Tectonic Summaries for Web-served Earthquake Responses, Southeastern North America

by Russell L. Wheeler[1]

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ABSTRACT

This report documents the rationale and strategy used to write short summaries of the seismicity and tectonic settings of domains in southeastern North America. The summaries are used in automated responses to notable earthquakes that occur anywhere east of the Rocky Mountains in the United States or Canada. Specifically, the report describes the geologic and tectonic information, data sources, criteria, and reasoning used to determine the content and format of the summaries, for the benefit of geologists or seismologists who may someday need to revise the summaries or write others. These tectonic summaries are designed to be automatically posted on the World Wide Web as soon as an earthquake's epicenter is determined. The summaries are part of a larger collection of summaries that is planned to cover the world.

INTRODUCTION

Personnel in the USGS Earthquake Hazards Program are expanding their ability to quickly serve earthquake information to the public over the World Wide Web, in the minutes to hours after a notable earthquake occurs anywhere in the world. One component of this work is the development of an automated system that will assemble and serve pre-packaged information about the earthquake and its tectonic and seismicity setting as soon as the epicenter is determined. Meanwhile, seismologists and analysts of the National Earthquake Information Center (NEIC) will be assembling more detailed, tailored information to be presented in revised or additional Web pages. For earthquakes in or affecting the United States, the initial Web page will contain (1) identification of the State or other region in which the earthquake occurred, (2) a list of computed properties of the earthquake, and (3) a tectonic summary of the seismicity, geology, faults, and plate-tectonic setting of the region containing the epicenter.

The purpose of this report is to document the geologic and tectonic information, data sources, criteria, and reasoning used to produce tectonic summaries for earthquakes that occur in North America east of the Rocky Mountains. The report will assist those who might have to modify the tectonic summaries in the future, or write others. The first near-real-time use of these tectonic summaries was for the Fort Payne earthquake (**M** 4.6, April 29, 2003) at the southwestern end of the Eastern Tennessee seismic zone.

THE STABLE CONTINENTAL REGION

A stable continental region (SCR) is a continent or part of a continent that has not undergone major, geologically recent deformation or any accompanying metamorphic or igneous processes (Johnston, 1989; Kanter, 1994). North America east of the Rocky Mountains is the type example of an SCR, because the concept of an SCR was developed to identify global analogs of the central and eastern United States (CEUS) as part of a strategy to better characterize CEUS seismic hazard (Coppersmith and others, 1987). Each continent has at least one SCR and Asia has five (Kanter, 1994).

Deformation within SCRs differs from that at or near plate boundaries. Although SCR seismicity is evidence of current deformation, the amount of deformation in SCRs is small and the rate of deformation is slow compared to those at or near plate boundaries. The comparatively slow accumulation of slip on most SCR faults means that geologically recent surface ruptures on SCR faults are rare (Crone and others, 1997). Additionally, although epicenter maps show that seismicity is ubiquitous in the North American SCR, generally it is sparse and scattered compared to that at or near plate boundaries. Few places in the SCR have had enough instrumental earthquakes to illuminate the causative faults. Finally, plate boundaries are distant from the United States and southern Canadian part of the SCR, the closest being the Mid-Atlantic Ridge to the east, the Hispaniola Trough to the south, and the San Andreas fault system and Cascadia subduction zone to the west.

Because of these SCR characteristics, the relation between seismicity and plate tectonics is enigmatic in the southern part of the North American SCR. The enigma exists even in the SCR's most seismically active locality, the New Madrid seismic zone (Atkinson and others, 2000). In fact, the link between most SCR seismicity and known faults is also poorly understood, which severely limits the amount of information and understanding with which to write tectonic summaries for the SCR.

COMPONENTS OF THE TECTONIC SUMMARIES

Polygons

The North American SCR is here divided into variably sized polygons, and the tectonic summary of each polygon abstracts its seismicity and tectonic setting (Fig. 1). Sixteen polygons enclose concentrations of historical seismicity that are most likely to be of interest to United States citizens. The polygons range in size from less than one square degree to approximately 25 square degrees. Collectively, these sixteen polygons cover only a small fraction of the SCR. A much larger, seventeenth polygon includes the remainder of the SCR, in which historical seismicity is even sparser.

I delineated the polygons on the basis of seismicity listed in two catalogs that C.S. Mueller compiled for the 2002 USGS national seismic-hazard maps (Mueller and others, 1997). To my knowledge, these are the only current catalogs compiled to uniform standards that cover the entire CEUS and adjacent Canada throughout the historical period. Mueller compiled them from multiple catalogs, each of which has limited temporal and spatial coverage. Muller's compilations followed procedures designed to meet the particular needs of the hazard maps. Thus, they are not general-purpose catalogs. However, they suited my needs because they include earthquakes larger than M2.0 in one catalog and larger than M3.0 in the other; the latter catalog is a subset of the former. Dependent and duplicate events had been removed from both catalogs.

The large, seventeenth polygon extends to the boundaries of the SCR in all directions. I chose the southern part of the polygon (Fig. 1) as the area of greatest interest to United States citizens. The North American SCR encompasses the two-thirds of the continent that is east of the Rocky Mountains (Broadbent and Allan Cartography, 1994; Kanter, 1994). Because the main audience of the Web-served outreach product is the general public in the United States, I excluded the Greenland part of the SCR and, as explained later, I also excluded a few highly extended, submarine areas beneath the western Atlantic Ocean and northern Gulf of Mexico.

The boundary of the SCR polygon was determined from spatial changes in the geological and tectonic properties of the upper crust (Johnston, 1989; Kanter, 1994). Therefore, the boundary is based on more complex information than simply the locations of historical seismicity. Most of the western boundary of the SCR runs along the base of the Rocky Mountains through the United States and Canada (Muehlberger, 1996). More specifically, within the United States the polygon's boundary follows the western edge of the Great Plains physiographic province of Fenneman (1946) (Fig. 1). Physiographic provinces were used to delineate the tectonic boundary because the more active tectonics west of the SCR produce topography that reflects relatively higher rates of deformation. The western boundary of the SCR is also the eastern boundary being used by the geologists who are writing tectonic summaries of additional polygons that comprise the western United States (A.J. Crone, oral and written communs., June 2, 2003). When a notable earthquake occurs in the continental United States, a computer search routine will select the polygon that encloses the epicenter; this requires that the western United States polygons adjoin the SCR polygon without gaps or overlaps. Finally, the southwestern corner of the SCR includes a narrow sliver of Mexico east of the Basin and Range province (Broadbent and Allan Cartography, 1994; Kanter, 1994).

Three considerations influenced the location of the offshore boundary of the SCR polygon. (1) The shelf edge (King, 1969) is a guide to the likely offshore extent of large engineered structures, such as drilling platforms and pipelines, for which a nearby earthquake might be of public, corporate, or regulatory interest. (2) The geophysically-inferred transitions between unextended, slightly extended, and highly extended crust (Broadbent and Allan Cartography, 1994) are guides to likely changes in the numbers, styles, and sizes of young, potentially seismogenic faults. (3) The continent-ocean boundary (COB), which separates oceanic and continental crust (Broadbent and Allan Cartography, 1994; Muehlberger, 1996), is a possible guide to changes in strengths of fault rock, gross rheological properties of the upper crust, and thickness and strength of the lithosphere. The COB is the best approximation of both the shelf edge and the seaward increase in crustal extension from the northern end of the Rocky Mountains at the Arctic Ocean shore, clockwise around the SCR to about latitude 32° N., which is offshore from the Georgia-South Carolina state line. Accordingly, I chose the COB as the offshore boundary of the SCR everywhere north of Georgia.

From the Georgia-South Carolina state line, southward and westward to northeasternmost Mexico, seismicity is sparse near the coast and extended continental crust extends unusually far offshore (Broadbent and Allan Cartography, 1994; Dillon and Popenoe, 1988; Muehlberger, 1996; Salvador, 1991; Sawyer and others, 1991; Sheridan and others, 1988). In these regions it is difficult to estimate the likely offshore extent of earthquakes of public interest, so I arbitrarily drew the SCR boundary along the 500-m isobath. The isobath ranges from 30 km offshore near southeastern Florida to 280 km offshore near southwestern Florida.

Seismicity

Two paragraphs summarize the seismicity of a typical polygon under the heading "Earthquakes in (name of polygon)". The first paragraph summarizes the polygon's historical seismicity and the length of its record, for example by the date of the first known earthquake within the polygon. Much of the information was gleaned from the Web-searchable earthquake catalogs maintained by the NEIC, primarily the PDE (Preliminary Determinations of Epicenters), SRA (Stover-Reagor-Algermissen), and USHIS (United States Earthquake History) catalogs. In addition, regional catalogs such as those of local networks are useful supplements for certain polygons. The date and magnitude of the largest damaging earthquake was included if the earthquake was notable for its magnitude, recency, or effects. Moment magnitudes are available for only a few North American SCR earthquakes, except for the largest earthquakes and the most recent moderate-sized shocks. Johnston (1994; 1996) compiled moments or moment magnitudes for moderate and large earthquakes of the world's SCRs, and the literature has moment magnitudes for a few other, more recent SCR earthquakes in the CEUS and adjacent Canada. The sparse seismicity of SCRs means that, for some CEUS polygons, the largest historical earthquake is old enough that the best available magnitude is an m_{bLg}, or a felt-area estimate of it. The regression relations of Johnston (1996) show that, in SCRs generally and with some scatter, usually instrumental m_{bLg} exceeds instrumental **M** for the same earthquake if both are below 6.0-6.5. The difference increases for smaller magnitudes and is approximately 0.4 units at **M** 3.5. If available data allowed, I stated the frequency of moderately damaging earthquakes (Modified Mercalli Intensity at least VII) and felt earthquakes in the polygon as earthquakes per decade or decades per earthquake. This imprecision is necessary because most polygons have had too few historical earthquakes, and calculated rates vary too much between decades, to justify more specific statements that readers might mistake as authoritative.

The second paragraph is virtually the same for all polygons. It comprises four standard sentences that compare felt areas, felt radii, and damage radii for the CEUS and the West Coast.

Faults, geology, and plate tectonics

These three topics are summarized in two paragraphs under the heading "Faults", because the public usually wants to know which fault generated an earthquake. The paragraphs are designed to explain why we rarely can confidently associate an individual earthquake with a known fault east of the Rocky Mountains.

The first paragraph starts with a standard sentence: "Earthquakes everywhere occur on faults within bedrock, usually miles deep." The following few sentences summarize the geological evolution of the upper crust within the polygon, in terms of mountain ranges formed by colliding plates and the rifting of continents to form the present-day Atlantic Ocean.

Except for the summary of the New Madrid seismic zone, the second paragraph begins with two standard sentences: "At well-studied plate boundaries like the San Andreas fault system in California, often scientists can determine the name of the specific fault that is responsible for an earthquake. In contrast, east of the Rocky Mountains this is rarely the case." The paragraph then notes that the nearest plate boundaries are far from the CEUS and adjacent Canada, in the middle of the Atlantic Ocean, in the Caribbean Sea, or, for the western part of the SCR and the western part of the Illinois basin – Ozark dome area, along the West Coast. The Mid-Atlantic Ridge is the closest boundary only for the Charlevoix-Kamouraska seismic zone of Quebec and for northern New England. Most polygons are actually closer to the Hispaniola Trough in the Caribbean than to the Mid-Atlantic Ridge. However, generally both boundaries are mentioned because the Mid-Atlantic Ridge may be better known to most United States readers. Several sentences explain the difficulty of identifying the causative fault of an SCR earthquake. Except for the summary of the Charlevoix-Kamouraska seismic zone, the final sentence concludes that, as in most other regions west of the Rocky Mountains, the best guide to seismic hazards is the earthquakes themselves.

Individual faults are intentionally not mentioned in most of the tectonic summaries, to avoid becoming entangled in disputes about speculations. Many of the larger SCR faults have been mapped, particularly if exposed, but large numbers of smaller or more deeply buried faults may remain undetected. The locations of earthquakes and especially faults commonly have considerable uncertainty at hypocentral depths. Accordingly, few historical earthquakes can be clearly linked to known faults. The NEIC Web pages contain a longer discussion of this problem at URL http://neic.usgs.gov/neis/general/handouts/faults_east.html. Some seismologists and geologists in the CEUS disagree with my overall assessment for specific faults that they have studied. In my judgment, the present understanding of the links between most SCR faults and SCR seismicity is insufficient to resolve such disputes, so in the summaries I avoided the issue.

Review

There has been no formal review of individual summaries beyond the overall review of this report. However, the summaries were reviewed informally in three stages that spanned ten months.

First, I asked four regional ANSS (Advanced National Seismic System) representatives to review groups of summaries of areas within their regions of geographic expertise. Some of the ANSS representatives obtained informal reviews from colleagues. I received comments from four people.

Second, after revision, I emailed one to three summaries to each of 13 additional network operators and other seismologists in the central and eastern United States and the Geological Survey of Canada. I did not call ahead to request these second-stage reviews, but still received comments from three people.

Third, throughout the first two stages and later, NEIC colleagues working on other aspects of the improved Web responses provided numerous constructive suggestions. Thus, each summary was critiqued individually by at least one person, and, because of the similarities between summaries, many of the comments improved several or all of the summaries. I did not send the summaries to State Geologists because, east of the Rocky Mountains, few state surveys have staff with seismological expertise.

PECULIARITIES OF WRITING STYLE

The manner in which the tectonic summaries will be presented imposes unusual but reasonable stylistic constraints on the writing. Geologists and seismologists who will write future summaries or revise existing ones might not anticipate all of these constraints; I didn't. Accordingly, the following suggestions might save these future authors some rewriting.

I insisted that no summary exceed one single-spaced page. This decision was driven by the realization that concise information is more likely to be read. The length limit imposed a premium on clarity, but the limit increased the temptation to use jargon because most jargon is shorter than its explanation.

Nonetheless, jargon would be fatal to the impact of the summaries. The summaries are written for Web surfers who lack scientific or perhaps even technical training, scientists who lack earth-science training, and geologists and seismologists who seek useful information. Accordingly, the summaries should be scientifically accurate but jargon-free. Identifying jargon can be difficult and is subjective, but a useful criterion might be "is this word likely to appear in a newspaper article written by the average science (for which, read 'mostly medical') reporter?" I assumed that essentially all of the present-day audience would at least understand the terms "plate tectonics" or "plate movements," and the idea that plate motions form oceans and mountains. The alternative is to explain these ideas, which probably would require a typical tectonic summary to be longer than one single-spaced page.

The tectonic summary should not have an overall title, but only the two sectional headings described earlier. This recommendation arises from the use to which the summary may be put in the hours and days following an earthquake and its automatic posting. The more notable the earthquake, the more likely that others will append additional paragraphs to the summary. If the summary had an overall title, then the title might refer to the entire seismic zone, region, or physiographic province that is summarized. In contrast, appended paragraphs about the effects of the specific earthquake or the response to it would refer to a single small part of the summarized area. Therefore, the wording of the appended paragraphs might be inconsistent with an overall title. At the other extreme, an appended paragraph about the ANSS could refer to seismographs nationwide, and would also be inconsistent with the overall title. These inconsistencies could be resolved with careful rewording. However, the press of events during the earthquake response is likely to preclude revisions until the earthquake has become old news. All of these problems occurred during the response to the **M** 4.6 Fort Payne, Alabama, earthquake of April 29, 2003.

In most cases, a tectonic summary should omit mention of anything outside the polygon of interest. Readers will be most interested in the earthquake and its setting, and a longer, more general summary may be less likely to be read.

Avoid text that will become outdated within days after the earthquake. There will be little or no time to revise the text while it is still of interest to its audience. The most obvious example of overly perishable text is to refer to “today’s earthquake.” That phrase appeared in a paragraph that was appended to the tectonic summary immediately after the Fort Payne earthquake.

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APPENDIX I: TECTONIC SUMMARIES

Ten of the seventeen polygons outline well-known concentrations of seismicity, or seismic zones, with established names. Most of the other polygons are named informally here, although several have long been recognized as more seismically active than their surroundings and a few have been named in one study or another. Crone and Wheeler (2000) reviewed the geological evidence for Quaternary tectonic faulting in many of the polygons and noted some of their main earthquakes. The tectonic summaries follow in italics. Note that, as explained earlier, the underlined headings are not parts of the summaries.

Ten seismic zones with established names

Anna seismic zone:

EARTHQUAKES IN THE ANNA SEISMIC ZONE

This small seismic zone in western Ohio has had moderately frequent earthquakes at least since the first one was reported in 1875. The largest earthquake (magnitude 5.1) caused damage in 1937. Moderately damaging earthquakes strike the Anna seismic zone every two or three decades, and smaller earthquakes are felt two or three times per decade.

Earthquakes in the central and eastern U.S., although less frequent than in the western U.S., are typically felt over a much broader region. East of the Rockies, an earthquake can be felt over an area as much as ten times larger than a similar magnitude earthquake on the west coast. A magnitude 4.0 eastern U.S. earthquake typically can be felt at many places as far as 100 km (60 mi) from where it occurred, and it infrequently causes damage near its source. A magnitude 5.5 eastern U.S. earthquake usually can be felt as far as 500 km (300 mi) from where it occurred, and sometimes causes damage as far away as 40 km (25 mi).

FAULTS

Earthquakes everywhere occur on faults within bedrock, usually miles deep. Most of the Anna seismic zone's bedrock was formed as several generations of mountains rose and were eroded down again a billion or more years ago.

At well-studied plate boundaries like the San Andreas fault system in California, often scientists can determine the name of the specific fault that is responsible for an earthquake. In contrast, east of the Rocky Mountains this is rarely the case. The Anna seismic zone is far from the nearest plate boundaries, which are in the center of the Atlantic Ocean and in the Caribbean Sea. Several faults are known in the seismic zone. Some of the earthquakes in the zone appear to coincide with the Anna-Champaign fault, although other earthquakes occur far from any known fault. Numerous smaller or deeply *buried faults may remain undetected. Even the known faults are poorly located at earthquake depths. Accordingly, few earthquakes in the seismic zone can be linked to named faults. It is difficult to determine if a known fault is still active and could slip and cause an earthquake. As in most other areas east of the Rockies, the best guide to earthquake hazards in the Anna seismic zone is the earthquakes themselves.*

<u>Central Virginia seismic zone</u>:

EARTHQUAKES IN THE CENTRAL VIRGINIA SEISMIC ZONE

Since at least 1774, people in central Virginia have felt small earthquakes and suffered damage from infrequent larger ones. The largest damaging earthquake (magnitude 4.8) in the seismic zone occurred in 1875. Smaller earthquakes that cause little or no damage are felt each year or two.

Earthquakes in the central and eastern U.S., although less frequent than in the western U.S., are typically felt over a much broader region. East of the Rockies, an earthquake can be felt over an area as much as ten times larger than a similar magnitude earthquake on the west coast. A magnitude 4.0 eastern U.S. earthquake typically can be felt at many places as far as 100 km (60 mi) from where it occurred, and it infrequently causes damage near its source. A magnitude 5.5 eastern U.S. earthquake usually can be felt as far as 500 km (300 mi) from where it occurred, and sometimes causes damage as far away as 40 km (25 mi).

FAULTS

Earthquakes everywhere occur on faults within bedrock, usually miles deep. Most bedrock beneath central Virginia was assembled as continents collided to form a supercontinent about 500-300 million years ago, raising the Appalachian Mountains. Most of the rest of the bedrock formed when the supercontinent rifted apart about 200 million years ago to form what are now the northeastern U.S., the Atlantic Ocean, and Europe.

At well-studied plate boundaries like the San Andreas fault system in California, often scientists can determine the name of the specific fault that is responsible for an earthquake. In contrast, east of the Rocky Mountains this is rarely the case. The Central Virginia seismic zone is far from the nearest plate boundaries, which are in the center of the Atlantic Ocean and in the Caribbean Sea. The seismic zone is laced with known faults but numerous smaller or deeply buried faults remain undetected. Even the known faults are poorly located at earthquake depths. Accordingly, few, if any, earthquakes in the seismic zone can be linked to named faults. It is difficult to determine if a known fault is still active and could slip and cause an earthquake. As in most other areas east of the Rockies, the best guide to earthquake hazards in the seismic zone is the earthquakes themselves.

<u>Charleston, South Carolina area</u>:

EARTHQUAKES IN THE CHARLESTON, SOUTH CAROLINA AREA

Charleston and its surroundings were devastated in 1886 by a very large earthquake (magnitude 7.3). Aftershocks, some of them large enough to be damaging by themselves, continued for years. Prehistoric earthquakes of similar size to the 1886 shock have occurred in coastal South Carolina at intervals of several centuries to several thousands of years. In recent decades, smaller earthquakes that cause little or no damage have been felt roughly once a year in coastal South Carolina and a small part of adjacent Georgia.

Earthquakes in the central and eastern U.S., although less frequent than in the western U.S., are typically felt over a much broader region. East of the Rockies, an earthquake can be felt over an area as much as ten times larger than a similar magnitude earthquake on the west coast. A magnitude 4.0 eastern U.S. earthquake typically can be felt at many places as far as 100 km (60 mi) from where it occurred, and it infrequently causes damage near its source. A magnitude 5.5 eastern U.S. earthquake usually can be felt as far as 500 km (300 mi) from where it occurred, and sometimes causes damage as far away as 40 km (25 mi).

FAULTS

Earthquakes everywhere occur on faults within bedrock, usually miles deep. Most bedrock beneath the Charleston area was assembled as continents collided to form a supercontinent about 500-300 million years ago, raising the Appalachian Mountains. Most of the rest of the bedrock formed when the supercontinent rifted apart about 200 million years ago to form what are now the southeastern U.S., the Atlantic Ocean, and Africa.

At well-studied plate boundaries like the San Andreas fault system in California, often scientists can determine the name of the specific fault that is responsible for an earthquake. In contrast, east of the Rocky Mountains this is rarely the case. The Charleston area is far from the nearest plate boundaries, which are in the center of the Atlantic Ocean and in the Caribbean Sea. Bedrock and its faults are buried beneath sand, silt, clay, and sedimentary rocks that may be as thick as 1-3 km (1-2 mi). Accordingly, few earthquakes in the Charleston area can be linked to named faults. It is difficult to determine if most known faults are still active and could slip and cause an earthquake. As in most other areas east of the Rockies, the best guide to earthquake hazards in the Charleston area is the earthquakes themselves.

Charlevoix-Kamouraska seismic zone:

EARTHQUAKES IN THE CHARLEVOIX-KAMOURASKA SEISMIC ZONE

The Charlevoix-Kamouraska seismic zone straddles the St. Lawrence River in southeastern Quebec. People in the seismic zone have felt small earthquakes and suffered damage from larger ones for three and a half centuries. The zone is one of the most *seismically active in North America east of the Rocky Mountains. The first and largest known damaging earthquake (magnitude about 7) in the seismic zone occurred in 1663. Several others have caused damage since then, most notably in 1925 (magnitude 6.2), and the most recent damage from an earthquake in the seismic zone was in 1979 (magnitude 4.8). Earthquakes cause damage in the seismic zone every few decades. Smaller earthquakes are felt roughly two or three times a year.*

Earthquakes east of the Rocky Mountains, although less frequent than in the west, are typically felt over a much broader region. East of the Rockies, an earthquake can be felt over an area as much as ten times larger than a similar magnitude earthquake on the west coast. A magnitude 4.0 eastern earthquake typically can be felt at many places as far as 100 km (60 mi) from where it occurred, and it infrequently causes damage near its source. A magnitude 5.5 eastern earthquake usually can be felt as far as 500 km (300 mi) from where it occurred, and sometimes causes damage as far away as 40 km (25 mi).

FAULTS

Earthquakes everywhere occur on faults within bedrock, usually miles deep. Various plate motions formed most bedrock and faults beneath the seismic zone over the last billion years. Ancient continents rifted apart to form oceans, and land masses collided to raise mountains that were then eroded down. The Charlevoix-Kamouraska seismic zone straddles the boundary between billion-year-old rocks of ancient North America on the northwest, and younger rocks of the Appalachian Mountains on the southeast.

At well-studied plate boundaries like the San Andreas fault system in California, often scientists can determine the name of the specific fault that is responsible for an earthquake. In contrast, east of the Rocky Mountains this is rarely the case. The Charlevoix-Kamouraska seismic zone is far from the nearest plate boundary, which is in the center of the Atlantic Ocean. Current thinking is that larger earthquakes in the seismic zone may occur on large faults that parallel the St. Lawrence River, whereas most of the smaller earthquakes may occur in highly fractured rock near the large faults.

Eastern Tennessee seismic zone:

EARTHQUAKES IN THE EASTERN TENNESSEE SEISMIC ZONE

The Eastern Tennessee seismic zone extends across Tennessee and northwestern Georgia into northeastern Alabama. It is one of the most active earthquake areas in the Southeast. Although the zone is not known to have had a large earthquake, a few earthquakes in the zone have caused slight damage. The largest known (magnitude 4.6) occurred on April 29, 2003, near Fort Payne, Alabama. Earthquakes too small to cause damage are felt about once a year. Earthquakes too small to be felt are abundant in the seismic zone, and seismographs have recorded hundreds of them in recent decades.

Earthquakes in the central and eastern U.S., although less frequent than in the western U.S., are typically felt over a much broader region. East of the Rockies, an earthquake *can be felt over an area as much as ten times larger than a similar magnitude earthquake on the west coast. A magnitude 4.0 eastern U.S. earthquake typically can be felt at many places as far as 100 km (60 mi) from where it occurred, and it infrequently causes damage near its source. A magnitude 5.5 eastern U.S. earthquake usually can be felt as far as 500 km (300 mi) from where it occurred, and sometimes causes damage as far away as 40 km (25 mi).*

FAULTS

Earthquakes everywhere occur on faults within bedrock, usually miles deep. Most of eastern Tennessee's bedrock originated several hundred million years ago, as the Appalachian Mountains were formed.

At well-studied plate boundaries like the San Andreas fault system in California, often scientists can determine the name of the specific fault that is responsible for an earthquake. In contrast, east of the Rocky Mountains this is rarely the case. The Eastern Tennessee seismic zone is far from the nearest plate boundaries, which are in the center of the Atlantic Ocean and in the Caribbean Sea. The Eastern Tennessee seismic zone is laced with known faults but numerous smaller or deeply buried faults remain undetected. Even the known faults are poorly located at earthquake depths. Accordingly, few, if any, earthquakes in the Eastern Tennessee seismic zone can be linked to named faults. It is difficult to determine if a known fault is still active and could slip and cause an earthquake. As in most other areas east of the Rockies, the best guide to earthquake hazards in the seismic zone is the earthquakes themselves.

<u>Lancaster seismic zone</u>:

EARTHQUAKES IN THE LANCASTER SEISMIC ZONE

Since colonial times, people in the Lancaster seismic zone of southeastern Pennsylvania have felt small earthquakes and suffered damage from larger ones. Earthquakes are felt once or twice per decade, with some decades having none and the 1990s having as many as six.

Earthquakes in the central and eastern U.S., although less frequent than in the western U.S., are typically felt over a much broader region. East of the Rockies, an earthquake can be felt over an area as much as ten times larger than a similar magnitude earthquake on the west coast. A magnitude 4.0 eastern U.S. earthquake typically can be felt at many places as far as 100 km (60 mi) from where it occurred, and it infrequently causes damage near its source. A magnitude 5.5 eastern U.S. earthquake usually can be felt as far as 500 km (300 mi) from where it occurred, and sometimes causes damage as far away as 40 km (25 mi).

FAULTS

Earthquakes everywhere occur on faults within bedrock, usually miles deep. Most bedrock beneath the seismic zone was assembled as continents collided to form a supercontinent about 500-300 million years ago, raising the Appalachian Mountains. Most of the rest of the bedrock formed when the supercontinent rifted apart about 200 million years ago to form what are now the northeastern U.S., the Atlantic Ocean, and Europe.

At well-studied plate boundaries like the San Andreas fault system in California, often scientists can determine the name of the specific fault that is responsible for an earthquake. In contrast, east of the Rocky Mountains this is rarely the case. The Lancaster seismic zone is far from the nearest plate boundaries, which are in the center of the Atlantic Ocean and in the Caribbean Sea. The seismic zone is laced with known faults but numerous smaller or deeply buried faults remain undetected. Even the known faults are poorly located at earthquake depths. Accordingly, few, if any, earthquakes in the seismic zone can be linked to named faults. It is difficult to determine if a known fault is still active and could slip and cause an earthquake. As in most other areas east of the Rockies, the best guide to earthquake hazards in the Lancaster seismic zone is the earthquakes themselves.

New Madrid seismic zone:

EARTHQUAKES IN THE NEW MADRID SEISMIC ZONE

The New Madrid seismic zone of southeast Missouri and adjacent States is the most seismically active in North America east of the Rockies. During the winter of 1811-1812, three very large earthquakes devastated the area and were felt throughout most of the Nation. They occurred a few weeks apart on December 16, January 23, and February 7. Hundreds of aftershocks, some severely damaging by themselves, continued for years. Prehistoric earthquakes similar in size to those of 1811-1812 occurred in the middle 1400's and around 900 A.D. Strong, damaging earthquakes struck the southwestern end of the seismic zone near Marked Tree, Arkansas in 1843 (magnitude 6.3), and the northeastern end near Charleston, Missouri in 1895 (magnitude 6.6). Since 1900, moderately damaging earthquakes have struck the seismic zone every few decades. About twice a year people feel still smaller earthquakes that do not cause damage.

Earthquakes in the central and eastern U.S. are typically felt over a much broader region than in the western U.S. East of the Rockies, an earthquake can be felt over an area as much as ten times larger than a similar magnitude earthquake on the west coast. A magnitude 4.0 eastern U.S. earthquake typically can be felt at many places as far as 100 km (60 mi) from where it occurred, and it infrequently causes damage near its source. A magnitude 5.5 eastern U.S. earthquake usually can be felt as far as 500 km (300 mi) from where it occurred, and sometimes causes damage as far away as 40 km (25 mi).

FAULTS

Earthquakes everywhere occur on faults within bedrock, usually miles deep. The earthquakes of the New Madrid seismic zone occur within a large network of faults called the Reelfoot rift. The rift formed about 500 million years ago, when this region was stretched in the northwest-southeast direction. Along a northeast-southwest zone at least 70 km (40 mi) wide and 500 km (300 mi) long, the rocks in the rift were slowly dropped down about 1-2 km (1 mi) along some of the faults. Now the region is undergoing east-west shortening, and the ancient faults of the Reelfoot rift are being reactivated to generate earthquakes. Today the Reelfoot rift and the New Madrid seismic zone are 2,000 km (1,200 mi) from the nearest plate boundary, which is in the Caribbean Sea.

The network of faults in the seismic zone is buried beneath hundreds to thousands of feet of sand and mud. Four of the largest faults are recognized as alignments of abundant small earthquakes, and movements along two of these faults dammed rivers and created lakes during the earthquakes of 1811-1812. A few more deeply buried faults were detected during oil and gas exploration, and a few small faults are known from geologic mapping. However, many earthquakes occur away from the few known faults, so there must be additional, unknown faults that can generate earthquakes in the seismic zone. Accordingly, the best overall guide to seismic hazard in the New Madrid seismic zone is the earthquakes themselves.

Niagara-Attica zone:

EARTHQUAKES IN THE NIAGARA-ATTICA ZONE

This part of southern Ontario and western New York State has had moderately frequent earthquakes at least since the first one was reported in 1840. The largest (magnitude 4.9) caused moderate damage in 1929 near Attica, New York. Earthquakes too small to cause damage are felt roughly three or four times per decade, although only one was felt during the 1940s and eight were felt during the 1960s.

Earthquakes east of the Rocky Mountains, although less frequent than in the west, are typically felt over a much broader region. East of the Rockies, an earthquake can be felt over an area as much as ten times larger than a similar magnitude earthquake on the west coast. A magnitude 4.0 eastern earthquake typically can be felt at many places as far as 100 km (60 mi) from where it occurred, and it infrequently causes damage near its source. A magnitude 5.5 eastern earthquake usually can be felt as far as 500 km (300 mi) from where it occurred, and sometimes causes damage as far away as 40 km (25 mi).

FAULTS

Earthquakes everywhere occur on faults within bedrock, usually miles deep. Most of this area's bedrock was formed as several generations of mountains rose and were eroded down again over the last billion or more years.

At well-studied plate boundaries like the San Andreas fault system in California, often scientists can determine the name of the specific fault that is responsible for an *earthquake. In contrast, east of the Rocky Mountains this is rarely the case. The Niagara – Attica zone is far from the nearest plate boundaries, which are in the center of the Atlantic Ocean and in the Caribbean Sea. The zone is laced with known faults but few have been traced to earthquake depths. Numerous smaller or deeply buried faults may remain undetected. Accordingly, only a few earthquakes in the zone can be linked to named faults. It is difficult to determine if a known fault is still active and could slip and cause an earthquake. As in most other areas east of the Rockies, the best guide to earthquake hazards in the Niagara – Attica zone is the earthquakes themselves.*

<u>Northeast Ohio seismic zone</u>:

EARTHQUAKES IN THE NORTHEAST OHIO SEISMIC ZONE

The Northeast Ohio seismic zone has had moderately frequent earthquakes at least since the first one was reported in 1823. The largest earthquake (magnitude 4.8) caused damage in 1986 in northeasternmost Ohio, and the most recent damaging shock (magnitude 4.5) occurred in 1998 at the seismic zone's eastern edge in northwestern Pennsylvania. Earthquakes too small to cause damage are felt two or three times per decade.

Earthquakes in the central and eastern U.S., although less frequent than in the western U.S., are typically felt over a much broader region. East of the Rockies, an earthquake can be felt over an area as much as ten times larger than a similar magnitude earthquake on the west coast. A magnitude 4.0 eastern U.S. earthquake typically can be felt at many places as far as 100 km (60 mi) from where it occurred, and it infrequently causes damage near its source. A magnitude 5.5 eastern U.S. earthquake usually can be felt as far as 500 km (300 mi) from where it occurred, and sometimes causes damage as far away as 40 km (25 mi).

FAULTS

Earthquakes everywhere occur on faults within bedrock, usually miles deep. Most of the seismic zone's bedrock was formed as several generations of mountains rose and were eroded down again over the last billion or more years.

At well-studied plate boundaries like the San Andreas fault system in California, often scientists can determine the name of the specific fault that is responsible for an earthquake. In contrast, east of the Rocky Mountains this is rarely the case. The Northeast Ohio seismic zone is far from the nearest plate boundaries, which are in the center of the Atlantic Ocean and in the Caribbean Sea. The seismic zone is laced with known faults but numerous smaller or deeply buried faults remain undetected. Even the known faults are poorly located at earthquake depths. Accordingly, few, if any, earthquakes in the seismic zone can be linked to named faults. It is difficult to determine if a known fault is still active and could slip and cause an earthquake. As in most other areas east of the Rockies, the best guide to earthquake hazards in the Northeast Ohio seismic zone is the earthquakes themselves.

Western Quebec seismic zone:

EARTHQUAKES IN THE WESTERN QUEBEC SEISMIC ZONE

People in the large Western Quebec seismic zone have felt small earthquakes and suffered damage from larger ones for three centuries. The two largest damaging earthquakes occurred in 1935 (magnitude 6.1) at the northwestern end of the seismic zone, and in 1732 (magnitude 6.2) 450 km (280 mi) away at the southeastern end of the zone where it caused significant damage in Montreal. Earthquakes cause damage in the zone about once a decade. Smaller earthquakes are felt three or four times a year.

Earthquakes east of the Rocky Mountains, although less frequent than in the west, are typically felt over a much broader region. East of the Rockies, an earthquake can be felt over an area as much as ten times larger than a similar magnitude earthquake on the west coast. A magnitude 4.0 eastern earthquake typically can be felt at many places as far as 100 km (60 mi) from where it occurred, and it infrequently causes damage near its source. A magnitude 5.5 eastern earthquake usually can be felt as far as 500 km (300 mi) from where it occurred, and sometimes causes damage as far away as 40 km (25 mi).

FAULTS

Earthquakes everywhere occur on faults within bedrock, usually miles deep. Most of the bedrock in the Western Quebec seismic zone was formed as several generations of mountains rose and were eroded down again over the last billion or so years.

At well-studied plate boundaries like the San Andreas fault system in California, often scientists can determine the name of the specific fault that is responsible for an earthquake. In contrast, east of the Rocky Mountains this is rarely the case. The Western Quebec seismic zone is far from the nearest plate boundaries, which are in the center of the Atlantic Ocean and in the Caribbean Sea. The seismic zone is laced with known faults but numerous smaller or deeply buried faults remain undetected. Even the known faults are poorly located at earthquake depths. Accordingly, few, if any, earthquakes in the seismic zone can be linked to named faults. It is difficult to determine if a known fault is still active and could slip and cause an earthquake. As in most other areas east of the Rockies, the best guide to earthquake hazards in the Western Quebec seismic zone is the earthquakes themselves.

Other polygons

Adirondack region:

EARTHQUAKES IN THE ADIRONDACK REGION

The Adirondack region of northern New York State is one of the more seismically active parts of the northeastern U.S. The three largest known earthquakes in the region caused *about $20 million of damage (in 2002 dollars) to Cornwall, New York, and to Massena, Ontario in 1944 (magnitude 5.8), caused slight damage in a sparsely settled part of the southern Adirondack Mountains in 1983 (magnitude 4.9), and damaged the vicinity of Plattsburg, New York, on April 20, 2002 (magnitude 5.0). Moderately damaging earthquakes strike somewhere in the region every few decades, and smaller earthquakes are felt about once every three or four years.*

Earthquakes in the central and eastern U.S., although less frequent than in the western U.S., are typically felt over a much broader region. East of the Rockies, an earthquake can be felt over an area as much as ten times larger than a similar magnitude earthquake on the west coast. A magnitude 4.0 eastern U.S. earthquake typically can be felt at many places as far as 100 km (60 mi) from where it occurred, and it infrequently causes damage near its source. A magnitude 5.5 eastern U.S. earthquake usually can be felt as far as 500 km (300 mi) from where it occurred, and sometimes causes damage as far away as 40 km (25 mi).

FAULTS

Earthquakes everywhere occur on faults within bedrock, usually miles deep. Most of the Adirondack region's bedrock was formed as several generations of mountains rose and were eroded down again over the last billion or so years.

At well-studied plate boundaries like the San Andreas fault system in California, often scientists can determine the name of the specific fault that is responsible for an earthquake. In contrast, east of the Rocky Mountains this is rarely the case. The Adirondack region is far from the nearest plate boundaries, which are in the center of the Atlantic Ocean and in the Caribbean Sea. The region is laced with known faults but numerous smaller or deeply buried faults remain undetected. Even the known faults are poorly located at earthquake depths. Accordingly, few Adirondack earthquakes can be linked to named faults. It is difficult to determine if a known fault is still active and could slip and cause an earthquake. As in most other areas east of the Rockies, the best guide to earthquake hazards in the Adirondack region is the earthquakes themselves.

Illinois basin – Ozark dome region:

EARTHQUAKES IN THE ADIRONDACK REGION

The Adirondack region of northern New York State is one of the more seismically active parts of the northeastern U.S. The three largest known earthquakes in the region caused about $20 million of damage (in 2002 dollars) to Cornwall, New York, and to Massena, Ontario in 1944 (magnitude 5.8), caused slight damage in a sparsely settled part of the southern Adirondack Mountains in 1983 (magnitude 4.9), and damaged the vicinity of Plattsburg, New York, on April 20, 2002 (magnitude 5.0). Moderately damaging earthquakes strike somewhere in the region every few decades, and smaller earthquakes are felt about once every three or four years.

Earthquakes in the central and eastern U.S., although less frequent than in the western U.S., are typically felt over a much broader region. East of the Rockies, an earthquake can be felt over an area as much as ten times larger than a similar magnitude earthquake on the west coast. A magnitude 4.0 eastern U.S. earthquake typically can be felt at many places as far as 100 km (60 mi) from where it occurred, and it infrequently causes damage near its source. A magnitude 5.5 eastern U.S. earthquake usually can be felt as far as 500 km (300 mi) from where it occurred, and sometimes causes damage as far away as 40 km (25 mi).

FAULTS

Earthquakes everywhere occur on faults within bedrock, usually miles deep. Most of the Adirondack region's bedrock was formed as several generations of mountains rose and were eroded down again over the last billion or so years.

At well-studied plate boundaries like the San Andreas fault system in California, often scientists can determine the name of the specific fault that is responsible for an earthquake. In contrast, east of the Rocky Mountains this is rarely the case. The Adirondack region is far from the nearest plate boundaries, which are in the center of the Atlantic Ocean and in the Caribbean Sea. The region is laced with known faults but numerous smaller or deeply buried faults remain undetected. Even the known faults are poorly located at earthquake depths. Accordingly, few Adirondack earthquakes can be linked to named faults. It is difficult to determine if a known fault is still active and could slip and cause an earthquake. As in most other areas east of the Rockies, the best guide to earthquake hazards in the Adirondack region is the earthquakes themselves.

<u>Inland Carolinas region</u>:

EARTHQUAKES IN THE INLAND CAROLINAS REGION

Since at least 1776, people living inland in North and South Carolina, and in adjacent parts of Georgia and Tennessee, have felt small earthquakes and suffered damage from infrequent larger ones. The largest earthquake in the area (magnitude 5.1) occurred in 1916 . Moderately damaging earthquakes strike the inland Carolinas every few decades, and smaller earthquakes are felt about once each year or two.

Earthquakes in the central and eastern U.S., although less frequent than in the western U.S., are typically felt over a much broader region. East of the Rockies, an earthquake can be felt over an area as much as ten times larger than a similar magnitude earthquake on the west coast. A magnitude 4.0 eastern U.S. earthquake typically can be felt at many places as far as 100 km (60 mi) from where it occurred, and it infrequently causes damage near its source. A magnitude 5.5 eastern U.S. earthquake usually can be felt as far as 500 km (300 mi) from where it occurred, and sometimes causes damage as far away as 40 km (25 mi).

FAULTS

Earthquakes everywhere occur on faults within bedrock, usually miles deep. Most bedrock beneath the inland Carolinas was assembled as continents collided to form a supercontinent about 500-300 million years ago, raising the Appalachian Mountains. Most of the rest of the bedrock formed when the supercontinent rifted apart about 200 million years ago to form what are now the northeastern U.S., the Atlantic Ocean, and Europe.

At well-studied plate boundaries like the San Andreas fault system in California, often scientists can determine the name of the specific fault that is responsible for an earthquake. In contrast, east of the Rocky Mountains this is rarely the case. The inland Carolinas region is far from the nearest plate boundaries, which are in the center of the Atlantic Ocean and in the Caribbean Sea. The region is laced with known faults but numerous smaller or deeply buried faults remain undetected. Even the known faults are poorly located at earthquake depths. Accordingly, few, if any, earthquakes in the inland Carolinas can be linked to named faults. It is difficult to determine if a known fault is still active and could slip and cause an earthquake. As in most other areas east of the Rockies, the best guide to earthquake hazards in the seismic zone is the earthquakes themselves.

New England:

EARTHQUAKES IN NEW ENGLAND

People in New England, and in its geological extension southward through Long Island, have felt small earthquakes and suffered damage from infrequent larger ones since colonial times. Moderately damaging earthquakes strike somewhere in the region every few decades, and smaller earthquakes are felt roughly twice a year. The Boston area was damaged three times within 28 years in the middle 1700's, and New York City was damaged in 1737 and 1884. The largest known New England earthquakes occurred in 1638 (magnitude 6.5) in Vermont or New Hampshire, and in 1755 (magnitude 5.8) offshore from Cape Ann northeast of Boston. The Cape Ann earthquake caused severe damage to the Boston waterfront. The most recent New England earthquake to cause moderate damage occurred in 1940 (magnitude 5.6) in central New Hampshire.

Earthquakes in the central and eastern U.S., although less frequent than in the western U.S., are typically felt over a much broader region. East of the Rockies, an earthquake can be felt over an area as much as ten times larger than a similar magnitude earthquake on the west coast. A magnitude 4.0 eastern U.S. earthquake typically can be felt at many places as far as 100 km (60 mi) from where it occurred, and it infrequently causes damage near its source. A magnitude 5.5 eastern U.S. earthquake usually can be felt as far as 500 km (300 mi) from where it occurred, and sometimes causes damage as far away as 40 km (25 mi).

FAULTS

Earthquakes everywhere occur on faults within bedrock, usually miles deep, although some New England earthquakes occur at shallower depths. Most of New England's and Long Island's bedrock was assembled as continents collided to form a supercontinent 500-300 million years ago, raising the northern Appalachian Mountains. The rest of the bedrock formed when the supercontinent rifted apart 200 million years ago to form what are now the northeastern U.S., the Atlantic Ocean, and Europe.

At well-studied plate boundaries like the San Andreas fault system in California, often scientists can determine the name of the specific fault that is responsible for an earthquake. In contrast, east of the Rocky Mountains this is rarely the case. New England and Long Island are far from the nearest plate boundaries, which are in the center of the Atlantic Ocean and in the Caribbean Sea. New England is laced with known faults but numerous smaller or deeply buried faults remain undetected. Even the known faults are poorly located at the depths of most earthquakes. Accordingly, few, if any, earthquakes in New England can be linked to named faults. It is difficult to determine if a known fault is still active and could slip and cause an earthquake. As in most other areas east of the Rockies, the best guide to earthquake hazards in New England and Long Island is the earthquakes themselves.

<u>New York – Philadelphia – Wilmington urban corridor</u>:

EARTHQUAKES IN THE NEW YORK – PHILADELPHIA – WILMINGTON URBAN CORRIDOR

Since colonial times people in the New York – Philadelphia – Wilmington urban corridor have felt small earthquakes and suffered damage from infrequent larger ones. New York City was damaged in 1737 and 1884. Moderately damaging earthquakes strike somewhere in the urban corridor roughly twice a century, and smaller earthquakes are felt roughly every 2-3 years.

Earthquakes in the central and eastern U.S., although less frequent than in the western U.S., are typically felt over a much broader region. East of the Rockies, an earthquake can be felt over an area as much as ten times larger than a similar magnitude earthquake on the west coast. A magnitude 4.0 eastern U.S. earthquake typically can be felt at many places as far as 100 km (60 mi) from where it occurred, and it infrequently causes damage near its source. A magnitude 5.5 eastern U.S. earthquake usually can be felt as far as 500 km (300 mi) from where it occurred, and sometimes causes damage as far away as 40 km (25 mi).

FAULTS

Earthquakes everywhere occur on faults within bedrock, usually miles deep. Most bedrock beneath the urban corridor was assembled as continents collided to form a supercontinent about 500-300 million years ago, raising the Appalachian Mountains. Most of the rest of the bedrock formed when the supercontinent rifted apart about 200 *million years ago to form what are now the northeastern U.S., the Atlantic Ocean, and Europe.*

At well-studied plate boundaries like the San Andreas fault system in California, often scientists can determine the name of the specific fault that is responsible for an earthquake. In contrast, east of the Rocky Mountains this is rarely the case. New York City, Philadelphia, and Wilmington are far from the nearest plate boundaries, which are in the center of the Atlantic Ocean and in the Caribbean Sea. The urban corridor is laced with known faults but numerous smaller or deeply buried faults remain undetected. Even the known faults are poorly located at earthquake depths. Accordingly, few, if any, earthquakes in the urban corridor can be linked to named faults. It is difficult to determine if a known fault is still active and could slip and cause an earthquake. As in most other areas east of the Rockies, the best guide to earthquake hazards in the New York – Philadelphia – Wilmington urban corridor is the earthquakes themselves.

<u>Stable continental region</u>:

EARTHQUAKES IN THE STABLE CONTINENTAL REGION

Most of North America east of the Rocky Mountains has infrequent earthquakes. Here and there earthquakes are more numerous, for example in the New Madrid seismic zone centered on southeastern Missouri, in the Charlevoix-Kamouraska seismic zone of eastern Quebec, in New England, in the New York – Philadelphia – Wilmington urban corridor, and elsewhere. However, most of the enormous region from the Rockies to the Atlantic can go years without an earthquake large enough to be felt, and several U.S. states have never reported a damaging earthquake. The earthquakes that do occur strike anywhere at irregular intervals.

Earthquakes east of the Rocky Mountains, although less frequent than in the West, are typically felt over a much broader region. East of the Rockies, an earthquake can be felt over an area as much as ten times larger than a similar magnitude earthquake on the west coast. A magnitude 4.0 eastern U.S. earthquake typically can be felt at many places as far as 100 km (60 mi) from where it occurred, and it infrequently causes damage near its source. A magnitude 5.5 eastern U.S. earthquake usually can be felt as far as 500 km (300 mi) from where it occurred, and sometimes causes damage as far away as 40 km (25 mi).

FAULTS

Earthquakes everywhere occur on faults within bedrock, usually miles deep. Most of the region's bedrock was formed as several generations of mountains rose and were eroded down again over the last billion or so years.

At well-studied plate boundaries like the San Andreas fault system in California, often scientists can determine the name of the specific fault that is responsible for an earthquake. In contrast, east of the Rocky Mountains this is rarely the case. All parts of *this vast region are far from the nearest plate boundaries, which, for the U.S., are to the east in the center of the Atlantic Ocean, to the south in the Caribbean Sea, and to the west in California and offshore from Washington and Oregon. The region is laced with known faults but numerous smaller or deeply buried faults remain undetected. Even most of the known faults are poorly located at earthquake depths. Accordingly, few earthquakes east of the Rockies can be linked to named faults. It is difficult to determine if a known fault is still active and could slip and cause an earthquake. In most areas east of the Rockies, the best guide to earthquake hazards is the earthquakes themselves.*

Washington – Baltimore urban corridor:

EARTHQUAKES IN THE WASHINGTON-BALTIMORE URBAN CORRIDOR

Since at least 1877 people in the urban corridor have felt small earthquakes. They occur about once per decade, although some decades have none and the 1990s had three. None are known to have caused damage since the arrival of European colonists. The corridor is between more seismically active regions to the southwest and northeast, and residents of Washington or Baltimore have felt several earthquakes that caused damage in those other, more active regions.

Earthquakes in the central and eastern U.S., although less frequent than in the western U.S., are typically felt over a much broader region. East of the Rockies, an earthquake can be felt over an area as much as ten times larger than a similar magnitude earthquake on the west coast. A magnitude 4.0 eastern U.S. earthquake typically can be felt at many places as far as 100 km (60 mi) from where it occurred, and it infrequently causes damage near its source. A magnitude 5.5 eastern U.S. earthquake usually can be felt as far as 500 km (300 mi) from where it occurred, and sometimes causes damage as far away as 40 km (25 mi).

FAULTS

Earthquakes everywhere occur on faults within bedrock, usually miles deep. Most bedrock beneath the Washington-Baltimore urban corridor was assembled as continents collided to form a supercontinent about 500-300 million years ago, raising the Appalachian Mountains. Most of the rest of the bedrock formed when the supercontinent rifted apart about 200 million years ago to form what are now the northeastern U.S., the Atlantic Ocean, and Europe.

At well-studied plate boundaries like the San Andreas fault system in California, often scientists can determine the name of the specific fault that is responsible for an earthquake. In contrast, east of the Rocky Mountains this is rarely the case. The Washington – Baltimore urban corridor is far from the nearest plate boundaries, which are in the center of the Atlantic Ocean and in the Caribbean Sea. The urban corridor is laced with known faults but numerous smaller or deeply buried faults remain undetected. Even the known faults are poorly located at earthquake depths. Accordingly, few, if any, earthquakes in the urban corridor can be linked to named faults. It is difficult to *determine if a known fault is still active and could slip and cause an earthquake. As in most other areas east of the Rockies, the best guide to earthquake hazards in the Washington – Baltimore urban corridor is the earthquakes themselves.*

APPENDIX II: POLYGON SOURCES

This appendix summarizes the sources from which each polygon's boundary was digitized. In several of the following paragraphs, the entry "Wheeler (unpub. results, 2003)" refers to a large-format, unpublished map of Mueller's two earthquake catalogs (A.C. Tarr, written commun., Dec. 13, 2002; see "Polygons" in main text). The map contains a one-degree graticule on which I chose several points to enclose one or more sides of a given cluster of seismicity. I estimated the points' coordinates to the nearest tenth of a degree. If I verified the resulting polygon by comparison to an independent, published map or figure showing the cluster of seismicity, that source is also cited.

Polygon vertices are not listed here because several polygons contain hundreds to thousands of vertices. These are the SCR polygon and those that follow intricate state or international boundaries. Those few readers who might want the polygon boundaries in digital form should contact me (303-273-8589) or Paul S. Earle (303-273-8417) with a description of the use to which the polygons will be put. The polygons were designed specifically for the use described in this report, and their properties may make them unsuitable for other uses. In particular, they should not be used for most seismic-hazard analyses. If, after discussion of the planned use, the reader and we agree that the polygons are suitable, we will be glad to send the digital files that contain the vertices.

<u>Adirondack region</u>: The northern and eastern boundaries of the polygon follow the New York State borders. The southwestern boundary is from Wheeler (unpub. results, 2003).

<u>Anna seismic zone</u>: Wheeler (unpub. results, 2003). The result was compared to Schwartz and Christensen (1988).

<u>Central Virginia seismic zone</u>: Wheeler (unpub. results, 2003). The result was compared to Bollinger and Sibol (1985).

<u>Charleston, South Carolina area</u>: Wheeler (unpub. results, 2003).

<u>Charlevoix-Kamouraska seismic zone</u>: The polygon is the irregular octagon that was used as a source zone in the computations for the 2002 USGS national seismic-hazard maps. I obtained the coordinates of the octagon from C.S. Mueller (written commun., Dec. 11, 2002).

<u>Eastern Tennessee seismic zone</u>: The polygon is the irregular quadrilateral that was used as a source zone in the computations for the 2002 USGS national seismic-hazard maps. I obtained the coordinates of the quadrilateral from C.S. Mueller (written commun., Dec. 11, 2002).

Illinois basin – Ozark dome region: Wheeler (unpub. results, 2003). The result was compared to Mitchell and others (1991).

Inland Carolinas regions: Wheeler (unpub. results, 2003).

Lancaster seismic zone: Wheeler (unpub. results, 2003). The result was compared to Armbruster and Seeber (1987) and Seeber and others (1998).

New England: The northern and western boundaries of the polygon are inland and they follow the borders of Connecticut, Massachusetts, Vermont, New Hampshire, and Maine. The eastern and southern boundaries are offshore and they are from Wheeler (unpub. results, 2003).

New Madrid seismic zone: The polygon is the one that was used as a source zone in the computations for the 2002 USGS national seismic-hazard maps. I obtained the coordinates of the polygon from C.S. Mueller (written commun., Dec. 11, 2002). Wheeler and Frankel (2000) described the reasoning behind the choice of boundaries.

New York – Philadelphia- Wilmington urban corridor: Wheeler (unpub. results, 2003).

Niagara – Attica zone: Wheeler (unpub. results, 2003).

Northeast Ohio seismic zone: Wheeler (unpub. results, 2003). The result was compared to Seeber and Armbruster (1993).

Stable continental region: The "Polygons" section of the main text describes the selection of lines to be digitized from various sources. The lines were compiled onto photocopies of the maps of Fenneman (1946) and Broadbent and Allan Cartography (1994) and digitized from there.

Washington – Baltimore urban corridor: Wheeler (unpub. results, 2003).

Western Quebec seismic zone: The southern boundary of the polygon follows the United States - Canada international border. Other polygon boundaries are from Wheeler (unpub. results, 2003).

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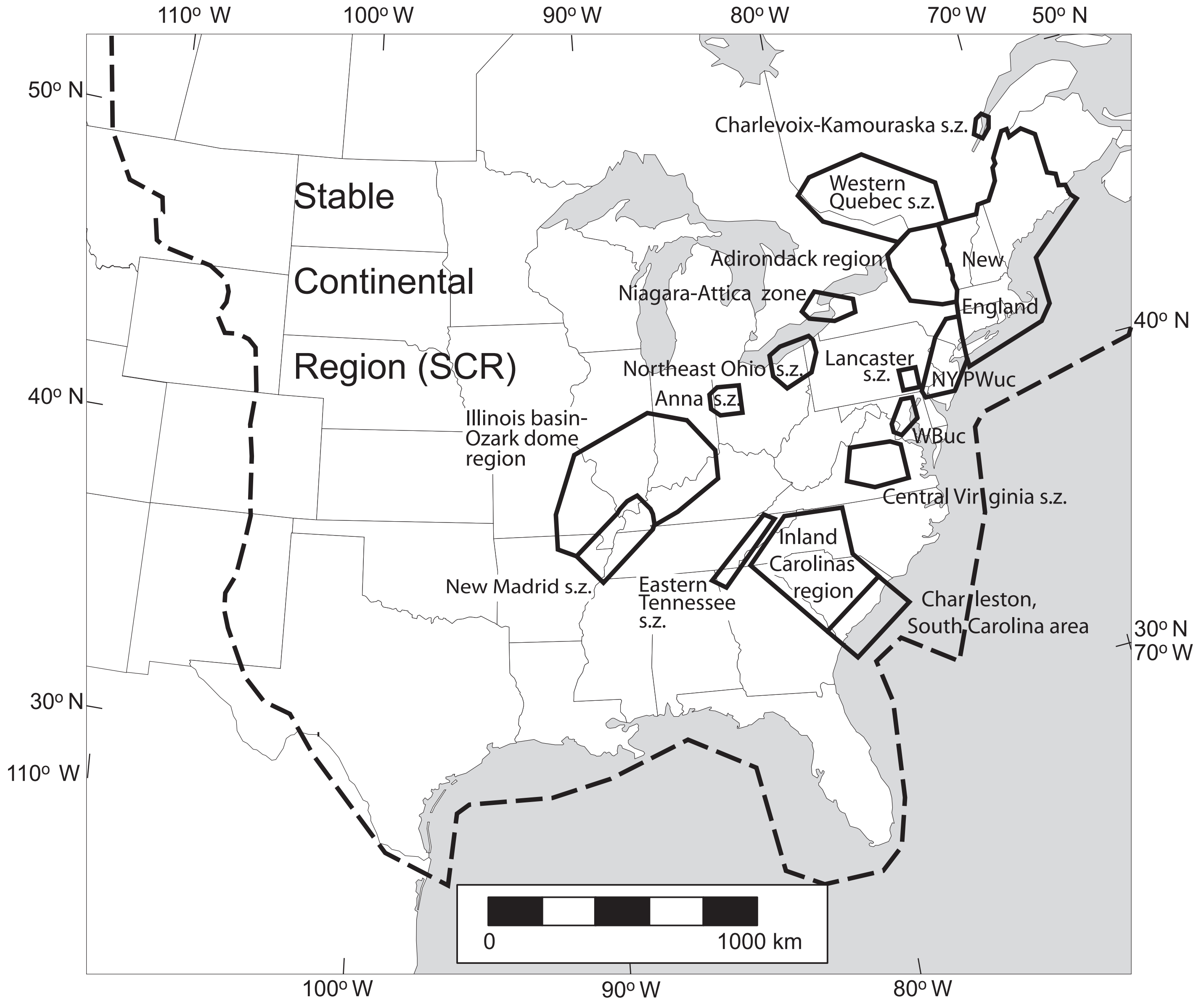

FIGURE 1. North America east of the Rocky Mountains is divided into seventeen polygons for the purpose of preparing tectonic summaries. Heavy dashed line: southern part of polygon outlining North American stable continental region (SCR, see text); heavy solid lines: outlines of other polygons within the SCR; s.z.: seismic zone; NYPWuc: New York - Philadelphia - Wilmington urban corridor; WBuc: Washington - Baltimore urban corridor. Polygons were drawn by eye for this figure. For exact locations, refer to coordinates in Appendix II.