D
APPENDIX
DATA SUMMARY TABLES

Default Source Characteristics for CEUS SSC Project Study Region

RLME Sources

Seismotectonic Zones

Mmax Zones

Criteria for defining the MESE/NMESE boundary for the two-zone alternative are discussed in Section 6.2.2. MESE-N includes ECC-AM, ECC-GC, AHEX, GHEX, RR, SLR, NAP, GMH, and PEZ-N. MESE-W differs from MESE-N in that it adopts the wide alternative geometries (i.e., PEZ-W, RR-RCG, and IBEB). See the tables listed above for data pertinent to the definition of the boundaries of the zones and evidence for Mesozoic and younger tectonism. Default future earthquakes rupture parameters (Table 4.1.3-1) are assigned to both the one-zone and two-zone Mmax sources.

Introduction

The Data Summary tables were developed to provide information on the various data that were considered during the course of the characterization of seismic sources. The table designation is linked to the chapter and section where the table is first cited. In some cases, information related to multiple seismic sources is included in a single table. The tables provide the citations to the data and a description of the key conclusions and their potential relevance to SSC. Full citations of references listed in the tables are provided in Chapter 10. All data sets included in the tables were reviewed, although not all were ultimately used to characterize a particular seismic source. Additional information on the Data Summary tables is provided in Section 4.1.2.2.

Please note that magnitudes are reported in the magnitude scale designated in the cited publication.

Table D-5.4 Data Summary
Future Earthquake Characteristics

Citation	Title	Description and Relevance to SSC
Atkinson (2004)	Empirical Attenuation of Ground-Motion Spectral Amplitudes in Southeastern Canada and the Northeastern United States	Presents a database of 1,700 digital seismograms from 186 earthquakes of magnitude M_N 2.5–5.6 that occurred in SE Canada and the NE United States from 1990 to 2003. The focus of the paper is the development of ground motion attenuation relationships, but the database represents high-quality instrumental recordings; source parameters are given for all events. This information can be used to examine various future earthquake characteristics such as focal depth.
Chapman et al. (1997)	A Statistical Analysis of Earthquake Focal Mechanisms and Epicenter Locations in the Eastern Tennessee Seismic Zone	This paper reports that 26 well-constrained focal mechanism solutions are derived using a new velocity model and relocated hypocenters. The results suggest that strike-slip motion on steeply dipping planes is the dominant mode of faulting throughout the 300 km (186 mi.) long Eastern Tennessee seismic zone. Most of the mechanisms can be grouped into two populations. The larger population is characterized by steeply dipping N-S- and E-W-striking nodal planes with right-lateral and left-lateral slip, respectively. The second population differs from the first by an approximate 45° eastward rotation about the B-axis. The results suggest a series of NE-trending en echelon basement faults, intersected by several east-trending faults. Most of the larger-magnitude instrumentally located earthquakes in the seismic zone occurred close to the statistically identified potential faults.
Dineva et al. (2004)	Seismicity of the Southern Great Lakes: Revised Earthquake Hypocenters and Possible Tectonic Controls	Using data from 27 seismograph stations for the period 1990–2001, 106 hypocenters with magnitudes of 0.9–5.4 were relocated in the region of the southern Great Lakes. Both the seismicity and magnetic anomalies exhibit statistically significant preferred orientations at N40°E–N45°E, but the correlation of the earthquake clusters with specific magnetic lineaments remains uncertain. Three preliminary focal mechanisms of earthquakes with magnitudes M_N 3.1–3.8 show unusual normal faulting, with nodal planes in almost the same direction as the magnetic trends, N42°E–N52°E.
Heidbach et al. (2008) (World Stress Map)	The World Stress Map Project Database Release 2008	Compilation of stress indicators for the CEUS shows consistent tectonic stress directions in the NE quadrant. No strong evidence for stress subprovinces.

Table D-5.4 Data Summary
Future Earthquake Characteristics

Citation	Title	Description and Relevance to SSC
Horton et al. (2005)	The 6 June 2003 Bardwell, Kentucky, earthquake sequence: Evidence for a Locally Perturbed Stress Field in the Mississippi Embayment	Includes a compilation of earthquake focal mechanisms of the earthquakes that occurred in the central U.S. since 1960s, including Reelfoot rift, Rough Creek graben in western Kentucky, and Wabash Valley fault system along SE Illinois/SW Indiana border. Special study of the June 6, 2003, Bardwell, Kentucky, earthquake, including a number of aftershocks, has been done to provide high-quality locations and focal mechanisms. Mechanisms are primarily strike-slip, with a component of reverse faulting. Focal mechanisms of earthquakes in the New Madrid seismic zone with E-W-trending nodal planes have different trending P axes, suggesting a strong perturbation in the stress field over a distance of about 60 km (37 mi.).
Kim (2003)	The 18 June 2002 Caborn, Indiana, Earthquake: Reactivation of Ancient Rift in the Wabash Valley Seismic Zone?	Presents an assessment of the June 18, 2002, Caborn, Indiana, earthquake (M_w 4.6) using regional and teleseismic waveform data, and concludes that the event occurred on a steeply dipping fault at a depth of about 18 km (11 mi.). The source mechanism determined from regional waveform analysis is predominantly strike-slip along near-vertical nodal planes. The June 2002 event at 18 km (11 mi.) depth and the south-central Illinois earthquake on November 9, 1968 (M_w 5.3), which occurred at 25 km (15.5 mi.) depth, suggest that seismogenic depth in the Wabash Valley seismic zone extends to at least 18 km (11 mi.).
Kim and Chapman (2005)	The 9 December 2003 Central Virginia Earthquake Sequence: A Compound Earthquake in the Central Virginia Seismic Zone	The December 9, 2003, central Virginia earthquake sequence was a compound earthquake consisting of two nearly identical events occurring about 12 sec apart. The source mechanism determined from regional waveform inversion indicates predominantly thrust faulting at a depth of approximately 10 ± 2 km (6 ± 1 mi.). A regional stress model for the Central Virginia seismic zone derived from the December 9, 2003, events and 11 previous earthquakes indicates a thrust-faulting stress regime. The December 9, 2003, earthquake sequence occurred among the systems of Paleozoic and Mesozoic faults above the southern Appalachian décollement, which is at 12–19 km (7–12 mi.) depth in the Piedmont geologic province of central Virginia.
Mai et al. (2005)	Hypocenter Locations in Finite-Source Rupture Models	The paper compiles data related to hypocenter depths in relation to the normalized downdip width of fault rupture for crustal faults and subduction zones. The relationships can be used to assess expected depth distribution of earthquakes as a function of earthquake magnitude.

Table D-5.4 Data Summary
Future Earthquake Characteristics

Citation	Title	Description and Relevance to SSC
Marshak and Paulsen (1997)	Structural Style, Regional Distribution, and Seismic Implications of Midcontinent Fault-and-Fold Zones, United States	Summarizes steeply dipping faults and associated monoclinal forced folds, which were active in pulses during the Phanerozoic, although it is suggested that they initiated during episodes of Proterozoic extensional tectonism. Based on fault-trace orientation, Midcontinent fault-and-fold zones are divided into two sets—one trending N-NE and the other trending W-NW. Many W-NW-trending fault-and-fold zones link along strike to define semicontinuous NW-trending deformation corridors. One of these, the 200 km (124 mi.) wide Transamerican tectonic zone (TTZ), traces over 2,500 km (1,553 mi.) from Idaho to South Carolina. Seismicity most frequently occurs where N-NE-trending fault-and-fold zones cross the TTZ, suggesting that intracratonic strain in the U.S. currently concentrates at or near intersecting fault zones within this corridor.
Mazzotti (2009 CEUS SSC Workshop 2 presentation)	Strain (and Stress) Constraints on Seismicity in the St. Lawrence Valley	Map showing ~50 focal mechanisms indicates primarily reverse faulting, with a component of strike-slip. Plots of interpreted maximum compressive stress directions show that both α1 and α2 are horizontal. Also shown are differences in the orientation of α1 for events to the north of the axis of the St. Lawrence (in the NE quadrant) versus south (approximately E-W).
NAGRA (2004)	Probabilistic Seismic Hazard Analysis for Swiss Nuclear Power Plant Sites (PEGASOS Project)	This large PSHA was conducted for four nuclear power plant sites in Switzerland, which is characterized by a seismotectonic setting very similar to the CEUS. Presents an approach to characterize the depth distribution of future earthquake ruptures using the focal depth distribution of observed hypocenters. The approach takes advantage of observed seismicity as well as studies of the magnitude dependence of focal depths.
Seeber et al. (1998)	The 1994 Cacoosing Valley Earthquakes near Reading, Pennsylvania: A Shallow Rupture Triggered by Quarry Unloading	The paper discusses the m_{bLg} 4.6 main shock on January 16, 1994, in the Cacoosing Valley, 10 km (6 mi.) west of Reading, SE Pennsylvania. This zone matches the nodal plane with reverse and left-lateral slip (strike 135°, dip 54°SW, and rake 55°) of a focal mechanism obtained from aftershock first motions and from main-shock waveforms.
Shumway (2008)	Focal Mechanisms in the Northeast New Madrid Seismic Zone	Earthquakes in the NE New Madrid seismic zone from June 1995 to June 2006 were relocated using a velocity model of the Mississippi embayment with appropriate depths to bedrock beneath seismic stations. Focal mechanisms were generated for events on the NE-trending alignments. The results show that most of the earthquakes are strike-slip and approximately half the focal mechanisms have a N-NE-striking nodal plane and a right-lateral, strike-slip component consistent with earlier studies of the NMNF to the southwest.

Table D-5.4 Data Summary
Future Earthquake Characteristics

Citation	Title	Description and Relevance to SSC
Sibson (1982)	Fault Zone Models, Heat Flow, and the Depth Distribution of Earthquakes in the Continental Crust of the United States	Models of fault zones in continental crust, based on analysis of rock deformation textures, suggest that depth of seismic activity is controlled by the passage from a pressure-sensitive, dominantly frictional regime to strongly temperature-dependent, quasi-plastic mylonitization at greenschist and higher grades of metamorphism. Based on models of the frictional and rheological properties of quartz-bearing rocks, crude strength-depth curves for different geotherms are developed. In such models, shear resistance peaks sharply at the inferred seismic-aseismic transition. Depth at which 90% of microseismic activity occurs is plotted on the modeled strength-depth curves for various heat flow provinces of the conterminous U.S.
Sibson (1984)	Roughness at the Base of the Seismogenic Zone: Contributing Factors	Observational data such as earthquake focal depths and considerations of the strength profile of continental crust are both used to draw conclusions regarding the controls of the thickness of the seismogenic zone. Implications are drawn regarding the likely depths of large earthquakes and their magnitude dependence.
Sibson (2007)	Au-Quartz Mineralization near the Base of the Continental Seismogenic Zone	The base of the continental seismogenic zone is defined within individual fault zones by the transition with depth from pressure-sensitive factional (FR) faulting to temperature-sensitive quasi-plastic (QP) ductile shearing. The depth of this FR-QP transition fluctuates principally as a consequence of variations in geothermal gradient and crustal lithology but other factors (e.g., fluid pressure level, strain rate) also play a role. Topographic irregularities in the seismic-aseismic transition determine rupture nucleation sites and probably play a critical role in focusing the discharge of overpressured metamorphic fluids into the seismogenic layer. This information has implications to the depth of larger earthquakes and their nucleation near the base of the seismogenic zone.
Sibson and Xie (1998)	Dip Range for Intracontinental Reverse Fault Ruptures: Truth Not Stranger than Friction?	Histograms of fault dips have been compiled for moderate to large (M > 5.5) reverse-slip intracontinental earthquakes with the slip-vector raking 90° ± 30° in the fault plane. The principal data set is restricted to earthquakes where the fault plane in the focal mechanism can be unambiguously distinguished from the auxilliary plane; the reverse fault dips are bracketed within the range of 12°–60° with a prominent peak in the 25°–35° interval and a subsidiary peak in the 45°–55° interval.

Table D-5.4 Data Summary
Future Earthquake Characteristics

Citation	Title	Description and Relevance to SSC
Somerville et al. (2001)	Ground Motion Attenuation Relations for the Central and Eastern United States	As part of developing ground-motion attenuation relations, the authors first developed earthquake source scaling relations for use in generating ground motions. The source models have spatially varying slip distributions on the fault plane, and are described by self-similar scaling relations between seismic moment and source parameters such as fault dimensions and rise time derived from the slip models of three recent earthquakes in eastern Canada. Scaling relationships of earthquake rupture models are presented relating fault rupture area and seismic moment that are deemed to be appropriate for eastern North America.
Sykes et al. (2008)	Observations and Tectonic Setting of Historic and Instrumentally Located Earthquakes in the Greater New York City–Philadelphia Area	As part of discussions of seismicity in the New York region, high-quality earthquake locations and focal depths are given. The focal depth distribution provides information on seismogenic crustal thickness for the region.
Talwani (2009 CEUS SSC Workshop 2 presentation)	The Source and Magnitude of the Charleston Earthquake	The presentation summarized the latest instrumental seismicity data for the Charleston region. Included in the talk was a plot of focal depth distribution for instrumental events in the region.
Tanaka (2004)	Geothermal Gradient and Heat Flow Data in and Around Japan (II): Crustal Thermal Structure and Its Relationship to Seismogenic Layer	The high-quality database of seismicity of Japan (Japan Meteorological Agency, or JMA) and an extensive compilation of thermal measurements (Tanaka et al., 2004) are used to quantify the concept of temperature as a fundamental parameter for determining thickness of the seismogenic zone. Qualitative comparisons between each data of heat flow and geothermal gradient, and the lower limit of crustal earthquake hypocentral distributions beneath the Japanese Islands show that, as expected, the lower limit of seismicity is inversely related to heat flow and geothermal gradient. Gridded heat flow or geothermal gradient and D_{90}, the depth above which 90% of earthquakes occur, correlated well with each other. The evaluated temperatures for D_{90} range between 250°C and 450°C except for higher heat flow data. The consistency of temperature for D_{90} over a large depth interval almost all over the Japanese islands support the concept that the temperature is the dominant factor governing the focal depth in the crust.

Table D-5.4 Data Summary
Future Earthquake Characteristics

Citation	Title	Description and Relevance to SSC
Tanaka and Ishikawa (2002)	Temperature Distribution and Focal Depth in the Crust of the Northeastern Japan	Comparisons are made between heat flow, thermal gradient and earthquake databases for NE Japan. Temperatures in the crust were calculated using a steady-state one-dimensional heat-conductive transport model with heat generation as a function of heat flow and thermal gradient. The evaluated temperatures for D_{90}, the depth above which 90% of earthquakes occur, range between 200°C and 500°C except for high heat flow and thermal gradient data. The consistency of temperature for D_{90} over a large depth interval supports the theory that temperature is the dominant factor governing the focal depth in the crust.
van Lanen and Mooney (2007)	Integrated Geologic and Geophysical Studies of North American Continental Intraplate Seismicity	The paper provides a histogram of earthquake focal depth in eastern North America (ENA) as a function of moment magnitude. The compilation for ENA is compared to other stable continental regions. The paper concludes that seismicity is correlated with the NE-SW structural grain of the crust of ENA, which in turn reflects the opening and closing of the proto- and modern Atlantic Ocean. This structural grain can be discerned as clear NE-SW lineaments in the Bouguer gravity and aeromagnetic anomaly maps. Stable continental region seismicity either (1) follows the NE-SW lineaments, (2) is aligned at right angles to these lineaments, or (3) forms clusters at what have been termed stress concentrators.
Wesnousky (2008)	Displacement and Geometrical Characteristics of Earthquake Surface Ruptures: Issues and Implications for Seismic-Hazard Analysis and the Process of Earthquake Rupture	This paper includes a compilation of empirical data regarding the seismologic and geologic characteristics of earthquake ruptures. The data set is aimed at establishing rupture characteristics and their uncertainties for use in seismic hazard and fault displacement hazard analyses. A relationship between fault length-to-width aspect ratio versus magnitude is presented.
Zoback (1992)	Stress Field Constraints on Intraplate Seismicity in Eastern North America	Focal mechanisms of 32 North American CEUS earthquakes are evaluated to determine if slip is compatible with a broad-scale regional stress field derived from plate-driving forces and, if so, under what conditions. Independent information on in situ stress orientations from well bore breakout and hydraulic fracturing data is used to assess relative stress magnitudes. The evaluation of the data confirmed a roughly north-to-south contrast in stress regime between the CEUS and SE Canada: most CEUS earthquakes occur in response to a strike-slip stress regime, whereas SE Canada events require a thrust-faulting stress regime.

Table D-5.4 Data Summary
Future Earthquake Characteristics

Citation	Title	Description and Relevance to SSC
Zoback (2010)	CEUS SSC stress data set	Database updates the compilation for the CEUS developed originally for the World Stress Map. Uses a variety of indicators (e.g., earthquake focal mechanisms, in situ stress measurements) of the orientation of the maximum compressive stresses. Stress data based on earthquake focal mechanisms and other in situ stress indicators were compiled for the past 10 years and added to the existing world stress map. Orientations of maximum compressive stress directions are consistent with those compiled earlier. There is no longer compelling evidence for a northwesterly directed stress province along the Atlantic margin, as postulated in the 1980s. There is some suggestion of stress rotation within the New Madrid seismic zone, which would suggest a weak zone, but the evidence is not strong.

Table D-6.1.1 Data Summary
Charlevoix RLME

Citation	Title	Description and Relevance to SSC
Geologic Structures Interpreted from Geologic, Gravity, Magnetic, and Seismic Profile Data		
Lemieux et al. (2003)	Structural Analysis of Supracrustal Faults in the Charlevoix Area, Quebec: Relation to Impact Cratering and the St-Laurent Fault System	Two major sets of fault orientations (N290°–N320° and N020°–N040°) are found outside the impact zone, with minor fault sets trending N270–N280 and N000–N020. Within the impact crater, fault orientations are more scattered but are similar to the NW- and NE-trending systems of the external domain. The spread of orientations within the central portion of the crater is attributed to the impact-related polygonal pattern of normal faults, whereas the NW and NE fault sets represent the youngest reactivation. Coarse-grained cataclastic breccias up to 50 m thick are exposed along brittle faults striking NE and NW outside the impact crater. Similar cataclastic breccias are also found within the impact crater but are usually less than a few meters thick. Polymictic clastic matrix breccia is found exclusively within the impact crater. Fragments of cataclastic breccia are present, suggesting recurrent brecciation during incremental faulting events. Pseudotachylyte and foliated gouge are locally related to the cataclastic breccia, indicating that these rocks originate from a post-impact single and progressive tectonic event along the St. Lawrence rift system. The St-Laurent fault influenced the deposition of Ordovician deposits during late stages of the Taconian orogeny by syndepositional faulting preserved as major lateral thickness variations within the section, presence of slump deformation in almost all stratigraphic units, preservation of pseudotachylyte within synsedimentary breccias, and occurrence of fault breccia clasts. However, the geometry and structural characteristics of faulting are consistent with Mesozoic fault reactivation due to rifting of the North Atlantic region.

Table D-6.1.1 Data Summary
Charlevoix RLME

Citation	Title	Description and Relevance to SSC
Tremblay and Lemieux (2001)	Supracrustal Faults of the St. Lawrence Rift System Between Cap-Tourmente and Baie-Saint-Paul, Quebec	The Cap-Tourmente and St. Lawrence faults are late Proterozoic–early Paleozoic normal faults attributed to rifting during the opening of the Iapetus Ocean. The St. Lawrence rift system is a NE-trending half graben that links the NW-trending grabens of the Ottawa-Bonnechere and Saguenay aulacogens. The St. Lawrence fault trends N020°–N050° and dips 60°–70° to the southeast. Fault rocks consist of fault breccia, cataclastite, foliated gouge, and pseudotachylyte with a minimum thickness of 20 m near Sault-au-Cochon. Fault rocks exposed at Cap-Tourmente consist of 10–15 m thick zones of protocataclasite, cataclasite, and fault breccia. Within the Charlevoix area, the St. Lawrence fault is characterized by a well-developed and extensive series of cataclastic rock, gouge, and associated pseudotachylyte. The Cap-Tourmente fault trends E-W and dips approximately 80° to the south. Fault rocks consist mostly of fault breccia more than 10 m thick, as well as cataclastic rocks and dark pseudotachylyte veins. The St. Lawrence fault is crosscut by the Cap-Tourmente fault at Cap-Tourmente. West of Cap-Tourmente, the Montmorency Falls fault occupies the same structural position as the St. Lawrence fault, suggesting that they formed from en echelon faults trending parallel to the axis of the St. Lawrence rift. The Cap-Tourmente fault possibly represents a transfer fault, producing an oblique relay between two longitudinal normal faults. The St. Lawrence fault crosses the Charlevoix impact crater without major trend deflection or fault offsets within or at the boundaries of the Devonian impact structure. This observation suggests that impact-related faults did not significantly alter the orientation of preexisting structures and that reactivation is younger than the impact structure, most probably concurrent with the opening of the Atlantic Ocean in the Mesozoic.

Table D-6.1.1 Data Summary
Charlevoix RLME

Citation	Title	Description and Relevance to SSC
Tremblay et al. (2003)	Supracrustal Faults of the St. Lawrence Rift System, Quebec: Kinematics and Geometry as Revealed by Field Mapping and Marine Seismic Reflection Data	Presents strike orientations, dip angles, and pitch angles for faults with evidence for frictional sliding in the St. Lawrence rift system. NE-trending longitudinal faults show three trends (N025, N040, and N070) and generally dip to the SE, although a minor number dip to the NW. Transverse faults show two trends (N290 and N310) and dip to the NE or SW, which is consistent with the horst-and-graben geometry. Both sets of faults are high-angle faults with dip angles averaging 75°–80°. The pitch value of fault lineations is greater than 70°, indicating that most structures are dip-slip faults. Longitudinal and transverse faults show mutual crosscutting relationships, suggesting that they represent conjugate structures related to the same tectonic event. The St-Laurent fault has experienced at least 800 m of vertical throw at Sault-au-Cochon. The Cap-Tourmente fault has a minimum vertical fault throw of 700 m. The Montmorency fault has an 80 m fault scarp near Quebec City, and stratigraphic analysis suggests that fault throw should be less than 150 m, which is considerably less than the other faults. Several offshore faults subparallel to that fault may have vertical downthrow displacements up to 1 km (0.6 mi.). Longitudinal faults likely result from the development of en echelon faults trending parallel to the rift axis, and transfer faults represent transfer faults or accommodation zones. Variations in fault throw are likely a result of propagation of extension along transfer faults. The presence of cataclastic rocks, pseudotachylytes, and fault gouge is consistent with changes of deformation mechanics during progressive and incremental deformation in the upper crust. High-resolution seismic profiles in the St. Lawrence estuary indicate that the Laurentian Channel trough transitions from a half graben to a graben structure from SW to NE. The authors speculate that reactivation of the St. Lawrence rift system is post-Ordovician, younger than the Devonian impact cratering event, and that it experienced additional fault throw and shoulder uplift during the Mesozoic opening of the North Atlantic.

Table D-6.1.1 Data Summary
Charlevoix RLME

Citation	Title	Description and Relevance to SSC
Magnitude Estimates		
Bent (1992)	A Re-examination of the 1925 Charlevoix, Québec Earthquake	Analysis of additional waveforms resulted in magnitude estimates of M_w 6.2, M_s 6.2 ± 0.3, and m_b 6.5 ± 0.4. Due to insufficient 1-sec period data, m_{bLg} was not determined.
Ebel (1996)	The Seventeenth Century Seismicity of Northeastern North America	Ebel (1996) assigned a M ≥ 7.0 ± 0.5 to the 1663 Charlevoix earthquake. This interpretation is based on accounts of landsliding and liquefaction along the St. Lawrence River and several of its tributaries, and on felt effects in Quebec, Acadia (Maine), and eastern Massachusetts. Based on this distribution of felt effects, the magnitude of the 1663 event is somewhat larger than the 1925 Charlevoix earthquake.
Ebel (2006b)	Thoughts Concerning Earthquake Sources in the Northeastern U.S.	Postulated that if the total length of the Charlevoix seismic zone (70 km) produced a single rupture, the 1663 event would be M 7.5, and all modern seismicity can be thought of as aftershocks of this event.
Ebel (2009)	On the Magnitude of the 1663 Charlevoix, Quebec Earthquake	A rupture length of 70 km (43.5 mi.; the length of the seismic zone) could produce a main-shock magnitude of M 7.1–7.5. Interpreted MMI VI reports at Roxbury, Massachusetts, with an intensity-attenuation relationship as an M_{Lg} 7.5 (M 7.8), and with recent ground-motion attenuation relationships as an M 7.5. These lines of evidence suggest a magnitude of M 7.5 ± 0.3 for the 1663 Charlevoix event.
Lamontagne et al. (2008)	Significant Canadian Earthquakes of the Period 1600-2006	Repeated large-magnitude historical earthquakes have occurred in Charlevoix: February 5, 1663, M 7; December 6, 1791, M 5.8; October 17, 1860, M 6; October 20, 1870, M 6.5; and March 1, 1925, M 6.2.
Recurrence		
Doig (1990)	2300 Yr History of Seismicity from Silting Events in Lake Tadoussac, Charlevoix, Quebec	Inferred a variable recurrence rate for the Charlevoix seismic zone from silt layers in lakes due to earthquake-induced landslides. Some silt layers in the section were correlated with historic earthquakes from 1638, 1663, 1791, 1870, and 1925. From 320 BC to AD 800, determined a 120-year recurrence interval, 270 years between AD 800 and 1500, and 75 years from AD 1500 to the present.

Table D-6.1.1 Data Summary
Charlevoix RLME

Citation	Title	Description and Relevance to SSC
Filion et al. (1991)	A Chronology of Landslide Activity in the Valley of Rivière du Gouffre, Charlevoix, Quebec	Sampled tree trunks buried in landslide flow materials from four sectors along the Gouffre River between Saint-Urban and Baie-Saint-Paul. The age distribution of tree trunks indicates that landslides have occurred at 5,670, 3,170, 2,500, and 1,870 yr BP, with most ages <600 yr BP. Comparison of tree-ring widths throughout the study area suggests that trees died during the latent period between the 1662 and 1663 growing seasons, possibly due to synchronous landslides. The authors interpret these two landslides as having been caused by the February 1663 Charlevoix earthquake. These results provide no evidence for the 1925 earthquake. The authors emphasize the importance of tree-ring techniques to delineate the areal extent of landslides caused by the 1663 earthquake and to caution against exaggerating the geomorphic consequences of earthquakes.
Tuttle and Atkinson (2010)	Localization of Large Earthquakes in the Charlevoix Seismic Zone, Quebec, Canada, During the Past 10,000 Years	Provides evidence for three Holocene paleoearthquakes in Charlevoix with M ≥ 6.2, including at least two prehistoric episodes at 5 and 10 ka.
Seismicity—Focal Mechanisms and Fault Geometry		
Baird et al. (2009)	Stress Channeling and Partitioning of Seismicity in the Charlevoix Seismic Zone, Quebec, Canada	Seismicity is localized along two elongate bands of seismicity bounded by rift faults extending NE of the Charlevoix impact crater. In a 2-D stress model, faults are represented as frictional discontinuities, and the impact crater as an elastic continuum of reduced modulus. Stress trajectories flow around the weak impact crater, concentrating stress along weak faults into the impact crater, resulting in seismicity in linear bands. The asymmetric placement of the rift faults through the crater results in increased seismicity potential along the rift, north of the crater. Observed seismicity, is therefore interpreted as a result of stress concentration due to the interaction of the crater (local zone of weakness) and rift faults (large-scale weak zone). Small to moderate seismicity occurs within the crater and larger earthquakes are localized along the rift faults. Three-dimensional modeling would be able to accurately model the bowl shape of the crater and may be able to examine why seismicity extends below the crater into Grenville basement. Current observations of reverse reactivation of rift faults associated with glacial rebound could not be assessed with the 2-D model presented in this paper and would require examination with a 3-D model.

Table D-6.1.1 Data Summary
Charlevoix RLME

Citation	Title	Description and Relevance to SSC
Bent (1992)	A Re-examination of the 1925 Charlevoix, Québec Earthquake	Analysis of additional waveforms resulted in source parameters of strike 42° ± 7°, dip 53° ± 7°, rake 105° ± 10°, depth 10 km (6.2 mi.), seismic moment 3.1 ± 2.5 × 10^{25} dyne cm (M_w 6.2), M_s 6.2 ± 0.3, m_b 6.5 ± 0.4, source duration 5 sec, and stress drop 35 bars. The dip is shallower than would be expected from observed surface faults but consistent with recent seismicity. The focal mechanism is consistent with horizontal compression in the NW-SE direction, which is orthogonal to the regional stress field, indicating an anomalous stress field in Charlevoix that may be depth dependent.
Lamontagne and Ranalli (1996)	Thermal and Rheological Constraints on the Earthquake Depth Distribution in the Charlevoix, Canada, Intraplate Seismic Zone	Compares the depth distribution of Charlevoix earthquakes to rheological models of the region. The maximum depth of earthquakes can be controlled by either the brittle-ductile transition or the velocity-weakening to velocity-strengthening fault behavior. The rheological change at the brittle-ductile transition was modeled by calculating geotherms assuming a variety of rock compositions in the upper and middle crust. The depth distribution of earthquakes in Charlevoix requires geotherms very close to the upper limit for felsic rocks and a wet lower crust. The temperature-controlled sliding stability transition can occur at 300°C and 450°C for quartz or feldspar plasticity. Hydrolytic weakening of feldspars at 350°C occurs at 25 km (15.5 mi.) for the upper geotherms. The maximum crustal stress difference has an upper limit of about 100–200 MPa, requiring high pore fluid pressure or low coefficient of friction in mid- to lower crust. Thrust reactivation of steeply dipping faults requires a low coefficient of friction. The authors attribute the presence of earthquakes in the Charlevoix region to brittle-ductile transition deeper than 25 km (15.5 mi.), corresponding to higher than average geotherms; onset of ductility for hydrated feldspar at about 350°C; high pore-fluid pressure; and a low friction coefficient, possibly related to unhealed zones of intense fracturing.

Table D-6.1.1 Data Summary
Charlevoix RLME

Citation	Title	Description and Relevance to SSC
Lamontagne and Ranalli (1997)	Faults and Spatial Clustering of Earthquakes near La Malbaie, Charlevoix Seismic Zone, Canada	Focal mechanisms for earthquakes larger than M 3 show reverse faulting, whereas smaller-magnitude earthquakes indicate both normal and strike-slip mechanisms, suggesting that local stress and/or strength conditions control their occurrence. However, focal mechanisms for larger events of the Charlevoix seismic zone suggest reactivation of paleo-rift faults in response to regional stresses. The distribution of spatially clustered events (doublets and triplets) within the Charlevoix seismic zone indicates that very few events have occurred on the same fractures with similar focal mechanisms, implying that these fault zones occur in highly fractured rocks. These observations, indicate that the Charlevoix seismic zone is characterized by highly fractured zones responding to regional stresses and local perturbations in stress or strength, possibly enhanced by pore fluid pressures.
Geodetic and Modeling Studies—Hypotheses for Causes of Intraplate Seismicity		
Mazzotti and Adams (2005)	Rates and Uncertainties on Seismic Moment and Deformation Rates in Eastern Canada	Modeled seismic moment rates from earthquake statistics from the Charlevoix seismic zone can reach up to 2–10 × 10^{17} N m yr^{-1}, equivalent to a magnitude M_w = 7 earthquake every 35–150 years. Relative motion and strain rates derived from earthquake statistics may reach up to 1–2 mm yr^{-1} for the Charlevoix seismic zone. The lack of deformation suggests that the high strain rate might represent a short-term process such as postglacial rebound.
Seismic Source Characterization Models		
Adams and Halchuk (2003)	Fourth Generation Seismic Hazard Maps of Canada: Values for Over 650 Canadian Localities Intended for the 2005 National Building Code of Canada	Charlevoix is separated as a zone in the H model and combined with other St. Lawrence seismicity in the R model. The authors modeled recurrence rates with a beta value of 1.74 ± 0.11 with a maximum magnitude of 7.5.
Tuttle and Atkinson (2010)	Localization of Large Earthquakes in the Charlevoix Seismic Zone, Quebec, Canada, During the Past 10,000 Years	The absence of liquefaction features to the south in the Trois-Rivières seismic zone of the GSC H model (TRR on Figure 3-3) suggests that large-magnitude events in Charlevoix are spatially stationary.

Table D-6.1.2 Data Summary
Charleston RLME

Citation	Title	Description and Relevance to SSC
Geologic Structures Interpreted from Geologic, Geomorphic, Geophysical and Seismic-Profile Data		
Bartholomew and Rich (2007)	The Walls of Colonial Fort Dorchester: A Record of Structures Caused by the August 31, 1886 Charleston, South Carolina, Earthquake and Its Subsequent Earthquake History	The Dorchester fault is proposed as a near-vertical, NW-striking, reverse-oblique (right-lateral) fault. As proposed, the Dorchester fault is a subsurface feature that extends from a depth of about 8 km (5 mi.) below the ground surface downward to a depth between 13 and 25 km (8 and 15.5 mi.). The existence of this proposed fault is not based on direct evidence, but rather is inferred based on the analysis of (1) cracks in the walls of colonial Fort Dorchester; (2) local and regional stress orientations, including borehole breakouts; and (3) fault plane solutions from local microseismicity. There is no direct geologic or geomorphic evidence for the Dorchester fault, thus the existence of this structure is assessed to be questionable.
Behrendt and Yuan (1987)	The Helena Banks Strike-Slip (?) Fault Zone in the Charleston, South Carolina, Earthquake Area; Results from a Marine, High-Resolution, Multichannel, Seismic-Reflection Survey	Data from 24 marine seismic-reflection profiles totaling ~600 km (373 mi.) offshore from Charleston across strands of the Helena Banks fault zone show Miocene strata that are warped in a reverse-faulting sense. Helena Banks fault is described as 110 km (68.4 mi.) long, ~N66°E-striking, and comprising several segments 10–40 km (6.2 to 25 mi.) long. Interpreted as compressional reactivation of an extensional Mesozoic basin-bounding fault.
Behrendt et al. (1981)	Cenozoic Faulting in the Vicinity of the Charleston, South Carolina, 1886 Earthquake	Data from onshore multichannel seismic-reflection profiles in the 1886 meizoseismal area show evidence of Cenozoic faulting, including the NE-striking reverse (?) Cooke fault. Data suggest that most recent slip on the Cooke fault is Eocene or later. Data from offshore multichannel seismic-reflection profiles and single-channel high-resolution data show the Helena Banks fault as a 30+ km (18.5+ mi.) long structure with most recent movement in post-Miocene or Pliocene time.

Table D-6.1.2 Data Summary
Charleston RLME

Citation	Title	Description and Relevance to SSC
Behrendt et al. (1983)	Marine Multichannel Seismic-Reflection Evidence for Cenozoic Faulting and Deep Crustal Structure Near Charleston, South Carolina	Seismic-reflection data collected offshore from Charleston show Helena Banks fault as NE-striking, west-dipping reverse fault that extends upward to about 10 km (6.2 mi.) from the sea bottom. Interpreted as a Mesozoic extensional fault reactivated as reverse-oblique fault at least as young as Miocene or Pliocene. Also interpreted a subhorizontal detachment at 11.4 ± 1.5 km (7 ± 1 mi.) depth. Suggested Charleston seismicity is primarily caused by movement along the detachment and that movement on high-angle reverse faults (e.g., the Helena Banks fault and others) may also cause earthquakes.
Chapman et al. (2007)	Attenuation in the Atlantic Coastal Plain of Virginia and Cenozoic Faulting Imaged in the Epicentral Area of the 1886 Charleston, South Carolina Earthquake, Using Data from Seismic Reflection Profiles	Reprocessed seismic-reflection lines near Charleston reveal presence of "fault C," interpreted as reactivated Mesozoic normal fault (reactivated in oblique-reverse sense, up to the east). Fault C is traced upward into Eocene-age deposits in line VT-3b, but cannot be traced higher in section due to poor data resolution in shallow section. Fault C postulated to be the fault that ruptured in 1886 Charleston earthquake. Strike, length, and age of feature unresolved. See also Chapman and Beale (2008).
Chapman and Beale (2008)	Mesozoic and Cenozoic Faulting Imaged at the Epicenter of the 1886 Charleston, South Carolina, Earthquake	Reprocessed seismic-reflection lines near Charleston reveal presence of "fault C," interpreted as reactivated Mesozoic normal fault (reactivated in oblique-reverse sense, up to the east). Fault C is traced upward into Eocene-age deposits in line VT-3b, but cannot be traced higher in section due to poor data resolution in shallow section. Fault C is postulated to be the fault that ruptured in 1886 Charleston earthquake. Strike, length, and age of feature unresolved. See also Chapman et al. (2007).

Table D-6.1.2 Data Summary
Charleston RLME

Citation	Title	Description and Relevance to SSC
Chapman and Beale (2009)	Results of Reprocessing Seismic Reflection Data near Summerville, SC	Similar to Chapman and Beale (2008), reprocessed seismic-reflection lines near Summerville reveal Cenozoic compressional reactivation of a Mesozoic extensional basin, suggesting 1886 epicentral area lies within a zone of extensively faulted upper crust. These reflection data essentially reveal point images of fault at widely scattered locations, roughly coincident with the recently proposed Woodstock South, Woodstock North, and Sawmill Branch faults, inferred from a combination of earthquake hypocenters, focal mechanisms, geologic and geomorphic evidence, and intensity reports from 1886 (Dura-Gomez and Talwani, 2009; Talwani and Dura-Gomez, 2009). These faults strike NE and form a right-oblique (thrust) system. Woodstock North fault is a few km SE of the Cenozoic disturbance near Summerville imaged in lines VT4 and VT5, and crosses SC6 near the Cenozoic disturbance imaged in CMP 340. Seismicity attributed to Sawmill Branch fault is coincident with faults imaged in line VT3.
Chapman and Beale (2010)	On the Geologic Structure at the Epicenter of the 1886 Charleston, South Carolina, Earthquake	Reprocessed seismic-reflection lines near Summerville reveal Cenozoic compressional reactivation of a Mesozoic extensional basin, suggesting 1886 epicentral area lies within zone of extensively faulted upper crust. These reflection data essentially reveal point images of fault at widely scattered locations, roughly coincident with recently proposed Woodstock South, Woodstock North, and Sawmill Branch faults, inferred from a combination of earthquake hypocenters, focal mechanisms, geologic and geomorphic evidence, and intensity reports from 1886 (Dura-Gomez and Talwani, 2009; Talwani and Dura-Gomez, 2009). These faults strike NE and form a right-oblique (thrust) system. The Woodstock North fault is a few km SE of the Cenozoic disturbance near Summerville imaged in lines VT4 and VT5, and crosses SC6 near the Cenozoic disturbance imaged in CMP 340. Seismicity attributed to Sawmill Branch fault is coincident with faults imaged in line VT3.
Colquhoun et al. (1983)	Surface and Subsurface Stratigraphy, Structure and Aquifers of the South Carolina Coastal Plain	Early mapping of the proposed Charleston and Garner-Edisto faults based on subsurface stratigraphy and borehole control.

Table D-6.1.2 Data Summary
Charleston RLME

Citation	Title	Description and Relevance to SSC
Crone and Wheeler (2000)	Data for Quaternary Faults, Liquefaction Features, and Possible Tectonic Features in the Central and Eastern United States, East of the Rocky Mountain Front	Review of potential Quaternary tectonic features in the CEUS. Includes description of and primary reference citations for Charleston area liquefaction and paleoliquefaction features, Helena Banks fault, Cape Fear arch, and Cooke fault.
Doar and Willoughby (2006)	Revision of the Pleistocene Dorchester and Summerville Scarps, the Inland Limits of the Penholoway Terrace, Central South Carolina	Detailed and updated mapping of geomorphic scarps and terraces in the Coastal Plain of central South Carolina are interpreted as resulting from Pleistocene sea-level high stands, not tectonic activity. These include the Surry, Dorchester, Summerville, Macbeth, Bethera, Suffolk, and Awendaw scarps.
Dura-Gomez and Talwani (2008)	A Revised Seismotectonic Framework for the Charleston, South Carolina Earthquakes	Proposes a slightly revised depiction of faults spatially associated with Middleton Place–Summerville seismic zone and the roughly 6 km (3.7 mi.) wide stepover zone of the Woodstock fault. In this revised depiction, three NW-striking faults accommodate the stepover, the (1) Sawmill Branch; (2) Lincolnville; and (3) Charleston faults. This depiction of the Sawmill Branch fault is similar to that proposed by Talwani and Katuna (2004). The Lincolnville and Charleston faults newly proposed structures (the latter is not the same as the Charleston fault described by Lennon (1986) and Weems and Lewis (2002)). No figures accompany this abstract. See Dura-Gomez and Talwani (2009) and Talwani and Dura-Gomez (2009) for relevant maps.
Dura-Gomez and Talwani (2009)	Finding Faults in the Charleston Area, South Carolina: 1. Seismological Data	Article describes relocated microseismicity (1974–2004) in the Charleston area. These data are used to (1) refine mapping of and to characterize the proposed Woodstock, Sawmill Branch, and Ashley River faults; and (2) identify two proposed new faults, the Lincolnville and Charleston faults. Note: this is not the same Charleston fault described by Lennon (1986) and Weems and Lewis (2002). Each of these structures is located within or near the 1886 meizoseismal area and the Middleton Place–Summerville seismic zone. The Woodstock fault is described as a NE-striking, steeply NW-dipping oblique (right-lateral) reverse fault. The Woodstock fault in the near surface is divided into northern and southern segments by a ~6 km (3.7 mi.) wide left (compressional) step. The Sawmill Branch, Lincolnville, and Charleston faults are described as NW-striking faults within or near the stepover zone.

Table D-6.1.2 Data Summary
Charleston RLME

Citation	Title	Description and Relevance to SSC
Gangopadhyay and Talwani (2005)	Fault Intersections and Intraplate Seismicity in Charleston South Carolina: Insights from a 2-D Numerical Model	A simple 2-D numerical model comprising blocks with elastic properties representing simplified geology of the Middleton Place–Summerville seismic zone is used to explain observed seismicity and interpreted fault motions. Model is used to support idea that fault intersections act as stress concentrators and that these intersections may be loci of earthquakes.
Hamilton et al. (1983)	Land Multichannel Seismic-Reflection Evidence for Tectonic Features Near Charleston, South Carolina, Studies Related to the Charleston, South Carolina, Earthquake of 1886—Tectonics and Seismicity	Data from onshore seismic-reflection profiles show evidence for three postulated faults in the Charleston area: the Cooke, Gants, and Drayton faults. The postulated Cooke fault shows ~50 m of vertical displacement (SE-side-down) of a Jurassic basalt layer, with displacement decreasing upward within Cenozoic sediments. The strike of the Cooke fault is not well constrained but estimated at NE. The length of the Cooke fault is not defined. The postulated Gants fault shows similar vertical displacement and orientation as the Cooke fault and likewise shows displacement decreasing upward within Cenozoic sediments. The age of the NE-striking Drayton fault is constrained to the Late Cretaceous.
Hibbard et al. (2006)	Lithotectonic Map of the Appalachian Orogen, Canada–United States of America	Lithotectonic mapping at 1:1,500,000 scale of the Appalachian Mountains in the U.S. and Canada, including faults and shear zones. Mapped area does not cover the Coastal Plain.
Horton and Dicken (2001)	Preliminary Digital Geologic Map of the Appalachian Piedmont and Blue Ridge, South Carolina Segment	Geologic mapping at 1:500,000 scale of the South Carolina, excluding the Coastal Plain.
Lennon (1986)	Identification of a Northwest Trending Seismogenic Graben Near Charleston, South Carolina	Based on shallow (to 85 m) drilling and gamma logging in the 1886 meizoseismal area, inferred a NW-trending graben lying between Charleston and Kiawah Island, South Carolina. The proposed graben is bounded by three postulated faults: the Woodstock, Ashley River, and Charleston faults. Note: this is not the same Charleston fault as described by Dura-Gomez and Talwani (2009) and Talwani and Dura-Gomez (2009).

Table D-6.1.2 Data Summary
Charleston RLME

Citation	Title	Description and Relevance to SSC
Marple and Miller (2006)	Association of the 1886 Charleston, South Carolina, Earthquake and Seismicity Near Summerville with a 12º Bend in the East Coast Fault System and Triple-Fault Junctions	Seismic-reflection data, microseismicity, and other geologic and geophysical data are used to map faults near Charleston, including the newly postulated NW-striking Berkeley fault. These data also are interpreted to show a 12° bend in the southern segment of the East Coast fault system. Ongoing microseismicity in the Middleton Place–Summerville seismic zone and the 1886 Charleston earthquake are interpreted as related to: (1) this fault bend; and (2) fault intersections between the East Coast fault system and the Ashley River, Charleston, Summerville, and Berkeley faults in the Summerville area. Paper includes useful summary of data used to constrain faults near Charleston. As part of this summary, Marple and Miller (2006) call into question the existence of the Adams Run fault of Weems and Lewis (2002).
Marple and Talwani (1990)	Field Investigations of the Woodstock Lineament	Abstract describing preliminary geologic field investigations of the Woodstock lineament. Results and additional work are described in greater detail in subsequent publications (e.g., Marple and Talwani 1993; 2000).
Marple and Talwani (1993)	Evidence for Possible Tectonic Upwarping Along the South Carolina Coastal Plain from an Examination of River Morphology and Elevation Data	Identifies the Zone of River Anomalies as possible geomorphic expression of ongoing slip and surface deformation related to the underlying Woodstock fault. Zone of River Anomalies defined as N-NE-trending alignment of subtle topographic highs and morphologic changes in rivers (including river bends, incised channels, and convex-up longitudinal profiles) in the South Carolina Coastal Plain between the Edisto and Little Pee Dee Rivers. Suggests that the 1886 Charleston earthquake may have occurred on Woodstock fault. Additional studies are described in Marple and Talwani (2000).

Table D-6.1.2 Data Summary
Charleston RLME

Citation	Title	Description and Relevance to SSC
Marple and Talwani (2000)	Evidence for a Buried Fault System in the Coastal Plain of the Carolinas and Virginia—Implications for Neotectonics in the Southeastern United States	Identifies and describes the postulated East Coast fault system as a N-NE-striking, roughly 600 km (373 mi.) long buried fault in the Coastal Plain of the Carolinas and Virginia. This fault system extends from south of Charleston, South Carolina, to east of Richmond, Virginia, as series of three right-stepping en echelon fault segments. Evidence for the existence of these faults segments weakens progressively to the north. Evidence for the southern segment is equivocal and includes the Zone of River Anomalies (see also Marple and Talwani 1993), linear magnetic anomalies, and seismicity and seismic-reflection data in the Middleton Place–Summerville area. Suggests the 1886 Charleston earthquake may have occurred on the southern segment of the East Coast fault system.
Marple and Talwani (2004)	Proposed Shenandoah Fault and East Coast-Stafford Fault System and Their Implications for Eastern U.S. Tectonics	Identifies postulated NW-striking Shenandoah fault in Virginia that coincides with an apparent ~110 km (68 mi.) wide left step separating East Coast fault system from Stafford fault. Implication is that the postulated East Coast fault system and the Stafford fault form a ~1,100 km (684 mi.) long fault system.
McCartan et al. (1984)	Geologic Map of the Area Between Charleston and Orangeburg, South Carolina	Geologic mapping at 1:250,000 scale of greater Charleston area. No faults mapped.
Nystrom (1996)	Earthquake Hazards Map of the South Carolina Coastal Plain	Compilation at 1:400,000 scale showing previously mapped 1886 liquefaction and paleoliquefaction features, and areas susceptible to landsliding and collapse. Map also shows areas of potential liquefaction, which are generally confined to an area within roughly 50 km (31 mi.) of the coast and farther inland along active rivers and streams.
Prowell (1983)	Index of Faults of Cretaceous and Cenozoic Age in the Eastern United States	Map and brief descriptions of postulated Cretaceous and Cenozoic-age faults in eastern U.S.
Seeber and Armbruster (1981)	The 1886 Charleston, South Carolina Earthquake and the Appalachian Detachment	Judging by coseismic and post-seismic strain indicators, back slip over a portion of the Appalachian detachment may have caused 1886 Charleston earthquake, similar to the great Indian detachment earthquakes of 1905 (M ~ 8) and 1934 (M ~ 8.3).

Table D-6.1.2 Data Summary
Charleston RLME

Citation	Title	Description and Relevance to SSC
Talwani and Dura-Gomez (2009)	Finding Faults in the Charleston Area, South Carolina: 2. Complementary Data	This companion paper to Dura-Gomez and Talwani (2009) includes data other than relocated microseismicity used to (1) refine mapping of and to characterize the proposed Woodstock, Sawmill Branch, and Ashley River faults; and (2) identify two proposed new faults, the Lincolnville and Charleston faults. Note: this is not the same Charleston fault described by Lennon (1986) and Weems and Lewis (2002). Each of these structures is located within or near the 1886 meizoseismal area and the Middleton Place–Summerville seismic zone. Woodstock fault is described as a NE-striking, steeply NW-dipping oblique (right-lateral) reverse fault. Woodstock fault in the near-surface is divided into northern and southern segments by a ~6 km (3.7 mi.) wide left (compressional) step. Sawmill Branch, Lincolnville, and Charleston faults are described as NW-striking faults within or near the stepover zone.
Talwani and Katuna (2004)	Macroseismic Effects of the 1886 Charleston Earthquake	Field trip guidebook describes four locations near Charleston where surficial effects of the 1886 earthquake can be seen. Liquefaction features formed during the 1886 earthquake are described at one location near Hollywood. The three remaining locations are described as locations of possible evidence for primary 1886 surface rupture. However, the cracks in Drayton family tomb at Magnolia Gardens, cracks in walls of Colonial Fort Dorchester, and apparent clockwise rotation of St. Paul's Episcopal Church in Summerville likely are result of strong ground shaking and not primary surface rupture.
Trenkamp and Talwani (n.d.)	GPS Derived Strain and Strain Zonation near Charleston, South Carolina	This as-yet-unpublished study presents campaign GPS data from a 20-station grid near Charleston that suggest average shear strain rate (~10^{-9} to 10^{-7} radians/yr) that is one to two orders of magnitude higher than the surrounding region. Measurements were taken in three surveys between 1994 and 2000, and are combined with National Geodetic Survey data that were collected from 1920s to 1990s. Study suffers from admitted monument instability, small number of surveys (three), and short period of GPS measurements (six years). Strain orientations generally consistent with SH max (~N60°E). Largest strains located in the Middleton Place–Summerville seismic zone and attributed to local fault intersections.

Table D-6.1.2 Data Summary
Charleston RLME

Citation	Title	Description and Relevance to SSC
Weems and Lewis (2002)	Structural and Tectonic Setting of the Charleston, South Carolina, Region: Evidence from the Tertiary Stratigraphic Record	Using borehole data and structure contour maps on the Coastal Plain sedimentary units, Weems and Lewis (2002) map the NW-striking Charleston and Adams Run faults. Viable alternate (nontectonic) explanations exist for these features. Marple and Miller (2006) call into question existence of Adams Run fault.
Weems and Obermeier (1990)	The 1886 Charleston Earthquake—An Overview of Geological Studies	Article provides review of geological data describing 1886 Charleston earthquake. Indicates that there is no known surface or near-surface expression of the causative fault. Suggests that the only evidence for geologically recent (upper Pleistocene?) tectonic deformation near Charleston comes from domal features (including the Bonneau, Mt, Holly, and Fort Bull domes) recognized in subsurface Coastal Plain sediments. These domes are not associated with any microseismicity. Describes evidence for three, and possibly four, middle to late Holocene earthquakes preserved in geologic record as paleoliquefaction features, as well as evidence for events as old as 30 ka.
Wentworth and Mergner-Keefer (1983)	Regenerate Faults of the Southeastern United States	Proposes that Mesozoic normal faults in the Piedmont and Coastal Plain have been reactivated as reverse and reverse-oblique faults. Suggests the 1886 Charleston earthquake may have occurred on a NE-striking reactivated Mesozoic normal fault. Also suggests that, based on the existence of Mesozoic normal faults throughout much of the Atlantic Coastal Plain, earthquakes at least as large as 1886 Charleston may occur elsewhere in the domain.
Wheeler (2005)	Known or Suggested Quaternary Tectonic Faulting, Central and Eastern United States—New and Updated Assessments for 2005	Updated review of potential Quaternary tectonic features in the CEUS. Includes description of and primary reference citations for the East Coast fault system.

Table D-6.1.2 Data Summary
Charleston RLME

Citation	Title	Description and Relevance to SSC
Wildermuth and Talwani (2001)	A Detailed Gravity Survey of a Pull-Apart Basin in Northeast South Carolina	Marple and Talwani (2000) propose the East Coast fault system as a right-lateral reverse oblique fault comprising three segments (south, central, and north) configured in a right-stepping en echelon pattern. As such, the right stepover separating the southern and central segments should form an area of extension. Wildermuth and Talwani (2001) test this hypothesis by performing a microgravity survey in the vicinity of the stepover. Their data are consistent with presence of a pull-apart basin, but few details are provided in this abstract.
Willoughby and Nystrom (2005)	Generalized Geologic Map of South Carolina	Generalized geologic mapping at 1:1,000,000 scale of South Carolina, including Coastal Plain wave-cut scarps. No faults mapped in Coastal Plain. Mapping too simplified to be of use in source characterization.
Seismicity and 1886 Earthquake Intensity		
Bakun and Hopper (2004b)	Magnitudes and Locations of the 1811-1812 New Madrid, Missouri, and the 1886 Charleston, South Carolina, Earthquakes	Intensity-based study of 1886 Charleston earthquake. Intensity center computed to be located offshore, but preferred estimate is at Middleton Place–Summerville seismic zone. Magnitude of 1886 Charleston earthquake is estimated to be between M_w 6.4 and 7.2 (at 95% confidence level), with preferred estimate of M_w 6.9.
Bakun and McGarr (2002)	Differences in Attenuation Among the Stable Continental Regions	Systematic differences in the attenuation of large earthquake ground motions exist between different stable continental regions (SCRs) worldwide. Eastern North America attenuation in seismic waves is less than that for other SCRs. As such, some previous studies of 1886 Charleston earthquake that used worldwide average SCR attenuation (e.g., Johnston, 1996c) overestimate the magnitude of this earthquake.
Bollinger (1977)	Reinterpretation of the Intensity Data for the 1886 Charleston, South Carolina, Earthquake	MMI isoseismals for the 1886 Charleston earthquake based primarily on original observations in Dutton (1889). Highest intensities (MMI X) at/near Charleston.
Bollinger (1983)	Speculations on the Nature of Seismicity at Charleston, South Carolina	Estimates 1886 earthquake at m_b 6.7, with rupture length approximately 25 km (15.5 mi.), width approximately 12 km (7.5 mi.), average slip 1 m (3.3 ft.), based on empirical relations. Notes ongoing microseismicity concentrated in 1886 meizoseismal area.

Table D-6.1.2 Data Summary
Charleston RLME

Citation	Title	Description and Relevance to SSC
Johnston (1996c)	Seismic Moment Assessment of Earthquakes in Stable Continental Regions—III. New Madrid 1811-1812, Charleston 1886, and Lisbon 1755	Using isoseismal-area-regression methods, the magnitude of the 1886 Charleston earthquake is estimated at M_w 7.3 ± 0.26. Bakun and McGarr (2002) argue that Johnston (1996c) overestimates the magnitude of the 1886 Charleston earthquake.
Madabhushi and Talwani (1990)	Composite Fault Plane Solutions of Recent Charleston, South Carolina, Earthquakes	Reassessment of Middleton Place–Summerville seismic zone seismicity suggests two distinct groups of seismicity: (1) composite focal mechanism with right-lateral strike-slip motion, small dip-slip component, nodal plane oriented N-NE, and hypocentral depths from 3 to 8 km (2 to 5 mi.); and (2) composite focal mechanism with NW-oriented thrust dipping SW and hypocentral depths from 4 to 10 km (2.5 to 6.2 mi.). Data are interpreted as indicating microseismic activity on the postulated intersecting Woodstock and Ashley River faults.
Madabhushi and Talwani (1993)	Fault Plane Solutions and Relocations of Recent Earthquakes in Middleton Place–Summerville Seismic Zone Near Charleston, South Carolina	Single fault-plane solutions obtained for 35 earthquakes in Middleton Place–Summerville seismic zone and grouped into five subsets. Seismicity is attributed to reverse faulting on NW-striking, SW-dipping Ashley River fault and right-lateral strike-slip on the N-NE-striking vertical Woodstock fault. Seismicity is interpreted as concentrated near the intersection of these two faults.
Smith and Talwani (1985)	Preliminary Interpretation of a Detailed Gravity Survey in the Bowman and Charleston, S.C. Seismogenic Zones	Gravity surveys conducted in the vicinity of the Bowman seismic zone suggest presence of NW-trending features, as previously interpreted from magnetic anomaly data.
South Carolina Seismic Network (2005)	List of Earthquakes in Charleston Between 1974 and 2002	Tabulation of microseismicity in the local Charleston area, recorded between 1974 and 2002. Useful to show local Charleston earthquakes with magnitudes smaller than those listed in the CEUS SSC earthquake catalog.
Talwani (1982)	An Internally Consistent Pattern of Seismicity Near Charleston, South Carolina	Relocated seismicity in the 1886 meizoseismal area suggests (1) right-lateral strike-slip events on NE-striking Woodstock fault, and (2) SW-side-up thrust events on NW-striking Ashley River fault.
Talwani (1999)	Fault Geometry and Earthquakes in Continental Interiors	Intersecting faults are proposed as the loci of strain accumulation and seismicity in the upper crust of continental interiors. Postulated Woodstock and Ashley River faults near Charleston are cited as an example of fault intersection model.

Table D-6.1.2 Data Summary
Charleston RLME

Citation	Title	Description and Relevance to SSC
Tarr and Rhea (1983)	Seismicity Near Charleston, South Carolina, March 1973 to December 1979	Description of microseismicity defining the Middleton Place–Summerville, Bowman, and Adams Run seismic zones based on a temporary seismic network installed in 1973 and a permanent network installed in 1974.
Tarr et al. (1981)	Results of Recent South Carolina Seismological Studies	Description of microseismicity defining the Middleton Place–Summerville, Bowman, and Adams Run seismic zones based on a temporary seismic network installed in 1973 and a permanent network installed in 1974. Suggests that 1886 earthquake occurred within the Middleton Place–Summerville seismic zone. Observes that, whereas earthquakes in the Piedmont tend to be scattered, those in the Coastal Plain tend to cluster. This is interpreted as the result of localized stresses on or near intersecting faults or in zones of weakness between crustal blocks.
Liquefaction and Paleoliquefaction		
Ambraseys (1988)	Engineering Seismology	Presents a magnitude-bound relation for liquefaction.
Amick (1990)	Paleoliquefaction Investigations Along the Atlantic Seaboard with Emphasis on the Prehistoric Earthquake Chronology of Coastal South Carolina	Search for paleoliquefaction features along U.S. East Coast at over 1,000 sites from southern Georgia to New Jersey. Features found only in coastal Carolinas. Includes rough maps of areas searched in which no features found, as well as sketches and photographs of selected features. Describes evidence for six M_w 7+ earthquakes near Charleston in the past ~2 kyr. Return period estimated at roughly 500–600 years. Includes discussion of criteria by which seismically induced liquefaction features may be distinguished from “pseudoliquefaction” features.
Amick and Gelinas (1991)	The Search for Evidence of Large Prehistoric Earthquakes Along the Atlantic Seaboard	Search for paleoliquefaction features along U.S. East Coast at over 1,000 sites from southern Georgia to New Jersey. Features found only in coastal Carolinas. Return period estimated at 500–600 years. In general, largest paleoliquefaction features are at sites near Charleston, suggesting repeated large earthquakes near Charleston. Majority of paleoliquefaction features can be explained by a source near Charleston, but the possibility of a separate (moderate?) source located ~100 km (62 mi.) NE is suggested.

Table D-6.1.2 Data Summary
Charleston RLME

Citation	Title	Description and Relevance to SSC
Amick, Gelinas, et al. (1990)	Paleoliquefaction Features Along the Atlantic Seaboard	Search for paleoliquefaction features along U.S. East Coast at over 1,000 sites from southern Georgia to New Jersey. Features found only in coastal Carolinas. In general, largest paleoliquefaction features are at sites near Charleston, suggesting repeated large earthquakes near Charleston. Includes rough maps of areas searched in which no features found, as well as sketches and photographs of selected features. Describes evidence for six M_w 7+ earthquakes near Charleston in the past ~2 kyr. Return period estimated at roughly 500–600 years. Includes discussion of criteria by which seismically induced liquefaction features may be distinguished from "pseudoliquefaction" features.
Amick, Maurath, and Gelinas (1990)	Characteristics of Seismically Induced Liquefaction Sites and Features Located in the Vicinity of the 1886 Charleston, South Carolina Earthquake	Describes evidence for six M_w 7+ earthquakes near Charleston in the past ~2 kyr. Return period estimated at roughly 500–600 years. Includes discussion of criteria by which seismically induced liquefaction features may be distinguished from "pseudoliquefaction" features. Similar to Amick (1990) and Amick, Gelinas, et al. (1990), but with less detail.
Andrus and Heidari (2009) Crone and Wheeler (2000)	Mapping Liquefaction Potential of Soil Deposits near Charleston, SC Data for Quaternary Faults, Liquefaction Features, and Possible Tectonic Features in the Central and Eastern United States, East of the Rocky Mountain Front	Both reports review potential Quaternary tectonic features in the CEUS. These include description of and primary reference citations for Charleston area liquefaction and paleoliquefaction features, Helena Banks fault, Cape Fear arch, and Cooke fault.
Dutton (1889)	The Charleston Earthquake of August 31, 1886	Near-contemporary report of macroseismic effects of 1886 Charleston earthquake, including intensity observations, isoseismal maps (Rossi-Forrel scale), and distribution of sandblow "craterlets." Highest intensities and greatest number of craterlets found in/near Charleston, decreasing with distance up and down coast. Suggests 1886 epicentral location at Charleston.
Gassman et al. (2009)	Magnitudes of Charleston, South Carolina Earthquakes from In Situ Geotechnical Data	Abstract describing geotechnical analyses of paleoliquefaction in Charleston area. Based on standard penetration test (SPT), cone penetration test (CPT), and shear-wave velocity (V_S) data, Gassman et al. (2009) suggest a preferred magnitude range of M_w 6.7 to 7.0 for prehistoric, historic, and future earthquakes in Charleston seismic zone.

Table D-6.1.2 Data Summary
Charleston RLME

Citation	Title	Description and Relevance to SSC
Gelinas et al. (1998)	Paleoseismic Studies in the Southeastern United States and New England	Search for paleoseismic and paleoliquefaction features along U.S. East Coast, focusing on South Carolina and New England. Numerous features documented in coastal Carolinas. In general, largest paleoliquefaction features are at sites near Charleston, suggesting repeated large earthquakes near Charleston. Inland search for paleoliquefaction features was performed on 3.2 km (2 mi.) stretch of Big Browns Creek in Union County, South Carolina. No features identified.
Hu et al. (2002a)	In-Situ Properties of Soils at Paleoliquefaction Sites in the South Carolina Coastal Plain	Geotechnical estimates of in situ soil properties (including depth and thickness of source layer, normalized shear-wave velocity, percent fines, etc.) at Charleston paleoliquefaction sites. Data not useful for characterizing Charleston paleoearthquake source, but are used by Hu et al. (2002b).
Hu et al. (2002b)	Magnitudes of Prehistoric Earthquakes in the South Carolina Coastal Plain from Geotechnical Data	Magnitude estimates for Charleston paleoearthquakes based on geotechnical estimates of in situ soil properties described in Hu et al. (2002a). Magnitude estimates range from M_w 6.8–7.8 for “large” regional Charleston events to M_w 5.5–7.0 for “moderate” local events at Georgetown. Leon et al.’s (2005) subsequent study, with two of the same three coauthors as Hu et al. (2002a, 2002b), presents lower magnitude estimates for prehistoric Charleston earthquakes.
Leon (2003)	Effect of Aging of Sediments on Paleoliquefaction Evaluation in the South Carolina Coastal Plain	Magnitude estimates for Charleston paleoearthquakes based on geotechnical assessments accounting for the effects of sediment age. Magnitude estimates range from M_w 5.5–7.2 for “large” regional Charleston events to M_w 4.3–6.4 for “moderate” local events at Bluffton and Georgetown. These estimates are lower than those presented in a previous study by Hu et al. (2002b).
Leon et al. (2005)	Effect of Soil Aging on Assessing Magnitudes and Accelerations of Prehistoric Earthquakes	Magnitude estimates for Charleston paleoearthquakes based on geotechnical assessments accounting for effects of sediment age. Magnitude estimates range from M_w 5.5–7.2 for “large” regional Charleston events to M_w 4.3–6.4 for “moderate” local events at Bluffton and Georgetown. These estimates are lower than previous studies, including that of Hu et al. (2002b), which had two of the same three coauthors (Gassman and Talwani).

Table D-6.1.2 Data Summary
Charleston RLME

Citation	Title	Description and Relevance to SSC
Martin and Clough (1994)	Seismic Parameters from Liquefaction Evidence	Based on geotechnical analyses and critiques of previous estimates, preferred magnitude estimate for 1886 earthquake is "...no larger than M = 7.5, possibly as low as M = 7..." (p. 1360).
Noller and Forman (1998)	Luminescence Geochronology of Liquefaction Features Near Georgetown, South Carolina	Interprets liquefaction evidence for 1886 earthquake and two or three paleoliquefaction events at Gapway Ditch site, where Amick, Gelinas, et al. (1990); Amick, Maurath, and Gelinas (1990); and Talwani and Schaeffer (2001) interpreted one paleoliquefaction event.
Obermeier (1996b)	Using Liquefaction-Induced Features for Paleoseismic Analysis	Describes criteria for recognizing earthquake-induced liquefaction features in the geologic record, with discussion of Charleston paleoliquefaction data. Shows distribution of 1886 liquefaction and paleoliquefaction sites in coastal South Carolina and southernmost coastal North Carolina, and rough outline of area searched. Large diameters (3+ m) of some prehistoric craters suggest that these likely were caused by earthquakes "...much stronger than M 5 to 5.5..." (p. 350). Also observes that sandblow craters that formed roughly 600 and 1,250 yr BP extend along the coast at least as far as 1886 features, suggesting that some prehistoric earthquakes likely were at least as large as 1886.
Obermeier and Pond (1999)	Issues in Using Liquefaction Features for Paleoseismic Analysis	Summary paper describing issues regarding the use of paleoliquefaction data as evidence of strong ground shaking.
Obermeier et al. (1989)	Liquefaction Evidence for Repeated Holocene Earthquakes in the Coastal Region of South Carolina	Describes distribution of paleoliquefaction features throughout much of coastal South Carolina and southernmost North Carolina. Estimates at least three prehistoric earthquakes in past 7.2 kyr with m_b > ~5.5. Notes that size and spatial concentration of both 1886 liquefaction and paleoliquefaction features are greatest near Charleston, and decrease with distance up and down the coast, despite similarities in liquefaction susceptibility throughout region. This indicates repeated large earthquakes located at or near Charleston.

Table D-6.1.2 Data Summary
Charleston RLME

Citation	Title	Description and Relevance to SSC
Obermeier et al. (1990)	Earthquake-Induced Liquefaction Features in the Coastal Setting of South Carolina and in the Fluvial Setting of the New Madrid Seismic Zone	Describes criteria for recognizing earthquake-induced liquefaction features in the geologic record, with discussion of Charleston paleoliquefaction data. Describes possible origins other than earthquakes for sand-blow craters and vented sand volcanoes, including compaction-induced dewatering, landslides, artesian springs, and ground disruption by fallen root-wadded trees. Estimates spatial extents of 1886 and prehistoric liquefaction fields. Estimates at least three prehistoric earthquakes in past 7.2 k.y with $m_b >$ ~5.5. Notes that the abundance and diameters of prehistoric sandblow craters are greatest within the 1886 meizoseismal zone for a given age of craters, indicating repeated large earthquakes located at or near Charleston.
Olson et al. (2005b)	Revised Magnitude Bound Relation for the Wabash Valley Seismic Zone of the Central United States	Presents an updated magnitude-bound relationship for paleoliquefaction in the CEUS.
Talwani (2000)	The Charleston Earthquake Cycle	Radiocarbon dating of paleoliquefaction features in coastal South Carolina suggests return period of M_w 7+ earthquakes is approximately 500 years. Campaign GPS survey suggests strain rate of 0.04 p rad/year (uncertainty unspecified). This is interpreted as consistent with ~2 m slip events every 500 years at Charleston.
Talwani and Schaeffer (2001)	Recurrence Rates of Large Earthquakes in the South Carolina Coastal Plain Based on Paleoliquefaction Data	Compilation of paleoliquefaction feature locations and radiocarbon age constraints from sites throughout coastal South Carolina and southernmost coastal North Carolina. Construction of earthquake chronology based on radiocarbon ages with 1-sigma error bounds. Considered scenarios with (1) mix of large (M_w ~ 7) regional and moderate (M_w ~ 6) local events; and (2) large regional events only. Paleoliquefaction record judged to be complete for past ~2 kyr, possibly complete for past ~6 kyr. Preferred estimate of 500–600 years for recurrence of large (M_w ~ 7) earthquakes.
Talwani et al. (2008)	Studies Related to the Discovery of a Prehistoric Sandblow in the Epicentral Area of the 1886 Charleston SC Earthquake: Trenching and Geotechnical Investigations	Description of newly discovered paleoliquefaction feature near Fort Dorchester, South Carolina. Feature is undated but, based on burial depth and soil formation, estimated to pre-date the 1886 Charleston earthquake. Paleoearthquake magnitude estimated at ~6.9 (scale unspecified) based on unspecified geotechnical analyses.

Table D-6.1.2 Data Summary
Charleston RLME

Citation	Title	Description and Relevance to SSC
Recent Source Characterizations		
Bollinger (1992)	Specification of Source Zones, Recurrence Rates, Focal Depths, and Maximum Magnitudes for Earthquakes Affecting the Savannah River Site in South Carolina	Seismic source characterization for the Savannah River Site describes input parameters for PSHA. Local Zone 1 (LZ1, Charleston) M_{max} = m_b 6.9. Seismogenic thickness estimated at 14 and 25 km (9 and 15.5 mi.), respectively, for "Local Charleston" and "SC Piedmont and Coastal Plain" seismic sources..
Chapman and Talwani (2002)	Seismic Hazard Mapping for Bridge and Highway Design in South Carolina	Charleston source characteristic earthquakes (M_w 7.0–7.5) modeled as combination of one area source ("coastal") and two line ("ZRA" and "three parallel faults") sources. Magnitudes (M_w) [and weights]: 7.1 [0.2]; 7.3 [0.6]; and 7.5 [0.2]. Mean return period: 550 years.
Frankel et al. (1996)	National Seismic-Hazard Maps: Documentation	Charleston source characteristic earthquakes modeled by one areal source zone drawn to encompass (1) a narrow source zone defined by P. Talwani (to represent the Woodstock fault and the Zone of River Anomalies); and (2) a larger zone drawn by S. Obermeier and R. Weems constrained by the areal distribution of paleoliquefaction locations, although the source zone does not encompass all the paleoliquefaction sites. A characteristic rupture model of M_w 7.3 earthquakes is assumed, based on the estimated magnitude of the 1886 event (Johnston, 1996). Assumes recurrence time of 650 years, based on dates of paleoliquefaction events. Assumes vertical faults with random strikes distributed throughout the areal source zone when calculating the hazard. Each of these fictitious faults is centered on a grid cell within the source zone.

Table D-6.1.2 Data Summary
Charleston RLME

Citation	Title	Description and Relevance to SSC
Frankel et al. (2002)	Documentation for the 2002 Update of the National Seismic Hazard Maps	Charleston source characteristic earthquakes (M_w 6.8–7.5) modeled by two areal source zones, weighted at 0.50 each: (1) a narrow zone representing Woodstock lineament and a portion of Zone of River Anomalies; and (2) the same broader zone used in the 1996 model. Assumes a mean recurrence time of 550 years for characteristic earthquakes in the Charleston, South Carolina, region, as presented in the description of paleoseismic evidence by Talwani and Schaeffer (2001). This average recurrence time is derived from the recurrence intervals determined from the 1886 event and three earlier earthquakes of similar size, based on the areal extent of their paleoliquefaction effects. For both areal zones, faults are oriented with strikes parallel to long axis of narrow areal zone. Fault lengths are determined from Wells and Coppersmith (1994). Some of the faults extend outside of source zone boundary. Magnitudes (M_w) [and weights] based on expert opinion and recent work by Bakun and Hopper (2002): 6.8 [0.2], 7.1 [0.2], 7.3 [0.45], 7.5 [0.15].
Petersen et al. (2008)	Documentation for the 2008 Update of the United States National Seismic Hazard Maps	Charleston source characteristic earthquakes (M_w 6.8–7.5) modeled by two areal source zones, weighted 50/50: (1) a geographically narrow zone that follows the Woodstock lineament and an area of river anomalies, and (2) a broader zone that encompasses many of the known liquefaction features resulting from past earthquakes. At the urging of NSHMP Advisory Panel, the SE edge of the larger zone has been extended offshore (relative to 2002 zone) to capture the Helena Banks fault. Assumes a mean recurrence time of 550 years for characteristic earthquakes in the Charleston, South Carolina, region, as presented in description of paleoseismic evidence by Talwani and Schaeffer (2001). Each zone combines a characteristic model with same magnitudes and weights as 2002 model. Additionally, a truncated Gutenberg-Richter model with m_{bLg} from 5.0 to 7.5 accounts for background events in the extended margin, including Charleston zone. The background seismicity has random fault strike.
Silva et al. (2003)	Ground Motion and Liquefaction Simulation of the 1886 Charleston, South Carolina, Earthquake	Simulations of an M_w 7.3 “1886 Charleston-like” earthquake. Rupture plane of 1886 earthquake modeled as (1) 100 km—or 62 mi.—long, 20 km—or 12.5 mi.--wide (static stress drop 27 bars) fault; and (2) 50 km—or 31 mi.--long, 16 km—or 10 mi.—wide (static stress drop 107 bars) fault. Fault assumed coincident with the Woodstock fault.

Table D-6.1.3 Data Summary
Cheraw Fault RLME

Citation	Title	Description and Relevance to SSC
Fault Geometry		
Crone (1997)	Fault Number 2330, Cheraw Fault, in Quaternary Fault and Fold Database of the United States	Cheraw fault was first recognized during regional geologic mapping in late 1960s and 1970s (Sharps, 1976). Structurally, fault is located above W-NW-sloping basement surface between N-trending Las Animas arch to the east and the Denver basin to the NW. Down-to-the-NW sense of motion that occurred during late Quaternary faulting events has same vertical sense as cumulative tectonic relief on Precambrian crystalline rocks. The Las Animas arch is a prominent, but relatively low-relief, 300 km (186.5 mi.) long positive structural element in SE Colorado. Crest of the arch is approximately 20–40 km (12.5–25 mi.) east of the fault. Minor uplift probably occurred along the arch in late Paleozoic time, but most of present relief is Laramide in age. Fault does not appear to have a long history of recurrent movement. Interpretation of structure contours on top of Lower Cretaceous Dakota sandstone shows a similar offset (6–8 m [19.7–26.2 ft.] of down-to-the-NW throw) to that of early Quaternary alluvial deposits along the fault. Length: 44 km (89.5 mi.), avg. strike: N44°E; sense of movement: not well known, inferred to be down-to-the-NW motion on a normal fault based on the attitude of near-surface faults exposed in trench across the fault. The only detailed paleoseismic study of the fault is that by Crone, Machette, Bradley, et al. (1997). Timing of the latest Pleistocene displacements raises possibility that surface-faulting earthquakes have occurred as a temporal cluster. Cumulative vertical offset on the Pleistocene erosional surface cut on Cretaceous shale is 3.2–4.1 m (10.5–13.5 ft.), which represents the total offset from the three post-latest Quaternary (<25 ka) displacements. Lower Pleistocene Rocky Flats Alluvium, which has an estimated age of about 1.2 m.y., is only offset about 7–8 m (23–26 ft.) by the fault. Displacement events older than about 25 ka probably occurred before about 100 ka, based on estimated time needed to incise, widen, and backfill the paleostream channel that is now filled with latest Pleistocene deposits. Temporal clustering of earthquakes, in which relatively short time intervals of activity (e.g., 15–20 k.y.) are separated by long intervals of quiescence (e.g., 100 k.y.) are suggested. A suggested 8 k.y. average recurrence interval is based solely on

Table D-6.1.3 Data Summary
Cheraw Fault RLME

Citation	Title	Description and Relevance to SSC
		estimated timing of the latest Pleistocene and Holocene displacement events documented in trenching study. During a quiescent phase, surface-faulting earthquakes may not occur for hundreds of thousands of years. Best estimate of a long-term slip rate is less than or equal to 0.007 mm/yr, based on a cumulative offset of about 8 m (26 ft.) on the 1.2 Ma Rocky Flats Alluvium. Latest Pleistocene-Holocene slip rates are between 0.14 and 0.18 mm/yr (determined by dividing the amount of offset, 3.6 m (11.8 ft.), on oldest faulted deposits by the age of deposits, 20–25 k.y.).
A. Crone (pers. comm., March 3, 2010)		Crone provided a DEM (originally from Dan Clark of Geoscience Australia) showing the Cheraw fault scarp, which may extend farther to the NE than previously thought. He noted that possible NE extension of the Cheraw remains unconfirmed, and its existence was originally suggested based on analysis of SRTM topographic data by Dan Clark (Geoscience Australia). Crone agreed with the TI team's observations that sections of feature are suspiciously parallel and close to cultural features, so SRTM data could easily be capturing cultural effects that fortuitously align with a projection of the fault. Given the highly uncertain nature of possible NE extension, he agrees that it should be assigned low weight in a logic tree evaluation.
A. Crone (pers. comm., April 21, 2010)		After reexamination of Crone et al. (1997) and original trench logs and field photos, Dr. Crone concluded that neither the two-event nor three-event scenario can be ruled out, and that logic tree assessment should reflect this uncertainty. He agreed with TI team's conclusion that "out of cluster" event(s) are mostly unconstrained, and he stated that it seems wise to weight shorter-term history more heavily. In response to a query about age of Rocky Flats Alluvium, Crone stated that "the 1.2 Ma number that we used was the conventional thinking at the time we did our report 15 years ago. Folks have pondered this question for decades, and apparently the latest information is that the age of the deposit varies depending on distance from the mountain front. In a 2006 paper in *Geomorphology*, Riihimaki et al. use TCN analyses to estimate the age of the Rocky Flats Alluvium between Boulder and Golden. They conclude that the Rocky Flats is as young as 400 ka near the mountains and as old as 2 Ma farther to the east. This is certainly a much wider age range than anyone would have guessed in the past. So, if this conclusion can be extrapolated as far east as the Cheraw area, then our age guesstimate could be too young." Crone concluded that "overall, the logic tree you've constructed is reasonable and captures the options and uncertainties that are associated with the Cheraw fault."

Table D-6.1.3 Data Summary
Cheraw Fault RLME

Citation	Title	Description and Relevance to SSC
Crone et al. (1997)	Late Quaternary Surface Faulting on the Cheraw Fault, Southeastern Colorado	Provides information on a 110 m (361 ft.) long trench excavated across Cheraw fault. Evidence for three episodes of surface faulting was revealed and age dates were obtained. Ages of the surface-rupturing events were estimated to occur at about 8 k, 12, and 20–25 ka (one early Holocene and two latest Pleistocene events). Interpretation of amounts of vertical offset on Cheraw fault is as follows: Most recent event: ~0.5–1.1 m (~1.6–3.6 ft.) Penultimate event: ~1.1–1.6 m (~3.6–5.2 ft.) Oldest event: ~1.5 m (~5 ft.)
Crone and Wheeler (2000)	Data for Quaternary Faults, Liquefaction Features, and Possible Tectonic Features in the Central and Eastern United States, East of the Rocky Mountain Front	This fault is classified as Class A. The fault is located about 140 km (87 mi.) east of the range front of Rocky Mountains and was originally mapped in 1970s as part of a regional mapping program. In 1994, a trench was excavated across the scarp, exposing a record of late Quaternary surface ruptures. Sense of motion on fault is inferred to be down-to-the-NW on a normal fault. Length of fault is about 45 km (28 mi.). Average recurrence interval is about 8 kyr, with 4–12 kyr between individual displacement events, in the past about 25 kyr.
Petersen et al. (2008)	Documentation for the 2008 Update of the United States National Seismic Hazard Maps	Cheraw fault in eastern Colorado shows evidence of Holocene and earlier faulting, based on a study by Crone, Machette, Bradley, et al. (1997). They infer that surface-rupturing earthquakes on fault occurred about 8, 12, and 20–25 ka, which may represent an active earthquake phase. In contrast, displacement events older than about 25 ka must have occurred prior to 100 ka, thus representing a quiescent period of some 75 kyr or more. All parameters for Cheraw fault are retained from 2002; fault was modeled using slip rate of 0.15 mm/yr, based on data from the last two displacement events and maximum magnitude of 7.0 ± 0.2 determined from the Wells and Coppersmith (1994) fault length for all slip types relation. A fixed recurrence time of 17.400 kyr is used with a truncated Gutenberg-Richter model from **M** 6.5–7.0. This yields mean recurrence time of 5 kyr for earthquakes with minimum magnitude of 6.5.

Table D-6.1.4 Data Summary
Oklahoma Aulacogen RLME

Citation	Title	Description and Relevance to SSC
General for Region		
Luza and Lawson (1993)	Oklahoma Seismic Network	Describes local network funded to investigate seismicity in Oklahoma, in particular, seismicity potentially related to Nemaha uplift. Presents earthquakes recorded from 1987 through 1992. Discusses association of seismicity with the Anadarko basin, Arkoma-Ouachita region, and other areas. Loose associations are made between earthquakes and structures, but there is no strong argument for activity on any structure. The depth distributions of earthquakes are likely not well constrained, but they suggest the seismic depth within Oklahoma extends to 15–20 km (9.3–12.4 mi.).
Meers Fault		
Burrell (1997)	Evaluation of Faulting Characteristics and Ground Acceleration Associated with Recent Movement Along the Meers Fault, Southwestern Oklahoma	Investigated the potential for strong earthquakes along Meers fault based on analyses of balanced granite boulders, stream deflections and offsets, and excavation of a fault exposure. Concludes that the presently observable scarp formed in four events with a return period of approximately 2.6–4.3 kyr, with less slip per event then previously suggested, and that magnitudes were significantly less than predicted by other researchers.
Cetin (2003)	Comment on “Known and Suggested Quaternary Faulting in the Midcontinent United States” by Russell L. Wheeler and Anthony Crone”	Summarizes evidence for a 30 km (18.6 mi.) extension of Meers fault to the NW of extent mapped by Ramelli et al. (1987) in an attempt to refute conclusion of Wheeler and Crone (2001) that the Holocene scarp does not extend further to NW.
Crone (1994)	Fault Number 1031b, Meers Fault, Southeastern Section, in Quaternary Fault and Fold Database of the United States	Provides summary of published information on the characteristics of Quaternary activity on Meers fault.
Crone and Wheeler (2000)	Data for Quaternary Faults, Liquefaction Features, and Possible Tectonic Features in the Central and Eastern United States, East of the Rocky Mountain Front	Provides summary of published information on the characteristics of Quaternary activity on Meers fault.

Table D-6.1.4 Data Summary
Oklahoma Aulacogen RLME

Citation	Title	Description and Relevance to SSC
Jones-Cecil (1995)	Structural Controls of Holocene Reactivation of the Meers Fault, Southwestern Oklahoma, from Magnetic Studies	Used local magnetic data obtained perpendicular to the Meers fault trace to constrain fault structure. Concludes that magnetic data suggests (1) slip is occurring on the Paleozoic fault, (2) splays along the SW end of the fault are not controlled by Paleozoic structure, and (3) the NW end of the fault appears to be a rupture barrier.
Kelson and Swan (1990) Swan et al. (1993)	Paleoseismic History of the Meers Fault, Southwestern Oklahoma, and Its Implications for Evaluations of Earthquake Hazards in the Central and Eastern United States Draft Report: Investigation of the Quaternary Structural and Tectonic Character of the Meers Fault (Southwestern Oklahoma)	These two publications present the results of the same study, but the report of Swan et al. (1993) is the most detailed. They present the results of an extensive study of Quaternary faulting history of Meers fault based on trenching, soil pits, auger samples, geomorphic analysis, and radiocarbon dating. They identify two Holocene events on the fault (approximately 1,300–1,400 yr BP and 2,100–2,900 yr BP) and a quiescence of approximately 200–500 kyr before the previous events. Swan et al. (1993) also discuss potential evidence for activity along the Criner fault and other portions of the Wichita frontal fault system.
Luza et al. (1987a) Luza et al. (1987b) Crone and Luza (1990)	Investigation of the Meers Fault in Southwestern Oklahoma Investigation of the Meers Fault, Southwestern Oklahoma Style and Timing of Holocene Surface Faulting on the Meers Fault, Southwestern Oklahoma	These three publications report the results of the same trenching and excavation study of Meers fault. They identify one Holocene surface-rupturing event. Their best estimate for the date of the event based on stratigraphic relationships and radiocarbon dating is 1,200–1,300 yr BP.
Madole (1986) Madole (1988)	The Meers Fault: Quaternary Stratigraphy and Evidence for Late Holocene Movement Stratigraphic Evidence of Holocene Faulting in the Mid-Continent: The Meers Fault, Southwestern Oklahoma	These two publications report the results of the same study. They identify one Holocene event on the Meers fault, and constrain the age of the event to approximately 1,280 yr BP (C-14 years), based on stratigraphic relations and radiocarbon dating of deposits distal (tens to hundreds of meters) from the scarp.
Miller et al. (1990)	Shallow Seismic Reflection Survey Across the Meers Fault, Oklahoma	A high-resolution reflection survey was conducted to investigate shallow structure of the fault. Survey elucidated local splay faults off the Meers and demonstrated the presence of high-angle to vertical up-to-the-north displacement along fault.

Table D-6.1.4 Data Summary
Oklahoma Aulacogen RLME

Citation	Title	Description and Relevance to SSC
Ramelli and Slemmons (1990)	Implications of the Meers Fault on Seismic Potential in the Central United States	General discussion of the state of knowledge of Meers fault at time of study, including hazard implications. A significant contribution from this study is discussion of surface rupture length and the possibility that the easternmost extension of the fault may not have the same slip history as the better-studied western portion.
Ramelli et al. (1987) Ramelli and Slemmons (1986)	The Meers Fault: Tectonic Activity in Southwestern Oklahoma Neotectonic Activity of the Meers Fault	Provides detailed mapping of Meers fault scarp based on low-sun-angle aerial photography. Based on this mapping, the Holocene scarp of Meers fault was extended further to SE than previously identified. Also documents search for other scarps along northern edge of Wichita Uplift. Digitized trace of fault used for CEUS SSC Project taken from compilation of USGS Quaternary Fault and Fold Database.
Wheeler and Crone (2001)	Known and Suggested Quaternary Faulting in the Midcontinent United States	Summarizes evidence for Quaternary faulting throughout CEUS. With respect to Meers fault, evaluates the suggestion of one researcher that the Holocene scarp associated with Meers fault extends 48 km (30 mi.) to NW of scarp defined by Ramelli et al. (1987), and concludes that there is no strong evidence to support this postulated NW extension of the Holocene scarp.
Wheeler and Crone (2003)	Reply to "Comment on Evaluation of Meers Fault, Oklahoma in 'Known and Suggested Quaternary Faulting in the Midcontinent United States' by Russell L. Wheeler and Anthony Crone"	Provides further justification for decision not to extend to the NW the Holocene Meers fault scarp beyond that mapped by Ramelli et al. (1987), refuting claims of Cetin (2003) that scarp extends further.
Oklahoma Aulacogen Source Zone		
Axtman (1983)	Structural Mechanisms and Oil Accumulation Along the Mountain View-Wayne Fault, South-Central Oklahoma, Part I	Examines structural and stratigraphic relationships of Mountain View fault and discusses the displacement history of fault in relation to structural and tectonic history of Oklahoma aulacogen.
Brewer (1982)	Study of Southern Oklahoma Aulacogen, Using COCORP Deep Seismic-Reflection Profiles	Summarizes how COCORP reflection data constrains timing and structural style of the Oklahoma aulacogen and Wichita uplift. Provides support for interpretation that the aulacogen extends from Hardeman basin (south of Wichita uplift) to Anadarko basin (north of Wichita uplift).

Table D-6.1.4 Data Summary
Oklahoma Aulacogen RLME

Citation	Title	Description and Relevance to SSC
Brewer et al. (1981)	Proterozoic Basin in the Southern Midcontinent of the United States Revealed by COCORP Deep Seismic Reflection Profiling	Provides summary of COCORP data from Oklahoma aulacogen showing layered ~1.2 Ga deposits south of Wichita uplift. Makes preliminary conclusions that these deposits suggest the aulacogen is more expansive or older than previously thought. Ideas are refined in later papers by Brewer.
Brewer et al. (1983)	COCORP Profiling Across the Southern Oklahoma Aulacogen: Overthrusting of the Wichita Mountains and Compression Within the Anadarko Basin	Uses COCORP reflection data to detail structure and timing of deformation related to formation of Oklahoma aulacogen and Wichita uplift. Suggests that extent of Oklahoma aulacogen may be more restricted than previously considered.
Coffman et al. (1986)	An Interpretation of the Crustal Structure of the Southern Oklahoma Aulacogen Satisfying Gravity Data	Presents cross section of crustal structure across Oklahoma aulacogen based on gravity data.
Gilbert (1983b)	Timing and Chemistry of Igneous Events Associated with the Southern Oklahoma Aulacogen	Summarizes timing of Oklahoma aulacogen formation as recorded in the record of igneous rocks.
Good et al. (1983)	COCORP Deep Seismic Reflection Traverse Across the Southern Oklahoma Aulacogen	Summarizes initial results of COCORP study of Oklahoma aulacogen. Results and conclusions are similar to papers by Brewer and others (in this table). Main conclusions are the presence of a Proterozoic basin to the south of the Wichita uplift and thrust faults that accommodate overthrusting of the Wichita mountains over the Anadarko basin.
Ham et al. (1964)	Basement Rocks and Structural Evolution of Southern Oklahoma	Provides maps of basement structure and faults of the Amarillo-Wichita-Arbuckle uplift.
Hanson et al. (1997)	Quaternary Deformation Along the Criner Fault, Oklahoma: A Case Study for Evaluating Tectonic Versus Landslide Faulting	Concludes that earlier investigations suggesting Quaternary activity of the Criner fault had misinterpreted landslide deposits and that, in fact, there have been no Holocene events along the Criner.
Keller and Stephenson (2007)	The Southern Oklahoma and Dnieper-Donets Aulacogens: A Comparative Analysis	Summarizes geophysical studies of the Oklahoma aulacogen and provides synthesis velocity and gravity models of the aulacogen and surrounding basins. Interprets base of the Anadarko basin as having rift-fill deposits.

Table D-6.1.4 Data Summary
Oklahoma Aulacogen RLME

Citation	Title	Description and Relevance to SSC
Larson et al. (1985)	Petrologic, Paleomagnetic, and Structural Evidence of a Paleozoic Rift System in Oklahoma, New Mexico, Colorado, and Utah	Presents petrologic and paleomagnetic data supporting interpretation that rifting related to the Oklahoma aulacogen extended into New Mexico, Colorado, and Utah.
Liang and Langston (2009)	Three-Dimensional Crustal Structure of Eastern North America Extracted from Ambient Noise	Maps three-dimensional shear-wave velocity throughout the CEUS and discusses presence of rifting episodes apparent in the data.
McConnell (1989)	Determination of Offset Across the Northern Margin of the Wichita Uplift, Southwest Oklahoma	Uses well data to constrain structural relationships of Wichita uplift frontal thrust system. Derives estimates of direction and amount of slip along frontal thrust faults during the Ouachita orogeny.
McConnell and Gilbert (1990)	Cambrian Extensional Tectonics and Magmatism Within the Southern Oklahoma Aulacogen	Uses presence of Cambrian igneous rocks to interpret history of aulacogen formation. Uses gravity and magnetic signature of these rocks to define extent of the Cambrian aulacogen.
Perry (1989)	Tectonic Evolution of the Anadarko Basin Region, Oklahoma	Summarizes tectonic history of Anadarko basin on north side of Oklahoma aulacogen.
Pratt et al. (1992)	Widespread Buried Precambrian Layered Sequences in the U.S. Mid-Continent: Evidence for Large Proterozoic Depositional Basins	Discusses previously published COCORP data for Hardeman basin, south of Wichita uplift. Uses correlation with borings to suggest the basin is potentially filled with 1.3–1.5 Ga felsic igneous rocks interbedded with sedimentary rocks. No real discussion of subsidence history or formation of the aulacogen.
Swan et al. (1993)	Draft Report: Investigation of the Quaternary Structural and Tectonic Character of the Meers Fault (Southwestern Oklahoma)	Assessed the potential for Quaternary activity along Wichita frontal fault system, with emphasis on Meers and Criner faults. Meers fault is discussed in that section of this data summary table. Concludes that only the Meers fault, and potentially the Criner fault, has evidence of Quaternary activity.
Texas BEG (1997)	Tectonic Map of Texas	Provides updated maps of basement structure and faults of the Amarillo-Wichita-Arbuckle uplift.
Viele and Thomas (1989)	Tectonic Synthesis of the Ouachita Orogenic Belt	Presents idea that Oklahoma aulacogen is a “leaky transform” and not a failed rift arm. Cites the existence of extensive volcanism and plutonism and the absence of rift-related sedimentary facies.

Table D-6.1.4 Data Summary
Oklahoma Aulacogen RLME

Citation	Title	Description and Relevance to SSC
Walker (2006)	Structural Analysis of the Criner Hills, South-Central Oklahoma	Constructed a detailed subsurface structural model of the Criner fault in the region where Quaternary activity had previously been suggested. Demonstrates that Criner fault is a relatively small secondary fault branching off the major Kirby fault. Based on these structural relationships, concludes that Criner had not slipped since the last activity on the Kirby (early Pennsylvanian).
Williamson (1996)	Observations on the Capability of the Criner Fault, Southern Oklahoma	Conducted a detailed analysis of previously cited evidence of Holocene/Quaternary activity of the Criner fault and determined that there is no evidence of Quaternary activity along the fault.
Zhang et al. (2009b)	Tomographic Pn Velocity and Anisotropy Structure in the Central and Eastern United States	Maps Pn (upper mantle) velocity structure throughout the CEUS and hypothesizes a potential correlation between edges of high-velocity zones and locations of intraplate seismic zones.

Table D-6.1.5 Data Summary
Reelfoot Rift–New Madrid Seismic Zone (NMSZ) Region

Geologic Structures Interpreted from Geologic, Gravity, Magnetic, and Seismic-Profile Data		
Braile et al. (1986)	Tectonic Development of the New Madrid Rift Complex, Mississippi Embayment, North America	Geological and geophysical studies of NMSZ have revealed a buried late Precambrian rift beneath the upper Mississippi embayment area. The rift has influenced tectonics and geologic history of the area since late Precambrian time and is presently associated with contemporary earthquake activity of the NMSZ. The rift formed during late Precambrian to earliest Cambrian time as a result of continental breakup and has been reactivated by compressional or tensional stresses related to plate tectonic interactions. Configuration of the buried rift is interpreted from gravity, magnetic, seismic-refraction, seismic-reflection, and stratigraphic studies. The increased mass of crust in the rift zone, which is reflected by regional positive gravity anomalies over the upper Mississippi embayment area, has resulted in periodic subsidence and control of sedimentation and river drainage in this cratonic region since formation of the rift complex. Correlation of the buried rift with contemporary earthquake activity suggests that earthquakes result from slippage along zones of weakness associated with ancient rift structures. Slippage is due to reactivation of the structure by the contemporary, nearly E-W regional compressive stress, which is the result of plate motions.
Braile et al. (1997)	New Madrid Seismicity, Gravity Anomalies, and Interpreted Ancient Rift Structures	Epicentral patterns, correlative geophysical data, and historical seismic energy release indicate significance of New Madrid area seismicity, both within Reelfoot segment of rift structures and in areas outside of this segment, particularly to the north. Deep structure of the crust, including thickness variations in the upper crust and the presence of a high-density lower-crustal layer, is a controlling factor in New Madrid seismicity.
Clendenin et al. (1989)	Reinterpretation of Faulting in Southeast Missouri	Mine, field, and borehole core observations are reported for late Proterozoic–early Cambrian rift-related faulting in SE Missouri. The principal fault set is composed of NW-striking transfer faults. Initial late Cambrian reactivations extended faults NW across Midcontinent and formed several major lineaments. Transpressive wrench-fault reactivations during late Pennsylvanian–Early Permian time uplifted St. Francois igneous terrane into a positive flower structure. During Cretaceous rifting, the faults acted as transfer faults, and intersections with related extension faults localized associated intrusive activity.

Table D-6.1.5 Data Summary
Reelfoot Rift–New Madrid Seismic Zone (NMSZ) Region

Csontos et al. (2008)	Reelfoot Rift and Its Impact on Quaternary Deformation in the Central Mississippi River Valley	A structure-contour map and 3-D computer model of the top of Precambrian crystalline basement define the NE-trending Reelfoot rift, which is crosscut by SE-trending basement faults. Reelfoot rift consists of two basins separated by intra-rift uplift that are further subdivided into eight subbasins bounded by NE- and SE-striking rift faults. The rift is bounded to the south by White River fault zone and to the north by Reelfoot normal fault. Reelfoot thrust fault is interpreted as an inverted basement normal fault. A structure-contour map of the Pliocene-Pleistocene unconformity (top of Eocene base of Mississippi River alluvium) reveals both river erosion and tectonic deformation. Deformation of the unconformity appears to be controlled by NE- and SE-trending basement faults. NE-trending rift faults have undergone Quaternary dextral transpression that has resulted in displacement of two major rift blocks (uplift in SE half; subsidence in NW half) and formation of the Lake County uplift, Joiner Ridge, and southern half of Crowley's Ridge as compressional stepover zones, which appear to have originated above basement fault intersections. Lake County uplift has been tectonically active over the past ~2,400 years. The aseismic Joiner Ridge and southern portion of Crowley's Ridge may reflect earlier uplift, thus indicating Quaternary strain migration within Reelfoot rift.
Dart and Swolfs (1998)	Contour Mapping of Relic Structures in the Precambrian Basement of the Reelfoot Rift, North American Midcontinent	Presents contour map of the basement of the Reelfoot rift constructed from drillhole and seismic-reflection data and showing the general surface configuration as well as several major and minor structural features. Major features are two asymmetric intrarift basins, bounded by three structural highs, and the rift margins. The basins are oriented normal to NE trend of rift. Two of the highs appear to be ridges of undetermined width that extend across the rift; the third high is an isolated dome or platform located between the basins. Minor features are three linear structures of low relief oriented subparallel to trend of rift. Two of these, located within the rift basins, may divide the rift basins into paired subbasins. These mapped features may be remnants of initial extensional rifting, half graben faulting, and basement subsidence. The rift basins are reinterpreted as having formed as opposing half grabens, and the structural highs are interpreted as having formed associated accommodation zones. Some of these features appear to be reactivated seismogenic structures within the modern Midcontinent compressional

		stress regime.
Hildenbrand (1982)	Model of the Southeastern Margin of the Mississippi Valley Graben near Memphis, Tennessee, from Interpretation of Truck-Magnetometer Data	Modeling of data from detailed magnetic-anomaly profiles suggests (1) that graben margins represent both structural boundaries and conduits for ascending magma and (2) that about 2 km (1.2 mi.) of vertical offset associated with normal faulting occurs within an interpreted 5.5 km (3.4 mi.) wide zone in which magnetic basement has an average dip of 20°NW into the graben. The high apparent susceptibility of magnetic basement associated with this fault zone and with the uplifted block suggests either that ascending magma intruded the upblock or that the two blocks differed lithologically prior to formation of the graben.
Hildenbrand and Hendricks (1995)	Geophysical Setting of the Reelfoot Rift and Relations Between Rift Structures and the New Madrid Seismic Zone	Provides discussion of several potential field features inferred from magnetic and gravity data that may focus earthquake activity in the northern Mississippi embayment and surrounding region. Summarizes complex tectonic and magmatic history of the rift.
Hildenbrand et al. (2001)	Geologic Structures Related to New Madrid Earthquakes near Memphis, Tennessee, Based on Gravity and Magnetic Interpretations	Defines boundaries of regional structures and igneous complexes in the region north of Memphis, Tennessee, and south of latitude 36° that may localize seismicity.
Langenheim and Hildenbrand (1997)	Commerce Geophysical Lineament—Its Source, Geometry, and Relation to the Reelfoot Rift and New Madrid Seismic Zone	The Commerce geophysical lineament (CGL) is a NE-trending magnetic and gravity feature that extends from central Arkansas to southern Illinois over a distance of >400 km (>250 mi.). The CGL is parallel to trend of Reelfoot graben, but offset >40 km (25 mi.) to the NW of the western margin of rift floor. Modeling indicates that the source of the magnetic and gravity anomalies is probably a mafic dike swarm. Age of the source of the CGL is not known, but the linearity and trend of the anomalies suggest a relationship with Reelfoot rift, which has undergone episodic igneous activity. The CGL coincides with several topographic lineaments, movement on associated faults at least as young as Quaternary, and intrusions of various ages. Several earthquakes (m_b > 3) coincide with the CGL, but the diversity of associated focal mechanisms and the variety of surface structural features along the length of the CGL obscure its relation to the release of present-day strain. With the available seismicity data, it is difficult to attribute individual earthquakes to a specific structural lineament such as the CGL.

Table D-6.1.5 Data Summary
Reelfoot Rift–New Madrid Seismic Zone (NMSZ) Region

McKeown et al. (1990)	Diapiric Origin of the Blytheville and Pascola Arches in the Reelfoot Rift, East-Central United States: Relation to New Madrid Seismicity	Earthquakes in the NMSZ correlate spatially with the Blytheville arch and part of the Pascola arch, which are interpreted to be the same structure. Both arches were formed by diapirism. Rocks in the arch are more highly deformed, and are therefore weaker, than adjacent rocks. Seismicity is hypothesized to be localized in these weaker rocks.
Mooney et al. (1983)	Crustal Structure of the Northern Mississippi Embayment and a Comparison with Other Continental Rift Zones	Information on the deep structure of the northern Mississippi embayment, gained through an extensive seismic refraction survey, supports a rifting hypothesis. The confirmation and delineation of a 7.3 km/s layer, identified in previous studies, implies that lower crust has been altered by injection of mantle material. Results indicate that this layer reaches a maximum thickness in the north-central embayment and thins gradually to the SE and NW, and more rapidly to the SW along axis of graben. The apparent doming of 7.3 km/s layer in the north-central embayment suggests that rifting may be the result of a triple junction located in the Reelfoot basin area.
Nelson and Zhang (1991)	A COCORP Deep Reflection Profile Across the Buried Reelfoot Rift, South-Central United States	Deep reflection profile line reveals features of the late Precambrian (?)/early Paleozoic Reelfoot rift. The Blytheville arch, an axial antiformal feature, as well as lesser structures indicative of multiple episodes of fault reactivation, is evident on profile.
Odum et al. (1995)	High-Resolution, Shallow, Seismic Reflection Surveys of the Northwest Reelfoot Rift Boundary near Marston, Missouri	Presents and discusses interpretation of six high-resolution seismic-reflection profiles in the epicentral area of the 1811-1812 earthquakes. Three profiles show a master and antithetic fault pair that can be traced for 6 km (3.7 mi.). Geomorphic evidence suggests that the structures are at least 15 km (9 mi.) long. Trend of the fault pair (N50°–55°N) subparallels the magnetically defined Reelfoot rift boundaries and other major structures. Normal and reverse displacement of a Paleozoic surface reflector decreases from 30 m (98 ft.) upward toward the surface. There is evidence for minor amounts of movement into the Eocene. Lack of surface and near-surface deformation may indicate that strike-slip movement became prevalent in the late Tertiary.

Odum et al. (2003)	Variable Near-Surface Deformation Along the Commerce Segment of the Commerce Geophysical Lineament, Southeast Missouri to Southern Illinois, USA	Concludes that there is a plausible link between surface and near-surface tectonic features and the vertical projection of the Commerce geophysical lineament (CGL). The CGL is a 5–10 km (3–6 mi.) wide zone of basement magnetic and gravity anomalies traceable for more than 600 km (373 mi.), extending from Arkansas, through SE Missouri and southern Illinois, and into Indiana. Interprets 12 km (7.5 mi.) of high-resolution seismic-reflection data, collected at four sites along a 175 km (109 mi.) segment of the projection, to show varying amounts of deformation involving Tertiary and some Quaternary sediments. Some of the locally anomalous geomorphic features in the northern Mississippi embayment region (i.e., paleoliquefaction features, anomalous directional changes in stream channels, and areas of linear bluff escarpments) overlying CGL can be correlated with specific faults and/or narrow zones of deformed (faulted and folded) strata that are imaged on high-resolution seismic-reflection data. There is an observable change in near-surface deformation style and complexity progressing from SW to NE along trace of CGL. The seismic-reflection data corroborate mapping evidence that suggests that this region has undergone a complex history of deformation, some of which is documented to be as young as Quaternary, during multiple episodes of reactivation under varying stress fields.
Potter et al. (1995)	Structure of the Reelfoot–Rough Creek Rift System, Fluorspar Area Fault Complex, and Hicks Dome, Southern Illinois and Western Kentucky—New Constraints from Regional Seismic Reflection Data	Interprets an 83 km (51.5 mi.) segment of seismic-reflection data across the northern part of the Reelfoot rift—Fluorspar Area fault complex (FAFC)—in SE Illinois and western Kentucky. Notes that NMSZ appears bounded on the north and south by Cambrian accommodation zones that linked segments with differing rift geometry. A series of grabens and horst in the FAFC document a late Paleozoic reactivation of Cambrian rift. Beneath two of the FAFC grabens, the bounding faults meet within the Knox Group and do not continue to depth. Other normal faults in the FAFC clearly offset the top of Precambrian basement.

Table D-6.1.5 Data Summary
Reelfoot Rift–New Madrid Seismic Zone (NMSZ) Region

Pratt (2009)	Insights into the Structure and Long-Term Deformation in the New Madrid Region from Seismic Reflection Profiles	Summarizes general observations and interprets all available seismic-reflection profiles in the New Madrid region (including Vibroseis profiles acquired by USGS, industry Vibroseis profiles purchased by USGS, COCORP profile across the embayment, and shallow seismic-reflection profiles acquired by USGS). The Blytheville arch is the most prominent feature that can be associated with the NMSZ. The arch is an antiform in Precambrian and early Paleozoic rift strata (as much as 20 km, or 12 mi., wide and 200 km, or 124 mi., long) that coincides with the SE arm of seismicity. The prominent erosional surface that truncates the top of the arch indicates that the arch was largely formed before the erosional surface was cut in the Paleozoic. This erosional surface is slightly folded (Quaternary or Holocene in age). Prominent faults include one coinciding with the Bootheel lineament and one with the SE arm of seismicity; other faults are evident over a wider area of the embayment. The arch appears to coincide with a major crustal boundary. Data are consistent with a rift model in which middle- and lower-crustal reflectivity are associated with rifting, and deformation is distributed across rift zone.
Van Arsdale and TenBrink (2000)	Late Cretaceous and Cenozoic Geology of the New Madrid Seismic Zone	Presents structure-contour maps constructed from well, seismic-reflection, and outcrop data of the tops of the Paleozoic section, Upper Cretaceous section, Paleocene Midway Group, and Eocene section used to illustrate post-Paleozoic structure of the NMSZ region. Maps reveal reactivation of the underlying late Precambrian to Cambrian Reelfoot rift during Midway Group deposition, but no reactivation during Late Cretaceous or Eocene deposition. The maps indicate a subtle, south-plunging depression on the tops of the Paleozoic, Upper Cretaceous, and Midway Group along axis of northern Mississippi embayment that is referred to as a trench. This trench is 50 km (31 mi.) wide, has a maximum depth of 100 m (328 ft.), and appears to have formed during the Eocene. The trench's western boundary coincides with Blytheville arch/Lake County uplift, and its SE margin underlies Memphis. The SE margin, like the NW margin, may be fault-controlled.
Van Arsdale et al. (2007)	Upland Complex of the Central Mississippi River Valley: Its Origin, Denudation, and Possible Role in Reactivation of the New Madrid Seismic Zone	Summarizes information on the distribution of the Upland Complex (Lafayette gravel) in early Pliocene (5.5–4.5 Ma) and what sea level was (+100 m, or 328 ft.) at time of deposition. Subsequent sea-level lowering to –20 m (–65.5 ft.) at 4 Ma resulted in incision that formed the high-level terrace; subsequent denudation of up to 100 m (328 ft.) of sediment may have perturbed the local stress field, possibly reactivating the NMSZ.

Table D-6.1.5 Data Summary
Reelfoot Rift–New Madrid Seismic Zone (NMSZ) Region

Wheeler (1996)	Relative Seismic Hazards of Six Iapetan Rifts and Grabens in Southeastern North America	Ranks six Iapetan rifts and grabens according to their seismic hazard based on seismicity and geologic criteria. Criteria include activity rate (seismicity), indirect evidence that their faults extend to the depths at which earthquakes typically occur in eastern North America, and evidence for Mesozoic extension. From most hazardous to least, the rankings are as follows: Reelfoot rift and Ottawa rift (highest); southern Oklahoma aulacogen and Saguenay rift (intermediate hazard); and Rough Creek and Rome trough (lower relative hazard indistinguishable from that of sparsely seismic cratonic interior regions).
Wheeler et al. (1994)	Map Showing Structure of the Mississippi Valley Graben in the Vicinity of New Madrid, Missouri	Compilation map showing bedrock geology; epicenters; geologic and subcrop contacts; structure contours; radon concentrations; selected wells; selected faults; and arches, troughs, and faulted boundaries of Mississippi Valley graben.
Williams et al. (2009)	Post-Eocene Deformation Observed in Seismic Profiles Across the Southwestern Blytheville Arch, Crowley's Ridge, and Western Reelfoot Rift Margin, Arkansas	Interpretation of three high-resolution minivibe P-wave reflection profiles in NE Arkansas about 70 km (43.5 mi.) NW of Memphis. Profiles are higher resolution than previously acquired in this area. Preliminary results from Crowley's Ridge, an anomalous topographic high, are consistent with previous COCORP and USGS reflection data and strongly suggest that the 50 m (164 ft.) high topography of the ridge is caused by post-Eocene tectonic uplift related to near-vertical ridge-bounding faults. The Lepanto profile images a monocline in Paleozoic and younger reflectors within a seismically active area on eastern margin of buried Blytheville arch (maximum uplift on the Paleozoic through Eocene reflector sequence is 100 m, or 328 ft.). Above the Eocene and possibly into the Quaternary, the sediments thicken east of the monocline, suggesting ongoing growth. Along western Reelfoot rift margin, a 2 km (1.2 mi.) wide zone of deformation is observed, with faulting that displaces Paleozoic and Eocene reflectors about 20–30 m (66–98 ft.) in an up-to-the-west sense. Across the 11 km (7 mi.) length of the profile (that crosses other small faults), the Paleozoic-Cretaceous section gradually rises to the west about 75 m (246 ft.).

Table D-6.1.5 Data Summary
Reelfoot Rift–New Madrid Seismic Zone (NMSZ) Region

Zoback et al. (1980)	Recurrent Intraplate Tectonism in the New Madrid Seismic Zone	Provides information on subsurface structure revealed through a program of seismic-reflection profiling. These data show that New Madrid seismicity can be linked to specific structural features. Major faults are coincident with the main earthquake trends in the area and with structural deformation apparently caused by repeated episodes of igneous activity. Notes that the zones of intense seismicity in the CEUS are associated with ancient rift zones that are favorably oriented for failure relative to the current stress field.
Northern Terminus of Reelfoot Rift		
Bear et al. (1997)	Seismic Interpretation of the Deep Structure of the Wabash Valley Fault System	Interpretation of recently compiled seismic-reflection data suggests that structures associated with the Wabash Valley fault system may not be directly linked to NE-trending structures in New Madrid area. The authors note that a graben may exist within the southern Indiana arm (Braile et al., 1982), but it is limited in geographic extent and is not structurally continuous with the Reelfoot rift–Rough Creek graben.
Heigold and Kolata (1993)	Proterozoic Crustal Boundary in the Southern Part of the Illinois Basin	Concludes that structures associated with the NMSZ may be distinct from structures to the NE (in the Wabash Valley zone), as evidenced by the E-SE-trending geophysical anomaly that separates two areas of distinctly different crust.
Hildenbrand and Hendricks (1995)	Geophysical Setting of the Reelfoot Rift and Relations Between Rift Structures and the New Madrid Seismic Zone	Inspection of regional magnetic and gravity anomaly maps suggests that NW margin does not continue northeastward into southern Indiana. A preferred geometry is that both the NW and SE margins bend to the east and merge with the Rough Creek graben.
Hildenbrand and Ravat (1997)	Geophysical Setting of the Wabash Valley Fault System	Concludes from high-resolution magnetic data and the lack of regional potential-field features extending south from Wabash Valley that the Wabash Valley fault system apparently is not structurally connected to the faults related to the NMSZ.
Kolata and Hildenbrand (1997)	Structural Underpinnings and Neotectonics of the Southern Illinois Basin: An Overview	Summarizes geologic and geophysical information that suggests that cause of earthquakes in the NMSZ is unrelated to that in the region north of Reelfoot rift system.

Table D-6.1.5 Data Summary
Reelfoot Rift–New Madrid Seismic Zone (NMSZ) Region

Pratt et al. (1989)	Major Proterozoic Basement Features of the Eastern Midcontinent of North America Revealed by Recent COCORP Profiling	Interpretation of deep seismic-reflection data from southern Illinois and southern Indiana indicates the absence of a thick section of rift-related sedimentary rocks.
Wheeler (1997)	Boundary Separating the Seismically Active Reelfoot Rift from the Sparsely Seismic Rough Creek Graben	Concludes that the structural boundary between the relatively high hazard of the Reelfoot rift and low hazard of the Rough Creek graben is marked by bends and ends of large faults, a Cambrian transfer zone, and the geographic extent of alkaline igneous rocks.
Seismogenic Faults		
Baldwin et al. (2002)	Preliminary Paleoseismic and Geophysical Investigation of the North Farrenburg Lineament: Primary Tectonic Deformation Associated with the New Madrid North Fault?	Presents geomorphic, geologic, seismic-reflection, trench, and microtextural data that strongly suggest that the North Farrenburg lineament, as well as the South Farrenburg lineament, may be the surface expression of an underlying tectonic fault that ruptured during January 23, 1812, earthquake. NE-trending contemporary microseismicity beneath Sikeston Ridge and previously inferred New Madrid North locations align partly with the lineaments.
Baldwin et al. (2005)	Constraints on the Location of the Late Quaternary Reelfoot and New Madrid North Faults in the New Madrid Seismic Zone, Central United States	Synthesis of existing unpublished and published data with subsurface and geomorphic information to clarify locations of Reelfoot and New Madrid North faults. The Reelfoot fault is interpreted to trend NW across the Kentucky Bend of the Mississippi River as a NW-facing scarp coincident with a slough near New Madrid, Missouri, and anomalous elevated topography on southern Sikeston Ridge NW of New Madrid. Quaternary faulting and folding imaged from seismic-reflection profiles coincide with bedrock structural lineaments, a NE-trending band of contemporary microseismicity, and a distinct NW-trending post-Tertiary change in alluvial thickness. The Reelfoot fault is traced as much as several kilometers NW of the Mississippi River, where it either dies out or steps N-NE to merge with the New Madrid North fault. The New Madrid North fault appears to be expressed geomorphically as left-stepping, en echelon NE-trending fractures preserved in Pleistocene glacial outwash material comprising Sikeston Ridge. The fractures coincide with Quaternary faults and folds, as well as deeper Cretaceous and Paleozoic faults and flexures, imaged in geophysical profiles.

Baldwin et al. (2006)	Geological Characterization of the Idalia Hill Fault Zone and Its Structural Association with the Commerce Geophysical Lineament, Idalia, Missouri	Recent geologic and geophysical studies along faults overlying the Commerce geophysical lineament (CGL) support the notion that the prominent geophysical anomaly may be a source of future large-magnitude earthquakes. Results of geomorphic mapping and acquisition of seismic-reflection and ground-penetrating-radar data, together with paleoseismic trenching and borehole investigations, provide evidence of late Pleistocene to early Holocene deformation on Idalia Hill fault zone. Seismic-reflection data image a 0.5 km (0.3 mi.) wide zone of NE-striking, near-vertical faults that offset Tertiary and Quaternary reflectors and coincide with near-surface deformation. The regional NE strike of the fault zone, coupled with the presence of near-vertical faults and complex flowerlike structures, and preferential alignment with the contemporary central U.S. stress regime, indicate that the fault zone likely accommodates right-lateral transpressive deformation. Stratigraphic and structural relationships in trenches provide evidence for at least two late Quaternary faulting events on the Idalia Hill fault zone overlying Commerce section of the CGL. The penultimate event occurred in the late Pleistocene (prior to 23.6–18.9 ka). The most recent event occurred in the late Pleistocene to early Holocene (18.5–7.6 ka). The events overlap in age with two prehistoric events interpreted by Vaughn (1994) that occurred 23–17 ka and 13.4–9 ka and one event recognized by Harrison et al. (1999) that occurred 35–25 ka. The results of this study and previous studies provide evidence of late Pleistocene to early Holocene deformation along approximately 75 km (46.6 mi.) of the CGL.
Baldwin et al. (2008)	Geophysical and Paleoseismic Evaluation of the Penitentiary Fault and Its Association with the Commerce Geophysical Lineament, Tamms, Southern Illinois	Results of study provide evidence for linking observed Pleistocene-Holocene deformation with previously mapped faults overlying the CGL. The fault is accommodating dextral transpression based on interpretation of seismic data, regional focal mechanisms data, geomorphic data (i.e., deflected streams), regional topography, and previous studies. Data suggest that Penitentiary fault is likely a Paleozoic (?) fault that developed into a fault-line scarp during pre-Quaternary time and has been reactivated in late Quaternary time. Faults project upsection into the latest Pleistocene Henry Formation (older than ~25 kyr) and possibly Holocene Cahokia Formation. Vertical offset of reflectors ranges from 2 to 6 m (6.5 to 20 ft.).

Table D-6.1.5 Data Summary
Reelfoot Rift–New Madrid Seismic Zone (NMSZ) Region

Champion et al. (2001)	Geometry, Numerical Models and Revised Slip Rate for the Reelfoot Fault and Trishear Fault-Propagation Fold, New Madrid Seismic Zone	Analysis of trench excavations, shallow borings, a digital elevation model of topography, and bathymetry shows that Reelfoot monocline is a forelimb on a fault-propagation fold that has accommodated relatively little shortening. Reelfoot fault is a reactivated Paleozoic structure. A late Holocene fault slip rate of 3.9 ± 0.1 mm/year is based on 9 m (29.5 ft.) of structural relief, the 2,290 ± 60 yr BP age of folded sediment, and a 75° dip for the fault. The fault tip is 1,016 m (3,333 ft.) beneath the surface. The thrust is flatter at deeper levels (5–14 km, or 3.1–8.7 mi.) based on the location of earthquake hypocenters (~40°SW for northern segment, ~35°W for central segment, ~45°SW for southern segment).
Chiu et al. (1997)	Seismicity of the Southeastern Margin of Reelfoot Rift, Central United States	Coincidence of seismicity along SE flank of Reelfoot rift suggests that this rift flank is seismically active but at a lower level than main intra-rift NMSZ. Style of faulting as inferred from seismicity is complex, the dominant pattern being right-lateral strike-slip with reverse movement. Authors conclude that seismic data is sufficient to show that SE rift margin contains seismically active faults and has the potential of producing a major (**M** ~ 7) earthquake.
Cox, Van Arsdale, and Harris (2001)	Identification of Possible Quaternary Deformation in the Northeastern Mississippi Embayment Using Quantitative Geomorphic Analysis of Drainage-Basin Asymmetry	The SE Reelfoot rift margin coincides with a 150 km (93 mi.) long linear topographic scarp from near Memphis to the Tennessee-Kentucky line. S-wave reflection profiles, auger data, and a trench excavation reveal late Wisconsinan to early Holocene surface faulting and late Holocene liquefaction associated with this fault-line scarp. Variation in sense of throw along strike and flower-structure geometry suggest that this is a strike-slip fault. Temporal shifts in strain accommodation may give rise to short-term seismicity patterns and/or geodetic velocities that do not reveal long-term tectonic patterns.
Cox, Van Arsdale, et al. (2001)	Neotectonics of the Southeastern Reelfoot Rift Zone Margin, Central United States, and Implications for Regional Strain Accommodation	Suggests that the 150 km (93 mi.) long SE Reelfoot rift margin fault system may be accommodating significant northeastward transport as a right-lateral fault capable of producing earthquakes of **M** ≥ 7. Results of paleoseismological investigations show the following: no Holocene movement at the Union City site (north of intersection with Reelfoot fault); ≥3 m vertical displacement of ~Peoria loess (~20 ka) at the Porter Gap site (south of intersection with Reelfoot fault); and approximately 9.68 ka deposits postdate main events, while minor liquefaction postdates ~4.3 ka.

Table D-6.1.5 Data Summary
Reelfoot Rift–New Madrid Seismic Zone (NMSZ) Region

Cox, Van Arsdale, and Larsen (2002)	Paleoseismology of the Southeastern Margin of the Reelfoot Rift in the Vicinity of Memphis, Tennessee	Confirms that SE Reelfoot rift margin is a fault zone with multiple high-angle faults and associated folding based on shallow seismic profiles and paleoseismological investigations. Documents evidence for 8–15 m (26.2–49.2 ft.) of right-lateral offset of a late Wisconsinan paleochannel (~20 ka) at a site near Porter Gap, suggesting an average slip rate of between 0.85 and 0.37 mm/year. Provides evidence for an earthquake ca. 2,500–2,000 yr BP on SE Reelfoot rift margin that ruptured ≥80 km (50 mi.) from Shelby County (15–25 km, or 9.3–15.5 mi., north of Memphis metropolitan area) to Porter Gap (just south of intersection with Reelfoot fault).
Cox et al. (2006)	Paleoseismology of the Southeastern Reelfoot Rift in Western Tennessee and Implications for Intraplate Fault Zone Evolution	Analysis of shallow S-wave reflection profiles, coring, and trenches show that SE Reelfoot rift is a right-lateral system with high-angle faults showing both up-to-the-NW and down-to-the-NW separations. Offset of a Wisconsinan paleochannel at Porter Gap indicates 8–15 m (26–49 ft.) of right-lateral strike-slip, suggesting that this rift margin may have accommodated much of the regional strain. Age constraints from paleoseismic investigations at Shelby County and at the Porter Gap site are consistent with an earthquake ca. 2,500–2,000 years ago (most recent event) that ruptured ≥80 km (50 mi.). Late Wisconsinan and Holocene faulting along SE rift margin fault system is observed adjacent to the hanging wall of the Reelfoot thrust, but only Wisconsinan faulting is noted adjacent to the footwall of the thrust. It is hypothesized that the NE segment of the SE rift margin turned off in Holocene when the Reelfoot stepover thrust turned on.
Cramer et al. (2006)	The Possibility of Northeastward Unilateral Rupture for the January 23, 1812 New Madrid Earthquake	Suggests that unilateral rupture within New Madrid fault zone led to extraordinary strong motions to the NE. This explanation is compatible with observations of triggered earthquakes in northern Kentucky and liquefaction in the northern New Madrid region and White County, Illinois. This rupture hypothesis cannot be unequivocally established due to lack of intensity data to the SW with which to show an asymmetric pattern of intensities.

Crone (1992)	Structural Relations and Earthquake Hazards of the Crittenden County Fault Zone, Northeastern Arkansas	Interpretation of about 135 km (84 mi.) of seismic-reflection data provides information on the structural relations between the Crittenden County fault zone (CCFZ) and subjacent rift-bounding faults along SE margin of Reelfoot rift in the NMSZ. Rift margin is 4–8 km (2.5–5 mi.) wide and coincides with the margin defined by magnetic data. The CCFZ is a NE-trending zone of high-angle (up-to-the-NW throw) reverse faulting that extends at least 32 km (20 mi.). The fault zone (varying from well-developed reverse faults to 1–3 km [0.6–1.9 mi.] wide zone of warped and disrupted reflectors) is structurally linked to the subjacent rift-bounding faults. Estimated vertical displacement of Cretaceous marker horizon measured across multiple seismic varies from 10 to 49 m (32.8 to 160.8 ft.). Evidence for a history of recurrent reverse slip that began shortly before deposition of the Upper Cretaceous sedimentary rocks and extended into at least the Eocene. The reverse slip may be related to bending-moment faulting in a localized compressional stress field that developed in response to subsidence of the Mississippi embayment. The CCFZ may have the potential for generating major earthquakes, or conversely; however, the possibility that the CCFZ is a bending-moment fault argues against its being an extremely hazardous fault.
Crone (1998a)	Defining the Southwestern End of the Blytheville Arch, Northeastern Arkansas: Delimiting a Seismic Source Zone in the New Madrid Region	Interprets Vibroseis seismic-reflection profiles to document the southwesterly extent of the Blytheville arch and the length (134 km, or 83 mi.) of a fault zone that coincides with the arch.
Crone and Schweig (1994)	Fault Number 1023, Reelfoot Scarp and New Madrid Seismic Zone	The Crittenden County fault zone (feature 1023-6) in NE Arkansas has no known surface expression, but extensive seismic-reflection studies suggest that Quaternary sediments are deformed by movement on the fault (Luzietti et al., 1992). The fault zone, in part, coincides with SE margin of Reelfoot rift and has sense of vertical offset that is opposite to the net structural relief in the underlying rift (Crone, 1992). Drillhole and seismic-reflection data show that the top of Paleozoic rocks is vertically offset about 80 m (262 ft.) across the fault zone and that shallower strata are offset progressively less (Luzietti et al., 1992; Crone, 1992). Deformation associated with the fault zone can be confidently traced through Tertiary rocks that fill the Mississippi embayment (Luzietti et al.,

		1992). Very high-resolution reflection data confirm that late Quaternary deposits are faulted, and a deformed reflector as shallow as 6 or 7 m (20 or 23 ft.) could be resolved with these data (Williams et al., 1995). Lack of nearby stratigraphic control precluded determining if this reflector represented Holocene strata. An exploratory trench coincident with the very high-resolution reflection profile failed to find any unequivocal evidence of Holocene movement on the fault zone (Crone et al., 1995).
Crone et al. (1995)	Paleoseismic Studies of the Bootheel Lineament, Southeastern Missouri, and the Crittenden County Fault Zone, Northeastern Arkansas, New Madrid Seismic Zone, Central United States	Presents results of trenching studies across structures previously identified from interpretation of high-resolution seismic-reflection data: (1) Bootheel lineament and (2) Crittenden County fault zone (CCFZ). The absence of conclusive evidence of faulting associated with the Bootheel lineament was possibly due to young age of sediments (1,000–200 years old) and characteristics of surficial deposits that limit the likelihood of finding evidence of brittle failure (faulting). Liquefaction features in the trench were attributed to the 1811-1812 earthquakes: the site had not been subjected to comparable ground motion for over 1,500 years. Data from the CCFZ trench do not provide absolute evidence for the origin of a monoclinal warp in an unconformity exposed in trench excavations; relief on the unconformity could relate to a paleochannel, or alternatively, could be related to deformation observed in the underlying deeper sediments as imaged in seismic data.
Fischer-Boyd and Schumm (1995)	Geomorphic Evidence of Deformation in the Northern Part of the New Madrid Seismic Zone	Based on geomorphic evaluation, several locations of anomalous surface features within the NMSZ are identified. These include (1) anomalies in the slope, course, sinuosity, and dimensions of the Mississippi River related to the Lake County uplift; (2) anomalous channel behavior near Caruthersville, Missouri, and Barfield, Arkansas, suggestive of structural control; (3) angular course in the Black River suggestive of fracture control; (4) course changes of the Black, St. Francis, and Little rivers that may be tectonically controlled; and (5) topography along Crowley's Ridge that suggests it is composed of at least three structural blocks that are bounded by NE-trending faults. Some can be directly linked to mapped structures in the region, whereas others may result from previously unidentified areas of surface deformation.

Gomberg and Ellis (1994)	Topography and Tectonics of the Central New Madrid Seismic Zone: Results of Numerical Experiments Using a Three-Dimensional Boundary Element Program	Presents results of numerical experiments using seismicity and subtle topographic constraints. Surface displacement fields are calculated for the NMSZ under both far-field (plate tectonic scale) and locally derived driving strains. Results demonstrate that surface displacement fields cannot distinguish between either a far-field simple or pure shear strain field or one that involves a deep shear zone beneath the upper crustal faults. Thus neither geomorphic nor geodetic studies alone are expected to reveal the ultimate driving mechanism behind present-day deformation. Results of testing hypotheses about strain accommodation within the New Madrid contractional stepover by including linking faults, two SW-dipping and one vertical, show that only those models with stepover faults are able to predict the observed topography. These models suggest that the gently dipping central stepover fault is a reverse fault and that the steeper fault, extending to the SE of the stepover, acts as a normal fault over the long term.
Guccione (2005)	Late Pleistocene and Holocene Paleoseismology of an Intraplate Seismic Zone in a Large Alluvial Valley, the New Madrid Seismic Zone, Central USA	Summary paper that provides overview of paleoseismic investigations that have identified and characterized seven fault segments within the NMSZ. Three of the segments (Reefoot fault, New Madrid North fault, and Bootheel fault) have recognized surface deformation. The Reefoot fault is a compressive stepover along the strike-slip fault and has up to 11 m (36 ft.) of surface relief (Guccione et al., 2002). The New Madrid North apparently has only strike-slip motion and is recognized by modern microseismicity, geomorphic anomalies, and sand cataclasis (Baldwin et al., 2002). The Bootheel fault, which is not associated with present microseismicity, is associated with extensive liquefaction and offset channels (Guccione et al., 2005); it is dominantly strike-slip but also has a vertical component of slip. Other recognized surface deformation includes relatively low-relief folding at Big Lake/Manila high (Guccione et al., 2000) and Lake St. Francis/Marked Tree high (Guccione and Van Arsdale, 1995), both along the Blytheville arch.

Table D-6.1.5 Data Summary
Reelfoot Rift–New Madrid Seismic Zone (NMSZ) Region

Harris and Street (1997)	Seismic Investigation of Near-Surface Geological Structure in the Paducah, Kentucky Area	In this study, P- and S-wave seismic-refraction and seismic-reflection data were used to characterize shallow geological conditions in Paducah, Kentucky, area for use in earthquake hazard studies. Structure maps of a shallow unconformity and the Paleozoic bedrock surface show subsurface structural variability throughout the area. Ranges of shear-wave velocity for the sediments and bedrock, as well as estimates of the shear-wave velocity contrast at the unconformity and the bedrock, have been determined for the area. These two surfaces are important variables in site response analysis to evaluate ground motion amplification in the Paducah area.
Harrison and Schultz (1994)	Strike-Slip Faulting at Thebes Gap, Missouri and Illinois: Implications for New Madrid Tectonism	Documents evidence for Quaternary faulting in trenches in the Benton Hills of SE Missouri. Shows 12 earthquakes near the proposed trace of the Commerce geophysical lineament (CGL) and suggests that these earthquakes can be related to movement along structures associated with CGL.
Harrison and Schultz (2002)	Tectonic Framework of the Southwestern Margin of the Illinois Basin and Its Influence on Neotectonism and Seismicity	Describes neotectonism along the Commerce geophysical lineament (CGL). The CGL is interpreted to consist of en echelon faults and intrusions in basement related to the Neoproterozoic to early Paleozoic Reelfoot rift, but may have older ancestry. Faults in Thebes Gap and English Hills overlie the CGL; the faults cut Paleozoic, Mesozoic, and Cenozoic deposits and have had a long-lived and episodic tectonic history, including Pleistocene and Holocene activity. In the past 25 years, several dozen m_b 2–4 earthquakes have occurred along or near CGL.
Harrison et al. (1999)	An Example of Neotectonism in a Continental Interior:Thebes Gap, Midcontinent, United States	Documents evidence for four episodes of Quaternary faulting: one in late to post-Sangamon, pre- to early Roxana time (~60–50 ka), one in syn- or post Roxana, pre-Peoria time (~35–25 ka), and two in Holocene time (middle to late Holocene and possibly during 1811-1812 earthquake sequence). The overall style of neotectonic deformation is interpreted as right-lateral strike-slip faulting.
Harrison et al. (2002)	Geologic Map of the Scott City 7.5-Minute Quadrangle, Scott and Cape Girardeau Counties, Missouri	Provides description of geomorphology and surficial geology, general structural geology, and results of trenching investigations at localities within the English Hills. At least two events may have occurred in the latest Holocene (just after 2σ calibrated calendar ages of 3747 to 3369 BC and AD 968 to 639).

Table D-6.1.5 Data Summary
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Johnston and Schweig (1996)	The Enigma of the New Madrid Earthquakes of 1811-1812	Associated each of three 1811-1812 earthquakes with a specific fault by using historical accounts and geologic evidence: • Event D1—BA/CDF or BL • Event J1—East Prairie fault • Event F1—RF
Luzietti et al. (1992)	Shallow Deformation Along the Crittenden County Fault Zone near the Southeastern Boundary of the Reelfoot Rift, Northeast Arkansas	Interpretation of nine Mini-Sosie seismic-reflection profiles (sedimentary strata imaged to a depth of 800 m [2,625 ft.]). Estimates of structural relief across the Crittenden County fault zone (CCFZ) at the Paleocene level range between 14 and 70 m (46 and 230 ft.). Overlying Middle-to-Late Eocene section shows a similar or slightly smaller amount of thinning, indicating that much of the movement on the CCFZ dates from Middle to Late Eocene. Displacement, flexure, and thinning in the geologic section increases as CCFZ converges with Reelfoot rift boundary (SW). Reflections from the Quaternary-Eocene unconformity show warping, dip, or interruptions in places over the CCFZ that suggest at least 16 km (10 mi.) of near-surface deformation; this deformation may represent possible Quaternary or Holocene movement.
B. Magnani (pers. comm. May 29, 2009)	[Preliminary map showing locations of interpreted faults]	Presents map showing preliminary interpretation of near-surface faults observed in high-resolution seismic-reflection profile along the Mississippi River from Caruthersville, Missouri, to Helena, Missouri. Results of the survey suggest that the eastern Reelfoot margin fault may extend south from Memphis along the river (east of the boundary of the Reelfoot rift).
Magnani et al. (2009)	Long-Term Deformation History in the Mississippi Embayment: The Mississippi River Seismic Survey	Seismic survey collected a 300 km (186 mi.) long high-resolution seismic-reflection profile along the Mississippi River from Helena, Arkansas, to Caruthersville, Missouri. Identified three zones of deformation and faulting involving quaternary sediments. Two areas lie outside the NMSZ, suggesting that the long-term seismic activity in this area might extend over a broader region than previously suspected.

McBride et al. (2003)	Variable Post-Paleozoic Deformation Detected by Seismic Reflection Profiling Across the Northwestern Prong of New Madrid Seismic Zone	High-resolution shallow seismic-reflection profiles in the vicinity of the Olmstead fault (which is close to and parallel with the straight segment of the Ohio River) on trend with the westernmost of two groups of NE-aligned prongs of epicenters) show Tertiary reactivations of complex Cretaceous deformations (including normal graben faults). A possible fault-propagation fold associated with one of these faults appears to affect Holocene sediments near the ground surface.
McBride, Nelson, and Stephenson (2002)	Integrated Geological and Geophysical Study of Neogene and Quaternary-Age Deformation in the Northern Mississippi Embayment	Presents results of program of shallow drilling, trenching, outcrop mapping, and seismic-reflection acquisition in southern Illinois just north of NMSZ. Detailed structural cross sections over five NE-trending faults that continue from the Fluorspar Area fault complex (FAFC) southward into the embayment indicate narrow grabens into which latest Cretaceous, Paleocene, and Eocene sediments were dropped and protected from erosion. Bounding faults were active during Neogene through middle Pleistocene time. Definitive faulting of Wisconsinan loess or Holocene alluvium is not observed at any site, which would indicate that the faults have been inactive for at least 55 ka (basal loess ages) to 128 ka (youngest Illinoian age). Seismic profiles indicate that faults in Quaternary sediment penetrate Paleozoic bedrock, and thus are tectonic. Faults exhibit vertical to steeply dipping normal and occasional reverse displacements that outline a variety of structures, including a series of narrow grabens and local folding. Proposes a dynamic structural model that suggests a mechanism by which seismicity and active (Holocene) faulting have shifted within the central Mississippi Valley (away from the FAFC) over the last several ten thousand years.
Mihills and Van Arsdale (1999)	Late Wisconsin to Holocene Deformation in the New Madrid Seismic Zone	Interprets a structure-contour map of the unconformity between the Eocene strata and overlying Quaternary Mississippi River alluvium as representing the late-Wisconsinan-to-present strain field of the NMSZ. Areas of Holocene uplift include the Lake County uplift, Blytheville arch, and Crittenden fault. Areas of Holocene subsidence include Reelfoot Lake, historical Lake Obion, the Sunklands of NE Arkansas, and possibly areas east and west of the Crittenden County fault.

Table D-6.1.5 Data Summary
Reelfoot Rift–New Madrid Seismic Zone (NMSZ) Region

Mueller and Pujol (2001)	Three-Dimensional Geometry of the Reelfoot Blind Thrust: Implications for Moment Release and Earthquake Magnitude in the New Madrid Seismic Zone	According to seismicity data and structural analysis, the Reelfoot blind thrust is a complex fault that changes in geometry along-strike. The thrust is bounded to the north by an east-trending strike-slip fault. The southern end is defined by seismicity; it is not truncated by a known transverse fault. The northern part of the thrust steepens to 75°–80° at shallow depths (within upper 4 km, or 2.5 mi.), forming a listric shape. The center of the central part of the thrust strikes N-S and dips between 31° and 35° west; the north and south segments strike between N10°W and N22°W, respectively. The SE fault segment is oriented N28°W and dips 48°–51° SW. Available data suggest that the thrust flattens to <35° between about 2 and 4 km (1.2 and 2.5 mi.) depth (possibly at the Precambrian basement/Paleozoic cover contact at about 3 km, or 1.9 mi., depth).
Mueller et al. (1999)	Fault Slip Rates in the Modern New Madrid Seismic Zone	Estimates slip rate of 6.1 ± 0.7 mm/year for the past 2,300 ± 100 years, based on structural and geomorphic analysis of late Holocene sediments deformed by fault-related folding above the blind Reelfoot thrust fault. Calculates slip rate of 4.8 ± 0.2 mm/year using an alternative method based on the structural relief across the scarp and the estimated dip of the underlying blind thrust. Geometric relations suggest that right-lateral slip rate on the NMSZ is 1.8–2.0 mm/year. The onset of shortening across the Lake County uplift is estimated to be between 9.3 and 16.4 ka, with a preference for the younger age.
Nelson et al. (1997)	Tertiary and Quaternary Tectonic Faulting in Southernmost Illinois	Interprets the Fluorspar Area fault complex (FAFC) as a series of strike-slip pull-apart grabens bounded by N20°E–N40°Estriking normal and reverse faults. The faults probably originated as normal faults during an episode of crustal rifting of latest Proterozoic to early Cambrian time that formed the Reelfoot rift (locally, the Lusk Creek fault zone). Evidence exists for episodic reactivation of these faults in post-Pennsylvanian, pre-Cretaceous, and again in late Neogene to Quaternary time. Results of shallow drilling, trenching, outcrop mapping, and seismic-reflection acquisition in southern Illinois just north of New Madrid zone show evidence for Quaternary-age faulting on larger mapped faults in the FAFC in southernmost Illinois. NE-trending faults downdrop Mounds Gravel of Late Miocene to early Pleistocene age (1 Ma to 11 ka) approximately 150 m (490 ft.) in the deepest graben and locally displace

		Metropolis terrace gravel believed to be Illinoian (~185–128 ka) or older. FAFC faults are oriented for reactivation as strike-slip or oblique-slip faults in current stress field: apparent extensional component of slip not a good match for the nearly E-W maximum horizontal stress direction.
Nelson et al. (1999)	Quaternary Grabens in Southernmost Illinois: Deformation near an Active Intraplate Seismic Zone	Grabens are part of the Fluorspar Area fault complex (FAFC), which has been recurrently active throughout Phanerozoic time. The FAFC strikes directly toward the NMSZ, and both the NMSZ and FAFC share origin in a failed Cambrian rift (Reelfoot rift). Every major fault zone of the FAFC in Illinois exhibits Quaternary displacement. The structures appear to be strike-slip pull-apart grabens, but magnitude and direction of horizontal slip and their relationship to the current stress field are unknown. Upper Tertiary strata are vertically displaced more than 100 m (328 ft.); Illinoian and older Pleistocene strata 10–30 m (33–98 ft.); and Wisconsinan deposits 1 m (3.3 ft.) or less. No Holocene deformation has been observed. Average vertical slip rates are estimated at 0.01–0.03 mm/year, and recurrence intervals for earthquakes of M 6–7 are on the order of tens of thousands of years for any given fault.
Odum et al. (1998)	Near-Surface Structural Model for Deformation Associated with the February 7, 1812, New Madrid, Missouri, Earthquake	Integrates geomorphic data and documentation of differential surficial deformation (supplemented by historical accounts) with interpretation of seismic-reflection data to develop a tectonic model of near-surface structures in New Madrid area. Model consists of two primary components: a N-NW-trending thrust fault (Reelfoot fault) and a series of NE-trending strike-slip tear faults. The authors estimate an overall length of at least 30 km (18.6 mi.) and a dip of ~31° for the Reelfoot fault.
Odum et al. (2001)	High-Resolution Seismic-Reflection Imaging of Shallow Deformation Beneath the Northeast Margin of the Manila High at Big Lake, Arkansas	The authors interpret 7 km (4.3 mi.) of high-resolution seismic-reflection data across NE margin of the Manila high to examine its near-surface bedrock structure and possible association with underlying structures such as the Blytheville arch. The Manila high is an elliptical area 19 km (11.8 mi.) long (N-S) by 6 km (3.7 mi.) wide (E-W) located W-SW of Big Lake, Arkansas, that has less than 3 m (10 ft.) of relief. Sense of displacement and character of imaged faults support interpretations for either a NW-trending 1.5 km (0.9 mi.) wide block of uplifted strata or a series of parallel NE-trending faults that bound horst and graben structures. The favored interpretation is that deformation of the Manila high resulted from faulting generated by reactivation of right-lateral strike-slip fault motion along this portion of the Blytheville arch.

Table D-6.1.5 Data Summary
Reelfoot Rift–New Madrid Seismic Zone (NMSZ) Region

Odum et al. (2002)	Near-Surface Faulting and Deformation Overlying the Commerce Geophysical Lineament in Southern Illinois	Seismic-reflection and microgravity data demonstrate post-Devonian displacement associated with the Commerce geophysical lineament in the Tamms area of southern Illinois. Several faults are imaged to the Paleozoic/Quaternary interface, and at one site, deformed Quaternary strata may have been faulted 5–10 m (16.4–32.8 ft.).
Odum et al. (2010)	Multi-Source, High-Resolution Seismic-Reflection Imaging of Meeman-Shelby Fault and Possible Tectonic Model for a Joiner Ridge–Manila High Structure in the Upper Mississippi Embayment Region	Reinterpretation of the Meeman-Shelby fault (MSF) based on high-resolution seismic-reflection profiles, combined with existing industry data and recent structural interpretations. MSF fault trace above the Paleozoic surface is constrained to having an up-to-the-west reverse displacement along a near-vertical (80°) plane that projects to the surface just east of the profiles. Using seismic-reflection data that were both reinterpreted and newly acquired, the authors interpret an orientation of approximately N13°W for the MSF and provide evidence to support an interpretation that the MSF forms the eastern boundary of Joiner Ridge tectonic structure. The authors suggest that Joiner Ridge and Manila high surfical uplift may collectively be considered as segments of a tectonic structure similar to the Reelfoot fault stepover. They concur with Csontos et al. (2008) that Joiner Ridge is a right-lateral compressional stepover between the Eastern Reelfoot Rift margin and the axial fault zone that formed in response to Quaternary N60°E maximum horizontal compressive stress field. Scientific knowledge is not sufficient to speculate about seismic hazard significance of the 50 km (31 mi.) long Joiner Ridge–MSF structure.
Palmer, Hoffman, et al. (1997)	Shallow Seismic Reflection Profiles and Geological Structure in the Benton Hills, Southeast Missouri	Two shallow, high-resolution seismic-reflection surveys (Mini-Sosie method) across southern escarpment of the Benton Hills segment of Crowley's Ridge imaged numerous post-Late Cretaceous faults and folds. The survey did not resolve reflectors within upper 75–100 m (246–328 ft.) of two-way travel time (about 60–100 m, or 197–328 ft.), which would include all of Tertiary and Quaternary and most of Cretaceous. The Paleozoic-Cretaceous unconformity produced an excellent reflection, and locally a shallower reflector within the Cretaceous was resolved. The English Hill fault zone, striking N30°E–N35°E, imaged in one of the seismic lines, has been observed by previous workers to have Pleistocene loess faulted against Eocene sands. The Commerce fault zone, striking N50°E, overlies a major regional basement geophysical lineament and is present on both seismic lines at southern margin of escarpment.

Table D-6.1.5 Data Summary
Reelfoot Rift–New Madrid Seismic Zone (NMSZ) Region

Palmer, Shoemaker, et al. (1997)	Seismic Evidence of Quaternary Faulting in the Benton Hills Area, Southeast Missouri	Seismic profiles show English Hill area to be tectonic in origin. Individual faults have near-vertical displacements with maximum offsets on the order of 15.2 m (50 ft.). Faults are interpreted as flower structures with N-NE-striking, vertically dipping, right-lateral oblique-slip faults. These data suggest that previously mapped faults at English Hill are deep-seated and tectonic in origin.
Parrish and Van Arsdale (2004)	Faulting Along the Southeastern Margin of the Reelfoot Rift in Northwestern Tennessee Revealed in Deep Seismic-Reflection Profiles	Deep seismic-reflection profiles in NW Tennessee reveal structure of SE margin of Reelfoot rift. Rift margin consists of at least two major down-to-the-west late Precambrian to Cambrian normal faults. Dominantly reverse faulting, folding, and positive flower structures in the shallow section indicate Eocene and younger transpression. Numerous faults displace the youngest reflectors, and therefore the age of most recent faulting is not known. SE rift margin is subject to right-lateral movement and transpression within current stress field.
Pujol et al. (1997)	Refinement of Thrust Faulting Models for the Central New Madrid Seismic Zone	Seismicity cross sections define the downdip geometry of the Reelfoot thrust.
Purser and Van Arsdale (1998)	Structure of the Lake County Uplift: New Madrid Seismic Zone	Lake County uplift, which includes the Tiptonville dome and Ridgely Ridge, is interpreted to be a consequence of deformation in the hanging wall above the NW-striking, SW-dipping Reelfoot reverse fault. The Reelfoot fault dips 73° from the surface to the top of the Precambrian at a depth of approximately 4 km (2.5 mi.). From 4 to 12 km (2.5 to 7.5 mi.) depth, the fault dips 32° and is seismically active. Based on a fault-bend fold model, the Reelfoot fault becomes horizontal and aseismic at the top of the quartz brittle-ductile transition zone, at approximately 12 km (7.5 mi.) depth. Western margin of the Tiptonville dome–Ridgely Ridge and western margin of the Lake County uplift are bounded by east-dipping kink bands (backthrusts). The Reelfoot fault, which is postulated to be the source of the February 7, 1812, **M** 8 earthquake, has less surface area than is necessary for an **M** 8 earthquake. A possible solution to this discrepancy between magnitude and fault plane area is that the associated backthrusts are seismogenic.

Russ (1979)	Late Holocene Faulting and Earthquake Recurrence in the Reelfoot Lake Area, Northwestern Tennessee	Discusses results of trenching investigations across Reelfoot scarp in NW Tennessee. In excess of 3 m (10 ft.) of vertical displacement believed to be of deep-seated origin occurs across a 0.5 m wide zone of east-dipping normal faults near scarp base. Stratigraphic and geomorphic relationships suggest that little (<0.5 m) or no near-surface fault movement occurred across the zone during 1811-1812 earthquake sequence. Faults, folds, and sand dikes were identified in the trench. Crosscutting geologic features and local geomorphic history suggest that at least two periods of faulting predate sediments deposited before AD 1800. A recurrence interval of approximately 600 years or less is suggested for large earthquakes in the New Madrid area.
Russ (1982)	Style and Significance of Surface Deformation in the Vicinity of New Madrid, Missouri	Lake County uplift is an elongate, composite Quaternary structure associated with faults and modern seismicity. It is subdivided into Tiptonville dome, Ridgely Ridge, and the south end of Sikeston Ridge. The Tiptonville dome is an asymmetrical monocline; the steep eastern flank is bounded by Reelfoot scarp, a complex monoclinal fold that has a zone of normal faults (displacement about 3 m, or 10 ft.) at its base. The zone of faults overlies, and is probably continuous, with Reelfoot fault, a high-angle dip-slip fault that offsets Paleozoic, Mesozoic, and Tertiary rocks. Surface uplift accounts for about 1/5 of the displacement. Most of Tiptonville dome formed between 200 and 2,000 years ago. Ridgely Ridge is a NE-trending symmetrical buldge underlain by a similarly oriented zone of faults. Much of the ridge appears older than Tiptonville dome, but younger than 6,000 yr BP. The southern end of Sikeston Ridge and adjoining areas has undergone broad shallow warping. Deformation probably occurred in late Wisconsinan or early Holocene time. The New Madrid region has been shaken by at least three earthquakes of $m_b \geq 6.2$ in the past 2,000 years.

SAIC (2002)	Seismic Investigation Report for Siting a Potential On-Site CERCLA Waste Disposal Facility at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky	Conclusions from this study are as follows: • Field observations made along Ohio River in the vicinity of the Paducah Gaseous Diffusion Plant (PGDP) found no large liquefaction features. • The absence of large paleoliquefaction features within 24 km (15 mi.) of PGDP suggests that local strong ground motion has not occurred within the past few thousand years • The literature does report some small liquefaction features located along the banks of the Ohio River, about 13 km (8 mi.) NE of PGDP, and along the Post Creek Cutoff, about 19 km (12 mi.) NW of PGDP. • The site-specific fault study identified a series of faults beneath Site 3A. For most of the faults beneath Site 3A, relative movement along main fault plane is normal, with the downthrown side to the east. These normal faults, along with their associated splays, either form a series of narrow horst and graben features or divide local sediments into a series of rotated blocks. Several of the faults extend through Porters Creek Clay and into materials underlying the surficial loess of latest Pleistocene age (radiocarbon dated at 13,500–15,600 yr BP). Three of these faults extend to within 6 m (20 ft.) of ground surface. This study did not find Holocene displacement of faults at Site 3A. At the Barnes Creek site located 18 km (11 mi.) NE of PGDP, this study found the following: • The relative timing of observed deformations in the geologic structures varies. • Radiocarbon ages confirm that repeated deformation has occurred along some of the observed faults. Deformation began prior to deposition of the lower Metropolis (late Pleistocene), continued during deposition of the upper Metropolis (5,000–7,000 years old) and most recently occurred in the middle Holocene, after deposition of the upper Metropolis (within the last 5,000 years). Therefore, faults observed at Barnes Creek site did extend into Holocene-age deposits. • The maximum displacement observed in a single event is approximately 0.3 m (1 ft.) in the lower Metropolis. • Investigation of the terrace graben area concluded that observed stratigraphy is consistent with a combination of two models: (1) a

		graben with up to 15 m (50 ft.) of displacement within the past 12,000 years, and (2) an erosional feature with up to 15 m (50 ft.) of infilling within the past 12,000 years. Radiocarbon ages in the terrace graben area at the Barnes Creek site indicate that deep fine-grained sediments beneath the Metropolis are approximately 11,000 years old, suggesting that overlying Metropolis dates from late Pleistocene or early Holocene.
Schumm and Spitz (1996)	Geological Influences on the Lower Mississippi River and Its Alluvial Valley:	Identifies different reaches of the Mississippi River based on studies of photographs, maps, and channel morphology. The river is not monotonous in appearance, and therefore, it is not completely controlled by hydrology and hydraulics. Results of the study suggest that the Mississippi River has reacted to uplift, faults, clay plugs, outcrops of Tertiary clay, and Pleistocene gravel in its bed and tributaries.
Schweig and Ellis (1992)	Distributed Faulting Along the Bootheel Lineament—Smoothing Over the Rough Spots in the New Madrid Seismic Zone	Shallow seismic-reflection work in the area of the Bootheel lineament shows that the lineament is underlain by a complex zone of deformation consisting of multiple flower structures and fractured rock that show up to 25 m (82 ft.) of vertical relief. Flower structures and lineament occur over a zone at least 5 km (3 mi.) wide. Their discontinuous nature strongly resemble physical models in which flower structures form in less rigid material in response to low finite displacement across a discrete strike-slip shear zone in a rigid basement. The Bootheel lineament links two well-established, seismically active strike-slip zones in the New Madrid region and may be acting to smooth the trace of the NMSZ as displacement increases.
Schweig and Ellis (1994)	Reconciling Short Recurrence Intervals with Minor Deformation in the New Madrid Seismic Zone	Comparison of present-day strain rates to long-term geologic offsets suggests that the NMSZ is a young feature, possibly as young as several tens of thousands of years and no older than a few million years.
Schweig and Marple (1991)	A Possible Coseismic Fault of the Great New Madrid Earthquakes	Identifies the Bootheel lineament from a remote sensing examination of the NMSZ. The lineament may be the surface expression of one of the coseismic faults of the 1811-1812 New Madrid earthquakes. It extends for about 135 km (84 mi.) in a N-NE direction. Morphology suggests that it is a strike-slip fault. The lineament does not coincide with any of the major arms of seismicity. A possible inference is that the arms of seismicity do not precisely reflect the faults that ruptured in 1811-1812.

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Schweig and Van Arsdale (1996)	Neotectonics of the Upper Mississippi Embayment	Summarizes geologic and geophysical evidence of neotectonic activity, including faulting in Benton Hills and Thebes Gap, paleoliquefaction in Western Lowlands, subsurface faulting beneath and tilting of Crowley's Ridge, subsurface faulting along the CCFZ, and numerous indicators of historical and prehistoric large earthquakes in NMSZ.
Schweig et al. (1992)	Shallow Seismic Reflection Survey of the Bootheel Lineament Area, Southeastern Missouri	The pattern and character of geomorphic features associated with the Bootheel lineament traces are very similar in geometry to a right-lateral strike-slip fault. Seismic-reflection profiles are interpreted to show a complex zone of deformation consisting of multiple flower structures and fractured rock, with deformation at least as young as the base of the Quaternary.
Sexton and Jones (1986)	Evidence for Recurrent Faulting in the New Madrid Seismic Zone from Mini-Sosie High-Resolution Reflection Data	Interpretation and integration of three seismic-reflection data sets provides evidence for recurrent movement along the Reelfoot fault, the major reverse fault associated with the Reelfoot scarp. Estimated displacements vary from 61 m (200 ft.) for late Paleozoic rocks to 15 m (50 ft.) for Late Eocene sedimentary units. A graben structure is interpreted to be caused by tensional stresses resulting from uplift and folding of the sediments. The location of the graben coincides with normal faults in Holocene sediments observed in trenches. These features are interpreted to be related and caused by reactivation of the Reelfoot fault.
Spitz and Schumm (1997)	Tectonic Geomorphology of the Mississippi Valley Between Osceola, Arkansas, and Friars Point, Mississippi	A geomorphic study of the Mississippi River and its alluvial valley identified anomalous surface features indicative of relatively recent deformation that can be linked to the following known geological structures: Big Creek fault zone, White River fault zone, Bolivar-Mansfield tectonic zone, Blytheville arch, Crittenden County fault zone, and Reelfoot Rift margins. Faults and plutons appear to affect drainage networks, and the morphology of Crowleys Ridge suggests significant fault control. The authors conclude that (1) many anomalies probably reflect a fractured sub-alluvial surface, and (2) although movement along these fractures will most likely occur in seismically active areas, the probability of movement elsewhere is high.

Stephenson et al. (1995)	Characterization of the Cottonwood Grove and Ridgely Faults near Reelfoot Lake, Tennessee, from High-Resolution Seismic Reflection Data	High-resolution seismic-reflection data delineate Cottonwood Grove and Ridgely faults, as well as a new, potentially major fault with approximately 40 m (131 ft.) of apparent vertical displacement east of Ridgely fault. The new fault trends NW—opposite in trend direction to the Cottonwood Grove and Ridgely faults—and dips vertically. The NE-trending Cottonwood Grove fault has as much as 30 m (98.5 ft.) of apparent vertical displacement of all imaged strata, from the Cretaceous/Paleozoic boundary to the Middle Eocene horizon; this suggests faulting began post-Middle Eocene. The NE-trending Ridgely fault appears to be a zone of faults bounding a horst-like feature; apparent vertical displacements across easternmost strand suggest recurrent displacement, with roughly 22–26 m (72.2–85.3 ft.) of apparent offset on Cretaceous/Paleozoic boundary and 18–22 m (59–72.2 ft.) of apparent offset on Middle Eocene deposits. The Quaternary/Eocene boundary was not sufficiently imaged to determine whether faulting has occurred later than post-Middle Eocene.
Stephenson et al. (1999)	Deformation and Quaternary Faulting in Southeast Missouri Across the Commerce Geophysical Lineament	High-resolution seismic-reflection data at three sites along the Commerce geophysical lineament (CGL) reveal post-Cretaceous faulting extending into Quaternary. At Qulin site, ~20 m (65.5 ft.) of apparent Quaternary vertical displacement is observed. At Idalia Hill, a series of reverse and possibly right-lateral strike-slip faults with Quaternary displacement are imaged. At Benton Hills, a complicated series of anticlinal and synclinal fault-bounded blocks occur directly north of CGL.
Van Arsdale (2000)	Displacement History and Slip Rate on the Reelfoot Fault of the New Madrid Seismic Zone	Develops a displacement history and slip rates for the Reelfoot fault in the NMSZ from a seismic-reflection profile and trench data. Average slip rate estimates—seismic profile: • 0.0009 mm/year (past 80 Ma) • 0.0007 mm/year (late Cretaceous) • 0.002 mm/year (Paleocene Midway Group) • 0.001 mm/year (Paleocene-Eocene Wilcox Form) • 0.0003 mm/year (post-Wilcox/pre-Holocene) • 1.8 mm/year (Holocene)

		Average slip rate estimates—trench data: • 4.4 mm/year (past 2,400 years based on 10 m [33 ft.] of topographic relief and a fault dip of 73°) • 6.2 mm/year (maximum; estimated 5.4 m [17.7 ft.] cumulative displacement for two events between AD 900 and 1812).
Van Arsdale et al. (1999)	Southeastern Extension of the Reelfoot Fault	This evaluation of microseismicity, seismic-reflection profile data, and geomorphic anomalies indicates that prehistoric and 1811-1812 coseismic uplift in the hanging wall of the Reelfoot fault has produced subtle surface warping that extends from Reelfoot Lake to Dyersburg, a total distance of 70 km (43.5 mi.).
Van Arsdale et al. (2002)	Investigation of Faulting Beneath the City of Memphis and Shelby County, Tennessee	Two N-NE-trending faults marked by 20 m (66 ft.) steps, referred to as the Memphis and Ellendale faults, are identified from structure-contour maps on Plio-Pleistocene to Eocene datums. Quaternary activity on both faults is indicated from analysis of the structure-contour maps and from topographic, drainage, and paleodrainage analyses. An anticlinal fold in floodplain sands is observed along the Ellendale fault. Radiocarbon dates indicate that folding occurred between AD 390 and 450 and liquefaction observed in the crest of the anticline occurred after AD 450. Modeling of the fold, which appears to be tectonic, is consistent with 5 m of right-lateral offset.
Velasco et al. (2005)	Quaternary Faulting Beneath Memphis, Tennessee	Structure-contour maps and cross sections of the top of the Pliocene-Pleistocene Upland Complex (Lafayette gravel), Eocene Upper Claiborne Group, and Eocene Lower Claiborne Group reveal two 20 m (66 ft.) down-to-the-NW faults that strike approximately N30°E. Western fault is called the Memphis fault, and eastern fault is the Ellendale fault. Anticlinal folding and liquefaction features are observed coincident with the Ellendale fault. Radiocarbon dates indicated that folding occurred between AD 390 and 450, and that liquefaction occurred after AD 450. Seismic-reflection lines indicate that the fold extends to more than 60 m (197 ft.) depth in the Lower Claiborne Group, has a length of more than 1 km (0.6 mi.), and is therefore judged to be tectonic. It is postulated that the anticline formed during ~5 m (16.5 ft.) of Quaternary right-lateral strike-slip movement on the N25°E-trending fault.

William Lettis & Associates (2006)	Investigation of Holocene Faulting at Proposed C-746-Landfill Expansion	Unpublished report presents findings of a fault hazard investigation for C-746-U landfill's proposed expansion at the Department of Energy's Paducah Gaseous Diffusion Plant (PGDP), in Paducah, Kentucky, within the Fluorspar Area fault complex. The geologic assessment was based on (1) review of relevant geologic and geotechnical data from the site vicinity, (2) analysis of aerial photography, (3) field reconnaissance, (4) collection and stratigraphic analysis of 86 subsurface sediment cores, and (5) laboratory chronological (dating) analyses. Geologic cross sections prepared from the direct-push technology core data identified laterally continuous horizontal strata for assessing possibility of fault displacement, and for evaluating timing of such displacements. Deposits encountered in the cores range in age from about 16 ka to greater than 125 ka. Upper three units (15.4–50.7 ka) generally are flat-lying and they mantle preexisting topography. The lower, older units (53.6–75.5 and ≥125–180 ka) exhibit occasional subtle to abrupt undulations of basal contacts, which may reflect fluvial processes and/or tectonic-related deformation. If late Quaternary displacement has occurred beneath the site, the most-recent displacement occurred following deposition of the Unnamed Intermediate Silt between 53.6 and 75.5 ka. Although unlikely, the data do not preclude possibility of displacement of the Roxana Silt beneath the site, which is approximately 34.6–47.2 ka. There is no perceptible displacement of the base of the Upper Peoria Loess, which is approximately 16.6–23.5 ka. If late Pleistocene faulting occurred at the site, age of such deformation would be similar to youngest age of faulting previously interpreted along NE-striking faults in southern Illinois. As part of this study, reconnaissance-level review of exposures where SAIC (2004) reported evidence for Holocene faulting was reviewed with John Nelson. Based on (1) an apparent absence of faulting observed in upper, younger deposits (i.e., presence of only a fracture); (2) uncertain origin of observed fractures (e.g., possibly related to roots); and (3) absence of distinct stratigraphic offset of Holocene deposits, it was concluded that while relatively young geologic deformation is present, the interpretation of Holocene faulting is equivocal.

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Williams et al. (1995)	High-Resolution Seismic Imaging of Quaternary Faulting in the Crittenden County Fault Zone, New Madrid Seismic Zone, Northeastern Arkansas	Interpretation of three very high-resolution compressional-wave seismic-reflection profiles across surface projections of faults observed on coincident Mini-Sosie and Vibroseis seismic-reflection profiles. Deformation at and above the Quaternary-Eocene unconformity suggests that Crittenden County fault zone (CCFZ) has been active during the latest Quaternary and may be a possible source of earthquakes. Some evidence supports recurrent events in the Quaternary. There is a lack of clear connection between the faults observed in high-resolution data and the deeper faults imaged in other seismic data. Cites preliminary results of trenching that did not show evidence for faulting in a 2.5–3 m (8.2–9.8 ft.) deep trench excavated across the 7 m (23 ft.) deep fault as imaged in the seismic data. Possible explanation for this is that the shallow, rootless faults are bending-moment faults that relate to monoclinal bulge associated with the CCFZ. Evidence is cited for preference for tectonically driven deformation on the CCFZ. Some aspects of the fault observations fit a strike-slip faulting regime.
Williams et al. (2001)	Seismic-Reflection Imaging of Tertiary Faulting and Post-Eocene Deformation 20 km North of Memphis, Tennessee	Interprets a 4.5 km (2.8 mi.) long Mini-Sosie seismic-reflection profile across eastern bluff along Mississippi River in the Meeman-Shelby Forest State Park north of Memphis. Identifies the Meeman-Shelby fault (MSF), a high-angle (75°) reverse fault that displaces Paleozoic and Cretaceous rocks and upwarps Tertiary deposits. Paleozoic and Cretaceous rocks are vertically faulted about 70 and 40 m (230 and 131 ft.), respectively, in an up-to-west sense of displacement. Overlying Paleocene and Eocene deposits, which are probably the youngest deposits imaged, are upwarped about 50–60 m (164–197 ft.) with the same sense of displacement. Sense of displacement, amplitude, and appearance of the fault in seismic data are very similar to the Crittenden County fault zone (CCFZ), 15 km (9 mi.) west of this profile. Projecting a fault trend of N33°E (same general trend as the CCFZ), a similar fault is observed in a seismic profile 33 km (20.5 mi.) NE of MSF fault pick.

Woolery and Street (2002)	Quaternary Fault Reactivation in the Fluorspar Area Fault Complex of Western Kentucky—Evidence from Shallow SH-Wave Reflection Profiles	Interpreted shallow shear-wave seismic-reflection profiles collected over SW projection of the Fluorspar Area fault complex in the northern Jackson Purchase Region of western Kentucky image clear evidence of fault and apparent fold propagation into the near-surface Quaternary units (less than 10 m [32.8 ft.] below ground surface). Profiles show evidence of various structural styles associated with episodic movement. The exact timing of the latest tectonic episode exhibited on the profiles is not known because of the lack of more accurate stratigraphic detail coincident with the lines. Instrumentally recorded seismic events are located in the immediate vicinity of study area.
Woolery et al. (2009)	Site-Specific Fault Rupture Hazard Assessment—Fluorspar Area Fault Complex, Western Kentucky	Assesses location and recency of faulting at one location along southerly projection of the Fluorspar Area fault complex. Evidence for stratigraphic anomalies associated with five high-angle geophysical anomalies (in a 1 km, or 0.6 mi., long seismic-reflection profile). A total of 86 closely spaced 9.1 m (30 ft.) deep continuous cores were collected above seismic profile anomalies. Interpretation of the resultant geologic cross sections identified stratigraphic anomalies. Stratigraphic anomalies were generally constrained to postdate a 53.6–75.5 ka loess deposit: no perceptible displacement was found at the base of younger loess dated between 16.6 and 23.5 ka.
Magnitude Estimates		
Atkinson and Hanks (1995)	A High-Frequency Magnitude Scale	Based on a high-frequency magnitude scale the 1812 New Madrid event is estimated to be M 7.7 ± 0.3.
Bakun and Hopper (2004b)	Magnitudes and Locations of the 1811-12 New Madrid, Missouri, and the 1886 Charleston, South Carolina, Earthquakes	Estimates **M** for the three largest events in the 1811-1812 New Madrid sequence. (M_I is intensity magnitude based on inverting observations of intensity.) • M_I 7.6 (**M** 6.8–7.9 at 95% confidence level) for December 16, 1811, event (NM1) that occurred in the NMSZ on the Bootheel lineament or on the Blytheville seismic zone. • M_I 7.5 (**M** 6.8–7.8 at 95% confidence level) for January 23, 1812, event (NM2) for a location on the New Madrid north zone of the NMSZ. • M_I 7.8 (**M** 7.0–8.1 at 95% confidence level) for February 7, 1812, event (NM3) that occurred on the Reelfoot blind thrust of the NMSZ.

Hough (2009)	The 1811-1812 New Madrid Sequence: Mainshocks, Aftershocks, and Beyond	Discusses uncertainties associated with intensity assignments, and development of a set of consensus intensities for the four principal New Madrid events, based on independent assignments of four researchers (with experience analyzing historical earthquakes). The consensus values from these assessments are generally lower than those assigned by Hough et al. (2000). Using the Bakun and Wentworth (1997) method with two published attenuation models for the CEUS, intensity magnitude estimates range from M_I 6.5 to 7.0 for the December main shock, “dawn aftershock,” and January main shock, and from M_I 7.3 to 7.6 for the February main shock. Magnitude estimates based on assignments by individual experts for the December 16, 1811, and February 7, 1812, main shocks vary over a range of 0.3 to 0.4 units. Using revised magnitudes, distribution is characterized by a *b*-value of 1 between roughly M 6 and 7.5. The modern instrumental catalog also reveals that, in low strain-rate regions, moment release will be strongly controlled by the tendency of seismicity to cluster, and an *a*-value inferred from a short instrumental record will tend to significantly underestimate the long-term rate of small events in the region.
Hough and Martin (2002)	Magnitude Estimates of Two Large Aftershocks of the 16 December 1811 New Madrid Earthquake	Estimates locations and magnitudes for two large aftershocks: • NM1-A: **M** ~ 7, thrust mechanism on a SE limb of the Reelfoot fault. • NM1-B: **M** 6.1 ± 0.2, location of event not well constrained, but probably beyond the southern end of the NMSZ, near Memphis, Tennessee (within the SW third to half of the band of seismicity identified by Chiu et al. [1997]).
Hough et al. (2000)	On the Modified Mercalli Intensities and Magnitudes of the 1811-1812 New Madrid, Central United States, Earthquakes	Reinterprets intensity data, obtaining maximum magnitude estimates from 7.0 to 7.5 for the main three events in the 1811-1812 earthquake sequence: • December 16, 1811: **M** 7.2–7.3 • January 23, 1812: **M** 7.0 • February 7, 1812: **M** 7.4–7.5 (thrust event)

Hough et al. (2005)	Wagon Loads of Sand Blows in White County, Illinois	Based on anecdotal accounts of possible liquefaction that occurred at several sites in southern Illinois during the 1811-1812 New Madrid sequence, the authors conclude that (1) either large NMSZ events triggered substantial liquefaction at distances greater than hitherto realized, or (2) at least one large "New Madrid" event occurred significantly north of the NMSZ. Neither can be ruled out, but the following lines of evidence suggest that January 23, 1812, main shock occurred in White County, Illinois, near the location of the 1968 m_b 5.5 southern Illinois earthquake and recent microearthquake activity. Descriptions report substantial liquefaction (sand blows) as well as a 3.2 km (2 mi.) long E-W-trending crack along which 0.6 m (2 ft.) of south-side-down displacement occurred. A modest offset in Paleozoic strata is observed in seismic-reflection survey data at this location. Additional field investigations are needed to further document extent and size of paleoliquefaction features and demonstrate the presence or absence of an E-W fault.
Johnston (1996b)	Seismic Moment Assessment of Earthquakes in Stable Continental Regions—III. New Madrid 1811-1812, Charleston 1886, and Lisbon 1755	Estimates magnitudes for the three largest events of the 1811-1812 earthquake sequence based on intensity data: • D1 (December 16, 1811): **M** 8.1 ± 0.3 • J1 (January 23, 1812): **M** 7.8 ± 0.3 • F1 (February 7, 1812): **M** 8.0 ± 0.3
Johnston and Schweig (1996)	The Enigma of the New Madrid Earthquakes of 1811-1812	This review paper focuses on the 1811-1812 earthquakes, their geophysical setting, fault rupture scenarios, and magnitude estimates based on intensity data. Using historical accounts and geologic evidence, the authors associate the three main 1811-1812 earthquakes with specific structures.
Mueller and Pujol (2001)	Three-Dimensional Geometry of the Reelfoot Blind Thrust: Implications for Moment Release and Earthquake Magnitude in the New Madrid Seismic Zone	The area of the blind thrust (1,301 km^2 [502.3 $mi.^2$]), coupled with estimates of displacement in the February 7, 1812, earthquake, is used to estimate values of seismic moment from 6.8×10^{26} to 1.4×10^{27} dyne-centimeters, with preferred values between 6.8×10^{26} and 8.7×10^{26} dyne-centimeters. Computed M_w for this event ranges from M_w 7.2 to 7.4, with preferred values between M_w 7.2 and 7.3. The moment magnitude for the AD 1450 event is computed as M_w 7.3.

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Mueller et al. (2004)	Analyzing the 1811-1812 New Madrid Earthquakes with Recent Instrumentally Recorded Aftershocks	Instrumentally recorded aftershock locations and models of elastic strain change are used to develop a kinematically consistent rupture scenario for three of the four largest earthquakes of the 1811-1812 earthquake sequence. Three events (NM1, NM1-A, and NM3) likely occurred on two contiguous faults (the strike-slip Cottonwood Grove fault and the Reelfoot thrust fault). The third main shock (NM2), which occurred on January 23, 1812, is inferred to be a more distant triggered event that may have occurred as much as 200 km (124.3 mi.) to the north in the Wabash Valley of southern Illinois-southern Indiana. Magnitudes assigned to each of these events are NM1 (**M** 7.3); NM1-A (**M** 7.0); NM2 (**M** 6.8); and NM3 (**M** 7.5).
Tuttle (2001)	The Use of Liquefaction Features in Paleoseismology: Lessons Learned in the New Madrid Seismic Zone, Central United States	Uses two approaches to estimate magnitude: • Magnitude-bound—estimates minimum magnitude for AD 900 and 1450 events of **M** 6.9 and **M** 6.7, respectively, based on Ambraseys's (1988) relationship between **M** and epicentral distance to surface manifestations of liquefaction. • Energy stress—estimates **M** 7.5 to 8.3 from in situ geotechnical properties similar to **M** ≥ 7.6 from Ambraseys's relation for largest 1811-1812 earthquakes.
Tuttle et al. (2002)	The Earthquake Potential of the New Madrid Seismic Zone	Size, internal stratigraphy, and spatial distributions of prehistoric sand blows indicate that AD 900 and 1450 earthquakes had source zones and magnitudes similar to those of the three largest shocks in the 1811-1812 sequence.
Recurrence		
Cramer (2001)	A Seismic Hazard Uncertainty Analysis for the New Madrid Seismic Zone	A 498-year mean recurrence interval is obtained based on a Monte Carlo sampling of 1,000 recurrence intervals and using the Tuttle and Schweig (2000) uncertainties as a range of permissible dates (± two standard deviations). From these results, 68% confidence limits range from 267 to 725 years; 95% confidence limits range from 162 to 1,196 years (one and two standard deviation ranges, respectively).

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Holbrook et al. (2006)	Stratigraphic Evidence for Millennial-Scale Temporal Clustering of Earthquakes on a Continental-Interior Fault: Holocene Mississippi River Floodplain Deposits, New Madrid Seismic Zone, USA	Presents reconstruction of Holocene Mississippi River channels from maps of floodplain strata to identify channel perturbations reflective of major displacement events on Reelfoot thrust fault. Provides evidence of temporal clustering of earthquakes in a compressive Midcontinent intraplate on short-term cycles (months), as well as evidence for longer-term reactivation cyles (10^4–10^6). The study makes a case for a ~1,000-year cluster of earthquakes with 10^2 yr spacing on the Reelfoot fault, beginning with a coseismic slip event near end of the middle Holocene at ~2200 to ~1600 BC. This Holocene cluster appears separated from the modern episode of seismicity (beginning ~AD 900) by at least 1,700 years of tectonic quiescence.
Kelson et al. (1996)	Multiple Late Holocene Earthquakes Along the Reelfoot Fault, Central New Madrid Seismic Zone	Based on seismic-reflection data, the authors interpret the scarp as a fault propagation fold over a west-dipping reverse fault. Trench exposures provide evidence for three episodes of deformation in the past 2,400 years: between AD 780 and 1000, between AD 1260 and 1650, and during AD 1812. Each episode had a slightly different style of deformation. The relations suggested that graben development increased through time concomitant with growth of monocline or that the earthquakes are of different magnitude.
Al-Shukri et al. (2005)	Spatial and Temporal Characteristic of Paleoseismic Features in the Southern Terminus of the New Madrid Seismic Zone in Eastern Arkansas	Results of this study show that the 10 km (6.2 mi.) long lineament is associated with sand blows. A fracture that crosscuts the sand blows has a strike similar to that of the lineament and may be related to faulting. Its length and morphology as well as parallelism to the nearby White River fault zone suggest that the lineament is fault controlled. However, additional work, including geophysical and geological investigations, is needed to verify presence of a fault below the layer that liquefied. There appears to be at least a 5–10 kyr long history of strong ground shaking along the Daytona Beach lineament and possibly across the Marianna area. At Daytona Beach SE2 site, trench observations confirm interpretations of geophysical data of at least one major sand dike and a large sand blow at this site. Not imaged by ground-penetrating radar, the trenches revealed additional smaller sand dikes and an older sand blow. Both generations of liquefaction features are very weathered, like the sand blow at the original Daytona Beach site, suggesting they may be as oldh as 5.5 ka. Radiocarbon dating of buried silt loam soil provides maximum age constraint of 10.1 kyr for the younger of the two sand blows and minimum age constraint for the older sand blow. Optically

		stimulated luminescence dating is under way and should help to further constrain ages of the sand blows. Sand blows in the Marianna area predate those in the NMSZ and are much more weathered. No sand blows have yet been found in the area that are less than 5 ka and could have formed during the AD 900, 1450, and 1811-1812 New Madrid earthquakes. Therefore, the Marianna sand blows do not represent distant effects of earthquakes generated by the NMSZ. Instead, their large size and spatial relations to local faults suggest that the causative earthquakes were centered in Marianna. Furthermore, the compound nature of some of the Marianna sand blows are indicative of sequences of large earthquakes resulting from complex fault interaction similar to the behavior of the New Madrid fault zone.
Al-Shukri et al. (2006)	Three-Dimensional Imaging of Earthquake-Induced Liquefaction Features with Ground Penetrating Radar near Marianna, Arkansas	High-resolution 3-D ground-penetrating radar (GPR) surveys, together with a profiling survey conducted at three sites to study earthquake-related sand blows in east-central Arkansas, were used to site trenches. Trench results confirmed presence of sand dikes at the locations interpreted from GPR results.
Tuttle (2001)	The Use of Liquefaction Features in Paleoseismology: Lessons Learned in the New Madrid Seismic Zone, Central United States	Major earthquakes occurred in New Madrid region in AD 900 ± 100 years and AD 1450 ± 150 years. There is evidence for earlier events, but age estimates and areas affected are poorly constrained. Judging by similarities in size and spatial distribution of paleoliquefaction features from these events and close spatial correlation to historical features, NMSZ was the probable source of two of these. This study is consistent with other paleoliquefaction studies in the region and with studies of fault-related deformation along Reelfoot scarp (e.g., Kelson et al., 1996).
Tuttle et al. (2002)	The Earthquake Potential of the New Madrid Seismic Zone	Recurrence intervals are based on studies of hundreds of earthquake-induced paleoliquefaction features at more than 250 sites. The fault system responsible for New Madrid seismicity generated very large earthquakes temporally clustered in AD 900 ± 100 years and AD 1450 ± 150 years, as well as 1811-1812. Given uncertainties in dating liquefaction features, the time between the past three events may be as short as 200 years or as long as 800 years, with an average of 500 years. Evidence suggests that prehistoric sand blows probably are either compound structures, resulting from multiple earthquakes closely clustered in time, or earthquake sequences.

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Tuttle et al. (2006)	Very Large Earthquakes Centered Southwest of the New Madrid Seismic Zone 5,000–7,000 Years Ago	Large earthquake-induced sand blows and related sand dikes are present at two sites in Marianna area about 180 km (112 mi.) SW of center of the NMSZ (80 km, or 50 mi., SW of the southern limit of NMSZ). Based on radiocarbon dating, liquefaction features at the Daytona Beach and St. Francis sites formed about 3500 and 4800 BC (5 and 7 ka), respectively. These events predate paleoearthquakes attributed to NMSZ faults. The Marianna sand blows are similar in size to NMSZ sand blows, suggesting that they formed as the result of very large earthquakes centered near Marianna and outside NMSZ. Liquefaction features similar in age to, but smaller than, the Daytona Beach sand blow occur near Blytheville (150 km, or 93.2 mi., NE of Marianna) and Montrose, Arkansas (175 km, or 108.7 mi., SE of Marianna). A very large (**M** > 7.2) earthquake centered near Marianna about 3500 BC may account for liquefaction in all three areas. The large sand blows at the St. Francis site are similar to compound sand blows in the NMSZ, suggesting that a NMSZ-type earthquake sequence was centered near Marianna about 4800 BC. Several faults in the Marianna area (including the Eastern Reelfoot rift margin [ERRM], the White River fault zone [WRFZ], and Big Creek fault zone [BCFZ]), are thought to be active, based on apparent influence on local topography and hydrography. ERRM appears to be the most likely source of very large earthquakes during middle Holocene.
Vaughn (1991)	Evidence for Multiple Generations of Seismically Induced Liquefaction Features in the Western Lowlands, Southeast Missouri	Identifies evidence for as many as three to four major (M ≥ 5.5) earthquakes: the great 1811-1812 New Madrid event and two to three prehistoric events. Preliminary estimates of the ages based on archaeological data and radiocarbon dates on materials associated with buried or truncated liquefaction features suggest the following: (1) event F, 22.75 to 357 ka, and very likely more than 13.4 ka; (2) event L, with maximum timing of 13.43 ka and minimum timing of ca. 5.0 ka; and (3) event R, 12.57 to 0.59 ka, probably closer to 0.59 ka. Potentially, event R could correlate with one of the two major prehistoric earthquakes on the Reelfoot scarp.

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Seismicity—Focal Mechanisms and Fault Geometry		
Bakun and Hopper (2004a)	Catalog of Significant Historical Earthquakes in the Central United States	Modified Mercalli intensity assignments are used to estimate source locations and moment magnitude M for 18 nineteenth-century and 20 early twentieth-century earthquakes in the central U.S. for which estimates of M are otherwise not available. The 1811-1812 New Madrid earthquakes apparently dominated CUS seismicity in the first two decades of nineteenth century. M 5–6 earthquakes occurred in the NMSZ in 1843 and 1878, but none have occurred since 1878.
Chiu et al. (1990)	High-Resolution PANDA Experiment in the Central New Madrid Seismic Zone	Accurate earthquake locations from PANDA seismic array deployed in mid-October of 1989 define a narrow and clustered seismic zone. Seismicity is concentrated in upper crust beneath the sedimentary layer and above 15 km (9.3 mi.). Single-event fault plane solutions are well constrained by P-wave first motion and S-wave polarities, which suggest predominantly strike-slip motion with some thrust-component in the region.
Chiu et al. (1992)	Imaging the Active Faults of the Central New Madrid Seismic Zone Using PANDA Array Data	PANDA data clearly delineate planar concentrations of hypocenters that allow for interpretation as active faults. The results corroborate the vertical (strike-slip) faulting of SW (axial), N-NE, and western arms and define two dipping planes in the central segment. Seismicity in the left-step zone between the two NE-trending vertical segments is concentrated around a plane that dips at ~31°SW; a separate zone to the SE of the axial zone defines a plane that dips at ~48°SW. These planes project updip to surface along the eastern boundary of Lake County uplift and the western portion of Reelfoot Lake. Seismic activity in the central NMSZ occurs continuously between ~5 and 14 km (3.1 and 8.7 mi.) depth.
Csontos and VanArsdale (2008)	New Madrid Seismic Zone Fault Geometry	In this study, 1,704 earthquake hypocenters obtained between 1995 and 2006 were analyzed in 3-D space to more accurately map fault geometry in the NMSZ. Most of the earthquakes appear to align along fault planes. Identifies New Madrid North (29°, 72°SE), Risco (92°, 82°N), Axial (46°, 90°), Reelfoot North (167°, 30°SW), and Reelfoot South (150°, 44°SW) faults. A diffuse zone of earthquakes exists where the Axial fault divides the Reelfoot fault into Reelfoot North and Reelfoot South faults. Regional mapping of the top of the Precambrian crystalline basement indicates that the Reelfoot North fault has an average of 500 m (1,640 ft.) and the

		Reelfoot South fault has 1,200 m (3,937 ft.) of down-to-the-SW normal displacement. Since previously published seismic-reflection profiles reveal reverse displacement on top of the Paleozoic and younger strata, the Reelfoot North and South faults are interpreted to be inverted basement normal faults. Reelfoot North and South faults differ in strike, dip, depth, and displacement, and only the Reelfoot North fault has a surface scarp (monocline). Thus the Reelfoot fault is actually composed of two left-stepping restraining bends and two faults that together extend across entire width of Reelfoot rift.
Herrmann and Ammon (1997)	Faulting Parameters of Earthquakes in the New Madrid, Missouri, Region	Combines traditional regional seismic network observations with direct seismogram modeling to improve estimates of small earthquake faulting geometry, depth, and size. Evaluates three earthquakes that occurred within the vicinity of the NMSZ. Comparing new and revised results with existing earthquake mechanisms in the region, this paper concludes that tension axes are generally aligned in a N-S to NW-SE direction, while compression axes are aligned in a NE to E direction. Interesting exceptions to this pattern are the March 3, 1963, earthquake, and two nearby earthquakes that lie within a well-defined 30 km (18 mi.) long left step in seismicity near New Madrid. Depth of well-located events in the Reelfoot rift is ≤16 km (10 mi.).
Himes et al. (1988)	Indications of Active Faults in the New Madrid Seismic Zone from Precise Locations of Hypocenters	Based on examination of hypocenters for more than 500 earthquakes in the NMSZ, the relocated earthquakes are separated into three trends: (1) ARK, the SW-trending zone from Caruthersville, Missouri, to Marked Tree, Arkansas; (2) DWM, the NE-trending zone from New Madrid to Charleston, Missouri; and (3) CEN, the central, left-stepping offset zone from Ridgely, Tennessee, to New Madrid, Missouri. Vertical profiles along and across the ARK and DWM trends verify the strike and dip of dominantly strike-slip motion on near-vertical active faults along these trends—in agreement with previously determined composite focal mechanism solutions for these trends. No coherent picture for CEN is obtained. Velocity models from the inversion are found to be reasonably uniform throughout the NMSZ and support the presence of a shallow low-velocity zone in the central part of Mississippi embayment.

Shumway (2008)	Focal Mechanisms in the Northeast New Madrid Seismic Zone	Earthquakes in NE part of the NMSZ from June 1995 to June 2006 were relocated using a velocity model of the Mississippi embayment with appropriate depths to bedrock beneath seismic stations. Focal mechanisms were generated for events on NE-trending alignments. Results show that approximately half the focal mechanisms have a N-NE-striking nodal plane and a right-lateral strike-slip component consistent with earlier studies of the NMNF to the SW. This shows that this part of the NE NMSZ (1) is influenced by the same fault pattern and stress regime as the NMNF, (2) may be an extension of the NMSZ, and (3) therefore may represent alternate locations of January 23, 1812, rupture. Focal depths for 19 earthquakes range from about 3 to 15 km (1.9 to 9.3 mi.).
Stauder (1982)	Present-Day Seismicity and Identification of Active Faults in the New Madrid Seismic Zone	Results of four years of data from a regional seismic network established in 1974 showed the following: • a diffuse seismicity over the regional area; • NE-SW trends of faulting within the network varying in length from 25 to 120 km (15.5 to 75 mi.) from Cairo, Illinois, into NW Arkansas; • a major offset in these trends in region between New Madrid, Missouri, and Ridgely, Tennessee; • focal mechanism studies indicate right-lateral, predominantly strike-slip motion on the major NE-trending seismic trend; and • a low-velocity zone extends at least 150 km (93.2 mi.) into upper mantle beneath the region of highest seismicity.
Geodetic and Modeling Studies-Hypotheses for Causes of Intraplate Seismicity		
Calais and Stein (2009)	Time-Variable Deformation in the New Madrid Seismic Zone	This paper speculates that earthquake hazard estimates—assuming that recent seismicity reflects long-term steady-state behavior—may be inadequate for plate interiors and may overestimate hazard near recent earthquakes and underestimate it elsewhere. Recent geodetic results in the NMSZ have shown motions between 0 and 1.4 mm/yr, allowing opposite interpretations. The upper bound is consistent with steady-state behavior, in which strain accumulates at a rate consistent with repeat time for M ~ 7 earthquakes of about 600–1,500 years, as seen in the earthquake record. The lower bound cannot be reconciled with this record, which implies that the recent cluster of

		large-magnitude events does not reflect long-term fault behavior and may be ending. New analysis suggests strain rates lower than 1.3×10^{-9}/yr, less than predicted by a model in which large earthquakes occur because the NMSZ continues to be loaded as a deeper weak zone relaxes (e.g., Kenner and Segall, 2000). At a steady state, a rate of 0.2 mm/yr implies a minimum repeat time of 10,000 years for low M = 7 earthquakes with ~2 m (~6.6 ft.) of coseismic slip and one longer than 100,000 years for M = 8 events. Strain in the NMSZ over the past several years has accumulated too slowly to account for seismicity over past ~5,000 years; hence steady-state fault behavior is excluded. Elsewhere throughout the plate interior, GPS data also show average deformation less than 0.7 mm/yr, and paleoseismic records show earthquake migration and temporal earthquake clustering. These imply that fault loading, strength, or both vary with time in the plate interior. Time variations in stress could be due to local loading and unloading from ice sheets or sediments or after earthquakes on other faults.
Calais et al. (2006)	Deformation of the North American Plate Interior from a Decade of Continuous GPS Measurements	Two independent geodetic solutions using data from close to 300 continuous GPS stations covering CEUS show that surface deformation in the plate interior is best fit by a model that includes rigid rotation of North America with respect to International Terrestrial Reference Frame (ITRF) 2000 and a component of strain qualitatively consistent with that expected from glacial isostatic adjustment. No detectable residual motion at the 95% confidence level is observed in the NMSZ. On the basis of a 0.7 mm/yr weighted RMS value for the residual velocities of NMSZ sites, random deviations from a rigid plate model in the NMSZ region do not exceed 1.4 mm/yr, the 95% confidence level. This is assumed to represent a conservative upper bound on the magnitude of any long-term slip in the study area. Assuming a simple model where characteristic earthquakes repeat regularly on a given active fault, the results imply a minimum repeat time of about 3,000–8,000 years for future M 8 earthquakes with 5–10 m (16–33 ft.) of coseismic slip, and a minimum repeat time of 600–1,500 years for future M 7 earthquakes with 1–2 m (3.3–6.6 ft.) of coseismic slip. This is consistent with recent and historical earthquake catalogs, which predict a recurrence interval that exceeds 1,000 years for M 7 earthquakes, and 10,000 years for M 8 earthquakes, and is consistent with paleoseismic data, which imply recurrence intervals of 400–1,000 years.

Table D-6.1.5 Data Summary
Reelfoot Rift–New Madrid Seismic Zone (NMSZ) Region

Calais et al. (2009)	Time-Variable Deformation in the New Madrid Seismic Zone	New analysis of GPS measurements across the NMSZ shows that deformation accumulates at a rate indistinguishable from zero and less than 0.2 mm/yr. At steady state, a (maximum) rate of 0.2 mm/yr implies a (minimum) repeat time of 10,000 years for low M 7 earthquakes, in contrast with the 500- to 900-year repeat time of paleoearthquakes. This, along with geological observations that large earthquakes and significant motions on Reelfoot fault started in the Holocene, suggests a transient burst of seismic activity rather than steady-state behavior. The authors postulate a model in which stress changes are caused by the Quaternary denudation/sedimentation history of the Mississippi Valley. Flexural stresses are sufficient to trigger earthquakes in a continental crust at failure equilibrium. Resulting viscoelastic relaxation leads to failure again on the main fault (lower strength threshold) and on neighboring faults. In the absence of significant far-field loading, this process can only maintain seismic activity for a few thousand years.
Crone et al. (2003)	Paleoseismicity of Two Historically Quiescent Faults in Australia: Implications for Fault Behavior in Stable Continental Regions	Temporal clustering, in which faults turn on to generate a series of large earthquakes and then turn off for a long time, may reflect the evolution of pore fluid pressure in the fault zone. In this model, low-permeability seals form around the fault zone as stress accumulates, raising pore pressure until an earthquake happens and each of the temporally clustered earthquakes relaxes some of the accumulated strain, and eventually the surrounding crust is sufficiently relaxed to make the fault quiescent.
Forte et al. (2007)	Descent of the Ancient Farallon Slab Drives Localized Mantle Flow Below the New Madrid Seismic Zone	Viscous flow models based on high-resolution seismic tomography show that descent of the ancient Farallon slab into deep mantle beneath central North America induces a highly localized flow directly below the NMSZ. This localization arises because of structural variability in the Farallon slab and low viscosity of the sublithospheric upper mantle, and it represents a heretofore unrecognized and possibly significant driving mechanism for the enigmatic intraplate seismicity in CEUS.
Grana and Richardson (1996)	Tectonic Stress Within the New Madrid Seismic Zone	Refraction data indicate a significant high-density rift pillow beneath the NMSZ. Linear and nonlinear viscoelastic finite-element modeling was conducted to determine whether support of the rift pillow may contribute significantly to the total present-day stress field. Results indicate that the nonlinear viscoelastic model with rheological stratification based on composition and temperature agrees well with observed deformation

		within the zone, and with estimates of regional stress magnitudes. The model predicts maximum compression of 30–40 megapascals above the rift pillow in the center of the rift axis. If the magnitude of local compression predicted by the nonlinear model produces inferred clockwise rotation on the order of 10°–30° in the direction of SHmax (maximum horizontal compression) near the rift axis, the magnitude of regional compression is a factor of one to two times that of local compression and is consistent with an origin due to ridge push forces. Addition of local stress associated with the rift pillow, however, results in an approximately 30% reduction in the resolved maximum horizontal shear stress. Thus, while the stress associated with the rift pillow can rotate the stress field to an orientation favorable for failure, reduction in the resolved shear stress requires a separate mechanism for strength reduction. Results of the modeling indicate that stresses from the load of the rift pillow may still be present in upper crust even after 100 Myr and may still play a role in present-day deformation and seismicity of the NMSZ. Local stress fields of significant tectonic magnitudes may also occur around other ancient rift pillows and help explain the observed correlation between intraplate seismicity and failed rift zones.
Grollimund and Zoback (2001)	Did Deglaciation Trigger Intraplate Seismicity in the New Madrid Seismic Zone?	Modeling of the removal of the Laurentide ice sheet ca. 20 ka changed the stress field in the vicinity of New Madrid and caused seismic strain to increase by about three orders of magnitude. The high rate of seismic energy release observed during late Holocene is likely to remain essentially unchanged for the next few thousand years.
Kenner and Segall (2000)	A Mechanical Model for Intraplate Earthquakes: Application to the New Madrid Seismic Zone	Postulates a time-dependent model for the generation of repeated intraplate earthquakes in which seismic activity is driven by localized transfer of stress from a relaxing lower-crustal weak body. Given transient perturbation to the stress field, the seismicity is also transient, but can have a significantly longer duration. This model suggests that interseismic strain rates computed between damaging slip events would not be geodetically detectable.

Li et al. (2007)	Stress Evolution and Seismicity in the Central-Eastern United States: Insights from Geodynamic Modeling	Explores evolution of stress and strain energy in intraplate seismic zones and contrasts it with interpolate seismic zones using simple viscoelastic finite-element models. General observations are as follows: • Large intraplate earthquakes can significantly increase Coulomb stress and strain energy in surrounding crust. • Inherited strain energy may dominate the local strain energy budget for thousands of years following main shocks, in contrast to interplate seismic zones, where strain energy is dominated by tectonic loading. • Strain energy buildup from the 1811-1812 large events in NMSZ may explain some of the moderate-sized earthquakes in this region since 1812. • Inherited strain energy is capable of producing some damaging earthquakes (M > 6) today in southern Illinois and eastern Arkansas, even in the absence of local loading. • Without local loading, however, the NMSZ would have remained in a stress shadow where stress has not been fully restored from the 1811-1812 events. • Results from compilation of a Pn (upper mantle) velocity map of the CEUS using available seismic data do support the NMSZ's being a zone of thermal weakening. • Predicted high Coulomb stress concentrates near margins of North American tectosphere, correlating spatially with most seismicity in the CEUS.
Li et al. (2009)	Spatiotemporal Complexity of Continental Intraplate Seismicity: Insights from Geodynamic Modeling and Implications for Seismic Hazard Estimation	Explores the complex spatiotemporal patterns of intraplate seismicity using a 3-D viscoelastic-plastic finite-element model. The model simulates tectonic loading, crustal failure in earthquakes, and coseismic and postseismic stress evolution. For a laterally homogeneous lithosphere with randomly pre-specified perturbations of crustal strength, the model predicts various spatiotemporal patterns of seismicity at different time scales, spatial clustering in narrow belts and scattering across large regions over hundreds of years, connected seismic belts over thousands of years, and widely scattered seismicity over tens of thousands of years. The orientation of seismic belts coincides with the optimal failure directions associated with assumed tectonic loading. Stress triggering

		and migration cause spatiotemporal clustering of earthquakes. Fault weakening can lead to repeated earthquakes on intraplate faults. The predicted patterns vary with the weakening history. Clusters of large intraplate earthquakes can result from fault weakening and healing, and these clusters can be separated by long periods of quiescence. The complex spatiotemporal patterns of intraplate seismicity predicted in this simple model suggest that assessment of earthquake hazard based on the limited historical record may be biased toward overestimating the hazard in regions of recent large earthquakes and underestimating the hazard where seismicity has been low during historical time.
Liu and Zoback (1997)	Lithospheric Strength and Intraplate in the New Madrid Seismic Zone	Proposes a simple hypothesis to explain occurrence of localized zones of tectonic deformation and seismicity within intraplate regions subjected to relatively uniform far-field tectonic stresses. The contrast in integrated lithospheric strength between the NMSZ and the surrounding continental region appears to be the principal reason why the New Madrid area is the most active intraplate seismic area in eastern North America. The lower lithosphere's strength in the NMSZ appears to be controlled by a slightly thickened crust and slightly higher heat-flow values compared to surrounding regions. This conclusion is supported by a contrast in Pn (upper mantle) velocity structure, the silica geothermometry, and the rate of Cenozoic subsidence and recurrence of late Mesozoic and possible Cenozoic magmatic activity. Because of localized deformation in the lower crust of the NMSZ, repeated earthquakes occur with recurrence times that are relatively short for intraplate areas.
McKenna et al. (2007)	Is the New Madrid Seismic Zone Hotter and Weaker Than Its Surroundings?	Evaluates sparse heat-flow data in the New Madrid area and concludes that there is no compelling case for assuming that the NMSZ is significantly hotter and weaker than its surroundings, and that this result is consistent with the migrating seismicity model and the further possibility that the NMSZ is shutting down, which is suggested by the small or zero motion observed geodetically. In this model, the present seismicity is aftershocks of the large earthquakes of 1811-1812, and such large earthquakes will not recur there for a very long time.

Table D-6.1.5 Data Summary
Reelfoot Rift–New Madrid Seismic Zone (NMSZ) Region

Newman et al. (1999)	Slow Deformation and Lower Seismic Hazard at the New Madrid Seismic Zone	Recent geodetic measurements indicate that the rate of strain accumulation is less than the current detection threshold. Global positioning system (GPS) data show no significant differences in velocities on either side of southern arm of NMSZ. Near-field and intermediate-field (primarily hard-rock) sites yield measurements of 0.6 ± 3.2 and –0.9 ± 2.2 mm/year, respectively. They are consistent with both 0 and 2 mm/year at 2-sigma. GPS data for upper Mississippi embayment show that interior of the Reelfoot rift is moving NE relative to the North American Plate. Modeling stable North America as a single rigid plate fits the site velocities, with a mean residual of 1.0 mm/year. The authors conclude that the present GPS data imply that 1811-1812-sized earthquakes are either much smaller or far less frequent than previously assumed (i.e., smaller than **M** 8 [5–10 m, or 16.4–32.8 ft., slip/event], or longer than a recurrence interval of 400–600 years).
Smalley et al. (2005)	Space Geodetic Evidence for Rapid Strain Rates in the New Madrid Seismic Zone of Central USA	Recent analysis of geodetic measurements from a permanent GPS array in mid-America installed in the mid- to late 1990s provides evidence for rapid strain rates in the NMSZ. Rates of strain are on the order of 10^{-7} per year, comparable in magnitude to those across active plate boundaries. The rates are consistent with known active faults in the region. Relative convergence across the Reelfoot fault is ~2.7 ± 1.6 mm/year. Relative fault-parallel, right-lateral motion of ~1 mm/year is measured across southern right-lateral strike-slip fault zone, which is highlighted by a prominent NE-trending and vertical zone of microseismicity and right-lateral focal mechanisms. Surface velocities at distances beyond a few fault dimensions (far-field) from active faults do not differ significantly from zero. It is not certain whether the driving force behind current surface velocities is related to post-1811-1812 postseismic processes or to accumulation of a locally sourced strain. Data indicate, however, that aseismic slip is almost certainly required across faults (or shear zones) within upper few kilometers of the surface.

Table D-6.1.5 Data Summary
Reelfoot Rift–New Madrid Seismic Zone (NMSZ) Region

Stuart et al. (1997)	Stressing of the New Madrid Seismic Zone by a Lower Crust Detachment Fault	The authors suggest that the cause of stress concentration onto the NMSZ is slip on a weak subhorizontal detachment fault or equivalent shear zone in the lower crust where high temperatures reduce rock strength. The proposed detachment fault is placed at or just above the top surface of a layer of lower crust with anomalous high-density and seismic velocity called the “rift pillow” or “rift cushion.” Regional horizontal compression induces slip on the fault, and the slip creates a stress concentration in upper crust above rift pillow dome. The model implies that rift pillow geometry is a significant influence on the maximum possible earthquake magnitude.
Zhang et al. (2009a)	Lithospheric Velocity of the New Madrid Seismic Zone: A Joint Teleseismic and Local P Tomographic Study	Inversion of teleseismic P and local P first-arrival times from a nine-year data set are used to infer the lithospheric velocity structure beneath the NMSZ. Results show that the seismically active zone is associated with a local NE-SW-trending low-velocity anomaly in the lower crust and upper mantle, instead of high-velocity intrusive bodies proposed in previous studies. The low-velocity anomaly is on the edge of a high-velocity lithospheric block, consistent with notion of stress concentration near rheological boundaries. This lithospheric weak zone may shift stress to upper crust when loaded, thus leading to repeated shallow earthquakes.
Seismic Source Characterization Models		
Cramer (2001)	A Seismic Hazard Uncertainty Analysis for the New Madrid Seismic Zone	Develops a logic tree of possible alternative parameters to characterize earthquake sources in the NMSZ. Source model alternatives include fictional faults from Frankel et al. (1996) and actual faults (Bootheel lineament, eastern rift boundary, NE arm, SW arm, Reelfoot fault, west arm, and western rift boundary).
Frankel et al. (2002)	Documentation for the 2002 Update of the National Seismic Hazard Maps	Identifies three alternative fault sources: a fault trace matching recent microearthquake activity, and two adjacent sources situated near borders of the Reelfoot rift. The center fault is given twice the weight of the other two. Mean recurrence interval = 500 years: **M** 7.3: (0.15 wt) **M** 7.5: (0.20 wt) **M** 7.7: (0.50 wt) **M** 7.9: (0.15 wt)

Table D-6.1.5 Data Summary
Reelfoot Rift–New Madrid Seismic Zone (NMSZ) Region

Petersen et al. (2008)	Documentation for the 2008 Update of the United States National Seismic Hazard Maps	Revisions to the characterization of the NMSZ include the following: • Reduced magnitudes in northern NMSZ by 0.2 unit and added logic-tree branch for recurrence rate of 1/750 years. • Added logic-tree branch for 1/1,000-year recurrence rate of earthquakes in New Madrid (recommended by advisory panel). • Implemented temporal cluster model for New Madrid earthquakes. • Modified fault geometry for New Madrid to include five hypothetical strands and increased weight on central strand to 0.7. • Revised dip of Reelfoot fault to 38°.
Toro and Silva (2001)	Scenario Earthquakes for Saint Louis, MO, and Memphis, TN, and Seismic Hazard Maps for the Central United States Region Including the Effect of Site Conditions	Develops alternative geometries for NMSZ. Uses fault sources identified by Johnston and Schweig (1996), augmented by alternative fault source model to the north (East Prairie extension), to represent more diffuse patterns of seismicity. Assumes that a large seismic-moment release in the region involves events on all three NMSZ faults occurring within a short interval. Occurrences of large earthquakes in the NMSZ are not independent in time. Uses mean recurrence intervals of 500 to 1,000 years.

Table D-6.1.9 Data Summary
Wabash Valley RLME

Citation	Title	Description and Relevance to SSC
General for Region		
Basement Structure		
Drahovzal et al. (1992)	The East Continent Rift Basin: A New Discovery	Integration of lithologic, stratigraphic, geochemical, gravity, magnetic, structural, and seismic data resulted in recognition of an eastern arm of the Midcontinent rift system named the East Continent rift basin (ECRB). An elongate N-S-trending Precambrian rift basin is present from SE Michigan through Ohio and Indiana, into central Kentucky. The ECRB is filled with red continental lithic arenites, minor red siltstones and shales, and volcanics. Gravity, magnetic, and seismic data indicate that the basin is composed of several subbasins. The basin is bounded by the Grenville Front to the east and by normal block faults to the west. The basin narrows to the north; the southern boundary is not well constrained. The basin is interpreted to be Keweenawan in age and associated with the middle Proterozoic Midcontinent rift system. The ECRB predates the Grenville orogeny, which resulted in folding and faulting of the rift-fill sequence. Post-Grenville erosion, Paleozoic inversion, and wrench faulting resulted in the present configuration of the basin.
Drahovzal (1994)	Basin-Floor Fan Complexes: A New Exploration Strategy for the Rough Creek Graben	Extent of possible extended basement crust below the southern Illinois basin is inferred from seismic-reflection data.
Harrison and Schultz (2002)	Tectonic Framework of the Southwestern Margin of the Illinois Basin and Its Influence on Neotectonism and Seismicity	The authors propose that along the SW margin of the Illinois basin, the Commerce geophysical lineament (CGL) to the south and the St. Charles lineament (SCL) to the north divide the region into three distinct tectonic domains. The authors suggest that these lineaments represent ancient shear zones, or accommodation zones, that juxtapose different-aged Proterozoic crustal blocks, and that these accommodation zones have partitioned strain throughout the Phanerozoic, which is reflected in the northward decrease of seismic activity in the region. The authors report that structural features within each of the three tectonic domains vary in deformational styles and orientations, reflecting decoupling of deformation across the two lineaments. (See also Midcontinent Data Summary Table for description of CGL and SCL.)

Table D-6.1.9 Data Summary
Wabash Valley RLME

Citation	Title	Description and Relevance to SSC
Harrison and Schultz (2008)	A Tectonic Model for the Midcontinent U.S. Lithosphere Based on Structural Analyses of Mesoproterozoic Through Cenozoic Deformation	The general conclusion from this abstract is that in the midcontinent U.S., some seismicity can be attributed to reactivation of vertical strike-slip fault zones that are not associated with any rift. Furthermore, some seismically active, old rift structures in the Midcontinent may be inherently related to an even older strike-slip fault system. Mesoproterozoic basement rocks of the St. Francois terrane possess an orthogonal pattern of vertical NW- and NE-trending strike-slip fault zones. The NW trend dominates Mesoproterozoic deformation and is inherent from an older fabric that controlled the location of Mesoproterozoic igneous activity. The assembly and breakup of Rodinia is recorded by accumulative left slip of 60–75 km (37.3–46.6 mi.) and 30–75 km (19–47 mi.) on NW-trending structures, pre-Late Cambrian vertical, right-lateral, strike-slip faulting on NW-trending in the St. Francois terrane, emplacement of dominantly NE-trending, 1.33 Ga mafic dikes, and uplift and erosion of ~2–4 km (~1.2–2.5 mi.) of rocks. Reactivation of NE-trending structures in the Late Cambrian resulted in formation of the Reelfoot rift and was accompanied by reactivation of vertical NW-trending structures with left-lateral displacement. Faulting in the Paleozoic, Mesozoic, and Cenozoic cover sequences documents reactivation of both vertical trends as far-field strike-slip faults during the Acadian, Taconic, Ouachita, Alleghany, and Laramide orogenies. Stepovers within the strike-slip fault system produced local uplift along restraining bends and subsidence in pull-apart grabens and basins. A tectonic model of the Midcontinent lithosphere is best portrayed as consisting of an orthogonal mosaic of vertical zones of shear that presumably penetrate the crust and upper mantle and are long-lived and prone to reactivation under lithospheric stresses.

Table D-6.1.9 Data Summary
Wabash Valley RLME

Citation	Title	Description and Relevance to SSC
Hildenbrand and Ravat (1997)	Geophysical Setting of the Wabash Valley Fault System	Analyses of gravity and magnetic data have been used to evaluate the geologic framework of the northern Mississippi embayment and Illinois basin regions. Inversion of high-resolution aeromagnetic data shows that interpreted ultramafic dikes closely follow mapped faults; their abundance suggests that the Wabash Valley fault system (WVFS) contains more faults than those mapped. Both dike pattern and mapped WVFS terminate near the Reelfoot–Rough Creek–Rome rift system. The Grayville graben (~20 km [~12.5 mi.] wide, ~700 m [~2,297 ft.] maximum basement relief, and <40 km [<25 mi.] long) underlying the Wabash Valley developed during rifting, perhaps in response to stress concentrations generated by a bend in the rift system. The Wabash Valley faults are interpreted to be minor tectonic structures (relative to the Reelfoot rift and Rough Creek graben) and probably do not represent a failed rift arm. There is a lack of any obvious relation between the WVFS and the epicenters of historical and prehistoric earthquakes. Five prehistoric earthquakes lie near structures associated with the Commerce geophysical lineament.
Hildenbrand et al. (2002)	The Commerce Geophysical Lineament and Its Possible Relation to Mesoproterozoic Igneous Complexes and Large Earthquakes in the Central Illinois Basin	Inversions of magnetic and gravity data provide insights on upper-crustal structures in the central Illinois basin. The results of 2-D and 3-D inversion techniques suggest that the source of the Commerce geophysical lineament (CGL) follows the SE boundary of a dense, magnetic, NE-trending igneous center named the Vincennes igneous center. The CGL, defining the 5–10 km (3–6 mi.) wide Commerce deformation zone (CDZ), appears to have influenced the structural development of the Vincennes igneous center. Overlying the igneous center is the Centralia seismic-reflection sequence, expressed as highly coherent reflectors. It is hypothesized that (1) the Vincennes igneous center is the source of inferred volcanic units of the Centralia sequence and is related to a rifted margin or a Proterozoic plate boundary; (2) the CDZ evolved in the Mesoproterozoic (1.1–1.5 Ga) as a major cratonic rheological boundary (possible rifted margin, suture, or accreted belt) and was the focus of episodic reactivation related to varying stress regimes throughout its history; and (3) spatial relations of the CDZ with large Pleistocene and Holocene earthquakes suggest that this major rheological boundary is intimately related to both surface and deep structures and to the seismic hazard of the Illinois basin region. Assuming recent right-lateral slip along the CDZ, a jog or left step in the Vincennes area leads to thrusting or a restraining bend, where associated stress accumulations may have resulted in nearby large prehistoric earthquakes.

Table D-6.1.9 Data Summary
Wabash Valley RLME

Citation	Title	Description and Relevance to SSC
Kolata and Hildenbrand (1997)	Structural Underpinnings and Neotectonics of the Southern Illinois Basin: An Overview	The southern end of the Illinois basin is one of the most structurally complex regions in the midcontinent U.S. Two major structural elements exist: (1) a broad SW-plunging cratonic depression across central Illinois and SW Indiana is characterized by moderate to high earthquake potential and enigmatic earthquake sources; and (2) the southernmost part is underlain by the Reelfoot rift and Rough Creek graben, a rift system that formed during late Precambrian to middle Cambrian time. Geological and geophysical information suggests that the cause of earthquakes in the New Madrid seismic zone is unrelated to that of the region north of the rift system.
Kolata and Nelson (1991)	Tectonic History of the Illinois Basin	The Illinois basin is a polyhistory basin that formed primarily during the Paleozoic era. The basin began as a failed rift concurrent with the breakup of a supercontinent during latest Precambrian or early Cambrian time. Following the rift basin phase, which lasted from early to middle Cambrian, the tectonic setting changed to a broad cratonic basin centered over the rift. Plate tectonic interactions along the eastern and southern margins of North America have repeatedly reactivated the rift and have influenced basin subsidence, sedimentation, formation of geologic structures, migration of subsurface fluids, and contemporary earthquake activity.
McBride and Kolata (1999)	Upper Crust Beneath the Central Illinois Basin, United States	Interpretation of industry seismic-reflection data provides information for understanding the structure and origin of the upper crust (0–12 km [0–7.5 mi.] depth) beneath the central Illinois basin. Highly coherent basement reflectivity is expressed as a synformal wedge of dipping and subhorizontal reflections situated beneath the center of the Illinois basin that thickens and deepens to the northeast (e.g., 0–5.3 km—or 0–3.3 mi.—thickness along a 123 km—76.5 mi.—N-S line). The boundaries of an anomalous subsequence of disrupted reflections located along the southern margin of this wedge are marked by distinct steeply dipping reflections (possible thrust faults) that continue or project up to antiformal disruptions of lower Paleozoic marker reflectors, suggesting Paleozoic or possibly later tectonic reactivation of Precambrian structures. There are multiple hypotheses for the origin of the Precambrian reflectivity, including basaltic flows or sills interlayered with clastic sediments and/or emplaced within felsic igneous rocks.

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Citation	Title	Description and Relevance to SSC
McBride et al. (2001)	Refining the Target for EarthScope in the Central Midcontinent	Overview summary stating that new images (industry data) of deep structure, extending at least as deep as about 65 km (40.5 mi.), represent the largest concentration of deep seismic-reflection profiles between the Appalachians and the Rockies. Interpretation of these data shows the presence of three highly coherent Precambrian "stratigraphic" sequences beneath the Paleozoic Illinois basin that continue down to 15–20 km (9–12.5 mi.) depth. Review of 3-D mapping of these sequences reveals broad "basinal" packages that may be related to a Proterozoic rift and/or volcanic episode. Normal-fault reflector offsets that progressively disrupt the sequences with depth are possibly related to a Proterozoic rift and/or volcanic episode related to the original thermal event that produced the Granite-Rhyolite province. These sequences may be analogous to younger Keweenawan-type rift-related volcanism and sedimentation that affected the central Midcontinent during the Proterozoic. The circular-to-oval shape of the sequences in plan view seems to argue against a linear rift origin and is more suggestive of a large rhyolitic collapsed caldera complex that could have developed in association with the Granite-Rhyolite province. The deeper parts of the seismic sequences correspond to subdued geopotential field values and spatial wavelengths, meaning that the seismic sequences are lacking in widespread high-density, high-magnetization rocks relative to the surrounding region. The outer margins, especially to the west and south, are marked by prominent coincident closed-contour magnetic and gravity anomalies, which do indicate mafic igneous source intrusions (expressed as highly diffractive zones on the deep-reflection profiles. The continuation of the subdued magnetic intensity character (as expressed in the first vertical derivative) to the north and east may point to the extension of the upper-crustal layering in those directions, beyond where regional seismic data are available. The geopotential field data preclude a large mafic igneous component to the crust, except for isolated igneous centers, suggesting that the rifting or volcanic episode must not have tapped deeply or significantly into the lower crust or upper mantle. The presence of newly observed mantle reflectivity beneath the Illinois basin indicates significant upper-mantle heterogeneity relative to other parts of the U.S. studied using reflection methods. The mantle reflectors do not obviously correlate to any particular geologic feature. The reprocessed profiles suggest that the seismogenic source beneath the seismically active southern Illinois basin may be closely associated with (1)

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Citation	Title	Description and Relevance to SSC
		midcrustal dipping reflectors associated with thrust-mechanism earthquakes and (2) seismically imaged steep faults in basement associated with strike-slip-mechanism earthquakes.
McBride et al. (2007)	Deep Faulting and Structural Reactivation Beneath the Southern Illinois Basin	Integrates seismicity, borehole, geophysical, and seismic profile data to create a 2.5-dimensional picture down to local seismogenic depth (0–15 km, or 0–9.3 mi.) along western flanks of two of the major structures within the Illinois basin: Wabash Valley fault system (WVFS), and La Salle anticlinal belt (LSA). The results of reprocessing seismic-reflection profiles, combined with earthquake hypocenter parameters, suggest three distinct seismotectonic environments in the upper crust. 1. A fault pattern that appears to correspond to the steep nodal plane of a strike-slip mechanism is delineated for the April 3, 1974, m_b = 4.7 earthquake. The focal mechanism is consistent with a dominant stress system of NE-striking dextral strike-slip. The fault pattern is interpreted to be a deeply buried rift zone or zone of intense normal faulting underpinning a major Paleozoic depocenter of the Illinois basin (Fairfield basin). 2. A similar earthquake (June 10, 1987, m_b = 5.2) and its well-located aftershocks define a narrow zone of deformation that occurs along and parallel to the frontal thrust of the LSA. The strike and dip of the NW-trending nodal plane were reported by Langer and Bollinger (1991) to be 312° and 80°SW, respectively. This frontal thrust is associated with an asymmetric Laramide-style fold in the Paleozoic section. The NW trend of local epicenters and the steep rupture plane are both consistent with the basement fault, defined from seismic-reflection profiles that core the monocline flexure within the basin sediments. 3. The hypocenter of largest earthquake (November 9, 1968; m_b = 5.5) may be spatially associated with a prominent zone of dipping middle-crustal reflections, just west of WVFS, which have been interpreted as a deeply buried blind thrust (McBride, Hildenbrand, et al., 2002). This may indicate that shallow Paleozoic structures are effectively decoupled from deeper seismogenic structure in this case. The earthquake was originally interpreted to have occurred on a N15°E-trending reverse fault dipping about 45°W; interpretation of seismic data indicates it may have occurred on a more NE-trending blind reverse fault in the basement (fault F). The geopotential field data display trends that mimic structural trends interpreted from reflection profiles and earthquake information. The proposed correlation of preexisting structures with earthquakes having consistently oriented structural

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Citation	Title	Description and Relevance to SSC
		parameters supports the reactivation of old deformation zones by contemporary stresses. The degree to which deformation has propagated upward from Precambrian basement into Paleozoic rocks varied significantly even over a small study area.
Pratt et al. (1992)	Widespread Buried Precambrian Layered Sequences in the U.S. Mid-Continent: Evidence for Large Proterozoic Depositional Basins	Seismic-reflection data in the Illinois region show a Precambrian layered assemblage extending 320 km (199 mi.) in an E-W direction and 200 km (124.3 mi.) in an N-S direction. The assemblage is approximately 12 km (7.5 mi.) thick. Apparent sequence boundaries (onlap, downlap) within the assemblage suggest they are part of a large depositional basin with diffractions and dipping strata due to faulting. The layered sequence correlates with regions of relatively long-wavelength and low-amplitude magnetic anomalies; the extent of this magnetic signature suggests that about 200,000 km^2 (77,220 sq. mi.) of Illinois, Indiana, and western Ohio may be underlain by similar Precambrian strata.
Sparlin and Lewis (1994)	Interpretation of the Magnetic Anomaly over the Omaha Oil Field, Gallatin County, Illinois	A magnetic anomaly identified in an aeromagnetic survey over southern Illinois is expressed in contours as a localized magnetic high on the west flank of a regional magnetic low. An industry well drilled near the apex of the Omaha structural dome, which is coincident with the anomaly, encountered two zones of ultramafic intrusive rock identified as mantle-derived ultramafic rock that can be associated with incipient stages of crustal rifting. The anomaly is modeled using two ultramafic sills with an igneous feeder plug.
PALEOZOIC STRUCTURES (Evidence for Reactivation)		
La Salle Anticlinorium		
Marshak and Paulsen (1997)	Structural Style, Regional Distribution, and Seismic Implications of Midcontinent Fault-and-Fold Zones, United States	This paper interprets the La Salle deformation belt as consisting of three segments composed of north-trending fault arrays. Each segment terminates at a NW-trending discontinuity. The authors note that this geometry resembles the pattern of rift segments linked at accommodation zones, typical of low-strain rifts.
McBride and Nelson (1999)	Style and Origin of Mid-Carboniferous Deformation in the Illinois Basin, USA—Ancestral Rockies Deformation?	Interprets the La Salle anticlinorium as the product of Late Paleozoic displacements on high-angle reverse faults in crystalline basement that propagated upward to monoclines and asymmetrical anticlines in Paleozoic sedimentary cover. This paper presents reflection profiles in the Fairfield basin that do not support the hypothesis presented by Marshak and Paulsen (1997).

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Citation	Title	Description and Relevance to SSC
Nelson (1995)	Structural Features in Illinois	Introduces the name La Salle anticlinorium for the feature that previously had been referred to as the La Salle anticlinal belt. The feature trends N-NW and extends for more than 320 km (200 mi.) from Lee County in the northwest to Lawrence County in the southeast. It comprises numerous subparallel anticlines, domes, monoclines, and synclines, several dozen of which are individually named. The pattern of the individual structures comprising the feature has previously been described as en echelon. The author, however, states that this term is misleading, that in a true en echelon fold belt the structures are aligned at an angle to the overall trend of the system, reflecting strike-slip deformation. The author reports that in the La Salle anticlinorium, individual folds are oriented predominantly parallel to the trend of the larger system. He also describes the individual folds as being offset from one another and partially overlap; toward the north, individual folds generally step to the west. The La Salle anticlinorium is described as locally exhibiting a branching pattern. The author reports that the primary uplift of the La Salle anticlinorium occurred in the Late Paleozoic. An angular unconformity at the base of Pennsylvanian-age strata is observed along the entire length of the structure. Seismic-reflection profiles across the Charleston monocline indicate that the entire Paleozoic sedimentary column (pre-Pennsylvanian) is folded and that the amount of structural relief does not change significantly with depth. High-angle reverse faults are documented at depth in several places along the southern part of the La Salle anticlinorium. The author's proprietary seismic-reflection profiles reveal faults on the west flank of the Lawrenceville dome, the east flank of the Bridgeport anticline, and the SW flank of the Hardinville anticline. These faults displace the top of Precambrian basement and overlying Cambrian strata, dying out at or below the Ordovician Knox Group. About 152 m (500 ft.) of displacement occurs on the basement surface of the Bridgeport anticline, and the largest fault on the Hardinville anticline has about 91–122 m (300–400 ft.) of throw. Based on borehole data in Cambrian sandstone at the northern part of the anticlinorium, several E-W-trending faults defining a graben are shown on the west side of the dome east of the Peru monocline. Borehole data in Coles County also indicate faulting in Mississippian strata near the west flank of Ashmore dome (a small dome near the southern end of the Murdock syncline). No orientations of these faults are reported. The author interprets the La Salle anticlinorium as the product of Late Paleozoic

Citation	Title	Description and Relevance to SSC
		displacements on high-angle reverse faults in crystalline basement that propagated upward to monoclines and asymmetrical anticlines in Paleozoic sedimentary cover. The faults could be classified as drape folds or fault-propagation folds. The complex arrangement of folds in the La Salle anticlinorium suggests a mosaic of faults in the basement of eastern Illinois.
Peru Monocline		
Heigold (1972)	Notes on the Earthquake of September 15, 1972, in Northern Illinois	Based on the proximity of this earthquake to the Peru monocline, this paper suggests that the earthquake was the result of faulting related to a zone of weakness near the region where the monocline merges with the Ashton anticline.
Herrmann (1979)	Surface Wave Focal Mechanisms for Eastern North American Earthquakes with Tectonic Implications	The 1972 earthquake occurred about 16 km (10 mi.) SE of the 1999 earthquake. A focal mechanism solution from the 1972 earthquake indicates movement on a high-angle strike-slip fault, either right-lateral to the N-NW or left-lateral to the E-NE.
Larson (2001) Larson (2002)	The Earthquake of September 2, 1999, in Northern Illinois: Big Lessons from a Small Earthquake The Earthquake of 2 September 1999 in Northern Illinois: Intensities and Possible Neotectonism	Descriptions of two recent earthquakes that have been associated with the Peru monocline: a September 1972 magnitude m_b 4.6 earthquake and a September 1999 magnitude m_b 3.5 earthquake. Within the precision of the seismographic data, the 1999 and 1972 earthquakes were located 5 and 13 km (3 and 8 mi.), respectively, below the Peru monocline. A third earthquake, which occurred May 27, 1881, also might be related to the Peru monocline, based on damage reports from La Salle, which sits directly on the structure, but an exact location for this earthquake is not known. The 2002 paper concludes that the spatial association of recent seismicity may suggest that Peru monocline is a reactivated Paleozoic structure.
Nelson (1995)	Structural Features in Illinois	Describes the Peru monocline, which lies within the northern La Salle deformation belt, as a 105 km (65 mi.) long NW-SE-trending fold belt in which the rocks dip steeply to the southwest into the Illinois basin. The structure is most prominent in La Salle County, where the relief on the SW limb is as much as 396 m (1,300 ft.). In some area coal mines, the coal beds dip 45° on the steep flank of the monocline. The Peru monocline is less pronounced to the northwest, where the relief decreases and the dip becomes very gentle as the structure merges with the Ashton anticline.

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Citation	Title	Description and Relevance to SSC
Du Quoin Moncline		
Marshak and Paulsen (1997)	Structural Style, Regional Distribution, and Seismic Implications of Midcontinent Fault-and-Fold Zones, United States	This paper includes the Du Quoin monocline within the broad southern La Salle deformation belt.
Nelson (1995)	Structural Features in Illinois	The Du Quoin monocline of southern Illinois trends N-S and warps Paleozoic strata down to the east. Normal faults of the Dowell and Centralia fault zones are coincident with the dipping flank of the fold, and displace strata down to the west. The paper reports that several high-resolution seismic lines across the Centralia fault zone indicate a normal fault dipping 70°–75° toward the west, affecting all reflectors down to Ordovician strata. Infers that the fault has undergone two episodes of movement. The greatest displacements on the structures took place during early to middle Pennsylvanian, with intermittent and lesser movements continuing into late Pennsylvanian and possibly Permian time. Post-Pennsylvanian extension and normal faulting occurred along the Centralia fault.
Su and McBride (1999)	Final Technical Report—Study of a Potential Seismic Source Zone in South-Central Illinois	This paper reports that low-resolution seismic-reflection data reveal a west-dipping reverse fault in the Precambrian basement beneath the monocline that cuts the top of the basement-cover contact. Faulting affects the upper Mississippian to Ordovician strata. The Centralia fault zone probably represents extensional reactivation of the basement structure beneath the Du Quoin monocline, and these structures likely connect at depth. The authors consider the Du Quoin monocline—and related Centralia fault—as a potential source for an earthquake that could have produced middle Holocene paleoliquefaction features in SW Illinois and possibly SE Missouri.
Tuttle, Chester, et al. (1999)	Paleoseismology Study Northwest of the New Madrid Seismic Zone	This paper, like Su and McBride (1999), considers the Du Quoin monocline, and related Centralia fault, as a potential source for an earthquake that could have produced middle Holocene paleoliquefaction features in SW Illinois and possibly SE Missouri. The conclusions are based on paleoliquefaction studies in southern Missouri and southern Illinois.

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Citation	Title	Description and Relevance to SSC
Louden Anticline		
Su and McBride (1999)	Final Technical Report—Study of a Potential Seismic Source Zone in South-Central Illinois	Reports that recent digital Vibroseis data over this feature, which is located directly NE of the Du Quoin monocline, reveals a major deep basement fault that projects to a depth of about 12 km (7.5 mi.) from the forward hinge point of the east-facing flexure of the dipping limb. A surface area of 252 km^2 (97 sq. mi.) for the fault is estimated based on the axial length of the anticline, 29 km (18 mi.), and the vertical length of the basement fault, 8.7 km (5.4 mi.). This associated basement fault may be a source structure for paleoliquefaction events.
Waterloo-Dupo Anticline		
Harrison and Schultz (2002)	Tectonic Framework of the Southwestern Margin of the Illinois Basin and Its Influence on Neotectonism and Seismicity	The Waterloo-Dupo anticline is a N-NW-trending asymmetrical anticline that has been interpreted to be a southern continuation of the Cap au Gres structures. Similar to the Cap au Gres structure, it experienced at least two periods of deformation: moderate folding in the Late Devonian and a major episode of folding during late Mississippian to early Pennsylvanian. Apparent offset of the Waterloo-Dupo anticline suggests right-lateral slip on the St. Louis fault. The authors conclude that this offset of the Waterloo-Dupo anticline is consistent with late Mississippian to early Pennsylvanian NE-SW compression.
Nelson (1995)	Structural Features in Illinois	The Waterloo-Dupo anticline has a steep western limb, >45° in places, and a gentle east limb. Slight post-Pennsylvanian folding may have occurred on the structure.
Tuttle, Chester, et al. (1999)	Paleoseismology Study Northwest of the New Madrid Seismic Zone	Based on the spatial distribution of prehistoric liquefaction features, the paper indicates that the Waterloo-Dupo anticline, Valmeyer anticline, and St. Louis fault are possible sources for paleoearthquake features observed in eastern Missouri, but also emphasizes that other scenarios relying on sources farther east are equally possible (i.e., on the Du Quoin monocline–Centralia fault).

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Citation	Title	Description and Relevance to SSC
Farmington Anticline		
Harrison and Schultz (2002)	Tectonic Framework of the Southwestern Margin of the Illinois Basin and Its Influence on Neotectonism and Seismicity	The Farmington anticline/Avon block is a broad (up to 19.3 km [12 mi.] wide) NW-trending low-relief structural feature that lies between Ste. Genevieve and Simms Mountain faults. Weak to moderate seismicity is clustered around this structure, which has been interpreted to occur above buried faults cutting middle Proterozoic basement rock. A zone of NW-trending horsts and grabens with subsidiary and contemporaneous NE-striking oblique-slip faults coincides with axis of the fold.
Peoria Folds		
Nelson (1995)	Structural Features in Illinois	Designates a series of subtle anticlines and synclines, originally identified in 1957, as the Peoria folds. Individual folds named are the Astoria, Farmington, Littleton, Bardolph, Brereton, St. David, Sciota, Seville, and Versailles anticlines and the Bryant, Bushnell, Canton, Elmwood, Fairview, Ripley, and Table Grove synclines; they were mapped from surface and subsurface data on various Pennsylvanian and Mississippian horizons. Nearly all strike slightly north of east. They are linear to slightly arcuate, with the convex side to the north. The folds plunge eastward, as does the regional dip. Most have less than 30 m (100 ft.) of structural relief. This paper notes the correspondence of these minor folds with topography, in particular the E-NE alignment of small streams. This is the only region in Illinois where topography appears to be so strongly influenced by bedrock structure through glacial drift. The source of the horizontal compression that may have formed these folds is unknown.
Sandwich Fault		
Kolata et al. (1978)	The Sandwich Fault Zone of Northern Illinois	The NW-trending Sandwich fault zone, which also lies within the northern La Salle deformation belt in NE Illinois, has a maximum vertical displacement of about 244 m (800 ft.).
Larson (2002)	The Earthquake of 2 September 1999 in Northern Illinois: Intensities and Possible Neotectonism	Notes that two historical earthquakes (in 1909 and 1912) may be associated with the Sandwich fault zone, and that these two earthquakes may indicate reactivation of a fault within the Precambrian basement associated with the Sandwich fault zone.

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Citation	Title	Description and Relevance to SSC
Nelson (1995)	Structural Features in Illinois	Movement along Sandwich fault zone may have been contemporaneous with formation of Peru monocline.
Plum River Fault Zone		
Bunker et al. (1985)	The Plum River Fault Zone and the Structural and Stratigraphic Framework of Eastern Iowa	Describes northward dips of late Quaternary loess-covered terraces along an ancient, south-flowing channel of Mississippi River where terraces cross Plum River fault zone. Although the northward dips could be interpreted as evidence of Quaternary slip on the fault zone, they could also be explained by terrace erosion and subsequent burial beneath a blanket of loess.
Crone and Wheeler (2000) Wheeler and Crone (2001)	Data for Quaternary Faults, Liquefaction Features, and Possible Tectonic Features in the Central and Eastern United States, East of the Rocky Mountain Front Known and Suggested Quaternary Faulting in the Midcontinent United States	Geologic evidence is insufficient to demonstrate Quaternary slip or deformation associated with the feature; therefore, the fault is characterized as non-Quaternary.
Nelson (1995)	Structural Features in Illinois	Plum River fault zone strikes E-W across NW Illinois and into NE Iowa. The author reports that primary movements on Plum River faults were post-Devonian and pre-Pennsylvanian. Structural relationships between Pennsylvanian strata and the fault zone preclude more than about 10 m (30 ft.) of post-Pennsylvanian movement.
Centralia Fault Zone		
Nelson (1995)	Structural Features in Illinois	Normal faults of Centralia fault zone are coincident with dipping flank of Du Quoin monocline and displace Paleozoic strata down to the west. The author reports that several high-resolution seismic lines across Centralia fault zone indicate a normal fault dipping 70°–75° toward the west, affecting all reflectors down to Ordovician strata. The author and Su and McBride (1999) infer that the zone has undergone two episodes of movement: reverse (west side up) during the Pennsylvanian to form Du Quoin monocline, and normal (west side down) after the Pennsylvanian.

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Su and McBride (1999)	Final Technical Report—Study of a Potential Seismic Source Zone in South-Central Illinois	Observes similar displacement of 30–49 m (100–160 ft.) for all levels imaged (upper Mississippian to Ordovician). The authors suggest that the Centralia fault zone represents extensional reactivation of the basement structure beneath the Du Quoin monocline, and that these structures likely connect at depth. Possible association of earthquakes located near the structural axis of the Centralia fault and Du Quoin monocline with focal mechanisms is consistent with strike-slip along north-trending structures. The Centralia fault zone may be the source of earthquakes that produced paleoliquefaction features in the region. Like Nelson (1995), this paper infers that the fault has undergone two episodes of movement: reverse (west side up) during the Pennsylvanian to form the Du Quoin monocline, and normal (west side down) after the Pennsylvanian.
Tuttle, Chester, et al. (1999)	Paleoseismology Study Northwest of the New Madrid Seismic Zone	In agreement with Su and McBride (1999), this paper suggests that the Centralia fault may be the source of earthquakes that produced paleoliquefaction features in the region.
Rend Lake Fault		
Nelson (1995)	Structural Features in Illinois	The Rend Lake fault zone parallels the west flank of the Benton anticline, which is located directly east of the Du Quoin monocline.
Su and McBride (1999)	Final Technical Report—Study of a Potential Seismic Source Zone in South-Central Illinois	Reports that seismic-reflection data indicate a pattern of basement-penetrating faulting in and near the Rend Lake fault zone that probably is a product of the same post-Pennsylvanian, E-W extensional stress regime that created the Centralia fault zone.
Cap au Gres Structure		
Harrison and Shultz (2002)	Tectonic Framework of the Southwestern Margin of the Illinois Basin and Its Influence on Neotectonism and Seismicity	Strikes of the axial surface of the fold and related faults range from N5°W to N85°W. The Cap au Gres structure, the north-striking Florissant dome, the Waterloo-Dupo anticline, and the Lincoln fold are all parts of the same deformational system. Although the feature has undergone recurrent movement, initial uplift occurred in Devonian and early Mississippian time. This paper summarizes studies related to the early deformational events on this structure. Based on kinematic indicators on faults and layer-parallel shortening associated with folding, the authors conclude that two episodes of deformation occurred along the Cap au Gres structure during

Table D-6.1.9 Data Summary
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Citation	Title	Description and Relevance to SSC
		the late Mississippian and earliest Pennsylvanian. The initial episode, which was relatively minor, resulted from N-S compression and produced extension along N-S segments of the structure. The next phase was a major episode of NE-SW compression that produced most of the deformational features along the structure. Following this period of deformation, some NW-striking segments of the structure were reactivated as high-angle normal faults. This deformation, which probably was of early Pennsylvanian age, appears to be the product of NW-SE maximum horizontal stress. The authors note that interpretation of possible deformation of Quaternary gravels (see Nelson, 1995, below) is tentative because of uncertainties in correlating individual erosional surfaces that may not represent contiguous or equivalent contacts, and the fact that the Grover Gravel occurs at various elevations.
Mateker and Segar (1965)	Gravity Investigation Along the Eastern Flank of the Ozark Uplift	Geophysical surveys (gravity) along the structure indicate that the faults are nearly vertical and extend at least several kilometers into the crust.
Nelson (1995)	Structural Features in Illinois	The Cap au Gres structure is a faulted monocline that exhibits an overall W-NW trend in Missouri and an E-W trend in Illinois. The north side has been raised as much as 366 m (1,200 ft.) relative to the south side. Various workers have concluded that this structure corresponds to a high-angle, north-dipping reverse fault in Precambrian basement rocks and the associated locally fractured fold near the surface. Apparent displacement of the Plio-Pleistocene Grover Gravel and its underlying peneplain indicates possible Tertiary tectonic activity on this structure. The gravel and underlying erosional surface on the south side of the flexure lie about 45.7 m (150 ft.) lower than on the north.
Eureka–House Springs Structure		
Clendenin et al. (1993)	Sequencing Reelfoot Extension Based on Relations from Southeast Missouri and Interpretations of the Interplay Between Offset Preexisting Zones of Weakness	Interprets Middle and Late Ordovician, Middle Devonian, and post-Mississippian episodes of deformation on the Eureka–House Springs structure, suggesting that it experienced a minimum of 10 km (6 mi.) of left-lateral strike-slip motion.

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Citation	Title	Description and Relevance to SSC
Harrison and Schultz (2002)	Tectonic Framework of the Southwestern Margin of the Illinois Basin and Its Influence on Neotectonism and Seismicity	This paper summarizes the various interpretations of the complex NW-striking Eureka–House Springs structure in eastern Missouri. The structure has been described as a doubly plunging anticline and associated faults or, alternatively, as three right-stepping en echelon fault segments. In addition, the Valmeyer anticline in Illinois may be an en echelon segment of the Eureka–House Springs structure. The general conclusion of this paper is that the zone may have originated as a Proterozoic structure and may extend north of the St. Charles lineament, although only those segments south of this lineament were reactivated at various times in the Phanerozoic.
Tuttle, Chester, et al. (1999)	Paleoseismology Study Northwest of the New Madrid Seismic Zone	Estimates of significant lateral strike-slip motion are considered tentative given the lack of piercing points and insufficient strike length for that displacement. The authors observe no clear evidence of recent fault activity associated with the Eureka fault system, but note that proximity to their Meramec River liquefaction site and the uncertainties regarding the exact nature of this structure may warrant additional study.
Ste. Genevieve Fault Zone		
Harrison and Schultz (2002)	Tectonic Framework of the Southwestern Margin of the Illinois Basin and Its Influence on Neotectonism and Seismicity	Detailed studies of this fault zone document contractional, extensional, and strike-slip movement along high-angle faults, as well as multiple periods of movement. The zone dies out near both the St. Charles and Commerce lineaments (see Midcontinent-Craton Data Summary Table), suggesting a genetic link and demonstrating the influence of these structural features on tectonism in the region. Deformation along this structure is correlative to the late Mississippian to middle Pennsylvanian tectonic episode identified elsewhere in the Midcontinent. The paper provides evidence for a period of extension probably of Late Pennsylvanian to Permian age. Detailed and reconnaissance mapping along the SGFZ for more than 75 years has revealed no evidence for Tertiary or Quaternary faulting.
Heigold and Kolata (1993)	Proterozoic Crustal Boundary in the Southern Part of the Illinois Basin	The fault may have originated as a crustal plate boundary or suture zone during the Proterozoic.

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Citation	Title	Description and Relevance to SSC
Nelson (1995) Nelson et al. (1997)	Structural Features in Illinois Tertiary and Quaternary Tectonic Faulting in Southernmost Illinois	The Ste. Genevieve fault zone (SGFZ) is mapped for approximately 193 km (120 mi.) along strike from SE Missouri into SW Illinois. It consists of numerous en echelon strands and braided segments having variable deformation styles and a complex history of reactivation. Displacement across the zone ranges from less than 198 m (650 ft.) to as much as 1,189 m (3,900 ft.). Detailed studies of this fault zone document contractional, extensional, and strike-slip movement along high-angle faults, as well as multiple periods of movement. In Illinois, compressional deformation is documented along the Ste. Genevieve fault in early Pennsylvanian rocks (Nelson, 1995). The later report, Nelson et al. (1997), however, indicates that some faults along the SE part of the SGFZ in Illinois displace Cretaceous and Tertiary sediments, but Quaternary deposits are not faulted.
Tuttle, Chester, et al. (1999)	Paleoseismology Study Northwest of the New Madrid Seismic Zone	Identifies soft-sediment deformation that could be related to low levels of ground shaking at one location along a strand of the fault. Diffuse seismicity occurs in the block between the SGFZ and Simms Mountain fault system. However, no evidence has been documented of any tectonic deformation of Quaternary deposits, nor has convincing evidence for paleoliquefaction been observed in this area.
Simms Mountain Fault System		
Clendenin et al. (1993)	Sequencing Reelfoot Extension Based on Relations from Southeast Missouri and Interpretations of the Interplay Between Offset Preexisting Zones of Weakness	Faults along the entire system were active in the late Cambrian as transfer faults related to Reelfoot rift extension.
Harrison and Schultz (2002)	Tectonic Framework of the Southwestern Margin of the Illinois Basin and Its Influence on Neotectonism and Seismicity	The Simms Mountain fault system in SE Missouri consists of numerous braided and en echelon fault strands that are continuous southward into the Cape Girardeau fault system. Together these fault systems extend more than 106 km (66 mi.), and in places reach as wide as 79 km (24 mi.). Left-lateral strike-slip movement occurred on the fault system, primarily before formation of Mississippi Valley–type ore deposits of Permian age, although some are later or of unknown age.

Table D-6.1.9 Data Summary
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Citation	Title	Description and Relevance to SSC
Bodenschatz-Lick Fault System		
Clendenin et al. (1993)	Sequencing Reelfoot Extension Based on Relations from Southeast Missouri and Interpretations of the Interplay Between Offset Preexisting Zones of Weakness	Similarities in strike, dip, and early Paleozoic history suggest that this fault system may be related to the Greenville fault, which has been interpreted as a major early Paleozoic extensional fault associated with the Reelfoot rift.
Harrison and Schultz (2002)	Tectonic Framework of the Southwestern Margin of the Illinois Basin and Its Influence on Neotectonism and Seismicity	The Bodenschatz-Lick fault system is a complex NE-striking zone that has been mapped for approximately 40 km (25 mi.) in SE Missouri and southern Illinois.
Tuttle, Chester, et al. (1999)	Paleoseismology Study Northwest of the New Madrid Seismic Zone	Two clusters of low-magnitude seismicity have been recorded by the New Madrid network near the SW part of the Bodenschatz-Lick fault system near its intersection with the Simms Mountain–Cape Girardeau fault systems. Field investigations in the areas of seismicity found no evidence of earthquake-induced paleoliquefaction in Holocene deposits.
Cape Girardeau Fault System		
Harrison and Schultz (2002)	Tectonic Framework of the Southwestern Margin of the Illinois Basin and Its Influence on Neotectonism and Seismicity	The Cape Girardeau fault system, which is a continuation of the Simms Mountain fault system, consists of numerous branching and anastomosing, dominantly NW-striking near-vertical faults. Although NE and N-NW-striking faults are less common, they appear to show evidence for the most recent deformation. There are rhomb-shaped pull-apart grabens related to strike-slip faulting that can be divided into three groups: (1) those that contain only Paleozoic rocks, (2) those that contain Upper Cretaceous and lower Tertiary formations, and (3) those that contain Quaternary strata. Unequivocal evidence of faulting of Quaternary gravel has been observed in a quarry and roadcut at the SE end of the fault system near its intersection with the Commerce geophysical lineament. Results of recent trenching show evidence for Quaternary faulting, possibly post-Sangamon in age. Unfaulted Peoria Loess (late Wisconsinan in age) and possibly Roxana Silt overlie the fault and graben fill. The authors interpret the Quaternary deformation to have formed under E-NE horizontal maximum principal stress. They favor erosion and fill as an alternative to the finding

Table D-6.1.9 Data Summary
Wabash Valley RLME

Citation	Title	Description and Relevance to SSC
		by Tuttle, Chester, et al. (1999) of a source of possible faulting in Quaternary gravel discovered on part of the Cape Girardeau fault system approximately 14.5 km (9 mi.) to the NW.
Wabash Valley Fault System		
Bear et al. (1997)	Seismic Interpretation of the Deep Structure of the Wabash Valley Fault System	This paper concludes that the fault system is not a northward continuation of the Reelfoot rift, because fault displacements of the WVFS decrease southward in the direction of the rift complex. Analysis of industry reflection data across the fault system indicates Cambrian fault movements as well as early Paleozoic dextral strike-slip along some of the faults.
Bristol and Treworgy (1979)	The Wabash Valley Fault System in Southeastern Illinois	Major structures within the Illinois portion of the Wabash Valley fault system are identified from interpretation of drillhole and downhole geophysical logs. The WVFS is about 90–100 km (55–60 mi.) long and as much as 48 km (30 mi.) wide. The faults of the WVFS outline elongate, gently tilted or arched horsts and grabens, with the axial part of the system down-faulted relative to the margins. Drillhole data indicate predominantly normal movement with vertical offset of as much as 146 m (480 ft.) along the faults that is post-late Pennsylvanian. The faults die out downward; some may reach basement but do not necessarily penetrate it.
Counts, Durbin, and Obermeier (2008)	Seismic Ground-Failure Features in the Vicinity of the Lower Wabash and Ohio River Valleys	Field trip guidebook that describes tectonically induced ground failures of Tertiary and Quaternary age in the lower Wabash River and Ohio River valleys of southern Illinois, SW Indiana, and western Kentucky.
Counts et al. (2009a)	Investigation of Quaternary Displacement on the Uniontown Fault, Western Kentucky	Paleoseismic investigations (trenching and boreholes) of a prominent north-trending scarp on the floodplain of the Ohio River suggest that the scarp is tectonic rather than erosional. The trench across the scarp exposed flat-lying floodplain strata east of the scarp and a 3 m (9.8 ft.) down-to-the-west monoclinal flexure at the scarp. The scarp displaces Quaternary sediment and thus represents Quaternary folding. Shallow seismic-reflection lines reveal faulting that extends from the Paleozoic bedrock, up into the Quaternary alluvium, to near the base of the scarp. The monoclinal flexure is interpreted to have formed as a consequence of underlying Quaternary reverse faulting. The fault, referred to as the Uniontown fault, is part of the Wabash Valley fault system. Movement on the Uniontown fault appears to have controlled the course of the Ohio River in a fashion similar to the New Madrid bend of the Mississippi River around the north-trending Reelfoot fault in SW Kentucky.

Table D-6.1.9 Data Summary
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Citation	Title	Description and Relevance to SSC
Counts et al. (2009b)	Paleoseismic Features Within the Wabash Valley Seismic Zones in Western Kentucky	Identifies several large clastic dikes in the banks of the Green River in Davies County. The largest was a weakly cemented gravel dike, 4–7 cm (1.6–2.8 in.) wide and 3.3 m (10.8 ft.) high, that was injected upward into silty floodplain deposits. The base of this dike penetrated clay bed containing 9,850 ± 70 yr BP wood, indicating that the earthquake occurred during the early to middle Holocene. A fault scarp 5 km (3 mi.) long was mapped in the Ohio River floodplain. The scarp trends north, faces west, and is 2.5 m (8.2 ft.) high at its southern end. Seismic-reflection profiles across the scarp show that faulting in the Paleozoic bedrock extends upward and offsets Quaternary sediments just below the base of the scarp. A monoclinal flexure 3 m (9.8 ft.) down to the west was exposed at the base of the scarp in a trench. Radiocarbon dates indicate that the strata were folded between 3,500 and 295 yr BP, so the scarp represents Holocene folding.
Fraser et al. (1997)	Geomorphic Response to Tectonically-Induced Ground Deformation in the Wabash Valley	In the restraining bend region along the western edge of the Commerce deformation zone, morphometric analysis of the land surface, detailed geologic mapping, and structural analysis of bedrock indicate west-dipping surfaces in the Wabash Valley.
Heigold and Larson (1994)	Geophysical Investigations of Possible Recent Ground Deformation and Neotectonism in White County, Illinois	At a locality in the lower Wabash Valley, the authors investigated two sites where suspected neotectonism and ground deformation were associated with historical seismicity. One of the sites experienced liquefaction during the 1811 New Madrid earthquake. The other was an escarpment (referred to as the Meadow Bank) along a projection of the Herald-Phillipstown fault zone. Vertical electrical soundings, seismic refraction profiling, resistivity profiling, and boreholes were used to evaluate the depth to Pennsylvanian bedrock across the escarpment. It was concluded that the escarpment probably formed as a result of erosion, possibly along the fault zone. The study found no evidence to support recent movement along preexisting or newly formed faults.
Nelson and Lumm (1987) Nelson (1995)	Structural Geology of Southeastern Illinois and Vicinity Structural Features in Illinois	The Wabash Valley fault system (WVFS) is a major zone of NE-trending, high-angle normal and strike-slip faulting along the border area of Illinois, Kentucky, and Indiana. These faults lie within and form the borders of the NE-trending Grayville graben. The WVFS includes the following faults: Albion-Ridgeway, Cottonwood, Herald-Phillipstown, Inman, Inman West, Inman East, Junction, Maunie, Mt. Carmel–New Harmony, North Fork, Pitcher Lake, and Ribeyre Island. The Grayville graben and WVFS are bounded to the south by the Rough Creek–Shawneetown fault system.

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Citation	Title	Description and Relevance to SSC
		The authors suggest that the WVFS most likely developed in the Early Permian and is therefore the same age as the Cottage Grove fault system. They note that individual faults within the zone are characterized by slightly arcuate segments that overlap. They also conclude that the WVFS does not cross the Rough Creek–Shawneetown fault zone. Based on previous interpretations of WVFS structures as primarily normal faults (Bristol and Treworgy, 1979), the conclusion of Nelson and Lumm (1987) is that the WVFS developed in response to W-NW and E-SE extension. Nelson (1995) proposes that the faults originated from a deformation episode that initially produced doming along a N-NE-trending axis.
Sexton et al. (1986)	Seismic Reflection Profiling Studies of a Buried Precambrian Rift Beneath the Wabash Valley Fault Zone	Based on interpretation of seismic-reflection profiles, this paper argues that the faults of the WVFS developed by reactivation of a Precambrian rift zone (Grayville graben) that was the northern extension of the Reelfoot–Rough Creek system. The paper also discusses regional and detailed gravity and magnetic anomaly data. Regional data sets had previously been used to infer the existence of a NE-trending rift beneath the Wabash Valley in SW Indiana and SE Illinois. Detailed gravity and magnetic profile data collected along the Wabash Valley seismic-reflection lines were also examined. Calculations of theoretical gravity anomalies associated with the locations of the Wabash Valley faults suggest that due to the small amplitude of the offsets, no identifiable anomalies would be expected in the detailed gravity anomaly data. Large, observed regional gravity and magnetic anomalies over the Wabash Valley fault area are almost certainly caused by density contrasts associated with the pre-Mt. Simon rocks and intrabasement sources.
Van Arsdale et al. (2009)	Quaternary Displacement Along the Hovey Lake Fault of Southern Indiana and Western Kentucky	A shallow S-wave seismic-reflection line acquired across the Hovey Lake fault in southern Indiana and western Kentucky reveals Paleozoic bedrock that is folded and normal faulted 10.5 m (34.4 ft.). The overlying Quaternary alluvium has 2 m (6.6 ft.) of reverse displacement at a depth of 5 m (16.4 ft.), thus revealing structural inversion. Although there is no surface scarp, a line of shallow borings, acquired across the seismically identified fault, indicates that the faulting may come to the surface. Trenching was not permitted at this site. Folding and faulting in Paleozoic bedrock and overlying Quaternary alluvium also was observed in a shallow S-wave seismic-reflection line that was acquired across a down-to-the-west scarp within the Hovey Lake fault system in western Kentucky. A trench exposed folded 3,500 yr BP Ohio River alluvium. The down-to-the-west fold, which has an amplitude of 3 m (9.8 ft.), is believed to have formed in response

Table D-6.1.9 Data Summary
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Citation	Title	Description and Relevance to SSC
		to underlying down-to-the-west Holocene fault displacement. Fractures within an undeformed unit that laps onto the scarp indicate that minor fault reactivation may have occurred within the last 295 years.
Wheeler et al. (1997)	Seismotectonic Map Showing Faults, Igneous Rocks, and Geophysical and Neotectonic Features in the Vicinity of the Lower Wabash Valley, Illinois, Indiana, and Kentucky	Describes possible neotectonic points in the lower Wabash Valley based on Heigold and Larson (1994).
Woolery (2005)	Geophysical and Geological Evidence of Neotectonic Deformation Along the Hovey Lake Fault, Lower Wabash Valley Fault System, Central United States	High-resolution seismic (shear-wave) reflection profiles collected along the Hovey Lake fault, a known Paleozoic fault within a system of faults in the southernmost Wabash Valley fault system in an area of recognized prehistoric and contemporary seismicity, show high-angle deformation extending above the Paleozoic bedrock and into Upper Quaternary sediment. Time-displacement calculations from the data show approximately 10.5 m (34.4 ft.) of offset on the top-of-bedrock horizon, located 7.7 m (25.3 ft.) below ground surface, suggesting fault movement at this site as late as ~37 ka.
Paleoliquefaction Studies (See also Table 6.1.9-1)		
Chester and Tuttle (2000)	Paleoseismology Study in the Cach River Valley, Southern Illinois	Six sand dikes were observed at four locations. The sand dikes range from 1 to 9 cm (0.4 to 3.5 in.) wide and pinch upward, extending to 1.1 m (3.6 ft.) above the water table or 2.4 m (7.9 ft.) below the top of the cutbank. Differences in weathering characteristics may indicate two generations of sand dikes. A radiocarbon date of AD 1020–1250 represents a maximum age for the younger generation, and possibly the older generation as well. The results are consistent with ground shaking of modified Mercalli intensity VIII-IX.
Counts et al. (2009b)	Paleoseismic Features Within the Wabash Valley Seismic Zones in Western Kentucky	Identifies several large clastic dikes in the banks of the Green River in Davies County. The largest was a weakly cemented gravel dike, 4–7-cm (1.6–2.8 in.) wide and 3.3 m (10.8 ft.) high, that was injected upward into silty floodplain deposits. The base of this dike penetrated clay bed containing 9,850 ± 70 yr BP wood, indicating that the earthquake occurred during the early to middle Holocene.

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Citation	Title	Description and Relevance to SSC
Green et al. (2005)	Engineering Geologic and Geotechnical Analysis of Paleoseismic Shaking Using Liquefaction Effects: Field Examples	This paper cites the assessment of the Vincennes paleoearthquake as a case study for implementing the methods outlined in Olson et al. (2005a) for assessing uncertainties in (1) the significance of changes in the geotechnical properties of post-liquefied sediments (e.g., aging and density changes); (2) the selection of appropriate geotechnical soil indices from individual paleoliquefaction sites; and (3) the methodology for integration of back-calculated results of strength of shaking from individual paleoliquefaction sites into a regional assessment of paleoseismic strength of shaking. Twelve sites that are at scattered locations in the Wabash Valley and that exhibit paleoliquefaction features are analyzed. The features are first provisionally attributed to the Vincennes earthquake, which occurred around 6,100 yr BP, and are used to illustrate the proposed approach for selecting representative soil indices of the liquefied sediments. These indices are used in back-calculating the strength of shaking at the individual sites, the results from which are then incorporated into a regional assessment of the moment magnitude, **M**, of the Vincennes earthquake. The regional assessment validated the provisional assumption that the paleoliquefaction features at the scattered sites were induced by the Vincennes earthquake, in the main, which was determined to have a magnitude of **M** ~ 7.5.
Hajic et al. (1995)	Distribution and Dating of Prehistoric Earthquake Liquefaction in Southeastern Illinois, Central U.S.	Presents results of a paleoliquefaction survey along streams in SE and central Illinois. A total of 127 paleoliquefaction sites are identified. Relatively wide dikes in the Sangamon and Kaskaskia river valleys at distances of 200 and 175 km (124.3 and 108.7 mi.) from Vincennes suggest either shaking from multiple sources or a noncircular distribution of features associated with the Vincennes earthquake. Stratigraphic, geomorphic, pedologic, archaeological, and preliminary radiocarbon evidence indicates that SE Illinois was shaken by substantial earthquakes at a minimum two, and possibly six, times in the past: possibly around 18,500 yr BP, around 6,100 yr BP, possibly around 3,750 yr BP, and during the 1811-1812 New Madrid earthquakes. Two additional Holocene earthquakes are possibly represented by liquefaction features along the Sangamon River (<9,200 yr BP) and lower Kaskaskia River.

Table D-6.1.9 Data Summary
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Citation	Title	Description and Relevance to SSC
Hajic and Wiant (1997)	Dating of Prehistoric Earthquake Liquefaction in Southeastern and Central Illinois	Presents results of an additional stream bank survey along reaches of Big Muddy, Miller, Mill, and Big creeks and an unnamed ditch in the Little Wabash Valley, all in SE Illinois. An additional stream bank survey along reaches of rivers and creeks in central and west-central Illinois and east-central Missouri resulted in negative evidence for any paleoliquefaction features, suggesting that the part of west-central Illinois north of St. Louis covered by these surveys was not struck by an earthquake of sufficient magnitude to cause liquefaction during the Holocene. The majority of paleoliquefaction observed in SE Illinois is attributable to the Vincennes earthquake. An earthquake near Mt. Auburn (subsequently referred to by McNulty and Obermeier (1999) as the Springfield earthquake) occurred after around 7,400 yr BP and before around 4,500 yr BP. Two other sites in Illinois are possibly attributable to the Skelton–Mt. Carmel earthquakes. Dikes at two SE Illinois sites most likely were emplaced about 19,800 ± 1,100 yr BP; these may be related to features observed in SW Indiana or they may be glaciotectonic.
McNulty and Obermeier (1999)	Liquefaction Evidence for At Least Two Strong Holocene Paleoearthquakes in Central and Southwestern Illinois	Discusses evidence for the timing and magnitude of two middle Holocene earthquakes in Illinois: the Springfield and Shoal Creek earthquakes. The Springfield earthquake occurred between 5,900 and 7,400 yr BP; dikes are as much as 0.4 m (1.3 ft.) in width near the presumed energy center about 35 km (21.7 mi.) NE of Springfield, Illinois; the magnitude is estimated to be at least **M** 6.2 and less than **M** 6.8. The Shoal Creek earthquake occurred around 5,700 yr BP; dikes probably extend approximately 35 km (22 mi.) from the energy center (assumed to be approximately 65 km, or 40.5 mi., E-SE of St. Louis, Missouri; dikes as wide as 0.5 m (1.6 ft.) are observed; the magnitude is estimated to be **M** 6.0 or greater.
Munson et al. (1997)	Liquefaction Evidence for Holocene and Latest Pleistocene in the Southern Halves of Indiana and Illinois—A Preliminary Overview	Identifies evidence for at least eight paleoearthquakes having magnitudes stronger than any in the historical era in southern Illinois and southern Indiana. At least six prehistoric earthquakes occurred during the Holocene and at least two others occurred during the latest Pleistocene. The two largest paleoearthquakes were centered in the lower Wabash Valley. The estimated magnitude of the largest earthquake, which occurred 6,100 ± 200 yr BP, is **M** 7.5–7.8. The next largest earthquake, an estimated **M** 7.1–7.3 earthquake, occurred 12,000 ± 1,000 yr BP. Two other paleoearthquakes likely had magnitudes of **M** ≥ 6.8. It is likely that liquefaction evidence has been discovered for all Holocene and latest Pleistocene paleoearthquakes with **M** ≥ 7 (radius of liquefaction effects > 50 km [31 mi.]) in southern Illinois and Indiana. However, in addition to the six or more **M** 6.0–7.0 earthquakes that have been discovered, numerous other earthquakes

Table D-6.1.9 Data Summary
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Citation	Title	Description and Relevance to SSC
		strong enough to potentially induce limited liquefaction could have struck other areas but, based on the lack of liquefiable deposits, left no evidence. In some parts of the southern halves of Indiana and Illinois, an earthquake with a potential radius of liquefaction effects of 30–40 km (18.6–25 mi.) could have struck without leaving liquefaction evidence.
Obermeier et al. (1993)	Liquefaction Evidence for One or More Strong Holocene Earthquakes in the Wabash Valley of Southern Indiana and Illinois, with a Preliminary Estimate of Magnitude	Provides criteria for interpreting an earthquake origin for dikes observed in the Wabash Valley. Concludes that virtually all of the dikes were formed by a single large earthquake that took place between 1.500 and 7.5 ka. The epicenter of the strongest earthquake(s) was near Vincennes, Indiana. The strength of the earthquake far exceeds the level of shaking and magnitude of the 1895 M 6.8 Charleston, Missouri, earthquake; the magnitude of the Vincennes earthquake appears to have been similar to that of the 1886 Charleston, South Carolina, earthquake (**M** ~ 7.5).
Obermeier (1998)	Liquefaction Evidence for Strong Earthquakes of Holocene and Latest Pleistocene Ages in the States of Indiana and Illinois, USA	Major conclusions outlined in this summary paper are as follows: • Virtually all dikes observed are from seismic liquefaction. Dikes were induced by prehistoric earthquakes whose energy centers (and epicenters) were almost exclusively in Indiana and Illinois (with the exception of some features in Cache Valley related to 1811-1812 New Madrid earthquakes). • Probably nine paleoearthquakes larger than historical earthquakes are identified, at least seven and probably eight Holocene earthquakes of which have a magnitude of **M** 6 or higher. • The largest, which occurred ~6,100 ± 100 yr BP, was on the order of **M** 7.5; the next largest (**M** ~ 7.1) occurred ~12,000 ± 1,000 yr BP. Three more had magnitudes of **M** > 6.5. • The two strongest were in proximity to each other and took place in the general vicinity of the most numerous and strongest historical earthquakes (**M** 4–5.5) in the lower Wabash Valley of Indiana and Illinois. Paleoearthquakes of lower magnitudes are more randomly distributed and have struck in regions having no significant historical seismicity. • Probably all earthquakes of **M** > 7 have been identified in Illinois and Indiana. • A significant number (10 or more) of moderate to strong paleoearthquakes (**M** 6–7) likely occurred during Holocene and latest Pleistocene time but are not recorded in paleoliquefaction record because of a lack of liquefiable deposits.

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Citation	Title	Description and Relevance to SSC
Olson et al. (2005a)	Geotechnical Analysis of Paleoseismic Shaking Using Liquefaction Effects: A Major Updating	Describes a new methodology proposed for the geotechnical analysis of strength of paleoseismic shaking using liquefaction effects. The proposed method provides recommendations for the selection of both individual and regionally located test sites, provides techniques for the validation of field data for use in back-analysis, and presents a recently developed energy-based solution to back-calculate paleo-earthquake magnitude and strength of shaking. The proposed method allows investigators to qualitatively assess the influence of post-earthquake density change and aging. The proposed method also describes how the back-calculations from individual sites should be integrated into a regional assessment of paleoseismic parameters.
Olson et al. (2005b)	Revised Magnitude Bound Relation for the Wabash Valley Seismic Zone of the Central United States	Provides a revised regional magnitude-bound curve for the central U.S. using a consistent site-to-source distance measure, a detailed review of liquefaction accounts resulting from historical earthquakes, and magnitude estimates for those historical earthquakes that have factored in data from recent seismological studies. Reassessed magnitudes for four paleoearthquakes in the Wabash Valley are approximately 0.5–0.7 magnitude units smaller than previously suggested. The revised magnitude estimates are **M** 7.3 (Vincennes earthquake), **M** 6.7 (Skelton earthquake), **M** 6.3 (Vallonia earthquake), and **M** 6.2 (Waverly earthquake).
Olson et al. (2007)	Quantifying Uncertainties in Paleoliquefaction Studies	A preliminary **M** 7.99 ± 0.27 is estimated for the Vincennes paleoearthquake (around 6,100 yr BP) using simplified and rigorous statistical and probabilistic methods to quantify uncertainties in liquefaction susceptibility (aging and density change, liquefaction severity, fines content adjustment, and overburden stress correction); field data quality (field observations and in situ test measurement, ground failure mechanism, and field setting); seismicity and seismic demand (attenuation relationships, magnitude scaling factor, depth reduction factor, and local site response); and a Bayesian updating framework that uses the magnitude bound method to estimate a prior distribution,.
Pond and Martin (1997)	Estimated Magnitudes and Accelerations Associated with Prehistoric Earthquakes in the Wabash Valley Region of the Central United States	Presents results of a geotechnical study of soil conditions at paleoliquefaction sites to estimate both the magnitude and accelerations of four prehistoric earthquakes. Using an energy-stress approach, the geotechnical and seismological estimates of surface accelerations suggest **M** 6.9 (Waverly earthquake), **M** 7.1 (Vallonia earthquake), **M** 7.3 (Skelton earthquake), and **M** 7.8 (Vincennes earthquake).

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Citation	Title	Description and Relevance to SSC
Su and McBride (1999)	Final Technical Report—Study of a Potential Seismic Source Zone in South-Central Illinois	Discusses interpretation of reprocessed seismic-reflection profiles across the Du Quoin monocline–Louden anticline region and paleoliquefaction reconnaissance along 90 km (56 mi.) of the Big Muddy River and its tributaries in the vicinity of these structures. No new paleoliquefaction features were observed, but this may be due to lack of liquefiable sediments. The report concludes that all previously recognized paleoliquefaction features in the study region could be induced by earthquakes on the Du Quoin monocline–Louden anticline structures.
Tuttle, Chester, et al. (1999)	Paleoseismology Study Northwest of the New Madrid Seismic Zone	The results of this study are summarized and updated in Tuttle (2005b); see below.
Tuttle (2005b)	Paleoseismological Study in the St. Louis Region: Collaborative Research	This paper summarizes and updates observations reported by Tuttle, Chester, et al. (1999). At least two generations of Holocene earthquake-induced liquefaction features, including sand and silt dikes and sills, and only two sand blows, are identified in the St. Louis region. Some features probably formed during the 1811-1812 or earlier New Madrid earthquakes, and others formed during a middle Holocene earthquake in 4520 BC ± 160 years. Late Holocene sand dikes, up to 26 cm (10.2 in.) in width, occur along the Kaskaskia River and its tributaries, Crooked, Shoal, and Silver creeks, as well as along Cahokia and Piasa creeks and the Cache, Castor, Marys, and Meramec rivers. The 4250 BC earthquake may or may not have been responsible for all of the middle Holocene features. The relatively large size of features identified near Germantown, Illinois, suggests that the earthquake source may be located east of St. Louis. Alternative sizes and locations are suggested. The Meramec River features could have formed as a result of a moderate-to-large earthquake centered in the St. Louis area or a very large earthquake centered 80–100 km (50–62 mi.) east of St. Louis.
Seismicity		
Bakun and Hopper (2004a)	Catalog of Significant Historical Earthquakes in the Central United States	Modified Mercalli intensity assignments are used to estimate source locations and moment magnitude **M** for 18 nineteenth-century and 20 early twentieth-century earthquakes in the central U.S. for which estimates of **M** are otherwise not available. There has been persistent seismic activity in the Illinois basin in southern Illinois and Indiana, with **M** > 5.0 earthquakes in 1895, 1909, 1917, 1968, and 1987. Historical earthquakes (pre-1952) in the Illinois basin have been associated with the Wabash Valley fault zone, the Cottage Grove fault zone, the Du Quoin monocline, the Ste. Genevieve fault zone, and the La Salle anticlinorium.

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Citation	Title	Description and Relevance to SSC
Hamburger et al. (2008)	Geodetic Observations from the Region Surrounding the M 5.2 Mt. Carmel, Illinois Earthquake	The April 18, 2008, M 5.2 earthquake was located close to the New Harmony fault at ~14 km (~8.7 mi.) depth. Analysis of GPS data suggests systematic NW motion of about 0.5–0.7 mm/yr with respect to the Stable North American Reference Frame. Block models, which assume boundaries along the Cottonwood Grove–Rough Creek Graben (CGRCG) and the WVFS, indicate marginal block velocities with possible strike-slip motion along the WVFS, and E-W motions along the CGRCG.
Hamburger et al. 2009)	Is There a Connection Between Seismicity and Deformation in the New Madrid and Wabash Valley Seismic Zones?	Comparison of geodetic and geophysical data between WVSZ and NMSZ. In both cases, regional seismic and potential field data provide evidence for high-angle, basement-penetrating faults that define narrow, elongate Precambrian grabens that lie beneath relatively undeformed Paleozoic or Mesozoic rocks. Data from a 56-site-campaign GPS geodetic network in the southern Illinois basin indicate systematic NW motion of about 0.5–0.7 mm/yr with respect to the Stable North American Reference Frame. Average results for the entire network show marginally significant strains, with an orientation rotated 45° from the overall direction of intraplate stress in the U.S. Midcontinent.
Kim (2003)	The 18 June 2002 Caborn, Indiana, Earthquake: Reactivation of Ancient Rift in the Wabash Valley Seismic Zone?	The June 18, 2002, M_w 4.6 earthquake occurred on a steeply dipping fault at a depth of about 18 km (11.2 mi.; better than ±2 km—or ±1.2 mi.—horizontal and vertical location accuracy). The source mechanism determined from regional waveform analysis is predominantly strike-slip along near-vertical nodal planes (dips 82° and 84°) striking 28° and 297°. The close proximity of the epicenter to the trace of the Caborn fault, and good agreement between the strike and dip of that fault and source mechanism for the June 18, 2002, earthquake suggest that the earthquake occurred on that fault. This earthquake may suggest that buried faults associated with a possible Precambrian rift system are being reactivated by the contemporary E–E-NE-trending regional horizontal compressive stress.
Larson et al. (2009)	Analysis of Effects from the April 18, 2008 Illinois Earthquake	Analyzes the April 18, 2008, M 5.4 earthquake that occurred in the Wabash Valley seismic zone at depth of 11.6 km (7.2 mi.). The earthquake was located in a mature oil and coal production region; E-W elongation of the Intensity IV and higher regions. Some of the E-W elongation may be attributed to the E-W focal mechanism of the earthquake, whereas other patterns coincide with major river channels (soil amplification) and a geologic structure.

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Citation	Title	Description and Relevance to SSC
McBride et al. (2007) McBride, Hildenbrand, et al. (2002)	Deep Faulting and Structural Reactivation Beneath the Southern Illinois Basin Interpreting the Earthquake Source of the Wabash Valley Seismic Zone (Illinois, Indiana, and Kentucky) from Seismic Reflection, Gravity, and Magnetic Intensity	Seismotectonic implications described above (Basement Structure section). McBride, Hildenbrand, et al. (2002) provide a table summarizing depths and magnitudes for instrumentally recorded earthquakes of the Wabash Valley seismic zone (m_{bLg} 3.1–5.2) that range from 4.9 ± 14.1 km (3 ± 8.8 mi.) to 23.4 ± 2.1 km (14.5 ± 1.3 mi.).
Withers et al. (2009)	Introduction and Background for the April 18, 2008 Illinois Earthquake	Discusses the April 18, 2008, Mt. Carmel, Illinois, earthquake, the largest earthquake in the Wabash Valley seismic zone in the past 20 years. The earthquake took place near Mt. Carmel, Illinois; the magnitude was M_w 5.2 (M_w 5.4 according to GCMT [http://www.global cmt.org]); a relatively long-lasting aftershock sequence included 37 earthquakes located by the network, with 3 earthquakes greater than magnitude 4).
Yang et al. (2009)	Determination of the Fault Plane for the April 18, 2008 Illinois Earthquake by Detecting and Relocating Aftershocks	Analysis of aftershocks using the sliding-window cross-correlation technique and the double-difference relocation algorithm gives a best-fit plane having a nearly E-W trend with an orientation of 248 and a dip angle of 81. The fault is nearly vertical down to ~20 km (~12.4 mi.).
Seismic Hazard Models		
Petersen et al. (2008)	Documentation for the 2008 Update of the United States National Seismic Hazard Maps	Although the Wabash Valley region in southern Indiana and Illinois is part of the craton, M 7.5 is used for Mmax there, based on the distribution of paleoliquefaction features resulting from past large earthquakes.
Wheeler and Cramer (2002)	Updated Seismic Hazard in the Southern Illinois Basin: Geological and Geophysical Foundations for Use in the 2002 USGS National Seismic-Hazard Maps	Based on estimates of the magnitudes (**M** 7.1 and **M** 7.5) of prehistoric earthquakes in the southern Illinois basin, this paper outlines three alternative source configurations that can be combined in a logic tree: the oval tri-state seismicity source zone that is centered on the two energy centers; a narrow source zone that follows the Vincennes bend in the Commerce geophysical lineament; and the Grayville graben. Mmax is set at 7.5 inside each alternative source.

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Initiation of Iapetan Rifting		
Abdel-Rahman and Kumarapeli (1998)	Geochemistry of Mantle-Related Intermediate Rocks from the Tibbit Hill Volcanic Suite, Quebec Appalachians	Major and trace-element geochemistry of intermediate volcanic rocks of the Tibbit Hill volcanic suite provide evidence for anorogenic A1 type suites, consistent with the earlier interpretation of an Iapetan triple junction. Trace-element modeling suggests that these intermediate magmas were produced by up to 20% fractional crystallization of alkaline to transitional basaltic melts, representing differentiates of basalts related to hotspot plumes or continental rift zones. The authors also suggest that the intermediate rocks of the Tibbit Hill volcanic suite are comagmatic and coeval with the Adirondack dike swarm and formed shortly before the onset of seafloor spreading.
Abdel-Rahman and Kumarapeli (1999)	Geochemistry and Petrogenesis of the Tibbit Hill Metavolcanic Suite of the Appalachian Fold Belt, Quebec–Vermont: A Plume-Related and Fractionated Assemblage	Presents the geochemistry of the Tibbit Hill mafic to felsic volcanic assemblage based on data presented in previous studies. The study concludes that the mafic basalts from the Tibbit Hill volcanic suite crystallized from basaltic magma produced by approximately 2.5% batch partial melting of garnet lherzolite with a final basaltic melt segregation depth of 80–100 km (50–62 mi.), which is consistent with melting within a rising mantle plume below the Sutton Mountains triple junction. Twenty-five percent fractionation of these basaltic magmas produced the intermediate melts. The Adirondack dike swarm is geochemically similar to the Tibbit Hill basalt and both differ from the geochemically depleted Grenville dike swarm, suggesting that Tibbit Hill (and therefore the Adirondack dike swarm) represent the youngest, pre-breakup, extension-related volcanism prior to the initiation of seafloor spreading. This paper does not consider the results of other Iapetan volcanics in the region—specifically, the work of McCausland and Hodych (1998).
Bédard and Stevenson (1999)	The Caldwell Group Lavas of Southern Quebec: MORB-Like Tholeiites Associated with the Opening of Iapetus Ocean	Trace-element and Nd isotopic data were obtained for the Caldwell Group lavas of southern Quebec. These undated rocks, which belong to the internal nappe domain of the Humber zone, were deformed during the Taconic orogeny. These rocks initially formed at an advanced stage in the transition from rift to drift along the Iapetan margin. Despite exhibiting clear evidence of hydrothermal alteration, several conclusions were inferred from the geochemistry of these basalts. These basalts crystallized from melts derived from normal mid-ocean ridge basalt (MORB) at low to medium pressure

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		fractional crystalization. Most lavas represent about 20% melting from a source slightly less depleted than fertile MORB mantle (asthenospheric mantle), whereas subpopulations of the Caldwell lavas are characterized by 6%–15% melting of the same source mantle. These data are substantiated by Nd-isotope data that indicate derivation from a light rare-earth-element-depleted mantle that is more radiogenic than other Iapetus basalts, implying that other basalts in the region were derived from a more enriched source. Sedimentary samples reflect a mixture of old (Archean) and juvenile (Iapetan) crustal sources for the basin.
Cawood et al. (2001)	Opening Iapetus: Constraints from the Laurentian Margin in Newfoundland	Evaluates the age relationships of the Skinner Cove Formation (550.5 +3/–2 Ma), the Lady Slipper pluton (555 +3/–5 Ma), and the youngest marine carbonate sediments (540–535 Ma) interpreted as the rift drift transition from within the Humber zone of the Appalachian orogen in Newfoundland. Compares these age relationships with the paleomagnetic data of McCausland and Hodych (1998) and data for other igneous activity on the eastern margin of Laurentia. Attributes these data to a two-stage rifting process along the eastern margin of Laurentia. Igneous activity 760–700 Ma in the Appalachian Blue Ridge corresponds with the opening of the proto-Pacific between East Australia / West Antarctic conjugate margins. The younger set of igneous activity observed in eastern Laurentia between 620 and 550 Ma involves rifting and separation of Laurentia from the West Gondwana cratons corresponding to the closure of the Mozambique Ocean and assembly of East and West Gondwana; initiation of subduction of the proto-Pacific beneath East Gondwana; and rifting of Baltica and Siberia from Laurentia and Gondwana. The Iapetus Ocean was initiated between Laurentia and Gondwana by 570 Ma, while Baltica had already separated from Laurentia. A proto-Pacific spreading center may have also propagated at that time.
Faill (1997a)	A Geologic History of the North-Central Appalachians. Part 1. Orogenesis from the Mesoproterozoic Through the Taconic Orogeny	Crustal extension and rifting late in the Neoproterozoic and into the earliest Cambrian separated the Neoproterozoic supercontinent Rodina into East Gondwana, West Gondwana, and Laurentia. This rifting event resulted in the development of the St. Lawrence rift system. The breakup of Rodinia spanned approximately 200 Myr, with separation of East Gondwana from western Laurentia approximately 750 million years ago and rifting of eastern Laurentia from West Gondwana resulting in the opening of several intervening oceans.

Citation	Title	Description and Relevance to SSC
		The Iapetus Ocean was initially defined as the early Paleozoic ocean between Baltica and Laurentia (Greenland); the Theic Ocean was defined as the ocean between Laurentia and Gondwana; and the Rheic Ocean between Baltica and Gondwana. Emphasizes that the subsequent usage of the name "Iapetus" to refer to the Paleozoic ocean off the Laurentia east margin became nearly universal, and that *sensu stricto* the Iapetus Ocean was closed in the Late Silurian Caledonia orogeny during the docking of Avalonia microcontinents with Laurentia. The remaining ocean that lay east of Avalonia is generally called Theic, leading the author to recognize the Paleozoic ocean east of Laurentia as Theia. This discussion uses the name Iapetus as given by various authors cited by Faill (1997a), recognizing the distinction between these three Paleozoic oceans.
Higgins and van Breemen (1998)	The Age of the Sept Iles Layered Mafic Intrusion, Canada: Implications for the Late Neoproterozoic/Cambrian History of Southeastern Canada	Authors obtained U-Pb ages of 565 ± 4 Ma for the Sept Iles layered mafic pluton located on islands and peninsulas of the Gulf of St. Lawrence. Combining these results with other published ages for Neoproterozoic to Cambrian igneous rocks from the Laurentian margin suggests three phases of magmatism: 1. Tholeiitic dike emplacement was diachronous along the Laurentian margin: the Long Range dike swarm in Newfoundland was dated at 615 ± 2 Ma over a distance of 400 km (249 mi.; Kamo et al., 1989); Grenville dike swarm formed synchronously with the Ottawa graben at 590 +2/–1 Ma over a distance of 400 km (249 mi.; Kumarapeli, 1993; Kamo et al., 1995). These dike swarms may have been produced by one or two mantle plumes between 615 and 590 Ma, possibly one at Sept Iles. 2. Following dike emplacement, alkaline plutons intruded into a relatively large region spanning Quebec, Ontario, Greenland, and Scandinavia as early as 578 Ma and as late as the Sept Iles intrusion (565 Ma). The authors attribute these plutons to a major plume and triple junction located at Sept Iles instead of the location below the Sutton Mountains proposed by Kumarapeli (1993), but acknowledge that the two dike swarms could be the result of two mantle plumes separated by 25 Myr. The authors also observe that the alkaline plutons were intruded along rift faults that developed after the emplacement of dikes. 3. Undated diabase dikes and metabasaltic flows occur throughout the

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		Northern Appalachians, indicating the earliest stages of the formation of the Iapetus Ocean. Tholeiitic lavas of the Tibbit Hill Formation have U-Pb zircon ages of 554 +4/–2 Ma (Kumarapeli et al., 1989), and alkaline volcanic rocks at Skinners Cove, Newfoundland, have U-Pb ages of 550 +3/–2 Ma (McCausland et al., 1997).
Hodych and Cox (2007)	Ediacaran U-Pb Zircon Dates for the Lac Matapédia and Mt. St.-Anselme Basalts of the Quebec Appalachians: Support for a Long-Lived Mantle Plume During the Rifting Phase of Iapetus Opening	U-Pb zircon ages for the Lac Matapédia basalt (565 ± 6 Ma and 556 ± 5 Ma) and the Mt. St.-Anselme basalt (550 ± 7 Ma) support the interpretation of a long-lived Sutton Mountains mantle plume. These data close the gap between the end of flood basalt and the beginning of plume magmatism and support a rift-drift transition at 540 Ma as opposed to 570 Ma (McCausland and Hodych, 1998). This hypothesis implies that Laurentia drifted northward more slowly than was suggested by McCausland and Hodych (1998).
Kamo et al. (1995)	Age of the Grenville Dyke Swarm, Ontario–Quebec: Implications for the Timing of Iapetan Rifting	Improves the geochronology of the Grenville dike swarm by obtaining U-Pb baddeleyite ages from the widest dikes throughout the Ottawa graben. These results give an age of 590 Ma, implying that the Grenville dike swarm was emplaced within a relatively short time span. These dikes are thought to have formed at the onset of rifting within the Ottawa graben, the Sutton Mountains triple junction, and the related segment of the Iapetan margin. Comparison with ages of similar rift-related igneous rocks along the Iapetan margin of Laurentia, including the Bakersville dike swarm of the Blue Ridge (570 Ma), Franklin swarm of northern Canadian Shield (723 Ma), and Long Range dikes of SE Labrador and Newfoundland (615 Ma), indicate that Iapetan rifting occurred along vast distances of the northern and eastern margins of Laurentia. The timing of initial rifting within the Ottawa graben is somewhat earlier than other parts of North America, suggesting that rift initiation progressed from the northern Laurentia margin at 723 Ma to Labrador and Newfoundland at 615 Ma, followed by the Grenville dike swarm at 590 Ma.

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Citation	Title	Description and Relevance to SSC
Kumarapeli (1985)	Vestiges of Iapetan Rifting in the Craton West of the Northern Appalachians	Proposes that a mantle plume produced the initial ruptures of Iapetan rifting along a triple junction that led to continental fragmentation and the development of an aulacogen in the Ottawa graben. Carbonatite complexes of the Ottawa and Saguenay grabens with ages of 565 and 564 Ma, respectively, support the view that these two rifts formed as parts of a single event. Alkaline to transitional bimodal volcanic rocks of the Tibbit Hill volcanics are deposited within the Sutton Mountains salient, east of the Ottawa graben, and are thought to be coeval with the Grenville dike swarm within the Ottawa graben. Interprets the Sutton Mountains as the triple junction that initiated Iapetan rifting.
Kumarapeli (1993)	A Plume-Generated Segment of the Rifted Margin of Laurentia, Southern Canadian Appalachians, Seen Through a Completed Wilson Cycle	Improves upon the model presented by the author in 1983 with the addition of geochronology of dike swarms and volcanic rocks. Proposes that initiation of rifting was accompanied by the emplacement of the 590 Ma Grenville mafic dike swarm of tholeiitic composition. Rifting continued for 35 million years until 554 Ma when alkaline to transitional basalts erupted at the Sutton Mountains triple junction. This was quickly followed by a short period of rift-facies clastic sedimentation consisting of conglomerates attributed to a large river delta. The rift-drift transition is indicated by the deposition of open marine sedimentation, thought to have occurred 550 Ma because of the presence of early Cambrian fauna above this transition.
Kumarapeli et al. (1988)	Volcanism on the Passive Margin of Laurentia: An Early Paleozoic Analogue of Cretaceous Volcanism on the Northeastern American Margin	Transitional to alkaline basalts and mid-ocean ridge basalts (MORBs) found within the Granby nappe of SE Quebec provide evidence for late Cambrian to Early Ordovician volcanism within transverse fracture zones analogous to Early Cretaceous volcanism in the Atlantic. The authors acknowledge that this data set is not sufficient to determine whether the volcanism took place during the drifting phase of the continental margin, because the precise age of these rocks is not known. These allochthonous blocks are thought to represent slabs dislodged from the ancient shelf-margin sequence, possibly by faults of the Ottawa graben in addition to NE-trending faults.

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Citation	Title	Description and Relevance to SSC
McCausland and Hodych (1998)	Paleomagnetism of the 550 Ma Skinner Cove Volcanics of Western Newfoundland and the Opening of the Iapetus Ocean	Authors obtained paleomagnetic data for volcanic flows and volcaniclastic sediments of the Skinner Cove Formation in western Newfoundland dated at 550 Ma that point to a paleolatitude of 19°S ± 9°. This result represents the paleolatitude of the Iapetan margin at that time. Comparison of these results to the 577 Ma Callander Complex of Ontario indicates rapid northward drift of Laurentia at approximately 570 Ma resulting from the opening of the Iapetus Ocean, which continued to the rift drift transition at approximately 550 Ma.
Puffer (2002)	A Late Neoproterozoic Eastern Laurentian Superplume: Location, Size, Chemical Composition, and Environmental Impact	Compiles a database of high field-strength elements for late Neoproterozoic to early Paleozoic flood basalts and dike swarms in eastern North America. Displaying these results on spider diagrams normalized to the bulk composition of the earth confirms that these rocks are derived from a mantle plume. The spatial distribution of these data reveals a peak concentration at the inferred Sutton Mountains triple junction, indicating that superplume magmatic activity peaked at 550 Ma. A second, earlier population of less geochemically enriched melts was derived from a subcontinental lithospheric mantle source mixed with mantle from a plume source. These older rocks (615–564 Ma) represent early lavas extruded from rifts, consistent with the early stages of mantle plume upwelling. The author favors the interpretation that these rocks are the result of one superplume as opposed to two plumes.
Ratcliffe (1987)	Basaltic Rocks in the Rensselaer Plateau and Chatham Slices of the Taconic Allochthon: Chemistry and Tectonic Setting	Tholeiitic to transitional alkaline basalts flows, sills, and metasedimentary rocks represent a restricted period of basaltic volcanic activity associated with Iapetan rifting. These volcanic rocks are interbedded with greywacke interpreted as turbidite fan complexes extending into deeper water. These assemblages are thought to form as short-lived rift-stage volcanics on a structurally evolving cratonic margin. The author proposes that these rocks formed in a fault-controlled continental margin with high relief and a narrow shoreline. Continental flood basalts capped the basement rocks, with flows erupting through local fissures into the water, and flowed onto greywacke fans.
St. Seymour and Kumarapeli (1995)	Geochemistry of the Grenville Dyke Swarm: Role of Plume-Source Mantle in Magma Genesis	Confirms a mantle source for the synrift Grenville dike swarm, suggesting that the triple junction formed over a mantle plume, with dikes crystallizing from melts derived from the cooler plume head.

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Citation	Title	Description and Relevance to SSC
Walsh and Aleinikoff (1999)	U-Pb Zircon Age of Metafelsite from the Pinney Hollow Formation: Implications for the Development of the Vermont Appalachians	U-Pb zircon age of 571 ± 5 Ma for metafelsite from the Pinney Hollow Formation of Vermont records the age of rhyolitic volcanism and deposition in a largely pelitic sequence interpreted as a pre-shelf rift-clastic sequence. This age agrees with other ages from rift-clastic volcanic rocks in the Appalachians. The relative distribution and thickness of metavolcanic and metafelsic sections throughout the Appalachians suggest that the basin that the Pinney Hollow Formation was deposited into was already well developed when the 571 Ma metafelsite was deposited. Therefore, the 554 Ma age for the Tibbit Hill volcanic suite at the Sutton Mountains triple junction does not represent the first pulse of volcanic activity during the initial opening of the Iapetan basin in the Vermont and Quebec Appalachians. This age also validates that the Wood Peak fault is a significant thrust fault separating the autochthonous and para-autochthonous cover sequence rocks, which supports the interpretation that the Taconic root zone is located in the hinterland of the Vermont Appalachians on the eastern side of the Green Mountain massif.
Faulting in St. Lawrence		
Faure et al. (1996b)	State of Intraplate Stress and Tectonism of Northeastern America Since Cretaceous Times, with Particular Emphasis on the New England–Quebec Igneous Province	Along the Ottawa-Bonnechere graben, E-W-trending Cretaceous normal faults mark the contact between Paleozoic rocks to the south and Grenvillian basement to the north. The NE-SW-directed extension associated with NW-SE-trending normal faults is more widespread and older than the N-S-directed extension associated with E-W-trending normal faults. The Ottawa-Bonnechere graben and associated basement faults acted as localized zones of weakness in the early stage of Cretaceous extension, resulting in reorientation of the regional stress field and formation of the localized zone of N-S-directed extension.

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Citation	Title	Description and Relevance to SSC
Kumarapeli and Saull (1966)	The St. Lawrence Valley System: A North American Equivalent of the East African Rift Valley System	Proposes a rift origin for the St. Lawrence valley system, including the Ottawa-Bonnechere and Saguenay grabens. Evidence supporting this conclusion includes the following: • Escarpments on the NW side of the St. Lawrence valley, north side of the Ottawa Bonnechere graben, and western margin of the Champlain valley. • South of the Ottawa-Bonnechere graben, tilting of the Madawaska Highlands to the south, NW tilting of the Adirondack massif, north tilting of a Laurentian block south of the Saguenay graben, and south block tilting of the Gaspé Peninsula. • En echelon normal faults along the NW boundary with vertical displacements between 450 and 1,200 m. • St. Barnabe fault is a 55 km (34 mi.) normal fault on the SE margin with 600 m of downthrow to the west. • Concentrations of historical seismicity along the St. Lawrence and Ottawa valleys and the St. Lawrence trough. • Presence of a negative Bouguer anomaly in the rift valley. • Connection of the St. Lawrence valley with the Mississippi embayment. • Westward continuation of the Ottawa-Bonnechere graben with the Midcontinent rift system. Because the publication pre-dated plate tectonics, many aspects of the authors' ideas are not consistent with current tectonic models of the region. After comparing St. Lawrence rift system to East African rift system, the authors suggest the Great Lakes may be analogous to Lakes Victoria and Kyoga. The authors also associate Monteregian alkaline intrusives with St. Lawrence valley. Recent work associates this with Cretaceous instrusion associated with reactivation of the Ottawa-Bonnechere graben. .

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Citation	Title	Description and Relevance to SSC
Lamontagne et al. (2003)	Seismotectonic Characteristics of the Lower St. Lawrence Seismic Zone, Quebec: Insights from the Geology, Magnetics, Gravity, and Seismics	Reviewed the seismotectonic model of the lower St. Lawrence seismic zone from focal depths, focal mechanisms, gravity and magnetic data, offshore seismic lines, and mapped onshore geology. Concluded that seismicity is generally located where regional Iapetan and later faults change orientation from SW-NE to mostly E-W. Based on the correlation of seismicity with faults and geopotential lineaments, small earthquakes are thought to have occurred in fractured rock as opposed to large normal faults. Localized seismicity of the lower St. Lawrence seismic zone may be the result of enhanced stress due to a number of factors, including change in regional fault strike, mafic rocks of the Sept Iles layered igneous complex, presence of fluids at depth, and low coefficient of friction where fault gauge exists.
Lemieux et al. (2003)	Structural Analysis of Supracrustal Faults in the Charlevoix Area, Quebec: Relation to Impact Cratering and the St-Laurent Fault System	Two major sets of fault orientations (N290–N320 and N020–N040) are found outside the impact zone with minor fault sets trending N270–N280 and N000–N020. Within the impact crater, fault orientations are more scattered but are similar to the NW- and NE-trending systems of the external domain. The spread of orientations within the central portion of the crater is attributed to the impact-related polygonal pattern of normal faults, whereas the NW and NE fault sets represent the youngest reactivation. Coarse-grained cataclastic breccias up to 50 m thick are exposed along brittle faults striking NE and NW outside the impact crater. Similar cataclastic breccias are also found within the impact crater but are usually less than a few meters thick. Polymictic clastic matrix breccia is found exclusively within the impact crater. Fragments of cataclastic breccia are present, suggesting recurrent brecciation during incremental faulting events. Pseudotachylyte and foliated gouge are locally related to the cataclastic breccia, indicating that these rocks originate from a post-impact, single, and progressive tectonic event along the St. Lawrence rift system. The St-Laurent fault influenced the deposition of Ordovician deposits during late stages of the Taconian orogeny by syndepositional faulting preserved as major lateral thickness variations within the section, presence of slump deformation in almost all stratigraphic units, preservation of pseudotachylyte within synsedimentary breccias, and occurrence of fault breccia clasts. However, the geometry and structural characteristics of faulting are consistent with Mesozoic fault reactivation due to rifting of the North Atlantic region.

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Citation	Title	Description and Relevance to SSC
Rocher et al. (2003)	Brittle Fault Evolution of the Montréal Area (St. Lawrence Lowlands, Canada): Rift-Related Structural Inheritance and Tectonism Approached by Palaeostress Analysis	NW-SE extension associated with the opening of the Iapetus Ocean resulted in the formation of N040-trending faults along the north shore of the St. Lawrence lowlands, the development of three major N090-trending faults that define a success of horsts and grabens on Montreal and Jesus islands, and N120-trending faults in the Montreal area. The three N090-trending faults have the following geometries: 1. The Bas-Sainte-Rose fault zone, the northernmost series of N090-trending faults in the Montreal area, is a steeply north-dipping fault with approximately 200 m of vertical displacement and nearly 3 km (2 mi.) of apparent left-lateral offset. Offsets on the Bas-Sainte-Rose fault zone decrease as the fault zone extends westward, where it apparently crosscuts the N020-trending Rivière-aux-Mille-Iles fault zone. 2. Rapide-du-Cheval-Blanc consists of a series of steeply south-dipping normal faults (the Ile-Bizard, the Rapide-du-Cheval-Blanc, and Outremont faults) with a total vertical offset of approximately 100 m. 3. The Sainte-Anne-de-Bellevue fault zone is a north-dipping normal fault with a left-lateral strike-slip component in the southern part of Montreal Island. Its vertical offset has not been precisely determined. All three faults clearly crosscut NNE-SSW-trending folds from the Appalachian Chambly-Fortierville syncline system in the Trois-Rivières seismic zone. WNW-ESE compressions followed by minor NNW compressional events are associated with Appalachian thrusting. WNW compression reactivated N090-trending faults into strike-slip right-lateral faults, and N040–070 and N120 faults as reverse to strike-slip faults. Subsequent NNW compression is responsible for strike-slip conjugate faults trending NW-SE and NNE. NE-SW and NNW-SSE extension is associated with the opening of the North Atlantic–Labrador Sea and reactivated faults with normal to strike-slip motions. NNW extension is responsible for the horst-and-graben geometry of the major N090 normal faults described above. Late NE-SW compression is recorded in Monteregian plutons. NE-SW compression postdating these events is associated with the formation of strike-slip faults that crosscut the Monteregian intrusions and is consistent with the current stress regime.

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Citation	Title	Description and Relevance to SSC
Roden-Tice, Brandt, and Tremblay (2009)	Apatite Fission-Track Evidence for Late Paleozoic to Early Mesozoic Unroofing and Potential Fault Reactivation Along the Saguenay River Graben, Quebec	Apatite fission-track age discontinuities across the Montmorency and Saint-Laurent faults are consistent with Late Jurassic to Early Cretaceous fault reactivation and uplift.
Spencer et al. (1989)	The Extension of Grenville Basement Beneath the Northern Appalachians: Results from the Quebec-Maine Seismic Reflection and Refraction Surveys	A master decollement separating autochthonous Grenville basement from overlying allochthonous rocks of the Appalachian orogen extends over a distance of 200 km (125 mi.) and can be traced from shallow depths beneath the St. Lawrence lowlands SE to about 25 km (15.5 mi.) depth beneath the SE edge of the Chain Lakes massif. Basement is offset by closely spaced en echelon normal faults with displacements between 200 and 1,000 m interpreted as Iapetan growth faults. The Baie Verte–Brompton line, separating Cambrian and Ordovician continental slope and rise deposits from oceanic arc and magmatic assemblages to the south, including the Chain Lakes massif, is imaged as a shallow, thin-skinned structure. The Chain Lakes terrane is thought to underlie much of the Connecticut Valley–Gaspe Synclinorium. The Acadian Guadeloupe fault disrupts the master decollement of the Taconian orogeny and thrust the Connecticut Valley–Gaspe Synclinorium over the Chain Lakes massif.
St. Julien and Hubert (1975)	Evolution of the Taconian Orogen in the Quebec Appalachians	Describes 11 lithostratiographic assemblages distributed among the autochthonous, external, and internal domains of Quebec Appalachians. The autochthonous domain contains Cambrian and Ordovician sandstones and carbonates representing transgressive shelf deposits, Middle and Upper Ordovician flysch deposits, and Upper Ordovician shale and sandstone representing the post-tectonic regressive sequence. This domain contains E-W- and N30E-trending normal faults active between late Precambrian and Late Ordovician.

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Tremblay and Lemieux (2001)	Supracrustal Faults of the St. Lawrence Rift System Between Cap-Tourmente and Baie-Saint-Paul, Quebec	The Cap-Tourmente and St. Lawrence faults are late Proterozoic–early Paleozoic normal faults attributed to rifting during the opening of the Iapetus Ocean. The St. Lawrence fault trends N020–N050 and dips 60°–70° to the SE. Fault rocks consist of fault breccia, cataclastite, foliated gouge, and pseudotachylyte with a minimum thickness of 20 m near Sault-au-Cochon. Fault rocks exposed at Cap-Tourmente consist of 10–15 m thick zones of protocataclasite, cataclasite, and fault breccia. Within the Charlevoix area, the St. Lawrence fault is characterized by a well-developed and extensive series of cataclastic rock, gouge, and associated pseudotachylyte. The Cap-Tourmente fault trends E-W and dips approximately 80° to the south. Fault rocks consist mostly of fault breccia more than 10 m thick, as well as cataclastic rocks and dark pseudotachylyte veins. The St. Lawrence fault is crosscut by the Cap-Tourmente fault at Cap-Tourmente. West of Cap-Tourmente, the Montmorency Falls fault occupies the same structural position as the St. Lawrence fault, suggesting that they formed from en echelon faults trending parallel to the axis of the St. Lawrence rift. The Cap-Tourmente fault possibly represents a transfer fault, producing an oblique relay between two longitudinal normal faults. The St. Lawrence fault crosses the Charlevoix impact crater without major trend deflection or fault offsets within or at the boundaries of the Devonian impact structure. This observation suggests that impact-related faults did not significantly alter the orientation of preexisting structures and that reactivation is younger than the impact structure, most probably concurrent with the opening of the Atlantic Ocean in the Mesozoic.
Tremblay et al. (2003)	Supracrustal Faults of the St. Lawrence Rift System, Quebec: Kinematics and Geometry Revealed by Field Mapping and Marine Seismic Reflection Data	This paper builds on work presented by Trembley and Lemieux (2001) and presents strike orientations, dip angles, and pitch angles for faults with evidence for frictional sliding in the St. Lawrence rift system. NE-trending longitudinal faults show three trends (N025, N040, and N070) and generally dip to the SE, although a minor number dip to the NW. Transverse faults show two trends (N290 and N310) and dip to the NE or SW, which is consistent with the horst-and-graben geometry. Both sets of faults are high-angle faults with dip angles averaging 75°–80°. The pitch value of fault

Citation	Title	Description and Relevance to SSC
		lineations is greater than 70°, indicating that most structures are dip-slip faults. Longitudinal and transverse faults show mutual crosscutting relationships, suggesting that they represent conjugate structures related to the same tectonic event. The St-Laurent fault has experienced at least 800 m of vertical throw at Sault-au-Cochon. The Cap-Tourmente fault has a minimum vertical fault throw of 700 m. The Montmorency fault has an 80 m fault scarp near Quebec City; stratigraphic analysis suggests that fault throw should be less than 150 m, which is considerably less than the other faults. Several offshore faults subparallel to that fault may have vertical downthrow displacements up to 1 km (0.6 mi.). Longitudinal faults likely result from the development of en echelon faults trending parallel to the rift axis, and transfer faults represent transfer faults or accommodation zones. Variations in fault throw are likely a result of propagation of extension along transfer faults. The presence of cataclastic rocks, pseudotachylytes, and fault gouge is consistent with changes of deformation mechanics during progressive and incremental deformation in the upper crust. High-resolution seismic profiles in the St. Lawrence estuary indicate that the Laurentian Channel trough transitions from a half graben to a graben structure from SW to NE. Tremblay et al. (2003) speculate that reactivation of the St. Lawrence rift system is post-Ordovician, younger than the Devonian impact cratering event, and experienced additional fault throw and shoulder uplift during the Mesozoic opening of the North Atlantic.
Faulting in the Ottawa-Bonnechere Graben		
Mereu et al. (1986)	The 1982 COCRUST Seismic Experiment Across the Ottawa-Bonnechere Graben and Grenville Front in Ontario and Quebec	Results of the 1982 Canadian Consortium for Crustal Reconnaissance Using Seismic Techniques (COCRUST) long-range seismic refraction experiment show a sharp, step-like displacement of the Moho beneath the south shoulder of the Ottawa graben, confirming the deep-seated nature of its faults and penetration of mantle melts into the crust. Furthermore, the COCRUST surveys show a poorly defined Moho at unusually shallow depths beneath the graben.

Table D-7.3.1 Data Summary
St. Lawrence Rift Zone

Citation	Title	Description and Relevance to SSC
Rimando and Benn (2005)	Evolution of Faulting and Paleo-Stress Field Within the Ottawa graben, Canada	Authors observe three periods of faulting in Cambro-Ordovician sedimentary rocks within the eastern end of the Ottawa graben, near Ottawa. The oldest generation of faults formed in a stress field with a horizontal maximum compressive stress (σ_1) oriented NW. These structures are kinematically congruent with the compression direction associated with the closing of the Iapetus Ocean. The second generation of faults indicates a WNW-oriented σ_1 and coincides with the emplacement of Cretaceous carbonatite dikes. The third generation of faults has a σ_1 oriented SW, which is consistent with the post-Cretaceous stress field in eastern North America.
Faulting in the Saguenay Graben		
Du Berger et al. (1991)	The Saguenay (Quebec) Earthquake of November 25, 1988: Seismologic Data and Geologic Setting	The Saguenay graben is defined by the Lac Tchitogama and Ste-Marguerite River normal faults on the north wall and the Lac Kénogami normal fault on the south wall. Ordovician limestones show downthrow of 500 m along the north wall. Subvertical brittle faults are found within and outside the graben. Lineaments in the regional cluster at 000°, 015°, 030°, 050°, 105°, and 160°. The 015 and 030 lineaments correspond to NNE late Grenvillian ductile belts and some post-Ordovician brittle faults. The St. Lawrence rift reactivated the 030° trend and produced the 050° trend. The 160 trend is parallel to glacial strike. The 105° trend is prominent only in the rosette of the Saguenay graben. The 000° trend corresponds to a complex array of en echelon oblique short breaks near the St. Maurice lineament, suggesting that the St. Maurice marks the transition between two structural domains.
Roden-Tice, Brandt, and Tremblay (2009)	Apatite Fission-Track Evidence for Late Paleozoic to Early Mesozoic Unroofing and Potential Fault Reactivation Along the Saguenay River Graben, Quebec	Apatite fission-track age discontinuities across the Sainte-Marguerite fault suggest Late Triassic to Early Jurassic reactivation, whereas age discontinuities across the Lac Kénogami fault to the south indicate Middle Jurassic reactivation.

Table D-7.3.1 Data Summary
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Citation	Title	Description and Relevance to SSC
Stratigraphic Evidence for Fault Activity		
Hersi et al. (2003)	Reappraisal of the Beekmantown Group Sedimentology and Stratigraphy, Montreal Area, Southwestern Quebec: Implications for Understanding the Depositional Evolution of the Lower-Middle Ordovician Laurentian Passive Margin of Eastern Canada	Detailed lithostratigraphic mapping and conodont biostratigraphy of the Beekmantown Group of SE Quebec indicates that the platform evolved as a distally steepened ramp during deposition of the Lower Ordovician Theresa Formation and the Ogdensburg Member of the Beauharnois Formation.
Lavoie et al. (2003)	Stratigraphic Framework for the Cambrian-Ordovician Rift and Passive Margin Successions from Southern Quebec to Western Newfoundland	In the Quebec Reentrant, platform rocks were only marginally involved in the tectonic stacking of the Taconic orogeny and form a spatially restricted frontal Taconian deformation zone known as the para-autochthonous or imbricate fault domain and therefore not considered part of the Humber Zone. The Quebec Reentrant is rooted in the autochthonous St. Lawrence platform. These structural relationships allow for stratigraphic and paleogeographic scenarios for the early evolution of the Quebec-Newfoundland segment of the continental margin slope of Laurentia. Neoproterozoic to latest early Cambrian rift volcanics are overlain by rift-drift transition successions of the early Cambrian Sauk I sequence. A global sea-level lowstand resulted in an unconformity that separates these rocks from shallow marine middle Cambrian to Middle Ordovician rocks of the Sauk II and Sauk III subsequences. An extensive debris flow unit resedimented the middle Cambrian slope succession and is attributed to tectonic instability during the middle to late Cambrian. The authors suggest that reactivation of the Saguenay graben could be responsible for the anomalous upper Cambrian succession. Similar syndepositional tectonic activity is observed in the younger St. Lawrence platform succession in the Charlevoix area during the Middle to Late Ordovician. The authors present locations of reentrants and promontories for the eastern margin of Laurentia farther north than those of Thomas (1991).

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Citation	Title	Description and Relevance to SSC
Longuépée and Cousineau (2005)	Reappraisal of the Cambrian Glauconite-Bearing Anse Maranda Formation, Quebec Appalachians: from Deep-Sea Turbidites to Clastic Shelf Deposits	Paleogeographic reconstruction led to a significant reinterpretation of the sedimentary environment of the Anse Maranda Formation, originally explained as proximal turbidites of a deep-sea fan and now explained as shelf sediments deposited in storm-influenced deep subbasins seaward of a headland (Montmorency promontory). These sediments were deposited along a narrow shelf with irregular topography south of the Saguenay graben.
Seismicity and Focal Mechanism Data		
Adams and Basham (1991)	The Seismicity and Seismotectonics of Eastern Canada	The western Quebec seismic zone consists of two bands of seismicity. The western band trends slightly west of northwest and lies along the Ottawa River between Lake Timiskaming and Montreal. This portion of the western Quebec seismic zone is attributed to rift faults of the Ottawa graben. Focal mechanisms for earthquakes within this zone are consistent with thrust faulting on NW-striking faults. The authors dispute the hypothesis that Mesozoic extension in the St. Lawrence rift extends SE into the Great Lakes.
Baird et al. (2009)	Stress Channeling and Partitioning of Seismicity in the Charlevoix Seismic Zone, Quebec, Canada	Seismicity is localized along two elongate bands of seismicity bounded by rift faults extending NE of the Charlevoix impact crater. In a 2-D stress model, faults are represented as frictional discontinuities, and the impact crater as an elastic continuum of reduced modulus. Stress trajectories flow around the weak impact crater, concentrating stress along weak faults into the impact crater, resulting in seismicity localized in linear bands. The asymmetric placement of the rift faults through the crater results in increased seismicity potential along the rift, north of the crater. Observed seismicity is therefore interpreted as a result of stress concentration due to the interaction of the crater (local zone of weakness) and rift faults (large-scale weak zone). Small to moderate seismicity occurs within the crater, and larger earthquakes are localized along the rift faults. Modeling in 3-D would be able to accurately represent the bowl shape of the crater but may not be able to explain why seismicity extends below the crater into Grenville basement. Current observations of reverse reactivation of rift faults associated with glacial rebound could not be assessed with the 2-D model presented in this paper and would need to be examined with a 3-D model.

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Citation	Title	Description and Relevance to SSC
Bent (1992)	A Re-examination of the 1925 Charlevoix, Québec, Earthquake	Analysis of additional waveforms resulted in source parameters of strike 42° ± 7°, dip 53° ± 7°, rake 105° ± 10°, depth 10 km (6.2 mi.), seismic moment 3.1 ± 2.5 × 1025 dyne cm (M_w 6.2), M_S 6.2 ± 0.3, m_b 6.5 ± 0.4, source duration 5 sec, and stress drop 35 bars. Due to insufficient 1-sec period data, m_{bLg} was not determined; however, Street and Turcotte (1977) obtained a m_{bLg} 6.6, and Atkinson and Boore (1987) obtained a m_{bLg} 6.8. Felt area estimates range from 3.3 × 106 km^2 (Street and Lacroix, 1979) to 5.2 × 106 km^2 (Smith, 1962). Drysdale and Cajka (1989) obtained a m_{bLg} 6.1 using Nuttli et al. (1979) and m_{bLg} 6.2 using Toro and McGuire (1987). The dip is shallower than would be expected from observed surface faults but consistent with recent seismicity. The focal mechanism is consistent with horizontal compression in the NW-SE direction that is orthogonal to the regional stress field, indicating an anomalous stress field in Charlevoix that may be depth dependent.
Bent (1996a)	An Improved Source Mechanism for the 1935 Timiskaming, Quebec Earthquake from Regional Waveforms	Analysis of seismograms from 11 stations for the November 1, 1935, Timiskaming earthquake led to the determination of seismic moment of 2.3 ± 1.3 × 1025 dyne cm, corresponding to M_w of 6.1 ± 0.2.
Lamontagne and Ranalli (1996)	Thermal and Rheological Constraints on the Earthquake Depth Distribution in the Charlevoix, Canada, Intraplate Seismic Zone	Compares the depth distribution of Charlevoix earthquakes to rheological models of the region. The maximum depth of earthquakes can be controlled by either the brittle-ductile transition or the velocity-weakening to velocity-strengthening fault behavior. The rheological change at the brittle-ductile transition was modeled by calculating geotherms assuming a variety of rock compositions in the upper and middle crust. The depth distribution of earthquakes in Charlevoix requires geotherms very close to the upper limit for felsic rocks and a wet lower crust. The temperature-controlled sliding stability transition can occur at 300°C and 450°C for quartz or feldspar plasticity. Hydrolytic weakening of feldspars at 350°C occurs at 25 km (15.5 mi.) for the upper geotherms. The maximum crustal stress difference has an upper limit of about 100–200 MPa, requiring high pore fluid pressure or low coefficient of friction in mid- to lower crust. Thrust reactivation of steeply dipping faults requires a low coefficient of friction. The authors attribute the presence of earthquakes in the Charlevoix region to brittle-ductile transition deeper than 25 km (15.5 mi.), corresponding to higher than average geotherms, onset of ductility for hydrated feldspar at about 350°C, high pore-fluid pressure and a low friction coefficient, possibly related to unhealed zones of intense fracturing.

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Citation	Title	Description and Relevance to SSC
Lamontagne and Ranalli (1997)	Faults and Spatial Clustering of Earthquakes near La Malbaie, Charlevoix Seismic Zone, Canada	Focal mechanisms for earthquakes larger than M 3 show reverse faulting, whereas smaller-magnitude earthquakes indicate both normal and strike-slip mechanisms, suggesting that local stress and/or strength conditions control their occurrence. Focal mechanisms for larger events of the Charlevoix seismic zone, however, suggest reactivation of paleo-rift faults in response to regional stresses. The distribution of spatially clustered events (doublets and triplets) within the Charlevoix seismic zone indicates that very few events have occurred on the same fractures with similar focal mechanisms, implying that these fault zones occur in highly fractured rocks. These observations indicate that the Charlevoix seismic zone is characterized by highly fractured zones responding to regional stresses and local perturbations in stress or strength, possibly enhanced by pore fluid pressures.
Ma and Atkinson (2006)	Focal Depths for Small to Moderate Earthquakes ($M_N \geq 2.8$) in Western Quebec, Southern Ontario, and Northern New York	Performs regional depth-phase modeling of earthquakes occurring in southern Ontario, western Quebec, and northern New York between 1980 and 2004. Events with depths greater than 15 km (9.3 mi.) are restricted to the Ottawa graben and western Quebec seismic zone. The wide depth distribution could indicate faults of throughgoing crustal extent or different faults that occur at different depths in the crust. In the entire study region, focal depths cluster at 5, 8, 12, 15, and 22 km (3, 5, 7.5, 9.3, and 13.7 mi.) and may reflect layering in seismogenic properties within the crust.
Ma and Eaton (2007)	Western Quebec Seismic Zone (Canada): Clustered, Midcrustal Seismicity Along a Mesozoic Hotspot Track	Deep earthquakes (greater than 17 km, or 10.6 mi., in depth) are localized as clusters at Timiskaming, Maniwaki, Mont Laurier, and Adirondack. The Timiskaming cluster is located near the 1935 Timiskaming earthquake, has a lower *b*-value than the other clusters and the regional average, and is spatially associated with faults of the Ottawa-Bonechere graben. The authors speculate that heat from the hotspot track weakened faults of the Ottawa-Bonechere graben, which explains the lack of historical seismicity along most of the extent of the graben system.

Table D-7.3.1 Data Summary
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Citation	Title	Description and Relevance to SSC
Paleoseismic Investigations		
Aylsworth et al. (2000)	Did Two Massive Earthquakes in the Holocene Induce Widespread Landsliding and Near-Surface Deformation in Part of the Ottawa Valley, Canada?	Examines large prehistoric landslides in abandoned channels of the Ottawa River and disturbed sediment of the erosional plane adjacent to the Ottawa River. Radiocarbon ages for buried wood and plant material from landslide debris cluster at 4,550 yr BP, which are thousands of years younger than the age of paleochannel abandonment. This observation cannot be attributed to either fluvial erosion or wet-weather-induced landslides. East of the landslides, disturbed sediment and possible sand boils dated at 7,060 yr BP are preserved within the flat erosional plane adjacent to the Ottawa River. These two age distributions are attributed to paleoearthquakes of uncertain magnitude and source.
Doig (1990)	2300 Yr History of Seismicity from Silting Events in Lake Tadoussac, Charlevoix, Quebec	Inferred a variable recurrence rate for the Charlevoix seismic zone from silt layers in lakes due to earthquake-induced landslides. Some silt layers in the section were correlated with historical earthquakes from 1638, 1663, 1791, 1870, and 1925. From 320 BC to AD 800, determined a 120-year recurrence interval, 270 years from AD 800 to 1500, and 75 years from AD 1500 to the present.
Doig (1991)	Effects of Strong Seismic Shaking in Lake Sediments, and Earthquake Recurrence Interval, Témiscaming, Quebec	Sampled lake sediments from Lac Tee, located within 15 km (9.3 mi.) of the epicenter of the 1935 magnitude 6.3 Timiskaming earthquake. Observed three silt layers in six sediment cores attributed to earthquake-induced landslides. A 15–22 cm thick chaotic mixture of black to brown organic material and large, partly tabular fragments of previously formed silt layers is interpreted as sediment redeposit during the 1935 Timiskaming earthquake. The basal silt layer may imply a two-stage event, such as a small foreshock or a major aftershock. A second 6 cm thick silt layer in core 4 and a 1–2 mm thick silt layer in cores 2 and 6 are interpreted as the result of a distant or smaller earthquake. A third silt layer at 100 cm overlain by gyttja containing lumps of silt is interpreted as a similar-sized event as the 1935 Timiskaming earthquake. The upper 2–3 cm from cores 2, 4, and 6 contain brown, homogeneous flocculent gyttja interpreted as normal accumulation of sediment since 1935. This sedimentation rate was used to infer ages of 400 and 1,500 years for the second and third silt layers, respectively. Doig (1991) does not explicitly correlate the second silt layer to the 1663 Charlevoix earthquake. This data set suggests two magnitude 6–6.5 events in 1,500 years.

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Citation	Title	Description and Relevance to SSC
Doig (1998)	3000-Year Paleoseismological Record from the Region of the 1988 Saguenay, Quebec, Earthquake	Author has determined a recurrence interval ranging from 350 to 1,000 years for the Saguenay graben based on evidence of earthquake-induced landslide deposits within lakes near the epicenter of the 1988 earthquake.
Filion et al. (1991)	A Chronology of Landslide Activity in the Valley of Rivière du Gouffre, Charlevoix, Quebec	Samples of tree trunks buried in landslide flow materials were collected from four sectors along the Gouffre River between Saint-Urban and Baie-Saint-Paul. The age distribution of tree trunks indicates that landslides have occurred at 5,670, 3,170, 2,500, 1,870 yr BP, with most occurring less than 600 yr BP. Comparison of tree-ring widths throughout the study area suggests that trees died during the latent period between the 1662 and 1663 growing seasons, possibly due to synchronous landslides. The authors interpret these two landslides as having been caused by the February 1663 Charlevoix earthquake. These results provide no evidence for the 1925 earthquake. The authors emphasize the importance of tree-ring techniques to delineate the areal extent of landslides caused by the 1663 earthquake and to caution against exaggerating the geomorphic consequences of earthquakes.
Tuttle and Atkinson (2010)	Localization of Large Earthquakes in the Charlevoix Seismic Zone, Quebec, Canada, During the Past 10,000 Years	Provides evidence for three Holocene paleoearthquakes in Charlevoix with $M \geq 6.2$, including at least two prehistoric episodes at 5,000 and 10,000 years ago.
Tuttle et al. (1990)	Liquefaction and Ground Failure Induced by the 1988 Saguenay, Quebec, Earthquake	Sand boil deposits and ground fissures were documented immediately following the November 25, 1988, M 5.9 Saguenay earthquake. Lateral spreading was the principal mode of ground failure during the 1988 earthquake and in the past, with displacements on the order of centimeters.
Tuttle et al. (1992)	Liquefaction Induced by Modern Earthquakes as a Key to Paleoseismicity: A Case Study of the 1988 Saguenay Earthquake	One, possibly two, earthquakes caused pre-1988 liquefaction features identified in Tuttle et al. (1990). One has a well-constrained age of 340 ± 70 radiocarbon yr BP, possibly corresponding to the 1663 Charlevoix earthquake.

Table D-7.3.2 Data Summary
Great Meteor Hotspot Zone

Citation	Title	Description and Relevance to SSC
Geologic Evidence for Hotspot Track		
Adams and Basham (1991)	The Seismicity and Seismotectonics of Eastern Canada	Postulated that differential uplift of the shield may have thermally stressed and fractured Precambrian crust during passage of the hotspot. Attributed localized release of seismic energy to this weakened crust. Speculated that New England may not exhibit same rates of seismicity because plutonism may have healed deep crustal fractures.
Crough (1981)	Mesozoic Hotspot Epeirogeny in Eastern North America	This study attributes a 600 km (373 mi.) wide zone of epeirogeny in SE Canada and New England during the Cretaceous and early Tertiary to the Great Meteor hotspot as evidenced by apatite fission-track dating.
Duncan (1984)	Age Progressive Volcanism in the New England Seamounts and the Opening of the Central Atlantic Ocean	Duncan (1984) obtained radiometric ages for dredged volcanic rocks from seven of the New England seamounts and concluded that the seamounts increase in age from SE (82 Ma for the Nashville seamount) to NW (103 Ma for the Bear seamount). Linear rate of migration of volcanisms of 4.7 cm/yr determined from these ages is in agreement with age of the Corner seamounts (70–75 Ma) and the youngest phase of igneous activity in White Mountains (100–124 Ma).
Faure et al. (1996b)	State of Intraplate Stress and Tectonism of Northeastern America Since Cretaceous Times, with Particular Emphasis on the New England–Quebec Igneous Province	Performed a paleostress analysis of Cretaceous dyke trends and regional- and mesoscopic-scale faults from the Monteregian plutons. Dykes display ESE-WNW and ENE-WSW trends and are spatially distributed in three E-W-trending dyke swarms 75 by 300 km (47 by 186 mi.) in area. Most dykes surrounding Cretaceous plutons are radially distributed and perpendicular to contacts with hosting sedimentary rocks. Leucocratic dykes occur closer to plutons and disappear within 3–4 km (2–2.5 mi.), likely recording local stress effects due to pluton emplacement. Crosscutting dykes clearly show a dominant E-W-trending orientation. Lamprophyre dykes occur independently of plutons and strike parallel to regional dyke swarms, recording regional far-field stresses. Southwest of Mont Brome and around Mont Megantic, N-S- to NE-SW-trending dykes found in slates strike parallel to the regional foliation of Taconic or Acadian metamorphic rocks. Their emplacement is controlled by preexisting anisotropy and, therefore, poorly records the paleostress. NW-SE-trending dykes indicate NE-SW-striking extension with a slight clockwise rotation near Montreal. E-W-trending dykes indicate a N-S-striking extension. In some

Citation	Title	Description and Relevance to SSC
		plutons, these E-W-trending dykes crosscut radially distributed dykes. Normal faults in the region display two orientations: 1. E-W-trending normal faults are found predominantly in the Montreal area parallel to graben boundaries and the axis of the Monteregian hills. These faults have vertical offsets ranging between 100 and 430 m (328 and 1,411 ft.) and record homogeneous N-S-trending extension. 2. NW-SE to WNW-ESE-trending normal faults record NE-SW-trending extension and are found everywhere in Quebec. These faults trend obliquely to graben boundaries with less than 100 m (328 ft.) of vertical offset. The stress orientation varies between NNE-SSW near Ottawa and Montreal and ENE-WSW in southern Quebec. The NW-SE to WNW-ESE faults are older than the E-W-trending faults but exhibit crosscutting relationships, suggesting that some were reactivated during the formation of the E-W-trending faults. Some E-W-trending brittle faults and joints are observed in several Cretaceous plutons with similar orientations to dykes that are locally crosscut by these normal faults, suggesting that dyke emplacement and faulting are contemporaneous. The NE-SW-directed extension is more widespread and older than the N-S-directed extension, suggesting that the Ottawa-Bonnechere graben and associated basement faults acted as localized zones of weakness in the early stage of Cretaceous extension, resulting in reorientation of the regional stress field and formation of the localized zone of N-S-directed extension. These orientations are attributed to to an initial NE-SW extension event associated with rifting between Labrador and Greenland at 140 Ma, opening of the South Atlantic at 130 Ma, and related reactivation of the Temiskaming graben. Subsequent N-S-oriented extension associated with the emplacement of the Monteregian Hills corresponds to global fragmentation of Pangaea when Iberia separated from Newfoundland when dominant tensional stress propagated along the Labrador rift. Conjugate sets of NE-SW dextral and ESE-WNW sinistral strike-slip faults and WNW-SSW reverse faults provide evidence for a compressional stress regime postdating emplacement of Cretaceous plutons. Stress regime shifted to ENE-WSW-directed compressional in early Tertiary when oceanic spreading rate decreased due to an increasing number of convergent boundaries in Pacific.

Table D-7.3.2 Data Summary
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Citation	Title	Description and Relevance to SSC
Faure et al. (2006)	Paleostress Analysis of Atlantic Crustal Extension in the Quebec Appalachians	Fault stress tensors indicate that most E-W- to ESE-WNW-oriented stress is found in Montreal and Gaspe area, whereas SE-NW stress is found in SE Quebec. Late Triassic–Jurassic dikes in New England and southern Quebec indicate SE-NW-oriented extension consistent with fault slip stress. The N-S-trending portion of a Jurassic dike in southern Quebec is consistent with regional E-W extensional stress axis, whereas the NE-SW branch of this dike is more compatible with a local and adjacent NW-SE extension. Stress axes exhibit clockwise rotation in White Mountain magma series, possibly due to local deviatoric stresses or a NE-SW-oriented basement fault. The authors attribute these two extensional paleostress trends to either (1) contemporaneous regional partitioning of ESE-WNW-oriented extension influenced by N-S-trending structures in Champlain Lake Valley and NE-SW-trending structures of St. Lawrence rift, or (2) an initial Late Triassic E-W extension related to formation of Bay of Fundy and South Georgia rift basins and Early Jurassic ESE-WNW extension related to central Atlantic rift system.
Heaman and Kjarsgaard (2000)	Timing of Eastern North American Kimberlite Magmatism: Continental Extension of the Great Meteor Hotspot Track?	Extends Great Meteor hotspot track NW to Rankin Inlet on west side of James Bay by identifying four periods of kimberlite magmatism (at 196, 180–176, 148–146, and 142–134 Ma) from U-Pb perovskite ages that extend from NW to SE from Rankin Inlet through to the Attawapiskat, Kirkland Lake, and Timiskaming fields. These results are not consistent with Morgan's (1983) study, which identified two Mesozoic hotspot tracks in New England separated by 40 Myr Heaman and Kjarsgaard (2000) suggest that this age progression and the change from kimberlitic to basaltic magmatism correspond to change from thick lithosphere to thinner lithosphere east of Monteregian Hills.
Matton and Jebrak (2009)	The Cretaceous Peri-Atlantic Alkaline Pulse (PAAP): Deep Mantle Plume Origin or Shallow Lithospheric Break-Up?	Cretaceous magmatism occurred along widely separated peri-Atlantic continental margins as widespread alkaline igneous activity. This volcanism, along with the Central Atlantic magmatic province associated with Jurassic rifting, has been attributed to either deep mantle plumes or a combination of tensional forces, lithospheric rifting, and structural controls. Matton and Jebrak (2009) propose that periodic reactivation of deep-seated preexisting zones of weakness during major stages of Atlantic tectonic evolution, combined with coeval asthenospheric upwelling due to edge-driven convection and continental insulation flow, enhanced the ascent of alkaline magmas. The authors prefer shallow, small-scale upwelling during periodic structural reactivation to a mantle plume as a mechanism for alkaline magmas.

Table D-7.3.2 Data Summary
Great Meteor Hotspot Zone

Citation	Title	Description and Relevance to SSC
McHone (1996)	Constraints on the Mantle Plume Model for Mesozoic Alkaline Intrusions in Northeastern North America	The author proposes that one or more deep-mantle plumes do not provide a satisfactory mechanism for distribution of Cretaceous alkaline rocks of NE New England. Observed that previous studies oversimplify evidence for a hotspot track across New England by ignoring important petrological data, including the following: • Jurassic syenite-monzonite-alkali granite of the White Mountain magma series has been described as separate province from Cretaceous intrusions, although many Early Jurassic dikes and several mafic to felsic plutons in the province are petrographically and chemically similar to Early Cretaceous intrusions that overlap. • Early Cretaceous dikes and plutons of the New England–Quebec igneous province have statistically similar paleomagnetic poles between 122 and 124 Ma and show no consistent trend for published ages in any direction across region. • Seamount volcanism is not limited to ages defined by a linear hotspot track, nor is it in line with the New England–Quebec province. • Cretaceous alkaline rocks do not exhibit a consistent chemical signature indicative of a mantle source. These observations indicate that lithospheric processes were necessary to start and stop generation of magmas from the same source in the mantle, and petrological studies should emphasize local and regional tectonic features.
McHone (2000)	Non-plume Magmatism and Rifting During the Opening of the Central Atlantic Ocean	Presents a model for Mesozoic rifting in the Atlantic based on several convection cells beneath the rift zone as opposed to a mantle plume. The presence of dikes with lengths up to 700 km (435 mi.) displaying uniform composition can be explained by either (1) flow of magma away from a single, local magma source for each large dike or dike swarm, or (2) vertically moving magmas from compositionally different subhorizontal layers that are homogeneous across large mantle source regions. Cretaceous intraplate hotspots postdate Jurassic tholeiitic magmatism and Atlantic Ocean rifting by 80 Myr or more. McHone (2000) proposes that rifting of Pangaea progressed through a series of linear zones of mantle upwelling that gradually coalesced into the modern segments of the mid-ocean ridges. The lithosphere promoted an increase in

Table D-7.3.2 Data Summary
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Citation	Title	Description and Relevance to SSC
		upper mantle temperatures beneath the incipient rift zone, culminating in the great Early Jurassic magmatic event. Subsequent cooling resulted in evolution of the rift into a zone of shallow linear upwelling and convection by which the mantle ejects ridge basalts and accretes new oceanic crust. This is supported by the presence of Cretaceous and Cenozoic alkaline igneous volcanoes in eastern North America, the northern North Atlantic, western Africa, South America, and as seamounts and islands throughout the central North Atlantic Ocean.
Morgan (1983)	Hotspot Tracks and the Early Rifting of the Atlantic	Study tested the hypothesis that hotspots are fixed in space by generating plate reconstructions for the Atlantic Ocean from the last 180 Myr using ages of known hotspot tracks. Morgan (1983) recognized two hotspot tracks passing through New England at different times: the Verde hotspot track at about 160 Ma and the Meteor hotspot at about 120 Ma. The Verde hotspot traveled from south of Hudson Bay to the New England seamounts from 180 to 130 Ma, and the Meteor track parallels the Verde track through Ontario, New England, and the New England seamounts approximately 40 Myr after the Verde track. The predicted track for the Great Meteor hotspot closely follows known ages for the White Mountain magma series in New Hampshire, the Cretaceous seamounts of offshore New England, the Corner Rise (recording when the mid-Atlantic Ridge crossed over the hotspot), and the Great Meteor seamount (11–17 Ma) in the Central Atlantic.
Poole et al. (1970)	Geology of Southeastern Canada	Alkaline rocks of the Monteregian Hills consist of nepheline, syenite, essexite, nordmarkite, pulaskite, yamaskite, and rougemontite forming circular plugs with steep walls and laccoliths within a 241 km (150 mi.) long west-trending line between Montreal and Lake Megantic in Quebec. These intrusions range in age from 84 to 123 Ma, with many falling between 100 and 115 Ma. Rocks may be related to a NW-striking kimberlite dike at Kirkland Lake (151 ± 8 Ma).
Roden-Tice and Tice (2005)	Regional-Scale Mid-Jurassic to Late Cretaceous Unroofing from the Adirondack Mountains Through Central New England Based on Apatite Fission-Track and (U-Th)/He Thermochronology	Apatite fission-track ages and (U-Th)/He ages from the Adirondack Mountains and eastern New York State, Vermont, western Massachusetts and Connecticut, and western New Hampshire indicate that widespread unroofing during the Middle Jurassic to Late Cretaceous occurred at a rate of 0.07 to 0.08 km/Myr This regional uplift is attributed to remnant heating from the Great Meteor hotspot. Differential unroofing was accommodated by extensional fault reactivation.

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Citation	Title	Description and Relevance to SSC
Roden-Tice and Wintsch (2002)	Early Cretaceous Normal Faulting in Southern New England: Evidence from Apatite and Zircon Fission-Track Ages	Apatite and zircon fission-track age transects across Hartford-Deerfield basin in Connecticut and Massachusetts increase to the east, indicating that unroofing occurred during the Late Jurassic through Early Cretaceous. Age of graben structure of Hartford Basin is Cretaceous and may not be an early Mesozoic “rift” basin.
Roden-Tice, West, et al. (2009)	Presence of a Long-Term Lithospheric Thermal Anomaly: Evidence from Apatite Fission-Track Analysis in Northern New England	Apatite fission-track ages across New Hampshire, NE Vermont, and western Maine range from 70 to 140 Ma and reflect widespread Early to Late Cretaceous cooling. This regional cooling and unroofing is attributed to passage of North America Plate over the Great Meteor hotspot, emplacement of White Mountain magma series in the Early Jurassic, and associated E-W and NW-SE extension. Regional uplift on the order of 5–7 km (3–4 mi.) may explain lack of rift basins in central New England and Quebec.
Sleep (1990)	Monteregian Hotspot Track: A Long-Lived Mantle Plume	From modeling the buoyancy flux of the Great Meteor hotspot, the author observed that the trace of the hotspot changes orientation, concluding that the plume was weak beneath Ontario and strong beneath Montreal where the track changed orientation through the White Mountains, and became weakened at the Nashville seamount where the track changed orientation to the Corner seamounts. Sleep (1990) also suggested that the lack of tracks west of the Monteregian Hills may be the result of the Canadian Shield’s being less vulnerable to the hotspot than the Paleozoic sediments of the Montreal area were.
Zartman (1977)	Geochronology of Some Alkalic Rock Provinces in Eastern and Central United States	Provides ages for the White Mountain plutonic suite, consisting of mildly alkaline rocks with compositions of granite, quartz syenite, syenite, and lesser amounts of intermediate and mafic units occupying a batholith, several stocks, and related ring dikes. The mapped relationships of these rocks indicate post-tectonic character from host rocks and a relatively slow intrusion of complexly evolved magma chambers into shallow crust. These rocks were emplaced over three rather broad pulses of magmatism at 220–235 Ma, 155–200 Ma, and 95–125 Ma but lack any regular time-transgressive pattern of ages. Alignment of these rocks with the Monteregian Hills of Quebec and Cretaceous seamounts of offshore New England can be attributed to the trace of a mantle hotspot between the Early Triassic to Early Cretaceous or to emplacement along fractures, indicative of intraplate stresses.

Table D-7.3.2 Data Summary
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Citation	Title	Description and Relevance to SSC
Geophysical Characteristics		
Eaton et al. (2006)	Crustal Thickness and V_P/V_S Variations in the Central Grenville Orogen (Ontario, Canada) from Analysis of Teleseismic Receiver Functions	Crustal thickness maps derived from teleseismic analysis and results of regional seismic-refraction surveys image the hotspot track NE of the Ottawa-Bonnechere graben as minima on these maps. Thinnest crust (34.5–37.0 km) coincides with the elevated seismicity rates of Western Quebec seismic zone, NE of Ottawa-Bonnechere graben.
Li et al. (2003)	Shear Velocity Structure and Azimuthal Anisotropy Beneath Eastern North America from Rayleigh Wave Inversion	Determined velocity structure and anisotropic variations in velocity structure from inversion of Rayleigh waves in order to detect asthenospheric flow beneath the thick continental lithosphere beneath NE United States and SE Canada. Rayleigh wave-phase velocity anomaly with a period of 33 s, corresponding to sensitivity to structure down to 40 km (25 mi.) in depth, indicates a low-velocity band oriented NE-SW. North American continental keel beneath Grenville province is imaged in the upper mantle down to roughly 200 km (124 mi.) in depth. The North American keel has an irregular shape and a low-velocity zone beneath eastern New York and central New England to 200 km (124 mi.), with particularly high amplitudes at depths of 60–140 km (37–87 mi.). This velocity anomaly is interpreted as the lateral contrast between relatively thick lithosphere beneath western New York and Pennsylvania and the warm asthenosphere beneath the thinned New England lithosphere caused by thermal erosion associated with the Cretaceous hotspot. Additionally, weak anisotropy observed from shear-wave splitting indicates that source must be at least 200 km (124 mi.) deep, suggesting that a sublithospheric shear zone may decouple motions of lithosphere and deeper mantle.
Rondenay et al. (2000)	Teleseismic Studies of the Lithosphere Below the Abitibi-Grenville Lithoprobe Transect	Travel-time inversions of teleseismic results from southern Ontario image a low-velocity corridor between 50 and 300 km (31 and 373 mi.) that crosscuts regional structures of the Grenville province and Ottawa-Bonnechere graben. This low-velocity corridor is coincident with northwestward continuation intrusions of Monteregian Hills. These results are attributed to a zone of contrasting thermal-compositional-anisotropic properties interpreted to have been formed by the same process responsible for emplacement of the Monteregian Hills (either a fixed mantle plume of the Great Meteor hotspot or rifting associated with opening of Atlantic Ocean). This anomaly is flanked on both sides by high seismic velocity, possibly representing zones of depleted residuum or transitions in mantle fabric.

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Citation	Title	Description and Relevance to SSC
Seismicity		
Adams and Basham (1991)	The Seismicity and Seismotectonics of Eastern Canada	The Western Quebec seismic zone contains two distinct bands of seismicity: a W-NW-trending band of seismicity along the Ottawa River between Ottawa and Lake Timiskaming associated with rift faults of the Ottawa River valley, and a N-NW-trending band extending from Montreal to the Baskatong Reservoir attributed to crustal fracturing associated with passage of a Cretaceous hotspot track. Recent seismicity of this second band includes the 1975 M 4.2 Maniwaki and 1978 M 4.1 St. Donat earthquakes. These two bands of seismicity converge near the St. Lawrence River.
Ma and Atkinson (2006)	Focal Depths for Small to Moderate Earthquakes ($M_N \geq 2.8$) in Western Quebec, Southern Ontario, and Northern New York	Performed regional-depth-phase modeling of earthquakes occurring in southern Ontario, western Quebec, and northern New York between 1980 and 2004. Events with depths greater than 15 km (9.3 mi.) are restricted to Ottawa graben and Western Quebec seismic zone (WQSZ). Hypocentral depths for events in WQSZ range from 2 to 25 km (1.2 to 15.5 mi.). The wide depth distribution could indicate faults of throughgoing crustal extent or different faults that occur at different depths in the crust. In entire study region, focal depths cluster at 5, 8, 12, 15, and 22 km (3, 5, 7.5, 9.3, and 13.7 mi.) and may reflect layering in seismogenic properties within the crust.
Ma and Eaton (2007)	Western Quebec Seismic Zone (Canada): Clustered, Midcrustal Seismicity Along a Mesozoic Hot Spot Track	The authors determined focal depths for 73 earthquakes, combined these data with those computed by Ma and Atkinson (2006), and compared the spatial distribution of earthquakes with focal mechanisms to evaluate tectonic controls of the Western Quebec seismic zone (WQSZ), a 160 km (100 mi.) wide band of intraplate seismicity extending 500 km (311 mi.) from Adirondack Highlands to James Bay. Shallow events with depths less than 8 km (5 mi.) are randomly distributed with reverse mechanisms attributed to glacial isostatic adjustment. Earthquakes with intermediate depths define a linear band of earthquakes. Deep earthquakes (greater than 17 km, or 10.6 mi., in depth) are localized as clusters at Timiskaming, Maniwaki, Mont-Laurier, and Adirondack. Timiskaming cluster is located near the 1935 Timiskaming earthquake, has a lower *b*-value than the other clusters and the regional average, and is associated with faults of the Ottawa-Bonechere graben. Adirondack cluster is located near the 1944 Cornwall-Massena earthquake, and two events within the cluster have focal mechanisms with an E-W-oriented P axis. The Mont-Laurier cluster is adjacent

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Citation	Title	Description and Relevance to SSC
		to paleoseismic evidence near Ottawa River studied by Aylsworth et al. (2000). Seismicity does not generally correlate with structure in WQSZ; shear zones of Grenville province cut across the NW-SE trend of WQSZ at a high angle. The Maniwaki cluster exhibits repeating events, with deep seismicity localized within the footwall of the Baskatong crustal ramp, and intermediate and shallow seismicity localized within the hanging wall. Clustered seismicity, with the exception of the Timiskaming clusters, has little spatial overlap with Ottawa-Bonnechere and Timiskaming graben structures. The authors speculate that localized seismicity in the WQSZ is attributed to either weakened faults and shear zones caused by reheating of crust by hotspot track, or to stress concentrations associated with the emplacement of major bodies in more felsic crust. Near-surface expression of the hotspot track progressively changes from kimberlitic melts in interior of craton to more voluminous crustal magmatism as the hotspot interacted with a progressively thinner lithosphere. The authors propose that the WQSZ represents an area of blind intrusions associated with entrapment of mantle-derived melt in the crust that is located between kimberlitic dikes to the NW and Monteregian intrusions to the SE.
Ma et al. (2008)	Intraplate Seismicity of a Recently Deglaciated Shield Terrane: A Case Study from Northern Ontario, Canada	Determined depth phases of 537 earthquakes occurring in Northern Ontario between 1980 and 2006. Identified two active clusters south of James Bay and near Kapuskasing where focal depths range from a few km to more than 20 km (12.4 mi.). James Bay cluster was not recognized until regional monitoring began in 2002. Cluster is centered around 53N, 80.7W with focal depths varying from 4 to 20 km (2.5 to 12.4 mi.), indicating that earthquakes occur along deep-rooted geologic structures. Largest magnitude observed in cluster is M_N 3.6. Kapuskasing cluster is located 100 km (62 mi.) NW of Western Quebec seismic zone (WQSZ), separated by an aseismic zone. Kapuskasing cluster contains the December 1, 1928, M_L 5.0; April 13, 1980, M_N 4.1; and December 7, 2007, M_N 4.2 earthquakes. Focal mechanisms from both clusters indicate thrust mechanisms with NW-striking nodal planes. Focal depths increase successively in time, consistent with progressive rupture migration down a fault. The authors attribute the Kapuskasing cluster to extension of WQSZ, and this seismicity to a combination of thermal rejuvenation of the crust and/or rheological contrast between igneous rocks and older crust resulting from passage of North America over the Great Meteor hotspot.

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Citation	Title	Description and Relevance to SSC
Paleoseismic Investigations		
Aylsworth et al. (2000)	Did Two Massive Earthquakes in the Holocene Induce Widespread Landsliding and Near-Surface Deformation in Part of the Ottawa Valley, Canada?	Examines large prehistoric landslides in abandoned channels of Ottawa River and disturbed sediment of the erosional plane adjacent to Ottawa River, south of Great Meteor Hotspot seismotectonic zone. Radiocarbon dates from buried wood and plant material that collected in landslide debris cluster at 4,550 yr BP, which is thousands of years younger than the age of paleochannel abandonment. This observation cannot be attributed to either fluvial erosion or wet-weather-induced landslides. East of the landslides, disturbed sediment and possible sand boils dated at 7,060 yr BP are preserved within flat erosional plane adjacent to Ottawa River. These two age distributions are attributed to paleoearthquakes of uncertain magnitude and source.

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Citation	Title	Description and Relevance to SSC
General for Region		
Adams et al. (1995)	Northeastern North American Earthquake Potential—New Challenges for Seismic Hazard Mapping	Presents rationale for source characterization used in the seismic hazard maps of Canada. The Northern Appalachian zone consists of crust of the northern Appalachians that overrode the Iapetan passive margin. The geometry extends from the landward limit of Mesozoic extensional faulting to the seaward limit of thinned Grenville crust of the Iapetan passive margin. The Miramichi earthquake is considered the paradigm earthquake.
Tremblay and Castonguay (2002)	Structural Evolution of the Laurentian Margin Revisited (Southern Quebec Appalachians): Implications for the Salinian Orogeny and Successor Basins	The northern Appalachians consist of several tectonostratigraphic zones: Humber, Dunnage, Gander, Avalon, and Meguma. The external Humber zone consists of sedimentary rocks and mafic volcanic rocks deformed into a series of imbricate NW-directed thrust nappes of prehnite-pumpellyite to sub-greenschist facies. The internal Humber zone consists of distal facies of external Humber zone units of greenschist to amphibolite metamorphic grade. The Dunnage zone consists of ophiolites, melanges, volcanic arc sequences, and flysch deposits. The surface boundary between the Humber and Dunnage zones defines the Baie Verte–Brompton line. In southern Quebec, the Dunnage zone is overlain by the Connecticut Valley–Gaspe trough.
Taconic Orogeny		
Faill (1997a)	A Geologic History of the North-Central Appalachians, Part 1: Orogenesis from the Mesoproterozoic Through the Taconic Orogen	The Middle to Late Ordovician Taconic orogeny extended from Labrador to Alabama and is currently exposed in the southern Appalachians in the Piedmont and Great Valley allochthons and western New England. Assemblages in the southern Appalachians contain complexes formed in the Theic Ocean, whereas assemblages of western New England consist of two magmatic arcs: the Halwey arc of the Brompton-Cameron terrane and the Ammonoosuc arc of the Central Maine terrane.
Faill (1997b)	A Geologic History of the North-Central Appalachians, Part 2: The Appalachian Basin from the Silurian Through the Carboniferous	Several Theic components, including microcontinents, magmatic arcs, and accretionary prisms were obducted along the broad carbonate shelf that existed on the eastern edge of Laurentia. These Taconic terranes formed a topographic barrier creating the Appalachian basin from Alabama to at least Quebec.

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Citation	Title	Description and Relevance to SSC
Faure et al. (2004)	Reconstruction of Taconian and Acadian Paleostress Regimes in the Quebec and Northern New Brunswick Appalachians	Paleostress analysis of brittle faults in Quebec and New Brunswick indicate that Taconic deformation produced N-S- to NE-SW-trending reverse conjugated brittle faults under a pure compressional stress regime late in the development of the orogeny. This Taconic compressional event also resulted in reactivation of Iapetan faults in the St. Lawrence Lowlands as E-NE/W-SW dextral and NW-SE sinistral faults.
Moench and Aleinikoff (2003)	Stratigraphy, Geochronology, and Accretionary Terrane Settings of Two Bronson Hill Arc Sequences, Northern New England	Volcanic arcs of the Bronson Hill anticlinorium developed in the late Cambrian within the Theic Ocean during the Penobscot orogeny. They were obducted to the Laurentian margin during the Middle to Late Ordovician Taconic orogeny. These arcs developed from multiple accretionary events with changing polarity shortly before the closing of the Iapetus Ocean at 460 Ma.
Spencer et al. (1989)	The Extension of Grenville Basement Beneath the Northern Appalachians: Results from the Quebec-Maine Seismic Reflection and Refraction Surveys	A master decollement separating autochthonous Grenville basement from overlying allochthonous rocks of the Appalachian orogen extends over a distance of 200 km (124 mi.) and can be traced from shallow depths beneath the St. Lawrence Lowlands SE to about 25 km (15.5 mi.) depth beneath the SE edge of the Chain Lakes massif. Basement is offset by closely spaced en echelon normal faults, with displacements between 200 and 1,000 m interpreted as Iapetan growth faults. The Baie Verte–Brompton line, separating Cambrian and Ordovician continental slope and rise deposits from oceanic arc and magmatic assemblages to the south, including the Chain Lakes massif, is imaged as a shallow, thin-skinned structure. The Chain Lakes terrane is thought to underlie much of the Connecticut Valley–Gaspe synclinorium. The Acadian Guadeloupe fault disrupts the master decollement of the Taconian orogeny and thrust the Connecticut Valley–Gaspe synclinorium over the Chain Lakes massif.
St. Julien and Hubert (1975)	Evolution of the Taconian Orogen in the Quebec Appalachians	Describes 11 lithostratigraphic assemblages distributed between the autochthonous, external, and internal domains of the Quebec Appalachians. The autochthonous domain contains Cambrian and Ordovician sandstones and carbonates representing transgressive shelf deposits, Middle and Upper Ordovician flysch deposits, and Upper Ordovician shale and sandstone representing the post-tectonic regressive sequence. This domain contains E-W- and N30E-trending normal faults active between late Precambrian and Late Ordovician. The external domain is divided into an outer belt containing imbricated thrusts and an inner belt composed of nappes separated by Logan's Line. Assemblages

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		of the autochthonous domain can be found within the thrust-imbricated belt. lower Cambrian clastic-carbonate, Cambrian shale-feldspathic sandstone, and upper Cambrian/Lower Ordovician shale-limestone conglomerate assemblages constitute nappes of the inner belt of the external domain. East-dipping reverse faults of the external belt repeat through successive imbricated structures on a decollement surface that cuts southeastward into progressively older rocks. Polarity of the nappes indicates that right-side-up nappes with the oldest rock assemblages always rest on nappes containing the youngest. Emplacement of the nappes is constrained by elevation and denudation of the nappes beginning in early Middle Ordovician and progressing westward until late Middle Ordovician and prior to dynamothermal metamorphism, as evidenced by a regional penetrative cleavage associated with a late fold system. The internal domain contains assemblages from the inner belt, and ophiolite, shale-melange, slate-sandstone tuff, and calk-alkaline volcanic assemblages. The internal domain is deformed by late recumbent folds genetically related to dynamothermal metamorphism in the latest Ordovician or earliest Silurian. Imbrication along major thrust faults likely occurred in the Upper Ordovician. These assemblages were accumulated on a Grenville-like basement to the west and newly formed oceanic crust to the east. The Taconian orogeny coincides with obduction of newly formed ocean crust in late Early Ordovician and subduction of oceanic crust during early and late Middle Ordovician. Rocks within the internal and external domains exhibit Devonian deformation associated with Acadian orogeny.
Stewart et al. (1993)	Global Geoscience Transect 8: Quebec-Maine-Gulf of Maine Transect, Southeastern Canada, Northeastern United States of America	Integrates interpretations from the Maine-Quebec seismic lines and provides descriptions of major tectonostratigraphic terranes, including the Laurentian craton, the Brompton-Cameron, Central Maine, Nashoba-Casco-Miramichi, and Atlantica composite terranes, and the Meguma terrane.
Salinian Orogeny		
Murphy and Keppie (2005)	The Acadian Orogeny in the Northern Appalachians	Late Cambrian–Middle Ordovician Penobscottian orogeny amalgamated composite terranes within arcs of the Iapetus Ocean, and therefore did not result in deformation within Laurentia. Late Ordovician–Silurian Salinic orogeny accreted the Gander, Avalon, Nashoba, and Carolina terranes to Laurentia during closing of the Iapetus Ocean during the Laurentia-Avalonia collision.

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Citation	Title	Description and Relevance to SSC
Tremblay and Castonguay (2002)	Structural Evolution of the Laurentian Margin Revisited (Southern Quebec Appalachians): Implications for the Salinian Orogeny and Successor Basins	Silurian metamorphism (430–410 Ma) in the northern Appalachians is attributed to retrograde metamorphism following the main compression event. The event involved SE-directed transport of Taconian crustal wedge followed by normal faulting (Saint-Joseph and Baie Verte–Brompton faults) and development of the fault-bounded sedimentary basins of the Connecticut Valley–Gaspé trough. This extension is inconsistent with coeval compression in Newfoundland, suggesting that the Salinian orogeny is geographically restricted or the entire Laurentian margin is characterized by crustal extension that induced the formation of major sedimentary basins during the Silurian and Devonian.
Tremblay and Pinet (2005)	Diachronous Supracrustal Extension in an Intraplate Setting and the Origin of the Connecticut Valley—Gaspé and Merrimack Troughs, Northern Appalachians	Attributes the late-stage extension to supracrustal extensional collapse due to late-stage delamination of the lithospheric mantle in a SE-dipping subduction zone.
Acadian Orogeny		
Faill (1997b)	A Geologic History of the North-Central Appalachians, Part 2: The Appalachian Basin from the Silurian Through the Carboniferous	The Acadian orogeny is expressed in the Appalachian basin as siliclastic sedimentation from the Middle to Late Devonian, with additional pulses of uplift occurring in the early and late Carboniferous. The principle tectonic activity occurred in New England.
Faure et al. (2004)	Reconstruction of Taconian and Acadian Paleostress Regimes in the Quebec and Northern New Brunswick Appalachians	Deformation from the Acadian orogeny is expressed as E-SE/W-NW compression in a transpressional regime, producing E-NE/W-NW dextral and NW-SE sinistral strike-slip faults that crosscut Taconian thrust faults in the Appalachians of Quebec and New Brunswick. This deformation also resulted in reactivation of Iapetan structures in the St. Lawrence Lowlands.
Murphy and Keppie (2005)	The Acadian Orogeny in the Northern Appalachians	The Devonian Acadian orogeny has been attributed to either the collision of Avalonia with Laurentia or the accretion of the Meguma terrane; however, recent work indicates that the Meguma terrane is the passive margin on the southern margin of Avalonia. The authors interpret the Acadian orogeny as forming along an Andean-type margin that possibly overrides a plume and swell.

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Citation	Title	Description and Relevance to SSC
Tremblay et al. (2000)	Acadian Metamorphism in the Dunnage Zone of Southern Québec, Northern Appalachians: 40Ar/39Ar Evidence for Collision Diachronism	Acadian metamorphism is well dated as 385–375 Ma in the southern part of the Dunnage zone.
Alleghanian Orogeny		
Faill (1998)	A Geologic History of the North-Central Appalachians, Part 3: The Alleghany Orogeny	The Alleghanian orogeny produced decollement tectonism in the central and southern Appalachians, along with early penetrative shortening, late low-angle thrusts, low-grade metamorphism, and transpressional shear zones. NE of the Pennsylvania salient, the Alleghany orogeny is confined to Carboniferous basins and rocks previously affected by the Taconic and Acadian orogenies. In New England, Alleghany tectonism was driven by docking of the Avalon terrane. The northern Appalachians exhibit high-pressure metamorphism of Taconic and Acadian crust in east-central Connecticut and Massachusetts and deformation of Appalachian deposits near the Hudson Valley.
Faure et al. (1996a)	Alleghanian Paleostress Reconstruction in the Northern Appalachians: Intraplate Deformation Between Laurentia and Gondwana	Brittle faults of the northern Appalachians exhibit three phases of compression during the Alleghanian orogeny: an early NNW-SSE compression, a NNE-SSW compression, and a late WNW-ESE compression.
Murphy and Keppie (2005)	The Acadian Orogeny in the Northern Appalachians	There is general consensus that the late Carboniferous–Permian Alleghany orogeny was due to terminal collision between Gondwana and Laurentia-Baltica that closed the Rheic Ocean and resulted in the formation of Pangaea.
Opening of the Atlantic		
Faure et al. (1996b)	State of Intraplate Stress and Tectonism of Northeastern America Since Cretaceous Times, with Particular Emphasis on the New England–Quebec Igneous Province	Results of a paleostress analysis of brittle faults in the Quebec Appalachians provide evidence for two distinct phases of Cretaceous extension: an initial geographically widespread NE-SW phase of extension and a later N-S phase of extension confined to southern Quebec. The authors attributed this Cretaceous volcanism to continued fragmentation of Pangaea. Early NE- to E-NE-oriented extension and associated magmatism between 140 and 90 Ma are correlated to rifting between Labrador and Greenland at ~140 Ma, early breakup stages of South Atlantic Ocean at 130 Ma, and N-S-oriented extension and emplacement of dikes at 125 Ma, corresponding to separation of Iberia from Newfoundland.

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Citation	Title	Description and Relevance to SSC
Faure et al. (2006)	Paleostress Analysis of Atlantic Crustal Extension in the Quebec Appalachians	Fault stress tensors indicate that most E-W- to ESE-WNW-oriented stress is found in the Montreal and Gaspe area, whereas SE-NW stress is found in SE Quebec. Late Triassic–Jurassic dikes in New England and southern Quebec indicate SE-NW-oriented extension consistent with fault slip stress. The N-S-trending portion of a Jurassic dike in southern Quebec is consistent with the regional E-W extensional stress axis, whereas the NE-SW branch of this dike is more compatible with a local and adjacent NW-SE extension. Stress axes exhibit clockwise rotation in the White Mountain magma series, possibly due to local deviatoric stresses or a NE-SW-oriented basement fault. The authors attribute these two extensional paleostress trends to either (1) contemporaneous regional partitioning of ESE-WNW-oriented extension that was influenced by N-S-trending structures in the Champlain Lake Valley and the NE-SW-trending structures of the St. Lawrence rift, or (2) an initial Late Triassic E-W extension related to the formation of the Bay of Fundy and South Georgia rift basins and Early Jurassic ESE-WNW extension related to the central Atlantic rift system.
Cretaceous Great Meteor Hotspot		
Crough (1981)	Mesozoic Hotspot Epeirogeny in Eastern North America	Attributes a 600 km (373 mi.) wide zone of epeirogeny in SE Canada and New England during the Cretaceous and early Tertiary to the Great Meteor hotspot, as evidenced by apatite fission-track dating.
Duncan (1984)	Age Progressive Volcanism in the New England Seamounts and the Opening of the Central Atlantic Ocean	The author obtained radiometric ages for dredged volcanic rocks from seven of the New England seamounts and concluded that the seamounts increase in age from the SE (82 Ma for the Nashville seamount) to the NW (103 Ma for the Bear seamount).
Faure et al. (1996b)	State of Intraplate Stress and Tectonism of Northeastern America Since Cretaceous Times, with Particular Emphasis on the New England–Quebec Igneous Province	Performed a paleostress analysis of the New England–Quebec igneous province that provided an alternative interpretation for the distribution of Cretaceous plutons. Dikes display ESE-WNW and ENE-WSW trends and are spatially distributed in three E-W-trending dike swarms 75 by 300 km (47 by 186 mi.) in area. Leucocratic dikes occur closer to plutons and disappear within 3–4 km (2–2.5 mi.), likely recording local stress affects due to pluton emplacement. Lamprophyre dikes occur independently of plutons and strike parallel to regional dike swarms, recording regional far-field stresses.

Citation	Title	Description and Relevance to SSC
		Normal faults in the regions display two orientations: (1) E-W-trending normal faults found predominantly in the Montreal area are parallel to graben boundaries and the axis of the Monteregian hills, with vertical offsets ranging between 100 and 430 m; and (2) NW-SE to WNW-ESE-trending normal faults oblique to graben boundaries with less than 100 m of vertical offset. The NW-SE to WNW-ESE faults are older than the E-W-trending faults but exhibit crosscutting relationships, suggesting that some were reactivated during the formation of the E-W-trending faults. Some E-W-trending brittle faults and joints are observed in several Cretaceous plutons with similar orientations to dikes that are locally crosscut by these normal faults, suggesting that dike emplacement and faulting are contemporaneous. Conjugate sets of NE-SW dextral and ESE-WNW sinistral strike-slip faults and NNW-SSE reverse faults provide evidence for a compressional stress regime postdating the emplacement of the Cretaceous plutons. The authors attribute these data to an initial NE-SW extension event associated with rifting between Labrador and Greenland at 140 Ma, opening of the South Atlantic at 130 Ma, and related reactivation of the Timiskaming graben. Subsequent N-S-oriented extension associated with the emplacement of the Monteregian Hills corresponds to global fragmentation of Pangaea when Iberia separated from Newfoundland when dominant tensional stress propagated along the Labrador rift. The stress regime shifted to ENE-ESE-directed compressional in the early Tertiary when the oceanic spreading rate decreased due to an increasing number of convergent boundaries in the Pacific. The authors conclude that the emplacement of Cretaceous intrusions is consistent with a lithospheric fracture model as opposed to a hotspot model, emphasizing the role of preexisting structure in the Ottawa-Bonnechere graben.
McHone (1996)	Constraints on the Mantle Plume Model for Mesozoic Alkaline Intrusions in Northeastern North America	The author proposes that one or more deep-mantle plumes do not provide a satisfactory mechanism for the distribution of Cretaceous alkaline rocks of NE New England, and observes that previous studies oversimplify the evidence for a hotspot track across New England by ignoring important petrological data, including the following: • Jurassic syenite-monzonite-alkali granite of the White Mountain magma series has been described as a separate province from Cretaceous intrusions, although many Early Jurassic dikes and several mafic to felsic plutons in the province are petrographically and chemically similar to Early

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Northern Appalachian Zone

Citation	Title	Description and Relevance to SSC
		Cretaceous intrusions that overlap. • Early Cretaceous dikes and plutons of the New England–Quebec igneous province have statistically similar paleomagnetic poles between 122 and 124 Ma and show no consistent trend for published ages in any direction across the region. • Seamount volcanism is not limited to ages defined by a linear hotspot track, nor is it in line with the New England–Quebec province. • Cretaceous alkaline rocks do not exhibit a consistent chemical signature indicative of a mantle source. These observations indicate that lithospheric processes were necessary to start and stop the generation of magmas from the same source in the mantle, and petrological studies should emphasize local and regional tectonic features.
Morgan (1983)	Hotspot Tracks and the Early Rifting of the Atlantic	Attributes this age distribution to two hotspot tracks passing through New England at different times: the Verde hotspot track at about 160 Ma and the Meteor hotspot about 120 Ma
Roden-Tice and Tice (2005)	Regional-Scale Mid-Jurassic to Late Cretaceous Unroofing from the Adirondack Mountains Through Central New England Based on Apatite Fission-Track and (U-Th)/He Thermochronology	Apatite fission-track ages and (U-Th)/He ages from the Adirondack Mountains and eastern New York state, Vermont, western Massachusetts and Connecticut, and western New Hampshire indicate that widespread unroofing during the Middle Jurassic to Late Cretaceous occurred at a rate of 0.07 to 0.08 km/Myr This regional uplift is attributed to remnant heating from the Great Meteor hotspot. Differential unroofing was accommodated by extensional fault reactivation.
Roden-Tice, West, et al. (2009)	Presence of a Long-Term Lithospheric Thermal Anomaly: Evidence from Apatite Fission-Track Analysis in Northern New England	Apatite fission-track ages across New Hampshire, NE Vermont, and western Maine range from 70 to 140 Ma and reflect widespread Early to Late Cretaceous cooling. This regional cooling and unroofing is attributed to passage of the North American Plate over the Great Meteor hotspot, emplacement of the White Mountain magma series in the Early Jurassic, and associated E-W and NW-SE extension. Regional uplift on the order of 5–7 km (3–4 mi.) may explain lack of rift basins in central New England and Quebec.

Table D-7.3.3 Data Summary
Northern Appalachian Zone

Citation	Title	Description and Relevance to SSC
Sleep (1990)	Monteregian Hotspot Track: A Long-Lived Mantle Plume	From modeling the buoyancy flux of the Great Meteor hotspot, the author observed that the trace of the hotspot changes orientation, concluding that the plume was weak beneath Ontario and strong beneath Montreal where the track changed orientation through the White Mountains, and became weakened at the Nashville seamount where the track changed orientation to the Corner seamounts. The author suggests that the lack of tracks west of the Monteregian Hills may be the result of the Canadian Shield's being less vulnerable to the hotspot than the Paleozoic sediments of the Montreal area were.
Zartman (1977)	Geochronology of Some Alkalic Rock Provinces in Eastern and Central United States	The author observed that although the mapped relationships of alkalic intrusive rocks of New Hampshire indicate post-tectonic character from their host rocks, relatively shallow emplacement depths, and alignments with the Monteregian Hills of Quebec and Cretaceous seamounts of offshore New England, radiometric ages of the New Hampshire plutons range from Early Triassic to Early Cretaceous but lack any regular time-transgressive pattern of ages.
Geophysical Anomalies		
Hughes and Luetgert (1991)	Crustal Structure of the Western New England Appalachians and the Adirondack Mountains	Interpreted seismic refraction data from the eastern Adirondack Mountains, northern Vermont, northern New Hampshire, and SE Maine. The lower crust has indistinct reflectors and was modeled with a velocity of 6.7 km/s. The depth to Moho thickens from 36 km (22 mi.) in western Maine to 40 km (25 mi.) in Vermont. Crust thins to the east along the transect. Coherent large-amplitude Moho reflections beneath Vermont and New Hampshire suggest compositional lamination at the base of the crust. Locally, the apparent velocity of the upper mantle exceeds 8.1 km/s (5 m/s).
Li et al. (2003)	Shear Velocity Structure and Azimuthal Anisotropy Beneath Eastern North America from Rayleigh Wave Inversion	Determined the velocity structure beneath NE United States and SE Canada using Rayleigh wave inversion. The North American continental keel beneath Grenville Province is imaged in the upper mantle down to roughly 200 km (124 mi.) in depth. The North American keel has an irregular shape and a low velocity zone beneath eastern New York and central New England to 200 km (124 mi.), with particularly high amplitudes at depths of 60–140 km (37–87 mi.). Thin lithosphere beneath west-central New England and easternmost New York may be caused by thermal erosion associated with the Cretaceous hotspot.

Table D-7.3.3 Data Summary
Northern Appalachian Zone

Citation	Title	Description and Relevance to SSC
Seismicity		
Brown and Ebel (1985)	An Investigation of the January 1982 Gaza, New Hampshire Aftershock Sequence	Presents source parameters for aftershocks of the January 19, 1982, Gaza, New Hampshire, earthquake. Arrival time data for these aftershocks indicate a northwestward progression of epicentral location with time, suggesting the potential for NW-trending basement structures in the region along with the presence of shallow, multidirectional fracture patterns.
Burke (2004)	Historical Seismicity in the Central Highlands, Passamaquoddy Bay, and Moncton Regions of New Brunswick, Canada, 1817-1961	The author revised magnitudes and locations for historical earthquakes within the Central Highlands subzone (October 22, 1869, M_N 5.7; May 16, 1896, m_{bLg} 4.0; August 8, 1908, m_{bLg} 4.4; July 22, 1922, m_{bLg} 4.9; January 4,1930, m_{bLg} 4.2; and September 30, 1937, m_{bLg} 4.8) and indentified additional historical earthquakes (March 16, 1863, m_{bLg} 4.0; December 18, 1903, m_{bLg} 4.2; March 20, 1911, m_{bLg} 4.5; June 27, 1915, m_{bLg} 3.8; and March 30, 1925, m_{bLg} 4.1). Identified the August 12, 1867, m_{bLg} 3.7 Moncton earthquake and revised the time for the February 8, 1824, M_N 5.2 Moncton earthquake. Also identified the February 25, 1935, m_{bLg} 3.2 earthquake and revised times and locations for the January 1, 1883, m_{bLg} 5.3; March 23, 1896, m_{bLg} 4.2; and December 11, 1912, m_{bLg} 4.7 Passamaquoddy Bay earthquakes.
Burke (2009)	Historical Earthquakes Felt in New Brunswick (1764, 1811-1960)	Presents a compilation of historical earthquakes in New Brunswick that updates findings in Burke (2004) and Leblanc and Burke (1985). The text contains a discussion of felt report, felt area for all events, and isoseismal area of intensity IV reports for selected earthquakes.
Ebel (1996)	The Seventeenth Century Seismicity of Northeastern North America	Places the epicenter for the June 11, 1638, earthquake in the seismically active part of central New Hampshire and estimates a magnitude of 6.5 ± 0.5 to account for felt effects in Trois Rivières, Quebec, and Boston, Massachusetts.
Ebel and Bouck (1988)	New Focal Mechanisms for the New England Region: Constraints on the Regional Stress Regime	Presents focal mechanisms for small to moderate events occurring in New England between 1981 and 1987. These mechanisms are predominantly reverse with a component of strike-slip. These mechanisms have variable strike directions, including NE-SW, NW-SW, N-S, and E-W.

Table D-7.3.3 Data Summary
Northern Appalachian Zone

Citation	Title	Description and Relevance to SSC
Ebel et al. (1986)	A Study of the Source Parameters of Some Large Earthquakes of Northeastern North America	Examines source parameters for the two earthquakes occurring in December 1940 near Ossipee, New Hampshire: the December 20 M_L 5.3 and the December 24 M_L 5.4 earthquakes. Synthetic seismograms for the December 20, 1940, Ossipee earthquake provide evidence for a predominantly thrust mechanism with either a N-S- or E-W-striking nodal plane.
Leblanc and Burke (1985)	Re-evaluation of the 1817, 1855, 1869, and 1904 Maine–New Brunswick Area Earthquakes	Compiled felt reports and determined magnitudes for the March 21, 1904, m_{bLg} 5.9; October 22, 1869, m_{bLg} 5.7; February 8, 1855, m_{bLg}, 5.2–5.5; and May 22, 1817, m_{bLg} 4.5–5 historical earthquakes in Maine and New Brunswick.
Structures		
Moench and Aleinikoff (2003)	Stratigraphy, Geochronology, and Accretionary Terrane Settings of Two Bronson Hill Arc Sequences, Northern New England	The Amonoosuc fault is a major Triassic normal fault extending 200 km (124 mi.) from northern New Hampshire SW to Springfield, Vermont, with about 4 km (2.5 mi.) of vertical displacement. Although Triassic displacement is assumed, several earlier displacements may have occurred.
Roden-Tice, West, et al. (2009)	Presence of a Long-Term Lithospheric Thermal Anomaly: Evidence from Apatite Fission-Track Analysis in Northern New England	Apatite fission-track ages across the Ammonoosuc fault in the Connecticut River valley do not display age discontinuities that would imply significant displacement; however, in NW New Hampshire, age discontinuities suggest normal displacement during the Late Cretaceous. Similar age discontinuities are observed between the Bill Little fault and west-dipping normal Northey Hill fault. Samples collected from the area between these two faults display modeled time-temperature histories representing higher structural levels that were downdropped in a grabenlike structure during the Late Cretaceous.
Tremblay and Castonguay (2002)	Structural Evolution of the Laurentian Margin Revisited (Southern Quebec Appalachians): Implications for the Salinian Orogeny and Successor Basins	The following faults have regional significance: • Logan's Line marks the end of the Appalachian front. • The Richardson fault forms the boundary between the external and internal Humber zones. • The Bennett-Brome fault forms a composite structure along the NW limbs of the Notre Dame and Sutton Mountains anticlinoria. • Saint-Joseph fault defines the SE limb of the Notre Dame Mountains anticlinorium. Exhibited normal faulting during the Late Silurian to Early Devonian.

Table D-7.3.3 Data Summary
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Citation	Title	Description and Relevance to SSC
		• The Baie Verte–Brompton line forms the SE limb of the Sutton Mountains anticlinorium. Exhibited normal faulting during the Late Silurian to Early Devonian. • The La Guadeloupe fault is an Acadian reverse fault. The unusual thrust geometry is attributed to tectonic inversion of normal faults during Acadian compression.
West and Roden-Tice (2003)	Late Cretaceous Reactivation of the Norumbega Fault Zone, Maine: Evidence from Apatite Fission-Track Ages	Apatite fission-track ages across the Norumbega fault zone in southern Maine range from 113 to 89 Ma west of the fault and 159 to 140 Ma east of the fault. This age distribution is attributed to 2 km (1.2 mi.) east-side-down vertical displacement during the Late Cretaceous.

Table D-7.3.4 Data Summary
Paleozoic Extended Crust Zone

Citation	Title	Description and Relevance to SSC
General for Region		
Adams et al. (1995)	Northeastern North American Earthquake Potential—New Challenges for Seismic Hazard Mapping	The authors developed seismic source zones based on hypothesis that stable continental earthquakes occur through reactivation of rift faults that break the integrity of continental crust, including Atlantic and Iapetan margins. Characterized faulted edge of Grenville continental crust that rifted during opening of Iapetus Ocean. Normal faults are currently reactivated as thrust faults within Canada and strike-slip faults in the U.S. The authors distinguish between Iapetan rift basins and failed Iapetan rifts.
Aleinikoff et al. (1995)	U-Pb Ages of Metarhyolites of the Catoctin and Mount Rogers Formations, Central and Southern Appalachians: Evidence for Two Pulses of Iapetan Rifting	The authors determined U-Pb ages for zircons sampled from Catoctin (564 ± 9 Ma) and Mount Rogers (758 ± 12 Ma) formations. Tholeiitic flood metabasalt of Catoctin Formation crops out on both flanks of Blue Ridge anticlinorium from SE Pennsylvania to central Virginia and is overlain by Lower Cambrian rocks of Chilhowee Group. Catoctin Formation is underlain by rhyolite and arkose of Mechum River Formation, which contains clasts of Mesoproterozoic basement and Neoproterozoic Robertson River Igneous Suite. These rhyolites are thought to be the extrusive equivalent of the Battle Mountain Alkali Feldspar Granite of the Robertson River Igneous Suite. Bimodal volcanic rocks and interlayered sedimentary rocks of 760 Ma Mount Rogers Formation crop out in SW Virginia, North Carolina, and Tennessee. The Mount Rogers Formation nonconformably overlies Mesoproterozoic Cranberry Gneiss and is overlain by glaciogenic Konnarock Formation, which is overlain by the Chilhowee Group. The authors attribute these ages to two rifting events between 760 and 700 Ma and 570 and 560 Ma and correlate rifting in Sutton Mountains region with younger event. Study suggests that thick sediments of Ocoee Supergroup represent a long, slow episode of crustal extension and that Mount Rogers embayment is older than South Mountain and Sutton Mountains embayments.

Table D-7.3.4 Data Summary
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Citation	Title	Description and Relevance to SSC
Bédard and Stevenson (1999)	The Caldwell Group Lavas of Southern Quebec: MORB-Like Tholeiites Associated with the Opening of Iapetus Ocean	The authors obtained trace element and Nd isotopic data for Caldwell Group lavas of southern Quebec. These undated rocks, within Internal Nappe domain of Humber zone, were deformed during the Taconic orogeny. The rocks initially formed at an advanced stage in transition from rift to drift along Iapetan margin. Despite exhibiting clear evidence of hydrothermal alteration, several conclusions were inferred from the geochemistry of these basalts. These basalts crystallized from melts derived from normal mid-ocean ridge basalt (MORB) at low- to medium-pressure fractional crystallization. Most lavas represent about 20% melting from a source slightly less depleted than fertile MORB mantle (asthenospheric mantle), whereas subpopulations of Caldwell lavas represent only 6%–15% melting of the same source mantle. These data are substantiated by Nd-isotope data that indicate derivation from a mantle depleted of light rare earth elements that is more radiogenic than other Iapetus basalts, implying other basalts in the region were derived from a more enriched source. Sedimentary samples reflect mixture of old (Archean) and juvenile (Iapetan) crustal sources for the basin.
Du Berger et al. (1991)	The Saguenay (Quebec) Earthquake of November 25, 1988: Seismologic Data and Geologic Setting	Saguenay graben is defined by Lac Tchitogama and Ste-Marguerite River normal faults on north wall and Lac Kénogami normal fault on south wall. Ordovician limestones show downthrow of 500 m (1,640 ft.) along north wall. Subvertical brittle faults are found within and outside the graben. Lineaments in the region cluster at 000°, 015°, 030°, 050°, 105°, and 160°. The 015 and 030 lineaments correspond to NNE late Grenvillian ductile belts and some post-Ordovician brittle faults. The St. Lawrence rift reactivated 030° trend and produced 050° trend. The 160° trend is parallel to glacial strike. The 105° trend is prominent only in the Saguenay graben rosette. The 000° trend corresponds to a complex array of en echelon oblique short breaks near St. Maurice lineament, suggesting that St. Maurice marks transition between two structural domains.

Table D-7.3.4 Data Summary
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Citation	Title	Description and Relevance to SSC
Faill (1997a)	A Geologic History of the North-Central Appalachians. Part 1. Orogenesis from the Mesoproterozoic Through the Taconic Orogeny	Crustal extension and rifting late in the Neoproterozoic and into the earliest Cambrian separated Neoproterozoic supercontinent Rodinia into East Gondwana, West Gondwana, and Laurentia. Breakup of Rodinia spanned approximately 200 Myr, with separation of East Gondwana from western Laurentia approximately 750 Ma, and rifting of eastern Laurentia from West Gondwana resulting in the opening of several intervening oceans. Iapetus Ocean initially defined as early Paleozoic ocean between Baltica and Laurentia (Greenland); Theic Ocean defined as ocean between Laurentia and Gondwana, and Rheic Ocean as ocean between Baltica and Gondwana. This study emphasizes that subsequent universal usage of Iapetus refers to the Paleozoic ocean off Laurentia east margin and that sensu stricto the Iapetus Ocean was closed in Late Silurian Caledonia orogeny during docking of Avalonia microcontinents with Laurentia. The remaining ocean that lay east of Avalonia is generally called Theic, leading the author to recognize Paleozoic ocean east of Laurentia as Theia. Evidence of initial breakup of Rodinia along western margin of Laurentia exists in southern Appalachian Virginia/North Carolina Blue Ridge as 760 Ma continental rift-facies volcanic Mount Rogers Formation and as largely nonvolcanic Ocoee rift deposits farther to the SW. The events may have been related to opening of Pacific Ocean. Rocks of Catoctin rift of Virginia, Maryland, and Pennsylvania comprise volcanic rocks of Catoctin Formation and sedimentary clastics of Chilhowee Group. These rocks, along with rocks of the St. Lawrence rift, suggest a fairly uniform-composition magma generation along eastern margin of Laurentia during the second phase of rifting.

Table D-7.3.4 Data Summary
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Citation	Title	Description and Relevance to SSC
Faure et al. (2006)	Paleostress Analysis of Atlantic Crustal Extension in the Quebec Appalachians	Fault stress tensors indicate that most E-W to ESE-WNW-oriented stress is found in Montreal and Gaspé area, whereas SE-NW stress is found in SE Quebec. Late Triassic–Jurassic dikes in New England and southern Quebec indicate SE-NW-oriented extension consistent with fault slip stress. The N-S-trending portion of a Jurassic dike in southern Quebec is consistent with regional E-W extensional stress axis, whereas the NE-SW branch of this dike is more compatible with a local and adjacent NW-SE extension. Stress axes exhibit clockwise rotation in the White Mountain magma series, possibly due to local deviatoric stresses or a NE-SW-oriented basement fault. Faure et al. (2006) attribute these two extensional paleostress trends to either (1) contemporaneous regional partitioning of ESE-WNW-oriented extension influenced by N-S-trending structures in the Champlain Lake Valley and by NE-SW-trending structures of the St. Lawrence rift, or (2) an initial Late Triassic E-W extension related to formation of Bay of Fundy and South Georgia rift basins and Early Jurassic ESE-WNW extension related to central Atlantic rift system.
Gates and Volkert (2004)	Vestiges of an Iapetan Rift Basin in the New Jersey Highlands: Implications for the Neoproterozoic Laurentian Margin	Neoproterozoic rift basin deposits of Chestnut Hill Formation allow correlation between Iapetan rift basins in both northern and southern Appalachians. Immature, locally derived sediments of Chestnut Hill Formation were deposited into early alluvial, and later fluvial, lacustrine, and deltaic environments. Outcrops of Chestnut Hill Formation are associated with Morgan Hill and Chestnut Hill fault systems, which display transition in normal faulting from ductile to brittle moving upward in the geologic section. The authors recognize that Chestnut Hill basin may not be the most inboard Neoproterozoic basin, and may in fact open the possibility that Iapetan margin contains other basins beneath Valley and Ridge cover.

Table D-7.3.4 Data Summary
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Citation	Title	Description and Relevance to SSC
Higgins and van Breemen (1998)	The Age of the Sept Iles Layered Mafic Intrusion, Canada: Implications for the Late Neoproterozoic/Cambrian History of Southeastern Canada	The authors obtained U-Pb ages of 565 ± 4 Ma for Sept Iles layered mafic pluton located on Gulf of St. Lawrence islands and peninsulas. Combining these results with other published ages for Neoproterozoic to Cambrian igneous rocks from Laurentian margin suggests three phases of magmatism: 1. Tholeiitic dike emplacement was diachronous along Laurentian margin: Long Range dike swarm in Newfoundland was dated at 615 ± 2 Ma over a distance of 400 km (250 mi.) (Kamo et al., 1989); Grenville dike swarm formed synchronously with the Ottawa graben at 590 +2/–1 Ma over a distance of 400 km (250 mi.) (Kumarapeli, 1993; Kamo et al., 1995). These dike swarms may have been produced by one or two mantle plumes between 615 and 590 Ma, possibly one at Sept Iles. 2. Following dike emplacement, alkali plutons intruded into a relatively large region spanning Quebec, Ontario, Greenland, and Scandinavia as early as 578 Ma and as late as Sept Iles intrusion (565 Ma). The authors attribute these plutons to a major plume located at Sept Iles instead of the location below the Sutton Mountains proposed by Kumarapeli (1993), but acknowledge that the two dike swarms could be result of two mantle plumes separated by 25 Myr The authors also observe that alkalic plutons were intruded along rift faults that developed after emplacement of dikes. 3. Undated diabase dikes and metabasaltic flows occur throughout northern Appalachians, indicating earliest stages of formation of Iapetus Ocean. Tholeiitic lavas of Tibbit Hill Formation have U-Pb zircon ages of 554 +4/–2 Ma (Kumarapeli et al., 1989); and alkali volcanic rocks at Skinners Cove, Newfoundland, have U-Pb ages of 550 +3/–2 Ma (McCausland et al., 1997).
Hodych and Cox (2007)	Ediacaran U-Pb Zircon Dates for the Lac Matapédia and Mt. St.-Anselme Basalts of the Quebec Appalachians: Support for a Long-Lived Mantle Plume During the Rifting Phase of Iapetus Opening	U-Pb zircon ages for Lac Matapédia basalt (565 ± 6 Ma and 556 ± 5 Ma) and Mt. St.-Anselme basalt (550 ± 7 Ma) support interpretation of a long-lived Sutton Mountains mantle plume. These data close the gap between end of flood basalt and beginning of plume magmatism, and support a rift-drift transition at 540 Ma, as opposed to 570 Ma (McCausland and Hodych, 1998). This hypothesis implies that Laurentia drifted northward more slowly than was suggested by McCausland and Hodych (1998).

Table D-7.3.4 Data Summary
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Citation	Title	Description and Relevance to SSC
Howell and van der Pluijm (1999)	Structural Sequences and Styles of Subsidence in the Michigan Basin	Subsidence of Michigan basin began in late Cambrian to Early Ordovician. Subsequent episodes of subsidence responded to Appalachian tectonic events, resulting in evolution of the style and geometry of subsidence. These observations do not indicate that Iapetan rifting affected the Michigan basin.
Kanter (1994)	Tectonic Interpretation of Stable Continental Crust	Northern and central portions of North America are an amalgamation of various Archean and Proterozoic domains assembled during the Mesoproterozoic. During the very late Neoproterozoic and continuing into the earliest Paleozoic, rifting occurred along eastern and southern margins, resulting in a passive margin. The author classified St. Lawrence–Ottawa domain (#227) as a Paleozoic rift, remnant of an east-facing continental margin of an ocean basin that closed during formation of Appalachian Mountains, as evidenced by Appalachian thrust sheets overlapping eastern edge. Domain is defined on basis of fractures and normal faults in basement, alkalic intrusions, and Paleozoic sedimentary rocks that overlie basement. The presence of coarse clastics presumed to be of late Proterozoic age in eastern end of Ottawa graben implies that initiation of this rift system may have occurred in late Neoproterozoic. The author did not classify as extended any other Paleozoic domains south of St. Lawrence–Ottawa domain along eastern margin. The Newfoundland (#220) and Acadia (#222) domains consist of large clastic wedges formed as a result of Taconic accretionary events. Portions of Piedmont domain (#223) were deformed during Taconic orogeny, were accreted during Acadian strike-slip deformation (which affected the entire Appalachians), and experienced intense deformation during the widespread Alleghanian orogeny. Valley and Ridge province (domain #224) consists of miogeoclinal sediments overlying Grenville-age basement deformed as a thin-skinned fold and thrust belt west of Piedmont domain. Outboard of these domains, the Eastern Seaboard domain (#218) records Mesozoic extension resulting from breakup of Pangaea. Study determined that the distinction between extended and non-extended domains was the only statistically significant variable on basis of maximum magnitude.

Table D-7.3.4 Data Summary
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Citation	Title	Description and Relevance to SSC
Kamo et al. (1995)	Age of the Grenville Dyke Swarm, Ontario, Quebec: Implications for the Timing of Iapetan Rifting	Updates geochronology of Grenville dike swarm by obtaining U-Pb baddeleyite ages from widest dikes throughout Ottawa graben. Revised age of 590 Ma suggests Grenville dike swarm was emplaced within a relatively short time span. These dikes are thought to have formed at onset of rifting within Ottawa graben, Sutton Mountains triple junction, and the related segment of Iapetan margin. Comparison with ages of similar rift-related igneous rocks along Iapetan margin of Laurentia, including Bakersville dike swarm of the Blue Ridge (570 Ma), Franklin swarm of northern Canadian Shield (723 Ma), and Long Range dikes of SE Labrador and Newfoundland (615 Ma), indicate that Iapetan rifting occurred along vast distances of northern and eastern margins of Laurentia. The timing of initial rifting within Ottawa graben is somewhat earlier than other parts of North America, suggesting that rift initiation progressed from northern Laurentia margin at 723 Ma to Labrador and Newfoundland at 615 Ma, followed by Grenville dike swarm at 590 Ma.
Kumarapeli and Saull (1966)	The St. Lawrence Valley System: A North American Equivalent of the East African Rift Valley System	Proposes rift origin for St. Lawrence valley system, including Ottawa-Bonnechere and Saguenay grabens. Discusses the evidence supporting this conclusion, including the following: • Escarpments on NW side of St. Lawrence valley, north side of Ottawa Bonnechere graben, and western margin of Champlain Lake Valley. • South of Ottawa-Bonnechere graben, tilting of Madawaska Highlands to the south, NW tilting of Adirondack massif, north tilting of a Laurentian block south of Saguenay graben, and south block tilting of Gaspé Peninsula. • En echelon normal faults along NW boundary with vertical displacements between 450 and 1,200 m (1,476 and 3,937 ft.). • St. Barnabe fault, a 55 km (34 mi.) normal fault on SE margin with 600 m (1,969 ft.) of downthrow to the west. • Concentrations of historical seismicity along St. Lawrence and Ottawa valleys and St. Lawrence trough. • Presence of a negative Bouguer anomaly in rift valley. • Connection of St. Lawrence valley with Mississippi embayment. • Westward continuation of Ottawa-Bonnechere graben with Midcontinent rift system.

Table D-7.3.4 Data Summary
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Citation	Title	Description and Relevance to SSC
		Because the publication pre-dated plate tectonics, many aspects of the authors' ideas are not consistent with current tectonic models of the region. After comparing St. Lawrence rift system to East African rift system, the authors suggest that the Great Lakes may be analogous to Lakes Victoria and Kyoga. The authors also associate Monteregian alkaline intrusives with St. Lawrence valley. Recent work associates them with Cretaceous intrusion that formed during reactivation of Ottawa-Bonnechere graben.
Kumarapareli (1985)	Vestiges of Iapetan Rifting in the Craton West of the Northern Appalachians	Proposes that a mantle plume produced initial ruptures of Iapetan rifting along a triple junction that led to continental fragmentation and development of an aulacogen in Ottawa graben. Alkalic to transitional bimodal volcanic rocks of the Tibbit Hill volcanics are deposited within Sutton Mountains salient, east of Ottawa graben, and are thought to be coeval with Grenville dike swarm within Ottawa graben. Interprets Sutton Mountains as the triple junction that initiated Iapetan rifting.
Kumarapeli et al. (1988)	Volcanism on the Passive Margin of Laurentia: An Early Paleozoic Analogue of Cretaceous Volcanism on the Northeastern American Margin	Transitional to alkaline basalts and mid-ocean ridge basalts (MORBs) found within Granby nappe of SE Quebec provide evidence for late Cambrian to Early Ordovician volcanism within transverse fracture zones analogous to Early Cretaceous volcanism in the Atlantic. The authors acknowledge that this data set is not sufficient to determine whether volcanism took place during drifting phase of continental margin because precise age of these rocks is not known. These allochthonous blocks are thought to represent slabs dislodged from the ancient shelf-margin sequence, possibly by Ottawa graben faults and NE-trending faults.
Kumarapeli (1993)	A Plume-Generated Segment of the Rifted Margin of Laurentia, Southern Canadian Appalachians, Seen Through a Completed Wilson Cycle	Updates mantle plume model presented by Kumarapeli (1985) with geochronology of dike swarms and volcanic rocks. Proposes that initiation of rifting was accompanied by emplacement of 590 Ma Grenville mafic dike swarm of tholeiitic composition. Rifting continued for 35 Myr until an outburst of alkaline to transitional basalts at Sutton Mountains triple junction dated at 554 Ma. This was quickly followed by a short period of rift-facies clastic sedimentation consisting of conglomerates attributed to a large river delta. Rift-drift transition is indicated by deposition of open-marine sedimentation, thought to have occurred 550 Ma based on presence of rocks with early Cambrian fauna above this transition.

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Citation	Title	Description and Relevance to SSC
Lavoie et al. (2003)	Stratigraphic Framework for the Cambrian-Ordovician Rift and Passive Margin Successions from Southern Quebec to Western Newfoundland	In the Quebec Reentrant, platform rocks were only marginally involved in tectonic stacking of Taconic orogeny, and form a spatially restricted frontal Taconian deformation zone that is known as the para-autochthonous or imbricate fault domain, and is therefore not considered part of Humber zone. The Quebec Reentrant is rooted in the autochthonous St. Lawrence platform. These structural relationships allow for stratigraphic and paleogeographic scenarios for early evolution of Quebec-Newfoundland segment of continental margin slope of Laurentia. Neoproterozoic to latest early Cambrian rift volcanics are overlain by rift-drift transition successions of early Cambrian Sauk I sequence. A global sea-level lowstand resulted in an unconformity that separates these rocks from shallow marine middle Cambrian to Middle Ordovician rocks of Sauk II and Sauk III subsequences. An extensive debris flow unit resedimented the middle Cambrian slope succession and is attributed to tectonic instability during middle to late Cambrian. The authors suggest that reactivation of Saguenay graben could be responsible for the anomalous upper Cambrian succession. Similar syndepositional tectonic activity is observed in the younger St. Lawrence platform succession in Charlevoix area during Middle to Late Ordovician. The authors present locations of reentrants and promontories for eastern margin of Laurentia farther north than those of Thomas (1991).
Lemieux et al. (2003)	Structural Analysis of Supracrustal Faults in the Charlevoix Area, Quebec: Relation to Impact Cratering and the St-Laurent Fault System	Two major sets of fault orientations (N290°–N320° and N020°–N040°) are found outside impact zone, with minor fault sets trending N270°–N280° and N000°–N020°. Within the impact crater, fault orientations are more scattered but are similar to NW- and NE-trending systems of external domain. Spread of orientations within central portion of crater is attributed to the impact-related polygonal pattern of normal faults, whereas NW and NE fault sets represent youngest reactivation. Coarse-grained cataclastic breccias up to 50 m (164 ft.) thick are exposed along brittle faults striking NE and NW outside impact crater. Similar cataclastic breccias are also found within the impact crater but are usually less than a few meters thick. Polymictic clastic matrix breccia are found exclusively within impact crater. Fragments of cataclastic breccia are present, suggesting recurrent brecciation during incremental faulting events. Pseudotachylyte and foliated gouge are locally related to cataclastic breccia, indicating that these rocks originate from a post-impact, single, and progressive tectonic event along

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Citation	Title	Description and Relevance to SSC
		St. Lawrence rift system. The St-Laurent fault influenced deposition of Ordovician deposits during late stages of Taconian orogeny as indicated by syndepositional faulting preserved as major lateral thickness variations within the section, presence of slump deformation in almost all stratigraphic units, preservation of pseudotachylyte within synsedimentary breccias, and occurrence of fault breccia clasts. However, the geometry and structural characteristics of faulting are consistent with Mesozoic fault reactivation due to rifting of North Atlantic region.
McBride et al. (2005)	Integrating Seismic Reflection and Geological Data and Interpretations Across an Internal Basement Massif: The Southern Appalachian Pine Mountain Window, USA	The authors trace the master Appalachian decollement from Inner Piedmont to Coastal Plain. They find that beneath the Carolina terrane, the decollement roots to the Moho, indicating the location of Acadian-Alleghanian suture.
McCausland and Hodych (1998)	Paleomagnetism of the 550 Ma Skinner Cove Volcanics of Western Newfoundland and the Opening of the Iapetus Ocean	The authors obtained paleomagnetic data for volcanic flows and volcaniclastic sediments of Skinner Cove Formation in western Newfoundland dated at 550 Ma that point to paleolatitude of 19°S ± 9°. This result represents paleolatitude of Iapetan margin at that time. Comparison of these results to those of 577 Ma Callander Complex of Ontario indicates rapid northward drift of Laurentia at approximately 570 Ma resulting from opening of Iapetus Ocean, which continued to the rift-drift transition at approximately 550 Ma.
Mereu et al. (1986)	The 1982 COCRUST Seismic Experiment Across the Ottawa-Bonnechere Graben and Grenville Front in Ontario and Quebec	Results of 1982 Canadian Consortium for Crustal Reconnaissance Using Seismic Techniques (COCRUST) long-range seismic refraction experiment show a sharp, step-like displacement of the Moho beneath south shoulder of Ottawa graben, confirming deep-seated nature of its faults and penetration of mantle melts into crust. Furthermore, COCRUST surveys show poorly defined Moho at unusually shallow depths beneath graben.
Petersen et al. (2008)	Documentation for the 2008 Update of the United States National Seismic Hazard Maps	The most recent model for the national seismic hazard maps for CEUS incorporates maximum magnitude distributions that are considered separately for the craton and the Iapetan rifted margin as determined by Wheeler (1995). Model selects values based on analogy with other stable continental regions: four values of moment magnitude between M 6.6 and M 7.2 (Charleston areal zone) for the craton, and four values of moment magnitude between M 7.1 (Charleston main shock) and M 7.7 (Bhuj, India) for the extended margin.

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Citation	Title	Description and Relevance to SSC
Pratt et al. (1988)	A Geophysical Study of the Earth's Crust in the Central Virginia: Implications for Appalachian Crustal Structure	The authors conclude that crustal thinning (at Taconic suture) in the Piedmont is responsible for Appalachian gravity gradient.
Rimando and Benn (2005)	Evolution of Faulting and Paleo-Stress Field Within the Ottawa Graben, Canada	The authors observe three periods of faulting in Cambro-Ordovician sedimentary rocks within eastern end of Ottawa graben, near Ottawa. The oldest generation of faults formed in stress field with a horizontal maximum compressive stress (σ_1) oriented NW. These structures are kinematically congruent with the compression direction associated with closing of Iapetus Ocean. Second generation of faults indicates a WNW-oriented σ_1 and coincides with emplacement of Cretaceous carbonatite dikes. Third generation of faults has a σ_1 oriented SW, which is consistent with post-Cretaceous stress field in eastern North America.
Rocher et al. (2003)	Brittle Fault Evolution of the Montréal Area (St. Lawrence Lowlands, Canada): Rift-Related Structural Inheritance and Tectonism Approached by Palaeostress Analysis	NW-SE extension associated with opening of Iapetus Ocean resulted in formation of N040-trending faults along north shore of St. Lawrence Lowlands and development of three major N090-trending faults that define a succession of horsts and grabens on Montréal and Jésus islands and N120-trending faults in Montreal area. The N090-trending faults have the following geometries: 1. Bas-Sainte-Rose fault zone, the northernmost series of N090-trending faults in Montreal area, is a steeply north-dipping fault with approximately 200 m (656 ft.) of vertical displacement and nearly 3 km (2 mi.) of apparent left-lateral offset. Offsets on Bas-Sainte-Rose fault zone decrease as fault zone extends westward, where it apparently crosscuts the N020-trending Rivière-aux-Mille-Iles fault zone. 2. Rapide-du-Cheval-Blanc consists of a series of steeply south-dipping normal faults (Ile-Bizard, Rapide-du-Cheval-Blanc, and Outremont) with a total vertical offset of approximately 100 m (326 ft.). 3. Sainte-Anne-de-Bellevue fault zone is a north-dipping normal fault with a left-lateral strike-slip component in southern part of Montréal Island. Its vertical offset has not been precisely determined. All three faults clearly crosscut NNE-SSW-trending folds from Appalachian Chambly-Fortierville syncline system in Trois-Rivières seismic zone. WNW-ESE compressions followed by minor NNW compressional events are

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		associated with Appalachian thrusting. WNW compression reactivated N090-trending faults as strike-slip right-lateral faults, and reactivated N040-070 and N120 faults as reverse to strike-slip faults. Subsequent NNW compression is responsible for strike-slip conjugate faults trending NW-SE and NNE. NE-SW and NNW-SSE extension is associated with opening of North Atlantic–Labrador Sea and reactivated faults with normal to strike-slip motions. NNW extension is responsible for horst-and-graben geometry of major N090 normal faults described above. Late NE-SW compression is recorded in Monteregian plutons. NE-SW compression postdating these events is associated with formation of strike-slip faults that crosscut Monteregian intrusions and is consistent with current stress regime.
Spencer et al. (1989)	The Extension of Grenville Basement Beneath the Northern Appalachians: Results from the Quebec-Maine Seismic Reflection and Refraction Surveys	A master decollement separating autochthonous Grenville basement from overlying allochthonous rocks of Appalachian orogen extends over a distance of 200 km (124 mi.) and can be traced from shallow depths beneath St. Lawrence Lowlands SE to about 25 km (15.5 mi.) depth beneath SE edge of Chain Lakes massif. Basement is offset by closely spaced en echelon normal faults, with displacements between 200 and 1,000 m (656 and 3,281 ft.) interpreted as Iapetan growth faults. The Baie Verte–Brompton line, separating Cambrian and Ordovician continental slope and rise deposits from oceanic arc and magmatic assemblages to south, including Chain Lakes massif, is imaged as shallow, thin-skinned structure. Chain Lakes terrane is thought to underlie much of Connecticut Valley–Gaspé synclinorium. Acadian Guadeloupe fault disrupts master decollement of Taconian orogeny and thrusts Connecticut Valley–Gaspé synclinorium over Chain Lakes massif.
St. Julien and Hubert (1975)	Evolution of the Taconian Orogen in the Quebec Appalachians	Describes 11 lithostratiographic assemblages distributed among autochthonous, external, and internal domains of Quebec Appalachians. The autochthonous domain contains Cambrian and Ordovician sandstones and carbonates representing transgressive shelf deposits, Middle and Upper Ordovician flysch deposits, and Upper Ordovician shale and sandstone representing the post-tectonic regressive sequence. This domain contains E-W- and N30E-trending normal faults active between late Precambrian and Late Ordovician.

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Swanson (1986)	Preexisting Fault Control for Mesozoic Basin Formation in Eastern North America	Correlates Mesozoic basin formation with reactivation of specific Paleozoic reverse and strike-slip faults along Appalachians.
Thomas (1991)	The Appalachian-Ouachita Rifted Margin of Southeastern North America	Synthesizes available data into an interpretation of mechanisms controlling shape and timing of Iapetan rifted margin. NW-SE extension along entire rift system resulted in NE-trending rift (normal) faults and NW-trending transform faults. Rifting began in late Precambrian along Blue Ridge rift. By beginning of Cambrian, Blue Ridge progressed to a passive margin flanked by Iapetus Ocean, extension occurred along Mississippi Valley, Rough Creek, Rome, and Birmingham fault systems, and mafic magmas were emplaced along Southern Oklahoma fault system, suggesting the spreading center moved from Blue Ridge rift to Ouachita rift in early Cambrian. This was accompanied by initiation of Alabama-Oakland transform and Southern Oklahoma fault system. Some extension was propagated into Mississippi Valley, Rough Creek, Rome, and Birmingham fault systems, but this did not result in opening of an ocean. By early late Cambrian, the entire rift and transform margin evolved into passive margin.
Thomas (2006)	Tectonic Inheritance at a Continental Margin	Explores tectonic inheritance of crustal structure through two Wilson cycles. The pre-Rodinia continental margin is unknown; however, possible inheritance from a dextral offset in older continental margin may result in the dextral bend of Grenville front beneath Gulf Coastal Plain. The New York–Alabama lineament, possibly an intra-Grenville suture, may represent either accretion along a straight segment of rifted margin or orogen-parallel slip across the shape of the margin. The palinspastically restored Iapetan margin consists of NE-striking rift segments offset by NW-striking transform faults, which in turn frame promontories and embayments of rifted continental margin. The trace of Alabama-Oklahoma transform corresponds to probable location of a large-scale dextral bend in Grenville front. Rift-parallel graben systems, including Rome trough and Birmingham graben, indicate late synrift extension inboard from the rifted margin; their relationship to older tectonic fabrics is obscure and presently unrecognized. A pervasive lithospheric fabric may result in successive reoccupation of traces of transform faults at continental margin and differential crustal subsidence along transform faults at rift offsets in continental embayments. The shape of Iapetan margin controlled orientation of Appalachian-Ouchita foreland structures and subsequent continental margin of

Citation	Title	Description and Relevance to SSC
		Atlantic and Gulf Coastal Plain.
Tremblay and Lemieux (2001)	Supracrustal Faults of the St. Lawrence Rift System Between Cap-Tourmente and Baie-Saint-Paul, Quebec	The Cap-Tourmente and St. Lawrence faults are late Proterozoic–early Paleozoic normal faults attributed to rifting during opening of the Iapetus Ocean. The St. Lawrence fault trends N020°–N050° and dips 60°–70° to SE. Fault rocks consist of fault breccia, cataclastite, foliated gouge, and pseudotachylyte with a minimum thickness of 20 m near Sault-au-Cochon. Fault rocks exposed at Cap-Tourmente consist of 10–15 m thick zones of protocataclasite, cataclasite, and fault breccia. Within Charlevoix area, the St. Lawrence fault is characterized by a well-developed and extensive series of cataclastic rock, gouge, and associated pseudotachylyte. The Cap-Tourmente fault trends E-W and dips approximately 80° to the south. Fault rocks consist mostly of fault breccia more than 10 m thick, as well as cataclastic rocks and dark pseudotachylyte veins. The St. Lawrence fault is crosscut by Cap-Tourmente fault at Cap-Tourmente. West of Cap-Tourmente, the Montmorency Falls fault occupies the same structural position as the St. Lawrence fault, suggesting that they formed from en echelon faults trending parallel to axis of St. Lawrence rift. The Cap-Tourmente fault possibly represents a transfer fault, producing an oblique relay between two longitudinal normal faults. The St. Lawrence fault crosses the Charlevoix impact crater without major trend deflection or fault offsets within or at the boundaries of the Devonian impact structure. This observation suggests that impact-related faults did not significantly alter the orientation of preexisting structures and that reactivation is younger than the impact structure, most probably concurrent with opening of the Atlantic Ocean in the Mesozoic.
Tremblay et al. (2003)	Supracrustal Faults of the St. Lawrence Rift System, Quebec: Kinematics and Geometry Revealed by Field Mapping and Marine Seismic Reflection Data	Presents strike orientations, dip angles, and pitch angles for faults with evidence of frictional sliding in the St. Lawrence rift system. NE-trending longitudinal faults show three trends (N025, N040, and N070) and generally dip to SE, although a minor number dip to NW. Transverse faults show two trends (N290 and N310) and dip to NE or SW, which is consistent with horst-and-graben geometry. Both sets of faults are high-angle faults with dip angles averaging 75°–80°. The pitch value of fault lineations is greater than 70°, indicating that most structures are dip-slip faults. Longitudinal and transverse

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		faults show mutual crosscutting relationships, suggesting that they represent conjugate structures related to same tectonic event. St-Laurent fault has experienced at least 800 m (2,625 ft.) of vertical throw at Sault-au-Cochon. Cap-Tourmente fault has a minimum vertical fault throw of 700 m (2,297 ft.). Montmorency fault has an 80 m (262 ft.) fault scarp near Quebec City; stratigraphic analysis suggests that fault throw should be less than 150 m (492 mi.), which is considerably less than the other faults. Several offshore faults subparallel to that fault may have vertical downthrow displacements up to 1 km (0.6 mi.). Longitudinal faults likely result from development of en echelon faults trending parallel to the rift axis, and transfer faults represent transfer faults or accommodation zones. Variations in fault throw are likely a result of propagation of extension along transfer faults. Presence of cataclastic rocks, pseudotachylytes, and fault gouge is consistent with changes of deformation mechanics during progressive and incremental deformation in upper crust. High-resolution seismic profiles in St. Lawrence estuary indicate that Laurentian Channel trough transitions from a half graben to a graben structure from SW to NE. The authors speculate that reactivation of St. Lawrence rift system is post-Ordovician, younger than the Devonian impact cratering event, and that the rift system experienced additional fault throw and shoulder uplift during Mesozoic opening of North Atlantic.
Valentino and Gates (1995)	Iapetan Rift-Related Turbidite-Fan Deposits from the Central Appalachian Piedmont	Peters Creek Formation of SE Pennsylvania and northern Maryland consists of two submarine turbidite-fan systems. Metaclastic strata of Peters Creek Formation preserve primary detrital and bedding features indicative of deposition in turbidite-fan systems. Presence of greenstone interlayered with feldspathic metasandstone suggests rift-related deposition. Granitic lithic fragments indicate unroofing of continental crust. Peters Creek Formation may represent deposits transported along an Iapetan rift-related transform fault linking southern Lynchburg rift basin with a comparable rift basin in southern New England.

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Walsh and Aleinikoff (1999)	U-Pb Zircon Age of Metafelsite from the Pinney Hollow Formation: Implications for the Development of the Vermont Appalachians	U-Pb zircon age of 571 ± 5 Ma for metafelsite from Pinney Hollow Formation of Vermont records age of rhyolitic volcanism and deposition in a largely pelitic sequence interpreted as pre-shelf rift-clastic sequence. This age agrees with other ages from rift-clastic volcanic rocks in the Appalachians. Relative distribution and thickness of metavolcanic and metafelsic sections throughout Appalachians suggest the basin that Pinney Hollow Formation was deposited into was already well developed when the 571 Ma metafelsite was deposited. Therefore, the 554 Ma age for Tibbit Hill Formation at Sutton Mountains triple junction does not represent first pulse of volcanic activity during initial opening of Iapetan basin in Vermont and Quebec Appalachians. This age also validates theory that Wood Peak fault is a significant thrust fault separating autochthonous and para-autochthonous cover sequence rocks, which in turn supports interpretation that the Taconic root zone is located in hinterland of Vermont Appalachians on eastern side of Green Mountain massif.
Wheeler (1995)	Earthquakes and the Cratonward Limit of Iapetan Faulting in Eastern North America	Recognizes that seismic activity within the Charlevoix, Quebec; Giles County, Virginia; Eastern Tennessee; and, possibly, Clarendon-Linden seismic zones is attributed to compressional reactivation of NE-trending Iapetan normal faults. Defines NW limit of potentially seismogenic Iapetan normal faults from a variety of data sets available at the time. This boundary, with an uncertainty of 21 km (13 mi.), separates lower rates of seismicity to the NW from higher rates to the SE and suggests that seismic zones to the SE of the line can produce large earthquakes such as those at Charlevoix.
Whitmeyer and Karlstrom (2007)	Tectonic Model for the Proterozoic Growth of North America	Breakup of Rodinia consists of diachronous disassembly. Early stages of rifting resulted in opening of a paleo-Pacific Ocean along western margin of Laurentia between 780 and 680 Ma, corresponding to separation of Australia, Antarctica, south China, and Siberia, and failed rifting along eastern margin of Laurentia. Complete breakup along eastern margin of Laurentia initiated by 620 Ma from Newfoundland to southern Appalachians. This final stage of breakup involved rifting of Argentina Precordillera terrane from Ouachita embayment. Transfer of Precordillera terrane across Iapetus Ocean requires relocating Iapetus spreading ridge from present-day Alabama to central Texas. This change in spreading may have occurred because of at least two incipient triple junctions that combined in SE United States in early Cambrian to initiate a new spreading ridge-transform system.

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Citation	Title	Description and Relevance to SSC
Geophysical Anomalies		
New York–Alabama (NY-AL) Lineament		
King and Zietz (1978)	The New York–Alabama Lineament: Geophysical Evidence for a Major Crustal Break in the Basement Beneath the Appalachian Basin	NY-AL lineament consists of series of linear magnetic gradients that correspond with west side of regional Appalachian gravity low. This lineament extends more than 1,600 km (994 mi.) from Mississippi embayment to Green Mountains of Vermont. It separates north-trending gravity anomalies on the NW from NE-trending anomalies to the SE. Magnetic gradient of NY-AL lineament faces SE for some sections and NE for others. Given that regions of high magnetic values are cut off by the lineament, it likely represents a strike-slip fault as opposed to a vertical displacement. The lineament constitutes a major break in crystalline basement rocks of Appalachian basement separating stable craton of continental interior from more mobile Appalachian block of continental margin.
Steltenpohl et al. (2010)	New York–Alabama Lineament: A Buried Right-Slip Fault Bordering the Appalachians and Mid-continent North America	NY-AL lineament is a N40E-trending magnetic lineament extending 1,600 km (994 mi.) from Vermont to southern Tennessee. From southern West Virginia to Tennessee, it separates a mottled pattern of magnetic highs and lows of the granite-rhyolite province and Neoproterozoic mafic rocks to the NW, from NE-trending magnetic lineaments of Appalachian orogen to the SE. NY-AL lineament is a fundamental tectonic boundary that may represent either an escape strike-slip fault related to Grenvillian contractual orogenesis, an axis of anatectic melting following continental collision, or an intra-Grenvillian suture. In Eastern Tennessee seismic zone (ETSZ), the Ocoee block is bounded by NY-AL lineament on the north and Clingman lineament on the south. NY-AL lineament is interpreted as strike-slip fault zone, based on truncation of Amish anomaly in West Virginia and on documentation of ~220 km (~137 mi.) of right-slip displacement and a trending magnetic high-low pair in SE block in Tennessee, Georgia, and Alabama. Linear fault segments that border Rome trough are parallel to and locally coincide with NY-AL lineament. SE border fault parallels lineament for nearly 250 km (155 mi.) from eastern KY to SW Pennsylvania. This segment of lineament was reactivated as a normal fault that underwent west-side-down dip-slip displacement during formation of Rome trough. Crust NW of NY-AL lineament behaved as a coherent block. Seismicity of ETSZ may be localized along the N15E-trending magnetic low

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		anomaly in the Ocoee block, which coincides with metasedimentary gneiss correlative with the Amish anomaly. Modern stress field is compatible with the one that initiated dextral motion along NY-AL lineament.
Structures		
Rome Trough		
Drahovzal (1997)	Proterozoic Sequences and Their Implications for Precambrian and Cambrian Geologic Evolution of Western Kentucky: Evidence from Seismic Reflection Data	Rough Creek graben and Rome trough exhibit Cambrian fan complexes deposited in a subsiding basin to the north. This subsidence likely occurred in late Precambrian and may represent inboard extension of Iapetan rifting along the Mesoproterozoic East Continent rift basin.
Faill (1997a)	A Geologic History of the North-Central Appalachians. Part 1. Orogenesis from the Mesoproterozoic Through the Taconic Orogeny	Rome trough consists of steep normal faults that become listric at depth, recording intracontinental extension during middle and late Cambrian. It acted as middle Cambrian sediment trap, with quartzose facies accumulating to the west during late Cambrian. Siliclastic deposition along eastern margin of Laurentia was replaced by carbonate deposition during early Cambrian.
Stark (1997)	The East Continent Rift Complex: Evidence and Conclusions	Attributes development of Rome trough and reactivation of Kentucky River fault system to late Neoproterozoic extension associated with opening of Iapetus Ocean within East Continent rift complex.
Steltenpohl et al. (2010)	New York–Alabama Lineament: A Buried Right-Slip Fault Bordering the Appalachians and Mid-continent North America	Linear fault segments that border Rome trough parallel and locally coincide with the NY-AL lineament. The SE border fault is parallel to lineament for nearly 250 km (155 mi.) from eastern Kentucky to SW Pennsylvania. This segment of lineament was reactivated as a normal fault that underwent west-side-down dip-slip displacement during formation of Rome trough.
Van Arsdale and Sergeant (1992)	Post-Pliocene Displacement on Faults Within the Kentucky River Fault System of East-Central Kentucky	Kentucky River fault system forms northern boundary of Rome trough, a Paleozoic aulacogen. The absence of post-Paleozoic deposits prevents determination of Mesozoic and early Tertiary displacements. Trenches in terrace materials indicate folding and faulting within last five million years, and probably within last million years.

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Citation	Title	Description and Relevance to SSC
Central Metasedimentary Belt Boundary Zone		
Forsyth, Milkereit, Davidson, et al. (1994)	Seismic Images of a Tectonic Subdivision of the Grenville Orogen Beneath Lakes Ontario and Erie	The authors observed extensional reactivation in Paleozoic section above Central Metasedimentary Belt boundary zone in eastern Lake Erie.
O'Dowd et al. (2004)	Structural Fabric of the Central Metasedimentary Belt of Southern Ontario, Canada, from Deep Seismic Profiling	Using results of Southern Ontario Seismic Project and analysis or regional magnetic data, the authors conclude that Central Metasedimentary Belt boundary zone must be located on west side of Mississauga domain, thereby placing it farther west.
Zones of Elevated Seismicity		
Clarendon-Linden Fault System		
Crone and Wheeler (2000)	Data for Quaternary Faults, Liquefaction Features, and Possible Tectonic Features in the Central and Eastern United States, East of the Rocky Mountain Front	Crone and Wheeler (2000) identify Clarendon-Linden fault zone in New York as Class C tectonic feature. Assessment is based on absence of paleoseismological evidence that fault zone has slipped during the Quaternary.
Dineva et al. (2004)	Seismicity of the Southern Great Lakes: Revised Earthquake Hypocenters and Possible Tectonic Controls	Hypocenters from earthquakes occurring between 1990 and 2001 were relocated; the redefined zones of seismicity delineate several clusters of events beneath Lake Ontario. The authors identified a cluster C that is parallel to Clarendon-Linden fault system but shifted slightly to SE by about 4 km (2.5 mi.). They note that during the 1990–2001 recording period for this analysis, little seismic activity occurred along Clarendon-Linden fault system, with only two events near southern end.
Fakundiny and Pomeroy (2002)	Seismic-Reflection Profiles of the Central Part of the Clarendon-Linden Fault System of Western New York in Relation to Regional Seismicity	Describes Clarendon-Linden fault system as broad zone of small faults with small displacements in lower Paleozoic bedrock. Fault system is at least 77 km (48 mi.) long and 7–17 km (4.5–10.5 mi.) wide; total vertical displacement across the zone is small (>91 m). Fault system is spatially coincident with a north-trending geophysical (combined magnetic and gravity) lineament within basement rock. Most earthquakes in the region cannot be unequivocally associated spatially with individual tectonic structures and lineaments.

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Citation	Title	Description and Relevance to SSC
Forsyth, Milkereit, Zelt, et al. (1994)	Deep Structure Beneath Lake Ontario: Crustal-Scale Grenville Subdivisions	Using deep crustal seismic images, at least three major shear zones are interpreted to underlie Lake Ontario. Elzevir-Frontenac boundary zone defined based on a shear zone transition exposed to north of Lake Ontario between these two terranes and linked to a seismically defined shear zone extending beneath Lake Ontario to south shore. Iroquoian high is defined on basis of gradual thinning of Paleozoic section over a crestal area of Elzevir-Frontenac boundary zone. Iroquoian high is interpreted to help explain Paleozoic fractures that formed Clarendon-Linden structure in New York.
Jacobi (2002)	Basement Faults and Seismicity in the Appalachian Basin of New York State	Evaluates regional sets of lineaments identified on Landsat images and their relationship to faults and earthquake epicenter locations. Identifies Clarendon-Linden fault system as the most prominent of western New York State fault sources. A seismicity swarm is located along western flank of the gravity high associated with this fault system. The swarm terminates on north where gravity high diminishes in amplitude.
Jacobi and Fountain (2002)	The Character and Reactivation History of the Southern Extension of the Seismically Active Clarendon-Linden Fault System, Western New York State	By integrating a variety of surface and subsurface data, the authors determined that Clarendon-Linden fault system in SW New York State consists of as many as 10 parallel, segmented faults. Fault segments are truncated by cross-strike discontinuities. The rock record indicates that fault blocks formed by the fault segments and that cross-strike discontinuities were active in Precambrian and subsequently reactivated multiple times until Late Devonian.
Ouassaa and Forsyth (2002)	Interpretation of Seismic and Potential Field Data from Western New York State and Lake Ontario	Lithoprobe and seismic data provide evidence of major zones of east-dipping Grenville deformed crust extending from north of Lake Ontario toward SW. In the vicinity of Clarendon-Linden fault, N-NE-trending magnetic and gravity anomalies are parallel to, but are not restricted to, the principal trend of this fault system. Surface continuity of inferred faults constituting Clarendon-Linden fault system is not strongly supported by reprocessed seismic data.
Paleoseismic Investigations		
Seeber and Armbruster (1993)	Natural and Induced Seismicity in the Lake Erie–Lake Ontario Region: Reactivation of Ancient Faults with Little Neotectonic Displacement	Historical and recent earthquake activity is interpreted to form a prominent seismic zone associated with Clarendon-Linden fault. Location of 1929 m_b 5.2 Attica earthquake suggests this event could have been associated with Clarendon-Linden fault. Also, earthquakes induced from injection of brine into wells in the Dale area could be associated with Clarendon-Linden fault.

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Citation	Title	Description and Relevance to SSC
Tuttle, Dyer-Williams, and Barstow (2002)	Paleoliquefaction Study of the Clarendon-Linden Fault System, Western New York State	Investigations indicated a lack of earthquake-induced liquefaction features in geologic units, which suggests the fault system did not generate large M > 6 earthquakes in past 12,000 years. It was concluded that the fault system could have produced small and moderate earthquakes, but probably not large ones, during late Wisconsinan and Holocene.
White et al. (2000)	A Seismic-Based Cross-Section of the Grenville Orogen in Southern Ontario and Western Quebec	Describes Elzevir-Frontenac boundary zone as major structural boundary zone based on prominent geophysical signatures. These make up a broad zone of SE-dipping reflections and midcrustal velocity contours that shallow at depths of 12–15 km (7.5–9.5 mi.).
Giles County (Virginia) Seismic Zone (GCVSZ)		
Seismicity and Fault Geometry Data		
Bollinger and Wheeler (1988)	The Giles County, Virginia, Seismic Zone—Seismological Results and Geological Interpretations	Defines 40 km (25 mi.) long seismic zone based on instrumental seismicity. A damaging earthquake that occurred in 1897 in Giles County is believed to have occurred within this seismic zone. Compressional reactivation of an Iapetan normal fault is likely responsible for formation of seismic zone.
Bollinger et al. (1991)	Seismicity of the Southeastern United States; 1698 to 1986	Provides an overview of historical and instrumental seismicity in SE United States. Describes dimensions of GCVSZ and notes that zone of seismicity is beneath rocks detached by thrusting, thus demonstrating the lack of association with fault structures observed at the surface. Release of seismic energy in GCVSZ most likely related to reactivation of Precambrian faults.
Gresko (1985)	Analysis and Interpretation of Compressional (P Wave) and Shear (SH Wave) Reflection Seismic and Geologic Data over the Bane Dome, Giles County, Virginia	Seismic-reflection data acquired in Giles County were analyzed. Interpreted thickening of basement rock beneath the Bane Dome is postulated to represent late Precambrian–early Cambrian rifting. Faults generated at that time may now be reactivated in the present stress regime.

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Paleoseismic Investigations		
Anderson and Spotila (2001)	The Relationship of Geologic Structure to the Giles County Seismic Zone in Southwest Virginia, Based on Fracture Mapping in Allochthonous Paleozoic Strata	Describes study to characterize brittle fractures that occur along 7 km (4.5 mi.) of discontinuous outcrops in Giles County. Fractures range from diffuse hairline cracks to through-going, clay-filled faults. Fracture orientations have no apparent relationship to local topography or karst-related subsidence. Earthquakes in region could have ruptured entire upper crust; however, without age control on the fractures, a strong conclusion cannot yet be made.
Bollinger et al. (1992)	Geologically Recent Near-Surface Faulting in the Valley and Ridge Province: New Exposures of Extensional Faults in Alluvial Deposits, Giles County, SW Virginia	Describes characteristics of two extensional faults that cut a series of alluvial terrace deposits along north side of New River Valley near Pembroke in Giles County. The age of neither the faults nor the sediments is known, but both appear to be relatively recent (Tertiary or Quaternary). The faults are important because they indicate at least local occurrence of geologically recent near-surface faulting. Seismic monitoring in area indicates earthquake hypocenters occur at depths greater than 5 km (3 mi.).
Chapman and Krimgold (1994)	Seismic Hazard Assessment for Virginia	Attributes earthquakes in GCVSZ to a 40 km (25 mi.) long NNE-trending, steeply dipping structure oriented approximately 20° counterclockwise to detached sedimentary structures mapped at surface. Earthquakes occur below Valley and Ridge thrust sheets at depths of 5–25 km (3–15.5 mi.). Focal mechanisms exhibit strike-slip motions on steeply dipping northerly and easterly planes with a maximum compressive stress direction that is northeasterly and nearly horizontal. This pattern of seismicity attributed to reactivation of one or more Eocambrian extensional faults. On basis of this information, Chapman and Krimgold delineated a separate seismic zone for Giles County region.
Crone and Wheeler (2000)	Data for Quaternary Faults, Liquefaction Features, and Possible Tectonic Features in the Central and Eastern United States, East of the Rocky Mountain Front	Describes Pembroke faults in terrace deposits of probable Quaternary age at a locality along north side of New River Valley near Pembroke, Virginia. These faults were reported but not named by others (e.g., Law et al., 1992). The faults overlie a steeply dipping tabular zone of hypocenters; however, it has not been determined whether they are tectonic or the result of solution collapse. Characteristics of the faults are described. Based on uncertainty in fault origin, Pembroke faults are assigned to Class B,

Table D-7.3.4 Data Summary
Paleozoic Extended Crust Zone

Citation	Title	Description and Relevance to SSC
Granger et al. (1997)	Quaternary Downcutting Rate of the New River, Virginia, Measured from Differential Decay of Cosmogenic ^{26}Al and ^{10}Be in Cave-Deposited Alluvium	Describes how cosmogenic radionuclides ^{26}Al and ^{10}Be in quartz can be used to infer time of emplacement of cave-deposited river sediment. Analyses of these radionuclides from caves high above New River indicate a downcutting rate of 27.3 + 4.5 m/Myr. A tectonic tilt rate over the late Quaternary of 1.05 + 0.35 m km^{-1} Myr^{-1} is estimated near GCVSZ.
Law et al. (1994)	Geologically Recent Near-Surface Faulting and Folding in Giles County, Southwest Virginia: New Exposures of Extensional and Apparent Reverse Faults in Alluvial Sediments Between Pembroke and Pearisburg	Describes faults and graben structures investigated in alluvial deposits at Pembroke excavation site on the New River. The ages of faults and sediments are unknown; however, unlithified nature of the deposits suggests relatively young ages (Tertiary or Quaternary). Excavation site is within defined area of GCVSZ. Authors use three models to explain formation of exposed fold and fault structures: landsliding, solution collapse, and basement faulting of tectonic origin.
Law et al. (2000)	Folding and Faulting of Plio-Pleistocene Sediments in Giles County, SW Virginia: (1) Surface Data and Interpretation	Describes excavations along New River Valley that have revealed series of extensional and reverse faults cutting alluvial terrace deposits. Terrace sediments are arched into broad, gently plunging antiform. Features are consistent with continued sedimentation in a depression formed by progressive solution of limestone, followed by inversion to form the anticlinal structure. The fine structure preserved in some terrace deposits precludes sudden slip on the faults and indicates slow slip rates.
Mills (1985)	Descriptions of Backhoe Trenches Dug on New River Terraces Between Radford and Pearisburg, Virginia, June 1981	Provides information on 20 backhoe trenches dug on terraces of the New River in and near Giles County. No evidence of seismic shaking, faulting, or surface rupture was found in the 2 trenches within GCVSZ or in 18 trenches near the zone.
Mills (1986)	Possible Differential Uplift of New River Terraces in Southwestern Virginia	Describes studies of terrace elevations along New River in SW Virginia. Differences in elevation between two areas can be explained by differential uplift between 30 and 200 mm/ka. Uplift is consistent with probable movements on faults associated with GCVSZ.

Table D-7.3.4 Data Summary
Paleozoic Extended Crust Zone

Citation	Title	Description and Relevance to SSC
Wheeler (2005)	Known or Suggested Quaternary Tectonic Faulting, Central and Eastern United States—New and Updated Assessments for 2005	Reviews information about GCVSZ. This seismic zone has no recognized geomorphic expression, and no geologic evidence has yet demonstrated Quaternary surface deformation caused by tectonic faulting within the zone. Accordingly, it is assigned to Class C. Nonetheless, occurrence of a significant historical earthquake in 1897 (M 5.9) and of continuing smaller earthquakes demonstrates that a notable level of seismic hazard exists for zone.
Geophysical Investigations		
Robinson et al. (1993)	A Seismic Refraction and Electrical Resistivity Survey of Faulted Alluvial Deposits in Giles County, VA	Imaged high-angle faults and a broad antiformal fold in young, unconsolidated sediment in Giles County, Virginia, were imaged with seismic refraction and electrical resistivity. Results from seismic refraction indicate the faults extend through sediments more than 40 m (131 ft.) thick and local topography exists at bedrock surface, which can be attributed to faulting, karst, or inherited topography. Results from resistivity survey indicate that high-angle anomalies are high-angle faults.
Robinson et al. (2000)	Folding and Faulting of Plio-Pleistocene Sediments in Giles County, SW Virginia: (3) Seismic Refraction, Potential Fields, and Borehole Data	Describes excavations along New River Valley that have revealed series of faults cutting alluvial terrace deposits. Terrace sediments are arched into broad, gently plunging antiform, with a graben in hinge zone of antiform. Subsurface investigations indicate that terrace deposits reach maximum of 40 m (131 ft.) thick and contain possible voids. Geophysical measurements in limestone basement do not reveal any features that might be related to fold and graben structures in overlying terrace deposits.
Williams et al. (2000)	Folding and Faulting of Plio-Pleistocene Sediments in Giles County, SW Virginia: (2) Ground-Penetrating Radar and Seismic Reflection Data	Describes excavations along New River Valley that have revealed series of faults cutting alluvial terrace deposits. Terrace sediments are arched into broad, gently plunging antiform, with a graben in hinge zone of antiform. Seismic-reflection and ground-penetrating radar were used to image faults below excavation level. This information indicates that exposed faults are contained within a larger system of SSE- and NNW-dipping normal faults and that there is a linear depression in limestone bedrock that corresponds to the graben in terrace deposits. The authors note that it is unlikely that the faults were caused by collapse of an isolated subcircular sinkhole.

Table D-7.3.4 Data Summary
Paleozoic Extended Crust Zone

Citation	Title	Description and Relevance to SSC
Eastern Tennessee Seismic Zone (ETSZ)		
Seismicity and Fault Geometry Data		
Bollinger et al. (1991)	Seismicity of the Southeastern United States; 1698 to 1986	Describes seismicity in eastern Tennessee. This area is the most seismically active in Southeast. Largest recorded earthquake reported at time of publication was 1973 M_s 4.6 Maryville-Alcoa event. Active faulting is reported as occurring on steeply dipping fault planes, the majority of which are located beneath the master Appalachian decollement.
Chapman (1996)	Focal Mechanisms and the Geometry of Basement Faults in the Eastern Tennessee Seismic Zone	Compares relocated hypocenters for 474 earthquakes with more than 40 focal mechanisms for earthquakes monitored between 1982 and 1993. Results indicate that earthquakes exhibit predominantly strike-slip motion that occur either on left-stepping en echelon basement faults striking SW-NE or on a conjugate system of E-W-striking faults.
Chapman et al. (1997)	A Statistical Analysis of Earthquake Focal Mechanisms and Epicenter Locations in the Eastern Tennessee Seismic Zone	Describes location and orientation of possible seismogenic basement faults based on information provided by focal mechanisms and earthquake epicenters. Spatial aspects of the seismicity are examined. Strike-slip motion on steeply dipping planes is dominant mode of faulting in the 300 km (186 mi.) long seismic zone. A series of NE-trending en echelon basement faults are intersected by several east-trending faults.
Chapman et al. (2002)	The Eastern Tennessee Seismic Zone: Summary after 20 Years of Network Monitoring	Provides information on focal depths and mechanisms of earthquakes in ETSZ. Focal mechanism solutions indicate strike-slip faulting on steeply dipping planes. Epicenters form linear segments that may reflect basement fault structure being reactivated in the modern stress regime. Largest historical earthquake in ETSZ was magnitude 4.6. Although no evidence for larger shocks has been found, microearthquakes suggest coherent stress accumulation within a large volume. The authors propose that a hydrologic element may link seismicity, uniform regional stress, and basement structure.
Dunn and Chapman (2006)	Fault Orientation in the Eastern Tennessee Seismic Zone: A Study Using the Double-Difference Earthquake Location Algorithm	Uses double-difference earthquake location algorithm to examine earthquake hypocenter relocations and resolve fault orientations. Relocations in the most seismically active portion of ETSZ indicate diffuse west-striking, north-dipping zone of hypocenters. Zone is consistent with a structure imaged on a seismic-reflection profile that appears to be a seismogenic basement fault.

Table D-7.3.4 Data Summary
Paleozoic Extended Crust Zone

Citation	Title	Description and Relevance to SSC
Johnston et al. (1985)	Seismotectonics of the Southern Appalachians	Describes majority of southern Appalachian seismicity as occurring in a concentrated zone beneath Valley and Ridge province of eastern Tennessee. Zone is bounded on NW by NY-AL lineament and on SE by Clingman/Ocoee lineaments. Analyses indicate that seismic activity occurs beneath the decollement, thus supporting hypothesis that Appalachian seismicity is unrelated to surficial geologic or tectonic features.
Kaufmann and Long (1996)	Velocity Structure and Seismicity of Southeastern Tennessee	Describes SE Tennessee seismic zone as located at confluence of major crustal features. Using a velocity model, the authors demonstrate that seismicity is concentrated in areas of average to below average velocity and does not appear to be associated with a major crustal feature. Instead, seismicity is characterized by distribution of hypocenters and their association with low-velocity regions at midcrustal depths.
Keller et al. (1982)	Evidence for a Major Late Precambrian Tectonic Event (Rifting?) in the Eastern Midcontinent Region	Describes large linear gravity anomaly that extends through eastern Kentucky and Tennessee and coincides with a zone of complex, high-amplitude magnetic anomalies. This area appears to have been location of an ancient rift that formed about 1,100 Ma and has been locally reactivated. Basement lithologies in area appear to be metamorphosed volcanics that are relatively strong.
King and Zietz (1978)	The New York–Alabama Lineament: Geophysical Evidence for a Major Crustal Break in the Basement beneath the Appalachian Basin	Defines NY-AL lineament that extends for more than 1,600 km (994 mi.), marked by series of magnetic gradients that trend NE. Seismic activity is correlated to location of lineament, with an active area to SE and an inactive area along NW side of lineament.
Long and Kaufmann (1994)	The Velocity Structure and Seismotectonics of Southeastern Tennessee	Evaluates relationship of midcrustal structures and seismicity from a velocity model derived from inversion of travel-time residuals and gravity data. The authors observed that spatial patterns of historical seismicity correlate with low velocity regions at midcrustal depths, which suggests that intraplate earthquakes occur in weakened crust. Velocity data does not support NY-AL lineament as a linear feature parallel to a deep sedimentary basin.

Table D-7.3.4 Data Summary
Paleozoic Extended Crust Zone

Citation	Title	Description and Relevance to SSC
Powell et al. (1994)	A Seismotectonic Model for the 300-Kilometer-Long Eastern Tennessee Seismic Zone	Describes characteristics of seismicity in ETSZ, including the association of earthquakes with major potential field anomalies; greatest density of epicenters is near NY-AL magnetic lineament. The authors propose that ETSZ is evolving, with earthquakes coalescing into NE-trending zone near juncture between relatively weak and strong basement crustal blocks. The authors suggest that deformation in ETSZ may evolve eventually into a longer through-going strike-slip fault.
Powell (2002)	Three-Dimensional Velocity Structure in the New Madrid and Other SCR Seismic Zones	Velocity images obtained for SCR areas reveal strong velocity contrasts that appear to control distribution of seismicity. Earthquakes tend to concentrate where strain energy is concentrated, which is in areas of low velocity or along edges of high-velocity zones. A prominent low-velocity zone was detected in ETSZ; most earthquakes occur in rocks that surround the lowest-velocity regions of this zone.
Tavernier and Williams (2002)	The Basement Faults in the East Tennessee Seismic Zone: Observations from the Swan Creek Gas Field	Seismic-reflection and well data from Swan Creek gas field in eastern Tennessee have been used to study basement structure and its relationship to NY-AL lineament in ETSZ. A system of normal faults is apparent in Precambrian basement NW of the field; the faults are locally coincident with NY-AL lineament. A left-lateral strike-slip fault is also recognized in Paleozoic basement rock. The two directions of basement faults are consistent with those of faults interpreted in ETSZ from earthquake focal mechanisms.
Teague et al. (1986)	Focal Mechanism Analyses for Eastern Tennessee Earthquakes (1981-1983)	The authors determined 10 single-event and 6 composite focal mechanisms from 37 events in eastern Tennessee occurring between September 1981 and July 1983. Focal mechanisms are predominantly strike-slip along nearly vertical N-S- (right-lateral) or E-W- (left-lateral) oriented nodal planes, consistent with compressionally reactivated Iapetan normal faults. The P axes systematically converge from N40°E to N50°E with depth. Distribution of P axes from this data set restricts the maximum compressive stress (σ_1) between N30°E and N76°E with plunge angles from 15° to –40°. Result is similar to that determined for GCVSZ and is consistent with values derived for the Midcontinent.
USGS (2003)	Poster of the Fort Payne, Alabama Earthquake of 29 April 2003—Magnitude 4.6	Provides information on April 29, 2003, Fort Payne earthquake of M 4.6 and summarizes seismic hazard in SE United States.

Table D-7.3.4 Data Summary
Paleozoic Extended Crust Zone

Citation	Title	Description and Relevance to SSC
Vlahovic et al. (1996)	P and S Wave Velocity Structure and Hypocenter Locations in the Eastern Tennessee Seismic Zone	The authors developed 3-D crustal velocity model from inversion of arrival time data and observed that higher velocities are associated with more seismogenic crust SE of NY-AL lineament, whereas lower-velocity anomalies are NW of lineament. Relocation of events with this model places most seismicity in a 30 km (19 mi.) wide block between 4 and 22 km (2.5 and 14 mi.) along entire length of seismic zone (300 km, or 186 mi.).
Vlahovic et al. (1998)	Joint Velocity Hypocenter-Velocity Inversion for the Eastern Tennessee Seismic Zone	Describes velocity structure model used to update focal mechanisms and hypocenters for earthquakes in ETSZ. Relocated hypocenters define a seismogenic volume consistent with a tectonic model of faulting along NY-AL lineament, which is characterized by sharp contrasts in strength of adjoining crustal blocks. Earthquakes tend to concentrate along steepest velocity gradients, suggesting they occur on ancient faults separating rocks of different compositions.
Wheeler (2005)	Known or Suggested Quaternary Tectonic Faulting, Central and Eastern United States—New and Updated Assessments for 2005	Summarizes characteristics of ETSZ. Small to moderate earthquakes in zone demonstrate active subsurface faulting; however, zone has had no historical earthquakes of M 5 or larger, and there is no surficial geologic evidence for occurrence of large earthquakes. Accordingly, ETSZ is assigned to Class C for lack of geologic evidence of large earthquakes.
Paleoseismic Investigations		
Whisner et al. (2003)	Disturbed Sediments in the East Tennessee Seismic Zone: Evidence of Large Prehistoric Earthquakes in East Tennessee?	Summarizes detailed geologic studies in ETSZ focused on trying to locate paleoseismic features. Geologic mapping in a 300 km^2 (186 $mi.^2$) area within most active part of ETSZ did not reveal concrete evidence of large prehistoric earthquakes. Information was provided from two localities in Tennessee where anomalously deformed sediments occur. The two localities include folded and faulted pebble layers at Tellico Plains site and clastic dikes in a small fault at Gray site (outside recognized ETSZ). Deformed sediments could indicate late Pleistocene or early Holocene earthquake activity.

Table D-7.3.7 Data Summary
Extended Continental Crust Zone—Atlantic Margin

Citation	Title	Description and Relevance to SSC
General for Region		
Austin et al. (1990)	Crustal Structure of the Southeast Georgia Embayment-Carolina Trough: Preliminary Results of a Composite Seismic Image of a Continental Suture(?) and a Volcanic Passive Margin	The authors use multichannel seismic-reflection data to image the Carolina platform and conclude that observed magnetic anomaly in this region is the product of Mesozoic rifting processes, not Paleozoic collision.
Bird et al. (2005)	Gulf of Mexico Tectonic History: Hotspot Tracks, Crustal Boundaries, and Early Salt Distribution	The authors interpret deep basement structural highs in Gulf of Mexico as hotspot tracks. In this interpretation, the basin began to form as the Yucatan experienced continental crustal extension and 22° of counterclockwise rotation (160–150 Ma). This was followed by a further 20° of counterclockwise rotation and seafloor spreading in the gulf.
Cook (1984)	Geophysical Anomalies Along Strike of the Southern Appalachian Piedmont	Documents trends in both Bouguer gravity and magnetic anomalies associated with the Appalachians in Georgia and Virginia.
Crough (1981)	Mesozoic Hotspot Epeirogeny in Eastern North America	Attributes a 600 km (373 mi.) wide zone of epeirogeny in SE Canada and New England during the Cretaceous and early Tertiary to the Great Meteor hotspot, as evidenced by apatite fission-track dating.
Daniels et al. (1983)	Distribution of Subsurface Lower Mesozoic Rocks in the Southeastern United States, as Interpreted from Regional Aeromagnetic and Gravity Maps	Concludes that Brunswick magnetic anomaly must be older than the Mesozoic features that it can be traced over, and is therefore not sourced by South Georgia rift. The authors performed a paleostress analysis of the New England–Quebec igneous province, which provides an alternative interpretation for the distribution of Cretaceous plutons. Dikes display ESE-WNW and ENE-WSW trends and are spatially distributed in three E-W-striking dike swarms 75 by 300 km (47 by 186 mi.) in area. Leucocratic dikes occur closer to plutons and disappear within 3–4 km (2–2.5 mi.), likely recording local stress effects due to pluton emplacement. Lamprophyre dikes occur independently of plutons and strike parallel to regional dike swarms, recording regional far-field stresses. Normal faults in the regions display two orientations: 1. E-W-striking normal faults found predominantly in Montreal area are parallel to graben boundaries and axis of the Monteregian Hills, with vertical offsets ranging between 100 and 430 m (328 and 1,411 ft.). 2. NW-SE to WNW-ESE-striking normal faults are oblique to graben boundaries, with less than 100 m (328 ft.) of vertical offset.

Table D-7.3.7 Data Summary
Extended Continental Crust Zone—Atlantic Margin

Citation	Title	Description and Relevance to SSC
		NW-SE to WNW-ESE faults are older than E-W-striking faults but exhibit crosscutting relationships, suggesting that some were reactivated during formation of the E-W-striking faults. Some E-W-striking brittle faults and joints are observed in several Cretaceous plutons with similar orientations to dikes that are locally crosscut by these normal faults, suggesting that dike emplacement and faulting are contemporaneous. Conjugate sets of NE-WS dextral and ESE-WNW sinistral strike-slip faults and WNW-SSW reverse faults provide evidence for a compressional stress regime postdating emplacement of the Cretaceous plutons.
Faure et al. (1996)	State of Intraplate Stress and Tectonism of Northeastern America Since Cretaceous Times, with Particular Emphasis on the New England–Quebec Igneous Province	Faure et al. (1996) attribute intraplate stress and tectonism in NE America to an initial NE-SW extension event associated with rifting between Labrador and Greenland at 140 Ma, opening of South Atlantic at 130 Ma, and related reactivation of Timiskaming graben. Subsequent N-S-oriented extension associated with emplacement of the Monteregian Hills corresponds to global fragmentation of Pangaea when Iberia separated from Newfoundland when dominant tensional stress propagated along Labrador rift. The stress regime shifted to ENE-ESE-directed compressional stress in early Tertiary when the oceanic spreading rate decreased because of an increasing number of convergent boundaries in the Pacific. Faure et al. (1996) conclude that emplacement of Cretaceous intrusions is consistent with a lithospheric fracture model as opposed to a hotspot model, emphasizing role of preexisting structure in Ottawa-Bonnechere graben.
Faure et al. (2006)	Paleostress Analysis of Atlantic Crustal Extension in the Quebec Appalachians	Identifies two phases of extension: (1) an initial Late Triassic E-W extension related to formation of rift basins in Bay of Fundy and southern Georgia, and (2) Early Jurassic ESE-WNW extension related to central Atlantic rift system.
Funck et al. (2004)	Crustal Structure of the Northern Nova Scotia Rifted Continental Margin (Eastern Canada)	The authors used seismic refraction to image along-strike variation in crustal structure where Atlantic margin transitions from volcanic to nonvolcanic rifting (Nova Scotia). They find that continental crust thins from 36 to 3 km (22 to 2 mi.) over a distance of 180 km (112 mi.). Further seaward, they find a 150 km (93 mi.) long section of serpentinized mantle overlain by a 3 km (2 mi.) thick section of continental crust. Beyond this transition zone, they find oceanic crust with average thickness of 4 km (2.5 mi.). These data support idea that Atlantic margin becomes progressively more nonvolcanic to the NE, and place the continent-ocean boundary 60 km (37 mi.) farther SE than did Keen and Potter (1995b).

Table D-7.3.7 Data Summary
Extended Continental Crust Zone—Atlantic Margin

Citation	Title	Description and Relevance to SSC
Hatcher et al. (1994)	E-5 Cumberland Plateau to Blake Plateau, Centennial Continent/Ocean Transect #18	Geologic cross section is based on surface geology, drillholes, shipboard and aeromagnetic anomaly data, and gravity and seismic-reflection data.
Hatcher et al. (2007)	Tectonic Map of the Southern and Central Appalachians: A Tale of Three Orogens and a Complete Wilson Cycle	Provides comprehensive review of formation and geologic history of Appalachian orogen.
Hibbard et al. (2004)	The Appalachian Orogen	Reviews structural geology, tectonics, and history of Appalachian orogen.
Hibbard et al. (2006)	Lithotectonic Map of the Appalachian Orogen, Canada–United States of America	Lithotectonic mapping at 1:1,500,000 scale of the Appalachians in the U.S. and Canada, including faults and shear zones. Mapped area includes western portion of ECC, namely Piedmont.
Hibbard et al. (2007)	A Comparative Analysis of Pre-Silurian Crustal Building Blocks of the Northern and the Southern Appalachian Orogen	The authors investigate each phase of orogeny in Appalachians and determine that pre-Silurian Appalachians were uniform from north to south. Heterogeneities must postdate Late Ordovician events.
Holbrook, Purdy, et al. (1994)	Seismic Structure of the U.S. Mid-Atlantic Continental Margin	Uses multichannel and wide-angle seismic data to investigate the nature of continent-ocean boundary of the Atlantic margin (Virginia). The authors find that continent-ocean boundary is not sharp, but is instead a 100 km (62 mi.) wide transition zone characterized by rift-related mafic igneous material, up to 25 km (15.5 mi.) thick. Location of these igneous rocks also coincides with East Coast magnetic anomaly (ECMA), and the authors therefore conclude the ECMA does not mark an Appalachian suture zone, but rather is sourced by igneous rocks emplaced during rifting. Supports the idea that Atlantic margin is strongly volcanic and not consistent with plume models.
Holbrook, Reiter, et al. (1994)	Deep Structure of the U.S. Atlantic Continental Margin, Offshore South Carolina, from Coincident Ocean Bottom and Multichannel Seismic Data	Combined seismic-reflection study and wide-angle ocean-bottom seismic profile of Carolina Trough. Finds rifted continental crust for the first 80 km (50 mi.) along transect, characterized by 1–4 km (0.6–2.5 mi.) of post-rift sediment overlying 30–34 km (19–21 mi.) thick crust. Further seaward, transitional crust is a 70–80 km (43–50 mi.) wide zone containing up to 12 km (7.5 mi.) of post-rift sediment overlying 10–24 km (6–15 mi.) thick crust. Beyond this, 8 km (5 mi.) thick oceanic crust is overlain by 8 km (5 mi.) of sediments. Transitional crust, which is the product of rifting-induced magmatism, produces the Brunswick and East Coast magnetic anomalies.

Table D-7.3.7 Data Summary
Extended Continental Crust Zone—Atlantic Margin

Citation	Title	Description and Relevance to SSC
Hutchinson et al. (1983)	Crustal Structure Beneath the Southern Appalachians: Nonuniqueness of Gravity Modeling	The authors modeled Appalachian gravity gradient and favor the interpretation that it marks a suture zone.
Johnston (1994)	Seismotectonic Interpretations and Conclusions from the Stable Continental Region Seismicity Database	Defines nine major and several minor stable continental regions (SCRs), finding that annual seismic moment released in rifted SCRs exceeds that in nonrifted SCR by a factor of 15.
Kanter (1994)	Tectonic Interpretation of Stable Continental Crust	Subdivides stable continental regions in North America (and world) into tectonic domains based on geologic and geophysical characteristics, such as age and whether domain is extended or non-extended. The characterization of the ECC-AM seismotectonic zone is influenced by Eastern Seaboard domain (#218) of extended Paleozoic continental crust.
Karner and Watts (1983)	Gravity Anomalies and Flexure of the Lithosphere at Mountain Ranges	Documents phenomenon of gravity gradients along Himalayas, Alps, and Appalachians and concludes that this gradient generally marks subsurface loads, which for Appalachians is attributed to foreland basin development.
Keen and Potter (1995a)	The Transition from a Volcanic to a Nonvolcanic Rifted Margin off Eastern Canada	The authors use seismic-reflection data SE of Nova Scotia to show presence of seaward-dipping reflectors (SDRs), also commonly found farther south along Atlantic margin. They interpret the SDRs to be derived by igneous and sedimentary material accreted into a widening, subsiding rift zone. Presence of both SDRs and strong East Coast magnetic anomaly (ECMA), combined with the disappearance of both these features farther north, suggests that ECMA is created by igneous rocks forming the SDRs. The relative abruptness with which both features disappear to north also argues for small-scale convection to be the volcanic source along this rift zone.
Keen and Potter (1995b)	Formation and Evolution of the Nova Scotia Rifted Margin: Evidence from Deep Seismic Reflection Data	The authors use seismic-reflection data to document a 100–200 km (62–124 mi.) wide zone of thinned continental crust (factor of 3) off coast of Nova Scotia, which is much wider than typical width of crustal extension along Atlantic margin farther south (~20 km, or 12 mi.). They propose that this may be related to the shift from volcanic rifting (to south) to nonvolcanic rifting (Nova Scotia). Thinning in this study is accommodated by simple shear in crust and pure shear in mantle lithosphere. The authors propose that continent-ocean boundary lies just seaward of the limit of synrift sediments, adjacent to a 100 km (62 mi.) wide zone of thinned (<9 km, or 6 mi.) continental crust that underlies the continental slope/rise.

Table D-7.3.7 Data Summary
Extended Continental Crust Zone—Atlantic Margin

Citation	Title	Description and Relevance to SSC
Keller and Hatcher (1999)	Some Comparisons of the Structure and Evolution of the Southern Appalachian-Ouachita Orogen and Portions of the Trans-European Suture Zone Region	Interprets Appalachian gravity gradient as marking a suture zone of the Alleghanian orogeny.
Klitgord et al. (1988)	U.S. Atlantic Continental Margin; Structural and Tectonic Framework	Mesozoic rifting resulted in breakup of Pangaea. This rifting is associated with separation of the North American and African plates, producing rift basins along Atlantic seaboard that are situated landward of hinge zone of continental margin. This landward region experienced considerably less crustal thinning than did the region seaward of hinge zone that includes the deeper marginal sedimentary basins. Basement hinge zone consists of series of parallel half graben structures that deepen seaward. At hinge zone, basement deepens steeply to east by a series of downdropped fault blocks from about 2–4 km (1–2.5 mi.) depth to over 8 km (5 mi.) depth. The character of block faulting at hinge zone varies along the margin and may reflect influence of older crustal structure on Mesozoic rifting. Half graben structures with seaward-dipping border faults are observed at Georges Bank hinge zone, whereas faulted blocks with landward-dipping faults form hinge zone in Baltimore Canyon trough.
LASE Study Group (1986)	Deep Structure of the U.S. East Coast Passive Margin from Large Aperture Seismic Experiments (LASE)	The authors use large-aperture seismic reflection to image Baltimore Canyon trough, revealing a continuous high-velocity deep-crustal layer that extends from beneath continental crust to oceanic crust. They interpret this layer as having formed either late in continental rifting process or early in seafloor spreading process.
Li et al. (2003)	Shear Velocity Structure and Azimuthal Anisotropy Beneath Eastern North America from Rayleigh Wave Inversion	The authors determined the velocity structure and anisotropic variations in velocity structure from inversion of Rayleigh waves in order to detect asthenospheric flow beneath the thick continental lithosphere beneath NE United States and SE Canada. Rayleigh wave–phase velocity anomaly with a period of 33 sec, corresponding to sensitivity to structure down to 40 km (25 mi.) in depth, indicates a low-velocity band oriented NE-SW. The North American continental keel beneath Grenville Province is imaged in upper mantle down to roughly 200 km (124 mi.) in depth. North American keel has an irregular shape and a low-velocity zone beneath eastern New York and central New England to 200 km (124 mi.), with particularly high amplitudes at depths of 60–140 km (37–87 mi.). This velocity anomaly is interpreted as lateral contrast between relatively thick lithosphere beneath western New York and Pennsylvania and warm asthenosphere beneath thinned New

Table D-7.3.7 Data Summary
Extended Continental Crust Zone—Atlantic Margin

Citation	Title	Description and Relevance to SSC
		England lithosphere caused by thermal erosion associated with the Cretaceous hotspot. Additionally, weak anisotropy that is observed from shear-wave splitting indicates that the source must be at least 200 km (124 mi.) deep, suggesting that a sublithospheric shear zone may decouple motions of the lithosphere and deeper mantle.
Manspeizer et al. (1989)	Post-Paleozoic Activity	Reviews rifting and igneous activity in the post-Paleozoic period.
McBride and Nelson (1988)	Integration of COCORP Deep Reflection and Magnetic Anomaly Analysis in the Southeastern United States: Implications for Origin of the Brunswick and East Coast Magnetic Anomalies	The authors suggest three possible sources for Brunswick magnetic anomaly: subducted root nappes of the Inner Piedmont, obducted upper mantle, or Mesozoic rifting. The authors do not strongly support a particular solution, but do suggest that the Brunswick and East Coast magnetic anomalies may have a continuous, related source.
McBride et al. (2005)	Integrating Seismic Reflection and Geological Data and Interpretations Across an Internal Basement Massif: The Southern Appalachian Pine Mountain Window, USA	The authors trace the master Appalachian decollement from Inner Piedmont to Coastal Plain. They find that beneath the Carolina terrane, the decollement roots to Moho, indicating the location of Acadian-Alleghanian suture.
McHone (1996)	Constraints on the Mantle Plume Model for Mesozoic Alkaline Intrusions in Northeastern North America	Proposes that one or more deep-mantle plumes do not provide a satisfactory mechanism for distribution of Cretaceous alkaline rocks of New England, and observes that previous studies oversimplify evidence for a hotspot track across New England by ignoring important petrological data, including the following: • Jurassic syenite-monzonite-alkali granite of the White Mountain magma series (WMMS) has been described as separate province from Cretaceous intrusions, although many Early Jurassic dikes and several mafic to felsic plutons in the province are petrographically and chemically similar to Early Cretaceous intrusions that overlap. • Early Cretaceous dikes and plutons of New England–Quebec igneous province have statistically similar paleomagnetic poles between 122 and 124 Ma and show no consistent trend for published ages in any direction across region. • Seamount volcanism is not limited to ages defined by linear hotspot track nor is it on trendwith New England–Quebec province. • Cretaceous alkaline rocks do not exhibit a consistent chemical signature

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Citation	Title	Description and Relevance to SSC
		indicative of a mantle source. These observations indicate that lithospheric processes were necessary to start and stop generation of magmas from the same source in mantle, and that petrological studies should emphasize local and regional tectonic features.
Murphy and Keppie (2005)	The Acadian Orogeny in the Northern Appalachians	Avalonia and Meguma terranes in Nova Scotia are separated by strike-slip system of faults.
Pe-Piper and Piper (2004)	The Effects of Strike-Slip Motion Along the Cobequid-Chedabucto-SW Grand Banks Fault System on the Cretaceous-Tertiary Evolution of Atlantic Canada	Proposes that reactivation of Cobequid–Chedabucto–SW Grand Banks fault system could explain several features related to Canadian Atlantic margin, including rapid subsidence on Scotian margin and deep-water margin off the SW Grand Banks.
Pratt et al. (1988)	A Geophysical Study of the Earth's Crust in Central Virginia: Implications for Appalachian Crustal Structure	Concludes that crustal thinning (at Taconic suture) in the Piedmont is responsible for Appalachian gravity gradient.
Shillington et al. (2006)	Evidence for Asymmetric Nonvolcanic Rifting and Slow Incipient Oceanic Accretion from Seismic Reflection Data on the Newfoundland Margin	The authors use seismic-reflection data to image Newfoundland nonvolcanic margin. They observe a region of extended continental crust (ECC) successively bordered by transitional basement and slow-spreading oceanic basement. They compare this structure to that of Iberian margin, the well-studied conjugate to Newfoundland. Two important differences are noted, however: 1. The ECC of Newfoundland has few if any normal faults accommodating extension. 2. The transitional basement is not exhumed peridotite. The authors infer instead that the transition is thinned continental crust denuded by late-stage rifting (via rolling-hinge or detachment faulting) and possibly altered by magmatic intrusions/oceanic accretion.
Spencer et al. (1989)	The Extension of Grenville Basement Beneath the Northern Appalachians: Results from the Quebec-Maine Seismic Reflection and Refraction Surveys	The authors image the contact between Grenville basement and overlying allochthonous rocks of the Appalachians.

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Citation	Title	Description and Relevance to SSC
Trehu et al. (1989)	Structure of the Lower Crust Beneath the Carolina Trough, U.S. Atlantic Continental Margin	The authors image Carolina trough along three seismic profiles and find a lens of high-velocity lower-crustal material spatially correlated with East Coast magnetic anomaly. They conclude that this layer was caused during either rifting or seafloor spreading.
Van Avendonk et al. (2009)	Extension of Continental Crust at the Margin of the Eastern Grand Banks, Newfoundland	The authors confirm previous reports of rapidly thinning crust beneath continental slope of offshore Newfoundland (from about 30 to 6 km, or 19 to 4 mi., producing a Moho dip of 50°). The thinned continental crust extends seaward for 80 km (50 mi.); this is interpreted as the result of strong (possibly gabbroic) lower crust that rotated upward during extension, localizing thinning to distal margin. The authors also observe high mantle seismic velocities at continent-ocean transition, a fairly unique observation that they interpret as evidence for nonserpentinized mantle. The lack of seaward-dipping normal faults in this region is explained by models that allow for large-scale detachment faults to be active during rifting.
Williams (1978)	Tectonic Lithofacies Map of the Appalachian Orogen	Maps location of both Paleozoic thrusts and later Mesozoic basins along the length of Appalachians.
Williams and Hatcher (1983)	Appalachian Suspect Terranes	Defines major suspect terranes of eastern North America and relates these to various orogenies responsible for uplift of Appalachians.
Zoback and Zoback (1989)	Tectonic Stress Field of the Continental United States	The authors conclude that direction of maximum horizontal compression in the eastern U.S. is oriented roughly NE-ENE, consistent with far-field ridge-push motion in the Atlantic.
Mesozoic Extension		
Benson (1992)	Map of Exposed and Buried Early Mesozoic Rift Basins/Synrift Rocks of the U.S. Middle Atlantic Continental Margin	Compilation of buried rift basins reveals high degree of parallelism with exposed basins and Paleozoic structural grain of Appalachians.
Cumbest et al. (1992)	Gravity and Magnetic Modeling of the Dunbarton Basin, South Carolina	Presents a model of Dunbarton extensional basin in South Carolina and Georgia in which gravity and magnetic anomalies are modeled simultaneously.
Hutchinson et al. (1986)	Rift Basins of the Long Island Platform	The authors map rift basins of Long Island platform using seismic-reflection, magnetic, and gravity data. They conclude that basin formation was controlled by Paleozoic structural trends.

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Citation	Title	Description and Relevance to SSC
Nelson et al. (1985)	Profiling in the Southeastern United States. Part I: Late Paleozoic Suture and Mesozoic Rift Basin	COCORP profile in western Georgia is interpreted as imaging the Paleozoic suture between North America and Africa.
Oh et al. (1995)	Seaward-Dipping Reflectors Offshore the Southeastern United States: Seismic Evidence for Extensive Volcanism Accompanying Sequential Formation of the Carolina Trough and Blake Plateau Basin	Presents evidence to suggest that seaward-dipping reflectors represent voluminous volcanism beneath Carolina trough and Blake Plateau basin and that breakup of NW Africa and North America was time-transgressive from north to south during early Middle Jurrassic.
Olsen et al. (1991)	Rift Basins of Early Mesozoic Age	Presents summary and mapping of Mesozoic extensional basins in eastern U.S.
Roden-Tice and Tice (2005)	Regional-Scale Mid-Jurassic to Late Cretaceous Unroofing from the Adirondack Mountains Through Central New England Based on Apatite Fission-Track and (U-Th)/He Thermochronology	Apatite fission-track ages across Adirondack Mountains, eastern New York, Vermont, western Massachusetts and Connecticut, and western New Hampshire provide evidence for differential unrooting that may have been accommodated by fault reactivation during Late Cretaceous. The authors attribute this regional unroofing to a change from extension to horizontal compression to the Great Meteor hotspot.
Roden-Tice and Wintsch (2002)	Early Cretaceous Normal Faulting in Southern New England: Evidence from Apatite and Zircon Fission-Track Ages	Apatite and zircon fission-track age transects across Hartford-Deerfield basin in Connecticut and Massachusetts increase to the east, indicating that unroofing took place during Late Jurassic through Early Cretaceous. Age of graben structure of Hartford Basin is Cretaceous and may not be an early Mesozoic "rift basin."
Roden-Tice, West, et al. (2009)	Presence of a Long-Term Lithospheric Thermal Anomaly: Evidence from Apatite Fission-Track Analysis in Northern New England	Apatite fission-track ages across New Hampshire, NE Vermont, and western Maine range from 70 to 140 Ma and reflect widespread Early to Late Cretaceous cooling. This regional cooling and unroofing is attributed to passage of North America Plate over Great Meteor hotspot, emplacement of White Mountain magma series in Early Jurassic, and associated E-W and NW-SE extension. Regional uplift on the order of 5–7 km (3–4 mi.) may explain lack of rift basins in central New England and Quebec.
Schlische (1993)	Anatomy and Evolution of the Triassic-Jurassic Continental Rift System, Eastern North America	Maps and details evolution of Mesozoic basins along Atlantic margin.

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Citation	Title	Description and Relevance to SSC
Schlische (2003)	Progress in Understanding the Structural Geology, Basin Evolution, and Tectonic History of the Eastern North America Rift System	Presents summary and mapping of Mesozoic extensional basins in eastern U.S.
Schlische and Olsen (1990)	Quantitative Filling Model for Continental Extensional Basins with Application to the Early Mesozoic Rifts of Eastern North America	Presents quantitative model for stratigraphic evolution of extensional basins with the simplifying assumptions of constant volume input of sediments and water per unit time, as well as uniform subsidence rate and fixed outlet level. The model makes it possible to extract from sedimentary record those events in the history of an extensional basin that are due solely to the filling of a basin growing in size through time, and those events that are due to changes in tectonics, climate, or sediment and water budgets.
Schlische et al. (1996)	Geometry and Scaling Relations of a Population of Very Small Rift-Related Normal Faults	The authors studied geometry and scaling relationships on normal faults within Solite Quarry of Dan River rift basin. The data indicate that there is no significant change in displacement geometry and linear length–displacement scaling relation between small and large faults.
Sheridan et al. (1993)	Deep Seismic Reflection Data of EDGE U.S. Mid-Atlantic Continental-Margin Experiment: Implications for Appalachian Sutures and Mesozoic Rifting and Magmatic Underplating	A seismic-reflection study across Virginia continental margin that outlines a Paleozoic suture, buried Appalachian terranes, and Mesozoic rifting and magmatic events.
Smoot (1985)	The Closed-Basin Hypothesis and Its Use in Facies Analysis of the Newark Supergroup	A sedimentological analysis of the Newark Supergroup using various basin models to decide which basins are open or closed and used to help reconstruct facies.
Swanson (1986)	Preexisting Fault Control for Mesozoic Basin Formation in Eastern North America	Correlates Mesozoic basin formation with reactivation of specific Paleozoic reverse and strike-slip faults along Appalachians.
Talwani and Abreau (2000)	Inferences Regarding Initiation of Oceanic Crust Formation from the U.S. East Coast Margin and Conjugate South Atlantic Margins	East Coast magnetic anomaly is associated with seaward-dipping reflectors that represent volcanic rocks. These reflectors and underlying intrusive rocks are interpreted as constituting earliest crust and upper mantle generated at the time of initial opening of Atlantic Ocean.

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Citation	Title	Description and Relevance to SSC
Withjack et al. (1998)	Diachronous Rifting, Drifting, and Inversion on the Passive Margin of Central Eastern North America: An Analog for Other Passive Margins	Uses new data to analyze and outline timeline of rifting along eastern North America (ENA). Features map of early Mesozoic rift basins of ENA.
Withjack et al. (2002)	Rift-Basin Structure and Its Influence on Sedimentary Systems	Describes four types of rift basins based on structure and their influence on processes within sedimentary systems.
Central Virginia Seismic Zone (CVSZ)		
Bollinger (1973)	Seismicity and Crustal Uplift in the Southeastern United States	Defines and names CVSZ as area of persistent, low-level seismicity in central Virginia.
Bollinger and Hopper (1971)	Virginia's Two Largest Earthquakes—December 22, 1875 and May 31, 1897	Largest earthquake in CVSZ occurred near center of zone on December 22, 1875, with m_b 5.0 and MMI VII.
Bollinger and Sibol (1985)	Seismicity, Seismic Reflection Studies, Gravity, and Geology of the Central Virginia Seismic Zone: Part I. Seismicity	Defines CVSZ as area of persistent, low-level seismicity that extends about 120 km (75 mi.) in N-S direction and about 150 km (93 mi.) in an E-W direction from Richmond to Lynchburg, Virginia. The largest historical earthquake in CVSZ is the December 22, 1875, m_b 5.0 (MMI VII) Goochland County event. Roughly three-quarters of the observed seismicity is located in upper 11 km (7 mi.) of crust.
Coruh et al. (1988)	Seismogenic Structures in the Central Virginia Seismic Zone	Interprets structures from I-64 seismic-reflection line. Suggests that seismicity in central and western parts of zone may be associated with west-dipping reflectors that form roof of a detached antiform; seismicity in eastern part of zone near Richmond may be related to near-vertical diabase dike swarm of Mesozoic age.
de Witt and Bayer (1986)	Seismicity, Seismic Reflection, Gravity, and Geology of the Central Virginia Seismic Zone: Part 3. Gravity	Provides clarification of figures in Keller et al. (1985).
Glover et al. (1995)	Tectonics of the Central Appalachian Orogen in the Vicinity of Corridor E-3; With Implications for Tectonics of the Southern Appalachians	Provides maps, cross sections, and discussion of major structures in vicinity of CVSZ and beyond. The authors thoroughly review paleogeography and associated pre-Mesozoic tectonics of central Appalachians; however, they provide little discussion of post-Paleozoic paleogeography or tectonics.

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Citation	Title	Description and Relevance to SSC
Keller et al. (1985)	Seismicity, Seismic Reflection, Gravity, and Geology of the Central Virginia Seismic Zone: Part 3. Gravity	The authors use a variety of techniques to model position of thrust fault separating Greenville basement from overlying units in Virginia.
Kim and Chapman (2005)	The 9 December 2003 Central Virginia Earthquake Sequence: A Compound Earthquake in the Central Virginia Seismic Zone	Describes December 9, 2003, earthquake as M_w 4.3 (≈ m_b 4.5) and Max MMI = VI, largest event recorded by seismograph in CVSZ. Predominantly thrust faulting with depth 10 ± 2 km (6 ± 1 mi.). Compound earthquake comprising two nearly identical events separated by 12 sec and 300 m (984 ft.) along an azimuth of ~195°). Focal mechanisms from December 9, 2003, event and 11 other events in CSVZ inverted to obtain local stress tensor: maximum principal stress trends 133° and plunges 14°; least principal stress trends 25° and plunges 52°. Indicates a broad-scale thrust-faulting stress regime in CSVZ. Maximum principal stress direction is rotated 68° clockwise relative to the average orientation of 65° for ENA.
Klose and Seeber (2007)	Shallow Seismicity in Stable Continental Regions	The authors investigate seismicity of stable continental regions (SCRs) and determine that while it has a bimodal depth distribution, ~80% of SCR earthquakes are shallow (<7 km, or 4 mi.).
Marple and Talwani (2000)	Evidence for a Buried Fault System in the Coastal Plain of the Carolinas and Virginia—Implications for Neotectonics in the Southeastern United States	Proposes the East Coast fault system (ECFS) in Coastal Plain of Carolinas and Virginia. ECFS comprises three segments: southern, central, and northern. Northern segment located in vicinity of CVSZ. The authors provide data suggesting existence is strongest for southern segment, weakens northward.
Marple and Talwani (2004)	Proposed Shenandoah Fault and East Coast-Stafford Fault System and Their Implications for Eastern U.S. Tectonics	Proposes that Shenandoah fault is a deep, NW-striking ~300 km (186 mi.) long basement fault that accommodates an apparent ~110 km (68 mi.) offset between the NE-striking Stafford and East Coast fault systems (restraining bend). Fault was formed by late Alleghanian indentation in Salisbury embayment by NW Africa. CVSZ seismicity may be related to compression at restraining bend.
Munsey and Bollinger (1985)	Focal Mechanism Analyses for Virginia Earthquakes (1978-1984)	Focal mechanisms from single earthquakes located in CVSZ show no consistent orientation and show both reverse and strike-slip faulting. Hypocentral locations are scattered geographically and no surface ruptures are known, so no systematic sense of movement is indicated for CVSZ.

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Citation	Title	Description and Relevance to SSC
Obermeier and McNulty (1998)	Paleoliquefaction Evidence for Seismic Quiescence in Central Virginia During Late and Middle Holocene Time	Survey of 300 km (186 mi.) of river banks for liquefaction and paleoliquefaction features along portions of Rapidan, Mataponi, North Anna (during high-water conditions with poor exposures), South Anna, Appomattox, and James rivers, including Rivanna, Hardware, Rockfish, Slate, and Willis tributaries. Moderately susceptible deposits of 2–3 ka are common; only three small prehistoric liquefaction features are identified. "Near total lack of widespread liquefaction features in large search area strongly suggests that very strong seismic shaking cannot have occurred often in 2–3 ka and for past 5 ka west and north of Richmond...Paucity of liquefaction features in central Virginia makes it seem unlikely that any earthquakes in excess of ~M 7 have struck there...even if M 6–7 earthquakes had been relatively abundant, then many more liquefaction effects would have been expected."
Seeber and Armbruster (1988)	Seismicity Along the Atlantic Seaboard of the U.S.: Intraplate Neotectonics and Earthquake Hazard	The authors investigate intraplate seismicity in the eastern U.S. and compare it to other intraplate regions, as well as to the western U.S. They determine that the Appalachian front spatially controls seismicity on a large scale and may be boundary of a stress province for the eastern U.S.
Weems and Edwards (2007)	Post-Middle Miocene Origin of Modern Landforms in the Eastern Piedmont of Virginia	Recognizes intermittent Cenozoic fault motion in the NE-striking Stafford fault system and north-striking Dutch Gap fault. Indicates a fault-bounded trough filled with Coastal Plain marine sediments of late Middle Miocene age.
Recent Source Characterizations of CVSZ		
Bollinger (1992)	Specification of Source Zones, Recurrence Rates, Focal Depths, and Maximum Magnitudes for Earthquakes Affecting the Savannah River Site in South Carolina	Estimates the following parameter values for areal source zone representing CVSZ: a = 1.18, b = 0.64, Mmax = m_b 6.4.
Chapman and Krimgold (1994)	Seismic Hazard Assessment for Virginia	Estimates the following parameter values for areal source zone representing CVSZ: a = 1.18, b = 0.64, Mmax = m_b 7.25.
Frankel et al. (1996)	National Seismic-Hazard Maps: Documentation	Does not designate a finite source or zone for CVSZ; modeled using a gridded seismicity cell network within extended margin region: Mmax = M_w 7.5. No source- or zone-specific *b*-value. Background *b*-value for extended margin region = 0.96.

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Citation	Title	Description and Relevance to SSC
Frankel et al. (2002)	Documentation for the 2002 Update of the National Seismic Hazard Maps	Does not designate a finite source or zone for CVSZ; modeled using a gridded seismicity cell network within extended margin region: Mmax = M_w 7.50. Assumes same *b*-value as Frankel et al. (1996), i.e., 0.96.
Petersen et al. (2008)	Documentation for the 2008 Update of the United States National Seismic Hazard Maps	Does not designate a finite source or zone for CVSZ; modeled using a gridded seismicity cell network within extended margin region: Mmax = M_w 7.50. Assumes same *b*-value as Frankel et al. (1996), i.e., 0.96.
Seismicity		
Ammon et al. (1998)	Faulting Parameters of the January 16, 1994 Wyomissing Hills, Pennsylvania Earthquakes	The January 1994 Wyomissing Hills, Pennsylvania, earthquake sequence was dominated by M 4.0 foreshock and M 4.6 main shock. The sequence was well recorded by U.S. and Canadian national seismic networks, which provided data for waveform modeling. Both events exhibit thrust-fault geometry with a nearly horizontal compression axis oriented NE-SW, consistent with regional stress patterns. A preferred depth of 3–5 km (2–3 mi.) is estimated for these two events, which are located in the region of historical seismicity termed the Lancaster seismic zone by Armbruster and Seeber (1987).
Armbruster et al. (1994)	The Jan. 1994 Wyomissing Hills Earthquakes (mbLg = 4.0 & 4.6) in Southeastern Pennsylvania: A 2-km-Long Northwest-Striking Fault Illuminated by Aftershocks	Abstract describes locations and magnitudes of the instrumentally observed January 1994 Wyomissing Hills earthquakes in SE Pennsylvania.
Bakun et al. (2003)	Estimating Locations and Magnitudes of Earthquakes in Eastern North America from Modified Mercalli Intensities	The authors create modified Mercalli intensity model for eastern North America, and use that model to determine the epicenter and magnitude of several historical earthquakes, including 1755 Cape Ann, Massachusetts, earthquake.
Bent (1995)	A Complex Double-Couple Source Mechanism for the M_S 7.2 1929 Grand Banks Earthquake	Analysis of additional seismographs indicates that M_S 7.2 1929 Grand Banks earthquake is in fact an earthquake with a complex source mechanism as opposed to a landslide. The first and largest sub-event was a strike-slip double-couple event occurring on a NW-striking plane. Two later sub-events were probably strike-slip double couples on NE-striking planes. All appear to have occurred at a depth of 20 km (12 mi.). The sum of sub-event moments corresponds to M_w of 7.2 ± 0.3.

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Citation	Title	Description and Relevance to SSC
Bollinger et al. (1991)	Seismicity of the Southeastern United States: 1698 to 1986	Seismicity within ECC is not randomly distributed, but tends to be clustered with intervening areas exhibiting low seismicity. Hypocenters of events in Coastal Plain regions are distributed throughout upper crust (~13 km, or 8 mi., deep), and focal-mechanism solutions indicate N-NE maximum compressive stress. The authors review the seismicity of SE United States as documented by the studies to date of historical and network databases. The reasons for that division are the differences in levels of completeness and accuracy with respect to earthquake size and location. A regional summary synthesizes historical, instrumental, and network seismicity results with respect to the regional host geologic/physiographic provinces. The authors note that the feature of Coastal Plain seismicity is the apparent NW trend, perpendicular to northeasterly tectonic fabric of adjoining Piedmont and Appalachian Highlands and their associated seismicity. Although various interpretations have been put forth, the faults associated with Coastal Plain earthquakes have not been unambiguously identified. In Georgia and Alabama, the Coastal Plain earthquakes are spatially and temporally sparse. The earthquakes of Georgia Piedmont have been interpreted to represent failure on planes of weakness or joints within 4 km (2.5 mi.) of surface. The largest earthquake in the SE United States during historical times occurred in this province in 1886 (m_b 6.7, M_S = 7.7, MMI = X). Epicenter was probably about 20–30 km (12–19 mi.) NW of Charleston in Middleton Place–Summerville seismic zone (see Charleston Table). The hypocenters of Coastal Plain shocks are distributed throughout upper 13 km (8 mi.) of crust where focal mechanisms indicate N-NE maximum compressive stress.
Bollinger and Wheeler (1988)	The Giles County, Virginia, Seismic Zone—Seismological Results and Geological Interpretations	The authors define Giles County seismic zone from a three-year study of microseismicity and interpret results in the context of the greater tectonic forces that formed Appalachians.

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Citation	Title	Description and Relevance to SSC
Dawers and Seeber (1991)	Intraplate Faults Revealed in Crystalline Bedrock in the 1983 Goodnow and 1985 Ardsley Epicentral Areas, New York	Presents argument that bedrock geologic studies in epicentral areas of 1983 Goodnow (M_w = 5.1) and 1985 Ardsley (m_L = 4.0) earthquakes in New York State suggest that seismogenic intraplate faults have subtle, but recognizable, expressions in crystalline bedrock along surface extrapolations of these well-defined earthquake ruptures. The 1983 Goodnow and 1985 Ardsley ruptures are correlated with Caitlin Lake fault zone (CLFZ) and Dobbs Ferry fault zone (DFFZ), respectively. The authors base these correlations on (1) spatial correlation of rupture plane, as defined by aftershock hypocenters, with a prominent fracture-controlled topographic lineament, and (2) observations of mesoscopic brittle structures along the lineaments that reflect larger-scale structures and, more importantly, that are consistent with both rupture orientation and sense of slip determined from seismic data. The authors point out that there is considerable uncertainty as to age of formation of both CLFZ and DFFZ, and some fault surfaces along DFFZ record evidence of reactivation in the form of superimposed slickensides. It is difficult to argue that the fault zones formed entirely in intraplate environment, instead; some of deformation could be Mesozoic in age. The authors speculate that the fault zones were activated as extensional structures during the Mesozoic and, being weaker than surrounding rock, remained active in the present intraplate regime. The authors state that the issue of small displacements on active structures that are relatively large and possibly old remains problematic.
Ebel (2000)	A Reanalysis of the 1727 Earthquake at Newbury, Massachusetts	Uses analysis of felt reports, aftershocks, and recent instrumental seismicity near Amesbury, Massachusetts, to infer main-shock source parameters for the 1727 Newburyport, Massachusetts, earthquake. Data suggest that 1727 earthquake was shallow, located NW of Newbury, Massachusetts, and had m_b about 5.6.
Ebel and Hart (2001)	Observational Evidence for Amplification of Earthquake Ground Motions in Boston and Vicinity	Uses analysis of felt reports, aftershocks, and recent instrumental seismicity near Amesbury, Massachusetts, to infer main-shock source parameters for the 1727 Newburyport, Massachusetts, earthquake. Data suggest that 1727 earthquake was shallow, located NW of Newbury, Massachusetts, and had m_b about 5.6.
Ebel (2006a)	The Cape Ann, Massachusetts Earthquake of 1755: A 250th Anniversary Perspective	The earthquake of November 18, 1755, is likely located about 40 km (25 mi.) ENE of Cape Ann, Massachusetts. Based on attenuation of MMI with epicentral distance, the magnitude was estimated as m_{bLg} 6.2 or M 5.9.

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Citation	Title	Description and Relevance to SSC
Hough and Seeber (1991)	Seismological Constraints on Source Properties of the m_b = 4.0, 1985 Ardsley, New York, Earthquake: A Characteristic Rupture?	Analyzes October 19, 1985, magnitude 4.0 earthquake that occurred in southern Westchester County, New York, approximately 30 km (19 mi.) north of central Manhattan. The earthquake was part of sequence of six events (m_b 1.8 to 4.0) that occurred along NW-trending Dobbs Ferry fault zone that cuts across Manhattan Prong. Hypocenters fall within 1 km (0.6 mi.) of each other, indicating rupture on a relatively small segment of Dobbs Ferry fault, which is at least 10 km (6 mi.) long. Aftershocks delineate a subvertical plane striking roughly 300° and define a rupture area roughly 700 m (2,300 ft.) across and between 4.5 and 5.5 km (3–3.5 mi.) deep. First-motion data indicate that left-lateral strike-slip motion predominates. The 500–1,000 m (1,640–3,281 ft.) wide rupture inferred from the hypocenter distribution corresponds to 1 km (0.6 mi.) long structurally defined segment of Dobbs Ferry fault zone.
Kafka et al. (1985)	Earthquake Activity in the Greater New York City Area: Magnitudes, Seismicity, and Geologic Structures	Describes locations and magnitudes of instrumentally observed seismicity in greater New York City area. Roughly half the earthquakes are located near Ramapo fault system, and many other earthquakes located near Newark basin. Despite these spatial associations, the cause of earthquakes in this area remains unknown.
Klose and Seeber (2007)	Shallow Seismicity in Stable Continental Regions	Presents a worldwide compilation of well-constrained fault ruptures and focal depths of earthquakes for stable continental regions (SCRs). Depth distributions of fault ruptures and earthquakes in well-monitored SCRs worldwide indicate the following features: • Many earthquakes and fault ruptures are bimodally distributed with depth modes in upper third of crust (<10 km, or 6 mi.) and lower third of crust (>20 km, or 12 mi.). • Depth and strength of contrasting modes vary regionally and indicate less stable intracrustal boundaries that may be located by seismic profiling. • Many medium-to-large earthquakes (4.5 < M < 8.0) tend to nucleate at very shallow depths (<7 km, or 4 mi.) and ruptures often reach surface. • Almost 80% of seismic moment density for shallow ruptures is released in uppermost 7 km (4 mi.) of crust. • Hypocentral depths of earthquakes are on average overestimated by 88% ± 30% (standard mean ± standard mean error).

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Citation	Title	Description and Relevance to SSC
Seborowski et al. (1982)	Tectonic Implications of Recent Earthquakes near Annsville, New York	The authors analyze a sequence of microearthquakes that occurred in January 1980 near Annsville, New York. The events yielded a composite focal mechanism solution indicating E-NE compression, resulting in thrust motion on N-NW-striking fault plane, with main shock having strike of N34°W and dip of 26°NE. A major structural feature of epicentral area is Annsville fault, a fault of Paleozoic age that strikes to NE and dips SE. The authors indicate that epicentral alignments and focal mechanism solutions for earthquakes near Annsville do not permit interpretation that movement occurred on this or other subparallel structures. Instead, the fault structure inferred to be associated with these earthquakes is transverse to Annsville fault. The active structure has no apparent surface expression and is possibly limited in spatial extent. Focal mechanisms reported for Annsville events suggest that major geologic structures may not be involved directly in current seismic activity of region. But the authors note that the structures may serve as zones of weakness that focus strain along less significant or less apparent structures within crust.
Seeber and Armbruster (1988)	Seismicity Along the Atlantic Seaboard of the U.S.: Intraplate Neotectonics and Earthquake Hazard	The authors discuss the potential for damaging earthquakes along Atlantic Seaboard and observe the following: • Seismicity along Atlantic Seaboard moderately high for an intraplate region and includes large, damaging earthquakes. These tend to be distributed among many faults with small ruptures about 1–2 km (0.6–1.2 mi.) across for ~M 5 earthquakes and may be characterized by high stress drops. • Damaging earthquakes in east can be generated by small faults that do not reach surface and that may not be detected by geological and geophysical investigations. • The Appalachian Front, defined as NW limit of allochthonous crystalline slab above the master detachment, appears to control spatial distribution of seismicity on a large scale. Further, stress indicators are ambiguous about a distinct stress province along Appalachians/Atlantic Seaboard. • At an intermediate scale, seismicity is also often controlled by preexisting structure. Newark basin is an example in that it is aseismic but is bounded by concentrations of seismicity. • The apparent lack of one-to-one correlation between seismicity and preexisting structural features may be the result of changes in patterns of seismicity that occur over periods longer than the available historical record.

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Citation	Title	Description and Relevance to SSC
Seeber and Armbruster (1989)	Low-Displacement Seismogenic Faults and Nonstationary Seismicity in the Eastern United States	Historical seismicity record shows that distribution of seismicity is nonrandom and that generally the pattern of seismicity derived from short-term instrumental data resembles that derived from long-term samples of historical data. The authors note that earthquake data associated with 1886 Charleston, South Caroline, earthquake suggests that hazard analysis based on assumption of stationarity may be appropriate for small- and intermediate-magnitude events, but may be misleading for large events.
Seeber and Dawers (1989)	Characterization of an Intraplate Seismogenic Fault in the Manhattan Prong, Westchester Co., N.Y.	The authors argue that there is close correlation in location, orientation, and sense of slip between Dobbs Ferry fault zone (DFFZ) and 1985 Ardsley earthquake rupture (m_b = 4.0) in southern Westchester County, New York. The DFFZ is a tabular zone of discontinuous faults and fractures rather than a single through-going fault, and cumulative offset across it is very small, considering size and Paleozoic age of structure. Mesoscopic structural data argue for predominantly left-lateral motion on DFFZ, while accumulated displacement on the fault zone shown by offset Paleozoic-age markers is right-lateral (20–30 m, or 66–98 ft.). While DFFZ is at least 8 km (5 mi.) long (later found to be at least 10 km, or 6 mi., long by Hough and Seeber [1991]), there is little evidence in surface outcrops of a single through-going fault; in addition, there is no evidence for Quaternary surface displacement. The authors consider that, given the small total accumulated displacement, Quaternary surface offset seems unlikely. They argue that segmented geometry of DFFZ suggests that structural data may provide criteria to constrain the largest possible ruptures on intraplate faults, as opposed to analyzing length of entire fault. Therefore, the concept of characteristic earthquake and characteristic rupture may be applicable to intraplate regions.
Wise and Faill (1998)	Lancaster County Seismic Zone (Penna.): Reactivation of a Taconic Structural Feature?	Abstract describes instrumentally observed seismicity in Lancaster County seismic zone of Pennsylvania. Suggests that if short, shallow faults of Lancaster seismic zone do not slip seismically, faults and earthquakes together might reflect some other, deeper geologic control on seismicity.
Zoback (1992)	Stress Field Constraints on Intraplate Seismicity in Eastern North America	Uses focal mechanisms from 32 midplate earthquakes in North America to determine how maximum horizontal compressive stress changes from the central eastern United States (strike-slip faulting stress regime) to SE Canada (thrust faulting stress regime).

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Citation	Title	Description and Relevance to SSC
Geologic Structures Interpreted from Geologic, Geomorphic, Geophysical, and Seismic-Profile Data		
Cook and Oliver (1981)	The Late Precambrian–Early Paleozoic Continental Edge in the Appalachian Orogen	Integration of geological and geophysical data indicates that eastern edge of the late Precambrian–early Paleozoic North American continent is buried beneath crystalline rocks of southern Appalachian orogen. The transition appears to be essentially coincident with strong gravity gradient that is continuous throughout much of the length of the orogen. COCORP seismic-reflection data in southern Appalachians indicate that most of near-surface crystalline rocks of Blue Ridge and Inner Piedmont are allochthonous and that reflection character in the crust changes near Inner Piedmont–Charlotte belt boundary. Layered reflectors beneath Kings Mountain belt, Charlotte belt, and Carolina slate belt in Georgia are interpreted as sedimentary (or metasedimentary) strata, and associated gravity change is interpreted as an edge effect corresponding to boundary between continental and former oceanic or attenuated continental crust.
Cook and Vasudevan (2003)	Are There Relict Crustal Fragments Beneath the Moho?	Images of upper mantle structure from lithoprobe seismic-reflection profile suggests that a relict Mesoproterozoic subduction zone lies beneath Moho in NW Canada.
Cook and Vasudevan (2006)	Reprocessing and Enhanced Interpretation of the Initial COCORP Southern Appalachians Traverse	The authors present results of reprocessed 1978–1980 COCORP Southern Appalachian seismic-reflection data that has produced improved images of structures related to emplacement of Blue Ridge–Inner Piedmont allochthon. Results enhance and extend the interpretation presented previously (Cook et al., 1979) that Blue Ridge and Inner Piedmont are allochthonous above a shallow and shallow-dipping detachment that can be followed from outcrop at the Blue Ridge/Valley and Ridge transition to at least beneath Carolina terrane. Continuity of reflections in the new images supports interpretation that southern Appalachian detachment is not rooted on east side of Inner Piedmont, but rather projects as a low-angle detachment (or zone of decoupling) to beneath Coastal Plain. An implication of this geometry is that terranes, such as Carolina terrane, between autochthonous North America and the Alleghanian suture beneath Coastal Plain are detached, thin flakes. Some key structures, such as layered supracrustal rocks beneath Appalachian detachment, were visible previously but are considerably improved. Other features (e.g., continuity of subhorizontal reflections beneath Carolina terrane and the shallowing of the Moho) that either were only marginally visible or were surmised based on ancillary information (e.g.,

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		palinspastic reconstructions) are now apparent. Still others, such as a prominent west-dipping midcrustal reflection beneath the Inner Piedmont ramp are visible for first time. These new results, combined with interpretations of regional reflection data recorded during 1980s south and west of the initial survey, have been incorporated into a schematic three-dimensional interpretation of crustal structure of the region. According to this interpretation, terranes (e.g., Carolina terrane) that were caught between ancient North American (Laurentian) lithosphere and African lithosphere are represented today as thin flakes that were juxtaposed with and emplaced above SE margin of Grenvillian basement.
Cook et al. (1979)	Thin-Skinned Tectonics in the Crystalline Southern Appalachians: COCORP Seismic Reflection Profiling of the Blue Ridge and Piedmont	COCORP seismic-reflection profiling in Georgia, North Carolina, and Tennessee and related geological data indicate that crystalline Precambrian and Paleozoic rocks of Blue Ridge, Inner Piedmont, Charlotte belt, and Carolina slate belt constitute an allochthonous sheet, generally 6–15 km (4–9 mi.) thick, which overlies relatively flat-lying autochthonous lower Paleozoic sedimentary rocks, 1–5 km (0.6–3 mi.) thick, of proto-Atlantic continental margin. Thus crystalline rocks of southern Appalachians appear to have been thrust at least 260 km (162 mi.) to west, and they overlie sedimentary rocks that cover an extensive area of central and southern Appalachians. The data show that Brevard fault is surface expression of an eastward-dipping splay of the main sole thrust, and the authors indicate that other major faults of this region have similar origins. The data support view that large-scale, thin crystalline thrust sheets may be significant features of orogenic zones.
Cook et al. (1980)	The Brevard Fault: A Subsidiary Thrust Fault to the Southern Appalachian Sole Thrust	COCORP seismic-reflection profiling data suggest that Brevard fault is a subsidiary thrust fault related to southern Appalachian detachment.
Cook et al. (1981)	COCORP Seismic Profiling of the Appalachian Orogen Beneath the Coastal Plain of Georgia	A southeastward extension onto Coastal Plain of an earlier COCORP traverse yielded the following results: • Confirmation of east-dipping layers beneath Charlotte belt and subhorizontal layers east of these. Such midcrustal layers are apparently extensive beneath Eastern Piedmont and are most easily interpreted as late Precambrian–early Paleozoic metasediments and metavolcanics. Lateral correlation of these reflectors implies that a major detachment extends eastward beneath crystalline rocks of Eastern Piedmont and Coastal Plain.

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Citation	Title	Description and Relevance to SSC
		• Recognition of a major SE-dipping reflector in crystalline basement that projects to surface location of Augusta fault and is thus interpreted as its subsurface extension. This feature extends 80 km (50 mi.) or more SE of surface trace of Augusta fault and is apparently a major lithologic and tectonic boundary in this area. • Recognition of upwardly concave reflectors that are listric into Augusta fault. These may be late Paleozoic thrust faults, Mesozoic listric normal faults, or both. • Observation of a significant thickness (up to 6.0 sec) of layered reflections beneath Augusta fault. One interpretation of these events is that they are late Precambrian–early Paleozoic basinal strata that have been thickened by repeated thrusting. • Discovery of an anticlinal feature in crystalline rocks beneath eastern Coastal Plain. Tectonic evolutionary models must now incorporate compressional deformation in North America at least as far east as eastern limit of Augusta fault (about 80 km, or 50 mi., east of its surface trace).
Gates and Costa (1998)	Multiple Reactivations of Rigid Basement Block Margins: Examples in the Northern Reading Prong, USA	Suggests that zones of crustal weakness in northern Reading Prong that formed during Grenville orogenesis were reactivated during subsequent tectonic events. As many as seven phases of reactivation are identified within Morgan Hill, Ramapo, and Reservoir faults.
Kean and Long (1981)	A Seismic Refraction Line Along the Axis of the Southern Piedmont and Crustal Thicknesses in the Southeastern United States	Describes COCORP seismic-reflection profiling data from southern Piedmont and estimates of crustal thickness.
Nelson et al. (1987)	Results of Recent COCORP Profiling in the Southeastern United States	The authors describe COCORP seismic-reflection profiling data from SE United States. They interpret reflections associated with Appalachian detachment, Alleghanian suture, South Georgia rift basin, and other features.
Talwani et al. (1995)	The Edge Experiment and the U.S. East Coast Magnetic Anomaly	The East Coast magnetic anomaly is spatially correlated with a zone of transitional igneous crust that extends along entire Atlantic margin. The authors suggest that basalts and underlying intrusives source the anomaly.

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Citation	Title	Description and Relevance to SSC
Faults with Cenozoic Activity		
Behrendt et al. (1981)	Cenozoic Faulting in the Vicinity of the Charleston, South Carolina, 1886 Earthquake	Data from onshore multichannel seismic-reflection profiles in 1886 meizoseismal area show evidence of Cenozoic faulting, including the reverse (?) Cooke fault. Data suggest that most recent slip on the Cooke fault is Eocene or later. Data from offshore multichannel seismic-reflection profiles and single-channel high-resolution data show Helena Banks fault as a 30+ km (19 mi.) long structure with most recent movement in post-Miocene or Pliocene time.
Behrendt et al. (1983)	Marine Multichannel Seismic-Reflection Evidence for Cenozoic Faulting and Deep Crustal Structure near Charleston, South Carolina	Seismic-reflection data collected offshore from Charleston show Helena Banks fault as NE-striking, west-dipping reverse fault that extends upward to about 10 km (6 mi.) from sea bottom. The authors interpret it as Mesozoic extensional fault reactivated as reverse-oblique fault at least as young as Miocene or Pliocene. They also interpret it as a subhorizontal detachment at 11.4 ± 1.5 km (7 ± 1 mi.) depth. They suggest that Charleston seismicity is primarily caused by movement along the detachment, and that movement on high-angle reverse faults (e.g., the Helena Banks fault and others) may also cause earthquakes.
Bramlett et al. (1982)	The Belair Fault: A Cenozoic Reactivation Structure in the Eastern Piedmont	The authors determined that Belair fault zone (near Augusta, Georgia) represents a tear fault in upper plate of Augusta fault and that most of the ~23 km (14 mi.) of lateral displacement estimated by Prowell and O'Conner (1978) occurred during Paleozoic Alleghanian orogeny and not post-Cretaceous time. During Late Cretaceous and Cenozoic, the Belair fault was reactivated as an oblique-slip reverse fault displacing Middendorf and Barnwell formations of Atlantic Coastal Plain. Prowell et al. (1975) and Prowell and O'Connor (1978) document Cenozoic brittle reverse slip on Belair fault. Quaternary slip on Belair fault is allowed but not demonstrated by the available data (i.e., Crone and Wheeler, 2000).
Darton (1950)	Configuration of the Bedrock Surface of the District of Columbia and Vicinity	Geologic mapping of extension of Stafford fault system at Fredricksburg, Virginia, suggests possible faulted fluvial terraces that may indicate post-Pliocene movement.
Faye and Prowell (1982)	Effects of Late Cretaceous and Cenozoic Faulting on the Geology and Hydrology of the Coastal Plain near the Savannah River, Georgia and South Carolina	Geologic and hydrologic studies in Coastal Plain of Georgia and South Carolina suggest faulted upper Cretaceous to lower Tertiary rocks near Millet, South Carolina. The postulated Statesboro fault strikes NE and shows apparent down-to-the-NW motion.

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Citation	Title	Description and Relevance to SSC
Jacobeen (1972)	Seismic Evidence for High Angle Reverse Faulting in the Coastal Plain of Prince Georges and Charles County, Maryland	Recognizes subsurface high-angle reverse Brandywine fault system in Cenozoic sediments of SW Maryland, based on seismic-reflection profiling.
Mayer and Wentworth (1983)	Geomorphic Differences East and West of the Stafford Fault System, Northeastern Virginia	Geomorphic relationships of fluvial terraces near Stafford fault system. Where faults are found to displace Cenozoic sediments of Coastal Plain, inferred cumulative rates tend to be less than 1 m (3 ft.) per million years (from Seeber and Armbruster, 1988).
Mixon and Newell (1978)	The Faulted Coastal Plain Margin at Fredericksburg, Virginia	The authors identify four en echelon NE-trending structures, including SE-dipping monoclines and NW-dipping high-angle reverse faults, along inner edge of Coastal Plain in NE Virginia termed the Stafford fault system. The structures affect the present distribution of Coastal Plain sediments with estimated displacements of 15–60 m (49–197 ft.). The fault system extends at least 56 km (35 mi.) parallel to Fall Line and NE-trending reach of the Potomac estuary where the authors hypothesize that the Fall Line and major river deflections along it have been tectonically influenced. The authors suggest possible relationship between Coastal Plain deformational belts and zones of weakness in crystalline basement rocks characterized by normal faulting in Triassic. The speculative relationship of Stafford fault system to Triassic or older basement structures is based on alignment of Stafford fault with Farmville basin Triassic fault trend and Brandywine fault system that could potentially mark a major zone of deformation in basement rocks that records recurrent movement in pre-Mesozoic, Mesozoic, and Cenozoic time.
Newell (1985)	Architecture of the Rappahannock Estuary—Neotectonics in Virginia	The authors describe Stafford fault system as zone of NW-dipping, en echelon reverse faults near the Fall Line in NE Virginia.
Pavich et al. (1989)	Investigations of the Characteristics, Origin, and Residence Time of the Upland Residual Mantle of the Piedmont of Fairfax County, VA	This study suggests that regolith of Piedmont most likely represents Pliocene and Quaternary weathering system that is product of interaction of bedrock and ground water in an actively eroding landscape. Variation in saprolite thickness, and therefore regolith thickness, is a function of distribution of minerals in the rock, grain contact relations, and structural fabric.
Pavlides (1994)	Continental Margin Deposits and the Mountain Run Fault Zone of Virginia—Stratigraphy and Tectonics	Provides descriptions and geologic mapping of NE-striking reverse Everona–Mountain Run fault zone in Virginia. From offset late Cenozoic gravels and rugged topography of scarps along Everona fault, the author infers possible Quaternary reactivation of Everona fault or some part of Mountain Run fault zone.

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Citation	Title	Description and Relevance to SSC
Pavlides et al. (1983)	Late Cenozoic Faulting Along the Mountain Run Fault Zone, Central Virginia Piedmont	The authors investigate faulting along Everona–Mountain Run fault zone near Everona, Virginia, including late Cenozoic stream gravels apparently offset vertically ~1.5 m (5 ft.).
Prowell (1983)	Index of Faults of Cretaceous and Cenozoic Age in the Eastern United States	Many investigators have recognized and documented post-rift faulting of Cretaceous and Cenozoic ages in Atlantic Coastal Plain. The author compiled information and describes evidence for possible Cretaceous and Cenozoic faults in the eastern U.S. Faults, fractures, and joints in eastern New York State generally trend N-NE, but none of these structures have been shown to displace Holocene deposits. Within the ECC, the geometry of the Coharie unconformity on adjacent sides of the Hares Crossroads fault plane suggests that significant lateral offset may have occurred on fault. It is considered to be a reverse fault that has a strike of N7°E and a dip of 63° to the SE. Basement rock affected by faulting includes Paleozoic Piedmont schist, slate, and phyllite. Sedimentary rocks (or sediments) affected by faulting include unconsolidated clayey sand of Coharie Formation (Pliocene-Pleistocene). Greatest vertical displacement is 2.8 m (9 ft.) and greatest horizontal displacement is 2 m (>6 ft.).
Prowell (1988)	Cretaceous and Cenozoic Tectonism on the Atlantic Coastal Margin	The author indicates that the predominant orientation of mapped Cretaceous and younger faults within ECC is N-S to NE-SW. Further, post-Cretaceous movement on these faults is reverse slip, with limited evidence for strike-slip movement. Within the ECC source zone, several NE-trending reverse fault zones in fault systems up to 100 km (62 mi.) long have experienced Cenozoic activity. These faults typically strike N-NE, dip steeply, and displace sedimentary rocks of Late Cretaceous to Miocene (100–5.3 Ma) age. Observed displacements are dip-slip, but some strike-slip may have occurred. Individual fault zone displacements are generally tens of meters, with a maximum cumulative offset of as much as 80 m (262 ft.). The available stratigraphic data generally show greater displacement on older units, indicating progressive displacement through time. The author describes vertical slip rates as ranging from 0.0003 to 0.00015 meters per thousand years (m/kyr) during the past 110 Ma, averaging 0.0005 m/kyr.

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Citation	Title	Description and Relevance to SSC
Prowell and O'Connor (1978)	Belair Fault Zone: Evidence of Tertiary Fault Displacement in Eastern Georgia	The authors describe Belair fault zone as comprising NE-striking oblique-slip reverse faults with as much as 30 m (98 ft.) of apparent vertical offset since deposition of Late Cretaceous–middle Tertiary Coastal Plain sediments. In contrast with Prowell et al. (1975), the authors indicate that no fault movement has occurred in past 2,000 years, but that movement may have occurred in late Tertiary time.
Prowell et al. (1975)	Preliminary Evidence for Holocene Movement Along the Belair Fault Zone near Augusta, Georgia	Describes results of paleoseismic trenching across Belair fault near Augusta, Georgia. Lenses of organic material are interpreted as faulted and deformed. A composite sample of this material yielded mid- to late Holocene ages.
Sykes et al. (2008)	Observations and Tectonic Setting of Historic and Instrumentally Located Earthquakes in the Greater New York City–Philadelphia Area	The authors compiled a catalog of 383 earthquakes (from historical and instrumental data) in SE New York, SW Connecticut, northern New Jersey, and eastern Pennsylvania. Observations from this study are as follows: • Most hypocenters are concentrated in older terranes bordering Mesozoic Newark basin in Reading, Manhattan, and Trenton prongs and in similar rocks found at shallow depth beneath Coastal Plain from south of New York City across central New Jersey. Historical shocks of m_{bLg} 3 and larger were more numerous in latter zone. • Most earthquakes are shallow (94% are ≤10 km, or 6 mi., deep). • Many earthquakes have occurred beneath 12 km (7.5 mi.) wide Ramapo seismic zone (RSZ) in eastern part of Reading Prong, where station coverage has been the most extensive since 1974. • The SE boundary of the RSZ, which is nearly vertical, extends from near the surface trace of Mesozoic Ramapo fault to depths of 12–15 km (7.5–9 mi.). Mesozoic border fault dips about 50°–60°SE; therefore, earthquakes are occurring within middle Proterozoic through early Paleozoic rocks. • Causative faults and their orientations within RSZ in eastern part of Reading Prong are uncertain. • Seismicity is nearly absent in Mesozoic sedimentary rocks of Newark basin and in Cambro-Ordovician rocks inferred beneath them. This is attributed to either those rocks being relatively weak, in the velocity-strengthening rheological regime, being decoupled from the basement beneath them by thrust and/or detachment faults along weak layers, or a lack of preexisting brittle faults that are suitably oriented with respect to contemporary stresses.

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Citation	Title	Description and Relevance to SSC
		• A newly identified feature—NW-trending Peekskill-Stamford seismic boundary—is nearly vertical, extends from near surface to depths of about 12–15 km (7.5–9 mi.), and is subparallel to brittle faults farther south in Manhattan Prong. • These brittle faults may have formed between Mesozoic basins to accommodate Mesozoic extension. • The Great Valley in NW part of study region is nearly devoid of known earthquakes. • Maximum compressive stress is nearly horizontal and is oriented about N64°E. • Extrapolation of the frequency-magnitude relationship indicates that an event of m_{bLg} – 6.0 is expected about once every 670 years. • Which faults are active in this intraplate region has been a subject of ongoing debate. Several faults displace Mesozoic sedimentary and igneous rocks, but evidence of faulting in younger sediments of Coastal Plain and in postglacial sediments is either missing or debatable.
Wentworth and Mergner-Keefer (1983)	Regenerate Faults of Small Cenozoic Offset—Probable Earthquake Sources of the Southeastern United States	Proposes that Mesozoic normal faults in Piedmont and Coastal Plain have been reactivated as reverse and reverse-oblique faults.
Postulated Faults		
Crone and Wheeler (2000)	Data for Quaternary Faults, Liquefaction Features, and Possible Tectonic Features in the Central and Eastern United States, East of the Rocky Mountain Front	The authors provide a compilation and evaluation of Quaternary faults, liquefaction features, and possible tectonic features in CEUS. They assigned faults to three classes, which they define by features as follows. Class A features are those for which geologic evidence demonstrates existence of a Quaternary fault of tectonic origin. Class B features are those for which the fault may not extend deeply enough to be a potential source of significant earthquakes, or for which currently available geologic evidence is not definitive enough to assign the feature to either Class C or Class A. Class C features are those for which geologic evidence is insufficient to demonstrate existence of a tectonic fault, Quaternary slip, or deformation associated with the feature. Class A structures or seismic zones within the ECC include the following: • Central Virginia seismic zone, Virginia—Zone of elevated seismicity.

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Citation	Title	Description and Relevance to SSC
		• Charleston-Bluffton-Georgetown liquefaction features (see Charleston Data Summary Table D-6.1.2) • Newbury, Massachusetts, liquefaction features. Class B—*There are no Class B faults in the ECC.* Class C structures and features within the ECC and explanation of Class C assignment are as follows: • Belair fault zone, Georgia—Two trenches record pre-Quaternary age. • Cacoosing Valley earthquake, Pennsylvania—No surface rupture from earthquake correlated to this fault. • Cape Fear arch, North Carolina–South Carolina—Lack of evidence for Quaternary faulting. • Catlin Lake–Goodnow Pond lineament, New York—No evidence of continuous fault zone and lacks paleoseismological evidence of Quaternary motion. • Champlain lowlands normal faults, New York–Vermont—No evidence for Quaternary motion. • Clarendon-Linden fault zone, New York—No paleoseismological evidence for Quaternary motion. • Cooke fault, South Carolina—Lack of evidence of faulting younger than Eocene. • Cornwall-Massena earthquake, New York–Ontario—No paleoseismological evidence for Quaternary motion. • Dobbs Ferry fault zone, New York—Earthquakes were too deep to produce any recognized surface cracking along trace of fault zone; no paleoseismologic evidence for Quaternary motion. • Everona fault–Mountain Run fault zone, Virginia—No detailed paleoseismologic or other investigations. • Hares Crossroads fault, North Carolina—Faulting is not demonstrably of Quaternary age. • Helena Banks fault zone, offshore South Carolina—No reported evidence for slip younger than Miocene. • Kingston fault, New Jersey—Faulting is not demonstrably of Quaternary

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Citation	Title	Description and Relevance to SSC
		age. • Lancaster seismic zone, Pennsylvania—No structural, stratigraphic, or paleoseismological evidence for Quaternary faulting. • Lebanon Church fault, Virginia—Faulting is not demonstrably of Quaternary age. • Moodus seismic zone, Connecticut—Causes and causative faults of the earthquakes remain enigmatic. • Mosholu fault, New York—Faulting is not demonstrably of Quaternary age. • New York Bight fault, offshore New York—Fault lacks documented Quaternary offset. • Offset glaciated surfaces, Maine–Massachusetts–New Hampshire–New York–Vermont—Their most likely origin is in frost heaving, not tectonics. • Old Hickory faults, Virginia—Faulting was probably of Pliocene age. • Pen Branch fault, South Carolina—Lack of evidence for post-Eocene slip. • Ramapo fault system, New Jersey–New York—Lack of evidence for Quaternary slip on fault. • Upper Marlboro faults, Maryland—Surficial structures do not extend to hypocentral depths.
Dominion Nuclear North Anna LLC (2004)	North Anna Early Site Permit Application Response to Request for Additional Information No.3.	The key observations and conclusions from the Dominion assessment regarding the East Coast fault system (ECFS-N segment) are summarized as follows: • No consistent co-occurrence of two or more anomalies along each of the drainages was observed, as may be expected if they have developed in response to uplift of northern zone of river anomalies (ZRA-N). • There is no consistent pattern of anomalies along trend of ZRA-N, as expected if structure was active along its entire length. • It was not possible to verify or duplicate geomorphic observations, such as channel incision. • The “upward displaced fluvial surfaces” are inferred only from qualitative analysis of convexities of river profiles, and therefore, this type of “anomaly” does not provide evidence for tectonic uplift and is inconsistent with other geomorphic observations. These features in most cases are

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		more objectively characterized as convexities, or local increases in gradient of longitudinal profiles of floodplains due to intersection of concave profiles at river confluences. • Direct stratigraphic evidence for no Quaternary deformation was documented in vicinity of a large meander of Nottoway River that Marple and Talwani (2000) interpreted to have formed in response to systematic folding and northeastward tiling. • The fluvial geomorphic features cited by Marple and Talwani (2000) are likely produced by nontectonic fluvial processes and are not anomalous, which does not support Marple and Talwani's interpretation of the presence and activity of ZRA-N (ECFS-N).
Marple and Talwani (2000)	Evidence for a Buried Fault System in the Coastal Plain of the Carolinas and Virginia—Implications for Neotectonics in the Southeastern United States	The authors postulate a N-NE-/S-SW-striking buried fault system in Coastal Plain of Carolinas and Virginia, named East Coast fault system (ECFS). Geomorphic analyses of Coastal Plain rivers led to differentiation of three nearly collinear, approximately 200 km (125 mi.) long segments (ECFS-S, ECFS-C, and ECFS-N) that were initially referred to as southern, central, and northern zones of river anomalies (ZRA-S, ZRA-C, and ZRA-N). Southern segment is located primarily in South Carolina; central segment is located primarily in North Carolina; and northern segment extends from NE North Carolina through Virginia. Identification of postulated fault system is based on alignment of geomorphic changes along streams, areas of uplift, and local evidence of faulting. The authors concluded that (1) ZRAs were produced by gentle late Quaternary uplift along an approximately 600 km (370 mi.) long buried fault system, and (2) because most of the river anomalies occur in unconsolidated floodplain sediments of upper Pleistocene (<130 ka) or younger age, deformation occurred during this period and may be ongoing.
Marple and Talwani (2004)	Proposed Shenandoah Fault and East Coast–Stafford Fault System and Their Implications for Eastern U.S. Tectonics	Comparison of Shenandoah igneous province, Central Virginia seismic zone, a NW-trending linear magnetic anomaly offshore Virginia, and other tectonic features in Virginia suggests presence of a deep crustal NW-striking basement fault, named Shenandoah fault. Along Shenandoah fault, the Central Virginia seismic zone coincides with an apparent –110 km (–68 mi.) offset between NE-striking Stafford fault zone and East Coast fault system (ECFS). The authors postulate that the following series of events likely occurred in the formation of the fault system: • Stafford fault zone and ECFS formed a continuous ~1,100 km (684 mi.)

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Extended Continental Crust Zone—Atlantic Margin

Citation	Title	Description and Relevance to SSC
		long East Coast–Stafford fault system (EC-SFS) extending from South Carolina to New Jersey before the Alleghanian orogeny. • During Alleghanian or an earlier orogeny, EC-SFS was beheaded by NW-vergent thrusting of allochthonous terranes, concealing it beneath those terranes. • Late Alleghanian indentation in Salisbury embayment by Reguibat uplift of NW Africa produced Shenandoah fault and offset EC-SFS left-laterally—110 km (–68 mi.) beneath allochthonous terranes in central Virginia. • Late Jurassic to Cenozoic dextral reactivation of ECFS and Stafford fault at depth fractured overlying terranes and may have produced N-NE-oriented linking faults that reconnected EC-SFS along a large left-step restraining bend. • The cause of seismicity in central Virginia may be from compression at the bend, which is causing displacements on a variety of faults in the area, including linking faults, Shenandoah fault, and older Paleozoic faults. • Late Jurassic and Middle Eocene dextral deformation along the large restraining bend along EC-SFS in central Virginia produced tension across Shenandoah fault to the NW. This tension caused normal sense reactivation of the fault beneath the allochthonous terranes of Blue Ridge and Valley and Ridge provinces. • Consequently, magma migrated up Shenandoah fault and then along bedding planes and NW joints within Valley and Ridge strata to form Shenandoah igneous province.
Progress Energy Carolinas, Inc. (2008)	Shearon Harris Nuclear Power Plants Units 2 and 3, Docket Nos. 52-022 and 52-023, Supplement 1 to Response to Requests for Additional Information Letter 030 Related to Basic Geologic and Seismic Information	The key observations and conclusions from the Progress Energy assessment of East Coast fault system (ECFS) are summarized as follows: • There is supporting geological, geophysical, and seismological information to suggest that geomorphic anomalies identified along southern half of ECFS-S segment may be associated with Quaternary displacement on Woodstock fault and that this fault may be source of Charleston earthquake (see Charleston Data Summary Table D-6.1.2). • There is no similar evidence to suggest that northern part of ECFS-S, ECFS-C, and ECFS-N segments are capable tectonic structures as defined by the U.S. Nuclear Regulatory Commission (Regulatory Guide 1.208).

Table D-7.3.7 Data Summary
Extended Continental Crust Zone—Atlantic Margin

Citation	Title	Description and Relevance to SSC
		• Observations and lines of evidence presented by Marple and Talwani (2000) do not provide convincing arguments in support of a buried N-NE-striking strike-slip fault (postulated ECFS-C) through North Carolina Coastal Plain region. • Evidence of neotectonic deformation (i.e., differential uplift of the Piedmont relative to the Coastal Plain regions, regional tilting, and broad zones of tilting or flexure) can be explained by lithospheric flexure (i.e., long-wavelength bending or warping of lithosphere) related to regional patterns of erosion and Cenozoic deposition. • Localized Cenozoic faulting observed near Piedmont–Coastal Plain boundary may be related to stresses in the region of greatest flexure (Pazzaglia, 1999). • The possibility cannot be precluded given the available data that some local structures along general trend of ECFS may be present and may be favorably oriented for reactivation in the present tectonic setting. • There are no geological data, however, to demonstrate Quaternary surface faulting. • There is no associated seismicity or reported evidence of paleoliquefaction to indicate activity along ECFS-C segment. • The implication that the postulated central and northern segments of ECFS if they exist may produce earthquakes of a similar size to the 1886 Charleston earthquake, as inferred by Marple and Talwani, is not demonstrated.
Wheeler (2005)	Known or Suggested Quaternary Tectonic Faulting, Central and Eastern United States-New and Updated Assessments for 2005	Provides 13 assessments, 12 of which are new; the 13th incorporates significant new information. The new assessments describe faults, fields of paleoliquefaction features, seismic zones, and geomorphic features for which too little geologic information was available to write an assessment before now. The following features are located within ECC and are all assigned to Class C for their respective reasons. Class C updated structures: • Eastern Border fault, Connecticut—No faulting demonstrated in Quaternary sediments. • East Coast fault system, North Carolina–South Carolina–Virginia—The 1886 and prehistoric liquefying earthquakes in coastal South Carolina

Table D-7.3.7 Data Summary
Extended Continental Crust Zone—Atlantic Margin

Citation	Title	Description and Relevance to SSC
		demonstrates occurrence of repeated Quaternary tectonic faulting, but the link between these earthquakes and East Coast fault system or Woodstock fault remains speculative. • Fall Lines of Weems, North Carolina, Virginia, and Tennessee—Fall zones are not demonstrably reproducible. Tectonic faulting is not yet demonstrated. • Hopewell fault, Virginia—No observed offsets of Pleistocene terrace deposits. • New Castle County faults, Delaware—Subsurface studies showed no evidence of Quaternary faulting. • Stafford fault system, Virginia—None of the strands of Stafford fault system are known to have moved during Quaternary.
Paleoseismic Investigations		
Amick (1990)	Paleoliquefaction Investigations Along the Atlantic Seaboard with Emphasis on the Prehistoric Earthquake Chronology of Coastal South Carolina	Search for paleoliquefaction features along U.S. East Coast at over 1,000 sites from southern Georgia to New Jersey. Features found only in coastal Carolinas. Includes rough maps of areas searched in which no features found, as well as sketches and photographs of selected features. Includes discussion of criteria by which to distinguish seismically induced liquefaction features from “pseudoliquefaction” features.
Amick, Gelinas, et al. (1990)	Paleoliquefaction Features Along the Atlantic Seaboard	Search for paleoliquefaction features along U.S. East Coast at over 1,000 sites from southern Georgia to New Jersey. Features found only in coastal Carolinas. Includes discussion of criteria by which to distinguish seismically induced liquefaction features from “pseudoliquefaction” features.
Amick and Gelinas (1991)	The Search for Evidence of Large Prehistoric Earthquakes Along the Atlantic Seaboard	Search for paleoliquefaction features along U.S. East Coast at over 1,000 sites from southern Georgia to New Jersey. Features found only in coastal Carolinas.
Obermeier and McNulty (1998)	Paleoliquefaction Evidence for Seismic Quiescence in Central Virginia During Late and Middle Holocene Time	Survey of 300 km (186 mi.) of river banks for liquefaction and paleoliquefaction features along portions of Rapidan, Mataponi, North Anna (high water with poor exposures), South Anna, Appomattox, and James rivers, including Rivanna, Hardware, Rockfish, Slate, and Willis tributaries. Moderately susceptible deposits of 2–3 ka common; only three small prehistoric liquefaction features identified. “Near total lack of widespread liquefaction features in large search area

Table D-7.3.7 Data Summary
Extended Continental Crust Zone—Atlantic Margin

Citation	Title	Description and Relevance to SSC
		strongly suggests that very strong seismic shaking cannot have occurred often in 2–3 ka and for past 5 ka west and north of Richmond...Paucity of liquefaction features in central Virginia makes it seem unlikely that any earthquakes in excess of ~M 7 have struck there...even if M 6–7 earthquakes had been relatively abundant, then many more liquefaction effects would have been expected."
Tuttle (2007)	Re-evaluation of Earthquake Potential and Source in the Vicinity of Newburyport, Massachusetts	Recent searches for earthquake-induced liquefaction features in Newburyport, Massachusetts, area yielded only one small sand dike.
Tuttle (2009)	Re-evaluation of Earthquake Potential and Source in the Vicinity of Newburyport, Massachusetts	Searches for earthquake-induced liquefaction features along several rivers south of Newburyport, in vicinity of Hampton Falls, and west of Hampton Falls in New Hampshire yielded only one liquefaction feature: a small sand dike along Hampton Falls River in New Hampshire.
Tuttle and Seeber (1991)	Historic and Prehistoric Earthquake-Induced Ground Liquefaction in Newbury, Massachusetts	The authors found both historical and prehistoric liquefaction features (sand dikes). The historical features were attributed to 1727 earthquake, and the prehistoric features were estimated to have formed during past 4,000 years.

Table D-7.3.9 Data Summary
Extended Continental Crust Zone—Gulf Coast

Citation	Title	Description and Relevance to SSC
Seismicity		
Angell and Hitchcock (2007)	A Geohazard Perspective of Recent Seismic Activity in the Northern Gulf of Mexico	Describes seismotectonic setting of northern Gulf of Mexico with specific reference to the 2006 earthquakes. Presents detailed information regarding seismic source characteristics of the 2006 earthquakes. Also addresses seismogenic capability of growth faults. Discusses implications to seismic hazard assessment in Gulf of Mexico. Presents a possible two-layer source model for Gulf of Mexico.
Davis et al. (1989)	A Compendium of Earthquake Activity in Texas	Comprehensive review and database of historical earthquake activity in Texas 1847–1986. Largest earthquakes have occurred in W Texas and are interpreted as resulting from either tectonic stresses or oil and gas field operations. Helps to constrain estimates of the minimum maximum earthquake magnitude for Gulf of Mexico coastal plain.
Dellinger and Nettles (2006) Dellinger, Dewey et al. (2007) Dellinger, Ehlers et al. (2007)	The 10 February 2006, Magnitude 5.2 Gulf of Mexico Earthquake: Insights and Implications Relocating and Characterizing the 10 Feb 2006 "Green Canyon" Gulf of Mexico Earthquake Using Oil-Industry Data The Green Canyon Event as Recorded by the Atlantis OBS Node Survey	Detailed analysis of the earthquake with focus on the relative amount and timing energy release during the event. Focuses on determining a location and magnitude for the event, and hypothesizes that the event is most consistent with a slow, nontectonic event (e.g., large-scale slump, landslide).
Dewey and Dellinger (2008)	Location of the Green Canyon (Offshore Southern Louisiana) Seismic Event of February 10, 2006	Presents analysis constraining location and depth of February 10, 2006, earthquake. Provides information on the seismotectonic setting of the earthquake, and minor discussion of potential causes of the event (i.e., nontectonic event).
Frohlich (1982)	Seismicity in the Central Gulf of Mexico	Provides general overview of the sparse seismicity in Gulf of Mexico and a more detailed discussion of July 24, 1978, M 5.0 earthquake. Interprets the location and reverse mechanism for the event to possibly indicate that the event is related to crustal subsidence and downwarping of Gulf of Mexico basin.

Table D-7.3.9 Data Summary
Extended Continental Crust Zone—Gulf Coast

Citation	Title	Description and Relevance to SSC
Frohlich and Davis (2002)	Texas Earthquakes	Provides catalog of earthquakes in Texas 1847–2001. Helps constrain minimum maximum magnitude estimate for the Gulf of Mexico coastal plain region. Provides only minor discussions of potential earthquake mechanisms for the region.
Gangopadhyay and Sen (2008)	A Possible Mechanism for the Spatial Distribution of Seismicity in Northern Gulf of Mexico	Modeling of regional stress concentrations and the mechanical properties of salt and surrounding sediments to investigate the possible mechanism for the 2006 Gulf of Mexico earthquakes. Results show that locations of high shear stress in the Gulf of Mexico correlate well with the spatial distribution of seismicity in the northern Gulf of Mexico, suggesting a possible causal association between mechanical differences between salt and surrounding sediment and regional shear stresses.
Gomberg and Wolf (1999)	Possible Cause for an Improbable Earthquake: The 1997 Mw 4.9 Southern Alabama Earthquake and Hydrocarbon Recovery	An investigation into possible causes of 1997 Alabama earthquake. Concludes that hydrocarbon recovery is likely cause, but that tectonic mechanisms or influence cannot be ruled out.
Nettles (2006)	Two Unusual Seismic Events in the Gulf of Mexico	Seismological analysis of the February 10, 2006, m_b 5.2 and April 18, 2006, M_S 4.8 earthquakes in the northern Gulf of Mexico. Concludes from waveforms and energy release that the two events are best modeled as gravity-driven “landslide” mechanisms.
Nettles (2007)	Analysis of the 10 February 2006 Gulf of Mexico Earthquake from Global and Regional Seismic Data	Describes analysis of February 10, 2006, m_b 5.2 earthquake and the conclusion that earthquake was gravity-driven and did not have a tectonic source.
Nunn (1985)	State of Stress in the Northern Gulf Coast	Addresses state of stress in Gulf of Mexico coastal plain region as related to Quaternary fault activity. Concludes that activity is consistent with lithospheric flexure caused by sediment loading in Gulf of Mexico. Also concludes that lack of seismicity may be due to relaxation of these stresses over time.
Peel (2007)	The Setting and Possible Mechanism of the 2006 Green Canyon Seismic Event	Describes geologic setting of February 10, 2006, m_b 5.2 earthquake. Presents an interpretation of the ocean-continent boundary as interpreted from industry seismic and nonseismic potential field geophysical data. Concludes that earthquake was restricted to growth sedimentary section in shallow upper crust.

Table D-7.3.9 Data Summary
Extended Continental Crust Zone—Gulf Coast

Citation	Title	Description and Relevance to SSC
Stevenson and McCulloh (2001)	Earthquakes in Louisiana	General description of earthquakes and fault activity in Louisiana with earthquake database. Concludes that most active faulting is associated with creeping growth faults.
Todd and Ammon (2007)	Characteristics of Recent Seismic Activity in the Gulf of Mexico	Presents information on depth and source characteristics of September 10 and February 10, 2006, earthquakes in Gulf of Mexico. Concludes that they occur within a “stable cratonic region” of North America and there are no well-known fault systems in the vicinity of the earthquakes, and therefore earthquakes of similar size may occur elsewhere in Gulf of Mexico. Provides constraints on the estimate of a minimum maximum earthquake magnitude for northern Gulf of Mexico.
Crustal Structure		
Anderson and Schmidt (1983)	The Evolution of Middle America and the Gulf of Mexico-Caribbean Sea Region During Mesozoic Time	Provides plate reconstruction model for the Gulf of Mexico and Caribbean region. Focuses on structures accommodating microplate motions in Mexico (e.g., Mojave-Sonora megashear).
Baksi (1997)	The Timing of Late Cretaceous Alkalic Igneous Activity in the Northern Gulf of Mexico Basin, Southeastern USA	Discusses distribution and age of Cretaceous igneous rocks in northern Gulf of Mexico. In particular, discusses Magnet Cove rocks of southern Arkansas that provide evidence of Mesozoic igneous activity in southern Arkansas.
Bird (2001)	Shear Margins: Continent-Ocean Transform and Fracture Zone Boundaries	Presents compilation of interpretations of plate tectonic continental shear margins worldwide. Compares plate tectonic models of Pindell (2000) to those of Buffler and Thomas (1994), and the implications of a Gulf Coast–parallel shear margin (Buffler and Thomas, 1994) to a shear margin along eastern coast of Mexico (Pindell, 2000).
Bird et al. (2005)	Gulf of Mexico Tectonic History: Hotspot tracks, Crustal Boundaries, and Early Salt Distribution	Provides constraints on location of ocean-continent crust boundary in northern Gulf of Mexico based on seismic-reflection and potential field geophysical data. Includes a comparison of the ocean-continent boundary as interpreted by multiple authors.
Buffler and Sawyer (1985)	Distribution of Crust and Early History, Gulf of Mexico Basin	Provides general overview of geologic and tectonic evolution of Gulf of Mexico. The tectonic reconstruction model is compared with previous models. Provides constraints on the locations of continental and oceanic crust in Gulf of Mexico.

Table D-7.3.9 Data Summary
Extended Continental Crust Zone—Gulf Coast

Citation	Title	Description and Relevance to SSC
Buffler and Thomas (1994)	Crustal Structure and Evolution of the Southwestern Margin of North America and the Gulf of Mexico Basin	Presents interpretations of E-W-trending tectonic elements in south-central U.S. (Alabama-Arkansas fault system and Suwanee-Wiggins suture) as major structural features associated with development of Gulf of Mexico. These E-W structures are important with respect to crosscutting relationships with NW-trending fracture zones in eastern Gulf of Mexico.
Byerly (1991)	Igneous Activity	Presents a synthesis of the igneous activity throughout Gulf of Mexico during the Mesozoic and Cenozoic.
Christenson (1990)	The Florida Lineament	Provides interpretations of location and geometry of a major NW-trending fracture zone (the Florida lineament) based on borehole, regional gravity, and regional magnetic data. Describes a major structure in eastern Gulf of Mexico located near September 10, 2006, M 5.8 earthquake.
Collins (2004)	Summary of the Balcones Fault Zone, Central Texas: A Prominent Zone of Tertiary Normal Faults Marking the Western Margin of the Texas Coastal Plain	Discusses tectonic history of Balcones fault zone.
Cook et al. (1979)	Crustal Structure and Evolution of the Southern Rio Grande Rift	Discusses southern extent of Rio Grande rift in New Mexico using geophysical data (gravity, heat flow, seismic reflection).
Cox et al. (2000)	Quaternary Faulting in the Southern Mississippi Embayment and Implications for Tectonics and Seismicity in an Intraplate Setting	Proposes existence of a Quaternary active Saline River fault zone in southern Arkansas based on equivocal observations of deformed Eocene and potentially Pliocene to Pleistocene deposits in natural exposures and shallow trenches.
Daniels et al. (1983)	Distribution of Subsurface Lower Mesozoic Rocks in the Southeastern United States, as Interpreted from Regional Aeromagnetic and Gravity Maps	Discusses extent of Mesozoic rocks in northwestern Gulf of Mexico, in particular, in Florida and Georgia. Presents figures showing extent of Bahamas fracture zone and South Georgia rift.
Dickerson and Muehlberger (1994)	Basins of the Big Bend Segment of the Rio Grande Rift, Trans-Pecos Texas	Discusses southern extent of Rio Grande rift in western Texas and northern Mexico. Presents maps of faults in Big Bend region of Texas and neighboring Mexico.

Table D-7.3.9 Data Summary
Extended Continental Crust Zone—Gulf Coast

Citation	Title	Description and Relevance to SSC
Dunbar and Sawyer (1987)	Implications of Continental Crust Extension for Plate Reconstruction: An Example from the Gulf of Mexico	Presents kinematic model for the opening of Gulf of Mexico.
Ewing and Lopez (1991)	Principal Structural Features of the Gulf of Mexico Basin	Map of geologic and structural features of Gulf of Mexico region.
Gordon et al. (1997)	Cenozoic Tectonic History of the North America-Caribbean Plate Boundary Zone in Western Cuba	Summarizes tectonic history of Cuba.
Gray et al. (2001)	Thermal and Chronological Record of Syn- to Post-Laramide Burial and Exhumation, Sierra Madre Oriental, Mexico	Presents thermo-chronological data constraining development of the Sierra Madre Oriental in western Gulf of Mexico.
Hall et al. (1982)	The Rotational Origin of the Gulf of Mexico Based on Regional Gravity Data	Presents interpretations of regional gravity data to constrain first-order tectonic elements in northern Gulf of Mexico. Provides review of previous interpretations of location and extent of oceanic crust.
Hall and Najmuddin (1994)	Constraints on the Tectonic Development of the Eastern Gulf of Mexico Provided by Magnetic Anomaly Data	Provides constraints on location of ocean-continent crust boundary in northern Gulf of Mexico. Also provides constraints on depth of oceanic crust.
Hatcher et al. (2007)	Tectonic Map of the Southern and Central Appalachians: A Tale of Three Orogens and a Complete Wilson Cycle	Comprehensive review of formation of Appalachians.
Hendricks (1988)	Bouguer Gravity Anomaly of Arkansas	Presents map of Arkansas. Discusses gravity anomalies of Arkansas and evidence of Cretaceous igneous activity.

Table D-7.3.9 Data Summary
Extended Continental Crust Zone—Gulf Coast

Citation	Title	Description and Relevance to SSC
Hildenbrand and Hendricks (1995)	Geophysical Setting of the Reelfoot Rift and Relations Between Rift Structures and the New Madrid Seismic Zone	Discusses geophysical signature of Reelfoot rift. Presents summary of Cretaceous igneous intrusions in southern Arkansas thought to indicate southernmost extent of rift.
Jacques et al. (2004)	Digital Integration of Potential Fields and Geologic Datasets for Plate Tectonic and Basin Dynamic Modeling—The First Step Towards Identifying New Play Concepts in the Gulf of Mexico Basin	Presents plate tectonic reconstructions of Gulf of Mexico showing major tectonic elements. Principal features are the location and extent of oceanic crust, major transform faults within oceanic crust, major NW-trending fracture zones in eastern Gulf of Mexico–related Atlantic rifting, and N- and NW-trending deep structural trends within transitional and thinned continental crust.
Kanter (1994)	Tectonic Interpretation of Stable Continental Crust	Presents locations of continental crust, extended crust, and oceanic crust in Gulf of Mexico region.
Klitgord et al. (1984)	Florida: A Jurassic Transform Plate Boundary	Discusses existence of Bahamas fracture zone that was active in the Jurassic during the opening of Gulf of Mexico. Presents maps of Florida delineating extent of Mesozoic rift basins and pre-Mesozoic crust.
Marton and Buffler (1994)	Jurassic Reconstruction of the Gulf of Mexico Basin	Presents detailed discussion of Gulf of Mexico structure and a model for the opening of Gulf of Mexico. Includes interpretation of extent of oceanic crust in Gulf of Mexico.
McBride and Nelson (1988)	Integration of COCORP Deep Reflection and Magnetic Anomaly Analysis in the Southeastern United States: Implications for Origin of the Brunswick and East Coast Magnetic Anomalies	Suggests three possible sources for the Brunswick magnetic anomaly (BMA): subducted root nappes of the Inner Piedmont, obducted upper mantle, or Mesozoic rifting. Authors do not strongly support a particular solution, but go on to suggest that the BMA and East Coast magnetic anomaly may have a continuous, related source.
McBride et al. (2005)	Integrating Seismic Reflection and Geological Data and Interpretations Across an Internal Basement Massif: The Southern Appalachian Pine Mountain Window, USA	Traces master Appalachian decollement from the Inner Piedmont to Coastal Plain. Authors find that beneath the Carolina terrane, the decollement roots to the Moho, indicating location of Acadian-Alleghanian suture.

Table D-7.3.9 Data Summary
Extended Continental Crust Zone—Gulf Coast

Citation	Title	Description and Relevance to SSC
McHuron and Rice (1974)	Tectonic Evolution of the Gulf Coast: Relation to Nuclear Power Plant Site Selection and Design Criteria	Delineates different crustal types in Gulf of Mexico and describes characteristics such as crustal type, relative stability, and history of stress application represented by tectonic fabrics. Directly addresses application of crustal characterization to seismic hazard and the siting of nuclear power plants in Gulf of Mexico coastal plain region.
Nagihara and Jones (2005)	Geothermal Heat Flow in the Northeast Margin of the Gulf of Mexico	Presents heat flow data for NE Gulf of Mexico and uses the data to revise estimates of location of oceanic crust within Gulf of Mexico.
Pindell and Dewey (1982)	Permo-Triassic Reconstruction of Western Pangea and the Evolution of the Gulf of Mexico/Caribbean Region	Presents a detailed reconstruction of Gulf of Mexico and Caribbean region. Outlines extent of oceanic crust within Gulf of Mexico.
Pindell and Kennan (2001)	Kinematic Evolution of the Gulf of Mexico and Caribbean	Presents plate tectonic reconstructions of Gulf of Mexico and Caribbean region. Helps to constrain location of oceanic crust in Gulf of Mexico.
Pindell et al. (2000)	Putting It All Together Again	Presents interpretations of location and geometry of oceanic crust beneath Gulf of Mexico basin. Northern margin agrees well with Peel (2007).
Russo (2006)	Earthquakes in the Gulf of Mexico	Presents possible mechanism for producing the September 10, 2006, M 5.8 earthquake. Influx of sediment into deep portions of Gulf of Mexico basin loads the underlying Mesozoic oceanic crust, causing flexure and buckling. Reverse earthquakes are produced by bending moment faults caused by buckling.
Salvador (1991)	Origin and Development of the Gulf of Mexico Basin	Presents comprehensive overview of geologic development of Gulf of Mexico. Provides information regarding distribution of crustal types and relationship to overlying growth-fault systems.
Sarwar (2002)	Northern Gulf of Mexico: A Passive or Passive Active Margin?	Presents alternative model for the modern tectonic setting of northern Gulf of Mexico that includes the region in a right-lateral mega-shear extending eastward from the Pacific–North America Plate margin.
Sawyer et al. (1991)	The Crust Under the Gulf of Mexico Basin	Presents interpretations of the deep crustal structure of Gulf of Mexico based on compilation of regional seismic-reflection, seismic-refraction, gravity, magnetic, and subsidence techniques. Presents a map and cross sections constraining the depth to basement and locations of different types of crust.

Table D-7.3.9 Data Summary
Extended Continental Crust Zone—Gulf Coast

Citation	Title	Description and Relevance to SSC
Thomas (1988)	Early Mesozoic Faults of the Northern Gulf Coastal Plain in the Context of Opening of the Atlantic Ocean	Discusses role of Mesozoic faults in the opening of Gulf of Mexico and the coincidence of some of those faults (e.g., Alabama-Arkansas transform) to transform faults associated with the Paleozoic rifting that opened the Iapetan ocean.
Thomas (2006)	Tectonic Inheritance at a Continental Margin	Presents interpretations of NW-trending transform faults in eastern Gulf of Mexico. Provides information on possible crustal source of September 10, 2006, M 5.8 earthquake.
Wheeler and Frankel (2000)	Geology in the 1996 USGS Seismic-Hazard Maps, Central and Eastern United States	Discusses the geologic data used in development of USGS National Seismic Hazard Map source model (e.g., source geometries).
White (1980)	Permian−Triassic Continental Reconstruction of the Gulf of Mexico−Caribbean Area	Presents kinematic model for the opening of Gulf of Mexico.
Growth Faults		
Bradshaw and Watkins (1994)	Growth-Fault Evolution in Offshore Texas	Presents line drawing of seismic data across major growth-fault systems in northern Gulf of Mexico. Presents conceptual model for evolution of the growth-fault systems. Provides important constraints on the depth distribution, kinematic style, and origin. These characteristics contribute to the understanding of seismic potential of growth faults.
Dokka et al. (2006)	Tectonic Control of Subsidence and Southward Displacement of Louisiana with Respect to Stable North America	Description of southern coastal Louisiana as part of a 7–10 km (4.3–6.2 mi.) thick allocthonous region detached from cratonic North America based on GPS data collected between 1995 and 2006. Describes a spatial association of post-1978 earthquakes with the allocthonous region. Concludes that earthquakes result from internal deformation of the allocthon. Cites subsidence rate of ~7 mm/yr relative to mean sea level.
DuBar et al. (1991)	Quaternary Geology of the Gulf of Mexico Coastal Plain	Provides description of Quaternary geology of Gulf of Mexico coastal plain of the U.S. Includes general discussion of fault activity due to movement on growth faults and man-induced seismicity associated with subsurface mineral withdrawal (oil, gas, and water).

Table D-7.3.9 Data Summary
Extended Continental Crust Zone—Gulf Coast

Citation	Title	Description and Relevance to SSC
Gagliano (2005)	Effects of Earthquakes, Fault Movements, and Subsidence on the South Louisiana Landscape	Describes growth faulting on Louisiana coast and its possible relationship to earthquake activity. No firm conclusions regarding source of earthquakes in the region, but suggests that movement on growth faults is the causative mechanism. Does not include a discussion of creep vs. strike-slip behavior, and the implications to earthquake generation potential of growth faults.
Jackson (1982)	Fault Tectonics of the East Texas Basin	Discussion of distribution, geometry, displacement history, and origin of Quaternary faulting in the East Texas basin, and implications to the siting of hypothetical high-level nuclear waste repositories. Concludes that none of the faults pose a seismic threat.
Karlo and Shoup (2000)	Classifications of Syndepositional Systems and Tectonic Provinces of the Northern Gulf of Mexico	Presents detailed overview of growth-fault systems in northern Gulf of Mexico, showing the style and relative ages of deformation. Provides important constraints on geometry and evolution of growth-fault systems.
Morton et al. (2001)	Shallow Stratigraphic Evidence of Subsidence and Faulting Induced by Hydrocarbon Production in Coastal Southeast Texas	Describes effects of growth faulting in coastal Texas and its relationship to hydrocarbon production. Concludes that fault activity is related to hydrocarbon withdrawal.
Peel et al. (1995)	Genetic Structural Provinces and Salt Tectonics of the Cenozoic Offshore U.S. Gulf of Mexico: A Preliminary Analysis	Provides overview of Gulf of Mexico growth-fault domain and provinces. Emphasizes the linked structural system of updip extension and downdip compression, and illustrates the development of the Sigsbee salt nappe.
Rowan et al. (1999)	Salt-Related Fault Families and Fault Welds in the Northern Gulf of Mexico	Presents a classification of different types of salt-related growth faults in northern Gulf of Mexico. Provides information on kinematics and origin of growth faults.
Watkins and Buffler (1996)	Gulf of Mexico Deepwater Frontier Exploration Potential	Describes deepwater environments of entire Gulf of Mexico that may contain significant hydrocarbon reserves. Shows cross section across Florida escarpment in the vicinity of September 10, 2006, M 5.8 earthquake. Provides information on the geologic environment of the earthquake.
Watkins et al. (1996)	Bipolar Simple-Shear Rifting Responsible for Distribution of Mega-salt Basins in Gulf of Mexico?	Describes relationship between basement structure (basins and fracture zones) and the setting of Louann "mother" salt in Gulf of Mexico. Shows a diagram emphasizing importance of NW-trending fracture zones in compartmentalizing salt accumulation and the development of salt basins.

Table D-7.3.9 Data Summary
Extended Continental Crust Zone—Gulf Coast

Citation	Title	Description and Relevance to SSC
Watkins et al. (1996)	Structure and Distribution of Growth Faults in the Northern Gulf of Mexico OCS	Overall description with seismic data examples of growth-fault systems of the Gulf of Mexico and Gulf coastal plain. Provides constraints on the map and cross-sectional geometry and location of growth faults, their depth extent and their relationship to underlying salt.
Wheeler (1999b)	Fault Number 924, Gulf-Margin Normal Faults, Texas, Quaternary Fault and Fold Database of the United States	Provides description of evidence and characteristics of Quaternary faulting in the coastal plain region of Texas, Louisiana, and Alabama. Concludes that fault activity is due to three driving forces: movement over mobile salt and shale, mineral extraction, and flexure of continental margin due to sediment loading in Gulf of Mexico.
Wu et al. (1990)	Allochthonous Salt, Structure and Stratigraphy of the North-Eastern Gulf of Mexico. Part II: Structure	Presents line drawing of seismic data across major growth-fault systems in northern Gulf of Mexico. Presents a conceptual model for evolution of growth-fault systems. Provides important constraints on depth distribution, kinematic style, and origin. These characteristics contribute to the understanding of the seismic potential of growth faults.
Seismic Source Models		
American Petroleum Institute (2000)	Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms—Working Stress Design (API RP 2A-WSD)	Provides guidance for seismic engineering design criteria for fixed structures in northern offshore Gulf of Mexico. Places the region in “Zone 0,” reflecting a design acceleration of 0.2 g.
Frankel et al. (2002)	Documentation for the 2002 Update of the National Seismic Hazard Maps	Presents seismic hazard model and seismic source characterization for the U.S. The northern Gulf of Mexico background source is assigned a maximum earthquake magnitude of M 7.5.
Johnston and Nava (1990)	Seismic-Hazard Assessment in the Central United States	Presents a seismic source zonation for Central U.S., including northern Gulf of Mexico coastal region. Characterizes Gulf coastal plain and northern offshore Gulf of Mexico as aseismic.
Johnston et al. (1994)	The Earthquakes of Stable Continental Regions	Presents maps and information constraining ages and types of crustal domains (e.g., extended vs. non-extended continental crust, oceanic vs. continental crust, etc.) in northern Gulf of Mexico and in Gulf coastal plain. These domains and seismotectonic characteristics provide some precedence for characteristics of an updated seismic source model for the region.

Table D-7.3.9 Data Summary
Extended Continental Crust Zone—Gulf Coast

Citation	Title	Description and Relevance to SSC
Petersen et al. (2008)	Documentation for the 2008 Update of the United States National Seismic Hazard Maps	Presents boundary of Mesozoic/Paleozoic crust in southern CEUS.
Potential ALM Source Zone		
Ambraseys (1988)	Engineering Seismology	Presents magnitude-bound relation for liquefaction.
Calais et al. (2006)	Deformation of the North American Plate Interior from a Decade of Continuous GPS Measurements	Uses regionally extensive continuous GPS stations throughout CEUS to determine the deformation field within the CEUS. No anomalies are present within the project study region, but it should be noted that there are very few stations within this region.
Cox (1994)	Analysis of Drainage-Basin Symmetry as a Rapid Technique to Identify Areas of Possible Quaternary Tilt-Block Tectonics: An Example from the Mississippi Embayment	Uses spatial distribution of drainage basin asymmetry to hypothesize existence of active faults and block tilting in Saline, Ouachita, and Arkansas River area.
Cox (2002)	Investigation of Seismically-Induced Liquefaction in the Southern Mississippi Embayment	NEHRP final report presenting results of paleoliquefaction trenching in Ashley and Desha Counties, Arkansas.
Cox (2009)	Investigations of Seismically-Induced Liquefaction in Northeast Louisiana	NEHRP technical report documenting preliminary results for the Louisiana liquefaction fields investigated by Cox. Identifies two sand blows in one field and one sand blow in another. Radiocarbon dating can only loosely constrain minimum ages, essentially providing no constraints on timing of sand blows. Cox notes that some of the blow-like features observed in aerial photos in Louisiana are eolian deposits.
Cox and Gordon (2008)	Sand Blows on Late Quaternary Surfaces in Northeast Louisiana	Abstract presenting preliminary results of paleoliquefaction investigations identifying sand blows in NE Louisiana.
Cox and Larsen (2004)	Investigation of Seismically-Induced Liquefaction in the Southern Mississippi Embayment	NEHRP final report presenting results of paleoliquefaction trenching in Ashley and Desha Counties, Arkansas.

Table D-7.3.9 Data Summary
Extended Continental Crust Zone—Gulf Coast

Citation	Title	Description and Relevance to SSC
Cox and Van Arsdale (1997)	Hotspot Origin of the Mississippi Embayment and Its Possible Impact on Contemporary Seismicity	Hypothesizes role of the Bermuda hotspot in the formation of Mississippi embayment and suggests that the hotspot may have significantly weakened the lithosphere. Also notes correlation between hotspot tracks and the Charleston, South Carolina and the St. Lawrence rift system, regions of moderate to large earthquakes.
Cox et al. (2000)	Quaternary Faulting in the Southern Mississippi Embayment and Implications for Tectonics and Seismicity in an Intraplate Setting	Hypothesizes existence of a Quaternary-active Saline River fault zone based on a concentration of historical seismicity and the apparent deformation of Pliocene-Pleistocene deposits in road cuts.
Cox, Forman, et al. (2002)	New Data of Holocene Tectonism in the Southern Mississippi Embayment	Abstract presenting preliminary results of paleoliquefaction trenching in Ashley County, Arkansas.
Cox, Harris, et al. (2004)	More Evidence for Young Tectonism Along the Saline River Fault Zone, Southern Mississippi Embayment	Abstract presenting preliminary results and interpretation of S-wave reflection profiles of Saline River fault zone and the relation of these structures to preliminary sand-blow dates.
Cox, Larsen, and Hill (2004)	More Paleoliquefaction Data from Southeastern Arkansas: Implications for Seismic Hazards	Abstract presenting preliminary results of paleoliquefaction trenching in Ashley and Desha Counties, Arkansas.
Cox, Larsen, Forman, et al. (2004)	Preliminary Assessment of Sand Blows in the Southern Mississippi Embayment	Presents compilation of all paleoliquefaction trenching and dating done through 2004 within the Saline River area. Hypothesizes a correlation between source of liquefaction and Cox's proposed Quaternary deformation features within Saline River area.
Cox et al. (2007)	Seismotectonic Implications of Sand Blows in the Southern Mississippi Embayment	Presents compilation of paleoliquefaction trenching and dating done from 2004 through 2007 within Saline River area. Also presents results of geotechnical studies of sand-blow host deposits and the implications for that data with respect to the amount of ground shaking required to cause liquefaction. Hypothesizes a correlation between source of liquefaction and Cox's proposed Quaternary deformation features within Saline River area.
Cushing et al. (1964)	General Geology of the Mississippi Embayment	Provides general discussion of geology and structure of Mississippi embayment.

Table D-7.3.9 Data Summary
Extended Continental Crust Zone—Gulf Coast

Citation	Title	Description and Relevance to SSC
Ewing (1991)	Structural Framework	Provides general discussion of tectonic and geologic structures of Gulf of Mexico region.
Garrote et al. (2006)	Tectonic Geomorphology of the Southeastern Mississippi Embayment in Northern Mississippi, USA	Uses the spatial distribution of drainage basin asymmetry to hypothesize the existence of active faults.
Gordon and Cox (2008)	Recurrent Mesozoic and Cenozoic Faulting along the Southern Margin of the North American Craton	Abstract hypothesizing that the Alabama-Oklahoma transform and related structures may be the tectonic feature that is source of strong ground shaking that caused the Arkansas liquefaction features and the deformed Saline River fault zone deposits.
Green et al. (2005)	Engineering Geologic and Geotechnical Analysis of Paleoseismic Shaking Using Liquefaction Effects: Field Examples	Presents examples of how to back-calculate ground motions (e.g., earthquake magnitudes) from paleoliquefaction data.
Harry and Londono (2004)	Structure and Evolution of the Central Gulf of Mexico Continental Margin and Coastal Plain, Southeast United States	Identifies location of the potential Precambrian, passive-margin, transform plate boundary that trends from Alabama to Oklahoma. Uses gravity modeling, industry seismic data, and well data to construct transects across the transform.
Hosman (1996)	Regional Stratigraphy and Subsurface Geology of Cenozoic Deposits, Gulf Coastal Plain, South-Central United States	Provides general discussion of structure and geology of Gulf coastal plain and Mississippi embayment from the perspective of an aquifer analysis.
Liang and Langston (2009)	Three-Dimensional Crustal Structure of Eastern North America Extracted from Ambient Noise	Maps three-dimensional shear-wave velocity throughout CEUS and discusses presence of rifting episodes apparent in the data.
Mickus and Keller (1992)	Lithospheric Structure of the South-Central United States	Constructs a N-S cross section from Gulf of Mexico to Missouri along the Texas-Louisiana border using primarily gravity data but qualitatively including seismic-reflection, well log, and geologic data.

Table D-7.3.9 Data Summary
Extended Continental Crust Zone—Gulf Coast

Citation	Title	Description and Relevance to SSC
Murray (1961)	Geology of the Atlantic and Gulf Coastal Province of North America	Provides general discussion of structure and geology of Gulf of Mexico region.
Obermeier and Pond (1999)	Issues in Using Liquefaction Features for Paleoseismic Analysis	Summary paper describes concerns about the use of paleoliquefaction data as evidence of strong ground shaking.
Olson et al. (2005a)	Geotechnical Analysis of Paleoseismic Shaking Using Liquefaction Features: A Major Updating	Presents methodology for how to back-calculate ground motions (e.g., earthquake magnitudes) from paleoliquefaction data.
Olson et al. (2005b)	Revised Magnitude Bound Relation for the Wabash Valley Seismic Zone of the Central United States	Presents an updated magnitude-bound relationship for paleoliquefaction in CEUS.
Salvador (1991)	Origin and Development of the Gulf of Mexico Basin	Provides general discussion of the structure of Gulf of Mexico region, as well as the tectonic history of the Gulf. Identifies location of Alabama-Oklahoma transform.
Saucier and Smith (1986)	Geomorphic Mapping and Landscape Classification of the Ouachita and Saline River Valleys, Arkansas	Presents detailed mapping of terraces within the Ouachita and Saline River valleys. Dating and terrace classification presented in this report was used by others (e.g., Cox, 1994) to correlate terraces in the basins.
Al-Shukri et al. (2005)	Spatial and Temporal Characteristics of Paleoseismic Features in the Southern Terminus of the New Madrid Seismic Zone in Eastern Arkansas	Presents preliminary results of investigation of liquefaction features further discussed by Tuttle et al. (2006).
Tuttle (2001)	The Use of Liquefaction Features in Paleoseismology: Lessons Learned in the New Madrid Seismic Zone, Central United States	Summary paper describing use of paleoliquefaction data within New Madrid seismic zone to constrain paleo-earthquakes within the zone.

Table D-7.3.9 Data Summary
Extended Continental Crust Zone—Gulf Coast

Citation	Title	Description and Relevance to SSC
Tuttle, Schweig, et al. (2002)	The Earthquake Potential of the New Madrid Seismic Zone	Presents summary of paleoseismic history of New Madrid seismic zone and the areas of liquefaction associated with New Madrid earthquakes.
Tuttle et al. (2006)	Very Large Earthquakes Centered Southwest of the New Madrid Seismic Zone 5,000–7,000 Years Ago	Presents results of paleoliquefaction trenching and dating in central-eastern Arkansas. Identifies at least two different sets of sand blows at ~5,500 and 6,800 yr BP.
Wheeler (2005)	Known or Suggested Quaternary Tectonic Faulting, Central and Eastern United States—New and Updated Assessments for 2005	Presents summary discussion of the Arkansas paleoliquefaction features discovered by Cox, and Cox's hypothesized Saline River fault zone.
Zhang et al. (2009b)	Tomographic Pn Velocity and Anisotropy Structure in the Central and Eastern United States	Maps Pn (upper mantle) velocity structure throughout CEUS and hypothesizes at a potential correlation between edges of high-velocity zones and the locations of intraplate seismic zones.

Table D-7.3.12 Data Summary
MidContinent-Craton Zone

Citation	Title	Description and Relevance to SSC
General for Region		
Atekwana (1996)	Precambrian Basement Beneath the Central Midcontinent United States as Interpreted from Potential Field Data	References previous geologic and geophysical investigations (Hinze et al., 1975; Klasner et al., 1982; Bickford et al., 1986; Van Schmus, 1992) that reveal that Precambrian basement within the Midcontinent region consists of several provinces that formed before 900 million years ago (Ma), including the Superior province (2.7 billion years ago [Ga]); Penokean province (1.83–1.88 Ga); Central Plains province (1.63–1.7 Ga); Eastern Granite-Rhyolite province (1.42–1.5 Ga); Midcontinent rift system (1.1–1.0 Ga); and Grenville province (0.8–1.1 Ga).
Li et al. (2009)	Spatiotemporal Complexity of Continental Intraplate Seismicity: Insights from Geodynamic Modeling and Implications for Seismic Hazard Estimation	This paper explores the complex spatiotemporal patterns of intraplate seismicity using a 3-D viscoelasto-plastic finite-element model. The model simulates tectonic loading, crustal failure in earthquakes, and coseismic and postseismic stress evolution. For a laterally homogeneous lithosphere with randomly prespecified perturbations of crustal strength, the model predicts various spatiotemporal patterns of seismicity at different time scales: spatial clustering in narrow belts and scattering across large regions over hundreds of years, connected seismic belts over thousands of years, and widely scattered seismicity over tens of thousands of years. The orientation of seismic belts coincides with the optimal failure directions associated with the assumed tectonic loading. Stress triggering and migration cause spatiotemporal clustering of earthquakes. Fault weakening can lead to repeated earthquakes on intraplate faults. The predicted patterns vary with the weakening history. Clusters of large intraplate earthquakes can result from fault weakening and healing, and the clusters can be separated by long periods of quiescence. The complex spatiotemporal patterns of intraplate seismicity predicted in this simple model suggest that assessment of earthquake hazard based on the limited historical record may be biased toward overestimating the hazard in regions of recent large earthquakes and underestimating the hazard where seismicity has been low during the historical record.

Table D-7.3.12 Data Summary
MidContinent-Craton Zone

Citation	Title	Description and Relevance to SSC
Liang and Langstrom (2009)	Three-Dimensional Crustal Structure of Eastern North America Extracted from Ambient Noise	Group velocity dispersion curves of surface waves extracted from ambient seismic noise are inverted to find 3-D shear-wave structure of the crust beneath eastern North America. The 3-D model consists of one sediment layer and another six layers with fixed depths of 5, 7.5, 10, 15, 25, and 43 km (3, 4.7, 6.2, 9.3, 15.5, and 26.7 mi.). Almost all failed ancient rifting earthquakes (e.g., the Reelfoot rift, Ouachita triple junction, and Midcontinent rift) and rifting-related earthquakes (e.g., the Ozark uplift and Nashville dome) are associated with high-velocity bodies in the middle and lower crust. Results suggest the existence of a triple-junction-like high-velocity body centered around the New Madrid and Wabash Valley seismic zones (NMSZ and WVSZ), with the Reelfoot rift, the Ozark uplift, and the Nashville dome being on its SW, NW, and SE arms, respectively. The Appalachian Mountains are characterized by high-velocity upper crust underlain with relatively low-velocity middle and lower crust. All major seismic zones are associated with either divergent or convergent events. The NMSZ and WVSZ are clearly associated with the failed Reelfoot rift. Both the eastern Tennessee seismic zone and the Ouachita orogen are located along convergent boundaries.
Marshak and Paulsen (1997)	Structural Style, Regional Distribution, and Seismic Implications of Midcontinent Fault-and-Fold Zones, United States	Paleozoic/Mesozoic strata of the U.S. continental interior contain arrays of steeply dipping faults and associated monoclinal forced folds. This paper hypothesizes that these structures were initiated during episodes of Proterozoic extensional tectonism. Two sets identified: one trending N-NE and the other trending W-NW. These sets break upper crust into blocks that cause slight movements in response to changes in stress state. Many W-NW-trending fault and fold zones link along strike to define semicontinuous NW-trending deformation corridors. One of these, the 200 km (124 mi.) wide Transamerican tectonic zone, traces over 2,500 km (1,553 mi.) from Idaho to South Carolina. Seismicity most frequently occurs where N-NE-trending fault and fold zones cross the Transamerican tectonic zone, suggesting that intracratonic strain in the U.S. currently concentrates at or near intersecting fault zones within this corridor.

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MidContinent-Craton Zone

Citation	Title	Description and Relevance to SSC
NICE Working Group (2007)	Reinterpretation of Paleoproterozoic Accretionary Boundaries of the North-Central United States Based on a New Aeromagnetic-Geologic Compilation	Presents a new tectonic province map, based on interpretation of a new aeromagnetic compilation, published geologic maps, and geochronologic data. The map shows a progressive accretion of juvenile arc terranes from ca. 1,900–1,600 Ma. The Spirit Lake tectonic zone, characterized by a sharp magnetic discontinuity that marks the southern limit of Archean and Penokean-interval rocks, is interpreted to represent an eastern analog of the Cheyenne belt suture zone in southern Wyoming. The data reveal a progressive tectonic younging to the south as the Laurentian craton grew southward and stabilized during the Proterozoic. Late Mesoproterozoic rift magmatism produced pronounced geophysical anomalies, indicating strong but localized crustal modification. Little tectonism has occurred here in the last billion years, providing a preserved record of the Precambrian evolution of the continental U.S. lithosphere.
Sims et al. (2005)	Preliminary Precambrian Basement Structure Map of the Continental United States—An Interpretation of Geologic and Aeromagnetic Data	The systematics of major regional post-assembly Precambrian basement structures throughout the continental U.S. point to a common causal mechanism for their development. The model presented accords with geodynamic models for North and South American Plate motions, based on seismic anisotropy beneath the continents that invoke mechanical coupling and subsequent shear between the lithosphere and asthenosphere such that a major driving force for plate movement is deep-mantle flow. Two orthogonal sets of shear zones and faults are predominant in the continent: (1) NE-striking, partitioned ductile shear zones, and (2) NW-trending strike-slip ductile-brittle faults. The NE-striking shear zones are interpreted as resulting from NW-SE shortening, apparently formed during the interval 1.76–1.70 Ga. The NW-trending (1.7–1.5 Ga) transcurrent fault system consists of W-NW to NW synthetic faults and northerly trending antithetic transfer faults; it is attributed to transpressional-transtensional deformation, i.e., strike-slip deformation that deviates from simple shear because of a component of shortening or extension orthogonal to the deformation zone. The NE- and NW-oriented shears and faults mimic orthogonal teleseismic images of the upper mantle. These structures were reactivated during the Mesoproterozoic and later times. The kinematics of regional basement structures within the continental U.S. suggest that deformation since at least early Proterozoic time has been predominantly transpressional. Transcurrent lithospheric structures formed

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Citation	Title	Description and Relevance to SSC
		during Proterozoic mantle deformation are oriented obliquely to the SW (absolute) motion of the North American Plate. Stress caused by traction between the asthenosphere and lithosphere during the SW drift focused on preexisting block boundaries repeatedly have reactivated basement zones of weakness, thus localizing sedimentation, magmatism, and generation of ore deposits.
Whitmeyer and Karlstrom (2007)	Tectonic Model for the Proterozoic Growth of North America	Presents a plate-scale model for the Precambrian growth and evolution of the North American continent. The core of the North American continent (Canadian shield) came together in the Paleoproterozoic (2.0–1.8 Ga) by plate collisions. The thick, buoyant, and compositionally depleted mantle lithosphere that now underlies North America, although dominantly of Archean age, took its present shape by processes of collisional orogenesis and likely has a scale of mantle heterogeneity similar to that exhibited in the overlying crust. In marked contrast, lithosphere of southern North America (much of the continental U.S.) was built by progressive addition of a series of dominantly juvenile volcanic arcs and oceanic terranes accreted along a long-lived southern (present coordinates) plate margin. The lithospheric collage that formed from dominantly juvenile terrane accretion and stabilization (1.8–1.0 Ga) makes up about half of the present-day North American continent. Throughout (and as a result of) this long-lived convergent cycle, mantle lithosphere below the accretionary provinces was more hydrous, fertile, and relatively weak compared to mantle lithosphere under the Archean core.
Zhang et al. (2009b)	Tomographic Pn Velocity and Anisotrophy Structure in the Central and Eastern United States	Inversion of tomographic data to map the velocity and anisotropy structure of the lithospheric mantle in the CEUS. The Pn tomographic model shows a broad region of very fast velocity under the North American craton (northern CEUS) and significant lateral variation within the rest of the CEUS. The surface locations of the major intraplate seismic zones are near the edges of high-velocity anomalies, which is consistent with the notion that stress accumulation—and hence focused deformation—is likely to occur at the rheological boundaries around the rigid lithospheric root. Ancient rifts show no clear correlation to the low-velocity anomalies in the lithospheric mantle.

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Citation	Title	Description and Relevance to SSC
Geophysical Anomalies		
Commerce Geophysical Lineament (CGL)		
Hildenbrand and Hendricks (1995) Langenheim and Hildenbrand (1997)	Geophysical Setting of the Reelfoot Rift and Relations Between Rift Structures and the New Madrid Seismic Zone Commerce Geophysical Lineament—Its Source, Geometry, and Relation to the Reelfoot Rift and New Madrid Seismic Zone	The Commerce geophysical lineament (CGL) is a NE-trending feature that extends from NE Arkansas to at least Vincennes, Indiana. This lineament comprises a series of linear, NE-trending magnetic and gravity anomalies traceable for more than 384 km (239 mi.). This feature has been interpreted to consist of en echelon faults and igneous intrusions in the basement that are related to the Neoproterozoic to early Paleozoic Reelfoot rift; however, it is postulated to have an even older ancestry.
Hildenbrand et al. (2002)	The Commerce Geophysical Lineament and Its Possible Relation to Mesoproterozoic Igneous Complexes and Large Earthquakes in the Central Illinois Basin	New inversions of existing magnetic and gravity data provide information on upper-crustal structures in the central Illinois basin. Results of 2-D and 3-D inversion techniques suggest that the source of the CGL follows the SE boundary of a dense and magnetic NE-trending igneous center named the Vincennes igneous center. The buried Vincennes igneous center is suggested to be the source of inferred volcanic units of the Centralia sequence and is related to a rifted margin or a Proterozoic plate boundary. Comparing gravity and magnetic fields of the Vincennes igneous center with those of the St. Francois Mountains igneous center in SE Missouri suggests that the associated sources in each region are similar in composition and perhaps origin. The CGL that is defined in this region by a 5–10 km (3–6 mi.) wide deformation zone appears to have influenced the structural development of the Vincennes igneous center. The Commerce deformation zone evolved in the Mesoproterozoic (1.1–1.5 Ga) as a major cratonic rheological boundary and has been the focus of episodic reactivation related to varying stress regimes throughout its history.

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MidContinent-Craton Zone

Citation	Title	Description and Relevance to SSC
South-Central Magnetic Lineament (SCML)		
Hildenbrand et al. (1983)	Digital Magnetic-Anomaly Map of Central United States: Description of Major Features	Describes a regional W-NW-trending lineament characterized by a band of steep magnetic gradients that coincides with a prominent Bouguer anomaly and the general position of the Cottage Grove fault system, Ste. Genevieve fault zone, and Hicks dome.
Kolata and Hildenbrand (1997)	Structural Underpinnings and Neotectonics of the Southern Illinois Basin: An Overview	Seismic-reflection profiles show that a layered Precambrian sequence in the upper crust in the southern Illinois basin terminates abruptly at this boundary.
St. Charles Lineament (SCL)		
Harrison and Schultz (2002)	Tectonic Framework of the Southwestern Margin of the Illinois Basin and Its Influence on Neotectonism and Seismicity	The St. Charles lineament (SCL) is the informal name given to an alignment of geochemical and geophysical features that extends from SW Ontario to SE Oklahoma. A paleotectonic history of the SCL is difficult to decipher because many structural features related to the lineament lie beneath the alluvial plain of the Missouri River. There is no apparent stratigraphic offset of Paleozoic strata across the SCL, but a zone of conjugate strike-slip faults of probable late Mississippian to early Pennsylvanian age is exposed along the SCL near Acton, Illinois. These faults do not displace overlying Pleistocene loess. Harrison and Schultz postulate two lines of weak and nondefinitive evidence for neotectonic activity along the SCL: (1) the Missouri River bends to a NE course upon encountering the SCL, suggesting a tectonic control on the river, which alternatively could reflect the influence of an older deformational fabric; and (2) the postdepositional tilting of Miocene (?) Grover Gravel may be due to faulting along the SCL.
Hildenbrand and Kucks (1992) Hildenbrand and Hendricks (1995)	Filtered Magnetic Anomaly Maps of Missouri Geophysical Setting of the Reelfoot Rift and Relations Between Rift Structures and the New Madrid Seismic Zone	This lineament is defined by a regional neodymium (Nd) isotopic boundary that coincides with linear geophysical trends along most of its length.

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Citation	Title	Description and Relevance to SSC
Mateker et al. (1966)	Geophysical Evidence for a Northeast Crustal Lineament near St. Louis	Notes that the SCL is parallel to the Reelfoot rift and the New Madrid seismic zone as well as to a trend of minor earthquake activity in the St. Louis–St. Charles area.
Sims (1990) Sims and Peterman (1986)	Precambrian Basement Map of the Northern Midcontinent, U.S.A. Early Proterozoic Central Plains Orogen: A Major Buried Structure in the North-Central United States	These publications map the boundary between Paleoproterozoic metamorphic/granitoid rocks and Mesoproterozoic rhyolitic/granitic rocks along the SCL, which they interpret as the margin of a Paleoproterozoic Central Plains orogen.
Sims et al. (1987)	Geology and Metallogeny of Archean and Proterozoic Basement Terranes in the Northern Midcontinent, U.S.A.—An Overview	Suggests that the margin coincident with the SCL is an ancient suture zone.
Van Schmus et al. (1996)	Proterozoic Geology of the East-Central Midcontinent Basement	Interprets the Nd isotopic boundary as a Paleoproterozoic crustal margin that separates late Paleoproterozoic lower-crustal rocks to the NW from early Mesoproterozoic lower-crustal rocks to the SE.
Seismicity *(Note: The Anna, Ohio, and Northeast Ohio seismicity zones are both discussed in the section on Paleoliquefaction Studies.)*		
Bakun and Hopper (2004a)	Catalog of Significant Historical Earthquakes in the Central United States	Modified Mercalli intensity assignments are used to estimate source locations and moment magnitude, **M**, for 18 nineteenth-century and 20 early twentieth-century earthquakes in the central U.S. for which estimates of M are otherwise not available. Four M > 5.0 central U.S. historical earthquakes have occurred: in Kansas in 1867, Nebraska in 1877, Oklahoma in 1882, and Kentucky in 1980.
Hinze and Hildenbrand (1988)	The Utility of Geopotential Field Data in Seismotectonic Studies in the Eastern United States	The Sharpsburg earthquake of July 27, 1980 (m_b = 5.1) originated at a depth of 15 km (9.3 mi.), in the vicinity of a prominent gravity gradient and complex magnetic anomalies caused by mafic Grenvillian (Precambrian) basement rocks, suggesting that this moderate-sized earthquake originated in the reactivation of a Precambrian zone of weakness.

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Citation	Title	Description and Relevance to SSC
Joeckel et al. (2003)	Earthquake History, Seismicity, and Related Tectonics in Nebraska	Nebraska experienced two significant earthquakes in 2002: a June 20, M 3.5 earthquake and a November 3, M 4.3 earthquake. About 50 earlier earthquakes, almost all M < 4, have occurred in Nebraska since 1867. A cluster of microearthquakes reported in 1979 in Red Willow County in SW Nebraska may have been related to petroleum production. Other earthquakes occurred at about the same time in SE Nebraska along the Nemaha uplift, a major N-S structure extending into basement rocks. Larger earthquakes seem to be related to the periodic release of accumulated regional stresses in major structures (Nemaha uplift, Midcontinent rift) and around proposed sutures resulting from the Proterozoic (1.8–1.6 Ga) accretion of island arcs across the region.
Structures		
Anton Escarpment, Colorado		
Wheeler (2005)	Known or Suggested Quaternary Tectonic Faulting, Central and Eastern United States—New and Updated Assessments for 2005	Classifies the Anton escarpment as a Class C feature. The NE-facing topographic escarpment is 20–30 m high. A trench excavated across the escarpment in 2004 did not expose any faults associated with the topographic feature; no significant vertical offset exists across the escarpment, as indicated by stratigraphy correlated between the trench and nearby boreholes. If the feature is a fault-line scarp, displacement has not occurred for a long time. The lack of a demonstrated fault-related origin for the escarpment justifies the Class C classification.
Brockton-Froid Fault Zone, Montana		
Crone and Wheeler (2000)	Data for Quaternary Faults, Liquefaction Features, and Possible Tectonic Features in the Central and Eastern United States, East of the Rocky Mountain Front	Classifies the Brockton-Froid fault zone as Class B.

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MidContinent-Craton Zone

Citation	Title	Description and Relevance to SSC
Wheeler (1999a)	Fault Number 707, Brockton-Froid Fault Zone, Quaternary Fault and Fold Database of the United States	Classified as a Class B fault, this feature is located in the glaciated plains of NE Montana. The fault zone contains Quaternary deformation; the deformation may not have occurred by faulting, but it also may indicate a basement fault that was reactivated during glacial or postglacial time. The linear fault zone is about 54 km (33.5 mi.) long and does not have an obvious fluvial, glacial, or glaciotectonic origin. The origin of the feature is enigmatic.
Wheeler and Crone (2001)	Known and Suggested Quaternary Faulting in the Midcontinent United States	The Brockton-Froid fault needs further study to determine whether it is a Quaternary tectonic fault. Late Wisconsinan outwash and Quaternary sheetwash alluvium and colluvium occupy a straight zone a few hundred meters wide and at least 53 km (33 mi.) long along the trace of the inferred fault zone. The narrow zone is bounded by till on both sides. Data from lines of auger holes show that the Quaternary deposits inside the zone are thicker than the adjacent deposits. The 1:24,000-scale topographic maps along the zone show its geomorphic expression as alignments of straight stream segments and valleys, elongated hills and ridges, and large, closed depressions; the zone descends to cross streams and rises to cross interfluves without obvious deflection. The authors reference Colton (1963a, 1963b), who interpreted the zone as a fault-bounded feature—yet nowhere are faults exposed that juxtapose outwash and till. Structure-contour and isopach maps of Paleocene lignites at depths of 240 m and less do not show detectable offset across the zone (Hardie and Arndt, 1988; Biewick et al., 1990). If the straight zone is bounded by faults, it is unclear whether the faults penetrate deeply enough into bedrock to pose a seismic threat.
Wong et al. (2005)	Probabilistic Earthquake Hazard Maps for the State of Montana	The Brockton-Froid fault zone was characterized as a possible fault source (probability of activity of 0.5) in a statewide seismic hazard study conducted for the State of Montana. The map data and length were from M. Stickney of the Montana Bureau of Mines and Geology (digital shape-files, May 1, 2002, to S. Olig, URS) after recent mapping by Bergantino and Wilde (1998a, 1998b), which includes a possible NE extension near Medicine Lake. Subsurface data is ambiguous with regard to the depth extent of this enigmatic structure and its sense of slip (Crone and Wheeler, 2000). Additionally, slip may have been related to postglacial relaxation and, if so, it may no longer be as active; thus the authors assigned a lower probability of activity. Slip rates are based on one or two possible post–late Wisconsinan (<40 ka) earthquakes (Crone and Wheeler, 2000).

Table D-7.3.12 Data Summary
MidContinent-Craton Zone

Citation	Title	Description and Relevance to SSC
Cape Girardeau Fault System, Missouri		
Harrison and Schultz (2002)	Tectonic Framework of the Southwestern Margin of the Illinois Basin and Its Influence on Neotectonism and Seismicity	The Cape Girardeau fault system, which is a continuation of the Simms Mountain fault system, consists of numerous branching and anastomosing, dominantly NW-striking, near-vertical faults. Although NE- and N-NW-striking faults are less common, they appear to show evidence for the most recent deformation. There are rhomb-shaped pull-apart graben related to strike-slip faulting that can be divided into three groups: (1) those that contain only Paleozoic rocks, (2) those that contain upper Cretaceous and lower Tertiary formations, and (3) those that contain Quaternary strata. Unequivocal evidence of faulting of Quaternary gravel has been observed in a quarry and roadcut at the SE end of the fault system near its intersection with the Commerce geophysical lineament. Results of recent trenching show evidence of Quaternary faulting, possibly post-Sangamon in age. Unfaulted Peoria Loess (late Wisconsinan in age) and possibly Roxana Silt overlie the fault and graben fill. The authors interpret the Quaternary deformation to have formed under E-NE horizontal maximum principal stress. They favor erosion and fill as an alternative to the finding by Tuttle, Chester, et al. (1999) of a source of possible faulting in Quaternary gravel discovered on part of the Cape Girardeau fault system approximately 14.5 km (9 mi.) to the NW.
Wheeler (2005)	Known or Suggested Quaternary Tectonic Faulting, Central and Eastern United States—New and Updated Assessments for 2005	Classifies the Slinkard quarry graben in Missouri as a Class A feature, noting that faults that bound the graben or are near it have undergone multiple periods of movement, including pre-Cenozoic, Paleocene, and at least two periods in the Quaternary, with the youngest being post-Sangamon Geosol (< 130 ka) and pre-Wisconsinan loess. The NW margin of the graben juxtaposes Quaternary gravel against late Tertiary Mounds Gravel. The fault on the NW margin strikes N35°–40°E and dips approximately 74°SE. Mounds Gravel in the footwall has been rotated to dip 54°–85°E, with strike parallel to the fault. The faults are assigned to a slip-rate category of less than 0.2 mm/yr. The sense of movement is normal dextral; the graben is interpreted to be a pull-apart graben in a dextral strike-slip system. The length of the Slinkard quarry graben is unknown, but the NW margin fault is at least 180 m long.

Table D-7.3.12 Data Summary
MidContinent-Craton Zone

Citation	Title	Description and Relevance to SSC
Criner Fault, Oklahoma		
Hanson et al. (1997)	Quaternary Deformation Along the Criner Fault, Oklahoma: A Case Study for Evaluating Tectonic Versus Landslide Faulting	This study summarizes field investigations at a locality (a natural stream exposure) along the Criner fault where deformation of late Pleistocene alluvium had been suggested as evidence for Quaternary faulting on the Criner fault, which is part of the 310 km (193 mi.) long Meers-Duncan-Criner fault system. Excavation and detailed mapping of the exposure, in which a steep shear zone juxtaposes Quaternary alluvium against bedrock, provided evidence to indicate that the deformation was due to landsliding.
Wheeler and Crone (2001)	Known and Suggested Quaternary Faulting in the Midcontinent United States	Summarizes studies that evaluated possible evidence for Quaternary deformation on the Criner fault. A topographic and vegetation lineament, a linear hill, and scarps 0.3–1.0 m high along the hill front and across gullies suggested possible Quaternary movement. This study cites the results of Hanson et al. (1997) that the preferred interpretation of the only locality where Quaternary deformation was clearly documented is that the faulting is due to landsliding rather than tectonic faulting.
Crooked Creek Fault		
Crone (1998b)	Fault Number 1032, Crooked Creek Fault, in Quaternary Fault and Fold Database of the United States	Classified in the USGS Quaternary Fault and Fold Database as a Class B feature because of the uncertainty concerning the cause of subsurface deformation. Deformation may be solely the result of dissolution of soluble subsurface strata or deep-seated tectonic movements. The postulated fault is defined largely on the basis of drillhole data and anomalous geomorphic features above the subsurface structure. No exposures of the fault are known. Deformation associated with the feature has resulted in a structural depression in the subsurface and an elongate topographic trough. Due to the absence of any clear surface expression, the postulated structure is poorly located and defined; the length is unknown. The sense of movement and dip are not well known; data suggest significant vertical movement, but no information exists to determine if the offset would be reverse or normal. Pleistocene and Holocene (sinkholes) deformation is associated with the postulated structure. Due to uncertainty related to the origin of this postulated structure, it is not possible to assign a time of the most recent paleo-earthquake or recurrence interval.

Table D-7.3.12 Data Summary
MidContinent-Craton Zone

Citation	Title	Description and Relevance to SSC
East Continent Rift Basin (ECRB)		
Drahovzal et al. (1992)	The East Continent Rift Basin: A New Discovery	Integration of lithologic, stratigraphic, geochemical, gravity, magnetic, structural, and seismic data resulted in recognition of an eastern arm of the Midcontinent rift system named the East Continent rift basin (ECRB). An elongate N-S-trending Precambrian rift basin is present from SE Michigan through Ohio and Indiana, into central Kentucky. The ECRB is filled with red continental lithic arenites, minor red siltstones and shales, and volcanics. Gravity, magnetic, and seismic data indicate that the basin is composed of several subbasins. The basin is bounded by the Grenville Front to the east and by normal block faults to the west. The basin narrows to the north; the southern boundary is not well constrained. The basin is interpreted to be Keweenawan in age and associated with the middle Proterozoic Midcontinent rift system. The ECRB predates the Grenville orogeny, which resulted in folding and faulting of the rift-fill sequence. Post-Grenville erosion, Paleozoic inversion, and wrench faulting resulted in the present configuration of the basin.
Farmington Anticline, Missouri		
Harrison and Schultz (2002)	Tectonic Framework of the Southwestern Margin of the Illinois Basin and Its Influence on Neotectonism and Seismicity	The Farmington anticline–Avon block is a broad (as much as 19.3 km, or 12 mi., wide) NW-trending low-relief structural feature that lies between the Ste. Genevieve and Simms Mountain faults. Weak to moderate seismicity is clustered around this structure, which has been interpreted to occur above buried faults cutting middle Proterozoic basement rock. A zone of NW-trending horsts and graben with subsidiary and contemporaneous NE-striking oblique-slip faults coincides with the axis of the fold.
Goodpasture Fault, Colorado		
Widmann (1997c)	Complete Report for Goodpasture Fault (Class A) No. 2329	The Goodpasture fault forms a fairly prominent escarpment and vegetation lineation that trends NW to the east of Hogback Mountain in the Wet Mountains in Colorado. The most recent fault displacement may have occurred in the early to middle Quaternary. Geomorphic features on Quaternary deposits indicative of youthful faulting have not been observed in aerial reconnaissance. The fault is 5 km (3 mi.) long.

Table D-7.3.12 Data Summary
MidContinent-Craton Zone

Citation	Title	Description and Relevance to SSC
Great Lakes Tectonic Zone (GLTZ), Minnesota		
Atekwana (1996)	Precambrian Basement Beneath the Central Midcontinent United States as Interpreted from Potential Field Data	Major E-NE Archean crustal boundary, which is observed on gravity and magnetic anomaly maps, separates greenstone-granite terranes (~2,700 Ma) on the north from gneiss terrane (3,600 Ma) on the south. The feature is a locus of repeated reactivation.
Sims et al. (1980)	The Great Lakes Tectonic Zone—A Major Crustal Structure in Central North America	The Great Lakes tectonic zone is a major Precambrian crustal feature more than 1,200 km (746 mi.) long extending eastward from Minnesota into Ontario, Canada. It is a zone of distinctive tectonism, affecting both Archean and early Proterozoic rocks along the northern margin of the early Proterozoic Penokean fold belt adjacent to the Archean Superior province. The zone coincides with the boundary between two Archean crustal segments recognized in the region: a greenstone-granite terrane (~2,700 Ma) to the north (Superior province) and an older (in part 3,500 Ma) gneiss terrane to the south. Tectonism along the zone began in the late Archean, during the joining together of the two terranes into a single continental mass, and culminated in the early Proterozoic, when steep or northward-facing overturned folds were formed in the supracrustal rocks, and intense cataclasis and a penetrative cleavage developed in subjacent basement rocks of the greenstone-granite terrane. The Proterozoic deformation took place under low to intermediate pressures. In the early Proterozoic, crustal foundering, which was parallel to the zone and was diachronous, initiated the structural basins in which the early Proterozoic sequences of the Lake Superior and Lake Huron regions were deposited. Later, during the Penokean orogeny (~1,850–1,900 Ma), compression deformed the sequences in both regions. Still later (~1,850–1,100 Ma), intermittent crustal extension provided sites for emplacement of abundant mafic igneous rocks. There is no definite evidence that any of the extensional events progressed to the stage of development of oceanic crust; probably the zone has been wholly intracratonal since its inception in late Archean time. During the Phanerozoic, minor differential movements occurred locally in the Great Lakes tectonic zone, as recorded by the thinning of Cretaceous strata and their subsequent tilting and by historical earthquakes in Minnesota.

Table D-7.3.12 Data Summary
MidContinent-Craton Zone

Citation	Title	Description and Relevance to SSC
Kentucky River Fault System, Kentucky		
Van Arsdale (1986)	Quaternary Displacement on Faults Within the Kentucky River Fault System of East-Central Kentucky	The Kentucky River fault system (KRFS) is the north-bounding fault system of the Rome Trough (a Paleozoic aulacogen). Recurrent Paleozoic movement is documented, but recognition of Mesozoic and lower Tertiary displacement is complicated by the absence of preserved post-Paleozoic stratigraphy. Numerous faults of the KRFS are partially overlain by Pliocene-Pleistocene terrace sediments. Preliminary drilling and electrical-resistivity surveys suggest that a number of the faults have been active since deposition of the terraces. The folding and faulting is interpreted to be tectonic in origin, indicating that the KRFS has been active within the past five million years and probably within the past million years.
Wheeler and Crone (2001)	Known and Suggested Quaternary Faulting in the Midcontinent United States	Notes that the seismic hazard associated with the Lexington and Kentucky River fault systems remains uncertain. A personal communication from R. Van Arsdale to the authors in 2000 indicates that although Van Arsdale favored the deformation as tectonic faulting, solution collapse cannot be ruled out as a cause of Quaternary deformation.
Midcontinent Rift Basin–Midcontinent Rift System (MRS)		
Behrendt et al. (1988)	Crustal Structure of the Midcontinent Rift System: Results from GLIMPCE Deep Seismic Reflection Profiles	Interpretation of Great Lakes International Multidisciplinary Program on Crustal Evolution (GLIMPCE) seismic-reflection profiles indicates that the 1,100 Ma Midcontinent rift system (MRS), or Keweenawan rift, of volcanic rocks and postvolcanic and interbedded sedimentary rocks extends to depths as great as 32 km (20 mi.; about 10.5 s reflection time) along profiles crossing western, central, and eastern Lake Superior and the northern end of Lake Michigan. The area may overlie the greatest thickness of intracratonic rift deposits on earth. Times to Moho reflections vary along strike from about 37–46 km (23–29 mi.) depth in the western portion, 55 km (34 mi.) in the central portion, and 42–49 km (26–29 mi.) depth in the eastern portion of Lake Superior. The prerift crust, however, was thinned 25–30 km (15.5–18.5 mi.) beneath the central rift (compared with its flanks), providing evidence for crustal extension by factors of about 3–4. The MRS differs from Phanerozoic rifts in having total crustal thicknesses equal to or greater than the surrounding (presumably unextended) regions.

Table D-7.3.12 Data Summary
MidContinent-Craton Zone

Citation	Title	Description and Relevance to SSC
Cannon (1994)	Closing of the Midcontinent Rift—A Far-Field Effect of Grenvillian Compression	The Midcontinent rift formed in the Laurentian supercontinent between 1,109 and 1,094 Ma. Soon after rifting, stresses changed from extensional to compressional, and the central graben of the rift was partly inverted by thrusting on original extensional faults. Thrusting culminated at about 1,060 Ma but may have begun as early as 1,080 Ma. On the SW-trending arm of the rift, the crust was shortened about 30 km (18.5 mi.); on the SE-trending arm, strike-slip motion was dominant. The rapid evolution from an extensional to a compressional feature was coincident with renewal of NW-directed thrusting in the Grenville, probably caused by continent-continent collision. Stresses transmitted from the Grenville province utilized the zone of weak lithosphere to close and invert the rift.
Cannon et al. (1989)	The North American Midcontinent Rift Beneath Lake Superior from GLIMPCE Seismic Reflection Profiling	The Midcontinent rift is a 1.1 Ga structure, generally buried beneath Paleozoic rocks but traceable by its strong gravity and magnetic anomalies. Seismic-reflection surveys by GLIMPCE imaged the deep structure of the rift beneath Lake Superior. Major observations are as follows: • Presence of a deep, asymmetrical central graben. • In addition to crustal sagging, normal faulting played a major role in subsidence of the axial region of the rift. • A sequence of volcanic and sedimentary rocks, in places >30 km (18.5 mi.) thick, fills the graben. • Thinner volcanic and sedimentary units lie on broad flanks of the rift outside of the graben. • Near the axis, the prerift crust is thinned to about one-fourth of its original thickness, by a combination of low-angle extensional faulting and ductile stretching or distributed shear. • The sense of asymmetry of the central graben changes along the trend of the rift, documenting the segmented nature of the structure and suggesting the existence of accommodation zones between the segments. • The location of the accommodation zones is inferred from abrupt disruptions in the Bouguer gravity signature. • Uplift of the central graben occurred when the original graben-bounding normal faults were reactivated as high-angle reverse faults with throws of 5 km (3 mi.) or more in places.

Table D-7.3.12 Data Summary
MidContinent-Craton Zone

Citation	Title	Description and Relevance to SSC
Cannon et al. (1991)	Deep Crustal Structure of the Precambrian Basement Beneath Northern Lake Michigan, Midcontinent North America	The Midcontinent rift is expressed by a northward-thickening wedge of strong, continuous reflections as deep as 7 s (921 km) that are interpreted as basalt flows. The very high gravity values in this region cannot be accounted for solely by the thick basalt section, but also require an unusually high density for the lower crust, which may be due to large volumes of rift-related mafic rocks intruded into the lower crust or upper mantle. The unusual thickness of the crust in this region may be caused, in part, by underplating of mafic rocks, as is suggested for comparably thick crust beneath Lake Superior.
Keller (2010)	An Integrated Geophysical Analysis of the Mid-Continent Rift System	Discusses the possible extension of the MRS through Oklahoma to at least the Wichita uplift. The structural grain of the Precambrian basement provides a basis to differentiate between features related to the MRS and older ones. It is noted that a major zone of seismicity in Oklahoma and Kansas follows the Nemaha fault zone/ridge and gravity and magnetic anomalies that are likely related to the MRS. Rose diagrams from processed potential maps delineate basement features that are parallel to the NW and NE-strike direction of lineaments identified from the seismic-reflection data. Basement structure lineaments were found to be parallel in orientation with the trend of lineaments seen within the Mississippian and Arbuckle Group. NW-striking lineaments are interpreted to be related to the late-Paleozoic tectonism that affected both the Precambrian and Paleozoic section in Osage County to the south. The NE lineaments are interpreted to be primarily related to features associated with the MRS/Nemaha fault zone. Based on the gravity maps, the MRS is interpreted to likely extend across Oklahoma, abutting against the Southern Oklahoma aulacogen. This cannot be substantiated at this time given available geochronologic ages. It is suggested that the relatively young MRS structures are the ones most likely to be tectonically reactivated, and that this assertion is supported by trends in historical seismicity.

Table D-7.3.12 Data Summary
MidContinent-Craton Zone

Citation	Title	Description and Relevance to SSC
Nyquist and Wang (1988)	Flexural Modeling of the Midcontinent Rift	A 2-D flexural model of basin formation for the Midcontinent rift at a latitude of 45°25′N is constrained from a seismic-reflection profile. Based on seismic refraction data and comparison with other rifts, this paper hypothesizes that a magmatic “rift pillow” intruded into the lower crust. The basaltic pillow subsequently solidified to produce a large, high-velocity region in the lower crust, centered under the rift axis, as determined from deep seismic refraction. This crystallization and cooling may be responsible for the “sag” phase of rift evolution, as evidenced by laterally widespread occurrence of postvolcanic sediments.
Trehu et al. (1991)	Imaging the Midcontinent Rift Beneath Lake Superior Using Large Aperture Seismic Data	Presents a detailed velocity model across the Midcontinent rift system (MRS) in central Lake Superior derived primarily from onshore-offshore large-aperture seismic and gravity data. Total crustal thickness decreases rapidly from 55 to 60 km (34 to 37 mi.) beneath the axis of the rift to about 40 km (25 mi.) beneath the south shore of the lake, and decreases more gradually to the north. Above the Moho is a high-velocity lower crust interpreted to result from syn-rift basaltic intrusion into and/or underplating beneath the Archean lower crust. Lower crust is thickest beneath the axis of the main rift half graben. A second region of thick lower crust is found ~100 km (62 mi.) north of the axis of the rift beneath a smaller half graben that is interpreted to reflect an earlier stage of rifting. The model resembles recent models of some passive continental margins and is in marked contrast to many models of both active and extinct Phanerozoic continental rift zones. In the absence of major tectonic activity, the Moho is very stable, since the large, abrupt variations in crustal thickness beneath the MRS have been preserved for at least a billion years.

Table D-7.3.12 Data Summary
MidContinent-Craton Zone

Citation	Title	Description and Relevance to SSC
Nemaha Ridge and Humboldt Fault Zone (NRHF)		
Bakun and Hopper (2004a)	Catalog of Significant Historical Earthquakes in the Central United States See below	Associates a 4.9 (4.5–5.2) magnitude earthquake on April 9, 1952, with the Nemaha fault in Oklahoma.
Gay (2003a, 2003b)	The Nemaha Trend—A System of Compressional Thrust-Fold, Strike-Slip Structural Features in Kansas and Oklahoma, Part 1; and Part 2 (Conclusion)	Association with seismicity: • References Koff (1978, unpublished MS thesis, University of Oklahoma), which shows possible association of seismicity with Oklahoma City fault. Crustal extent/bedrock deformation: • The Nemaha ridge/uplift was generated by thrusting in three regional compressional events that were contemporaneous with Appalachian (and probably Rocky Mountain) orogenic events. The main bounding thrust (generally on the east side) is steeply dipping or vertical (frequently mistaken for a normal fault). Based on well data, the fault has reverse displacement and dips steeply west. It appears to decrease in dip with depth in basement (becoming listric). • Considerable left-lateral (6 km) strike-slip movement occurred on the Nemaha system during later phases of thrusting. "Relaxation" normal faulting occurred in response to isostatic adjustments after the compressive phase ceased in Late Permian or post-Permian time. • An apparent misconception regarding the origin of the Nemaha system is that it is somehow related to the 1.1 Ga Proterozoic Midcontinent rift system (MRS). The MRS lies 40–60 km (25–40 mi.) to the west and is not parallel to the Nemaha trend, and it is more than 600 Myr older and was formed under a distinctly different structural regime. These may be relict weakness zones that were later reactivated, but author is not aware of them and has not seen this on magnetic data.
Niemi et al. (2004)	Investigation of Microearthquakes, Macroseismic Data, and Liquefaction Associated with the 1867 Wamego Earthquake in Eastern Kansas	Association with seismicity: • Historical felt earthquakes and instrumentally recorded microseismicity loosely associated with basement structures (Humboldt fault and subparallel Nemaha uplift). Seismicity is somewhat dispersed and does not follow a single, well-defined fault feature. Joint inversion with 3-D seismic velocity

Citation	Title	Description and Relevance to SSC
		variations. Crustal extent/bedrock deformation: • Possible association with 1867 M 5.2 Wamego earthquake basement Nemaha Ridge–Humboldt fault (NRHF) structures. The NRHF lies to the east and is roughly parallel to the Proterozoic MRS, which extends from Kansas NE to Lake Superior. • Nemaha Ridge (NR) is a N-NE-trending anticlinal structure of folded Paleozoic rocks overlying an uplifted Precambrian granitic rock core. Tectonic motion has been accommodated along the steeply dipping Humboldt fault that lies along the eastern boundary of the NR. The Abilene anticline structure overlies basement faults along the western boundary of the NR uplift. NR is complexly broken into a series of horsts and graben by cross faults and folds. The Humboldt fault (HF) is buried along most of its length, but is at the surface in NE Kansas where both right-lateral strike-slip and reverse motion are observed on surface faults offsetting late Paleozoic rocks. • Major uplift of the Nemaha structure occurred during the Pennsylvanian but the structure has been reactivated by post-Permian deformation. Precambrian offset as much as 1,000 m across the HF. Post-Permian throw of 75 m on high-angle faults (down to the east). Quaternary deformation-paleoseismicity: • Quaternary-age sediments overlie the HF. Field investigations confirm that sedimentary deposits with moderate liquefaction susceptibility are present in the vicinity of Wamego and Wabaunsee, Kansas, the preferred source location of the 1867 Wamego earthquake. Soft-sediment deformation features, including flame and dish structures, are present in late Holocene floodplain deposits of the Kansas River and appear to be concentrated in the horseshoe bend region of the Kansas River near Wamego and Wabaunsee, Kansas. • Initial results suggest that liquefaction features (e.g., clastic dikes), which may be attributed to seismically induced liquefaction, are present but may not be pervasive in this region. These data suggest that the 1867 M 5.2 Wamego earthquake may characterize the seismic source in this region.

Table D-7.3.12 Data Summary
MidContinent-Craton Zone

Citation	Title	Description and Relevance to SSC
Serpa et al. (1984)	Structure of the Southern Keweenawan Rift from COCORP Surveys Across the Midcontinent Geophysical Anomaly in Northeastern Kansas	Crustal extent/bedrock deformation observations: • COCORP profiling reveals structural basins and other features of the Precambrian Keweenawan rift buried beneath the Phanerozoic cover. • The main basin, which is asymmetric, is 40 km (25 mi.) wide and has a maximum depth of 3 km (2 mi.) on the east and 8 km (5 mi.) on the west. • Basin fill is characterized by a lower layered sequence of strong, west-dipping reflectors interpreted to be middle Keweenawan interbedded volcanic and clastic rocks exposed along the MGA in the Lake Superior region. Upper fill is correlated to upper Keweenawan sequence. • A shallower, tilted basin lies to the east of the main rift basin. • Mafic intrusions are interpreted to lie beneath the main rift basin. • Normal faults that are associated with the rift dip at moderate angles to the east. • The data for reactivation of preexisting structures is inconclusive.
Wheeler and Crone (2001)	Known and Suggested Quaternary Faulting in the Midcontinent United States	Summarizes the following observations from previous studies, concluding that the potential for large-magnitude earthquakes in the area remains uncertain: • Two damaging earthquakes occurred in the vicinity of the Humboldt fault zone on the Nemaha uplift: a M 5.5 in eastern Kansas in 1867 and a M 5.7 in central Oklahoma in 1952. • Felt historical earthquakes and microearthquakes located by a regional seismograph network tend to concentrate near the fault zone and uplift. • Historical accounts report possible liquefaction during the 1867 Kansas earthquake, but a search for these liquefaction features and for prehistoric liquefaction features was unsuccessful (see Niemi et al., 2004, results above).

Table D-7.3.12 Data Summary
MidContinent-Craton Zone

Citation	Title	Description and Relevance to SSC
Niagara Fault Zone		
Atekwana (1996)	Precambrian Basement Beneath the Central Midcontinent United States as Interpreted from Potential Field Data	Interpreted suture between a northern and southern zone: the northern consisting of early Proterozoic epicratonic rocks and associated Archean basement gneiss, and the southern consisting of volcanic and granitoid rocks (the Wisconsinan magmatic terrane).
Cannon et al. (1991)	Deep Crustal Structure of the Precambrian Basement Beneath Northern Lake Michigan, Midcontinent North America	Deep seismic-reflection profile in northern Lake Michigan provides a cross section of the crust across the 1,850 Ma Penokean orogen, in which an early Proterozoic island arc complex was deformed between two converging Archean continental masses. The Niagara fault zone is interpreted as a sharp inflection in the gravity profile; no strong reflectors can be ascribed to the fault surface, which is interpreted to dip steeply (80° to south), similar to an exposed section to the west.
Plum River Fault, Illinois		
Wheeler and Crone (2001)	Known and Suggested Quaternary Faulting in the Midcontinent United States	Summarizes previous studies that suggested there might be Quaternary deformation along the Plum River fault, an E-W-trending fault that offsets Paleozoic rocks in Iowa and Illinois. Late Quaternary loess-covered terraces along an ancient south-flowing channel of the Mississippi River have northward dips where the terraces cross the Plum River fault, but they could also be explained by terrace erosion and subsequent burial beneath a blanket of loess. No paleoseismic work has been done to evaluate the hypothesis of Quaternary tectonic faulting.
Potter County Fault, Texas		
Wheeler and Crone (2001)	Known and Suggested Quaternary Faulting in the Midcontinent United States	An apparent offset of a lithologic escarpment by the Potter Creek fault in the Texas panhandle that was considered possible evidence of Quaternary faulting was investigated through interpretation of aerial photographs and aerial and field reconnaissance studies. This paper summarizes the conclusions from studies by other researchers that showed no evidence of Quaternary faulting along the fault trace. Field studies showed that at two localities, the base of Miocene rocks is unfaulted at both sides of the fault.

Table D-7.3.12 Data Summary
MidContinent-Craton Zone

Citation	Title	Description and Relevance to SSC
Rampart Range Fault, Colorado		
Widmann (1997b)	Complete Report for Rampart Range Fault (Class A) No. 2328	This fault trends N-S along the eastern margin of the Front Range, north of Colorado Springs, for about 46 km (29 mi.). The fault is marked by topographic breaks and vegetation lineaments. It is a range-front fault that had reverse movement during the Laramide, but normal movement during the late Cenozoic. Approximately 8 m (26 ft.) of down-to-the-west Quaternary displacement has been reported. Trenching investigations indicated that the most recent displacement occurred between 600 ka and 30–50 ka.
Ste. Genevieve Fault Zone (SGFZ), Missouri and Illinois		
Harrison and Schultz (2002)	Tectonic Framework of the Southwestern Margin of the Illinois Basin and Its Influence on Neotectonism and Seismicity	Detailed studies of this fault zone document contractional, extensional, and strike-slip movement along high-angle faults, as well as multiple periods of movement. The zone dies out near both the St. Charles and Commerce lineaments (see the Geophysical Anomalies section of this table), suggesting a genetic link and demonstrating the influence of these structural features on tectonism in the region. Deformation along this structure is correlative to the late Mississippian to middle Pennsylvanian tectonic episode identified elsewhere in the Midcontinent. The paper provides evidence for a period of extension probably of late Pennsylvanian to Permian age. Detailed and reconnaissance mapping along the Ste. Genevieve fault zone for more than 75 years has revealed no evidence of Tertiary or Quaternary faulting.
Heigold and Kolata (1993)	Proterozoic Crustal Boundary in the Southern Part of the Illinois Basin	The fault may have originated as a crustal plate boundary or suture zone during the Proterozoic.

Table D-7.3.12 Data Summary
MidContinent-Craton Zone

Citation	Title	Description and Relevance to SSC
Nelson (1995) Nelson et al. (1997)	Structural Features in Illinois Tertiary and Quaternary Tectonic Faulting in Southernmost Illinois	The SGFZ is mapped for approximately 193 km (120 mi.) along strike from SE Missouri into SW Illinois. It consists of numerous en echelon strands and braided segments having variable deformation styles and a complex history of reactivation. Displacement across the zone ranges from less than 198 m (650 ft.) to as much as 1,189 m (3,900 ft.). Detailed studies of this fault zone document contractional, extensional, and strike-slip movement along high-angle faults, as well as multiple periods of movement. In Illinois, compressional deformation is documented along the Ste. Genevieve fault in early Pennsylvanian rocks (Nelson, 1995). The later report, Nelson et al. (1997), however, indicates that some faults along the SE part of the SGFZ in Illinois displace Cretaceous and Tertiary sediments, but Quaternary deposits are not faulted.
Tuttle, Chester, et al. (1999)	Paleoseismology Study Northwest of the New Madrid Seismic Zone	Identifies soft-sediment deformation that could be related to low levels of ground shaking at one location along a strand of the fault. Diffuse seismicity occurs in the block between the SGFZ and Simms Mountain fault system. However, no evidence has been documented of any tectonic deformation of Quaternary deposits, nor has convincing evidence for paleoliquefaction been observed in this area.
Simms Mountain Fault System, Missouri		
Harrison and Schultz (2002)	Tectonic Framework of the Southwestern Margin of the Illinois Basin and Its Influence on Neotectonism and Seismicity	The Simms Mountain fault system in SE Missouri consists of numerous braided and en echelon fault strands that are continuous southward into the Cape Girardeau fault system. Together these fault systems extend more than 106 km (66 mi.), and in places reach as wide as 79 km (24 mi.). Left-lateral strike-slip movement occurred on the fault system, primarily before formation of Mississippi Valley–type ore deposits of Permian age, although some are later or of unknown age (Harrison and Schultz, 2002).

Table D-7.3.12 Data Summary
MidContinent-Craton Zone

Citation	Title	Description and Relevance to SSC
Ute Pass Fault Zone		
Widmann (1997a)	Complete Report for Ute Pass Fault Zone (Class A) No. 2327	This fault zone consists of five generally NW-trending faults that define the west and SW margins of the Rampart Range west of Colorado Springs. There is evidence of late Cenozoic movement along most of the fault. Quaternary deposits do not appear to be offset across the north end of the fault zone; on the south end of the fault zone, scarps developed on Quaternary rockfall deposits may indicate Quaternary fault activity. No evidence of offset in late Pleistocene to Holocene deposits has been found. The length of the fault zone is about 71 km (44 mi.).
Vaughn Fault, New Mexico		
Wheeler and Crone (2001)	Known and Suggested Quaternary Faulting in the Midcontinent United States	Summarizes information regarding an escarpment along the north-striking Vaughn fault that impounds Quaternary sediments on its west side and blocks most local streams. Based on geologic mapping, an inferred 150–300 m of west-side-down subsurface offset is present along the fault. Although the evidence is suggestive of Quaternary faulting, such faulting has not been demonstrated, and the fault might be a near-surface effect of subsurface solution.
Valmont Fault, Colorado		
Wheeler and Crone (2001)	Known and Suggested Quaternary Faulting in the Midcontinent United States	Summarizes reported information on the Valmont fault that was inferred from a single road cut that exposes a 13 m wide zone of disrupted and shingled stones in Quaternary alluvium. The alluvium is offset 1.5 m across the zone. The fault lacks geomorphic expression. The faulting has been explained by both tectonic faulting and intrusion of a nearby dike.
Washita Valley Fault, Oklahoma		
Van Arsdale et al. (1989)	Post-Pennsylvanian Reactivation Along the Washita Valley Fault, Southern Oklahoma	This study searched for geomorphic, structural, and other geologic evidence of young faulting at sites along the Washita Valley fault. Two trenches at site A exposed unfaulted Holocene alluvium dated at 1,910 ± 80 yr BP. One trench and a natural exposure at site B contained unfaulted 12–15 ka terrace alluvium. Seven trenches and two natural exposures at site E revealed faulted Cretaceous strata overlain by unfaulted Wisconsinan terrace alluvium.

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Citation	Title	Description and Relevance to SSC
Wheeler and Crone (2001)	Known and Suggested Quaternary Faulting in the Midcontinent United States	This paper summarizes work by Van Arsdale et al. (1989) that found no evidence of Quaternary faulting along the Washita Valley fault.
Nontectonic Faults		
Wheeler and Crone (2001)	Known and Suggested Quaternary Faulting in the Midcontinent United States	Summarizes field studies that have shown that six previously inferred Quaternary faults have nontectonic origins: Barrera and Carlsbad faults, New Mexico; Fowler fault, Colorado; Harlan County fault, Nebraska; Ord escarpment, Nebraska; and two small faults west of Pierre, South Dakota.
Paleoliquefaction Studies		
Tuttle, Chester, et al. (1999)	Paleoseismology Study Northwest of the New Madrid Seismic Zone	Based on the spatial distribution of prehistoric liquefaction features, the paper indicates that the Waterloo-Dupo anticline, Valmeyer anticline, and St. Louis fault are possible sources for paleoearthquake features observed in eastern Missouri, but also emphasizes that other scenarios relying on sources farther east are equally possible (i.e., on the DuQuoin monocline–Centralia fault). (For further discussion of these structures, see the Illinois Basin-Wabash Valley Data Summary Table [Appendix Table D-6.1.9)
Tuttle (2005b)	Paleoseismological Study in the St. Louis Region: Collaborative Research	This paper summarizes and updates observations reported by Tuttle, Chester, et al. (1999). At least two generations of Holocene earthquake-induced liquefaction features, including sand and silt dikes and sills, and only two sand blows, are identified in the St. Louis region. Some features probably formed during the 1811-1812 or earlier New Madrid earthquakes, and others formed during a middle Holocene earthquake in 4520 BC ± 160 yr. Late Holocene sand dikes, up to 26 cm in width, occur along the Kaskaskia River and its tributaries, Crooked, Shoal, and Silver creeks, as well as along Cahokia and Piasa creeks and the Cache, Castor, Marys, and Meramec rivers. The 4250 BC earthquake may or may not have been responsible for all of the middle Holocene features. The relatively large size of features identified near Germantown, Illinois, suggests that the earthquake source may be located east of St. Louis. Alternative sizes and locations are suggested. The Meramec River features could have formed as a result of a moderate-to-large earthquake centered in the St. Louis area or a very large earthquake centered 80–100 km (50–62 mi.) east of St. Louis.

Table D-7.3.12 Data Summary
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Citation	Title	Description and Relevance to SSC
Anna Seismic Zone		
Atekwana (1996)	Precambrian Basement Beneath the Central Midcontinent United States as Interpreted from Potential Field Data	Portions of the NW-trending anomalies of the East Continent gravity high have been called the Fort Wayne rift (FWR) and are interpreted to be older than N-S-trending anomalies in central Ohio to Kentucky and the Grenville Front, further suggesting that the Grenville Front truncates the FWR. The author attributes the formation of the FWR to processes occurring in the formation of the Granite-Rhyolite province or later reactivation of preexisting basement structures. A whole-rock rubidium-strontium date of 1.325 Ga is older than dates reported for the Midcontinent rift system, suggesting that Fort Wayne rifting formed during an earlier rifting event.
Baranoski et al. (2009)	Unconformity-Bounded Seismic Reflection Sequences Define Grenville-Age Rift System and Foreland Basins Beneath the Phanerozoic in Ohio	Interprets four sequences of layered reflectors (A, B, C, and D) below the Phanerozoic deposits and above basement of the Granite-Rhyolite and Grenville provinces from reprocessed data of COCORP Line OH-1. Episodic deposition of these sequences records rifting and a westward shift of the major axis of depositional thickening that began as a series of half graben and culminated in a highly deformed foreland basin at the end of the Grenville orogeny. The unconformities at the top of sequences A, B, and C represent the end of an episode of crustal extension in the west and rejuvenation of crustal shortening in the east, recording a westward progression of thrusting and crustal loading during the Grenville orogeny. Sequences A and B are more localized and may contain volcaniclastic and alluvial sediments deposited above a NW-trending gravity low in a rapidly subsiding fault bounding the FWR. Each sequence becomes more widespread due to continued subsidence. The more widespread sequences C and D are correlated with the Middle Run Formation of the East Continent rift basin. The deposition of discontinuous, intertonguing clastic sediments of sequence D marks the end of subsiding rift basins in response to late Grenville collision, culiminating in a widespread regional foreland basin marking the end of the Grenville orogeny. Without datable drill core samples, the authors are unable to establish, on the basis of sequence stratigraphy, structural relationships, and geopotential field data, whether the FWR is coeval with the SE arm of the Midcontinent rift in Michigan.

Table D-7.3.12 Data Summary
MidContinent-Craton Zone

Citation	Title	Description and Relevance to SSC
Crone and Wheeler (2000)	Data for Quaternary Faults, Liquefaction Features, and Possible Tectonic Features in the Central and Eastern United States, East of the Rocky Mountain Front	Assigns the Anna seismic zone to Class C. (Geologic evidence is insufficient to demonstrate Quaternary fault displacement for features assigned to Class C.) Earthquakes associated with the seismic zone span approximately 80 km (50 mi.), with most of the seismicity concentrated within an area 30–35 km (18.6–21.7 mi.) across. Most epicenters cluster along the NW-striking Anna-Champaign fault, which has been mapped in the basement beneath Paleozoic platform strata. The largest earthquakes recorded in the zone were two that occurred in March 1937 and had intensities of VII and VIII and **M** 4.9 and 5.1. Focal mechanisms indicate strike-slip faulting. Selected stream banks and sand and gravel pits in the Anna area were examined by Obermeier (1995) for evidence of prehistoric liquefaction features; none were found. Based on the spacing of potentially liquefiable materials, he concluded that an earthquake larger than M 7 has not occurred in the past several thousand years, although smaller ones cannot be excluded.
Drahovzal et al. (1992)	The East Continent Rift Basin: A New Discovery	Identified the East Continent rift basin (ECRB) based on the following evidence: • presence of Middle Run Formation (a pre-Mt. Simon lithic arenite interbedded with basalt representative of continental flood basalts); • association with the East Continent gravity high, a NW-trending positive gravity anomaly from NE Indiana, SW Michigan, and central-western Ohio, crossing the Grenville Front tectonic zone into Kentucky and coincident with the Fort Wayne rift (FWR) in Indiana and Ohio; and • magnetic anomalies coincident with gravity anomalies, suggesting deep-rooted bodies of mafic composition, possibly emplaced during rifting. The ECRB and FWR have uncertain Proterozoic ages based on a few age dates from drill core. Less distinct magnetic anomalies east of the Grenville Front and east-dipping thrust sheets overlying Middle Run Formation in Kentucky indicate that the ECRB cannot be as young as Cambrian. The overthrust relationship between the Grenville and ECRB is not clear on data from COCORP line OH-1. Rifting associated with the ECRB may be contemporaneous with Keweenawan rifting in Michigan. The thickness of the basin-fill sequence exceeds 20,000 feet at several locations along the Grenville Front tectonic zone in central Kentucky and central Ohio and

Table D-7.3.12 Data Summary
MidContinent-Craton Zone

Citation	Title	Description and Relevance to SSC
		northern Ohio. The basin-fill sequence thins on an uplifted block in SE Indiana and along the trend of the FWR in the vicinity of COCORP line OH-1. The trend of the FWR defines a NW-trending basement high that separates deeper portions of the basin.
Hansen (1987)	July 1986 Auglaize County Earthquake	The July 12, 1986, M_L 4.5 earthquake in western Auglaize County, near St. Marys township, occurred on the Anna-Champaign fault, a NW-SE-trending structure that extends into Shelby, Auglaize, and Mercer counties. The ancient Teays River followed the trace of the Anna-Champaign fault before Pleistocene glaciations. The deep alluvial valley was thought to amplify ground motions during earthquakes, which was not observed during the July 12, 1986, earthquake. This observation suggests that relocating the March 2 and March 9, 1937, earthquakes to the vicinity of the July 12, 1986, earthquake and adjusting their magnitudes downward is not warranted. Review of a seismic record made of these 1937 earthquakes by a Jesuit priest suggests they occurred at or SE of Anna, Ohio. Such a location would be more consistent with the felt reports of the 1937 earthquakes and the isoseismal map of the 1986 earthquake. The July 12, 1986, earthquake had no associated foreshocks or aftershocks and produced MMI VI shaking confined to a small area surrounding the epicenter.
Hansen (1993)	Earthquakes and Seismic Risk in Ohio	The Anna seismic zone, also called the Western Ohio seismic zone, coincides with NW-SE-trending basement faults associated with the FWR in Shelby, Auglaize, and nearby counties. This zone has produced at least 40 felt earthquakes since 1875, including earthquakes in 1875, 1930, 1931, 1937, 1977, and 1986 that caused minor to moderate damage. The July 12, 1986, earthquake near the town of St. Marys in Auglaize County was the largest earthquake to occur in the zone since 1937. The author concludes that the historical record indicates a maximum magnitude of 5, but suggests that this zone was capable of producing a magnitude 6.0–7.0 earthquake.
Hauser (1993)	Grenville Foreland Thrust Belt Hidden Beneath the Eastern U.S. Midcontinent	Interprets the Middle Run Formation as forming in a Grenville foreland basin or, alternatively, as a constituent of the Granite-Rhyolite province. Does not recognize a rift origin.

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Citation	Title	Description and Relevance to SSC
McPhee (1983)	Regional Gravity Analysis of the Anna, Ohio, Seismogenic Region	Generated regional and local gravity and magnetic models to evaluate the relationship of seismicity and basement geology in the Anna seismic zone. The models require a large source of positive density contrast extending upward from the Moho into the lower crust beneath the FWR, interpreted as a deep crustal mafic source. Seismicity appears to be concentrated at the boundary between the rift-type mafic volcanic rocks of the FWR and the granitic body to the NE. This pattern of seismicity can be attributed to either reactivation of graben-type faults, activation of a zone of weakness at the contrasting lithologies, or extension of the Bowling Green fault in the basement.
Obermeier (1995)	Paleoseismic Liquefaction Studies—Central U.S. and Pacific Northwestern U.S.	Investigated stream banks in the vicinity of Anna, Ohio, and portions of the Auglaize, Great Miami, Stillwater, and St. Marys rivers and found no evidence of paleoliquefaction features indicative of a M 7 earthquake in the past several thousand years.
Ruff et al. (1994)	Geophysical Investigations of the Western Ohio–Indiana Region: Final Report 1986–September 1992	Describes earthquake activity in the western Ohio–Indiana region that was monitored with a regional seismograph network between 1977 and 1992. A total of 78 local and regional earthquakes were recorded by the network during this time period. The largest earthquake recorded was the July 12, 1986, St. Marys earthquake (m_b 4.5) within the Anna seismic zone. The focal mechanism indicated a strike-slip earthquake with an E-NE-striking compressional axis. The history of felt earthquakes in the Anna zone dates back to the late 1700s and includes several earthquakes of about magnitude 5. Attributes seismicity to the Anna-Champaign, Logan, and Auglaize faults.
Schwartz and Christensen (1988)	The 12 July 1986 St. Marys, Ohio Earthquake and Recent Seismicity in the Anna, Ohio Seismogenic Zone	Determined hypocenter of 3 mi. (5 km) for the magnitude (m_b) 4.5 earthquake and a focal mechanism (strike = 25°, dip = 90°, rake = 175°) representing mostly strike-slip, with a small oblique component approximately parallel to Anna-Champaign fault and a nearly horizontal P axis oriented E-NE.

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Citation	Title	Description and Relevance to SSC
Stark (1997)	The East Continent Rift Complex: Evidence and Conclusions	Informed with the work of Drahovzal et al. (1992), Stark extends the concept of the East Continent rift basin (ECRB) to a major multiphase rift complex in the eastern Midcontinent: the East Continent rift complex. This interpretation involves four phases: 1. Keweenawan extension (1.05–1.3 Ga) rifted the Granite-Rhyolite province along the ECRB/FWR, the English Graben/Flatrock subbasin, and the Southern Indiana graben into an internally complex half graben along rift margins containing considerable thickness of rift fill sediments and volcanic rocks. 2. Grenvillian contraction (880–990 Ma) resulted in overthrusting the eastern margin of the East Continent rift complex, emplacement of an allochthon of metamorphic strata above and adjacent to the rift strata, remobilization of NW-SE-trending transtensive wrench systems as transpressive detachment zones, and formation of a foreland basin with concomitant fold systems. 3. Pre-Eocambrian uplift and erosion (650–550 Ma) resulted in substantial syn- and/or postdepositional deformation before the Sauk unconformity, which may have removed most or all of the Grenvillian foreland basin. 4. Eocambrian extension (650–560 Ma) associated with the opening of the Iapetus Ocean initiated rifting of Reelfoot rift, Rough Creek graben, and Rome trough; and reactivation of Rough Creek graben/Shawneetown fault system, Kentucky River fault system, Lexington fault system, Bowling Green fault zone, and Warfield fault system. Middle Cambrian thermal subsidence downwarped these rifts, leading to widespread deposition of the Sauk Sequence carbonates. Deep wells along the FWR at the Anna seismic zone encountered mafic basalt fill sequence, whereas wells to the north and south encountered Middle Run Formation. This observation implies that structures associated with the Anna seismic zone were uplifted before the late Proterozoic erosion and therefore must have remobilized through geologic time, further suggesting that the Anna seismic zone is associated with an accommodation structure within the ECRB/FWR.

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Citation	Title	Description and Relevance to SSC
Northeast Ohio Seismic Zone		
Crone and Wheeler (2000)	Data for Quaternary Faults, Liquefaction Features, and Possible Tectonic Features in the Central and Eastern United States, East of the Rocky Mountain Front	Assigns Northeast Ohio seismic zone to Class C. (Geologic evidence is insufficient to demonstrate Quaternary fault displacement for features assigned to Class C.) Earthquakes associated with this zone form a diffuse cluster aligned NE-SW and about 80 km (50 mi.) long and 40 km (25 mi.) wide. The 11 largest epicenters lie along and NW of Akron magnetic lineament. Obermeier (1995) examined selected stream banks in this area for evidence of prehistoric liquefaction, but found none. Exposures that could provide definitive evidence of prehistoric earthquakes are scarce in region; still, the zone lacks paleoseismological evidence of Quaternary faulting.
Dineva et al. (2004)	Seismicity of the Southern Great Lakes: Revised Earthquake Hypocenters and Possible Tectonic Controls	Describes results of analyses to establish better constraints on epicenter locations and focal depth estimations for 106 earthquakes that occurred from 1990 to 2001 in southern Great Lakes region. Earthquakes within Northeast Ohio seismic zone, also referred to as a cluster of earthquakes south of Lake Erie on the Ohio-Pennsylvania border, were relocated. Earthquakes in this zone form a cluster that trends NE-SW and follows Lake Erie shoreline for about 60 km (37 mi.). Hypocenter locations are confined to the crust above 30 km (18.6 mi.); most occur above 20 km (12.4 mi.). Seismicity appears to be localized where preexisting tectonic structures (e.g., the Akron magnetic boundary) are favorably oriented with respect to present-day stress field, and where water is present at surface.
Hansen et al. (2001)	Seismic Spotlight Shines on Ashtabula	Describes the series of earthquakes in 1987 and 2001 that occurred in the vicinity of Ashtabula in NE Ohio. Before the 1987 earthquake, earthquakes had not been felt in this area since it was settled in the early 1800s. Portable seismographs deployed in the region and the Ohio Seismic Network implemented in 1999 provide detailed information on these earthquakes. An isoseismal map for areas of approximately equal MM intensity for the January 25, 2001, main shock at Ashtabula shows a N-S elongation for this shoreline earthquake; the cause of this phenomenon is reported as unknown.

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Citation	Title	Description and Relevance to SSC
Hartline (1995)	Deep Structural Analysis Related to the Akron Magnetic Boundary Using Geophysical Well Logs and Potential Field Data, East-Central Ohio	Reviews geophysical well logs, gravity data, magnetic data, and COCORP seismic data in Knox, Coshocton, Muskingum, and Licking counties, Ohio, and presents structure-contour and isopach maps on 16 key horizons in the Paleozoic cover to evaluate basement-controlled faulting associated with the Akron magnetic boundary. Finds no evidence of basement-controlled faulting along the Akron magnetic boundary; however, the study area is in central Ohio, not along the Northeast Ohio seismic zone.
Hoehn (1991)	An Integrated Geophysical Study of the Grenville Province in the Greater Lake Erie Region	Reprocesses Vibroseis seismic-reflection data from line LE-01 in Lake Erie and compares the results to potential field data. The reprocessed data can resolve reflections to a depth of 18 km (11.2 mi.). Decrease in the gravity profile across Akron magnetic boundary is attributed to an east-dipping low-density body in the upper crust. Interprets the Eastern Midcontinent magnetic belt as relic structures associated with a reversal of subduction polarity within the Proterozoic bound to the east by NW-directed thrusts of Akron magnetic boundary. Sedimentary units east of the Akron magnetic boundary exhibit extension within the Elzevir terrane. Multiple reflections within the first two seconds of the data obscure Akron magnetic boundary in the upper crust.
Lidiak and Hinze (1993)	Grenville Province in the Subsurface of Eastern United States	Interprets Akron magnetic boundary as a major Grenville suture separating contrasting magnetic anomalies and seismic reflectors. To the east of the Akron magnetic boundary, basement is characterized by lower-amplitude anomalies and west-dipping reflectors that exhibit ductile deformation. Crust to the west exhibits high-amplitude magnetic anomalies and east-dipping reflectors indicative of the Grenville front and related structures. The authors present a mapped location trending NE through eastern Lake Erie; they postulate that Akron magnetic boundary separates Elzevir terrane in the east from their proposed Eastern Midcontinent magnetic belt to the west.

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Citation	Title	Description and Relevance to SSC
Nicholson et al. (1988)	The Northeastern Ohio Earthquake of 31 January 1986: Was It Induced?	Describes the January 31, 1986, earthquake that occurred about 40 km (25 mi.) east of Cleveland, Ohio, with m_b 5.0 and intensity VI–VII at distances of 15 km (9.3 mi.). Focal depths for this earthquake and the aftershocks ranged from 2 to 6 km (1.2 to 3.7 mi.). The aftershocks occurred in a tight cluster about 1 km (0.6 mi.) wide and oriented to the N-NE, and focal mechanisms of the aftershocks represent predominantly oblique right-slip motion on nearly vertical planes oriented N15°–45°E, with a nearly horizontal P (maximum compressive stress) axis, consistent with the modern stress regime. Factors that suggest a natural origin for the earthquake include a history of small and moderate earthquakes in the region prior to the initiation of injection, and the lack of large numbers of small earthquakes typical of many induced sequences. The 1986 cluster is coincident with a N40°E-trending gravity and magnetic anomaly (Akron magnetic boundary).
Nicholson and Wesson (1990)	Earthquake Hazard Associated with Deep Well Injection—A Report to the U.S. Environmental Protection Agency	Includes descriptions of earthquakes that occurred about 40 km (25 mi.) apart in NE Ohio in January 1986 and July 1987 and reviews evidence for possible triggering of these earthquakes. Reviews the state of knowledge about earthquakes related to injection of fluid into deep wells. Describes the probable physical mechanism for the triggering and the criteria for predicting whether earthquakes will be triggered that depend on the local state of stress in the earth's crust, the injection pressure, and the physical and hydrologic properties of rocks into which the fluid is being injected. Concludes that the January 1986 earthquake had a natural origin, although triggering by well activities of at least a few small aftershock earthquakes could not be precluded, and that the July 1987 earthquakes were most likely induced.
Obermeier (1996a)	Summary of 1995 Paleoliquefaction Field Search in the Vicinity of Perry, Ohio	Letter report summarizing a paleoliquefaction investigation performed in the vicinity of the Perry Nuclear Power Plant along the Grand River, Trumbull Creek, and Cuyahoga River and near a tributary to Phelps Creek of NE Ohio. Based on observations along these streams, Obermeier made the following conclusions: • The lack of suitable exposures within 20 km (12.5 mi.) of the nuclear power plant at Perry, Ohio, precludes definitive statements as to whether there has been strong seismic shaking for most of Holocene time. • The lack of exposures with liquefiable sediment more than a few thousand years old and within 20–25 km (12.5–25 mi.) of the plant precludes any

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Citation	Title	Description and Relevance to SSC
		statement concerning whether there could have been strong shaking at the plant locale from even moderate-sized earthquakes (M ~ 6) occurring more than a few thousand years ago. • The lack of liquefaction features in latest Pleistocene sediment (moderate to high liquefaction susceptibility through time) in the locality of a large sand and gravel pit ("Pit-CL") does not provide sufficient data to make a statement on seismic shaking at a distance of 32 km (20 mi.) from the Perry Nuclear Power Plant. Obermeier noted in the letter report that perennial streams flowing subparallel and through a beach ridge/sand dune complex within 2–6 km (1.2–3.7 mi.) inland from the shore (identified from examination of the Soil Survey Report of Lake County) might offer the possibility of a field setting where liquefaction features could have developed for much of Holocene time.
Seeber and Armbruster (1993)	Natural and Induced Seismicity in the Lake Erie-Lake Ontario Region: Reactivation of Ancient Faults with Little Neotectonic Displacement	Defines the Northeast Ohio seismic zone on the basis of a 50+ km (31+ mi.) long belt of seismicity striking NE near the shoreline of Lake Erie. Proposes that the belt of seismicity may be associated with a major fault and related secondary faults. The Northeast Ohio seismic zone correlates spatially with the Akron magnetic lineament and a portion of the Akron magnetic boundary. The authors speculate that the Akron magnetic boundary may be associated with the Niagara-Pickering magnetic lineament/Central Metasedimentary Belt boundary zone as a continental scale Grenville-age structure. Evaluates the hypothesis that the July 13, 1987, m_{bLg} 3.8 Ashtabula earthquake and sequence of 36 aftershocks were triggered by fluid injection into a deep waste disposal well penetrating the basal Mt. Simon sandstone. The well had been in operation since July 1986. Well-located earthquakes of the Ashtabula sequence cluster in a narrow, east-trending vertical zone about 1.5 km (1 mi.) long and between 1.7 and 3.5 km (1.1 and 2.2 mi.) deep, located as close as 0.7 km (0.4 mi.) to the injection well. The depth to basement in this area is approximately 1.8 km (1.1 mi.), indicating that this cluster of seismicity is concentrated below the Mt. Simon–Grenville unconformity. The authors interpret this narrow zone as an active fault, referred to as the Ashtabula fault. Subsequent seismicity from 1987 to 1992 suggests a westward migration by 5–10 km (3.1–6.2 mi.), possibly along the proposed

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Citation	Title	Description and Relevance to SSC
		fault. However, because the temporary seismic network used to locate the aftershocks of the 1987 main shock was no longer in operation, the locations of the 1992 earthquakes are not as well constrained as the aftershocks of the main 1987 earthquake. Based on the assumption that the 1992 seismicity and the 1987 earthquakes defined a single rupture plane, the authors estimate that the postulated Ashtabula fault could produce a magnitude 5–6 earthquake.
Seeber et al. (2004)	A Fluid-Injection-Triggered Earthquake Sequence in Ashtabula, Ohio: Implications for Seismogenesis in Stable Continental Regions	Describes an earthquake sequence near Ashtabula in NE Ohio that is believed to have been triggered by fluid injection. The sequence began in 1987 with a m_{blg} 3.8 main shock; the largest earthquake recorded was a m_{blg} 4.3 earthquake in 2001. Well-located aftershocks of the June 3, 2001, m_{bLg} 3.0 and the July 17, 2003, m_{bLg} 2.5 earthquakes define a 7 km (4.3 mi.) long plane striking 96° and dipping 65° south. The authors interpret this plane as the source fault for the 2001 seismicity, which resembles the postulated E-W-striking fault with left-lateral slip defined by the 1987 seismicity (Seeber and Armbruster, 1993). These subparallel faults are 4.5 and 0.7 km (2.9 and 0.4 mi.) south of the injection well, respectively. Seeber et al. revise the previous interpretation of Seeber and Armbruster (1993) regarding the tectonic implications of the 1987 earthquake sequence and subsequent earthquakes in 1992 to conclude that the linear patch of 1987 earthquakes is a portion of a basement fault activated by high pore pressure rather than evidence of a single rupture. This conclusion was based in part on the observation that these earthquakes are scattered over the patch as opposed to clustering at the edges. Seeber et al. attribute the quiescence from 1995 to 2000 to a lack of favorably oriented structures between these two fault planes. They speculate that seismicity initiates when and where a significant pore-pressure rise intersects preexisting faults close to failure, and is turned off when pressure starts dropping back. They conclude that these faults are preexisting faults located in the uppermost portion of the Grenville basement reactivated by a high pore-pressure anomaly spreading from the injection site.

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Citation	Title	Description and Relevance to SSC
Wesson and Nicholson (eds.) (1986)	Studies of the January 31, 1986, Northeastern Ohio Earthquake—A Report to the U.S. Nuclear Regulatory Commission	This earthquake occurred about 17 km (10.5 mi.) south of the Perry Nuclear Power Plant and generated accelerations of 0.18 g of short duration at the plant. Analysis of the main shock and aftershocks indicated no obvious structure or fault with which the earthquakes could be associated. The earthquakes were located within 15 km (9.3 mi.) of three deep waste-disposal injection wells and could have been due to fluid injection that reactivated favorably oriented, preexisting fractures. Available information indicated that although triggering was a possibility, the probability that injection played a significant role should be regarded as low. It was reported that there was nothing to suggest the occurrence of an earthquake larger than expected for the region, or the activation of a major structure close to the wells or near the power plant.