Background Reading for Instructor

Note to instructor: *The following two articles are useful background material for those unfamiliar with earthquake hazards in the central and eastern United States. The risk in these regions is much higher than many realize. These articles, especially the first, also may be developed into and used for additional classroom discussions by the instructor if desired.*

1. The following article was adapted from *OPINION*, *Seismological Research Letters*, Volume 71, Number 3, May/June 2000. This provides additional background on US seismicity.

   Public Misconceptions about Faults and Earthquakes in The Eastern United States: Is It Our Own Fault?

   It seems to me that if we have learned anything at all during the past few decades about earthquake processes in the eastern United States, it's that there is no simple relationship between faults and earthquakes in this region. Yet, once a month or so, I am contacted by people who want to know about particular "earthquake faults" either located near their homes or that they heard run through major eastern cities. When an eastern earthquake occurs, I am invariably asked, "Where is the nearest fault?" No matter how hard I try to convince people that the distance to the nearest geologically mapped fault is not necessarily the most important question to ask, they usually remain unconvinced.

   For very good reasons, there has been much more emphasis among seismologists lately on estimating the probability of a given level of ground motion at a given site in the East than on "finding the nearest fault." So why is there such a mismatch between public perception and state-of-the-art research on earthquake hazard mapping in the eastern United States?

   Perhaps we shouldn't complain. A couple of decades ago, the typical response I received from people who found out that I study eastern U.S. earthquakes was, "Why aren't you living in California? There aren't any earthquakes in the eastern United States!" So I suppose we have done a good job of consciousness-raising about earthquake hazards here, but perhaps we were a bit too successful. Now people assume a direct correlation between mapped faults and earthquakes as if every fault in the East were another San Andreas waiting to rip.

   Unfortunately, a fair share of the blame for this oversimplified view of the earthquake/fault connection lies with seismologists themselves. Back in those heady, well-funded early days of plate tectonics research in the 1970s, seismologists seemed to be quite confident that the mystery of intraplate earthquakes would be easily resolved. With a minimum of data available, fanciful hypothesis generating often upstaged rigorous hypothesis testing. Two examples of hypotheses that seem to have been laid to rest in the light of data gathered

during the past two decades come to mind: the supposed existence of a "Boston-Ottawa seismic zone" (and its presumed relationship to extensions of oceanic fracture zones) and the presumed activity of the Ramapo Fault northwest of New York City. In spite of many such creative attempts to explain the cause of earthquakes in the East, their origins remain an enigma.

As an eastern U.S. seismologist, I am intrigued by the less-than-straightforward earthquake/fault connection for recent large earthquakes in California, where the earthquake process is presumably less complex, and the earthquakes are occurring near a well defined plate boundary. The Northridge earthquake was a "blind thrust" event that did not occur on the San Andreas Fault and for which the causative fault was not well identified prior to the event. The Landers earthquake occurred on a series of mapped faults, but those faults were not expected to rupture in a single major earthquake. The Hector Mine earthquake occurred along faults that had been mapped but that were not well identified as being active prior to the occurrence of the earthquake. If the earthquake/fault connection is complex in the case of California, how much more so in the East, where we are dealing with sporadic earthquakes that occur far from any well-defined plate boundaries? Nearly all eastern U.S. earthquakes seem to be blind thrusts, and those that aren't are usually at least blind if not thrusts.

So the past two decades have taught us that the earthquake/fault connection is not so simple, especially in intraplate areas. Yes, earthquakes certainly do occur in the East, and some of them have been quite large. Yes, there are many, many geologically mapped faults throughout the East. But there is no simple relationship between earthquakes and mapped faults in the East. Nonetheless, it seems that the fanciful hypotheses of a decade or two ago are well established in people's minds, and that's what people seem to remember when they think about research on eastern earthquakes. Also, the message that the earthquake/fault connection is very complex is inherently more subtle and hard for people to accept than, "We found a seismically active fault in your back yard." In an odd way, people seem to find it more comforting to know that seismologists found an active fault in their back yard than to hear ambiguous statements from scientists about how we know that large earthquakes occur in the East, but we don't really know "when" or "where." Yet, if we are honest with ourselves, I think that really is the state of our knowledge regarding earthquakes in the East.

We hear a lot of talk these days about the value of communicating our research results to a wider audience, in particular to the people who may be affected by our work. How do we convey the results of our research when our most recent results tell us that we know less than we used to think we knew? I have no definitive answer to this question, but I do think that we only make things worse when we announce correlations between faults and earthquakes when in reality what we have found is at best anecdotal evidence. Perhaps, in some cases, we would be better off not to announce our latest conjectures to the public. I think that we do a disservice to the public when we are not careful to distinguish between our

"interesting hypotheses" supported by anecdotal evidence versus scientifically tested hypotheses that are well supported by data.

Not only do I think we should be careful about how we present our research results to the public, but also in our own professional meetings and papers I think that caution is in order in this regard. Newspaper and television reporters do sometimes listen to our talks at meetings, and (one hopes) at least somebody out there is reading our papers. Communication between scientists and the public is a two-way street. What can we learn from the public's response to the past two decades of earthquake research in the East? We can learn that, if we are not cautious about what we say when we think we have found a seismically active fault, then we should not be surprised when an earthquake occurs and people expect us to tell them where the nearest active fault is.

Is this just an academic matter? I don't think so. There really is an earthquake hazard in the East (albeit less than in California), a hazard that we would be foolish to ignore. But if we assume (without scientific justification) that earthquakes are concentrated on a particular fault and that therefore future large earthquakes will occur along that same fault, then we are saying (without scientific justification) that the earthquake hazard is less in other areas.

We can say with some degree of confidence that earthquakes will continue to occur in the East. As for the "when" and "where", however, only many more years of monitoring and research will yield some discernible pattern –if indeed there even is one. In spite of our not having found "the answer," we must recognize that, if we are not up front about the limitations of our present state of knowledge about eastern earthquakes, the public (and policy makers) will continue to focus on questions about "the nearest fault." Better that we guide them to ask us more relevant questions, such as the probability of exceeding a given amount of ground motion at a given site –the kinds of questions that we can responsibly answer.

Alan L. Kafka
Weston Observatory
Department of Geology and Geophysics
Boston College

2. The New Madrid Seismic Zone, as discussed in earlier sessions, is an area of high hazard and risk. In fact, this region has the highest seismic hazard of any region outside of the western US. Thus, the following brief article provides a useful summary of recent thoughts on the seismicity of this region. (The following was adapted from: http://www.uky.edu/ArtsSciences/Geology/webdogs/virtky/)

Seismicity of the New Madrid Seismic Zone (NMSZ)

There are approximately 200 earthquakes in the NMSZ every year, of which only eight to 10 are large enough for us to feel (magnitude 3.0 and up). Due to the activity of the NMSZ and the potential for tremendous damage in the event of a large quake (6.5 or more), large amounts of seismic detection equipment began to be installed in the fault zone in 1974. Since then, these instruments have recorded over 4,000 earthquakes!

Based on the calculated recurrence intervals of different size (magnitude) earthquakes (i.e., how often a magnitude X.YZ earthquake occurs), seismologists have come up with a probability sequence for the NMSZ. In a nutshell, the table below describes the recurrence intervals (in years) of different sized quakes, as well as the probability (percentage) that a given size event will occur within the next 15 ($PROB_{15}$) and 50 ($PROB_{50}$) years (starting from 1990).

Periodicity of Earthquakes for the NMSZ

Magnitude	Recurrence	$PROB_{15}$	$PROB_{50}$
>8.0	550-1200	0.3-1	2.7-4.0
7.0	255-500	5-9	19-29
6.0	70-90	40-63	86-97
5.0	10-12	~100	~100
4.0	14 months	~100	~100

From the above chart, it is apparent that there is a great chance that a magnitude 6 earthquake will strike before the year 2040. What does this mean? We already have discussed the high population density of the area in and around the NMSZ. This, coupled with the fact that nearly none of the structures in this area were built to withstand an earthquake ("In *Kentucky*? Sure, if we lived in California, but not in Kentucky."), translates into the potential for massive amounts of property destruction and loss of life. It has been estimated that if an earthquake similar to that of December 16, 1811 were to strike today, thousands of deaths, as well as billions of dollars in damage, would result, including fallen buildings (especially those constructed on unconsolidated, alluvial sediments); landslides; land subsidence (including sinkhole collapse); and disruption of gas and electric utilities, and water and sewer services.

History of New Madrid Seismic Zone Area

The NMSZ is a series of strike/slip and dip/slip faults associated with what is called the Reelfoot Rift. The Reelfoot Rift is a failed Precambrian mid-continental rift, which is a fancy way of saying that a long, long time ago, the North American continent tried to split in two, but stopped before it succeeded.

This rifting resulted in the series of faults that make up the NMSZ. The rift itself is about 70 km wide, and follows the same NE-SW path as the NMSZ. The continental crust that is faulted in this region is very old, thick, and brittle, much more so than the crust in California split by the San Andreas Fault. This means is that the seismic waves generated from an earthquake in the NMSZ will travel longer distances than those from an equivalent quake in California. For example, the 1906 San Francisco earthquake (magnitude 7.8) was felt as far as central Nevada, 350 miles away. The December 16, 1811 earthquake in New Madrid, MO (magnitude 8.0) rang church bells in Boston, MA, more than 1,000 miles away!

Continuing the comparison with San Andreas, you may have seen some of the spectacular pictures of the San Andreas Fault cutting through the CA desert, but have you ever seen such pictures of the New Madrid? No, not unless you've seen some seismic interpretations, because the New Madrid faults are buried beneath several thousand feet of alluvium (river deposits of sand, silt, and mud sediments).

Is there anything going on there today?

Actually, the NMSZ is the most seismically active region in the United States east of the Rockies. There are other active regions, however, including the Nemaha Ridge in Kansas and Nebraska and the Southern Appalachian Seismic Zone that extends into the eastern areas of Kentucky. According to the Center for Earthquake Research and Information (CERI), there are approximately 200 earthquakes in the NMSZ every year, of which only 8 to 10 are large enough for us to feel (magnitude 3.0 and up). Due to the activity of the NMSZ and the potential for tremendous damage in the event of a large quake (6.5 or more), large amounts of seismic detection equipment began to be installed in the fault zone in 1974.