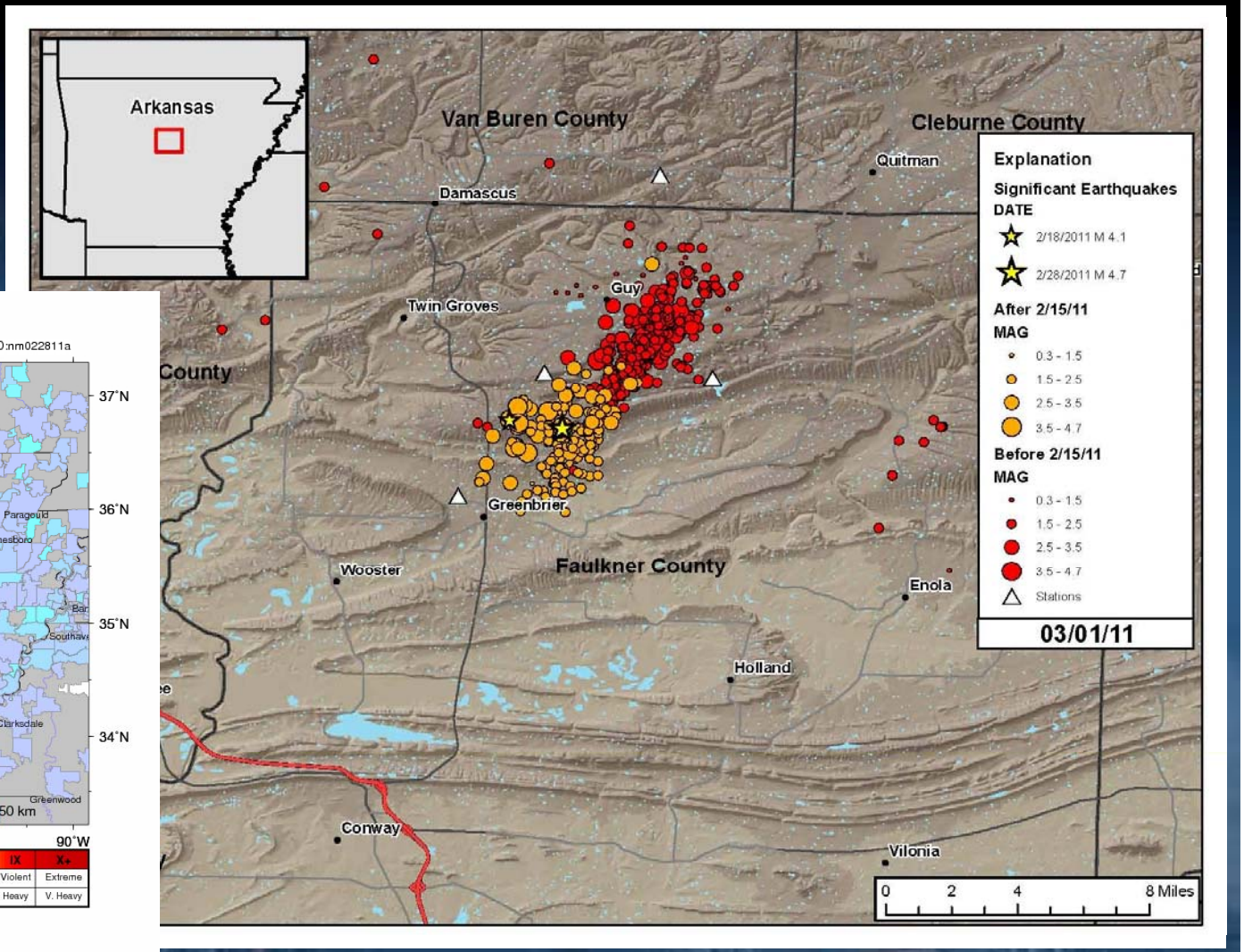


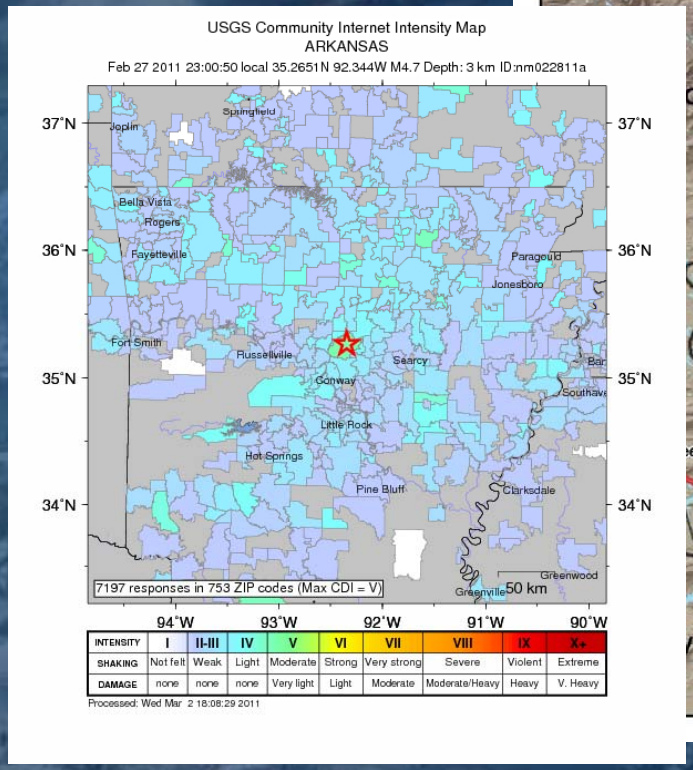
Difference





Earthquake swarms in Arkansas





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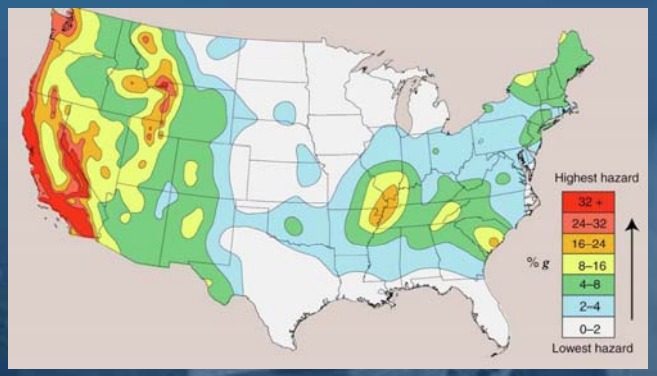
The USGS role in the National Earthquake Hazard Reduction Program

- Provide earthquake monitoring and notifications,
- Assess seismic hazards,
- Conduct targeted research needed to reduce the risk from earthquake hazards nationwide, and
- Undertake outreach activities.

USGS National Earthquake Information Center



nehrp

FEMA

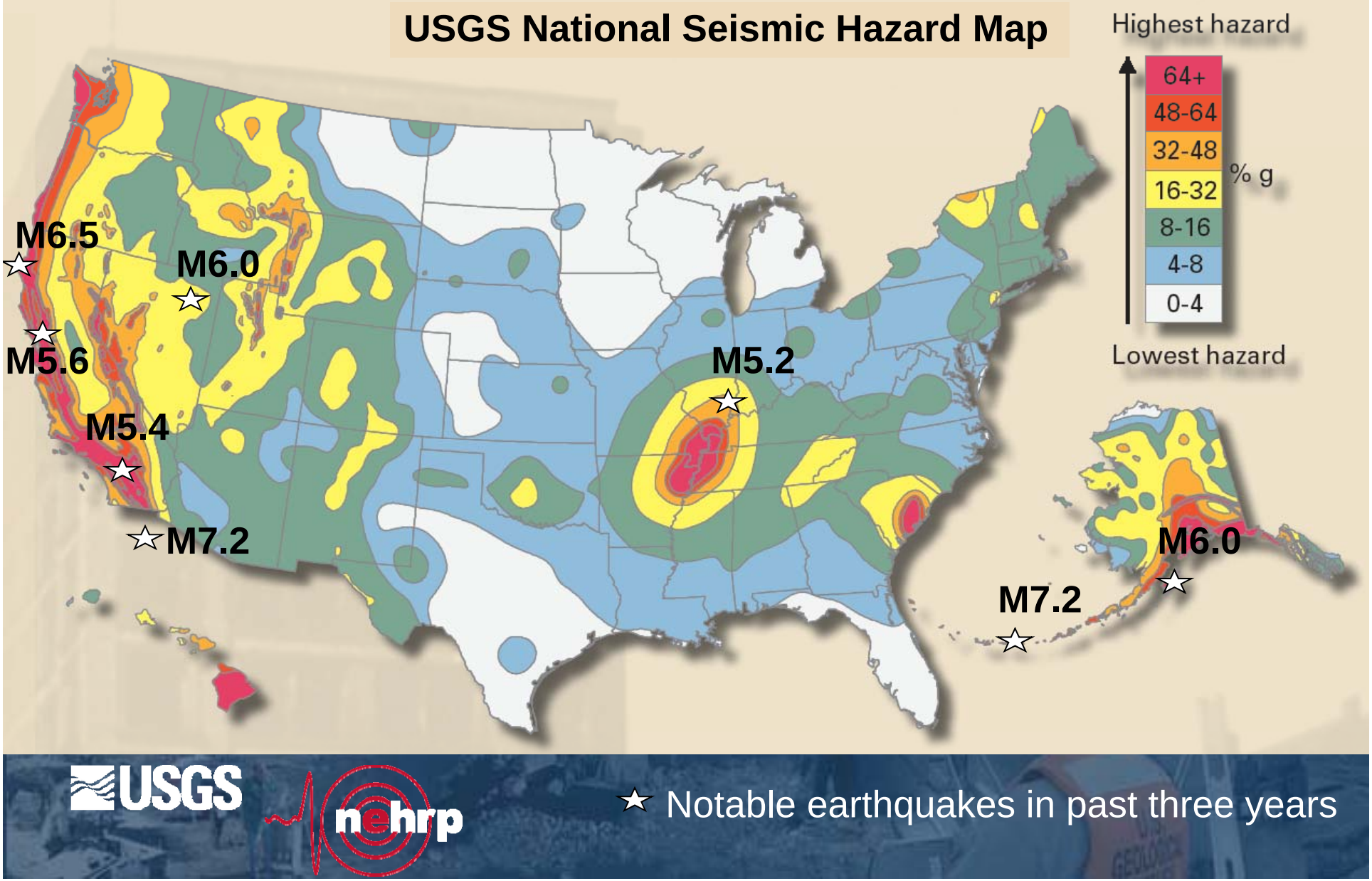
NIST National Institute of Standards and Technology

NSF

USGS science for a changing world

national earthquake hazards reduction program

Earthquakes are a national hazard

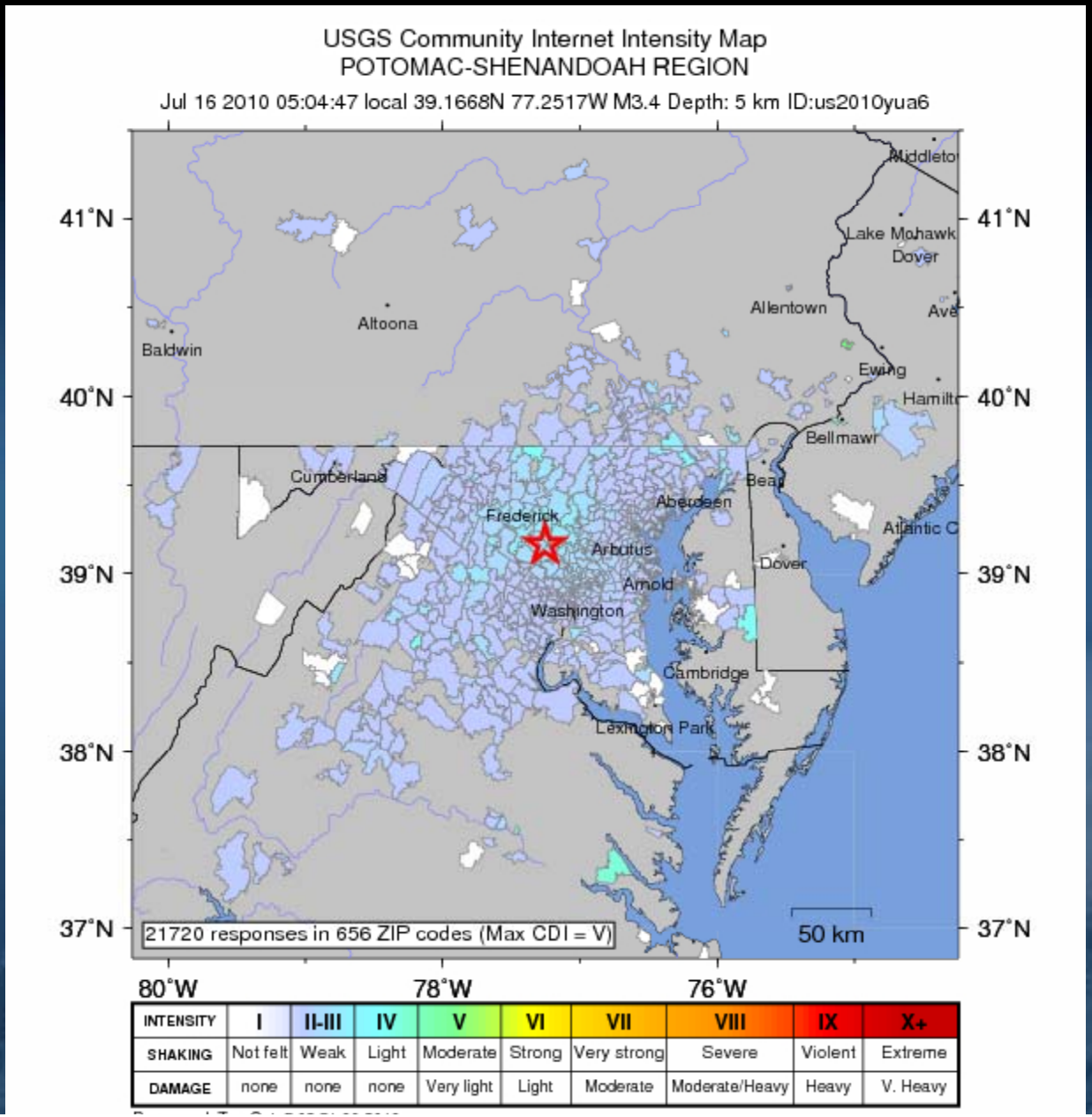


July's Great Gaithersburg Earthquake

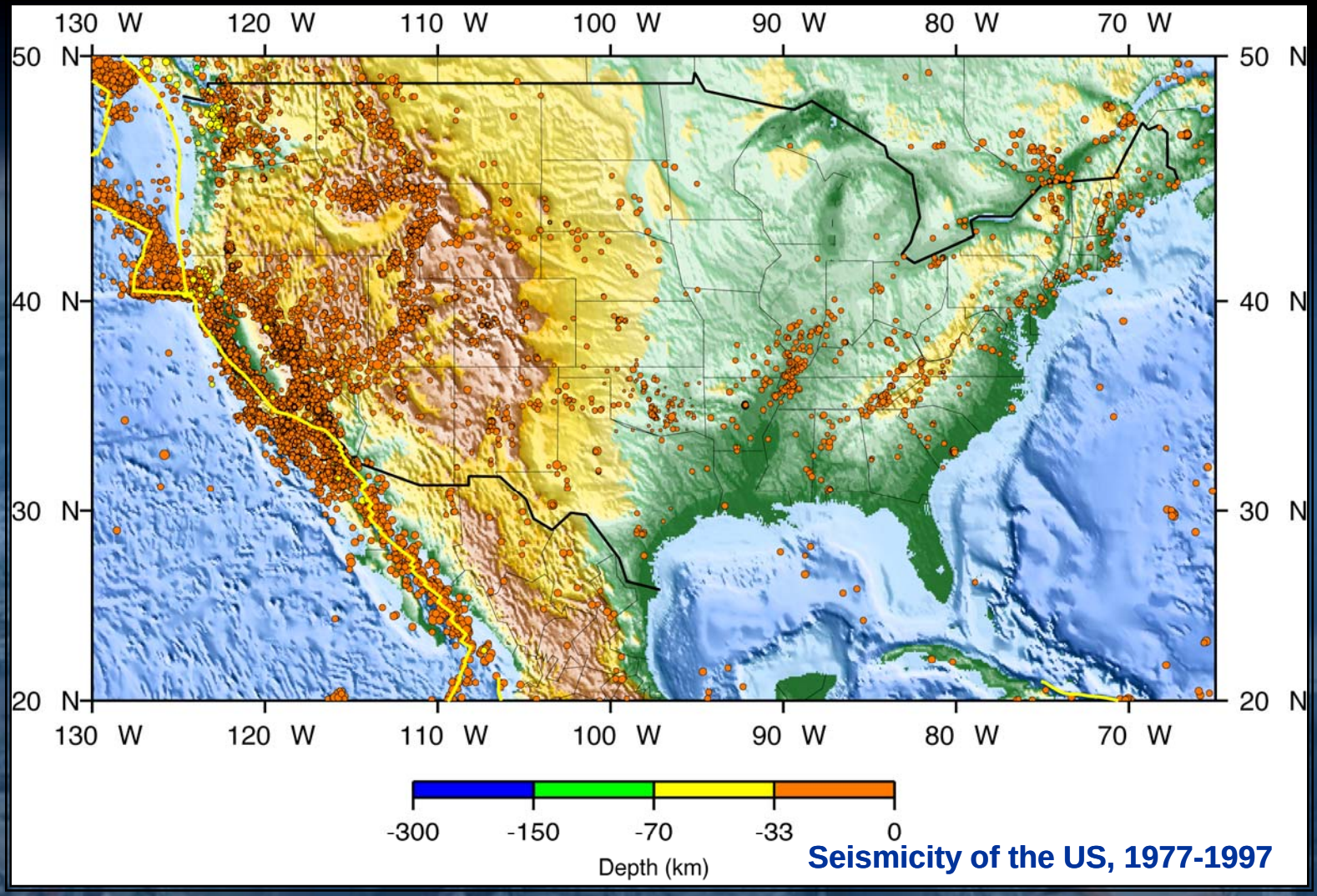
Magnitude-3.6

Light shaking felt in six states and DC

(except by yours truly)



Most earthquakes occur along plate boundaries but not all of them!

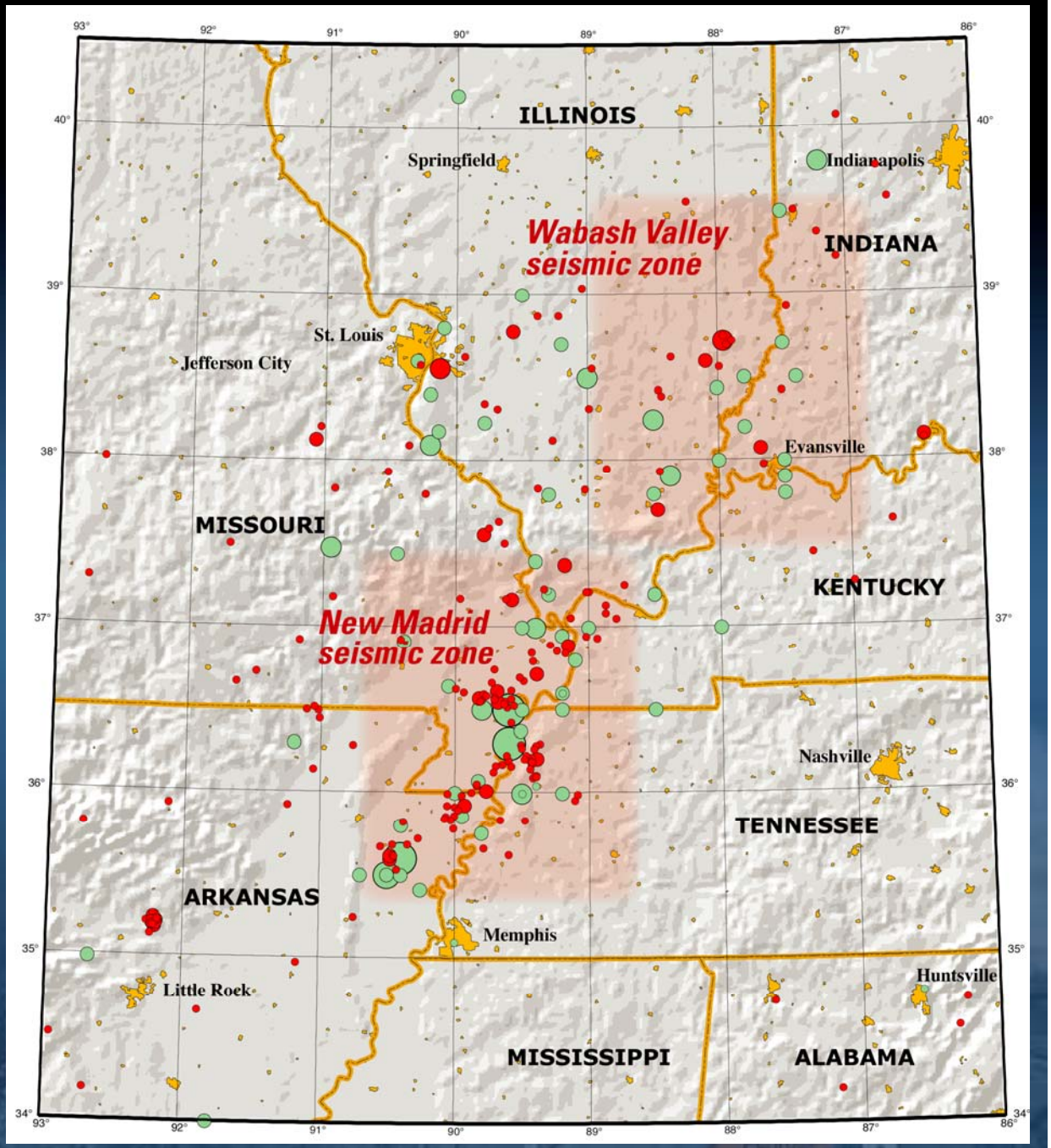


Seismicity of the US, 1977-1997

USGS

Earthquakes recorded in the New Madrid and Wabash Valley seismic zones

Red circles: 1974-2002
Green circles: Pre-1974
Larger earthquakes are represented by larger circles



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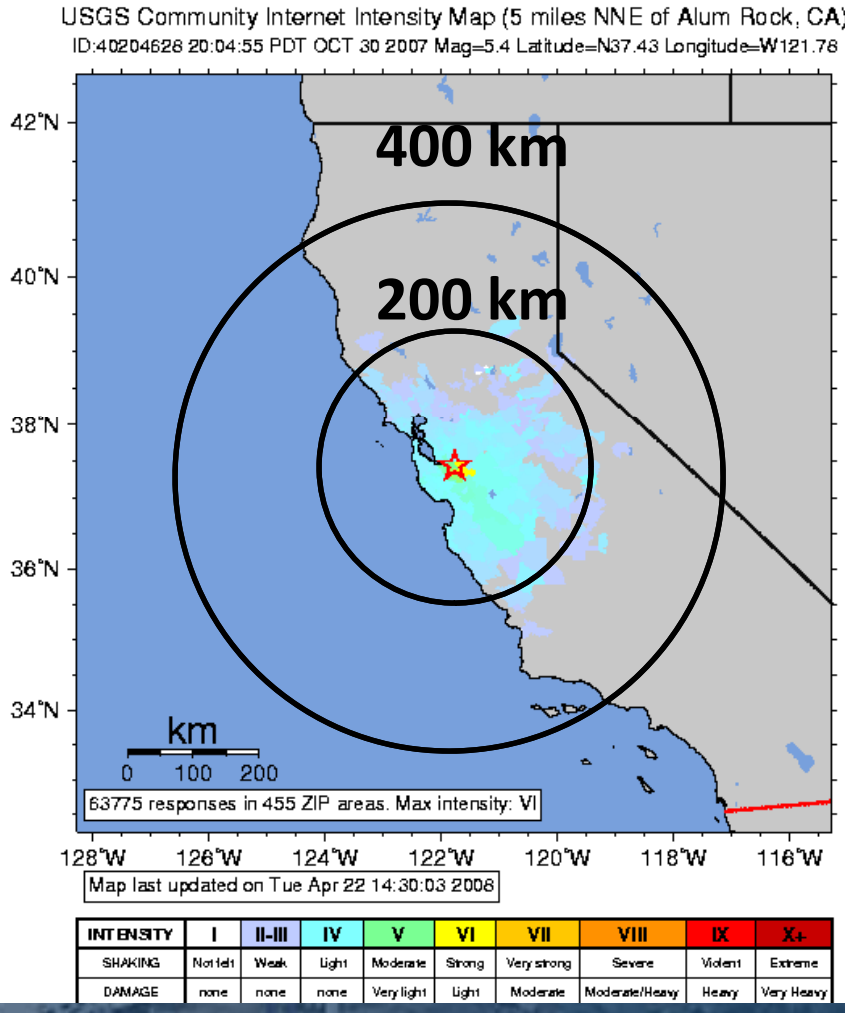
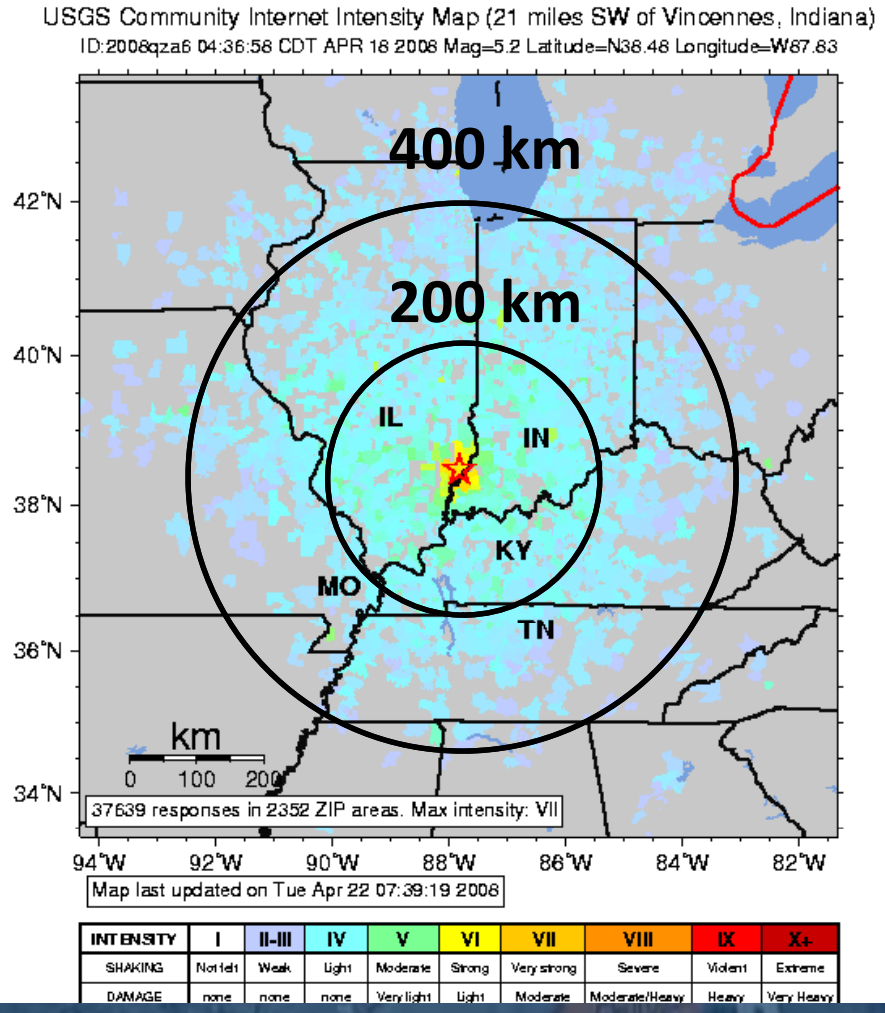
Central US earthquakes are widely felt

M5.4 Alum Rock, CA Oct 30, 2007

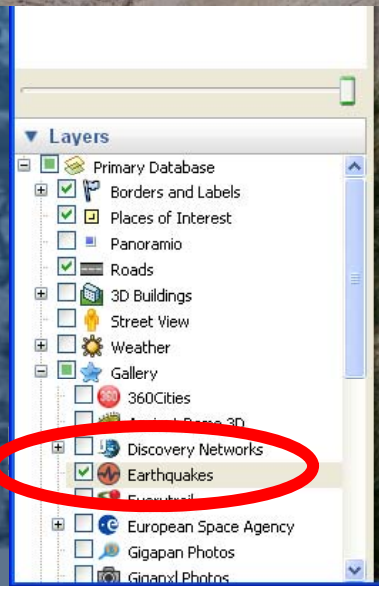


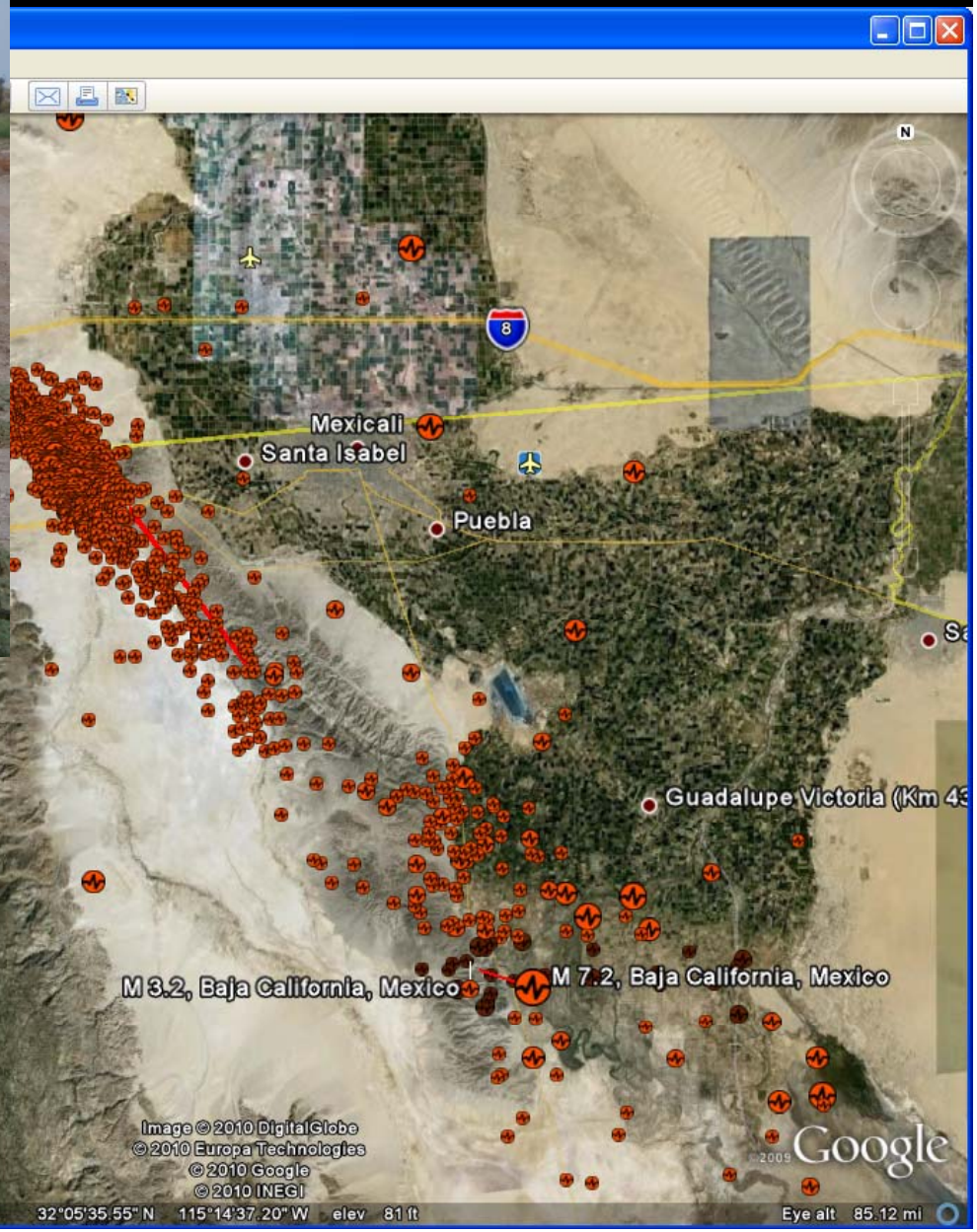
M5.2 Illinois, April 18, 2008



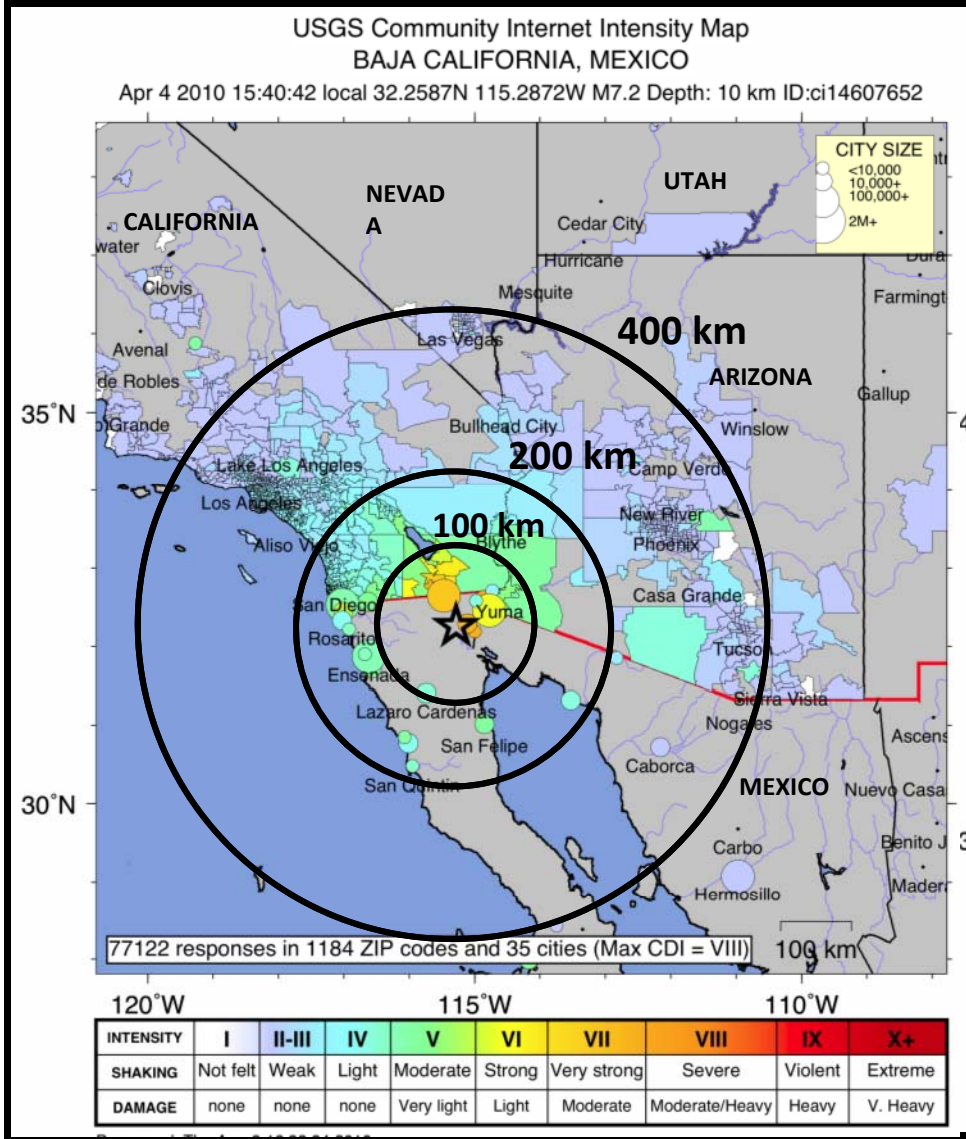
Magnitude-7.2, Northern Baja California 4/4/10

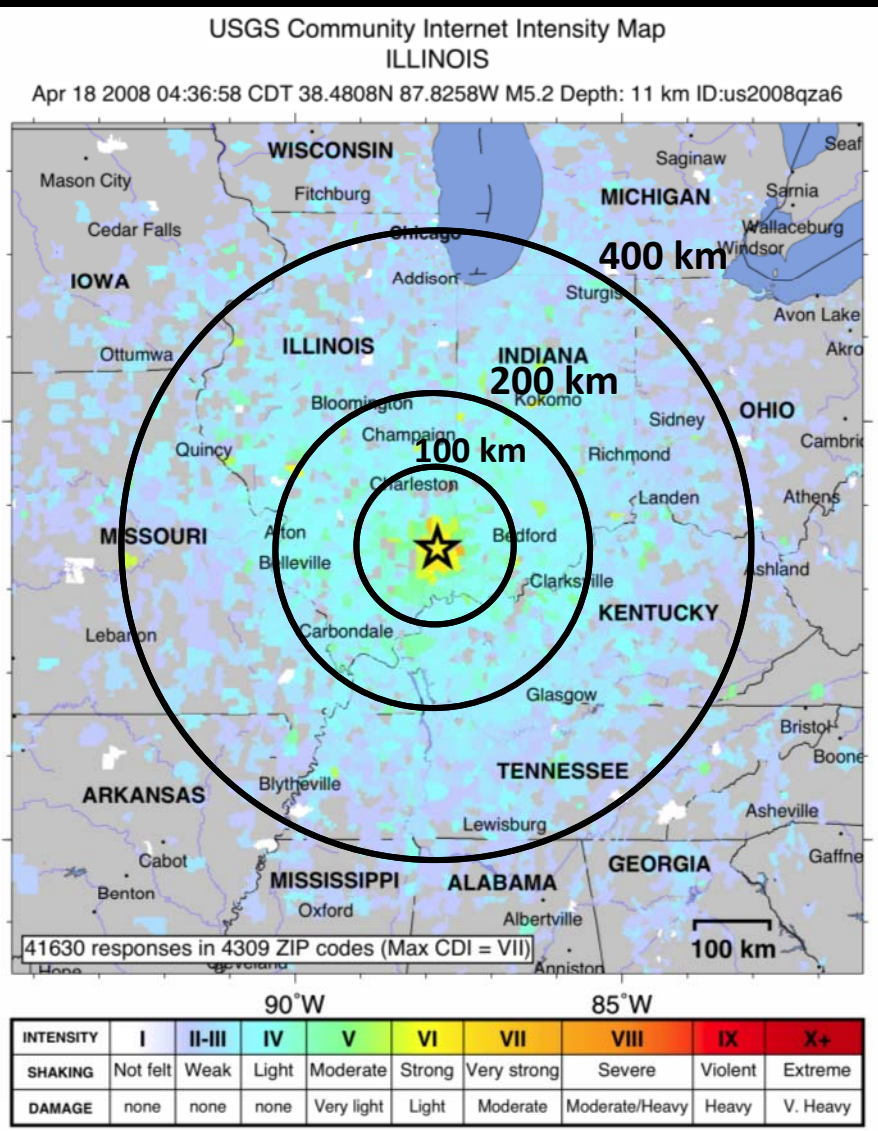
Photo by Heidi Stenner





Did You Feel It comparison: Baja and Illinois quakes





Magnitude 7.2

Magnitude 5.2

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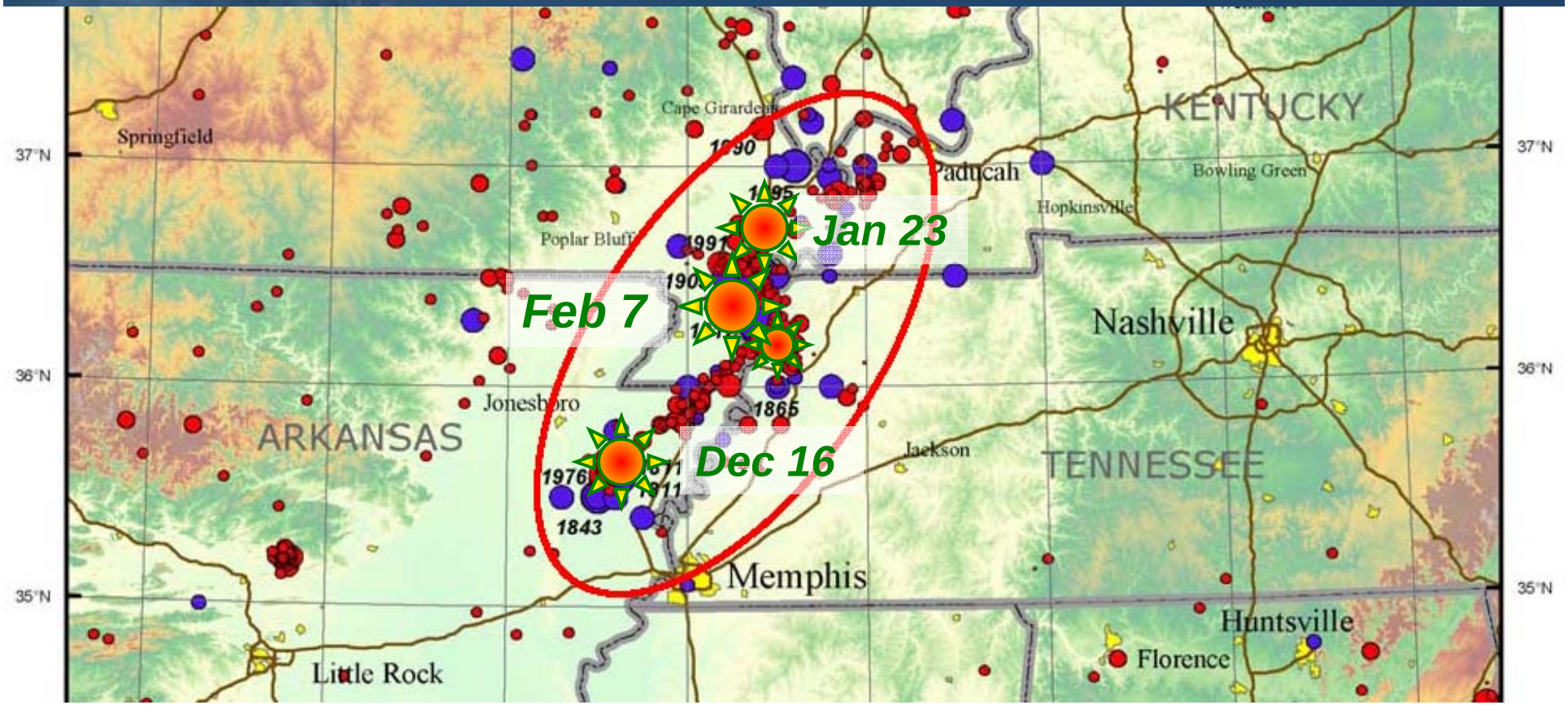
Figure courtesy of Dave Wald and Rob Williams, USGS

During the winter of 1811-1812,
three magnitude-7 or greater earthquakes
struck the New Madrid region along with
thousands of aftershocks.



Likely ground failures and impacts

- Slope failures along Chickasaw Bluffs could impact roads and major highways crossing the region
- Bank failures along rivers could affect ports and bridges and impede navigation especially of smaller rivers
- Levee failures along Mississippi River could lead to widespread flooding at time of event or later
- Widespread and severe liquefaction—leading to loss of bearing strength of soils and lateral spreading—could cause failures of foundations (bridge, building and tank), pipelines, and roads
- Uplift and subsidence of large tracts of land could alter rivers courses and drainage ditches
- Repeated large earthquakes and aftershocks could cause additional ground failures and damage to weakened structures

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Riverbanks caved

Riverbanks Falling In—Missouri River
Courtesy of the State Historical Society of Missouri,
Columbia, Mo.

Vast tracts of land sank and were uplifted

Reelfoot Lake

USGS

Movement of the Reelfoot fault in the Feb. 1812 earthquake produced waterfalls on the Mississippi River

Landslides occurred all along the bluffs

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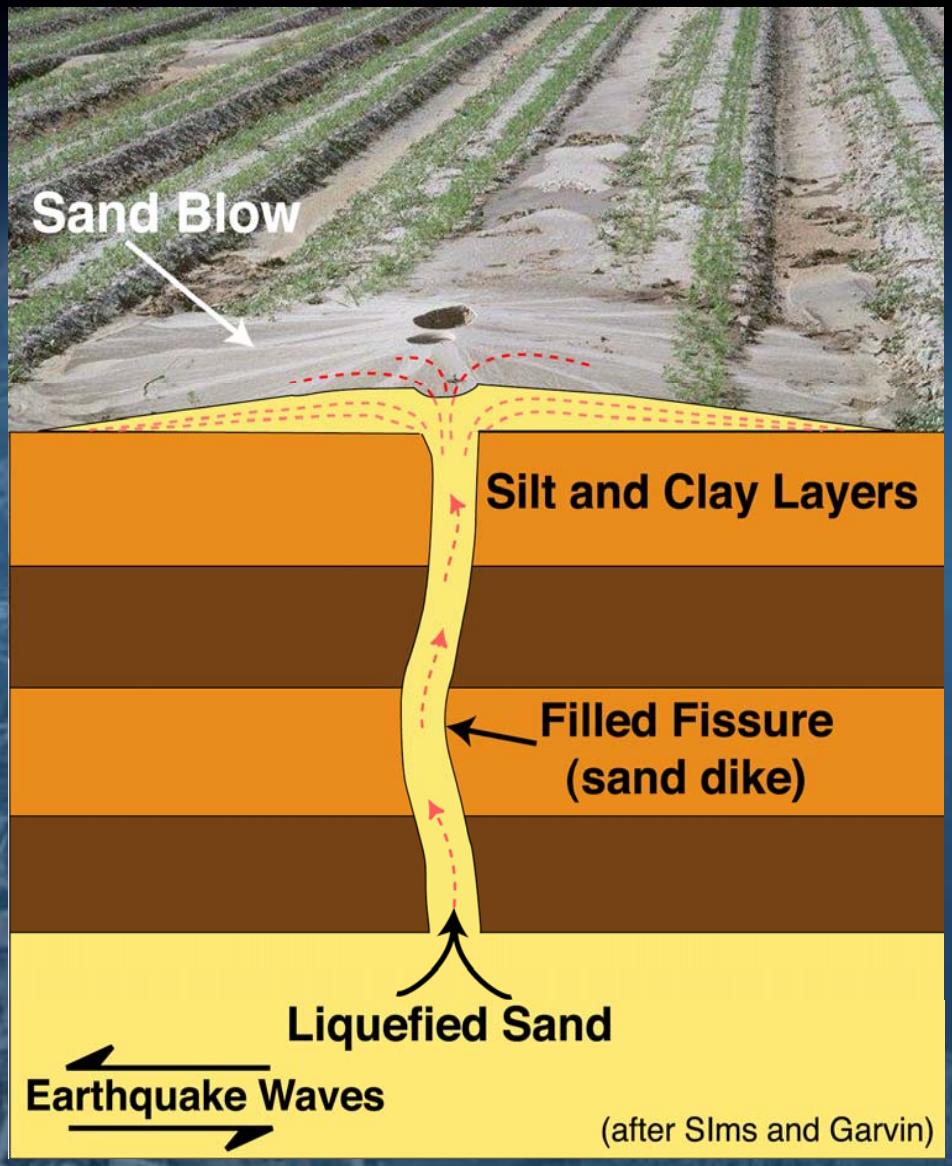
Sand blows erupted on floodplains …

From Fuller, 1912, *U.S. Geol. Surv. Bull. 494*

USGS nehrp

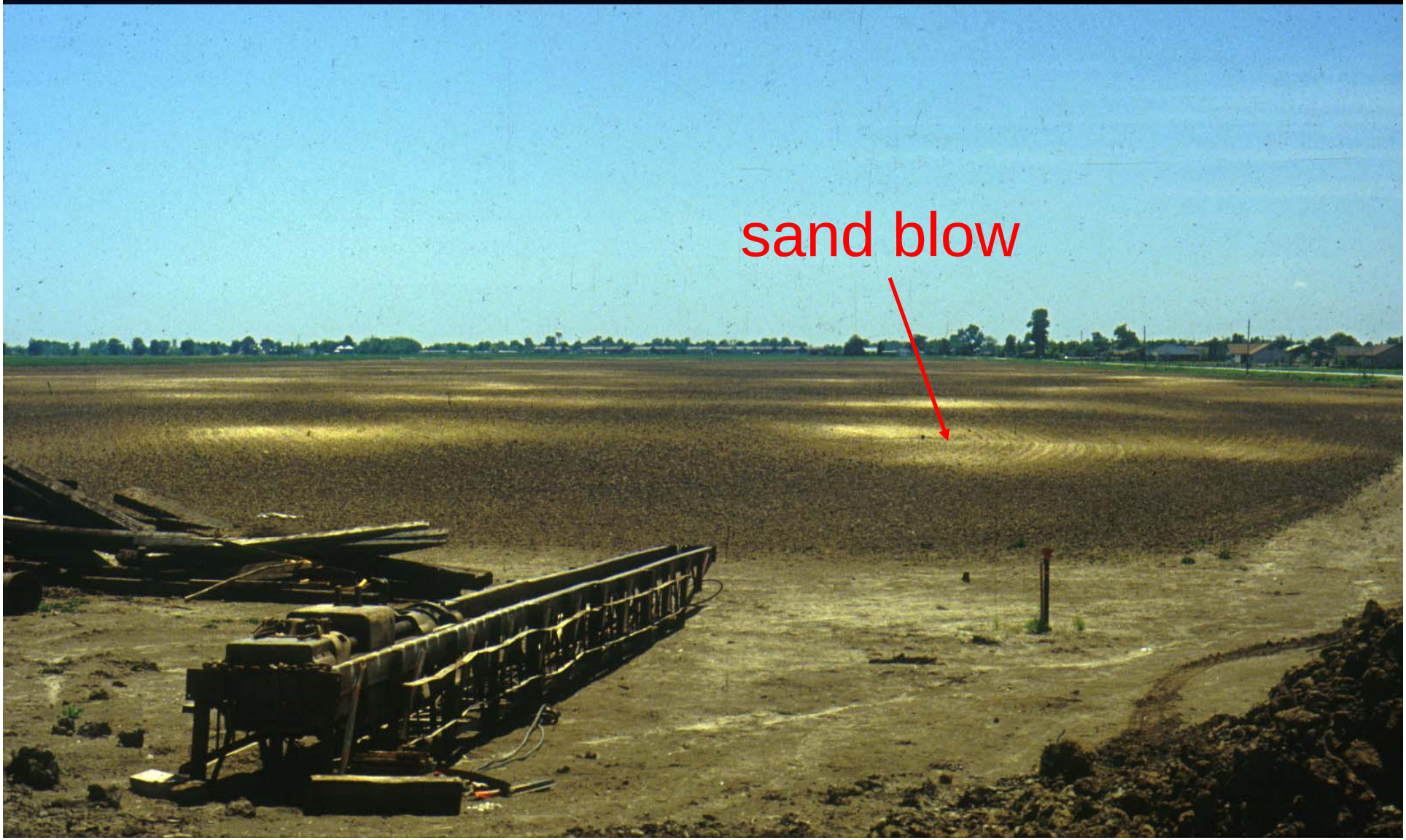
Liquefaction and sand blow formation



- During earthquake, water-saturated sand is shaken.
- If shaking is strong and lasts long enough, pore-water pressure builds up, sand loses its strength and acts like a liquid.
- A pressurized slurry of water and sand erupts to the surface, forming sand blows.

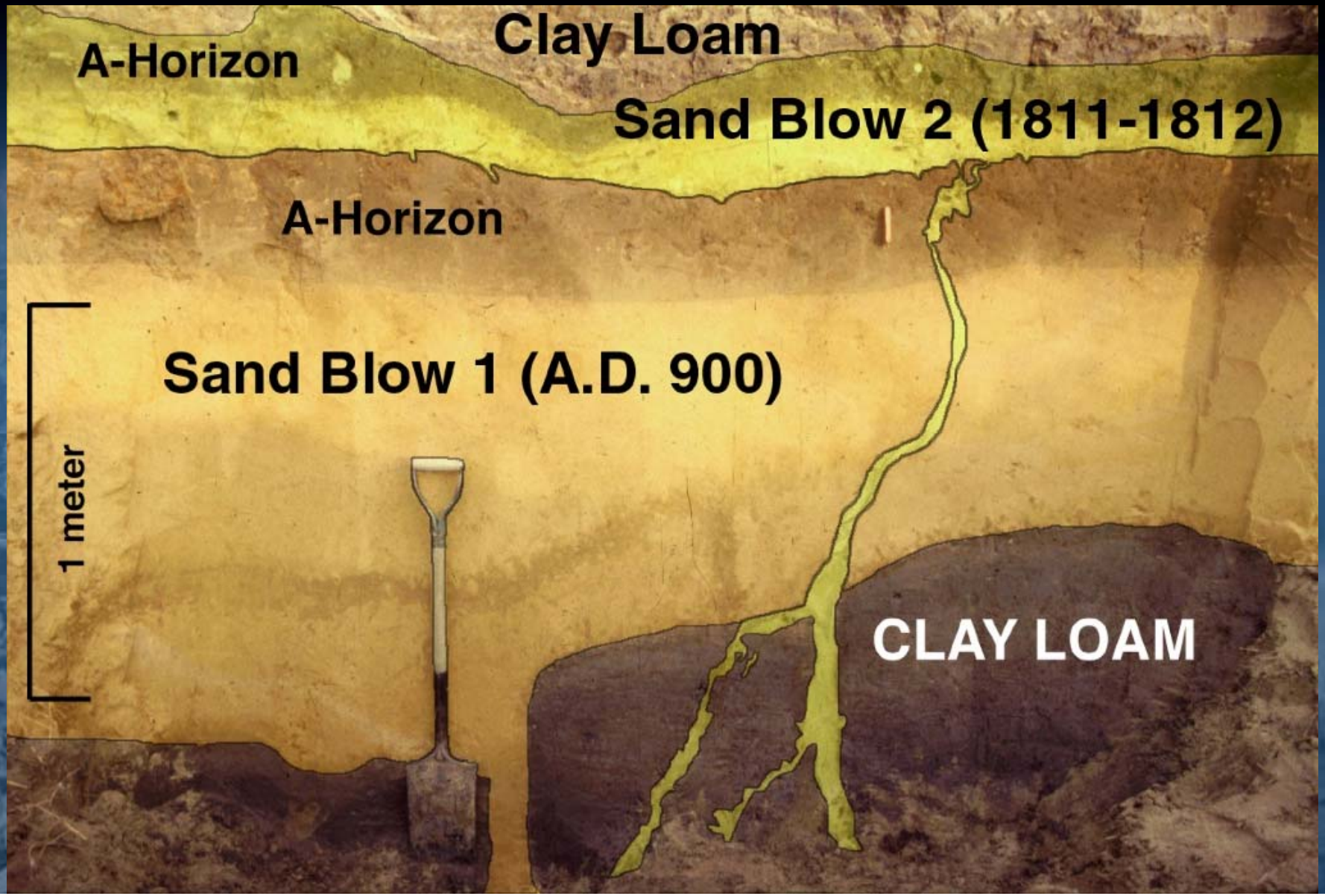
New Madrid sand blows cover a vast area

Blytheville, Arkansas



Smoking gun of large past earthquakes

Southeast Missouri



From geologic studies we now know

- New Madrid Seismic Zone produced large quakes in 1811-12, ~1450 AD, ~900 AD, and ~2350 BC
- The average time between these events is about 500 years at least during past 1200 years
- The prehistoric earthquakes were similar in size to the 1811-1812 earthquakes
- Each New Madrid event was a sequence of earthquakes, including multiple very large mainshocks, much like the 1811-1812 sequence

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Probabilities of large New Madrid earthquakes in the next 50 years

Magnitude ~ 7.5-7.7
(similar to 1811-1812 earthquakes)
Approximately 7-10%

Magnitude 6.0 or greater
(such as the 1843 Marked Tree, AR
and 1895 Charleston, MO earthquakes)
Approximately 25-40%

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Earthquake impacts modeled for FEMA catastrophic planning initiative

- The Mid-America Earthquake Center (MAEC) used HAZUS-MH to explore effects of New Madrid quakes were they to happen today.
  - *Modeled the (essentially) simultaneous rupture of entire zone, rather than several separate earthquakes.*
  - *Examined primary impacts of strong shaking.*
- 3500 fatalities, 80,000 injuries, 2 million needing shelter.
- Damage to buildings, bridges, dams, levees, pipelines.
- Direct economic losses $300 billion across eight states.

Mid-America Earthquake Center

The Great Central U.S. ShakeOut

Welcome to the Great Central U.S. ShakeOut! | OTHER SHAKEOUTS | SEARCH: GO

Be a Part of the ShakeOut
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GET READY TO SHAKEOUT!

Register now for the 2011 ShakeOut on April 28 at 10:15 a.m.!*

Participate in the Great Central U.S. ShakeOut to practice how to protect yourself during earthquakes, and to get prepared.

Learn how to participate below.

*Indiana will ShakeOut on April 19. Also, you can hold your drill at another time or day if best for your schedule.

Time to 2011 ShakeOut:
3 months, 7 days 21:35:48

ANNOUNCEMENTS

The Great Central U.S. ShakeOut is a linked event to NLE 2011

Who is Participating?

ShakeOut Resources: ShakeOut Drill Manuals, flyers, movies, and much more

Why Drop, Cover, and Hold On?

QUICK LINKS

How to plan your drill and get prepared:

Select your category...

Earthquake hazards in your state:

Select your state...

FAQ: Frequently Asked Questions

INTERACTIVE MAP

Over 850,000
Participants and Counting!

Click the map for details about each state

Other Areas

LEARN & PLAY

PLAY BEAT THE QUAKE

QUAKE QUIZ

ARE YOU READY? > PREPARE > PROTECT > RECOVER

FEMA | nehrp | Ready (Prepare. Plan. Stay Informed.®) | American Red Cross | USGS science for a changing world

http://www.shakeout.org/centralus/

http://newmadrid2011.org/

1811-2011 Bicentennial New Madrid Earthquakes

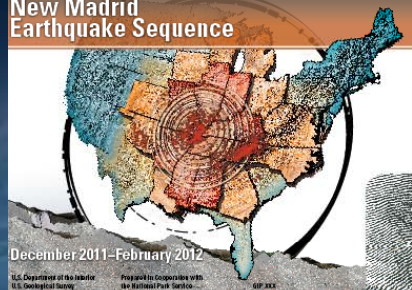
Earthquakes of the Past, Science of the Present, Understanding of the Future...

USGS science for a changing world

Bicentennial of the 1811–1812

New Madrid Earthquake Sequence

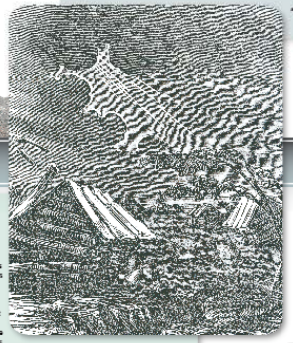
Personal Accounts from the 1811–1812 New Madrid Earthquakes



Little Prairie, Missouri

"I have heard accounts of the earthquake, on the other side of Mississippi, a great deal of the country in the neighborhood of Little Prairie is said to be much injured. Cracks are yet in the earth in place 18 feet wide...such large quantities of white sand have been thrown up that to many places that was formerly rich land looks like a sand beach – from all these stories I conclude that the shock has been severe, and that the country has sustained some injury. It is certainly true that many people are removing from it. I saw a gentleman who told me that he was in the barge twelve miles above New Madrid when the first shock we experienced took place – that in the morning during the shock he was the water in the river at some places boil[ed] up 12 or 15 feet higher than the surface of the surrounding river, that in those places large quantities of leaves, dirt, and as he supposed, stone-coal were thrown up; that the shock was so violent, that he saw cotton-wood trees 18 or 24 inches through snapped off; and that he thinks, at least, two hundred acres of land along the margin of the river, fell in".

—Extract of a letter written by a gentleman of great respectability resid in lower Tennessee to his friend in Knoxville, dated Jan. 25, 1812. Published in the Knoxville Gazette, February 15, 1812



Saint Louis, Missouri

Saint Louis, MO
Louisiana Gazette
Dec. 23, 1811

Earthquake

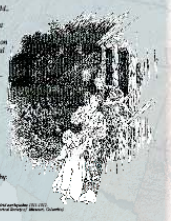
On Monday morning last, about a quarter past two, St. Louis and the surrounding country, was visited by one of the most violent shocks of earthquake that has been recorded since the discovery of our country. As we were all wrapt in sleep, each tells his story in his own way. I will also relate my simple tale. At the period above mentioned, I was roused from sleep by the clamor of windows, doors and furniture in tremulous motion, with a distant rumbling noise, resembling a number of carriages passing over pavement – in a few seconds the motion and subterraneous thunder increased more and more; believing the noise to proceed from N. or N.W. and expecting the earth to be relieved by a volcanic eruption, I went out of doors & looked for the dreadful phenomenon. The agitation had now reached its utmost violence. I entered the house to snatch my family from its expected ruins, but before I could put my design in execution the shock had ceased, having lasted about one and three fourth minutes. The sky was obscured by a thick hazy fog, without a breath of air. Fahrenheit thermometer might have stood at this time at about 35 or 40°. At forty seven minutes past two, another shock was felt without any rumbling noise and much less violent than the first, it lasted near two minutes. At thirty four minutes past three, a third shock nearly as tremulous as the first, but without as much noise, it lasted about fifty seconds, and a slight trembling continued at intervals for some time after. A little after day light, a fourth shock was felt, but with less violence than any of the others, it lasted nearly one minute. About 8 o'clock, a fifth shock was felt; this was almost as violent as the first, accompanied with the usual noise, it lasted about half a minute; this morning was very hazy and unusually warm for the season, the houses and fences appeared covered with a white frost, but on examination it was found to be vapour, not possessing the chilling cold of frost: indeed the morn was embraced in awful gloom. At half past eleven, a slight shock was felt, and about the same hour on Tuesday last, a smart shock was felt – several gentlemen declare, they felt shocks at other intervals.

—Street R. 1884. The Historical Seismicity of the Central United States: 1811–1812. Final Report, contract 14-08-0001-21191, U.S. Geological Survey, Append. A, 316 pp.

New Madrid, Missouri

"On the 16th of December, 1811, about two o'clock, A.M., we were visited by a violent shock of an earthquake, accompanied by a very awful noise resembling loud but distant thunder, but more hoarse and vibrating, which was followed in a few minutes by the complete saturation of the atmosphere, with sulphurious vapor, causing total darkness. The screams of the affrighted inhabitants running to and fro, not knowing where to go, or what to do – the cries of the birds and beasts of every species; the cracking of trees falling, and the roaring of the Mississippi – the current of which was retrograde for a few minutes, owing as it supposed, to an irruption in its bed – formed a scene truly horrible. From that time until about sunrise, a number of lighter shocks occurred; at which time one still more violent than the first took place, with the same accompaniments as the first, and the terror which had been excited in everyone, and indeed in all animal nature, was now, if possible doubled".

—1816 letter from Bliss Bryan (a resident of New Madrid) to her friend Lucinda Dark, who later published the letter in his biography: History of Cosmopolite



Nelson, Kentucky

"What are we gonna do? You cannot fight it cause you do not know how. It is not something that you can see. In a storm you can see the sky and it shows dark clouds and you know that you might get strong winds but this you can not see anything but a house that just lays in a pile on the ground – not scattered around and trees that just falls over with the roots still on it. The earth quake or what ever it is come again today. It was as bad or worse than the one in December. We lost our smands Jane in this one – a log fell on her. We will bury her upon the hill under a clump of trees where Bayes Ma and Pa is buried. A lot of people thinks that the devil has come here. Some thinks that this is the beginning of the world coming to a end".

—Bastiga Henrich Clay, January 23, 1812

Washington, D.C.

"The reverberation of earthquakes continues the uproar from certain quarters. They have slightly reached the state of N. T. and have been severely felt W. & S. Westerly. There was one here this morning at 5 or 6 minutes after 4 M. It was rather stronger that here than any preceeding one, & lasted several minutes, with sensible though very slight repetitions throughout the succeeding hour".

—James Madison, U.S. President, in a February 7, 1812 letter to Thomas Jefferson (Library of Congress)

Nashville, Tennessee

"An alarming earthquake was felt in this town and the adjoining country as far as we have heard, about 15 m past two o'clock yesterday morning. The shocks, which continued (until) after day, were some of them very severe – so much so that the heaviest houses seemed to be rocked to pieces, however we have heard of no real injury sustained, except the fall of some chimneys in the country...".

—An account of the December 16, 1811, mainshock as found in The Clarion & Tenn. Gazette Dec. 17, 1812

Mississippi River, Downstream from New Madrid, Missouri

"I resolved to wait until morning, and caused the boat to be moored to a small island, about five hundred yards above the entrance into the channel. After supper we went to sleep as usual; and in the night, about ten o'clock, I was awakened by a most tremendous noise, accompanied by so violent agitation of the boat that it appeared in danger of upsetting. Before I could get the bed, or rather the skin, upon which I lay, the four men who slept in the other cabin rushed in, and cried out in the greatest terror. I passed them with some difficulty, and ran to the door of the cabin, where I could distinctly see the river agitated as if by a storm; I could distinctly hear the crash of falling trees, and the screaming of the wild fowl on the river, but found that the boat was still safe at her moorings; I was followed by the men and the pardon, who, in accents of terror were still enquiring what it was... At day-light we had counted twenty-seven shocks during our stay on the island, but still found the chasm so that it might be passed. The river was covered with foam and drift timber, and had risen considerably, but our boat was safe".

—Bradbury, John (1810). Travels in the interior of North America in the years of 1809, 1810, and 1811

We have the following description of the earthquake from a gentleman who was in the Large Barge and lay at anchor in the Mississippi a few leagues below New Madrid, on the night of 15th of December. "At 2 o'clock all hands were awakened by the first shock. The impression was that the barge had dragged her anchor and was grounding on gravel. Such were the feeling for 45 or 60 seconds, when the shock started. The crew were so fully persuaded of the fact of their being aground, that they put out their poles, but found water enough. At seven the next morning a second and very severe shock took place, – the barge was underway, – the river rose several feet; the trees on the shore shook; the banks in the large columns tumbled in; hundreds of old trees that had lain perhaps half a century at the bottom of the river, appeared on the surface of the water, the battered race took the wing, the canopy was covered with geese and ducks and various other kinds of fowl; very little wind; the air was tainted with a nitrous and sulphurous smell; and everything was truely alarming for several minutes. The shocks continued to the 21st Dec. During that time, perhaps a hundred were distinctly felt".

—Knoxville Gazette, February 10, 1812

Charleston, South Carolina

"Another severe shock of an earthquake was felt in this city yesterday morning at four o'clock. Its duration was much longer than any that has preceded it. A gentleman who was up at the time ascertained it to exceed three minutes. Its undulatory motion was much shorter and quicker than any we have before experienced. Books and other articles were thrown from shelves, and chairs and other furniture standing against walls, made a rattling noise at the time. It was nearly calm and cloudy. Thermometer at eight o'clock A. M. stood at 52°.

—Anonymous, Charleston, S.C., Feb. 8

Further Reading

More eyewitness account of the New Madrid earthquake make gripping reading at *http://www.lcrr.memphis.edu/compendium/*.

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There is broad agreement in the scientific community that a continuing concern exists for a major destructive earthquake in the New Madrid seismic zone. The geologic record of pre-1811 earthquakes also reveals that the New Madrid seismic zone has repeatedly produced sequences of major earthquakes, including several of magnitude 7 to 8, over the past 4,500 years. The preponderance of evidence leads us to conclude that earthquakes can be expected in the future as frequently and as severely as in the past 4,500 years. Such high hazard requires prudent measures such as adequate building codes to protect public safety and ensure the social and economic resilience of the region to future earthquakes.

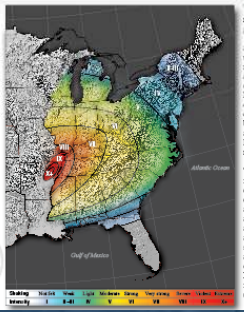
The USGS and the Center for Earthquake Research and Information of the University of Memphis estimate that similar NMSZ earthquakes have a 7%–10% chance of reoccurring within the next 50 years (USGS Fact Sheet FS–131–02; under "Sources of Information").

Disaster Relief Act

In 1814, Missouri Territorial Governor, William Clark (of the Lewis & Clark Expedition), asked for federal relief for the "inhabitants of New Madrid County." In response, Congress pledged $50,000 in 1815 for recovery. This was the first United States disaster relief act.

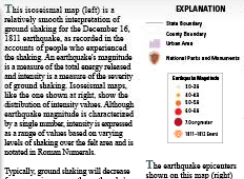
Image of the 1814 request, signed by Missouri Territorial Governor, William Clark.

Seismicity of the Central United States



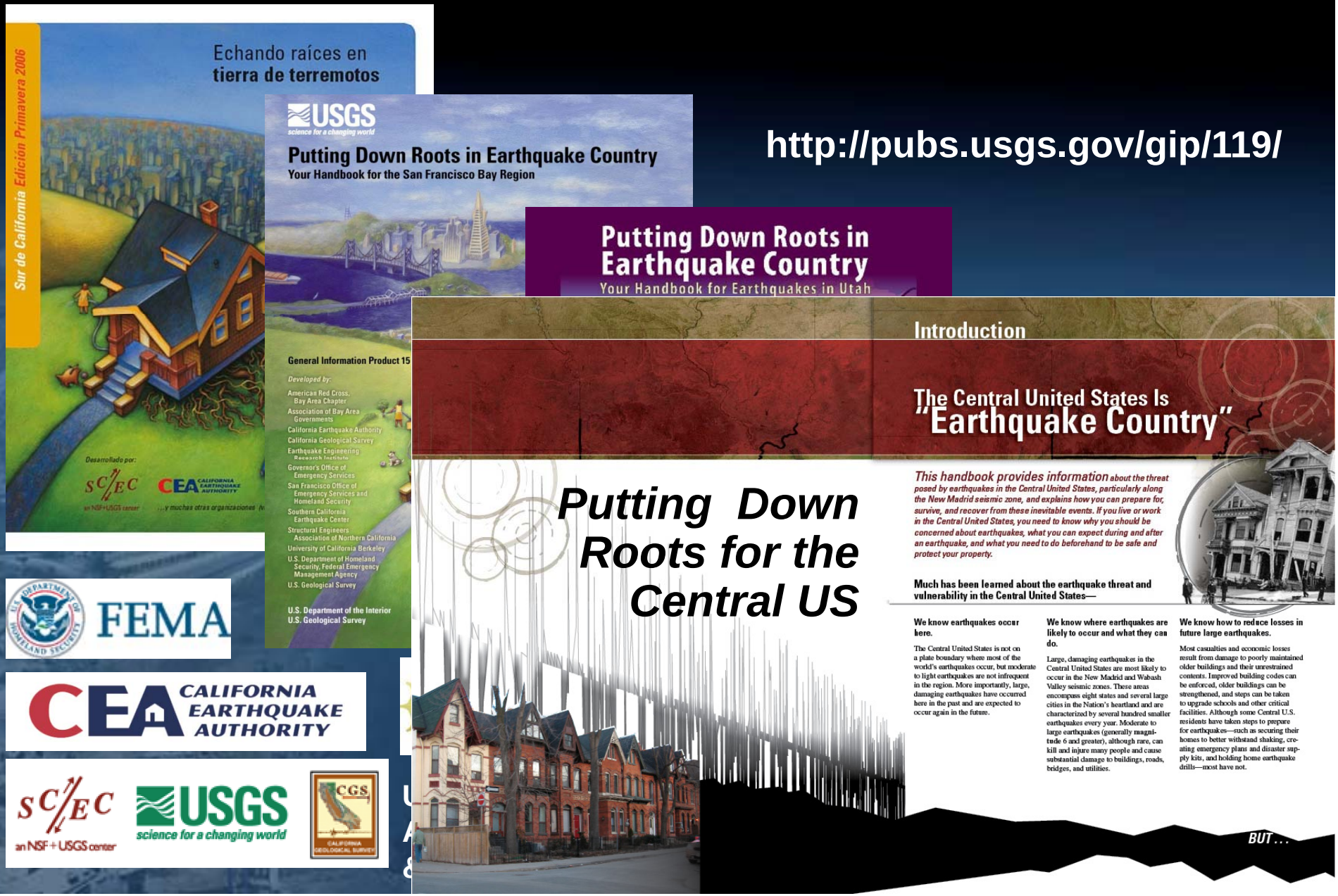
This isoseismal map (left) is a relatively smooth interpretation of ground shaking for the December 16, 1811 earthquake, as recorded in the accounts of people who experienced the shaking. An earthquake's magnitude is a measure of the total energy released and intensity is a measure of the severity of ground shaking. Isoseismal maps, like the one shown at right, show the distribution of intensity values. Although earthquake magnitude is characterized by a single number, intensity is expressed as a range of values based on varying levels of shaking over the fait area and is notated in Roman Numerals.

Typically, ground shaking will decrease from a maximum near the earthquake's epicenter to its lowest levels near the edge of the felt area. Intensity values are determined using the written accounts (letters, journals and diaries) and the published records (newspapers and official reports) of the ground shaking effects on people, buildings, and the landscape. These accounts are codified in the Modified Mercalli Intensity Scale; a range of values from I (barely felt or not felt) to XII (total destruction).



The earthquake epicenters shown on this map (right) include the 1811–1812 New Madrid earthquake mainshock (red bullseye) and selected historical and other instrumental events above magnitude 3.0 recorded from 1974 to early 2010. CAN WE SAY SOMETHING ABOUT THE NATIONAL PARKS?

Putting Down Roots in Earthquake Country



http://pubs.usgs.gov/gip/119/

USGS activities during NLE 2011

Activities in support of FEMA:

- Co-chair scenario and external affairs working groups
- Develop full suite of post-earthquake information products
- Deploy staff to National and Regional Response Coordination Centers and Master Control Cell

In-house exercises to test plans and capabilities:

- Exercise Hazard Response Executive Committee and Geospatial Information Response Team structures
- Test plans including NEIC response, NEHRP post-earthquake investigations, and Office of Communications
- Exercise response to secondary hazards including landslides, damming/flooding, toxic plumes.

USGS

NEHRP post-earthquake investigations

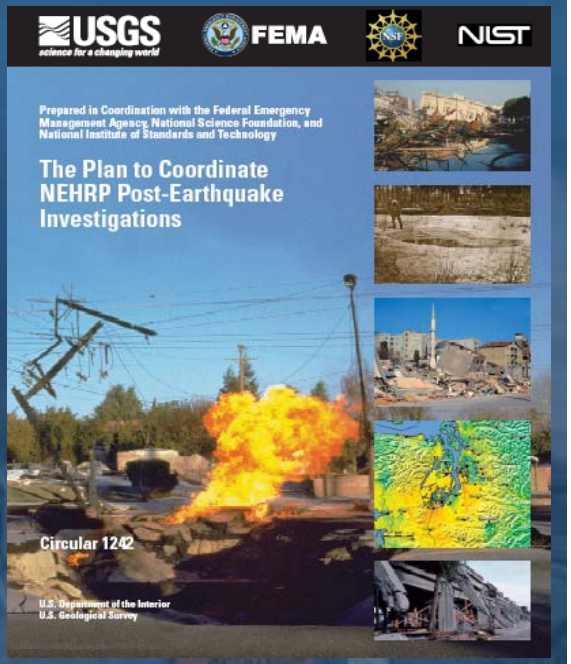
Days 0 to 3:

- USGS issues incident reports, establishes website, contacts NEHRP partners, assigns Investigations coordinator
- USGS works with States to erect technical clearinghouse
- NIST deploys National Construction Safety Team

Days 3 to 30:

- Investigation plans and priorities
- Recon field and clearinghouse operations
- Summary reports to responders
- NSF RAPID grants
- Budget supplemental request

USGS



Sources of additional information

U.S. Geological Survey:

Real-time and background information on earthquakes & hazards

http://earthquake.usgs.gov

Mid-America Earthquake Center:

A national earthquake engineering research consortium with headquarters at University of Illinois, Urbana-Champaign

Detailed earthquake impact analyses in 2008 and 2009 reports

http://mae.cee.uiuc.edu

New Madrid bicentennial web site:

http://newmadrid2011.org/

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USGS