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September 24, 2008

U.S. Nuclear Regulatory Commission
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ALNRC 00007

NRC PROJECT #750
AMERENUE – CALLAWAY PLANT UNIT 2
SUBMITTAL OF SUPPLEMENTAL INFORMATION FOR THE CALLAWAY PLANT UNIT 2 COMBINED LICENSE APPLICATION

Reference: Letter from T.E. Herrmann (AmerenUE) to U.S. Nuclear Regulatory Commission, "Application for Combined License for Callaway Unit 2, NRC Project Number 750," ALNRC 00004 dated July 24, 2008

During the NRC staff acceptance review of the Combined Operating License (COL) Application for Callaway Plant Unit 2, it was determined additional information was necessary in the following areas.

- Expanded Geologic and Tectonic Descriptions (FSAR 2.5.1)
- Seismic Catalog Updates (FSAR 2.5.2)
- Surface Faulting Update (FSAR 2.5.3)
- Documentation of Geologic Field Studies Performed (new FSAR 2.5 App. B)
- Updated Selected FSAR 2.5 Figures

The purpose of this letter is to provide the supplemental information requested by the staff related to the COL Application for Callaway Plant Unit 2 submitted in the reference listed above.

This supplemental information to FSAR sections 2.5.1, 2.5.2 and 2.5.3 is provided in Enclosures 1, 2, 3, 4 and 5 of this letter. This information will be incorporated into the next revision of the Callaway Plant Unit 2 COL Application.

D079

NRO

If you have any questions, or need additional information, please contact Scott Bond at (573) 676-8519 or David Shafer at (573) 676-4722.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on September 24, 2008

T. E. Herrmann
Vice President, Engineering

TEH/RCW/slk

Enclosures:

1) Supplement to FSAR 2.5 and 2.5.1; Expanded Geologic and Tectonic Descriptions

2) Supplement to FSAR 2.5.2; Seismic Catalog Updates

3) Supplement to FSAR 2.5.3; Surface Faulting Update

4) Supplement to FSAR 2.5; Documentation of Geologic Field Studies Performed (new FSAR 2.5 Appendix B)

5) Supplement to FSAR 2.5 Figures; Updated Selected FSAR 2.5 Figures

cc: (w/ enclosure)

Mr. Elmo E. Collins, Jr.
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Supplement to FSAR 2.5 and 2.5.1; Expanded Geologic and Tectonic Descriptions

FSAR 2.5.1 Page Affected	Description
2-853	Inserted sentence pointing to new FSAR 2.5 Appendix B.
2-854	Insert "A" provides a conclusion to paragraph 2.5.1.
2-874 through 2-878	Insert "B" providing replacement Sections 2.5.1.1.4.1 through 2.5.1.1.4.1.5 and revised 2.5.1.1.4.1.7.
2-880	Insert "C" replaces Section 2.5.1.1.4.2. and 2.5.1.1.4.1.8.
2-898	Inserted sentence pointing to new FSAR 2.5 Appendix B.
2-902	Insert "D" replaces FSAR 2.5.1.2.6.4 and Insert "E" provides new references.

2.5 GEOLOGY, SEISMOLOGY, AND GEOTECHNICAL ENGINEERING

This section presents information on the geological, seismological, and geotechnical engineering properties of the {Callaway Plant Unit 2} site. Section 2.5.1 describes basic geological and seismologic data, {focusing on those data developed since the publication of the Final Safety Analysis Report (FSAR) for licensing Callaway Plant Unit 1}. Section 2.5.2 describes the vibratory ground motion at the site, including an updated seismicity catalog, description of seismic sources, and development of the Safe Shutdown Earthquake. Section 2.5.3 describes the potential for surface faulting in the site area, and Section 2.5.4 and Section 2.5.5 describe the stability of surface materials at the site.

Appendix D of Regulatory Guide 1.165, "Geological, Seismological and Geophysical Investigations to Characterize Seismic Sources," (NRC, 1997) provides guidance for the recommended level of investigation at different distances from a proposed site for a nuclear facility.

- The site region is that area within 200 miles (322 km) of the site location (Figure 2.5-5).
- The site vicinity is that area within 25 miles (40 km) of the site location (Figure 2.5-2).
- The site area is that area within 5 miles (8 km) of the site location (Figure 2.5-3).
- The site is that area within 0.6 mile (1 km) of the site location (Figure 2.5-4).

These terms, site region, site vicinity, site area, and site, are used in Sections 2.5.1 through 2.5.3 to describe these specific areas of investigation. These terms are not applicable to other sections of the FSAR.

The geological and seismological information presented in this section was developed from a review of previous reports prepared for the existing site, published geologic literature, interpretation of aerial photography, and a subsurface investigation and field and aerial reconnaissance conducted for preparation of this application. {The interpretation of the aerial photography and aerial reconnaissance was performed and reported in previous site-specific reports reviewed including the AmerenUE, 2004 Final Safety Analysis Report (AmerenUE, 2004) and Dames & Moore 1980 results of detailed excavation mapping for Callaway Plant Unit 1.} A review of published geologic literature was used to supplement and update the existing geological and seismological information. In addition, relevant unpublished geologic literature, studies, and projects were identified by contacting the U.S. Geological Survey (USGS), State geological surveys and universities. The list of references used to compile the geological and seismological information is presented in the applicable section.

{Field reconnaissance of the site was conducted by geologists in teams of two or more. A field reconnaissance visit in mid summer 2007 focused on exposed features along rivers, creeks, scarps and roads traversing the site within a 5 mile (8 km) radius of the Callaway Plant Unit 2 site. Key observations and discussion items were documented in field notebooks and photographs. Field locations were logged by hand on detailed topographic base maps and with hand-held Global Positioning System (GPS) receivers}. **FSAR 2.5 Appendix B provides additional detail on the field reconnaissance investigations performed}**.

This section is intended to demonstrate compliance with the requirements of paragraph c of 10 CFR 100.23, "Geologic and Seismic Siting Criteria" (CFR, 2007a).

2.5.1 BASIC GEOLOGIC AND SEISMIC INFORMATION

This section of the U.S. EPR FSAR is incorporated by reference with the following departure(s) and/or supplement(s).

The U.S. EPR FSAR includes the following COL Item in Section 2.5.1:

> A COL applicant that references the U.S. EPR design certification will use site-specific information to investigate and provide data concerning geological, seismic geophysical and geotechnical information.

The COL Item is addressed in the following sections.

This section presents information on the geological and seismological characteristics of the site region (200 mile (322 km) radius), site vicinity (25 mile (40 km) radius), site area (5 mile (8 km) radius) and site (0.6 mile (1 km) radius). Section 2.5.1.1 describes the geologic and tectonic characteristics of the site region. Section 2.5.1.2 describes the geologic and tectonic characteristics of the site vicinity and site location. The geological and seismological information was developed in accordance with the following NRC guidance documents:

- Regulatory Guide 1.70, Section 2.5.1, "Basic Geologic and Seismic Information," (NRC, 1978)
- Regulatory Guide 1.206, Section 2.5.1, "Basic Geologic and Seismic Information," (NRC, 2007) and
- Regulatory Guide 1.165, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion," (NRC, 1997). **INSERT A**

2.5.1.1 Regional Geology (200 miles (322 km) radius)

This section discusses the physiography, geologic history, stratigraphy, and tectonic setting within a 200 mile (322 km) radius of the site. The regional geologic map and explanation as shown in Figure 2.5-5 contains information on the geology, stratigraphy, and tectonic setting of the region surrounding {the Callaway Plant Site}. Summaries of these aspects of regional geology are presented to provide the framework for evaluation of the geologic and seismologic hazards presented in the succeeding sections.

{Sections 2.5.1.1.1 through 2.5.1.1.5 are added as a supplement to the U.S. EPR FSAR.

2.5.1.1.1 Regional Physiography and Geomorphology

The Callaway Plant Unit 2 site straddles the boundary between the Dissected Till Plains Section of the Central Lowlands Physiographic Province (Fenneman (1931) in AmerenUE, 2004) to the north and the Ozark Plateaus Physiographic Province to the south. The region within a 200 mile (322 km) radius of the site encompasses all or portions of numerous physiographic units which are discussed in the following paragraphs: Dissected Till Plains Section, The Till Plains Section, The Ozark Plateaus, The Coastal Plains Province, The Interior Low Plateaus Province, The Osage Plains and The Eastern Lake Section. Figure 2.5-1 shows the location of the site with respect to these physiographic units and specifics of these regions are discussed in detail in Sections 2.5.1.1.1.1 through 2.5.1.1.1.7. Site physiography is discussed in Section 2.5.1.2.1. Figure 2.5-1 also presents results from Hammond (1970) in Dahl, 2000 where variations are observed in the names and limits for these physiographic regions as well as a new region added within the Middle Western Upland Plain (Fenneman's Till Plains).

INSERT A

INSERT 'A' to FSAR Section 2.5.1

Basic Geologic and Seismic Information

(amended FSAR page 2-854)

{The following activities have been performed in order to reach the conclusion that no geologic or seismic hazards have the potential to impact the safety related facilities of Callaway Plant Unit 2.

- geotechnical and geophysical field investigations
- field reconnaissance
- geotechnical laboratory testing
- extensive research and review of relevant geologic literature

The New Madrid Seismic Zone and a small magnitude local earthquake occurring in the site region, are the primary basis for the seismic design basis for the plant. As reported in Section 2.5.2, these seismic sources were utilized in a detailed vibratory ground motion assessment, resulting in the development of the Callaway Plant Unit 2 site Safe Shutdown Earthquake (SSE) ground motion response spectra.}

geometry of the region. There are no structures which can readily relate to the lineament nearest the site, along the Missouri River.

At the junctions of Precambrian lineaments some cryptoexplosive structures exist. No proven cryptoexplosive structure is present, however, at the lineament junction nearest the site. This junction is associated with the Wardsville Fault and occurs 30 miles (48 km) west-southwest of the site. The nearest cryptoexplosive structure is the Crooked Creek structure 60 miles (97 km) to the south-southeast. No recorded seismic activity has been attributed to these two lineament junctions, but two epicenters have been reported near the Palmer Fault System where it joins the Crooked Creek structure.

2.5.1.1.4.1 ~~Regional Tectonic Structures~~ {SEE INSERT B ATTACHED}

~~The site lies in the Central Stable Region of the United States. Precambrian crystalline rocks are overlain by relatively flat-lying Paleozoic and Mesozoic sedimentary strata. Broad regional uplifts and depressions of the crust formed arches (domes) and basins, respectively, each containing more localized anticlines, synclines, and faults. These tectonic features were formed during the Paleozoic, with some (in the Mississippi Embayment) completing their formation in the Cretaceous. Nevertheless, seismic activity associated with some of these structures has persisted in the Mississippi Embayment area to the present time.~~

~~Individual structures within the 200 mile (322 km) radius of the site will be presented regionally. The major basins and structural features, in general, follow Riggs (1960). Local structures are described and referenced in detail in McCracken (1971) for Missouri, Nelson (1995) for Illinois, Harris and Parker (1964) for Iowa.~~

~~The seven main structural regions are the:~~

1. ~~Illinois Basin~~
2. ~~Mississippi Embayment~~
3. ~~Ozark Uplift and St. Francois Mountains~~
4. ~~Forest City Basin~~
5. ~~Lincoln Fold- Mississippi River Arch~~
6. ~~North-Central Missouri Region~~
7. ~~Cryptoexplosive Structural Lineament (38th parallel)~~

~~The North-Central Missouri Region is not a recognized tectonic region, but rather an area between basins and arches (uplifts). From a geometric viewpoint the contact between a basin and an arch (uplift) should be defined by the inflection points between the basin and each adjacent arch.~~

~~2.5.1.1.4.1.1 The Illinois Basin~~

~~The Illinois Basin (Figure 2.5-16) is a spoon-shaped structural trough surrounded by the Cincinnati Arch to the east, the Wisconsin Arch and uplands to the north, the Mississippi River Arch (or Lincoln Fold) to the northwest, and the Ozark Uplift to the southwest. Willman et al. (1975) give suggested limits of the basin:~~

1. ~~Minus 500 ft (152 m) msl contour on top of the Ordovician Galena Group~~
2. ~~Minus 1,000 ft (305 m) msl contour on top of the Ordovician Galena Group, or~~
3. ~~Area underlain by Pennsylvanian strata (Eastern Interior Coal Basin)~~

~~Delimiter No. 1 would place the southern limits of the basin along the Ste. Genevieve Fault Zone to the west, through Pulaski County, Illinois, southeast to Callaway County, Kentucky, eastward to include Stewart and Montgomery counties, Tennessee, and northeast through Robertson County, Tennessee and Barren County, Kentucky (Buschbach (1974) in AmerenUE, 2004).~~

~~Most of the Paleozoic systems thicken toward the center of the present Illinois Basin. Before they were uplifted and truncated by erosion at the end of the Paleozoic, the systems continued to thicken an unknown distance farther to the south. The southern limits of the Illinois Basin formed at about the end of Paleozoic time when the rocks in southeastern Missouri and northwestern Tennessee, between the Ozark Uplift and the Nashville Dome, were uplifted to form the Pascola Arch. The Precambrian basement rocks are 11,000 ft to more than 13,000 ft (3,353 m to more than 3,962 m) lower at the center of the basin than at the positive areas bordering it.~~

~~Structures within the Illinois Basin and within a 200 mile (322 km) radius of the site are listed in Table 2.5-3.~~

~~2.5.1.1.4.1.2 The Mississippi Embayment~~

~~This feature (Figure 2.5-16) has been described as a spoon-shaped depression area extending north from the Gulf Coast Embayment generally parallel to the Mississippi River in which sediments of Late Cretaceous and Early Tertiary age have been preserved. The structure is pre-Late Cretaceous (Gulfian) in age and was subjected to increased deepening in Early Tertiary time until the close of the Eocene (McCracken (1971); Cushing et al. (1964); Olive (1972); all in AmerenUE, 2004). Development of the structure may have begun as early as the end of the Paleozoic with tectonic movement associated with the Alleghenian Orogeny (Cushing et al. (1964) in AmerenUE, 2004). The eroded surface of Paleozoic rocks slopes from the Ozark escarpment southward under the Cretaceous and younger rocks at an average rate of 35 ft (10.7 m) per mile (1.6 km).~~

~~The Mississippi Embayment, especially the area surrounding the northern end of the Embayment, is the site of recent tectonic and seismic activity. Schwalb (1978) recognized that zones of weakness (fault zones) in the basement rocks (Precambrian) repeatedly (but infrequently) were reactivated since Precambrian time. Reactivation during the Cretaceous created a new feature, the Pascola arch, that trends northwest-southeast in western Kentucky and southeastern Missouri.~~

~~A summary of the structures of this tectonic region is shown in Table 2.5-4.~~

~~2.5.1.1.4.1.3 Ozark Uplift and St. Francois Mountains~~

~~The Ozark Uplift (Figure 2.5-16) is the dominant structural feature in Missouri. The structural center of this uplift is in Iron County, Missouri; however, the topographic axis extends northeast from Barry to Iron County. The boundaries of the Ozark Uplift are not well defined locally, particularly to the north and northwest; however, they generally correspond to the Ordovician-Mississippian rock contacts to the east and west and to the Mississippi Embayment on the south.~~

~~The Ozarks have been the subject of geological study since the early nineteenth century. Several hypotheses about the structural nature of the Ozarks have been advanced. Broadhead (1889) in AmerenUE, 2004 published the earliest comprehensive geological history of the Ozark region which mentions an up-warping or uplifting of the basement rocks to form the uplift. Broadhead cites "vertical uplifting forces" which he also calls "up-thrusting" as the mechanism of uplift. He describes the Ozark region as an "anticlinal" form which becomes "monoclinal" at its edge (which edge is not specified). Keyes (1894) in AmerenUE, 2004 called the Ozarks a geanticline and cited horizontal compression as the mechanism of formation, drawing an analogy with the Ouachitas. Keyes' hypothesis seemingly was not accepted as it was not mentioned again in the literature of the late 1800's and early 1900's.~~

~~Schuchert (1910) in AmerenUE, 2004 proposed that the ultimate cause of uplift was isostatic compensation for sedimentary loading of the continent in other areas. Twenhofel (1926) in AmerenUE, 2004 suggested that intrusion at depth produced the uplift, and he drew an analogy to the Rose Dome in southeastern Kansas. Dake (1927) in AmerenUE, 2004 pointed out that "doming" was episodic, with one main phase ending at the close of Bonneterre time. Their conclusion is based on the onlap relationship between the Potosi and the Bonneterre formations. Flint (1918) in AmerenUE, 2004 proposed that the only other important activity occurred during the Mississippian. Weller and St. Clair (1928) in AmerenUE, 2004 interpreted the block faulting (which they asserted was of Devonian age) as the result of "tension" arising from the extension of sedimentary rocks over the rising dome. Weller and St. Clair did an excellent job of mapping in Ste. Genevieve County. They recognized that some major faults were reverse faults, but contended that they were unrelated to the Ozark Dome. Wheeler (1965) in AmerenUE, 2004 advanced the hypothesis that the Ozarks are a huge klippe of an overthrust sheet rooted in the Ouachitas. His ideas have been generally rejected by most geologists (Franks (1966) and Muehlberger (1966) in AmerenUE, 2004). McCracken (1971) described the Ozark Uplift as a broad, slightly asymmetrical, quaquaversal fold. Structural mapping on the Roubidoux Formation (McCracken, 1967 in AmerenUE, 2004) suggested that the Ozarks were fractured in the form of a ruptured dome centered in Iron County, with movements continuing from post or late Paleozoic time.~~

~~Dake and Bridge (1932) in AmerenUE, 2004 concluded that the Ozark Region was a topographically positive region prior to early middle Cambrian time. The relief present at that time probably represented the erosional resistance of the thick silicic volcanics which comprise the Precambrian core of the St. Francois Mountains. The surface of the Precambrian rocks was deeply incised by streams before the onset of Cambrian sedimentation (at least 500 ft (152 m) of relief, Dake and Bridge (1932) in AmerenUE, 2004). The Cambrian and Ordovician sedimentary rocks were deposited over the preexisting topography and subjected to differential compaction. Much of the structural geometry of the region is a result of this pronounced paleotopographic effect (Dake and Bridge (1932); Weller and St. Clair (1928); both in AmerenUE, 2004).~~

~~The tectonic character of the region is the result of a sequence of episodes of relative vertical uplift, subsidence, and tilting of crustal blocks which are bounded by upthrust faults. The geometry of the blocks appears to be inherited from an older possibly Grenvillian, structural fabric. The traces of steeply dipping block-bounding faults, associations with faulted monoclines, the strikes of vertical Precambrian intrusives, fracture patterns in Precambrian rocks, fracture patterns in the sedimentary rocks of the region, and traces of minor faults all reflect a consistent geometry (Graves (1938); Robertson (1940); Tikrity (1968); Gibbons (1972); all in AmerenUE, 2004). Folding in the region is mainly the result of the passive draping of relatively weak sedimentary rocks over the edges of fault blocks or to the previously mentioned paleotopographic effects.~~

~~Although a lineament of cryptoexplosive structures crosses the Ozark Uplift Region, this feature will be discussed separately under 2.5.1.1.4.1.7.~~

~~A summary of the structures of the Ozark Uplift Region is shown in Table 2.5-5.~~

~~2.5.1.1.4.1.4 Forest City Basin~~

~~The Forest City Basin (Figure 2.5-16) is located in northwest Missouri and adjacent portions of Nebraska, Kansas and Iowa. It contains beds of Pennsylvanian and Permian age that dip toward a common center located near Forest City, Holt County, Missouri (McCracken, 1971). The structure is bounded on the west in Kansas and Nebraska by the Nemaha Uplift, on the south in Kansas by the Bourbon Arch, and on the north in Iowa by the Thurman-Redfield structural zone. To the east, the boundary is indistinct.~~

~~Lee (1943) in AmerenUE, 2004 believed the Forest City Basin was originally both a structural and topographic basin that did not come into existence until after Mississippian time. The basin was formed by rejuvenation of the Nemaha Anticline prior to Pennsylvanian deposition which was associated with down-warping of a post-Mississippian peneplain that had been formed by long continued erosion.~~

~~A summary of the structures of the Forest City Basin Region is shown in Table 2.5-6.~~

~~2.5.1.1.4.1.5 Lincoln Fold-Mississippi River Arch~~

~~The Lincoln Fold (Figure 2.5-15) is a major positive structural feature in Missouri. With the Mississippi River Arch, it forms a discontinuous arcuate succession of highs between the Ozark Uplift to the south and the Wisconsin highlands to the north. This succession of highs separates the Illinois Basin on the east from the Forest City Basin on the west.~~

~~The Lincoln Fold is an asymmetrical anticline with a regional trend of about North 45° West. The southwest flank has steep dips and some faulting, whereas the northeast flank as gentle dips with no known faulting. The fold extends for 165 miles (266 km) from the Cap au Gres Faulted Flexure on the south to Knox County on the north. Subsurface records and surface outcrops show the fold to have a maximum structural relief of 1,000 ft (305 m). Geophysical records and a few boreholes that reach Precambrian rocks suggest that a basement ridge existed beneath the present position of the Lincoln Fold before Cambrian sediments were deposited in the region. At the end of Silurian time, the fold appears to have begun to develop as a unique structural feature. Recurrent episodes of folding, erosion and deposition occurred throughout the Devonian and are responsible for much of its configuration. A long period of erosion followed this major movement, and the fold was tilted to the northwest. Mississippian strata were eroded along the axis of the fold, and in places they were almost completely removed. Pennsylvanian sediments covered the area after the post-Mississippian erosion. They were subsequently gently arched and most of them have been eroded away. No faulting affecting Pennsylvanian beds is known along the Lincoln Fold.~~

~~The Mississippi River Arch (Figure 2.5-16) is a broad, corrugated fold that extends generally north-south through the bulge of western Illinois. To the north, it blends with the Wisconsin uplands and to the south it intercepts the Lincoln Anticline. The arch separates the Illinois Basin from the Forest City Basin. Dating of movements along the arch is difficult because erosion has removed the Pennsylvanian strata. It appears, however, that the Mississippi River Arch existed early in Pennsylvanian time and was probably subjected to additional deformation at the end of Paleozoic time. The arch is cut by numerous cross folds that trend northwest-southeast and plunge southeastward into the Illinois Basin.~~

~~A summary of the structures of the Lincoln Fold tectonic region is shown in Table 2.5-7.~~

2.5.1.1.4.1.6 North-Central Missouri Region

The North-Central Missouri tectonic region is an area defined for this report devoid of recognizable regional basins or arches (uplifts). Nevertheless, it contains local structures, which are listed in Table 2.5-8.

2.5.1.1.4.1.7 Cryptoexplosive ~~Structures~~ Structural Lineament (38th Parallel)

Evans (2005), McCracken (1971), Snyder (1965a), Snyder (1965b), and Brown (1954) locate and describe several cryptoexplosive (also called cryptovolcanic or diatreme features) in Missouri and adjacent Kansas to the west and Illinois and Kentucky to the east. Unklesbay (1992) summarized details of these structures in Missouri.

These features lie along an east-west trending line near the 38th parallel (Figure 2.5-23) about 50 miles (80 km) south of the Callaway Site. In common, these features are small to medium in size (3.5 to 4.5 miles – 5.6 to 7.2 km - in diameter) to as compared with the listed features for North America from the Earth Impact Database, University of New Brunswick (UNB, 2008). These are circular or trough-like in shape and exhibit strata that have been disturbed by an explosive process, characteristic of volcanism or meteorite impact. From east to west the disturbances are: Rose Dome, Weaubleau-Osceola Structure, Decaturville Dome, Hazelgreen Volcanics, Crooked Creek Structure, Furnace Creek Volcanics and Avon Diatremes. This line of structures defines what has been called the "38th parallel lineament" because it closely approximates the 38th parallel line of latitude (Heyl, 1972). These features are described, in same order, as follows.

The Rose Dome Complex (Kansas)

Test drilling at Rose Dome showed that intrusive rock (lamproite) is just beneath the surface (Berendsen, 1991). The intrusive rock comprises granite and various sedimentary rock types. These intrusions at Silver City and Rose Dome took place along deep crust, pre-existing fractures. The intrusions are part of isolated but widespread mid-Cretaceous igneous activity across the central United States and not believed to be part of the lineament of meteorite impact features along the 38th parallel.

Weaubleau-Osceola Structure

In Missouri (St. Clair County.), the Weaubleau-Osceola structure (Evans, 2005) is 11.8 miles (19 km) in diameter. Mississippian-and Ordovician-age strata are intensely faulted and broken up (brecciated). They are overlain by undisturbed Pennsylvanian-age strata. The Weaubleau breccia contains well-preserved marine fossils (echinoderms, rugose corals, and conodonts) of Mississippian age. Consequently, the authors believe that this structure was formed by impact in the sea during Mississippian time.

Decaturville Dome

Continuing to the east along this line is the Decaturville dome in Laclede and Camden counties, Missouri. It comprises a 3.5 mile (5.6 km) diameter ring of low hills. A one mile (1.6 km) diameter core comprises intensely broken and crushed rock of granite-like texture. The core is surrounded by broken and down-faulted rocks and Cambro-ordovician age deformed and brecciated blocks, which have been uplifted up to 1,500 ft (457 m) above their normal stratigraphic position (Offield, 1979). These authors believe that the evidence indicates that this dome was formed from the impact of a meteorite or comet younger than the Pennsylvanian and, perhaps, as young as Cretaceous.

INSERT B

INSERT 'B' for FSAR Section 2.5.1.1.4.1 through 2.5.1.1.4.1.5
(amended FSAR pages 2-874 through 2-878)

{2.5.1.1.4.1 Regional Tectonic Structures

The site lies in the Central Stable Region of the United States. Precambrian crystalline rocks are overlain by relatively flat-lying Paleozoic and Mesozoic sedimentary strata. Broad regional uplifts and depressions of the crust formed arches (domes) and basins, respectively, each containing more localized anticlines, synclines, and faults. These tectonic features were formed during the Paleozoic, with some (in the Mississippi Embayment) completing their formation in the Cretaceous. Nevertheless, seismic activity associated with some of these structures has persisted in the Mississippi Embayment area to the present time.

Individual structures within the 200 mile (322 km) radius of the site will be presented regionally. The major basins and structural features, in general, follow Riggs (1960). Local structures are described and referenced in detail in McCracken (1971) for Missouri, Nelson (1995) for Illinois, Harris and Parker (1964) for Iowa.

Crone (Crone, 2000) compiled published geological information on Quaternary faults, folds, and earthquake-induced liquefaction in order to develop an internally consistent database on the locations, ages, and activity rates of major earthquake-related features throughout the United States. The Crone publication (Crone, 2000) is the compilation for such features in the Central and Eastern United States (CEUS), which for the purposes of the compilation, is defined as the region extending from the Rocky Mountain Front eastward to the Atlantic seaboard. A key objective of this national compilation is to provide a comprehensive database of Quaternary features that might generate strong ground motion and therefore, should be considered in assessing the seismic hazard throughout the country.

Category Definitions of the classes used in this compilation of Quaternary faults, liquefaction features, and deformation in the Central and Eastern United are listed below:

- Class A, Geologic evidence demonstrates the existence of a Quaternary fault of tectonic origin, whether the fault is exposed for mapping or inferred from liquefaction or other deformational features.
- Class B, Geologic evidence demonstrates the existence of a fault or suggests Quaternary deformation, but either (1) the fault might not extend deeply enough to be a potential source of significant earthquakes, or (2) the currently available geologic evidence is too strong to confidently assign the feature to Class C but not strong enough to assign it to Class A.
- Class C, Geologic evidence is insufficient to demonstrate (1) the existence of tectonic fault, or (2) Quaternary slip or deformation associated with the feature.
- Class D, Geologic evidence demonstrates that the feature is not a tectonic fault or feature; this category includes features such as demonstrated joints or joint zones, landslides, erosional or fluvial scarps, or landforms resembling fault scarps, but of demonstrable non-tectonic origin.

Only Class "A" features are listed for Missouri in Crone, 2000. No other type B, C or D features are listed for the state of Missouri. Features categorized in Class A have good geological evidence of tectonic origin and are potentially seismogenic. For these features, detailed evidence of Quaternary deformation or strong ground motion has been described and is well documented in the scientific literature. The published geologic evidence describing these features compellingly demonstrates evidence of Quaternary activity. The list of these features within the Callaway Plant site region includes: Albrecht Creek fault, Commerce fault, English Hill fault zone, Faults of Thebes Gap Area, Happy Hollow fault, Reelfoot scarp and New Madrid seismic zone, Sassafras Canyon faults, St. Louis–Cape Girardeau liquefaction features, and the Western Lowlands liquefaction features in the limits with Arkansas. All other Class "A" features in the site region are included within the New Madrid and Wabash Valley seismic zones.

The closest Class "A" feature to the site is located within the St. Louis–Cape Girardeau liquefaction features, 70 miles (113 km) east from the site, in a studied area that straddled the Mississippi River and the western edge of the Illinois basin (Crone, 2000 and Tuttle, 2005).

The second category in this compilation is Class B features where the geologic evidence of Quaternary tectonic activity is far less compelling than for Class A features (Crone, 2000). In some cases, Class B features may show clear evidence of Quaternary offset or deformation, but it is uncertain if these surface structures extend to sufficient depths to generate strong earthquakes and therefore produce strong ground motion. The second basis for assigning a feature to Class B is because the geologic and/or geomorphic evidence of Quaternary deformation is equivocal. The evidence reported in the geological literature may be incomplete or inconclusive, but is enough that the feature cannot be dismissed as probably non-seismogenic. Quaternary activity on these kinds of features is still a possibility; but considerable uncertainty remains about the feature's future seismogenic potential.

Faults and features assigned to Class C do not have demonstrated Quaternary activity and are not considered to be potential earthquake sources (Crone, 2000). Generally, Class C features are not known to have Quaternary slip. In some cases, detailed studies have revealed evidence showing that specific features actually have a non-tectonic origin. These non-tectonic features are assigned to a separate class, Class D, and include features such as solution collapses, features related to subsidence, landslides, and erosional scarps. Class C and D features are included in this compilation and in the database because their inclusion provides a complete record of all features that have been examined.

The seven (7) main structural regions in the site region are the:

1) Illinois Basin, including the Wabash Valley Seismic Zone
2) Mississippi Embayment, including the Reelfoot Scarp and New Madrid Seismic Zones
3) Ozark Uplift and St. Francois Mountains
4) Forest City Basin
5) Lincoln Fold- Mississippi River Arch

6) North-Central Missouri Region
7) Cryptoexplosive Structural Lineament (38th parallel)

The North-Central Missouri Region is not a recognized tectonic region, but rather an area between basins and arches (uplifts). From a geometric viewpoint the contact between a basin and an arch (uplift) should be defined by the inflection points between the basin and each adjacent arch.

2.5.1.1.4.1.1 The Illinois Basin

The Illinois Basin (Figure 2.5-16) is a spoon-shaped intracratonic basin bounded on the northwest by the Mississippi River Arch, on the northeast by the Kankakee arch, and on the south by the Cincinnati arch, the Pascola arch, and the Ozark uplift (Pitman, 1997). Willman et al. (1975) in Crone (2000) give suggested limits of the basin:

1. Minus 500 ft (152 m) MSL contour on top of the Ordovician Galena Group
2. Minus 1,000 ft (305 m) MSL contour on top of the Ordovician Galena Group, or
3. Area underlain by Pennsylvanian strata (Eastern Interior Coal Basin)

The southern limits of the basin is placed along the Ste. Genevieve Fault Zone to the west, through Pulaski County, Illinois, southeast to Callaway County, Kentucky, eastward to include Stewart and Montgomery counties, Tennessee, and northeast through Robertson County, Tennessee and Barren County, Kentucky (Buschbach (1974) in AmerenUE, 2004).

The Illinois Basin initially was a broad intracratonic embayment (aulacogen) that formed as a result of rifting in the early Paleozoic (Burke, 1973; Ervin, 1975 in Pitman, 1997). From Late Cambrian through Middle Ordovician, sediment accumulated in the depocenter of the basin overlying the rift complex, which encompassed the intersection of the Reelfoot rift and the Rough Creek graben. During the remainder of the Paleozoic, the basin experienced multiple periods of tectonic deformation in response to the Taconic, Acadian, and Ouachita orogenies. In the Mississippian and Pennsylvania, uplift of the LaSalle anticline occurred across east-central Illinois. Later, in the Pennsylvania and Permian time during the Ouachita orogeny, compressional stresses near the intersection of the Reelfoot rift and the Rough Creek graben led to extensive folding, faulting, and igneous intrusion at the southern margin of the basin (Nelson, 1991 in Pitman, 1997). The Illinois Basin attained its present structural configuration following the uplift of the Pascola arch in the late Paleozoic and early Mesozoic (Kolata & Nelson, 1991 in Pitman, 1997).

Located between the Illinois Basin, the Mississippi Embayment, and the Ozark Uplift and St. Francois Mountains is the St. Louis-Cape Girardeau Class "A" liquefaction features (Crone, 2000). They are specifically just north of the Ste. Genevieve Fault Zone, compassing an area equivalent to the northwestern end of the south-central magnetic lineament (SCML) described in Hildenbrand (1997). Immediately southeast of this area is the New Madrid seismic zone.

INSERT 'B' for FSAR Section 2.5.1.1.4.1 through 2.5.1.1.4.1.5

(amended FSAR pages 2-874 through 2-878)

Tuttle (1999) in (Crone 2000) examined sand blows, sand dikes, and sand sills that were found during systematic searches of streams in southeastern Missouri and southwestern Illinois. The search extended approximately 31 to 56 miles (50 to 90 km) west and east of the Mississippi River, between the St. Louis area on the northwest and the Cape Girardeau area on the southeast. The study area is named here informally after these two cities. Correlation and dating of the liquefaction features remain uncertain. The present interpretation involves an earthquake of moment magnitude M > 6, and perhaps exceeding 7, occurring approximately 6,500 years ago, roughly 37 miles (60 km) east of St. Louis. The smaller the earthquake east of St. Louis, the more likely it is that another earthquake of M > 5.2 occurred in or very near St. Louis. A second earthquake caused strong ground shaking in the area during the past 4,000 years.

The liquefaction was recognized as the type that is caused by strong ground motion (Obermeier, 1996 in Crone, 2000), and the strong motions are presumed to have been caused by slip on one or more preexisting faults. However, the causative faults have not been identified and the locations and sizes of the liquefaction features studied to date provide poor constraints on the sources of the shaking.

Regionally, bedrock consists of Paleozoic strata that dip northeastward from the Ozark uplift toward the center of the Illinois basin. Historical earthquakes are scattered throughout the study area. The earthquakes are part of the broad, diffuse halo of scattered seismicity that surrounds the New Madrid seismic zone. Numerous large faults, monoclines, and other folds of Paleozoic age are known throughout the region, and most involved the basement.

Among the recognized liquefaction features, sand dikes are far more numerous than sills or sand blows. The liquefaction features are in late Wisconsinan and Holocene deposits. Individual Quaternary faults have not been identified. Instead, prehistoric liquefaction features are recognized over a large area and attributed to several earthquakes that occurred on unidentified faults.

Most of the Paleozoic systems thicken toward the center of the present Illinois Basin. Before they were uplifted and truncated by erosion at the end of the Paleozoic, the systems continued to thicken an unknown distance farther to the south. The southern limits of the Illinois basin formed at about the end of Paleozoic time when the rocks in southeastern Missouri and northwestern Tennessee, between the Ozark Uplift and the Nashville Dome, were uplifted to form the Pascola Arch. The Precambrian basement rocks are 11,000 ft to more than 13,000 ft (3,353 m to more than 3,962 m) lower at the center of the basin than at the positive areas bordering it.

The southern end of the Illinois basin is one of the most structurally complex regions in the Mid-continent United States, with two major structural elements characterizing this part of the basin (Kolata, 1997): (1) The Wabash Valley Seismic Zone (described in detail in Section 2.5.1.1.4.1.1.1), a broad southwesternward plunging cratonic depression that extends across central Illinois and southwestern Indiana. Historical and prehistorical earthquakes in this part of the basin indicate that moderate to high earthquake potential exists, and still enigmatic seismogenic source. (2) The southernmost part of the basin is underlain by the Reelfoot Rift and Rough Creek Graben, a rift system that formed during the late Precambrian to Middle Cambrian time. Geodynamic processes operating within the rift since the late Precambrian have had a major influence on the tectonic history of the region. In addition, tectonic compressive stress appears to be reactivating ancient faults within the Reelfoot Rift, resulting in coherent linear segments of earthquakes epicenters called the New Madrid Seismic Zone. 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, 1997), and is described in detail in Section 2.5.1.1.4.1.2.

Structures within the Illinois Basin and within a 200 mile (320 km) radius of the site are listed in Table 2.5-3.

2.5.1.1.4.1.1 Wabash Valley Seismic Zone

The Wabash Valley region in southeastern Illinois and southwestern Indiana has been an area of persistent seismicity and the site of several moderate magnitude (M=4.5-5.8) historical earthquakes (Crone, 2000), but little is known about the causative faults. The most prominent network of faults in the region is the Wabash Valley fault system (Bristol, 1979 in Crone, 2000), a series of north-northeast-trending normal faults that are mapped at the surface. Seismic-reflection data show that the faults are rooted in Precambrian basement and define a 25 mile (40 km) long, 13.7 mile (22 km) wide graben named the Grayville graben (Bear, 1997). Dip-slip displacements on some of the faults are as much as 1968.5 ft (600 meter), and laterally offset structural trends suggest 1.2 – 2.5 mile (2-4 km) of lateral displacement on some faults.

There is no known Quaternary surface rupture on faults in the Wabash Valley region. Quaternary faults have recently been reported in southernmost Illinois, near Metropolis, but none can be linked with liquefaction features throughout the southern halves of Indiana and Illinois. The following discussion focuses on the presence of paleoliquefaction features throughout the study area that includes the southern halves of Indiana and Illinois. On the basis of the strong evidence that these liquefaction features are late Quaternary in age, they are listed as Class A features (Crone, 2000).

Clastic dikes filled with sand and gravel, interpreted to be the result of earthquake induced liquefaction, occur throughout much of southern Indiana and adjacent parts of Illinois. At least seven and probably eight prehistoric earthquakes have been documented during the Holocene, as well as, at least one during the latest Pleistocene. Nearly all of these liquefaction features originated from earthquakes centered in southern Indiana and Illinois, and not further south in the nearby source region of the 1811-12 New Madrid earthquakes.

The recognition of different earthquakes is based mainly on establishing limits on the timing of liquefaction features in combination with the regional pattern of liquefaction effects, but some earthquakes have been recognized only by geotechnical testing at sites of liquefaction.

Prehistoric magnitudes were probably on the order of moment magnitude M 7.5, which greatly exceeds the largest historical earthquakes of M 5.5 in the region. The strongest prehistoric earthquakes had epicenters in the vicinity of the lower Wabash Valley, where the valley borders both Indiana and Illinois. Precise location of the structures that produced the strong ground motion, which formed the liquefaction features, is unknown.

On the basis of gravity and magnetic data (Braile, 1982 in Crone, 2000) proposed that the Wabash Valley fault zone is part of the northeastern arm of a late Precambrian-early

Phanerozoic rift complex in the central mid-continent. However subsequent studies indicate that the Wabash Valley faults are the expression of relatively minor tectonic structures and are probably not part of a failed rift arm (Hildenbrand, 1997). At present, the seismicity in the region cannot be directly associated with any bedrock structures at shallow depth, although a geophysical magnetic and gravity lineament seems to be a good candidate (Hildenbrand, 1997), and a possible fault zone has been located at depth. The lineament, some 373 miles (600 km) in length, extends from Arkansas into the Wabash Valley, and terminates in the epicentral region of the strongest paleoearthquakes (M~7.5 and 7.1).

Some historical seismicity also persists throughout southern Indiana-Illinois, but the strongest events are concentrated in the vicinity of the Wabash Valley. Earthquake focal mechanisms for events in the Wabash Valley region indicate dominantly strike-slip and reverse-slip motion (Herrmann, 1979; Taylor, 1989; Langer, 1991, in Crone, 2000). Without knowledge of the structural features that are present at hypocentral depths, it is impossible to determine the preferred nodal planes for the focal mechanisms (Crone, 2000). Causative fault do not have any surface expression. The only evidence of the paleoearthquakes (related to the strong ground motion) is liquefaction features exposed along the banks of major rivers in the area.

Detailed studies (in Crone, 2000) describe the characteristics and distribution of the dikes and offer magnitude estimates of earthquakes that likely caused the liquefaction. The persistent historical seismicity in the region suggested the possibility of significant seismic source zones in the region. A systematic search for paleoliquefaction features was begun in 1990, and more than 1000 paleoliquefaction dikes have been discovered. The dikes are typically filled with sand and gravel, are planar, and have a near-vertical orientation. In the river-bank exposures, many of the dikes extend as much as 13 ft (4 m) above the source beds.

The timing of most recent paleoevent is the latest Quaternary (<15 ka) (Crone, 2000). At least seven notable paleoevents probably occurred during the Holocene, and one occurred about 12,000 yr BP. Nearly all events probably had magnitudes in excess of M 6. No historical earthquakes in the Wabash Valley region have been strong enough to cause liquefaction. It is likely that numerous other M6 to M7 Holocene earthquakes have struck the region, but did not leave a record because of the lack of liquefiable deposits in large parts of the region.

Recurrence intervals on individual faults have not been definitively determined, however a regional recurrence interval for M >6 earthquakes of at least every 500-1,000 years is reasonable in the southern half of Indiana and Illinois (Crone, 2000). Causative faults have not been identified in the Wabash Valley area. In the absence of well-determined data on the timing of paleoevents and the amount of tectonic slip associated with those events, it is impossible to estimate reliable or even meaningful Holocene or late Quaternary slip rates.

2.5.1.1.4.1.2 The Mississippi Embayment

This feature (Figure 2.5-16) has been described as a southwest-plunging sedimentary trough, extending north from the Gulf Coast to the southeast region of Missouri, approximately parallel to the Mississippi River. It is characterized, on the surface, by a large alluvial plain interrupted by a line of low hills (MODNR, 2007). The Embayment is underlain by the early Paleozoic Mississippi Valley graben basement fault complex, which was created by late Precambrian- early Paleozoic rift system (Hildenbrand, 1985). The complex tectonic evolution of the upper Mississippi Embayment started in the late Precambrian or Cambrian with a major rifting event involving the formation of a large graben along a pre-existing shear zone. Reactivations occurred in Permian and Cretaceous time, which caused the Reelfoot rift area to subside and the Pascola arch to form. The formation of the present Mississippi Embayment and fault zones then appears to be influenced from rift structures (Hildenbrand, 1985).

Another theory to the development of the Mississippi Embayment is presented by Cox, 2002. Previous authors have attributed Embayment subsidence to the opening of the Gulf of Mexico, which created rift structures. However, the Embayment subsided 60 million years after the cessation of the sea-floor spreading in the Gulf. Cox suggests that progressive (northwest-to-southeast) mid-Cretaceous volcanism that crosses the Mississippi Embayment coincides with the predicted Bermuda hotspot path. During the mid-Cretaceous, the weak crust of the Mississippi Valley graben complex moved west of the hotspot, subsided, and the eroded region became a topographic low that filled with fluvio-marine sediments, the Mississippi Embayment.

The Mississippi Embayment, especially the area surrounding the northern end of the Embayment, is the site of continued tectonic and seismic activity. The present-day seismicity pattern suggests linear active zones (Stauder, 1982 in Hildenbrand, 1985).

A summary of the structures of this tectonic region is shown in Table 2.5-4.

2.5.1.1.4.1.2.1 Reelfoot Scarp and New Madrid Seismic Zone

These features are located in the central part of the Mississippi River Valley. At present, structural and tectonic information about specific seismogenic faults is limited, in part because the seismogenic faults are not expressed or are poorly expressed at the surface. Furthermore, the entire river valley is covered by latest Quaternary sediments, so only the geologically youngest deformation is expressed at the surface. The Reelfoot scarp is a topographic escarpment that extends south-southeastward from near the town of New Madrid, Missouri, along the western margin of Reelfoot Lake, to a point south of the lake. It is the most prominent geomorphic feature in the entire seismic zone that is clearly known to have a tectonic origin.

In the winter of 1811-1812, at least three major earthquakes occurred in the New Madrid seismic zone, and the area remains the most seismically active area in central and eastern North America. The 1811-1812 earthquakes were among the largest historical earthquakes to occur in North America and were perhaps the largest historical intraplate earthquakes in the world. The earthquakes produced widespread liquefaction throughout the seismic zone and prominent to subtle surface deformation is several areas, but they did not produce any known surface faulting. Other than the pervasive sand blows throughout the seismic zone, the Reelfoot scarp is the most prominent geomorphic feature that has been produced by the modern tectonism. Recent studies of the scarp have provided valuable information on the recurrence of deformation on the scarp, calculated uplift rates, and the history of faulting.

INSERT 'B' for FSAR Section 2.5.1.1.4.1 through 2.5.1.1.4.1.5

(amended FSAR pages 2-874 through 2-878)

Many features shown on maps of the New Madrid seismic zone are not discrete faults; the most notable exception is the Reelfoot scarp, which is located along the western shore of Reelfoot Lake in extreme northwestern Tennessee. The three most commonly noted features associated with the contemporary deformation are: (1) the Lake County uplift and Reelfoot scarp, (2) areas of suspected co-seismic subsidence, and (3) areas of abundant liquefaction during the 1811-1812 earthquakes. The locations of these features are derived from the digital data used to generate the suite of seismotectonic maps of the New Madrid, Missouri area.

The modern seismicity in the New Madrid Seismic Zone is intimately associated with the Reelfoot rift, a northeasterly-trending, 43.5 mile (70 km) wide graben that has as much as 1.2 mile (2 km) of structural relief on magnetic basement. The rift is best defined by magnetic data, which also reveals the presence of major positive magnetic anomalies along the flanks and axis of the rift that are inferred to be mafic plutons (Braile, 1997, and Hildenbrand, 1982 in Crone, 2000).

The following sequence of events summarizes the geologic history of the Reelfoot rift and the current tectonic setting of the New Madrid seismic zone. Crustal extension that resulted in development of the Reelfoot rift began in latest Precambrian or Early Paleozoic time. It is likely that the Reelfoot rift is generally contemporaneous with other large-scale late Precambrian-Early Paleozoic, extensional features along the rifted margin of southeastern North America, including the Southern Oklahoma aulacogen, the Rough Creek-Rome graben system, and the Marathon rift (Thomas, 1991, in Crone, 2000).

Active rifting ceased by Late Cambrian time and the Reelfoot rift was filled with a 0.6 to 2.5 mile (1 to 4 km) thick sequence of marine clastic and carbonate sedimentary rocks. During the Late Paleozoic and much of the Mesozoic, the region was uplifted, and several kilometers of sedimentary rocks were eroded from the crest of the Pascola arch. In Permian time, mafic-igneous dikes and sills intruded the sedimentary rocks; radiometric dating of a mica-peridotite dike in a drill hole near Reelfoot Lake in northwestern Tennessee yielded an age of 267 Ma. Near the end of the Mesozoic, probably beginning in early to middle Cretaceous time, regional subsidence occurred again. Also in early Cretaceous time, a series of igneous intrusions were emplaced along the margins of the rift; the emplacement of these intrusions is cited as evidence of reactivation of the rift, although extensional features are not known.

During the late Cretaceous and continuing through the Eocene, subsidence resulted in formation of the Mississippi embayment. The embayment was filled with a southward-thickening wedge of predominantly clastic marine and continental sediments. Oligocene sediments are generally absent in the northern Mississippi embayment.

In late Quaternary time and probably in earlier episodes, tremendous volumes of glacial melt-water from much of North America flowed down the Mississippi-Ohio Rivers drainage system and through the northern embayment. Braided streams that transported the melt-water deposited outwash sand and gravel in the embayment that is typically tens of meters thick in the New Madrid region. In early Holocene time, the Mississippi River changed from a braided stream to a meandering regime and began developing the modern meander belt. As a meandering river, fine-grained overbank sediment that was deposited as annual floods spread across wide expanses of the modern river valley.

The contemporary seismicity and current deformation in the New Madrid region is controlled by a regional stress field in which the maximum compressive stress is oriented approximately east-northeast-west-southwest. Within this stress field, ancient faults, most of which originally formed as extensional features during rifting, have been reactivated mainly as strike-slip faults. The modern seismicity is concentrated into three major trends that form a zigzag pattern that has an overall northeasterly trend. The modern seismicity is largely associated with rift-related features. The southwestern-most trend is a narrow, linear, 74.6 miles (120 km) long zone of earthquakes in northeastern Arkansas and extreme southeastern Missouri; this zone of earthquakes roughly coincides with the position of an axial fault zone that is commonly present along the center of most rifts.

The sense of movement on active faults is derived from seismological data, which is summarized in the preceding section. These data indicate that the regional deformation is dominated by dextral slip in the two northeast-trending linear zones of seismicity. The two linear seismicity trends are linked by a zone of northwest-trending seismicity. Accurately located earthquakes in this northwesterly trend suggest the presence of a southwesterly dipping reverse fault.

Based on combined information from seismological, seismic-reflection profiling, geomorphic, and geological studies, the Reelfoot Scarp is interpreted as an east-dipping monocline which is the surface expression of a fault-propagation fold associated with the underlying blind Reelfoot thrust fault (Van Arsdale, 1995 and 2000, in Crone, 2000).

The geomorphology of the New Madrid seismic zone is dominated by the fluvial features of the Mississippi River and the latest Pleistocene braided stream terraces that are primarily composed of outwash sand and gravel. The most prominent geomorphic expression of contemporary tectonism is the Lake County uplift, a teardrop-shaped uplift in extreme northwestern Tennessee that has a maximum length of about 31 mile (50 km) and maximum width of about 14.3 miles (23 km) (Russ, 1982 in Crone, 2000). Geomorphic studies indicate that recent deformation the uplift has elevated the late Holocene fluvial sediments as much as 29.5 feet (9 meters).

The most widespread expression of recent strong earthquakes in the New Madrid region is the abundant liquefaction features (sand blows and sand-filled fissures), which are concentrated in a 24.9 to 37.3 mile (40 to 60 km) wide belt from near Charleston, Missouri on the northeast to south of Marked Tree, Arkansas (Obermeier, 1988, in Crone, 2000). Geologic conditions in the New Madrid region are near optimum for the development of liquefaction features during strong earthquakes: a thin (6.6 – 26.2 feet (2-8 m) thick, fine-grained "topstratum" deposit overlies water-saturated, unconsolidated "substratum" sand and gravel. Extensive liquefaction occurred during the 1811-1812 earthquakes; locally the ground surface was buried by more than 3.3 feet (1 m) of liquefied sand, and hundreds of square kilometers of the land surface are have been mapped as being more than 25 percent covered by liquefied sand (Obermeier, 1988, in Crone, 2000).

Detailed studies of the Reelfoot scarp in northwestern Tennessee have documented evidence of three deformation events within the past 2,400 years and characterized the style of near surface deformation associated with the scarp (Kelson, 1996 in Crone , 2000). Late Holocene fluvial deposits are warped into an 26.2 feet (8 m) high, east-facing monocline. Borehole data and trenches at three sites characterized the style of near-surface deformation associated with the scarp and constrain the timing of three deformation events on the scarp.

Deformation on the scarp associated with the 1811-1812 New Madrid earthquake sequence produced extensive liquefaction, folded the fluvial sediments, and caused minor reactivation of small faults that bound an extensional graben in the uplifted (hanging wall) of the Reelfoot scarp. The penultimate deformation event occurred between A.D. 1260 and 1650 (350-740 yr B.P.), produced about 4.3 feet (1.3 m) of throw in the graben bounding faults, and caused folding and development of the scarp. The oldest documented event associated with the scarp occurred between A.D. 780 and 1000 (1000-1120 yr B.P.), and initially produced the small graben in the hanging wall of the Reelfoot fault.

Despite considerable efforts, reliable geologic data on the recurrence of strong, potentially damaging earthquakes in the New Madrid Seismic Zone (NMSZ) has been elusive, and the currently available data are limited, inconclusive and contradictory. Paleoseismic studies have suggested a recurrence interval of about 500-1100 years for earthquakes that are large enough to produce significant surface deformation or liquefaction in various parts of the seismic zone, with most recent studies suggesting that there were about 900 years between the last two New-Madrid-size events (A.D. 900 to A.D. 1811) and that widespread liquefaction occurs every few hundred years (Crone, 2000). However, the record studied thus far is too short to be used for a long-term recurrence rate. The detailed investigations of the Reelfoot scarp described above provide information that permitted (Kelson, 1996 in Crone, 2000) to estimate a recurrence interval of 150-900 years, with a more likely range of about 400-500 years. It is not clear if these rate estimates reflect the overall behavior of major events for the entire seismic zone or only apply to the Reelfoot scarp.

Despite the lack of well-constrained slip-rate data for specific faults in the New Madrid region, some general inferences can be made about general deformation rates using structural and stratigraphic data. A wide range of fault slip rates can be calculated in the New Madrid region depending on time intervals and datums that are being considered. Geodetic studies in the New Madrid seismic zone have yielded results that imply contrasting slip rates. One geodetic study in part of the New Madrid seismic zone yields a contemporary slip rate of 0.2 - 0.28 inches/year (5-7 mm/yr) (Liu, 1992 in Crone, 2000), but this high slip rate is considered to be an anomalously high, very short-term rate, considering the lack of regional topography that would reflect such a deformation rate. Also, if sustained, these rates would have produced much more faulting and deformation in Paleozoic and Cretaceous rocks than actually exists. A more recent geodetic study has questioned whether the Liu, 1992 in Crone 2000 results are statistically significant (Newman, 1999 in Crone, 2000). Geodetic data analyzed by the latter indicates virtually no significant deformation is currently occurring, that is, their results show that the measured rate does not differ significantly from zero. The significance of the divergent results from these two studies remains unresolved and is the subject of considerable discussion.

The NMSZ is defined on the basis of abundant and widespread historical and microseismicity that is concentrated in three prominent trends. These concentrations of microseismicity and the major earthquakes that occurred in 1811-1812 indicate that quaternary faulting is occurring in the seismic zone, but with the exception of the Reelfoot scarp, discrete faults are not expressed at the surface. Therefore it is difficult to assign a specific length for the entire zone. Overall, the abundant seismicity extends from near Marked Tree, Arkansas, on the southwest to near Charleston, Missouri, on the northeast, which is a distance of about 112 miles (180 km), but diffuse seismicity extends a greater distance.

Recent studies (multiple authors in Crone, 2000) have shown that the Reelfoot scarp is about 19.9 miles (32 km) long and the subjacent Reelfoot fault may be as much as 43.5 miles (70 km) long. However, this fault is the only feature that has conspicuous surface expression and therefore can be studied at the surface. Based on the historical seismicity, there may be other significant but unexposed faults in the seismic zone.

The New Madrid seismic zone is not a single feature but is defined by the region of abundant seismicity in the central Mississippi River Valley. Accordingly, it is not possible to define an average strike but most of the seismicity is associated with the Reelfoot rift, which has a northeasterly trend. The Reelfoot scarp is a well-defined feature, but is small in comparison to the general dimensions of the seismic zone. The average azimuth of the Reelfoot scarp is 337°.

The New Madrid earthquakes consisted of a series of at least 3 and possibly 4 major ($M \geq 7.5$) events during a period of 2 months in the winter of 1811 and 1812. Strong aftershocks persisted in the region for at least one year. The first major earthquake occurred at 2:15 a.m. (all times are local times) on December 16, 1811. It was followed by another major earthquake at 8:15 a.m. the same day that was the smallest of the 4 major events; most reports of the New Madrid earthquakes note three principle events, and this event is commonly not cited as one of the principle earthquakes. The next major event occurred at 9 a.m. on January 23, 1912; historical accounts suggest that this event was intermediate in size between the first and last major shocks. The last and largest earthquake occurred at 3:45 a.m. on February 7, 1812.

2.5.1.1.4.1.3 Ozark Uplift and St. Francois Mountains

The Ozark Uplift (Figure 2.5-16) is the dominant structural feature in Missouri. The structural center of this uplift is in Iron County, Missouri; however, the topographic axis extends northeast from Barry to Iron County. The boundaries of the Ozark Uplift are not well defined locally, particularly to the north and northwest; however, they generally correspond to the Ordovician-Mississippian rock contacts to the east and west and to the Mississippi Embayment on the south.

This structural feature was an area of positive topographic relief through most of the Paleozoic, based on the lack of deposition of carbonate rocks on the top of the uplift (Nelson, 1996). Since the Ozark uplift does not occur at, or near, a tectonically active plate boundary, Brown, 2004, has suggested that the formation and persistence of the uplift reflects multiple phenomena. Initially, the area of uplift was a felsic intrusive/ extrusive center during the Proterozoic, thickening the crust with low-density rock. Second, regional crustal shortening during the late Paleozoic shortened the region reactivating faults that outline the block, so it could tilt up like a foreland basement- cored uplift. Such uplift may have been enhanced by thrust-sheet loading in the Ouachitas to the south and stabilized by short-term flow of a mid-crustal weak zone. Explanations for possible post-Paleozoic uplift of the plateau have been harder to formulate. It is not clear whether the present-day elevations are a residual of earlier uplift, or are a consequence of renewed movement on border faults (Brown, 2004).

The tectonic character of the region is the result of a sequence of episodes of relative vertical uplift, subsidence, and tilting of crustal blocks which are bounded by upthrust faults. The geometry of the blocks appears to be inherited from an older possibly Grenvillian, structural fabric. The traces of steeply dipping block-bounding faults, associations with faulted monoclines, the strikes of vertical Precambrian intrusives, fracture patterns in Precambrian rocks, fracture patterns in the sedimentary rocks of the region, and traces of minor faults all reflect a consistent geometry (Graves (1938); Robertson (1940); Tikrity (1968); Gibbons (1972); all in AmerenUE, 2004). Folding in the region is mainly the result of the passive draping of relatively weak sedimentary rocks over the edges of fault blocks or to the previously mentioned paleotopographic effects.

Although a lineament of cryptoexplosive structures crosses the Ozark Uplift Region, this feature will be discussed separately under 2.5.1.1.4.1.7.

A summary of the structures of the Ozark Uplift Region is shown in Table 2.5-5.

2.5.1.1.4.1.4 Forest City Basin

The Forest City Basin (Figure 2.5-16) is located in northwest Missouri and adjacent portions of Nebraska, Kansas and Iowa. This structural basin occupies part of a broad depositional region known as the Northern Midcontinent Shelf within the Midcontinent Basin (Heckel, 1999 in Witzke, 2003). It contains beds of Pennsylvanian and Permian age that dip toward a common center located near Forest City, Holt County, Missouri (McCracken, 1971). The structure is bounded to the west by the Nemaha Uplift, to the south by the Bourbon Arch, to the north by the Transcontinental Arch, and to the east by the Ozark Dome (Brown, 2005).

Lee (1943) using isopach maps, created a hypothesis of the formation of the Forest City Basin. The Forest City Basin was originally both a structural and topographic basin that did not come into existence until after Mississippian time. The basin was formed by the sharp displacement on the east flank of the Nemaha Anticline prior to Pennsylvanian deposition which was associated with down-warping of a post-Mississippian peneplain that had been formed by long continued erosion. During the early to middle Pennsylvanian the Forest City Basin was influenced by the orogenic activity of the convergent Ouachita system in present-day southeastern Oklahoma such that the Nemaha fault system was actively creating substantial topography on the karsted Mississippian surface (Ham & Wilson, 1967 in Brown, 2005).

A summary of the structures of the Forest City Basin Region is shown in Table 2.5-6.

INSERT 'B' for FSAR Section 2.5.1.1.4.1 through 2.5.1.1.4.1.5

(amended FSAR pages 2-874 through 2-878)

2.5.1.1.4.1.5 Lincoln Fold-Mississippi River Arch

The Lincoln Fold (Figure 2.5-15) is a major positive structural feature in Missouri. With the Mississippi River Arch, it forms a discontinuous arcuate succession of highs between the Ozark Uplift to the south and the Wisconsin highlands to the north. This succession of highs separates the Illinois Basin on the east from the Forest City Basin on the west.

The Lincoln Fold, along with the Cap au Grès structure, is a forced fold over a high-angle reverse fault in Precambrian crystalline basement (Nelson, 1996). The axis of the fold follows a general northwesterly trend but turns easterly at its southernmost exposures (ISGS, 2002). It extends more than 93 miles (150 km) across northeastern Missouri and Western Illinois (Collinson et al., 1954 in Nelson, 1996). Structural relief across the fold reaches 984 feet (300 m) in Missouri (McCracken, 1971 in Nelson, 1996) and 1,312 feet (400 m) in Illinois (Rubey, 1952 in Nelson, 1996). The Lincoln anticline portions of the structure has a steeply dipping (45° or steeper) southwest limb and a gently dipping (less than 5°) northeast limb. Near the southeast end where it crosses into Illinois, this fold curves to an easterly trend and becomes the narrow <1.2 miles (< 2 km wide) Cap au Grès faulted flexure, a monocline with a vertical to overturned southwest limb that is cut by several parallel high-angle faults (Nelson, 1996).

Major uplift along this structure took place during Late Mississippian to Early Pennsylvanian time, but this structure was also active during the Devonian Period. This movement involved uplift and regional tilting of the Silurian and older rocks. In sum, the Lincoln Fold- Cap au Grès structure was clearly a positive structure by the late Middle Devonian time, and uplift along the structure persisted into the Mississippian (Nelson, 1996).

The Lincoln Fold is an asymmetrical anticline with a regional trend of about North 45° West. The southwest flank has steep dips and some faulting, whereas the northeast flank as gentle dips with no known faulting. The fold extends for 165 miles (266 km) from the Cap au Grès Faulted Flexure on the south to Knox County on the north. Subsurface records and surface outcrops show the fold to have a maximum structural relief of 1,000 ft (305 m). Geophysical records and a few boreholes that reach Precambrian rocks suggest that a basement ridge existed beneath the present position of the Lincoln Fold before Cambrian sediments were deposited in the region. At the end of Silurian time, the fold appears to have begun to develop as a unique structural feature. Recurrent episodes of folding, erosion and deposition occurred throughout the Devonian and are responsible for much of its configuration. A long period of erosion followed this major movement, and the fold was tilted to the northwest. Mississippian strata were eroded along the axis of the fold, and in places they were almost completely removed. Pennsylvanian sediments covered the area after the post-Mississippian erosion. They were subsequently gently arched and most of them have been eroded away. No faulting affecting Pennsylvanian beds is known along the Lincoln Fold.

The present structure of the Mississippi River Arch can be attributed to its predecessor, the Northeast Missouri Arch. The Northeast Missouri Arch is a regional north-northeast-trending uplift that extends north from the Ozark Dome. Along the arch, Middle Ordovician through Middle Silurian strata are tilted, beveled, and unconformably overlain by Middle Devonian strata. The Northeast Missouri Arch was clearly uplifted tectonically at some time between Middle Silurian and early Middle Devonian time. Post-Mississippian uplift in the same general area produced the structure now known as the Mississippi River Arch (Bunker et al., 1985 in Nelson, 1996).

The Mississippi River Arch (Figure 2.5-16) is a broad, corrugated fold that extends generally north-south through the bulge of western Illinois. To the north, it blends with the Wisconsin uplands and to the south it intercepts the Lincoln Anticline. The arch separates the Illinois Basin from the Forest City Basin. Dating of movements along the arch is difficult because erosion has removed the Pennsylvanian strata. It appears, however, that the Mississippi River Arch existed early in Pennsylvanian time and was probably subjected to additional deformation at the end of Paleozoic time. The arch is cut by numerous cross folds that trend northwest-southeast and plunge southeastward into the Illinois Basin.

A summary of the structures of the Lincoln Fold tectonic region is shown in Table 2.5-7.}

therefore, supports the second hypothesis. An aligned meteorite impact would have occurred during a short period of time. Rampino (1996) were impressed by the analogy in 1994 when fragments of Comet P/Shoemaker-Levy 9 slammed into the planet Jupiter along a straight line. Evans (2005) strongly supports the meteorite origin for the Decaturville, Crooked Creek, and Weaubleau-Osceola structures. A meteorite origin for the others in this set is not supported. If some structures were from impacts and others from magmatism, a unifying hypothesis would need to be proposed. In fact, Rampino (1999) argues that such magmatism could have been initiated (and later rejuvenated) by a meteorite impact. Although their origin is still problematic, possible tectonic forces that could have produced these structures were not active since the Cretaceous. **INSERT C**

2.5.1.1.4.2 ~~Regional Jointing~~

~~Regional joint or fracture patterns are consistent and well developed throughout the region. Two systems of fractures are prevalent. The most common and the most widely distributed fracture system is made up of two sets that parallel the general regional structural trends (northwest and northeast). This system is present in the basement rocks and is represented there by fractures intruded by ultrabasic rocks of known Precambrian age. The second system is subordinate and has two joint sets that strike north-northwest and east-northeast. The two systems are statistically difficult to distinguish in large samples and may represent local variants of the same system. The near right angle of intersection and vertical attitude of both systems suggest that these are regional orthogonal fracture systems common to areas that have been uplifted by upthrust tectonics (Gibbons (1972) in AmerenUE, 2004).~~

2.5.1.1.4.3 Seismic Sources Defined by Regional Seismicity

In 1986, the Electric Power Research Institute (EPRI) developed a seismic source model for the Central and Eastern United States (CEUS), which included the Callaway Site region (EPRI, 1986). The CEUS is a stable continental region (SCR) characterized by low rates of crustal deformation and no active plate boundary conditions. The EPRI source model included the independent interpretations of six Earth Science Teams and reflected the general state of knowledge of the geoscience community as of 1986. Each of these teams developed a tectonic framework, defined as the collection of tectonic features thought to have a non-negligible probability of generating magnitude 5 (mb) or greater earthquakes in the present stress regime due to tectonic processes, using comprehensive geophysical and seismological databases compiled in initial stages of the project. In order to develop their individual framework each of the six groups did: (1) interpret the crustal stress regime, (2) identify the tectonic features that might produce moderate to large earthquakes, (3) list and evaluate criteria for assessing the likelihood of activity of those features, and (4) quantify the probability of activity of each feature. Using this tectonic framework they later extended the tectonic evaluations and seismic source zones assessment to the entire Central and Eastern United States, for which they estimated seismicity parameters based on advanced and traditional analyses of the historical earthquake data set by means of a consistent, systematic format with full documentation (EPRI, 1986).

Seismic source zones have been configured either to coincide with tectonic features, or to envelope tectonic features and adjacent patterns of observed seismicity. The original seismic sources identified by EPRI are thoroughly described in the EPRI study reports (EPRI, 1986) and details for each are summarized in Sections 2.5.1.1.4.3.1 through 2.5.1.1.4.3.6. These sections present particulars of the interpretations from each of the six Tectonic Evaluation Contractors (TECs): Weston Geophysical Corporation, Dames & Moore, Law Engineering Testing Company, Woodward-Clyde Consultants, Bechtel Group, Inc., and Rondout Associates Incorporated. Each TEC was initially responsible for a particular region of the Central and Eastern United States. After these regional tectonics evaluations were made, each of the TECs extended the tectonic

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INSERT 'C' to FSAR Sections 2.5.1.1.4.1.8 and 2.5.1.1.4.2

(amended FSAR page 2-880)

2.5.1.1.4.1.8 {Gravity and Magnetic Data and Features of the Site Region and Site Vicinity

Significant gravity and magnetic anomaly datasets of the site region include regional maps of the gravity and magnetic fields in North America. The Bouguer gravity anomaly dataset here used (Kucks, 1999) is available in digital format via internet from the USGS website. The magnetic anomaly map was published in 2002 with improved reprocessing of existing data and compilation of a new and more complete database (Bankey, 2002 and USGS, 2002). These two data sets are illustrated on Figure 2.5-146 (Regional Magnetic Anomaly Map) and Figure 2.5-147 (Regional Gravity Anomaly Map)

Other sources of gravity and magnetic data are available from researchers in the New Madrid Seismic Zone (Mississippi Embayment) and Wabash Valley Seismic Zones (Illinois-Indiana), where interpretation of existing regional magnetic and gravity data as well as new local high-resolution aeromagnetic data provide insights into the tectonic history and structural development of these, and other local features (Hildenbrand, 1997; Bear, 1997; and Braile, 1997).

Recent publications have advanced the processing of the data and improved the data collection process, making it possible to refine the characteristics and tectonic interpretation of the structural complexities of the New Madrid and Wabash Valley Seismic Zones. However, the gravity and magnetic data published since the field investigation for Callaway Plant Unit 1 FSAR do not reveal any new anomalies related to geologic structures that were not identified previously.

2.5.1.1.4.1.8.1.1 Gravity Data and Features

The Bouguer gravity anomaly dataset used here (Kucks, 1999) is available in digital format via internet from the USGS website. Regional gravity anomaly maps are based on Bouguer anomalies onshore and free air gravity anomalies offshore.

The Bouguer gravity anomaly map shows no significant anomalies or gradients in the site vicinity or Central and Northern Missouri. On the other hand, the Bouguer gravity anomaly map does show a wide gravity high anomaly associated with the Reelfoot Rift, Mississippi Embayment, and the Illinois-Indiana border, south of the Illinois Basin.

The New Madrid seismic zone Bouguer anomaly map on Figure 2.5-147 reflects the seismic feature parallel to the Reelfoot Rift and suggests its close relation with the Reelfoot Rift as illustrated on Figure 2.5-148 (Regional Gravity Anomaly Map with Earthquake Overlay) which overlays the epicenters in the region on the gravity data shown on Figure 2.5-147. This Figure 2.5-148 shows that the gravity anomaly is associated with the earthquake activity in the Reelfoot Rift, Mississippi Embayment, and the Illinois-Indiana border, south of the Illinois Basin.

2.5.1.1.4.1.8.2 Magnetic Data and Features

The magnetic anomaly map was published in 2002 with improved reprocessing of existing data and compilation of a new and more complete database (Bankey, 2002 and USGS, 2002). The digital magnetic anomaly database and map for the North American continent is the result of a joint effort by the Geological Survey of Canada, U.S. Geological Survey, and Consejo de Recursos Minerales de Mexico.

INSERT 'C' to FSAR Sections 2.5.1.1.4.1.8 and 2.5.1.1.4.2

(amended FSAR page 2-880)

As seen on Figure 2.5-146, the site vicinity lies in a magnetic low reflecting the thick sedimentary rock cover found in the site vicinity, with basement found close to 2000 ft deep.

As described in section 2.5.1.1.4.1, in Hildenbrand (1997) for the Reelfoot Rift and Illinois Basin region, the major geophysical features include the south-central magnetic lineament (SCML) and the Paducah gravity lineament (PGL), both shown in Figure 2.5-146 and Figure 2.5-147. Even though the figures are based on two different data types, their relationship is evident.

2.5.1.1.4.1.8.3 **Summary Interpretation**

The maps on Figure 2.5-147 and Figure 2.5-146 show a belt of linear, but discontinuous gravity highs, with several positive aeromagnetic anomalies in the eastern part of the region of the site—well removed from the site. Positive gravity anomalies in the Mississippi Embayment are interpreted to be caused by high density rocks beneath the embayment that were emplaced during the late Pre-Cambrian to early Paleozoic rifting event or during Mesozoic reactivation of the rift.

As discussed in Hildenbrand (1997) for the Reelfoot Rift and Illinois Basin region, the major geophysical features include the south-central magnetic lineament (SCML) and the Paducah gravity lineament (PGL), both shown in Figure 2.5-146 and Figure 2.5-147. Even though these maps are for two different data types, their relationship is evident; Furthermore, the overlay of the seismicity on Figure 2.5-148, shows the relationship of modern tectonics and earthquake occurrences to the gravity and magnetic fields. Finally, it is apparent that the site is well removed from the effect of the anomalies and the major seismicity of the region.

2.5.1.1.4.2 REGIONAL FOLDING, FAULTING AND JOINTING

2.5.1.1.4.2.1 Regional Folding

Discussions of regional folding are confined primarily to folds within 50 miles (80.5 km) of the site area; however, distant or very large features, such as the Mississippi Embayment, that have a bearing on the various regional and site considerations with regard to geology and seismology are also included. These features are presented in Callaway Plant Unit 1 FSAR (AmerenUE, 2004) and updated with the information provided in MODNR (2007c), an institution engaged in collecting and cataloguing all structural features in Missouri into a searchable database.

Regional tectonic relationships suggest that most of the folding within the study region is Paleozoic in age (Gibbons 1972 in AmerenUE, 2004). Post-Paleozoic movement on some folds is suggested; however, the age of movement for some folds cannot be defined due to the absence of a younger rock sequence. The only area in the study region where past-Paleozoic folding can be demonstrated is in the Mississippi Embayment, where major movements occurred during the Cretaceous and Early Tertiary (see Section 2.5.1.1.4.1.2).

Movement of the Ozark Uplift during Late Paleozoic time has slightly affected the regional attitude of the rock strata. Within the site vicinity, a slight regional dip of 5 to 10 feet per mile to the northwest, away from the Ozark Uplift has been reported (Unklesbay, 1955 in AmerenUE, 2004). Folding in the site vicinity is discussed in Section 2.5.1.2.4.1.

INSERT 'C' to FSAR Sections 2.5.1.1.4.1.8 and 2.5.1.1.4.2

(amended FSAR page 2-880)

No seismic source is associated with any folded structure besides those described in Section 2.5.1.1.4.1, within the Class A features (Crone, 2000), in the Wabash Valley Seismic Zone, the Reelfoot Scarp and New Madrid Seismic Zone, and the St. Louis-Cape Girardeau liquefaction features in Section 2.5.1.1.4.3.2.

Dupo-Waterloo Anticline

The Dupo-Waterloo Anticline (No. 3 in Illinois on Figure 2.5-15) has an axial trend to the north-northwest. It extends from Monroe County, Illinois at its southern end, through St. Louis, Missouri and terminates before reaching the Cap au Grès Faulted Flexure about 12 miles (19 km) north of St. Louis (AmerenUE, 2004). Outcrops in the Dupo area reveal that the eastern flank of the structure has a dip of 2 to 3 degrees and the western flank has dips of up to 30 degrees. The anticline was probably active intermittently from Silurian time to post-Pennsylvanian time. Major movements appear to have occurred in late Mississippian or in pre-Pennsylvanian and pre-Pleistocene time (Bell, 1929 in AmerenUE, 2004). Near Waterloo, total structural relief is at least 500 feet 152 m).

Based upon outcrops and boring data, the southern end of the anticline is terminated in central Monroe County, Illinois about 35 miles (56.4 km) north of the Ste. Genevieve Fault Zone. Movements of the Ste. Genevieve Fault Zone occurred during the same period as did movements on the Dupo-Waterloo Anticline. Both structures may have resulted from the stresses established during elevation of the Ozark Uplift and downwarp of the Illinois Basin. No structural link, however is known or suspected to exist between the Dupo-Waterloo Anticline and the Ste. Genevieve Fault System.

MODNR (2007c) recognized the same structure crossing the Mississippi River and entering the City of St. Louis and noted its northwest-southeast extension passing the Compton Hill Reservoir and dying out near Grand Avenue. The St. Louis portion of this anticline is named the Workhouse anticline.

The Dupo oil field has been the largest producer of oil on the structure. Also, the Florissant field is located along the northern extension of this structure. It is an anticlinal structure steep to the west and gentler to the east with a series of closed structures lying along the apex.

Illinois Basin

The Wabash Valley Fault System is described in Section 2.5.1.1.4.1.1.1

LaSalle Anticlinal Belt

The LaSalle Anticlinal Belt (Figure 2.5-15) is an extensive asymmetrical fold that extends in Illinois from Lee County in the northwest to Lawrence County in the southeast. The west limb dips sharply into the deeper part of the Illinois Basin, while the east limb dips gently into the eastern shelf of the basin. The crest of the anticline plunges to the south-southeast. Initial deformation along the LaSalle Anticlinal Belt took place in post-Mississippian time. Deformation continued through Early Pennsylvanian time, particularly at the southern part of the structure. Renewed activity occurred after Pennsylvanian time, probably at the close of the Paleozoic Era (AmerenUE, 2004).

INSERT 'C' to FSAR Sections 2.5.1.1.4.1.8 and 2.5.1.1.4.2

(amended FSAR page 2-880)

Mississippi River Arch

The Mississippi River Arch is described in Section 2.5.1.1.4.1.5 with the combined Lincoln Fold.

Sangamon Arch

The Sangamon Arch (Figure 2.5-15) was formed by uplift in central and western Illinois during Devonian and Early Mississippian time. The arch extends from the Mississippi River Arch eastward to Macon and DeWitt counties in central Illinois. Although several hundred feet of Devonian and Silurian strata, normally present in surrounding areas, were either not deposited over or were eroded from the arch, later movements have masked the arch so that it does not show on structure maps of the area. It is a relic structure that is interpreted from stratigraphic evidence in the region.

Bourbon Arch

Merriam (1963 in AmerenUE, 2004) states that this is a low, indistinct, seemingly up-arched feature that rends almost east-west in eastern Kansas through parts of Bourbon, Allen, Anderson, Coffey, Woodson, Lyon, and Chase counties, separating the Forest City Basis on the north from the Cherokee Basin on the south (Figure 2.5-15). It is supposedly pre-Middle Pennsylvanian, post-Mississippian in age.

MODNR (2007c) describes this structure as a broad low structural divide of Mississippian rocks that separates the Forest City and Cherokee Basins. It trends to the northwest across Bourbon, Allen and Coffey Counties, Kansas and to the east from the Missouri-Kansas border into much of Vernon County, Missouri.

Cherokee Basin

The Cherokee Basin was formed by mild downwarp in Pennsylvania time (Merriam, 1963 in AmerenUE, 2004). It is bounded on the north by the Bourbon Arch and on the west by the Nemaha Uplift. It is the northern extension of the McAlester or Arkoma Basin of Oklahoma that developed in pre-Middle Pennsylvanian, post-Mississippian time. The maximum thickness of the sedimentary sequence in the basin is about 3,500 feet and consists of Permian and older rocks.

Nemaha Anticline

The Nemaha Anticline, or the Nemaha Uplift, is probably the most significant structural feature in Kansas. It is a major pre-Middle Pennsylvanian, post-Mississippian element that extends across Kansas from Nemaha County on the north to Summer County on the south and into Nebraska and Oklahoma (Merriam, 1963 in AmerenUE, 2004). The Nemaha has been subjected to extensive exploration. It is recognizable in surface rocks of Permian and Pennsylvanian age along most of its length but is more pronounced in the subsurface. The structure is faulted along the east side by both high angle reverse and normal faults. Precambrian rocks lie within 600 feet (183 m) of the surface along the crest of the uplift but plunge farther below the surface toward the south.

Forest City Basin

The Forest City Basin is described in Section 2.5.1.1.4.1.4.

The Mississippi Embayment

The Mississippi Embayment is described in Section 2.5.1.1.4.1.2.

The Ozark Uplift

The Ozark Uplift is described in Section 2.5.1.1.4.1.3.

Auxvasse Creek Anticline

The Auxvasse Creek Anticline (No. 2 in Missouri on Figure 2.5-15) is a structure in Township 8 North, Range 8 West, Callaway County, Missouri. It trends about North 75° West and is asymmetrical with a relatively steep (average of 6°) southwest limb and a gently dipping (1°) northeast limb. Devonian rocks occur at the surface along the axis of the fold, which has about 175 feet (53.3 m) of structural relief. Formation of the anticline occurred during Mississippian and possible as early as Devonian time. Pennsylvanian strata are deformed on the structure, indicating that the folding continued into Pennsylvanian time. No evidence of faulting has been reported.

MODNR (2007c) describes this broad asymmetrical structure as striking northwest with a steep southwest limb. The structure trends N. 75° W. Devonian rocks crop out on the crest and beds as young as Marmaton are deformed. Barrett (1940 in MODNR (2007c) thought this was an extension of the Browns Station anticline and that it was en echelon with the Mineola structure, and notes that the anticline has 175 ft (53.3 m) of structural relief. The southwest limb has a dip of 6.5°, while the northeast limb has a dip of less than 1°. The entire structure pitches at an angle of 5°, noting evidence for recurrent upward movements that were prior to Burlington deposition and post-Marmaton, and postulating the original structural development as possibly late Devonian.

Big Spring Anticline

The Big Spring Anticline (see No. 4 in Missouri on Figures 2.5-15) trends North 60° West in Sections 24 and 25, Township 47 North, Range 5 West, Montgomery County, Missouri. The fold is gentle, but brings a broad area of St. Peter Sandstone to the surface where it is surrounded by younger strata. MODNR (2007c) describes this structure as having an anticlinal axis trending N 60° W in the north-central part of the New Florence Quadrangle.

Brown Station Anticline

The Browns Station Anticline (see No. 9 in Missouri on Figure 2.5-15) trends northwest across northern Boone County, Missouri. It is a faulted asymmetrical anticline with dips up to 35° on the southwest flank. Total structural relief is approximately 400 feet (122 m). Movement occurred recurrently in Mississippian time (Unklesbay, 1952 in AmerenUE, 2004). Maximum movement probably took place at the end of the Mississippian. Significant movements continued at least into Pennsylvanian time, and perhaps there was some post-Pennsylvanian movement. The structural deformation can be seen in surface outcrops. Based on structure contours drawn on top of the Mississippian age Sedalia Formation from water well data obtained from the Missouri Geological Survey and Water Resources, the Browns Station Anticline terminates in Township 48 North, and Range 11 West, near the boundary between Boone and Callaway counties.

Cuivre Anticline

The Cuivre Anticline (see No. 18 in Missouri on Figure 2.5-15) is a small structure located southwest of the Lincoln Fold in Townships 49 and 50 North, Rages 1 West and 1 East, Lincoln County, Missouri. It is separated from the Lincoln Fold by the Troy-Brussels Syncline. The axis of the Cuivre Anticline strikes North 80° West and plunges southeast at about 40 feet per mile. The anticline has about 200 feet (61m) of structural relief and was mapped from borehole data in the area (Gross, 1949 in AmerenUE, 2004).

MODNR (2007c) describes the structure as a small anticline is separated from by the Troy-Brussels syncline. It plunges southeast at about 40 feet per mile. The axis strikes N. 80° W. and appears to fade out along the east boundary of the Elsberry quadrangle. The anticline is here named for Cuivre River, which flows through the area adjacent on the south.

Davis Creek Anticline

The Davis Creek Anticline (see No. 19 in Missouri on Figure 2.5-15) is a northwest trending structure in Townships 50 and 51 North, Ranges 9, 10, and 11 West, Audrain County. The anticline is covered by glacial drift and its presence has been established from borehole data. Pennsylvanian strata have been eroded from the crest of the structure, leaving an inlier of Mississippian rocks that is masked by glacial drift.

MODNR (2007c) describes the Davis Creek anticline as the structure extending northwest from Sec. 30, T. 50 N., R. 9 W., and is noted as a structure near the Gant settlement. McQueen (1943 in AmerenUE 2004) states that much of the Mississippian inlier is masked by drift on the surface. Subsurface data were used to map the structure. In addition, the Graydon conglomerate and the Burlington Limestone are exposed in the Valley of Davis Creek.

Eureka-House Springs Anticline

The Eureka-House Springs Anticline (see No. 21 in Missouri on Figures 2.5-15) extends northwestward from House Springs, Missouri, Section 3, Township 42 North, Range 4 East, through Eureka, Missouri, Section 36, Township 44 North, Range 3 East. The structure is best developed between Eureka and House Springs and appears to plunge both to the northwest and southeast. The structure persists in a northwest direction in several outcrops of the Chouteau Group between Wentzville and Wright City, Missouri. Wells drilled in the town of Laddonia encountered Mississippian strata immediately under a thin veneer of drift or alluvium (McCracken, 1971 in AmerenUE, 2004). The age of the anticline is postulated to be Late or post-Paleozoic.

MODNR (2007c) show this structure consisting of an anticline and a series of closely spaced faults that strike parallel to the axis of the anticline.

Clendenin in MODNR 2007c) separated the two structural features calling the anticline the Eureka-House Springs structure and the parallel faults the Eureka-House Springs fault system.

The anticline can be traced from Sulfur Springs northwestward in Glaze Creek through the House Springs-Eureka area to north of St. Albans island where the fold crosses the Missouri River to the Daniel Boone fault zone near Defiance, Missouri. Mapping indicates that this anticline is fairly continuous along strike and that it plunges southeast toward Sulfur Springs and northwest across the Missouri River toward Defiance. Exposures in Glaze Creek and along the Missouri River show that the fold is asymmetric with a steeper northeast flank.

The structure exposed south of Eureka on Route W and northeast of House Springs on Highway 30, which is referred to as the Eureka-House Springs structure, is part of what is here termed the Eureka-House Springs fault system. The Eureka-House Springs fault system strikes northwest and lies to the southwest of the previously described anticline. The two structures are subparallel and are separated by less than 1000 m through the House Springs-Eureka area. The juxtaposition of the two structures and the structural style of the Eureka-House Springs fault system are believed to be reasons for lack of differentiation."

The Eureka-House Springs fault system is a highly complex structure involving uplift and left lateral strike-slip.

Fish Creek Anticline

The Fish Creek Anticline (see No. 23 on Figure 2.5-15) trends northwest through northeastern Saline County, Missouri. It is part of the Saline County Arch. The structure is asymmetrical with a steep southwest flank. Uplift of more than 100 feet (30.5m) has brought the Mississippian Chouteau Formation to the surface. The anticline plunges gently to the southeast and terminates in Township 48 North, Range 14 West based on well data available from the Missouri Geological Survey and Water Resources.

Saline County Arch

Although shown as a prominent tectonic feature on the Structural Features Map of Missouri (McCracken, 1971 in AmerenUE 2004), the Saline County Arch is actually the southwest flank of the Fish Creek Anticline, and should not be considered as a separate and distinct structural feature. It is bounded on the southwest by the parallel-trending Saline City Fault.

MODNR (2007c) reports that this rather pronounced structure was described in Middle Ordovician rocks in an outcrop six miles north of Arrow Rock, while to the south and north, Mississippian crops out. The southwest limb is steep with a gentle northeast dip from a northwest axis (N. 55° W.). The crest crosses the Missouri River near Bluffport, NW corner of Sec. 31, T. 51 N., R. 18 W. Steep dips on the southwest limb show up near Buster Branch, Sec. 23, T. 50 N., R. 18 W.

The precise location of the crest of the fold, as described by Dwight, is one-fourth mile south of the north line of the NE ¼ Sec. 14, T. 50 N., R. 17 W., Howard County. The fold plunges southeast. This is the Howard County expression of the Saline City fault and anticline in Saline County to the northwest,

Kruegers Ford Anticline

The Kruegers Ford Anticline (see No. 36 in Missouri on Figure 2.5-15) is a fold in Gasconade and Osage counties, Missouri. The structure strikes northeast and has a steep southeast flank. There is about 50 feet (15.2 m) of structural relief that brings the Ordovician Roubidoux Formation to the surface where the crest crosses the Gasconade River. Some movement along the structure occurred in post-Pennsylvanian time.

MODNR (2007c) describes this structure as represented by a window of Roubidoux along the Gasconade River valley in the vicinity of Bay. It strikes northeast, with the steep flank on the southeast, and the similarity between this and the Mexico anticline. There has been no deep drilling on this structure which occurs in an area of thin Roubidoux. It may lie along a Precambrian ridge or peak.

Lincoln Fold

The Lincoln Fold is described in Section 2.5.1.1.4.1.5 with the combined Mississippi River Arch.

Mexico Anticline

The Mexico Anticline (see No. 45 in Missouri on Figure 2.5-15) strikes northeast through the town of Mexico, Audrain County, Missouri. The structure was mapped from subsurface records, and there appears to be more than 200 feet (61 m) of structural relief present on the Mississippian strata. Marked erosion of the Mississippian rocks occurred on top of the structures prior to deposition of the overlying Pennsylvanian strata. However, the latter were also involved in the folding, indicating that movement occurred during or after the close of Pennsylvanian time as well as at the close of Mississippian time.

McQueen (1943) in MODNR (2007c) describes this anticline as striking northeast approximately normal to the general northwest-trending structures of the area. The axis passes through the town of Mexico where it was detected by elevations of formations in well logs. Fire clay deposits mined by the A. P. Green Refractories Company are located along its east flank.

Mineola Dome

The Mineola Dome (see No. 46 in Missouri on Figures 2.5-15) is a closed anticline or asymmetrical dome, possibly faulted on its southwestern side, with a short north-south axis. It is located in Township 48 North, Range 6 West, Montgomery County, Missouri. It has a steep south-southwest dip and a more gentle north-northeast dip. The Mineola structure brings Cotter (Lower Ordovician) rocks to the surface in Loutre Creek, where they are surrounded by rocks ranging in age from Middle Ordovician to Pennsylvanian (McCracken, 1971 in AmerenUE, 2004).

Pascola Arch

The name Pascola Arch (see No. 52 in Missouri on Figure 2.5-15) was given by Grohskopf 1955 in AmerenUE 2004) to a subsurface structural feature affecting the Paleozoic rocks of southeast Missouri. The arch appears to have at least 8,000 (2438 m) and possibly as much as 12,000 feet (3658 m) of sedimentary rock removed by erosion in post-Paleozoic time and later subsided to form part of the upper Mississippi Embayment. Paleozoic rocks in the center of the arch are Cambrian in age with rocks of Ordovician age surrounding the core of the structure. It is possible that the Pascola Arch of Grohskopf is a separate domed area similar to the Farmington or Proctor anticlines in Missouri, but it is, in general, a part of the overall Ozark Uplift (McCracken, 1971 in AmerenUE, 2004). Buschbach (1978 in AmerenUE, 2004) pointed out that the epicenters of the 1811-1812 New Madrid earthquakes as well as much of the recent seismic activity in the New Madrid region are located in the structurally complex area where the Pascola Arch intersects the Reelfoot Rift and Mississippi Embayment. Stauder et al. 1976 in AmerenUE, 2004) found that northwest trending linear seismically active zones had been detected by a regional micro earthquake network in the New Madrid Seismic Zone. They determined that these trends are parallel to and possible related to the crest of the Pascola Arch.

Rhea and Wheeler describe in MODNR (2007c) the structure as a wide, gentle uplift that is elongated northwest-southeast. The broad dome of the Pascola arch coincides with the smaller Lake Country arch in Tennessee and the area of intense seismicity between New Madrid, Missouri and Dyersburg, Tennessee.

The arch is about 100 km wide from northeast to southwest (unpublished data, Dart, 1992). It trends across the Reelfoot rift and forms a divide between the Reelfoot basin located to the northeast and the Mississippi Valley basin located to the southwest.

The name Pascola arch was given by to a subsurface structural feature affecting the Paleozoic rocks of southeast Missouri. The arch appears to have been completely beveled in post-Paleozoic (post-Early Devonian) time and later downwarped to form part of the Mississippi embayment. Thus, the structural high is now in reality a topographic low.

Pershing-Bay-Gerald Anticline

The Pershing-Bay-Gerald Anticline was thought to be a regional structure trending generally northwest from western Franklin County through Gasconade County, Missouri (McQueen, 1943 in AmerenUE, 2004). In an attempt to define the Pershing-Bay-Gerald structure, logs of wells in the area from the Missouri Geological Survey and Water Resources files were examined. Based on this data, a structure contour map was drawn on top of the Roubidoux Formation, a reliable, easily recognizable, and conformable horizon over a large area. The resulting structure map did not show a northwest-southeast trending structure comparable to McQueen's Pershing-Bay-Gerald Anticline. In light of this subsurface data, which was not available to McQueen in 1943, it is concluded that there is not sufficient structural definition in the subsurface to warrant the designation of a northwest-southeast trending Pershing-Bay-Gerald Anticline.

MODNR (2007c) describes this structure as a regional anticline passing through the villages of Pershing, Bay, and near Gerald, to the faulted area near Anaconda. No information as to magnitude or symmetry of the structure is given

Proctor Anticline

The Proctor Anticline (see No. 56 in Missouri on Figure 2.5-15) is the main structural feature in Morgan County, Missouri. It trends North 25° to 30° West and extends to the southeast into Camden County. The steeper west flank dips about 4°, whereas, the east flank dips about 1°. The Cambrian Eminence Dolomite was brought to the surface in late Paleozoic or early Mesozoic time (Marbut, 1907 in AmerenUE, 2004). From Marbut's (1907 in AmerenUE, 2004) structure map, there appears to be about 200 feet (61 m) of structural relief on the anticline.

MODNR (2007c) dates the structure as late Paleozoic or early Mesozoic. Graves (1938) in AmerenUE (2004) considered this a part of a Precambrian fault block which had some later rejuvenation. At the southeast end of the Proctor anticline - fault, the fault is downthrown to the northeast forming one side of the Montreal graben.

Troy-Brussels Syncline

The Troy-Brussels Syncline (see No. 65 in Missouri on Figure 2.5-15) separates the Cap au Grès Faulted Flexure from the Ozark Uplift. The syncline extends westward from just south of Alton, Illinois, to Troy, Lincoln County, Missouri with its deepest part against the eastern flank of the Cap au Grès Structure (see Section 2.5.1.1.4.1.5). The synclinal axis plunges eastward and climbs gradually westward toward the Ozarks. The Troy-Brussels Syncline apparently formed as a result of drag along the downthrown side of the Cap au Grès Flexure (Rubey, 1952) from late Mississippian to post-Pennsylvanian time.

Krey (1924) in MODNR (2007c) described a syncline south of the Cap au Grès fault which plunged gently east with an east-west strike and named it the South Lincoln County syncline. The same structure was studied by Rubey (1952) in MODNR (2007c), who named it the Troy-Brussels syncline. He believed the syncline to be produced by drag along the downthrown side of the Cap au Grès fault. The name South Lincoln County syncline preceded Rubey's name; however, Rubey's term generally has been accepted.

Warren County Anticline

The Warren County Anticline (see No. 66 in Missouri on Figure 2.5-15) trends north-south in Township 4 North, Range 2 West, Warren County, Missouri. The Mississippian-age Chouteau Formation is exposed at the crest with younger Burlington Limestone surrounding the inlier. Major movement occurred in post-Mississippian time.

MODNR (2007c) describes this structure two miles (3.2 km) west of Warrenton. Chouteau limestone is exposed on the crest of the structure with Burlington limestone surrounding it. Both formations are Mississippian in age, suggesting a post-Mississippian age for the structure

Florissant Dome

The most productive oil field in Missouri is located on the Florissant Dome (see No. 24 in Missouri on Figure 2.5-15). This nearly circular, closed structure lies on a larger northwest-southeast trending structure, the Dupo-Waterloo Anticline, which passes through eastern St. Louis County, Missouri from the Cap au Grès Faulted Flexure, southeast to Dupo and Waterloo, Illinois. The Laclede Gas Company maps of the dome indicate 100 feet (30.5 m) of closure on the St. Peter Formation. The structure was drilled by Laclede Gas Company of St. Louis as an underground natural gas storage facility. The reservoir rock is the St. Peter Formation Sandstone of Middle Ordovician age.

Cuba Anticline

The Cuba Anticline (see No. 68 in Missouri on Figure 2.5-15) is adjacent and immediately to the west of the Cuba Fault. It extends approximately 25 miles (40.2 km) from Township 39 North, Range 6 West in Maries County north-northwest to Township 43 North, Range 7 West in Osage County, where it terminates. It has over 100 feet of relief based on contours on top of the Roubidoux Formation. Data for the Roubidoux map were obtained from the well log files at the Missouri Geological Survey and Water Resources and from Donald E. Miller, geologist, Missouri Geological and Water Resources during the field investigations for Callaway Plant Unit 1 FSAR (AmerenUE, 2004).

2.5.1.1.4.2.2 Regional Faulting

Discussions on regional faulting include faults within 50 miles (8o km) of the site area. Distant features that have a bearing on the various regional and site considerations with regard to geology and seismology are also included. Regional faults are updated with the information provided in MODNR (2007), an institution engaged in collecting and cataloguing all structural features in Missouri in a searchable database.

Three Class "A" features in Crone, 2000 were included in this section: the Faults of Thebes Gap Area (Missouri, No 6 in Figure 2.5-149), the Western Lowlands liquefaction features (Missouri-Arkansas, listed as No 3 in Figure 2.5-149), and the St. Louis-Cape Girardeau liquefaction features (Missouri-Illinois, listed as No 4 in Figure 2.5-149), were included in this section. Also included is the Slinkard Quarry Graben (Wheeler, 2005), a Class "A" feature within the city limits of Cape Girardeau, Missouri.

Centralia Fault

The Centralia Fault (see No. 1 in Illinois on Figure 2.5-14) trends nearly north-south parallel to and 1 mile (1.6 km) east of the DuQuoin Monocline in Marion and Jefferson counties, Illinois. It is a zone of several parallel faults. Net displacement is downward to the west, with maximum displacement of about 200 feet (61 m). The faults can be seen in several coal mines in the Centralia area, but they are not visible at the land surface. The faults appear to have developed after folding took place on the DuQuoin Monocline. Relief of the stresses was upward on the east side, opposed to the east dip of the monocline. The faulting occurred in post-Pennsylvanian, pre-Pleistocene time (Buschbach, 1973 in AmerenUE, 2004).

Fluorspar Area Fault Complex

The Fluorspar Area Fault Complex (see No. 2 in Illinois on Figure 2.5-14) is an area of numerous northeast to nearly east trending faults centered in Hardin and Pope counties, Illinois, and in Crittenden and Livingston counties in Kentucky. The complex extends southward from the Rough Creek Lineament to some focal point beneath the Cretaceous deposits of the Mississippi Embayment in western Kentucky. Maximum displacements of about 2,000 feet (610 m) are present on the northeast trending faults. Numerous cross faults with lesser displacements form a complex mosaic pattern (Baxter, 1963, 1965; 1967 all in AmerenUE, 2004). Although the faulting is reported to be dominantly normal, some faults have been formed by thrust (compression) faulting. Slickensides along the fault planes suggest that there have been important horizontal components in the movements. Displacements along some faults appear to have taken place at different angles at different times.

Crone, 2000 reports that the Fluorspar Area fault complex refers to the multitude of fractures in the fluorspar-mining district of southern Illinois and western Kentucky. Fault orientations vary, but most trend NE-SW in Illinois, curving to ENE-WSW eastward into Kentucky. Most faults dip 65 degrees or steeper and they comprise normal, reverse, strike-slip, and oblique slip faults, many showing evidence of two or more episodes of movement. Associated with faulting are Permian ultramafic dikes, sills, diatremes, and a large intrusive breccia structure known as Hicks Dome. This was historically the richest fluorite-mining district in the United States. Sizeable quantities of lead, zinc, silver, barite, and other minerals also were mined from vein and bedded-replacement deposits. The Fluorspar Area Fault Complex overlies the junction area of a Proterozoic-Cambrian failed rift complex that consists of the northeast trending Reelfoot rift and the east-trending Rough Creek graben. Of more than passing significance, the New Madrid seismic zone also lies within the Reelfoot Rift and is directly in line with the Fluorspar Area fault complex. The Fluorspar Complex consists of six (6) main subdivisions of faults. They are the Rock Creek Graben, Barnes Creek Fault, Hobbs Creek Fault, Raum Fault Zone, Lusk Creek Fault, and the Kelley Structure.

Rock Creek Graben
The Rock Creek graben is a large, complex graben of the Fluorspar Area Fault Complex. The Rock Creek follows a curving path southwestward from Union County, Kentucky into Hardin County, Illinois, back into Kentucky, finally returning to Pope and Massac Counties, Illinois where Quaternary activity is in evidence. Overall, the Rock Creek graben is composed dominantly of high-angle normal faults that trend northeast.

Barnes Creek Fault Zone
The fault zone has been mapped about 40 km across Illinois. It strikes NE-SW, and along most of its length consists of either a single fault or a pair of faults that outline a graben less than 300 m wide. Where it enters the Mississippi Embayment, the Barnes Creek widens to nearly 2 km and becomes much more complex. It is here that Quaternary deformation has been demonstrated. Strike-slip component is strongly suspected. A seismic profile shows positive and negative flower structures. Deep, narrow pull-apart grabens are common. Most faults dip 65 degrees or steeper.

Hobbs Creek fault zone
Seismic profiles show that most faults are high-angle normal, but a few reverse faults are present. As with other faults listed here, strike-slip appears likely, but no information on the magnitude or direction of strike-slip is available. Most faults dip to the southeast or northwest 70 to 90 degrees. Pairs of faults commonly outline grabens and horsts.

Raum fault zone
The Raum fault zone outlines the southeast side of the Dixon Springs graben, one of several large, complex grabens within the Fluorspar Area Fault Complex. Most faults are high-angle normal, but high-angle reverse faults are present. Most faults dip to the southeast and northwest 70 to 90 degrees.

Lusk Creek fault zone
The Lusk Creek fault zone delimits the northwest margin of the Fluorspar Area Fault Complex and also was a northwest boundary fault of the Proterozoic-Cambrian Reelfoot Rift. The net displacement is down to the southeast and increases toward the northeast, where the Lusk Creek merges with the western end of the Rough Creek Fault System. Principally high-angle normal faults, but high-angle reverse faults are present.

The Lusk Creek Fault Zone trends North 35° East from the northeastern corner of Massac County, Illinois and extends into Hardin County, Illinois where it terminates against the Herod Fault and the Shawneetown Fault Zone (Stonehouse and Wilson, 1955 in AmerenUE, 2004). According to Weller et al. (1952 in AmerenUE, 2004) and Lusk Creek Fault Zone is a complex structure consisting of normal and reverse faults. Closely spaced drilling has shown that faulting is more abundant and more complex than surface features indicate. The faulting cuts Pennsylvanian strata and the southern end of the Lusk Creek Fault Zone is overlain by unfaulted Cretaceous deposits (Willman et al., 1967 in AmerenUE, 2004). The faults are considered to be younger than igneous dikes which have intruded the sedimentary strata (Grogan and Bradbury, 1968 in AmerenUE, 2004). The igneous intrusions have been dated from stratigraphic relationships as later than Middle Pennsylvanian (Clegg and Bradbury, 1956 in AmerenUE, 2004) and from K-Ar methods as Permian or older (Zartman et al, 1967 in AmerenUE, 2004). From the history of crustal movements in the Illinois basin, faulting is post-Pennsylvanian, pre-Late Cretaceous, or possibly Paleocene (Atherton, 1971 in AmerenUE, 2004). There are a few faults in Kentucky near the Lusk Creek Fault Zone that displace Cretaceous deposits and possibly some Paleocene deposits (Olive, 1972 in AmerenUE, 2004). Olive shows no faults displacing the Claiborne Formation of Eocene age.

The southwestern part of the complex is in a seismically active area, and several workers have associated modern earthquakes with the faults. The intensity of these earthquakes, however, is lower than in the New Madrid Seismotectonic Region to the south (see discussion in Section 2.5.2).

Field work has been performed by the Illinois State Geological Survey in an effort to provide evidence which might support or negate the existence of structural continuity between the New Madrid Seismic Zone and the faulting in the Fluorspar Area Fault Complex. Faulting of the Paleozoic rocks on the northeast where they are exposed at the surface was confirmed as being post-Paleozoic and pre-Late Cretaceous in age.

Examination of apparent faulting in unconsolidated Tertiary and Quaternary deposits that overlie the Paleozoic rocks to the southwest beneath the Mississippi Embayment has been examined. However, it has yielded no unequivocal evidence of tectonic faulting in the Illinois part of the Mississippi Embayment during or after Late Cretaceous time. Faulting found in the overlying unconsolidated deposits was attributed to landslides and solution collapse (Kolata, 1978 in AmerenUE, 2004; Kolata et al., 1979 in AmerenUE, 2004).

Kelley structure

The Kelley structure, which trends N-S to NNW-SSE, lies along what may be a cross-fault connecting the Lusk Creek and Raum fault zones. Most faults are normal and reverse faults.

Rough Creek Lineament

The Rough Creek Lineament (see No. 3 in Illinois on Figure 2.5-14) is a series of faults and fault zones extending generally east-west through western Kentucky and southern Illinois. In

Kentucky, it includes the Rough Creek Fault Zone (Sutton, 1953 in AmerenUE, 2004; Stonehouse and Wilson, 1955 in AmerenUE, 2004). In Illinois, it includes the east-west portion of the Shawneetown Fault Zone to the east and the Cottage Grove Fault System to the west.

Heyl (1972, 1977 in AmerenUE, 2004) suggests that strike-slip faulting or wrench faulting is a major component in the Rough Creek Lineament. He tentatively includes the lineament in a line or zone of faults, monoclines, and igneous intrusions. The line extends east-west for 800 miles (1287.5 km) along the 38th parallel from West Virginia to at least as far west as the Ozark Uplift in south-central Missouri. In the Illinois-Missouri-Kentucky region the lineament appears as a complex of faults, associated magnetic and gravity anomalies, and breaks in magnetic anomaly patterns (Lidiak and Zietz, 1976 in AmerenUE, 2004; Hinze et al., 1977 in AmerenUE, 2004; Braile et al., 1978 in AmerenUE, 2004; Heyl, 1977 in AmerenUE, 2004).

The Rough Creek Lineament appears to form the northern boundary of the Rough Creek Graben that developed in Precambrian rocks before late Cambrian time. The zone of weakness was reactivated near the close of the Paleozoic Era (Buschbach, 1978 in AmerenUE, 2004). North of this lineament in southeastern Illinois is the Fairfield Basin, the deepest part of the Illinois Basin. The Rough Creek Graben is now considered to be relatively inactive, being seismically indistinguishable from the craton (Wheeler, 1997).

This feature lies within a structural province with demonstrated upthrusting associations. It is, therefore, likely that the Rough Creek-Cottage Grove-Shawneetown System may represent a series of upthrust faults along block boundaries similar to those in the eastern Ozarks

In Illinois, the lineament is dominated by numerous high angle reverse faults with the south side upthrown and there are a number of normal faults (Weller et al., 1952 in AmerenUE, 2004). The faults display evidence of some horizontal movement. The eastern part of the lineament, the Shawneetown Fault Zone, is dominated by thrust faulting. Displacement is locally as great as 3,400 feet (1036 m) and may be considerably more. The Shawneetown Fault Zone extends westward along the prominent hills in southern Gallatin County, curves southward from Cave Hill in Saline County, leaves the Rough Creek Lineament and joins the southwest-trending Herod Fault to the Lusk Creek Fault Zone.

The Shawneetown Fault Zone cuts Pennsylvanian strata and is presumed to be post-Pennsylvanian in age (Willman et al., 1967 in AmerenUE, 2004). The southern end of the Lusk Creek Fault is overlain by unfaulted deposits of Cretaceous age and therefore, it is inferred that the most recent faulting within the Shawneetown Fault Zone is post-Pennsylvanian, pre-Late Cretaceous (Buschbach, 1973 in AmerenUE, 2004). The western portion of the lineament, the Cottage Grove Fault System, extends from Saline County westward to Jackson County, Illinois and appears to have formed at roughly the same time as the Shawneetown. Displacements are diminished, with maximum displacements of about 250 feet (76 m). Pennsylvanian strata are cut by the faulting and therefore the age of faulting along the Cottage Grove Fault Zone is presumed to be post-Pennsylvanian, pre-Late Cretaceous (Willman et al., 1967 in AmerenUE, 2004; Buschbach, 1973 in AmerenUE, 2004).

The geometry described by Heyl (1972, 1977 in AmerenUE, 2004) does not coincide with the geometries of buried strike slip faults in analogous situations in other localities (Ottawa-Bonechere structure, Oklahoma en echelon fault zone, Montana Lineaments). These features display lineaments composed of en echelon normal faults, giving rise to an elongated belt of horst and graben terrain. No reverse faulting is predicted by dynamic models of such structures (Friedman, 1967 in AmerenUE, 2004; Billings, 1972 in AmerenUE, 2004). Limited reconnaissance by Gibbons (1972 in AmerenUE, 2004) during his study of the eastern Ozarks suggested strong similarities with the structural style of the Ste. Genevieve Fault System. Upthrust faulting and minor features observed by Heyl (1972, 1977 in AmerenUE, 2004). Large vertical displacements associated with reverse faulting, compensatory normal faults, monoclines and horizontal movements along minor faults are all common features in upthrust terrains (Prucha, et al., 1965 in AmerenUE, 2004). This feature lies within a structural province with demonstrated upthrusting associations. It is, therefore, likely that the Rough Creek-Cottage Grove-Shawneetown System may represent a series of upthrust faults along block boundaries similar to those in the eastern Ozarks.

Wabash Valley Fault System

The Wabash Valley Fault System (No. 5 in Illinois on Figure 2.5-14) is described in Section 2.5.1.1.4.1.1.1.

Chesapeake Fault Zone

The Chesapeake Fault (see No. 1 in Kansas and No. 8 in Missouri on Figure 2.5-14) is a major structure that is best developed in eastern Lawrence County, Missouri (McCracken, 1971 in AmerenUE 2004). MODNR (2007c) describes the fault as highly visible in quarries and road cuts. It was first described by Newton (1894) in MODNR (2007c) who gave it the name Chesapeake-Kirbyville anticline. Rutledge (1921a in MODNR 2007c) was the first to describe the structure as a fault extending from the center of the east line of Sec. 12, T. 27 N., R. 25 W., to some 25 miles northwest across Lawrence County into Dade County. He states that while brecciation along the fault plane is not conspicuous, some is present (SW ¼ NE ¼ Sec. 22, T. 28 N., R. 25 W., south side of road). Local dolomitization of the upper Burlington-Keokuk and Reeds Spring formations is found in the vicinity of the fault. He also noted that formations near the fault assume a steep dip in the direction of the down thrown side and are near-vertical near the fault plane. Rutledge named the fault and dated it as late Mississippian, since a Pennsylvanian channel sandstone that crosses the structure (Sec. 1, T. 27 N., R. 25 W.) is not displaced

McCracken and McCracken (1965 in AmerenUE 2004) extended the fault to the Kansas line by structure contouring of widely scattered drill hole data on the base of the Roubidoux Formation. Cole (1962, 1976 in AmerenUE 2004) extended the fault into Bourbon County, Kansas and shows approximately 100 feet (30.5 m) of downward displacement to the northeast. The control for extending this structure into eastern Kansas is extremely sparse and therefore, the extension of this fault into Kansas is inferred.

Thompson (1995 in AmerenUE 2004) in MODNR (2007c) show the fault crossing Interstate Highway 44 in Lawrence County. The fault extends into western Christian County and further south, in Stone and Taney Counties, is aligned with the Ponce de Leon graben and Ten O'clock fault and monocline.

For most of its course, the structure offsets Ordovician and Mississippian formations. Portions of the upthrown side form topographic highs. The throw of the structure is variable, but is as high as 175 feet (60 m). High angle dips are common along the structure

A small fault, also trending northwest t from the Kansas/Missouri border located north of the Chesapeake Fault, has been inferred from sparse control (Cole, 1976 in AmerenUE 2004). It had been previously interpreted as a bedrock valley. An extension of this fault is not mapped to the southeast in Missouri (Missouri Geological Survey, 1979 in AmerenUE 2004; McCracken 1971 in AmerenUE 2004).

INSERT 'C' to FSAR Sections 2.5.1.1.4.1.8 and 2.5.1.1.4.2
(amended FSAR page 2-880)

Bolivar-Mansfield Fault System

The Bolivar-Mansfield Fault System (see No. 5 in Missouri on Figure 2.5-14) is a broad zone of discontinuous, generally parallel faulting that extends northwest from Douglas through St. Clair and Bates counties, Missouri into Kansas. Many of the individual faults in this system have been named separately. This zone may extend southeastward into Arkansas (McCracken, 1971 in AmerenUE 2004) and has been extended northwestward through Bates County by Gentile (1965, 1976 in AmerenUE 2004). The Eldorado Springs North fault has been extended from Bates County into Kansas (McCracken, 1971 in AmerenUE 2004) and is shown as an unnamed fault on the top of the Precambrian in Linn County, Kansas by Cole (1976 in AmerenUE 2004). It had previously been interpreted as a valley on the basement surface (Cole, 1962 in AmerenUE 2004). The system appears to border the southwest flank of the Ozark Uplift. Faulting is mostly high angle normal, with throws of up to 300 feet (91.4 m) (McCracken, 1971 in AmerenUE 2004). The faulting involves beds ranging in age from early Pennsylvanian (Cherokee Group) to early Ordovician (Roubidoux Formation).

Cap au Grès Faulted Flexure

The Cap au Grès Faulted Flexure (see No. 7 in Missouri on Figure 2.5-14) is a sharp monoclinal fold that extends east-southeast through Lincoln County, Missouri, then generally east through southern Calhoun and Jersey counties in Illinois. The rocks dip steeply on the southern flank of the structure, and the maximum amount of structural relief is 1,000 to 1,200 feet (304.8 to 365.8 m). Faults that occur along the flexure generally are downthrown to the south and have displacements from a few to a few hundred feet. Limited exposures in the area make it difficult to determine the extent and continuity of the faults. Major deformation along the Cap au Grès Faulted Flexure took place in post-Middle Mississippian, pre-Pennsylvanian time. A minor amount of deformation occurred in post-Pennsylvanian, pre-Pleistocene time. Pennsylvanian strata south of the flexure are considerably lower than outliers of similar strata north of the flexure. In addition, the Calhoun peneplain bevels the edges of tilted Pennsylvanian strata in the area, indicating post-Pennsylvanian movement. Displacement probably occurred in Pliocene time and amounts to little more than 100 feet(30.5 m). No evidence has been found to indicate any deformation of Pleistocene deposits in the area (Buschbach, 1975 in AmerenUE 2004). A pair of northwest-trending anticlines, the Dupo-Waterloo Anticline to the south and the Lincoln Fold to the north, end abruptly against the flexure. Both anticlines have their steeper flanks to the west, and they appear to have similar geologic histories. The crests of the anticlines are offset about 30 miles (48.3 km) (Cole, 1961 in AmerenUE 2004).

Potter (1872) in MODNR (2007C) describes a great fault south of the anticlinal fold crossing Lincoln County in a N. 30° W. direction. He did not name the fault. Ringena (1949b) in MODNR (2007c) suggest the structure to be a "break thrust" fault. The alignment of the Lincoln fold and Waterloo-Dupo anticline (both old features dating from Precambrian time) is parallel to the major northwest-southeast structural grain of Missouri (MODNR, 2007c). Those features are offset at the Cap au Gres fault. In conclusion, Cole states, "It seems possible then from the foregoing evidence to conclude that the Cap au Gres is a left lateral fault that has experienced movement of approximately 30 miles, offsetting the Lincoln fold and the Dupo-Waterloo anticline."

Mapping by Harrison (1995) in MODNR (2007c) for the Eolia quadrangle expanded the geological understanding of the fault. The Cap au Grès structure, a major feature of regional extent, changes northward from a faulted asymmetrical, monoclinal fold having relatively high structural relief to a broad anticline having low structural relief. Within 20 miles northwest of the quadrangle, the Cap au Grès structure dies out, and structural relief steps over to the en echelon Lincoln fold, another feature of regional extent. Together, these structures constitute a fault-fold system that is consistently down to the southwest and that extends more than 200 miles. Structural relief across these features increases southeastward to a maximum of 1,000 feet on the Cap au Grès structure, approximately 20 miles southeast of the Eolia quadrangle.

Harrison (1995) in MODNR (2007c) also noted that The Cap au Grès structure is a faulted monocline, or drape fold, that has a steep southwestern limb. It bends sharply along strike and has a zigzag outcrop pattern. Although it terminates to the southeast in the St. Louis area, he concludes that the Cap au Grès structure and the Waterloo-Dupo faulted asymmetrical anticline in Illinois are probably parts of the same structural system. The Cap au Grès structure and related features in the Eolia quadrangle are thought to be directly controlled by faulting in the Middle Proterozoic basement. Deep drill hole data in the area indicate that basement is approximately 3,000 feet below the surface. Multiple episodes of basement faulting are interpreted from the surface geology.

Initially, the monocline formed as a result of compressional faulting in the basement. The time of deformation in the Eolia quadrangle is constrained by the age of the Mississippian (Osagean) Burlington Limestone - the youngest unit affected by faulting and folding - and by deposition of the Pennsylvanian (Morrowan to Desmoinesian) Cherokee Group. The critical area where Pennsylvanian rocks possibly overlie folded and faulted older rocks is covered by Pleistocene glacial deposits, but Pennsylvanian rocks are known to overlie the fault-bounded wedges of St. Peter sandstone. This indicates that they were deposited after deformation and erosion. Elsewhere, deformation on the Cap au Grès structure has been constrained as being post-St. Louis Limestone (Mississippian, Meramecian) and pre-Tradewater Formation (Pennsylvanian, Morrowan to Desmoinesian).

Cuba Fault

The Cuba Fault (see No. 10 in Missouri on Figure 2.5-14) passes 3 miles (4.8 km) west of Cuba, Missouri, across Crawford and Gasconade counties to Township 43 North, Range 7 East in Osage County, Missouri (McQueen, 1943 in AmerenUE 2004). Fox (1954 in AmerenUE 2004) proposed that the fault extends to the south and possibly joins the Crooked Creek Structure (see No. 9 in Missouri on Figure 2.5-14). Current work refutes Fox's concept. James A. Martin and James H. Williams of the Missouri Geological Survey and Water Resources accompanied James W. Smith of Dames & Moore in verifying the position of the fault essentially as mapped by McQueen (1943 in AmerenUE 2004).

The Cuba Fault is downthrown on the east side with a vertical displacement from 125 to 150 feet (38.1 to 45.7 m) (McCracken, 1971 in AmerenUE 2004). As Pennsylvanian strata may be cut by the fault, the age of the last movement is Pennsylvanian or younger.

MODNR (2007) describes the fault essentially north-south in direction with a slight trend to the northwest. It is downthrown to the northeast with a vertical displacement of from 125 to 150 feet. The upthrown side is broadly arched exposing rocks of Ordovician age as old as Gasconade Dolomite in places. The downthrown side is synclinal and probably controls the occurrence of fire clay in the Owensville, Rosebud and Gerald fire clay districts. In places the fault may be replaced by folding. It appears to die out in Osage County, and is expressed by silicified Roubidoux Sandstone in the east bank of the Meramec River, as well as by displacements of the Roubidoux and Gasconade formations.

Cuba Graben

McCracken (1971 in AmerenUE 2004) states that the Cuba Graben (see No. 11 in Missouri on Figure 2.5-14) is the downthrown area between the Cuba and Leasburg faults which has protected Pennsylvanian beds from erosion. The Cuba Graben is probably not due to horizontal tensional forces as with most grabens but is more likely due to vertical movements, since the bounding faults have associated anticlines (Figure 2.5-16).

Portions of both bounding faults of the Cuba Graben were found by subsurface contours drawn on the top of the Roubidoux Formation. This was substantiated by Donald E. Miller of the Missouri Geological Survey and Water Resources. Because the bounding faults may cut Pennsylvanian strata, the youngest mapped formations in the area, the last movement of the Cuba Graben may be Pennsylvanian or younger.

MODNR (2007C) describes the fault as the downthrown area between the Cuba and Leasburg faults, which has protected Pennsylvanian beds from erosion and contains much of the southern Missouri fire clay district.

Fox Hollow Fault

McCracken (1971 in AmerenUE 2004) and MODNR (2007C) describe the fault as a small, normal fault in Sec. 12, T. 46 N., R. 13 W., with a throw of approximately 120 feet. Additional mapping revealed a more complex structure. In MODNR (2007c) the structure is identified as a monocline because no definite fault plane was discovered and because the stratigraphic displacement can be accounted for by dip alone. However, it is probable that faulting and fracturing accompany the folding. The monocline is uplifted to the east relative to the west. Areas of Chouteau which have been uplifted relative to the overlying Burlington are exposed in the valleys of Bass Creek in section 28 and in small creek branches in sections 31 and 32.

South of Fox Hollow the structure's strike bends to the south and changes from a monocline to a fault. In Grider Branch (Sec. 24, T. 46 N., R. 13 W.) there is over 80 feet of throw on the west side of the fault strike.

A possible extension of this fault into Sec. 36, T. 46 N., R. 13 W. was noted by Gore (1949) in MODNR (2007c). His description notes that the quarry in the SW ¼ of the section has an excellent section of Chouteau limestone with Burlington limestone resting upon it. Approximately one-quarter mile southeast, he notes a cliff at the same elevation as the quarry section that is entirely comprised of Jefferson City Dolomite; additionally, one-eighth mile to the north-northeast of the quarry is another exposure of the Jefferson City at the same elevation. He notes there is no noticeable dip in either section.

Jeffriesburg Fault

The Jeffriesburg Fault is a short, northwest-trending fault that lies 3.5 miles (5.6 km) east of the Leasburg Fault in Township 43 North, Ranges 1 and 2 West, Franklin County, Missouri (see No. 22 in Missouri on Figure 2.5-14.. On the surface, Pennsylvanian sandstone is faulted against Jefferson City dolomite (McCracken, 1971 in AmerenUE 2004). According to subsurface contours on top of the Roubidoux Formation (data collected from the well logs on file at the Missouri Geological Survey and Water Resources), the southwest side of the fault appears to have been upthrown at least 100 feet 30.5 m). The fault, determined from Roubidoux contours, appears to terminate to the southeast in Section 36, Township 43 North, Range 1 West, and to the northeast in Section 11, Township 43 North, Range 2 West. Displaced Pennsylvanian rocks indicate the age of faulting to be Pennsylvanian or younger.

MODNR (2007C) describes the fault as having a strike of N. 50° W. and is downthrown to the northeast 100 feet (30.5 m). Along most of the fault Cotter is downthrown against Jefferson City. The northwest end of the fault encounters the St. Johns fault and the southeast end of the fault merges into the Hellings Lake basin structure.. Much of the middle segment of the fault is covered by cherty residuum and loess.

Leasburg Fault

The Leasburg Fault (see No. 24 in Missouri on Figure 2.5-14 generally trends from Section 22, Township 30 North, Range 2 West in Crawford County to Section 20, Township 43 North, Range 2 West, Franklin County, Missouri (McCracken, 1971). It appears to change strike several times from northeast to northwest but persists for a distance of some 40 miles. McQueen (1943 in AmerenUE 2004) describes the fault as downthrown to the northwest. The preservation of Pennsylvanian age sediments within the Cuba Graben suggests that the faulting is Late or post-Pennsylvanian in age.

Mapped by Dake (1926) in MODNR (2007C) Geologic Map of Missouri, it is described as being in the vicinity of Leasburg and continuing for some distance in a northerly direction. It appears to change strike several times from northeast to northwest, but persists for a distance of some 40 miles (64.4 km). First reference to the name "Leasburg fault" was in the 1939 Kansas Geological Society Guidebook. However, the name was in common usage among geologists of the state before that time.

The fact that the known magnetite-hematite deposits at Bourbon, Kratz Springs, and Pea Ridge all fall within the upthrown block along this fault make it of interest to the structural geologist. Little deep drilling has been done on the downthrown side of the fault to show the configuration or type of rock in the Precambrian. Magnetic data (Figure 2.5-145), however, indicate that there may be a different type of basement rock under the Cuba graben west of the Leasburg fault than there is to the east.

Mississippi Valley Faults

A series of faults located in the Mississippi Valley (see No. 42 in Missouri on Figure 2.5-14) in the Upper Mississippi Embayment has been described by Bond et al. (1971). According to the interpretation and description by H. Schwalb, in the work by Bond et al: "Many faults are exposed in the Paleozoic rocks around the northeastern edge of the embayment (Figure 25); some of these faults probably extend into the Reelfoot basin beneath the Mesozoic and Cenozoic strata. Because of the sparse subsurface control, only the major displacements can be plotted in the embayment area. A fault that trends northeast is downthrown on the west, has 700 to 800 feet (210 to 240 m) of displacement, and follows the course of the Mississippi River. A very large fault trending slightly south of east crosses the Mississippi River fault near the junction of the Missouri-Arkansas-Tennessee boundaries. Displacement exceeds 4,000 feet (1,220 m) at the Mississippi River and decreases eastward; the downthrown side is on the south, but the fault may scissor to the east, reversing the displacement. A third fault is mapped in Missouri almost parallel with the Mississippi River fault. The downthrown side is on the east, producing a graben within the Mississippi River flood plain. South of the major east-west fault, another displacement follows the trend of the Mississippi River, but downthrow is on the east."

MODNR (2007C) describes the fault as the Mississippi Valley Graben, a135 km long structure first identified from satellite imagery (Marple (1989) in MODNR (2007c) as a southwest-northeast-trending lineament.

The graben structure and shape were defined by geophysical, aeromagnetic, and gravity data (Figure 2.5-146 and Figure 2.5-147) with the edges of the graben are formed by Precambrian basement strata.

Newburg Fault Zone

The Newburg Fault Zone (see No. 26 in Missouri on Figure 2.5-14) is a series of faults trending northwest to west for about 4 miles (6.4 km) in Townships 36 and 37, North, Ranges 8 and 9 West, Phelps County, Missouri. This zone consists of three areas of faulting. The southern portion of the fault zone is a graben with the faults striking North 58 West. Maximum displacement is 60 feet (18.3 m). An intermediate zone occurs north of this feature. A normal fault farther to the northwest strikes almost due east. The downthrown side is to the south. Maximum throw along this segment is 100 feet (30.5 m). Ordovician age Gasconade and Roubidoux formations are present in fault blocks at the surface.

MODNR (2007C) describes the fault as a series of faults beginning in the upper reaches of Treable Creek and extending northwest for nearly four miles, the zone is divided into three divisions by Lee. The southern portion, along Treable Creek, is a graben with the faults striking N. 58° E. with a maximum displacement of 60 feet. An intermediate zone of small faults occurs north of this. The northwest portion, along Hickory Point, is downthrown to the south with a normal fault striking almost east-west.

Ste. Genevieve Fault System

The Ste. Genevieve Fault System is a complex fault zone of variable character (see No. 38 in Missouri on Figure 2.5-14). At various points along its trace, from two to four steeply dipping reverse faults and a faulted monocline account for most of the structural relief across the feature. Compensatory normal faults are generally present in the edge of the upthrown block. The character of the monocline changes form a small flexure whose steep limb dips approximately 40° northeast to a large feature with the steep limb overturned at lest 50 southwest. The dips of the reverse faults in the fault zone vary from vertical to 50°. The fault zone is uniformly upthrown on the west although evidence for minor reversals in the sense of movement along the fault does exist.

Stratigraphic displacement varies from approximately 450 feet (137 m) along the edge of the Potosi block, 900 feet (274 m) along the edge of the Farmington block, to a possible maximum of 2,000 feet (610) along the edge of the Perryville block. The Ste. Genevieve Fault Zone is interpreted as a boundary for several of the crustal blocks in the eastern Ozarks. It trends straight along the edges of the blocks, but may bend sharply where it intersects another block boundary, as at its intersection with the Big River and Saint Mary's Fault Systems.

The Ste. Genevieve Fault System is probably an inherited feature, the strike of whose segments represent a Precambrian structural grain and its position controlled by the dynamics of subcrustal block uplift. It has probably existed as an inter-related series of faults that comprise a major structural discontinuity in the region since at least late Precambrian time. It represents a major element in the limb between the Ozark Uplift and the Illinois Basin. Structural and magnetic lineaments of the 38th Parallel lineament discussed by Lidiak and Zietz (1977 in AmerenUE 2004) were found to be interrupted by the prominent northwest trending magnetic anomalies associated with the Ste. Genevieve Fault.

Northwest trending gravity anomalies also associated with the Ste. Genevieve Fault zone were recognized by Keller and Austin (1977 in AmerenUE 2004). The extension of the Ste. Genevieve Fault System into Illinois has been called the Rattlesnake Ferry Fault (see No. 4 in Illinois on Figure 2.5-14).

Weller and St. Clair (1928 in MODNR (2007C) described this fault as a faulted zone which crosses Ste. Genevieve County in an east-west direction. It is northwest-southeast, entering Ste. Genevieve County from Perry County in a land grant located in the southwest part of T. 37 N., R. 10 E., about three miles south of St. Mary. This fault zone strikes essentially east-west across Ste. Genevieve County from the Perry County line to near River Aux Vases in the N 1/2 Sec. 7, T. 36 N., R. 8 E., where it bends northwest, passing west of Weingarten. It crosses the St. Francois-Ste. Genevieve County line in Sec. 26, T. 36 N., R. 6 E. It continues across northern St. Francois County where it branches into two faults; one continues northwest (see Valles Mines-Vineland fault zone), while the other strikes southwest through St. Francois County (see Big River fault zone). East of Ste. Genevieve County, this zone extends east through Perry County through Lithium, and then southeast along the Mississippi River to south of Wittenberg where it crosses the Mississippi River into Illinois at Grand Tower (see Wittenberg fault zone, Red Rock thrust, Red Rock-Union School fault zone).

In general, this system of faulting is downthrown to the north and east. Maximum displacement is about 550 feet (167 m) for the northwest part of the fault and over 1,000 (305m) feet in the east-west section. Faulting is so intense within these blocks it would appear that they are preserved by tectonic rather than sedimentary processes. It is a long, narrow block of Jefferson City Formation surrounded by older rocks. The entire system may be tensional, developed by the rising Ozark mass against the sinking Illinois basin.

Wardsville Fault

McCracken (1971 in AmerenUE 2004) stated that the Wardsville Fault (see No. 41 in Missouri on Figure 2.5-14) trends from Section 7, Township 43 North, Range 11 West (west of Wardsville, Missouri) northeast to Section 35, Township 44 North, Range 12 West in Cole County, Missouri. The fault is downthrown 100 feet (30.5) to the northeast as substantiated by water well borings at the town of Wardsville.

Ward (1973) in MODNR (2007c) describes the Wardsville Fault as having approximately 50 feet (16.1 m) of downthrown to the northeast along its northeast extension. In the western half of Sec. 6, T. 43 N., R. 11 W., the fault changes to a more southerly direction. The fault trace at this location is expressed by a linear ridge of recemented Roubidoux sandstone. The fault is interpreted to be downthrown to the west-southwest at this location, although the evidence is not conclusive. The apparent explanation for the recemented sand is that the Roubidoux sandstone was caught in the fault zone, fractured and later recemented with silica. McCracken

(1971 in AmerenUE 2004) and MODNR (2007c) reports that the absence of 100 feet (30.5 m) of Eminence Dolomite in a well at the St. Martins Church, and surface evidence, indicates the fault to be downthrown to the northeast in the Wardsville area and northward.

Surface work by Martin (Missouri Geological Survey staff member) in the area east of the water well at Wardsville showed a collapse structure with Burlington Limestone preserved. The findings point to an extension of the Wardsville Fault beyond St. Martins, Missouri, and suggest the age of the fault to be post-Early Mississippian in age.

Reelfoot Lake Fault

Finch (1971) mapped an extensive concealed fault in southwestern Kentucky and northern Tennessee (see No. 1 in Kentucky on Figure 2.5-14). This area lies just north of the Reelfoot Lake region of faulting in Tennessee described by Fuller (1905), and is thought to be part of the same system. Although Finch found no evidence in the mapped quadrangle, he felt it reasonable to assume that this fault was active during the creation of Reelfoot Lake by the 1811-1812 earthquakes. Correlation of loess deposits has shown nearly 200 feet (61m) of vertical displacement in the main fault, which Finch postulates as a landslide block. A displacement of 70 feet 21.3 m) was proven in a shorter, associated fault. No movement has been recorded since the 1811-1812 earthquakes. Zoback (1979) has interpreted faulting in the Reelfoot Lake area from seismic reflection profiles. These faults have increased offset with depth, with maximum displacement of Paleozoic marker beds of 265 feet (80.8 m) measured. Local thinning of Cretaceous and Tertiary sections and the greater offsets in other strata indicate that deformation has continued since late Cretaceous time.

Kingdom City Fault

Kingdom City Fault (see No. 48 in Missouri on Figure 2.5-14) is proposed to trend east-northeast in Township 49 North, Range 9 West, Callaway County, Missouri. Based on data from well log No. 26595 in the Missouri Geological Survey and Water Resources well log files, it is a reverse fault and cuts the St. Peter Formation twice, displacing it 300 feet (91.4 m). On the basis of surrounding well information, the southeast side was downthrown.

MODNR (2007) do not describe this fault by this name but uses Fox Hollow Fault – Monocline, for a more complex structure revealed by additional mapping. The structure is referred as a monocline because no definite fault plane was discovered and because the stratigraphic displacement can be accounted for by dip alone. However, it is probable that faulting and fracturing accompany the folding. The monocline is uplifted to the east relative to the west. South of Fox Hollow the structure's strike bends to the south and changes from a monocline to a fault.

Ste. Mary's Fault

Mateker (1956) recognized a strong gravity gradient that trended northeasterly and crossed the Mississippi River at Ste. Mary's, Missouri (see No. 53 in Missouri on Figure 2.5-14). No faulting was recognized at the surface until road cuts for Interstate Route 50 were completed. Tikrity (1968) described 200 to 400 feet (61 to 122 m) of downward displacement to the southeast, toward the Illinois Basin, and considered it to be a northeast extension of the Ste. Genevieve Fault System. A wide fault zone that includes steeply dipping fault zones and monoclines was noted during reconnaissance for this study. This fault zone coincides with the gravity gradient noted by Mateker (1974) and with the southern boundary of the Farmington block.

MODNR (2007C) describes the fault as thought to be a northeast extension of the Ste. Genevieve fault system with structural mapping indicating the throw to be from 200 to 400 feet (61 to122 m) down to the southeast toward the Illinois basin.

Simms Mountain Fault

The Simms Mountain Fault separates the Precambrian terrain of the St. Francois Mountains from the Cambrian sedimentary rocks of the Missouri lead belt (see No. 37 in Missouri on Figure 2.5-14). The brittle basement rocks and dolomites along the fault trace have been severely shattered and a broad, gentle valley has been eroded along the fault trace along most of its length. The sedimentary rocks immediately adjacent to the fault trace dip approximately 45° to the east, probably representing the remnant of a faulted monocline. The fault is uniformly upthrown to the west and dips steeply, since its trace crosses topographic features of considerable relief without deflection. Total vertical stratigraphic separation is probably less than 200 feet (61 m).

MODNR (2007C) describes the fault as one of the major fault systems in the St. Francois Mountain area with the fault had been mapped by Buckley (1908) in MODNR (2007c) as the Irondale fault.

Mapping by Amos (1984, 1985) and Satterfield (1973) in MODNR (2007c) extended the fault system further to the southeast. It stretches from the Big River fault near Irondale to the Mississippi River floodplain at Cape Girardeau, a distance of almost 75 miles (121 km), and it ranges from 8 to 12 miles (13 to 21 km) in width.

Within the fault system are various shaped horsts (Cape Girardeau quadrangle), up to five miles in length, dipping blocks, and wedges. The geometric patterns of the faults are indicative of strike-slip movement.

Previously mapped structures such as the Radio Tower structure, Jackson fault, and Cape Girardeau fault are a part of the Simms Mountain fault system.

Big River Fault

The Big River Fault is a steeply dipping reverse fault. Its trace defines the boundary between the Farmington and Potosi blocks (see No. 3 in Missouri on Figure 2.5-14. Total structural relief across the feature is 280 feet (85.3 m) at Bonneterre, Missouri. Structural relief decreases along strike to the southwest, reflecting the tilting of the Farmington block. The Big River Fault terminates against the Ste. Genevieve Fault on the northeast and the Simms Mountain Fault on the southwest.

MODNR (2007C) describes the fault displaced a maximum of 120 feet, down to the northwest. The fault system is zigzag in strike having two distinct lines of displacement. It is high-angle, normal with a total length of about 17 miles (27 km), and is post-Roubidoux in age. It is complex in some places, consisting of several en echelon faults.

INSERT 'C' to FSAR Sections 2.5.1.1.4.1.8 and 2.5.1.1.4.2
(amended FSAR page 2-880)

Black Fault

The Black Fault is a steeply dipping fault whose trace trends northwesterly (see No. 4 in Missouri on Figure 2.5-14). Poor exposure makes precise definition of fault geometry impossible. The fault is downthrown to the west, and near the town of Black, Missouri, the entire vertical stratigraphic separation is within the thickness of the Bonneterre Formation (approximately 100 feet (30.5 m)). The Black Fault defines the western boundary of the St. Francois block and represents the easternmost structure on the western limb of the Ozark Uplift.

MODNR (2007C) describes the fault as having a displacement of 300 feet involving beds of Cambrian age, bringing Potosi against Bonneterre beds, and may extend northwestward to connect with (or be cut off by) the Palmer fault system. The structure is down to the southwest, with an average strike of N. 35° W. The structure intersects the Sabula basin. Dipping beds near Goodwater (Sec. 28, T. 35 N., R. 1 W.) point to a northwest extension.

A small fault branches off at the NW ¼ NW ¼ Sec. 16, T. 33 N., R. 1 W., and extends in a generally westerly direction for approximately one mile, then N. 10-15° W. for approximately 2 miles. The westerly portion is down to the north; the northerly portion is down to the east.

Anthonies Mill Fault

The Anthonies Mill Fault is described by McCracken (1971 in AmerenUE 2004) as being observed at the surface. Its existence was substantiated by drilling near the Pea Ridge iron deposit. The fault extends from Section 19, Township 39 North, Range 1 West, Washington County, Missouri, to Section 11, Township 39 North, Range 2 West, Crawford County, Missouri. The displacement on the fault is 150 to 200 feet with the downthrown side on the southwest (see No. 49 in Missouri on Figure 2.5-14).

MODNR (2007C) describes the fault as near Anthonies Mill, discovered at the surface and substantiated by drilling in the vicinity of the Pea Ridge iron deposit. Displacement is 150 to 200 feet (45 to 61 m) with the southwest side downthrown. The fault may extend northwest and southeast of the mapped structure

Catawissa Fault

The Catawissa Fault (see No. 50 in Missouri on Figure 2.5-14) is based on boring information from the Missouri Geological Survey and Water Resources well log files. It is located in the southwestern portion of Township 43 North, Range 2 East, Franklin County, Missouri. It has a displacement of 150 feet with the northwestern side downthrown (AmerenUE 2004).

Browns Station Fault

The Browns Station Fault, which is located on the southwestern limb of the Browns Station Anticline (see No. 51 in Missouri on Figure 2.5-14), Callaway County, Missouri, is interpreted as having 300 feet (91 m) of displacement. The southwestern block is downthrown (Laclede Gas Company, 1974 in AmerenUE 2004).

MODNR (2007C) describes the fault as the southernmost fault in the Valley Mills fault zone. The fault trends almost east-west and is downthrown to the north. Thomson (1986) in MODNR (2007c) states that the north side of the fault is Burlington-Keokuk Formation which forms gently sloping hills. The south side is Pierson and Elsey formations which have rougher topography.

Beveridge (1970) in MODNR (2007c) states that the glauconite found in the beds indicates that they are Keokuk Formation. To the west in Section 4, 1.2 miles (1.9 km) south and 0.22 miles (0.35 km) west of the northeast section corner, in the north draining stream, upthrown brown dolomite from the Middle Pierson Formation dips to the southeast at 4. Burlington-Keokuk Formation crops out in the stream bed on the north side of the fault showing a minimum throw of 70 feet. Probably the north side of the fault has been dropped from 100 to 170 feet (31 to 52 m)

Mineola Fault

Mineola Fault (No. 52 in Missouri on Figure 2.5-14) is located in the southwestern portion of Township 48 North, Range 6 West, Montgomery County, Missouri on the flank of the Mineola Dome. This is the closest reported geologic structure (fault or fold) to the site, at approximately 12 miles (19 km). Interpretation of well log data from the Missouri Geological Survey and Water Resources files (1974) indicates 200 feet (61 m) of downward displacement to the southwest.

MODNR (2007) describes the fault as the Mineola structure-Mineola dome, first mapped as a pronounced anticline in the vicinity of Mineola, with a N. 75° E. trend, and 10° to 20° dips on both flanks; the dips are generally steeper on the south limb. Later work showed the structure to be closed with a short north south axis. It is asymmetrical with a steep south southwest dip and more gentle north northeast dip. An additional closure was mapped and pointed to a number of closed anticlines or domes striking N. 70° W. in an en echelon pattern from the Mineola area to the Browns Station anticline in Boone County. The Mineola dome brings Cotter (lower Ordovician) rocks to the surface in Loutre Creek, where they are surrounded by rocks ranging in age from Middle Ordovician (St. Peter Formation) to Pennsylvanian (Cherokee Group).

Faults of Thebes Gap Area

The individual named faults discussed here are not sections of a single long fault. Instead, they are individual strands in a fault complex, shown as feature No 6 in Figure 2.5-149 (Crone, 2000). They have different strikes, dips, slip senses, and slip histories, where individual faults in the fault complex, and the longest faults, strike northeasterly to north-northeasterly, but numerous shorter cross faults strike easterly and northwest (Crone, 2000)

Several Quaternary faults occur in the Thebes Gap area. The better known faults recognized to date are: English Hill fault zone, Commerce fault, Happy Hollow fault, Sassafras Canyon faults, Albrecht Creek fault, and Lambert trench at intersection of English Hill and Albrecht Creek faults. Quaternary faulting at English Hill was first recognized by in the early 1940's and described as a northeast-striking graben that down dropped the late Wisconsinan Peoria Loess.

No further investigations were made on faulting at English Hill until the 1990's when the U.S. Geological Survey (USGS) and the Missouri Department of Natural Resources/Division of Geology and Land Survey (MDNR/DGLS) began cooperative studies in the area. These studies included trenching and geophysical investigations. Quaternary faulting along the Commerce fault was first recognized in 1994 from exposures in a road cut in Commerce, Missouri; the Happy Hollow fault and Sassafras Canyon faults were discovered in 1997 from fault-exploration trenching; and Quaternary faulting along the Albrecht Creek fault was discovered from detailed geologic mapping in 1994. The possibility of Quaternary faulting at the intersection of the English Hill and Albrecht Creek faults was raised by detailed geologic mapping and was substantiated by the Lambert trench (Crone, 2000).

Western Lowlands Liquefaction Features

INSERT 'C' to FSAR Sections 2.5.1.1.4.1.8 and 2.5.1.1.4.2
(amended FSAR page 2-880)

The Western Lowlands of Missouri and Arkansas form the part of the northwestern Mississippi embayment that lies west of the uplands of northeast-trending Crowleys Ridge, shown as feature No 3 in Figure 2.5-149 (Crone, 2000). Several prehistoric liquefaction features west of Crowleys Ridge are here informally grouped under the name Western Lowlands. The liquefaction was recognized as the type that is caused by strong ground motion and the strong motions are presumed to have been caused by slip on one or more preexisting faults. However, the causative faults have not been identified and the locations and sizes of the liquefaction features identified to date provide poor constraints on the sources of the shaking.

The prehistoric earthquakes are known only from locations and age estimates of liquefaction. No surface ruptures are known from the earthquakes and neither potential source is known to have had more than one earthquake, so no recurrence interval can be calculated (Crone, 2000).

St. Louis-Cape Girardeau Liquefaction Features

Tuttle (1999) in Crone, 2000 examined sand blows, sand dikes, and sand sills that were found during systematic searches of streams in southeastern Missouri and southwestern Illinois. The search extended approximately 31 to 56 miles (50 to 90 km) west and east of the Mississippi River, between the St. Louis area on the northwest and the Cape Girardeau area on the southeast. The study area is named here informally after these two cities and shown as feature No 4 in Figure 2.5-149.

Correlation and dating of the liquefaction features remain uncertain. The present interpretation involves an earthquake of moment magnitude M > 6, and perhaps exceeding 7, occurring approximately 6,500 years ago, roughly 37 miles (60 km) east of St. Louis. The smaller the earthquake east of St. Louis, the more likely it is that another earthquake of M > 5.2 occurred in or very near St. Louis. A second earthquake caused strong ground shaking in the area during the past 4,000 years (Crone, 2000).

The study area straddles the Mississippi River and the western edge of the Illinois basin, spanning approximately 37°-39° N. Immediately southeast of the study area is the New Madrid seismic zone. Regionally, bedrock consists of Paleozoic strata that dip northeastward from the Ozark uplift toward the center of the Illinois basin. Historical earthquakes are scattered throughout the study area. The earthquakes are part of the broad, diffuse halo of scattered seismicity that surrounds the New Madrid seismic zone. Numerous large faults, monoclines, and other folds of Paleozoic age are known throughout the region, and most involved the basement.

The number, location, and size of prehistoric earthquakes in the study area remain uncertain, and depend on uncertain correlation of liquefaction features.

Slinkard Quarry Graben

Wheeler (2005) references the Slinkard quarry graben as a Class "A" feature within the city limits of Cape Girardeau, Missouri. A Quaternary graben is partly exposed in the quarry, and strikes northeast, is approximately 500 ft (152 m) wide, and is filled with syntectonic gravel. 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 and pre-Wisconsinan loess. The northwest margin of the graben juxtaposes Quaternary gravel against late Tertiary Mounds Gravel. The fault on the northwest margin strikes N. 35°–40° E. and dips approximately 74° SE. Mounds Gravel in the footwall has been rotated to dip 54°–85° SE., with strike parallel to the fault.

INSERT 'C' to FSAR Sections 2.5.1.1.4.1.8 and 2.5.1.1.4.2
(amended FSAR page 2-880)

2.5.1.1.4.2.3 Regional Jointing

Regional joint or fracture patterns are consistent and well developed throughout the region. Two systems of fractures are prevalent. The most common and the most widely distributed fracture system is made up of two sets that parallel the general regional structural trends (northwest and northeast). This system is present in the basement rocks and is represented there by fractures intruded by ultrabasic rocks of known Precambrian age. The second system is subordinate and has two joint sets that strike north-northwest and east-northeast. The two systems are statistically difficult to distinguish in large samples and may represent local variants of the same system. The near right angle of intersection and vertical attitude of both systems suggest that these are regional orthogonal fracture systems common to areas that have been uplifted by upthrust tectonics (Gibbons (1972) in AmerenUE, 2004).}

Lamotte Formation. This formation has been penetrated in 3 borings, north of the Missouri River and in the site vicinity, in Boone, Gasconade and Audrain counties. The Bonneterre Formation has an approximate thickness throughout the site vicinity of 295 ft to 330 ft (90 to 101 m), with an average thickness of 307 ft (94 m).

The Lamotte Formation rests unconformably on Precambrian basement rocks. It is persistent in the subsurface throughout much of Missouri, but regional variations in thickness have been recognized. It is predominantly a quartzose sandstone that in many places grades laterally into arkose and conglomerate. Pebbles and boulders of felsite are the chief constituents of the conglomerates that immediately overlie Precambrian rocks in many places. The color of the sandstone ranges from light gray or white to yellow, brown or red. Red to purple silty shale is locally present, and lenses of arenaceous dolomite are scattered through the upper part of the formation. The Lamotte Formation has been penetrated in 3 borings, north of the Missouri River and in the site vicinity, in Boone, Gasconade and Audrain counties. The Lamotte Formation has an approximate thickness throughout the site vicinity of 130 ft to 385 ft (40 to 117 m), with an average thickness of 253 ft (77 m).

2.5.1.2.3.3.6 Precambrian Basement Rocks

The nearest exposures of Precambrian age rocks are located in the St. Francois Mountains, about 75 miles (121 km) southeast of the site. The nearest boring that reached Precambrian rocks (Robertson, 1974) is the Continental Ozark No. CO-10 located in the NE quarter of the NE quarter of Section 3, Township 44 North, Range 8 West, approximately 10 miles (16 km) south of the plant site. This boring was drilled in 1969 to a total depth of 1,955 ft (596 m). Precambrian basement was reached at a depth of 1,844 ft (562 m) (1,214 ft (370 m) below msl). At this location the Precambrian rocks consist of slightly to highly altered serpentine, which becomes porphyritic with depth and is underlain by rhyolite porphyry and tuff. Information from this well was not used to complete Table 2.5-9 because it is located south of the Missouri River, missing the upper deposits of Mississippian and Pennsylvanian age, as well as the Quaternary glacial and post glacial derived deposits.

2.5.1.2.4 Site Area Structural Geology

Geologic studies to determine the site structural characteristics have been performed utilizing data obtained from site borings, excavation mapping and geophysical surveys. In addition, bedrock exposures were mapped throughout the site area. Dip and strike measurements were taken on bedding planes and joints where possible. A thorough search for faulting was made throughout the site area **{as described in FSAR 2.5 Appendix B}.** Subsurface sections (Figure 2.5-32 and Figure 2.5-33) were prepared correlating boring data. Detailed mapping of all Category I excavations was also performed for Callaway Plant Unit 1 (Dames and Moore, 1980). No major structures have been encountered that would adversely affect construction and operation of the plant.

2.5.1.2.4.1 Site Folding

The effect of regional warping on the site area has been discussed in Section 2.5.1.1.4.1. Gentle warping of Pennsylvanian and older strata appears to have occurred in the site vicinity; it is evident also from the geologic cross sections in Figure 2.5-32 and Figure 2.5-33. At the site, the age of the broad fixtures cannot be determined precisely. Devonian and Mississippian age rocks appear to be involved. Reconnaissance geologic field data suggests that the Graydon Chert Conglomerate also reflects the gentle flexures. If the tentative age of Early Pennsylvanian is correct for the Graydon Conglomerate Formation, the age of the last warping must be Late or post-Pennsylvanian. There is no evidence to support any of these gentle movements during Pleistocene time.

major structures or zones of deformation have been encountered that adversely affect construction and operation of the plant.

2.5.1.2.6.4 Prior Earthquake Effects SEE INSERT "D"

~~Minor to moderate earthquake ground motion has been experienced at the site; however, there is no evidence from geomorphologic, lithologic, stratigraphic, structural geologic or geophysical studies that indicates any effect from earthquake ground motion.~~

2.5.1.2.6.5 Effects of Human Activities

Investigations at the site have not revealed any adverse geologic conditions that can be attributed to man's activity (AmerenUE, 2004). The addition or withdrawal of subsurface fluids, including ground water, at the site has not been significant. Material extraction in the site vicinity has consisted of minor amounts of surface quarrying of limestone and fire clay. At present, there are no active mining operations within 4.5 miles (7.2 km) of the plant site. There has been no mining or petroleum production in the site area that would cause any surface or subsurface subsidence. Based on current knowledge of the area, no mining or petroleum activity is anticipated. Central Missouri is not a promising area for oil or gas production (AAPG, 1971). Petroleum and gas associated drilling in Missouri (MODNR, 2007a) are shown on Figure 2.5-38, with the nearest producing oil or gas well located in the Florissant Field in St Louis County, 70 miles (112.7 km) from the plant site. This oil field is associated to the Lincoln Fold Structure, an anticline that extends from northern St. Louis northwest to Knox County (MODNR, 2007b), part of the only three areas with potential for conventional oil and gas production in Missouri: Forest City Basin, Lincoln Fold, and the Mississippi Embayment. There is no potential for gas storage in structures around the site due to the absence of suitable reservoir and cap rock units.

2.5.1.2.6.6 Site Groundwater Conditions

A detailed discussion of the regional and local groundwater environment is given in Section 2.4.13.

2.5.1.3 References SEE INSERT "E" FOR ADDITIONAL REFERENCES

This section is added as a supplement to the U.S. EPR FSAR.

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INSERT D

INSERT 'D' to FSAR Section 2.5.1.2.6.4

Prior Earthquake Events

(amended FSAR page 2-902)

{The site is located in a region that has experienced only infrequent minor earthquake activity, with the closest epicentral location (3.0 to 3.9 mb) situated approximately 38 miles (61 km) southwest of the Callaway Plant Unit 1 site, west of Cole County. Besides the latter there has been only one more cataloged earthquake within 50 miles (80 km) of the Callaway Plant Unit 1 site, this one (3.0 to 3.9 mb) approximately 45 miles (72 km) south-southeast of the, south of Gasconade County. Section 2.5.2 provides a full discussion on the seismicity analysis for the Callaway Plant site.

Based on this information, there are no significant hazard potential faults within a 25 mile (40 km) radius of the Callaway Plant Unit 2 Site as seen in Figure 2.5-14}

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INSERT E

INSERT 'E'

(additional references FSAR page 2-902)

{**Bankey, 2002.** Magnetic Anomaly Map of North America, U.S. Geological Survey, scale 1:10,000,000, 1 sheet, V. Bankey, A. Cuevas, D. Daniels, C. Finn, I. Hernandez, P. Hill, R. Kucks, W. Miles, M. Pilkington, C. Roberts, W. Roest, V. Rystrom, S. Shearer, S. Snyder, R. Sweeney and J. Velez, 2002.

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INSERT 'E'

(additional references FSAR page 2-902)

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Supplement to FSAR 2.5.2; Seismic Catalog Updates

FSAR 2.5.2 Page Affected	Description
2-907	Insert "F" text description added summarizing the three step procedure used to evaluate seismic hazards.
2-910	Insert "G" provides additional discussion on the updated seismic catalog data used.
2-922	Insert "H" expands the discussion on correlation of earthquake activity with seismic sources.
2-926	Insert "I" provides expanded discussion on seismic catalog updates.
2-1028, 2-1087	FSAR Table 2.5-10 seismic catalog updates.

2.5.2 VIBRATORY GROUND MOTION

The U.S. EPR FSAR includes the following COL Items for Section 2.5.2:

> A COL Applicant that references the U.S. EPR design certification will review and investigate site-specific details of the seismic, geophysical, geological, and geotechnical information to determine the safe shutdown earthquake (SSE) ground motion for the site and compare site-specific ground motion to the Certified Seismic Design Response Spectra (CSDRS) for the U.S. EPR.

This COL item is addressed as follows:

This section provides a detailed description of the vibratory ground motion assessment that was carried out for the {Callaway Plant Unit 2}; resulting in the development of the {Callaway Plant Unit 2} site Safe Shutdown Earthquake (SSE) ground motion response spectra. {Starting points for this site assessment are the United States Geological Service (USGS) 2002 documentation of the studies for the 2002 national seismic hazard maps, the EPRI-SOG probabilistic seismic hazard analysis (PSHA) methodology outlined in EPRI NP-4726-A 1988 (EPRI, 1988), and the Early Site Permit (ESP) Application for the Clinton NPP (EGC, 2006) submitted to the NRC on April 16, 2006 by Exelon Generation Company (EGC).

Nuclear Regulatory Commission (NRC) Regulatory Guide 1.208, "A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion," March, 2007, (NRC, 2007a) states in Section B, Discussion:

> "The CEUS is considered to be that part of the United States east of the Rocky Mountain front or east of Longitude 105 West (Refs. 13, 14). A PSHA in the CEUS must account for credible alternative seismic sources through the use of a decision tree with appropriate weighting factors that are based on the most up-to-date information and relative confidence in alternative characterizations for each seismic source. Seismic sources identified and characterized by Lawrence Livermore National Laboratory (LLNL) (Refs. 13-15) and the Electric Power Research Institute (EPRI) (Ref. 16, 17) were used for CEUS studies in the past. In addition to the LLNL and EPRI resources, the United States Geological Survey maintains a large database of seismic sources for both the CEUS and the WUS. The characterization of specific seismic sources found in these databases may still represent the latest information available at the time that a PSHA is to be undertaken. However, if more up-to-date information is available, it should be incorporated."

Regulatory Guide 1.165 provides the framework for assessing the appropriate SSE ground motion levels for new power generating nuclear plants. Regulatory Guide 1.165 also notes that an acceptable starting point for the SSE assessment at sites in the Central and Eastern United States (CEUS) is the PSHA conducted by the Electric Power Research Institute (EPRI) for the Seismicity Owners' Group (SOG) in the 1980's. Regulatory Guide 1.165 further specifies that the adequacy of the EPRI-SOG hazard results must be evaluated in light of more recent data and evolving knowledge pertaining to seismic hazard evaluation in the CEUS. **INSERT F**

Reference 16 of the NRC Regulatory Guide 1.208 (NRC, 2007a) is Electric Power Research Institute, "Probabilistic Seismic Hazard Evaluations at Nuclear Power Plant Sites in the Central and Eastern United States," NP-4726, All Volumes, 1989-1991. The title and number of the referenced document are not in agreement. The title of EPRI-4726 is "Seismic Hazard Methodology for the Central and Eastern United States." No document could be found that had the title provided by the NRC. In lieu of the reference 16, Section 2.5.2 of this document has

INSERT F

INSERT 'F' to FSAR Section 2.5.2
Vibratory Ground Motion
(amended FSAR page 2-907)

{A three-step procedure is used to evaluate new data and interpretations:

- Identify changes to seismic hazard characterization,
- Perform sensitivity analyses for significant changes to assess the effect,
- If significant effect is identified, perform an updated PSHA with new data.}

been missed. Thus, the USGS catalog forms a strong basis on which to estimate seismicity parameters. This report uses the catalog updated up to 2001 because this is the latest year for which the mb units are reported. The use of mb is required in view that the Guttenberg-Richter equation that describes the seismicity in area sources is considered to be valid in mb units.

Updated Seismicity Data **INSERT G**

Regulatory Guide 1.165 (NRC, 1997a) specifies that earthquakes of a Modified Mercalli Intensity (MMI) greater than or equal to IV or of a magnitude greater than or equal to 3.0 should be listed for seismic sources, "any part of which is within a radius of 200 mi (320 km) of the site (the site region)." The USGS catalog and methodology for determining seismicity parameters consider precisely the minimum magnitude of mb equal to 3.0

Figure 2.5-45 shows the Callaway Plant Unit 2 and its associated "site region," i.e., a window that incorporates the 200 mi (320 km) radius around the site. Figure 2.5-39 through Figure 2.5-44 also show this site region including epicenters of recorded earthquakes while Regulatory Guide 1.206 (NRC, 2007c) calls for the presentation of a seismicity map showing earthquake epicenters within 50 miles (80 km) of the site.

The USGS updated catalogs are compiled by examining and combining events listed in several CEUS source catalogs (Mueller and others, 1997). In this effort, the USGS intent is to develop a catalog dominated by entries from the best-researched sources and they use this priority to choose the best location and magnitude from among multiple source catalogs for each earthquake. In addition, secondary events have been filtered as explained in a recent USGS publication (USGS, 2008) as follows:

"Foreshocks and aftershocks are deleted using the declustering methodology of Gardner and Knopoff (1974); this simple algorithm requires no tuning parameters (that is, prejudgments about what are or are not aftershocks), and results are easily reproducible. Manmade seismic events are deleted if they are associated with a transient process that is no longer active (for example, earthquakes caused by deep fluid injection at the Rocky Mountain Arsenal near Denver), or if the process is ongoing but we have no reason to expect that future large, hazardous events will be associated with the activity (for example, earthquakes caused by fluid injection in the Paradox Valley of western Colorado, mining-related events in Colorado and Utah, and events related to oil production at the Dagger Draw field in New Mexico)."

The Clinton Early Site Permit (ESP) conducted paleoliquefaction evaluations where evidence of soil liquefaction that occurred in prehistoric times is inferred from features such as sand boils or blows, dikes, and sills. By estimating the date and geographical distribution of these features, it is possible to infer the magnitude of the earthquake that originated the features. Earlier investigations of paleoliquefaction features in the southern Illinois basin and in parts of Indiana, Illinois, and Missouri have identified paleoliquefaction occurrences that could have been caused by Holocene and latest Pleistocene earthquakes with estimated moment magnitudes (**M**) of 6 to approximately 7.8. Details about the paleoliquefaction reconnaissance carried out for the Clinton ESP Site seismic hazard evaluation are given in Section 2.1.4 and Attachment 1 of Appendix B of the Clinton ESP document (EGC, 2006). These details include a discussion of each of the identified features, pictures of the features, results of radiocarbon dating, and criteria for differentiating seismic versus non-seismic liquefaction features.

These paleoliquefaction studies have been utilized for developing improved representations of characteristic earthquakes in the New Madrid Fault System. It was also concluded, from these paleoliquefaction evaluations, that the range of maximum magnitude earthquakes assigned to

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INSERT G

INSERT 'G' to FSAR Section 2.5.2.1
Seismicity
(amended FSAR page 2-910)

{The following items have been identified as significant in terms of update of seismicity data or information:

- The use of the 2001 USGS catalog as an update to the EPRI-SOG 1984 seismic catalog,
- The update of the 2001 USGS catalog to the year of 2007; and
- The update of the New Madrid Seismic Zone (NMSZ) and the Wabash Valley Seismic Zone (WVSZ);

Details of the New Madrid and Wabash Valley updates are provided in Section 2.5.2.2.2.3 and Section 2.5.2.2.2.4 respectively. The nature of the update to the 2001 USGS catalog follows.

The USGS 2001 catalog is selected as an initial update to the EPRI-SOG 1984 seismic catalog. Foreshock and aftershock events are filtered out as recommended by USGS. Consequently, there is no double counting of the events in this catalog. The magnitude unit of earthquake events is assumed to be mbLg. The year 2001 is selected because this is the latest year for which the mb units are reported. The incorporation of the 2002 to 2007 seismicity data results in additional epistemic uncertainty related to magnitude unit conversion. A sensitivity analysis is performed using the reported magnitude, since differences between magnitudes of different units are small for low magnitude events.

The sensitivity study extended the 2001 USGS earthquake catalog to the year 2007. The update methodology adopted the approach described in the USGS open file report 2008-1128 "The 2008 Update of the United States National Seismic Hazard Maps" that USGS uses to update the USGS 2001 catalog to the year 2006 to reduce the additional epistemic uncertainty related to the magnitude conversion between different units to the mbLg unit used in the USGS 2001 catalog. It is assumed that the magnitude may be adopted from the reported values, since the difference resulting from the conversion between different units is negligible for small magnitude earthquakes.

The sensitivity study concluded that the update to the catalog does not have a significant effect on the b-parameter, seismic occurrence rate, and/or the entire PSHA study at the Callaway Plant Unit 2 site. The use of the updated earthquake catalog results in a reduction of the seismic occurrence rates, when compared to the USGS 2001 catalog. A comparison of the nature of the G-R parameters is provided by Figure 2.5-144. The resulting ground motion levels will be marginally lower, and are later compared in Section 2.5.2.4 at the level of the Uniform Hazard Response Spectra (UHRS) at top of rock.

The Clinton ESP Study also concludes that the update in the seismicity from the 1984 EPRI-SOG study does not significantly affect the seismicity parameters, i.e. the slope of the G-R (Guttenberg-Richter) equation (b parameter) and seismic rate (recurrent rate) in the region around the Clinton site. The same conclusion is reached in relation to the geometry of the seismic sources. The only relevant updates that were identified are the maximum magnitude of the Wabash Valley area source and the introduction of the New Madrid characteristic cluster events. A cluster model is required to represent the events that occurred in the three-series cluster with large magnitude (>7.5M). The seismic parameters related to the New Madrid events are not in agreement with the general G-R equation utilized in the area source hazard computation, and therefore need to be treated separately. Details of the New Madrid and Wabash Valley updates are provided in Section 2.5.2.2.2.3 and Section 2.5.2.2.2.4 respectively.

The G-R parameters from the USGS 2001 catalog have been adopted as the parameters of choice for the Callaway Unit 2 PSHA since:

(1) the effect on the seismic hazard of the 2002-2007 update is a marginal reduction in the ground motion levels, which is nonconservative; the reduction is verified by the comparison of G-R parameters (Figure 2.5-144) and the Uniform Hazard Response Spectra (UHRS) (Figure 2.5-145) at top of rock between the 2001 and 2007 cases.

(2) though small, there is additional epistemic uncertainty in the unit use of the 2002-2007 seismicity; and

(3) recent studies have reached similar conclusions related to the catalog updates that go back to 1984.}

The Clinton ESP (EGC, 2006) updated the maximum magnitude distribution for the Wabash Valley-Southern Illinois source zone is based on recent analysis of paleoliquefaction features in the vicinity of the lower Wabash Valley of Southern Illinois and Indiana. Such ESP reports an estimated **M** 7.5 magnitude for the Vincennes-Bridgeport earthquake, which occurred 6,011 ±200 years ago.

Based on interpretations of the size of the prehistoric earthquakes, the following maximum magnitude probability distribution was proposed to capture the uncertainty in the magnitude of the largest prehistoric earthquakes in the lower Wabash Valley region: **M** 7.0 (0.1), **M** 7.3 (0.4); **M** 7.5 (0.4);**M** 7.8 (0.1). The highest weight is given to the range from **M** 7.3 to 7.5 where most of the magnitude estimates lie.}

2.5.2.3 Correlation of Earthquake Activity with Seismic Sources

The U.S. EPR FSAR includes the following COL Item in Section 2.5.2.3:

> Correlation of earthquake activity with seismic sources is site specific and will be addressed by the COL applicant, consistent with the guidance of RG 1.208 and RG 1.165, as appropriate.

This COL Item is addressed as follows:

{Following Regulatory Guide 1.165 (NRC, 1997a) and 10 CFR 100.23 (CFR, 2007), a PSHA was conducted to determine the SSE and to account for uncertainties in the seismological and geological evaluations for the Callaway Plant Unit 2. The probabilistic approach was based on the PSHA conducted by the EPRI for CEUS in the mid to-late 1980s (EPRI, 1989a) with changes to incorporate updated data. Expert opinion was incorporated following a SSHAC2 approach (NRC, 1997b).

An updated USGS catalog, covering events between 1627 and 2001, has been adopted for assessing the Callaway Plant Unit 2 seismic hazard. This update is a refinement of the EPRI SOG catalog that listed earthquakes between 1627 and 1984 (EPRI, 1988). Figure 2.5-39 through Figure 2.5-44 show the distribution of earthquake epicenters from both the EPRI and updated 2001 USGS earthquake catalogs in comparison to the seismic sources identified by each of the EPRI ESTs. The comparison of earthquake distributions from both earthquake catalogs supports the following conclusions:

- The updated catalog does not show any earthquakes within the site region that can be associated with a known geologic or tectonic structure.
- The updated catalog does not show a unique cluster of seismicity that would suggest a new seismic source outside of the EPRI seismic source model (EPRI, 1986).
- The updated catalog does not show a pattern of seismicity that would require significant revision to the EPRI seismic source geometry.} **INSERT H**

2.5.2.4 Probabilistic Seismic Hazard Analysis (PSHA) and Controlling Earthquakes

The U.S. EPR FSAR includes the following COL Item in Section 2.5.2.4:

> The probabilistic seismic hazard analysis is site specific and will be addressed by the COL applicant, consistent with the guidance of NUREG/CR-6372, RG 1.165 and RG 1.208, as appropriate.

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INSERT 'H' to FSAR Section 2.5.2.3
Correlation of Earthquake Activity with Seismic Sources
(amended FSAR page 2-922)

{In addition events from 2002-2007 were assessed with the following results:

- Sensitivity analyses of the 2002-2007 timeframe data indicate that the seismicity recorded during this period does not impact the outcome of the PSHA and does not imply a significant change in G-R seismicity parameters (rate of activity, b-value).
- Table 2.5-10 provides the 2001 USG catalog plus the events recorded between 2002 and 2007. It is relevant to note that the events shown are those within the 200 mile (320 km) radius of the Callaway Plant Unit 2 site and that no significant event was recorded for this area in 2007.
- An update to the catalog included the increase in Mmax for the Wabash Valley seismic source zone, as detailed in Section 2.5.2.2.2.4. This update is required since the Wabash Valley seismic zone is an important contributor to the hazard at the site.
- An update to the PSHA included the new characterization of the New Madrid Fault Zone and related large-magnitude historical earthquakes that occurred during 1811 and 1812. These events are modeled as characteristic large-magnitude events along the New Madrid Fault System (Section 2.5.2.2.2.3).}

earth's crust. Equations are available for spectral frequencies of 100 Hz (equivalent to PGA), 25 Hz, 10 Hz, 5 Hz, 2.5 Hz, 1 Hz, and 0.5 Hz, and these equations apply to hard rock conditions.

EPRI has published updated estimates of aleatory uncertainty (EPRI, 2006a). This update reflected the observation that source of the aleatory uncertainties in the original EPRI attenuation study (EPRI, 2004) were probably too large, resulting in over-estimates of seismic hazard. The 2006 EPRI study (EPRI, 2006a) recommends a revised set of aleatory uncertainties (sigmas) with weights, that can be used to replace the original aleatory uncertainties published in the 2004 EPRI study (EPRI, 2004).

In accordance with RG-1.208 (NRC, 2007a), the hazard curves from the PSHA have to be defined for generic hard rock conditions, characterized by a shear wave velocity (V_s) of about 9200 ft/sec (2800 m/sec). Thus, 2004 EPRI model has been implemented in the rock hazard calculation for Callaway Plant Unit 2. This ground motion model provides a total of twelve median ground motion equations, representing the epistemic uncertainty. However, the EPRI (2006a) updated estimates of aleatory uncertainties have been used in lieu of the original aleatory uncertainties (EPRI, 2004).

In summary, the EPRI 2004 equations have been adopted for median ground motion estimates, and the EPRI 2006 log-sigma model is used to incorporate aleatory variability. Within this context, Figure 2.5-81 shows the logic tree for general area sources such as background or local source, and Figure 2.5-80 shows the logic tree for non-general sources such as New Madrid and Wabash Valley.

EPRI TR-1014381 (EPRI, 2006a) was used in lieu of the Regulatory Guide 1.208 cited document, i.e. EPRI Report 1013105 (EPRI, 2006b). EPRI Report 1013105 (EPRI, 2006b) was an Update Report while EPRI TR-1014381 (EPRI, 2006a) is the final report. For the purposes of revised estimates of aleatory uncertainty in the CEUS, there is no technical difference between the documents. The "Recommended CEUS Sigma" values and "Conclusions" of both reports are identical.

Earthquakes occurring within the area seismic sources were treated as point sources. Thus, the adjustments to the ground motion equations developed in EPRI (2004) to account for this point-source representation were incorporated in the hazard calculations.

2.5.2.4.5 Updated EPRI Probabilistic Seismic Hazard Analysis De-aggregation, and 1 Hz, 2.5 Hz, and 10 Hz Spectral Accelerations Incorporating Significant Increases Based on the Above Sensitivity Studies INSERT I

Figure 2.5-72 through Figure 2.5-78 are plots of the resulting updated probabilistic seismic hazard hard rock curves for the seven spectral ordinates [100 Hz (equivalent to PGA), 25 Hz, 10 Hz, 5 Hz, 2.5 Hz, 1 Hz, and 0.5 Hz]. The mean and fractile [5%, 15%, 50% (median), 85% and 95%] hazard curves are indicated as required by RG-1.208 (NRC, 2007a).

Figure 2.5-48 shows mean and median uniform hazard spectra at hard rock for 1E-4 and 1E-5 annual frequencies of exceedance from these calculations at the seven structural frequencies at which ground motion equations are available. Numerical values of these spectra are documented in Table 2.5-23.

The mean rock hazard has been de-aggregated for the 1E-4 and 1E-5 levels of probability of exceedance. The magnitude and distance bins for the de-aggregation table were taken from RG-1.208 (NRC, 2007a). The results have been plotted in Figure 2.5-49 through Figure 2.5-52, for

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INSERT 'I' to FSAR Section 2.5.2.4.5
(amended FSAR page 2-926)

{As described in Section 2.5.2.1, the USGS 2001 catalog is selected as an initial starting point for the area hazard integration. The year 2001 is selected because this is the latest year for which the mb units are reported. The 2002 to 2007 seismicity data was reviewed by means of a sensitivity analysis. The sensitivity study extended the 2001 USGS earthquake catalog to the year 2007. The update methodology adopted the approach described in the USGS open file report 2008-1128 "The 2008 Update of the United States National Seismic Hazard Maps" that USGS uses to update the USGS 2001 catalog to the year 2007 to reduce the additional epistemic uncertainty related to the magnitude conversion between different units to the mbLg unit used in the USGS 2001 catalog. It is assumed that the magnitude may be adopted from the reported values, since the difference resulting from the conversion between different units is negligible for small magnitude earthquakes.

The sensitivity study concluded that the update to the catalog does not have a significant effect on the b-parameter, seismic occurrence rate, and/or the entire PSHA study at the Callaway Plant Unit 2 site. The use of the updated earthquake catalog results in a reduction of the ground motion levels, as shown by Figure 2.5-145. The resulting ground motion levels are marginally lower, as shown by the comparison at the level of the Uniform Hazard Response Spectra (UHRS) at top of rock. The updated catalog does not justify an update of the G-R parameters.}

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FSAR Table 2.5-10

Seismic Catalog Update

Table 2.5-10—{USGS Earthquake Catalog for the CEUS with mb >= 3.0}

(Page 3 of 62)

m_b	Longitude (degree)	Latitude (degree)	Depth (km)	Year	Month	Day	Hour	Minute	Second	Catalog Reference
4	-82	39.9	0	1776	1	1	0	0	0	NCEER
3.3	-83	35.2	0	1776	11	5	0	0	0	NCEER
3.3	-84	36	0	1777	11	16	7	0	0	NCEER
3.8	-87.2	30.4	0	1780	2	6	0	0	0	NCEER
3.3	-70.9	42.5	0	1780	11	29	0	0	0	NCEER
4.9	-74.5	41	0	1783	11	30	3	50	0	NCEER
3.3	-71.2	46.8	0	1784	1	2	10	0	0	NCEER
3.3	-78.8	37.7	0	1791	1	13	9	0	0	NCEER
3.3	-77.5	37.5	0	1791	1	15	10	0	0	NCEER
4.5	-72.4	41.5	0	1791	5	16	13	22	0	NCEER
6	-70.5	47.4	0	1791	12	6	20	0	0	NCEER
3.3	-72.5	41.5	0	1792	8	29	3	0	0	NCEER
3.3	-72.5	41.5	0	1794	3	6	19	0	0	NCEER
3.4	-89.9	39	0	1795	1	8	9	0	0	NCEER
4	-79	42.9	0	1796	12	26	11	0	0	NCEER
4.4	-80	32.9	0	1799	4	11	8	20	0	NCEER
3.9	-76.39	40.12	0	1800	11	20	5	0	0	NCEER
3.3	-72.3	43.7	0	1800	12	20	0	0	0	NCEER
3.3	-71.1	41.9	0	1800	12	25	0	0	0	NCEER
3.3	-70.8	43.1	0	1801	3	1	20	30	0	NCEER
3.5	-79.1	37.4	0	1802	8	23	10	0	0	NCEER
3.3	-70.9	42.5	0	1803	1	18	14	50	0	NCEER
4.4	-87.8	42	0	1804	8	20	20	10	0	USHIS
4.2	-89	42	0	1804	8	24	20	10	0	NCEER
3.3	-70.9	42.5	0	1805	4	25	0	0	0	NCEER
3.3	-69	44.5	0	1805	6	12	12	30	0	NCEER
3.3	-72.5	41.5	0	1805	12	30	11	0	0	NCEER
3.3	-71.1	43	0	1807	1	14	4	0	0	NCEER
3.5	-79.1	37.4	0	1807	5	1	9	0	0	NCEER
3.3	-70.5	43.5	0	1807	5	6	18	0	0	NCEER
3.5	-69	44.4	0	1808	6	26	2	50	0	NCEER
3.9	-70.9	43	0	1810	11	10	2	15	0	NCEER
3.3	-80.2	36.1	0	1811	11	27	8	0	0	NCEER
3.3	-77.4	37.6	0	1812	2	2	9	30	0	NCEER
7.4	-89.6	36.5	0	1812	2	7	9	45	0	NCEER **Note 1**
3.3	-77.5	37.5	0	1812	4	22	4	0	0	NCEER
4	-70.3	43.7	0	1814	11	29	0	14	0	NCEER
3	-89.5	36.6	0	1816	7	25	15	0	0	NCEER
5.2	-73.6	45.5	0	1816	9	9	0	0	0	NCEER
5	-80	32.9	0	1817	1	8	9	0	0	USHIS
4.7	-67.2	45	0	1817	5	22	20	0	0	NCEER
4.2	-71.2	42.5	0	1817	10	5	16	45	0	NCEER
3.1	-84.5	38.5	0	1817	12	11	0	0	0	NCEER
3	-90.2	38.6	0	1818	4	11	20	0	0	NCEER
3.3	-71.2	46.9	0	1818	10	11	0	0	0	NCEER
3.3	-76.5	44	0	1818	12	7	0	0	0	NCEER
3.4	-89.7	37.7	0	1819	9	2	8	0	0	NCEER
3.1	-89.8	38.1	0	1819	9	17	4	0	0	NCEER

Table 2.5-10—{USGS Earthquake Catalog for the CEUS with mb >= 3.0}

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m_b	Longitude (degree)	Latitude (degree)	Depth (km)	Year	Month	Day	Hour	Minute	Second	Catalog Reference
3.1	-93.213	34.292	5	2001	8	4	1	13	25.3	PDE
4	-107.378	39.66	5	2001	8	9	22	38	54.5	PDE
4.5	-104.618	37.143	5	2001	9	5	10	52	7.8	PDE-W
4.3	-110.051	43.459	5	2001	9	27	22	5	21.7	PDE-W
3.2	-68.67	45.2	9	2001	10	25	0	24	29.8	PDE-W
3.4	-107.384	38.851	1	2001	11	5	8	34	23	PDE-W
3.3	-100.208	39.996	5	2001	11	13	1	56	13.1	PDE-W
3.1	-102.631	31.786	5	2001	11	22	0	7	8	PDE-W
3.1	-107.374	38.813	1	2001	12	4	18	20	9.1	PDE-W
3.9	-86.245	34.735	5	2001	12	8	1	8	21.5	PDE-W
3.3	-104.797	36.859	5	2001	12	15	7	58	31.3	PDE-W
3.8	-76.49	46.87	18	2001	12	24	16	58	21	PDE-W
3.6	-89.96	37.17	5	2002	3	12	8	30	48.3	PDE **Note 2**
4.6	-87.78	37.99	5	2002	6	18	17	13	15.2	PDE **Note 2**
3.1	-88.07	37.83	18	2003	1	3	16	17	9	PDE **Note 2**
3.2	-86.65	37.96	0.6	2003	5	2	8	10	13	ANSS **Note 2**
3.1	-91.50	38.15	2.5	2003	7	8	5	55	5	ANSS **Note 2**
3.2	-88.72	37.10	5	2003	8	26	2	26	56.8	PDE **Note 2**
3.0	-90.17	38.14	5	2003	12	29	9	2	8.61	PDE **Note 2**
4.2	-88.90	41.46	10	2004	6	28	6	10	52.2	PDE **Note 2**
3.8	-85.80	39.59	6	2004	9	12	13	5	19.1	PDE **Note 2**
3.0	-89.42	37.63	5	2005	6	27	15	46	52	PDE **Note 2**
3.6	-88.35	37.80	10	2006	1	2	21	48	57.1	PDE **Note 2**
3.0	-88.98	37.50	6	2006	3	1	17	42	42	PDE **Note 2**

Note 1. The New Madrid events occurred in a cluster of three events. The event shown in the catalog is determined by USGS as the New Madrid event for the 1811-1812 cluster set. Two other events are considered as the foreshock/aftershock events and are filtered out from the catalog by USGS. The event shown in the catalog is not considered in the general area source hazard integration since its magnitude is above the maximum magnitude limit considered. This New Madrid event is accounted for in the PSHA in the New Madrid Characteristic Cluster events. The following events are also part of the characteristic earthquake analysis:

Longitude (degree)	Latitude (degree)	m_b	Year	Month	Day	Hour	Minute	Event Group
-90	36	7.2	1811	12	16	8	15	1
-90	36	7.0	1811	12	16	14	15	
-89.6	36.3	7.1	1812	1	23	15	0	2
-89.6	36.5	7.4	1812	2	7	9	45	3

Note 2. 2002-2007 data within the 200 mile (320 km) radius influence for the Callaway Plant Unit 2 site. No events were recorded for this area in 2007. Information is retrieved from the USGS, PDE, and ANSS earthquake databases.

Supplement to FSAR 2.5.3; Surface Faulting Update

FSAR 2.5.3 Page Affected	Description
2-946 through 2-950	Section 2.5.3 replaced with Insert "J".

2.5.3 SURFACE FAULTING INSERT J

~~The U.S. EPR FSAR includes the following COL Item in Section 2.5.3.~~

> ~~A COL Applicant that references the U.S. EPR design certification will investigate site-specific surface and subsurface geologic, seismic, geophysical, and geotechnical aspects 5 miles (8 km) around the site and evaluate any impact to the design. The COL Applicant will demonstrate that no capable faults exist at the site in accordance with the requirements of 10 CFR 100.23 and Appendix S of 10 CFR 50. If non-capable surface faulting is present under foundations for safety-related structures, the COL Applicant will demonstrate that the faults will not have any impact on the structural integrity of safety-related structures, systems or components.~~

~~This COL item is addressed as follows.~~

~~{There is no potential for tectonic fault rupture and there are no capable tectonic sources within a 5 mile (8 km) radius of the Callaway Plant Unit 2 site. There are no surface faults at the site. All tectonic features within 50 miles (80.5 km) of the site have been discussed in Section 2.5.1.1.4.1, Regional Tectonic Features. A capable tectonic source is a tectonic structure that can generate both vibratory ground motion and tectonic surface deformation, such as faulting or folding at or near the earth's surface in the present seismotectonic regime (NRC, 1997). The following sections provide the data, observations, and references to support this conclusion. Information contained in these sections was developed in accordance with RG 1.165 (NRC, 1997), and is intended to satisfy 10 CFR 100.23, "Geologic and Seismic Siting Criteria" (CFR, 2007a) and 10 CFR 50, Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants" (CFR, 2007b).~~

~~Sections 2.5.3.1 through 2.5.3.9 are added as a supplement to the U.S. EPR FSAR.~~

~~2.5.3.1 Geological, Seismological, and Geophysical Investigations~~

~~The following investigations were performed to assess the potential for surface fault rupture at and within a 5 mile (8 km) radius of the Callaway Plant Unit 2 site:~~

- ~~Compilation and review of existing geologic and seismologic data~~
- ~~Interpretation of aerial photography performed for Callaway Plant Unit 1 FSAR (AmerenUE, 2004).~~
- ~~Interpretation of field and aerial (inspection by plane) reconnaissance for Callaway Plant Unit 1 FSAR (AmerenUE, 2004).~~
- ~~Interpretation of High Resolution Shear Wave Reflection Seismic Survey for Callaway Plant Unit 2 Site (Bay Geophysical, 2008).~~
- ~~Review of pre-EPRI and post-EPRI (1989) seismicity (e.g. earthquake catalog used in EPRI (1989) ended in 1983. Pre-EPRI catalog is 1500's through 1983; post-EPRI is 1983 through 2006).~~
- ~~Discussion of site area geology with researchers at the Missouri Department of Natural Resources (MODNR).~~

~~The geologic and geotechnical information available for the existing Callaway Plant Unit 1 Site, as well as the proposed Callaway Plant Unit 2 Site, is contained in three principal sources:~~

1. ~~Detail investigation performed for the existing Callaway Plant Unit 1 Site and complementary structures (AmerenUE, 2004) and (Dames & Moore, 1980); the latter including excavation description and mapping for Callaway Plant Unit 1 Site.~~

2. ~~Published and unpublished geologic mapping performed primarily by Missouri Department of Natural Resources (MODNR 2007, Gentile 2004, Thompson 1986, 1991, and 2003).~~

3. ~~Seismicity data compiled and analyzed in published journal articles and, more recently, as part of Section 2.5.2.~~

~~Existing information was supplemented by aerial and field reconnaissance within a 25 mile (40 km) radius of the site, and interpretation of aerial photography along all known faults within the 5 mile (8 km) radius of the site. These features were reviewed during the field reconnaissance and office-based analyses of aerial photography and are reported in Callaway Plant Unit 1 FSAR (AmerenUE, 2004) and in the present report findings. These field and office-based studies were performed to verify, where possible, the existence of mapped bedrock faults in the Callaway Plant Unit 1 site area and to assess the presence or absence of geomorphic features suggestive of potential Quaternary fault activity or previously undetected faults~~

~~Field reconnaissance of the site was conducted by geologists in teams of two. Details of these field activities are presented in Section 2.5.1.2.4. Geologic studies to determine the site structural characteristics have been performed utilizing data obtained from site borings, excavation mapping and geophysical surveys. In addition, bedrock exposures were described throughout the site area. Dip and strike measurements were taken on bedding planes and joints where possible. A thorough search for faulting was made throughout the site area. No major structures have been encountered that would adversely affect construction and operation of the plant.~~

~~2.5.3.2 Geological Evidence, or Absence of Evidence, for Surface Deformation~~

~~As discussed in Section 2.5.3.1, investigations for this site have not revealed any faults, active or inactive, within 5 miles (8 km) of the site, with the exception of minor, inactive displacements associated with slump features found in Ordovician deposits.~~

~~Interpreted seismic sections (Bay Geophysical, 2008) are displayed in Figure 2.5-37. In this figure interpreted seismic sections are identified by the correlation of the Graydon Chert Conglomerate and the Snyder Creek events traced across each seismic profile. The Graydon Chert Conglomerate is highlighted in orange and the Snyder Creek event is highlighted in yellow on each of the seismic figures.~~

~~The minimal vertical time shift noted in Reflection Line 1, 2, and 3 have not been interpreted as significant offsets within the Snyder Creek event that could be attributed to faulting. These offsets do not appear above or below the Snyder Creek event that were considered along with area geology, eliminates post-depositional movements as their cause. It is probable that apparent offsets could be a result of lenticular facies, erosion remnants, or a depositional feature within the Snyder Creek Formation (noted in Line Reflection Line 2 in Figure 2.5-37). Other apparent offsets may be the result of low fold (low statistical redundancy) that occurs at the line ends of seismic reflection data and thus reducing the confidence of the interpreted~~

~~apparent offsets. These offsets show minimal vertical time shift above the Snyder Creek event, and no evidence above the Graydon Chert Conglomerate event.~~

~~2.5.3.2.1 Stratigraphic Undulations~~

~~Folds shown in Figure 2.5-8, Figure 2.5-32 and Figure 2.5-33 are all pre-Pennsylvanian, preceding the deposition of the Graydon Conglomerate.~~

~~2.5.3.3 Correlation of Earthquakes with Capable Tectonic Sources~~

~~No reported historical earthquake epicenters have been associated with bedrock faults within the 25 mile (40 km) radius of the Callaway Plant Unit 2 Site vicinity.~~

~~2.5.3.4 Ages of Most Recent Deformations~~

~~As presented in, Section 2.5.3.2, faults and postulated folds and faults within 5 miles (8 km) of the Callaway Plant Unit 2 site do not exhibit evidence of Quaternary activity. Based on a review of available published geologic literature, field and aerial reconnaissance, and interpretation of aerial photography, structures on site are constrained to the Pennsylvanian and do not appear to affect Pleistocene deposits.~~

~~2.5.3.5 Relationship of Tectonic Structures in the Site Area to Regional Tectonic Structures~~

~~No faulting is known to exist within 12 miles (19.3 km) of the site, and no historic epicenters within 40 miles (64.4 km).~~

~~2.5.3.6 Characterization of Capable Tectonic Sources~~

~~Based on previous discussions in Section 2.5.3.4, there are no capable tectonic sources within 5 miles (8 km) of the Callaway Plant Unit 2 site.~~

~~2.5.3.7 Designation of Zones of Quaternary Deformation Requiring Detailed Fault Investigation~~

~~There are no zones of Quaternary deformation requiring detailed investigation within the Callaway Plant Unit 2 site area. Preliminary geologic investigations of the site have not revealed any evidence of faulting affecting Pennsylvanian or younger deposits (Graydon Conglomerate Formation as well as Quaternary glacial and post-glacial deposits). The closest Quaternary faults or folds are described 65 miles (105 km) to the ESE of the site in Jefferson and St Louis counties (USGS, 2000)~~

~~2.5.3.8 Potential for Tectonic or Non-Tectonic Deformation at the Site~~

~~The potential for tectonic deformation at the site is negligible. This is based on:~~

1. ~~The absence of faulting in deposits exposed along outcrops and road cuts within (except for inactive displacements associated with Ordovician age slump features) 5 miles (8 km) of the Callaway Plant Unit 2 site as shown in Figure 2.5-7 and Figure 2.5-8.~~

2. ~~The detailed mapping of the excavations for Callaway Plant Unit 1 revealed no evidence of folding or faulting, or any other feature that would adversely affect the safety of the plant (Dames & Moore 1980).~~

3. ~~The interpretation of aerial photography for Callaway Plant Unit 1 (AmerenUE, 2004).~~

~~Collectively, these data support the interpretation for the absence of any Quaternary surface faults or capable tectonic sources within the site area. In addition, there is no evidence of non-tectonic deformation at the site, such as glacially induced faulting, collapse structures, growth faults, salt migration, or volcanic intrusion.~~

~~2.5.3.9 References~~

~~**AmerenUE, 2004.** Final Safety Analysis Report (FSAR), Callaway Plant Unit 1, Revision 14, 2004.~~

~~**Bay Geophysical, 2008.** High Resolution Shear Wave Reflection, Seismic Survey, Callaway Power Plant, Callaway County, MO; preliminary Draft Report prepared for P.C. Rizzo Associates, Bay Geophysical Project Number: 7007RIZ, Bay Geophysical, 2008.~~

~~**Dames & Moore, 1980.** Results of detailed excavation mapping, ultimate heat sink area, essential service water system, and Unit 1 power block subgrade, Callaway Plant, Units 1 and 2, Dames & Moore, July 29, 1980.~~

~~**Gentile, 2004.** Paleozoic Succession in Missouri, Part 5, Pennsylvanian Subsystem of Carboniferous System, Missouri Department of Natural Resources, Geological Survey and Resource Assessment Division, Report of Investigation No. 70, (Part 5- Volume A Morrowan Strata through Cherokee Group, Part 5- Volume B Marmaton Group, Part 5- Volume C Pleasanton Group through Lansing Group, Part 5- Volume D Douglas Group through Wabaunsee Group), 1225 pp., Richard J. Gentile and Thomas L. Thompson, 2004.~~

~~**MODNR, 2007.** Missouri Environmental Geology Atlas (MEGA 2007), A collection of Statewide Geographic Information System Data Layers, Missouri Department of Natural Resources, Division of Geology and Land Survey, Missouri Department of Natural Resources (MODNR), 2007.~~

~~**Thompson, 1986.** Paleozoic Succession in Missouri, Part 4, Mississippian System, Missouri Department of Natural Resources, Division of Geology and Land Survey, Report of Investigation No. 70, 182 pp., Thomas L. Thompson, 1986.~~

~~**Thompson, 1991.** Paleozoic Succession in Missouri, Part 2, Ordovician System, Missouri Department of Natural Resources, Division of Geology and Land Survey, Report of Investigation No. 70, 282 pp., Thomas L. Thompson, 1991.~~

~~**Thompson, 1993.** Paleozoic Succession in Missouri, Part 3, Silurian & Devonian Systems, Missouri Department of Natural Resources, Division of Geology and Land Survey, Report of Investigation No. 70, 228 pp., Thomas L. Thompson, 1993.~~

~~**CFR, 2007a.** Title 10, Code of Federal Regulations, Part 100.23, Geologic and Seismic Siting Criteria, 2007.~~

~~**CFR, 2007b.** Title 10, Code of Federal Regulations, Part 50, Appendix S, Earthquake Engineering Criteria for Nuclear Power Plants, 2007.~~

~~**EPRI, 1986.** Seismic Hazard Methodology for the Central and Eastern United States: EPRI NP-4726, Electric Power Research Institute, 1986.~~

~~**NRC, 1997.** Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion, Regulatory Guide 1.165, Nuclear Regulatory Commission, March 1997.~~

~~**USGS, 2000.** Data for Quaternary Faults, Liquefaction Features, and Possible Tectonic Features in the Central and Eastern United States, East of the Rocky Mountain Front, Open-File Report 00-260, U.S. Geological Survey, A. Crone and R. Wheeler, 2000.~~

~~**USGS, 2005.** Known or Suggested Quaternary Tectonic Faulting, Central and Eastern United States – New and Updated Assessments for 2005, Open File Report 2005-1336, U.S. Geological Survey, R. Wheeler, 2005.}~~

2.5.4 STABILITY OF SUBSURFACE MATERIALS AND FOUNDATIONS

The U.S. EPR FSAR includes the following COL Item for Section 2.5.4:

> A COL Applicant that references the U.S. EPR design certification will present site-specific information about the properties and stability of all soils and rocks that may affect the nuclear power plant facilities, under both static and dynamic conditions including the vibratory ground motions associated with the Safe Shutdown Earthquake (SSE)

This COL item is addressed in the following sections.

This section addresses subsurface materials and foundation conditions {for the Callaway Plant Unit 2} site. It was prepared based on the guidance in relevant sections of NRC Regulatory Guide 1.206, Combined License Applications for Nuclear Power Plants (LWR Edition) (NRC, 2007).

{The information presented in this section is based on results of a subsurface investigation program implemented at the Callaway Plant Unit 2 site, and evaluation of the collected data, unless otherwise indicated. The Callaway Plant Unit 1 Final Safety Analysis Report (FSAR) (AmerenUE, 2004) contains a summary of the geotechnical information collected previously for the construction of Callaway Plant Unit 1. Callaway Plant Unit 2 is located adjacent to Callaway Plant Unit 1 (AmerenUE, 2004). The geologic and geotechnical work performed for the Callaway Plant Unit 2 is a "stand-alone" investigation. Its outcome and conclusions do not rely on the existing FSAR Unit 1 information. This document provides the complete investigation data set, including both geotechnical boring logs, and results from the laboratory testing program. The body, tables, and figures in the text organize the data, providing an engineering recommendation for the use of geotechnical parameters.}

2.5.4.1 Geologic Features

The U.S. EPR FSAR includes the following COL Item in Section 2.5.4.1:

> Geologic features are site-specific and will be addressed by the COL applicant.

This COL Item is addressed as follows.

Section 2.5.1.1 describes the regional geology, including regional physiography and geomorphology, regional geologic history, regional stratigraphy, regional tectonic and nontectonic conditions, and geologic hazards, as well as maps, cross-sections, and references. Section 2.5.1.2 addresses site-specific conditions, including site structural geology, physiography and geomorphology, site geologic history, site stratigraphy and lithology, seismic conditions, and a site geologic hazard evaluation, accompanied by figures, maps, and references. Pre-loading influences on soil deposits, including estimates of consolidation, pre-consolidation pressures, and methods used for their estimation are addressed in Section 2.5.4.2. Related maps and stratigraphic profiles are also addressed in Section 2.5.4.2

INSERT J

INSERT 'J' to FSAR Section 2.5.3

Surface Faulting

(amended FSAR page 2-946 through 2-950)

2.5.3 SURFACE FAULTING

The U.S. EPR DCD includes the following COL Item in Section 2.5.3.

> A COL Applicant that references the U.S. EPR design certification will investigate site-specific surface and subsurface geologic, seismic, geophysical, and geotechnical aspects within 25 miles (40 km) around the site and evaluate any impact to the design. The COL Applicant will demonstrate that no capable faults exist at the site in accordance with the requirements of 10 CFR 100.23 and Appendix S of 10 CFR 50. If non-capable surface faulting is present under foundations for safety-related structures, the COL Applicant will demonstrate that the faults have no significant impact on the structural integrity of safety-related structures, systems or components

This COL item is addressed as follows.

{There is no potential for tectonic fault rupture and there are no capable tectonic sources within a 25 miles (40 km) radius of the Callaway Plant Unit 2 site. In addition, there are no surface faults at the site. All tectonic features within 50 miles (80.5 km) of the site have been discussed in Section 2.5.1.1.4.1, Regional Tectonic Features.} A capable tectonic source is a tectonic structure that can generate both vibratory ground motion and tectonic surface deformation, such as faulting or folding at or near the earth's surface in the present seismotectonic regime (NRC, 1997). The following sections provide the data, observations, and references to support this conclusion. Information contained in these sections was developed in accordance with RG 1.165 (NRC, 1997), and is intended to satisfy 10 CFR 100.23, "Geologic and Seismic Siting Criteria" (CFR, 2007a) and 10 CFR 50, Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants" (CFR, 2007b).

2.5.3.1 Geological, Seismological, and Geophysical Investigations

{The following investigations were performed to assess the potential for tectonic and non-tectonic deformation and surface fault rupture at and within a 25 miles (40 km) radius of the Callaway Plant Unit 2 site:

- Compilation and review of existing geologic and seismologic data and references.
- Site Area Paleo-Liquefaction and Surface Faulting Investigation Program, described in Section 2.5 Appendix B.
- Interpretation of aerial photography performed for Callaway Plant Unit 1 FSAR (AmerenUE, 2004).
- Interpretation of field reconnaissance for Callaway Plant Unit 1 FSAR (AmerenUE, 2004).
- Interpretation of High Resolution Shear Wave Reflection Seismic Survey (Bay Geophysical, 2008).
- Review of USGS earthquake catalog and supporting data for the Callaway Plant Unit 2 Site Region, updated in 2007 (USGS, 2007).
- Discussion of site area geology with researchers at the Missouri Department of Natural Resources (MODNR).

- Interpretation of recent satellite imagery.

The geologic and geotechnical information available for the existing Callaway Plant Unit 1 Site location, as well as the proposed Callaway Plant Unit 2 Site location, is contained in three principal sources:

- Detailed investigation performed for the existing Callaway Plant Unit 1 Site and complementary structures (AmerenUE, 2004) and (Dames & Moore, 1980); the latter including excavation description and mapping for Callaway Plant Unit 1 Site.
- Published and unpublished geologic mapping performed primarily by Missouri Department of Natural Resources (MODNR 2007, Gentile 2004, Thompson 1986, 1991, and 2003).
- Seismicity data compiled and analyzed in published journal articles and, more recently, as part of Callaway Plant Unit 2 FSAR, Section 2.5.2.

2.5.3.1.1 Previous Callaway Site Investigations

Previous site investigations results for the existing Callaway Plant Unit 1 are summarized in Callaway Plant Unit 1 FSAR (AmerenUE, 2004). These previous investigations provide the following results documenting the absence of Quaternary faults at and within the area of the Callaway site:

- Interpretation of satellite photos, aerial pictures and topographic maps. This interpretation revealed no evidence of surface rupture, surface warping, or offset of geomorphic features indicative of active faulting.
- Interviews with personnel from government agencies and private organizations. These interviews concluded that no known faults are present at the surface in or beneath the existing Callaway Plant Unit 1 site area.
- Seismicity Analysis showed that no seismic activity has occurred within the 25 miles (40 km) radius of the Callaway Plant Unit 2 Site vicinity.
- Approximately 170 exploratory boreholes were drilled during Callaway Plant Unit 1 site field investigation. Borehole data have provided evidence for the lateral continuity of strata across the existing Callaway site area. The inspection of soil and rock samples has revealed no adverse effects indicative of geologically recent or active faulting.
- Field reconnaissance of many surface outcrops at the site and within the 5 mile (8 km) radius of the site, coupled with geophysical surveys, provided evidence for no faulting at the Callaway Plant Unit 1 site.

2.5.3.1.2 Previous and Current Geologic Mapping

At the time of the original studies for the Callaway Plant Unit 1 FSAR (AmerenUE, 2004), published maps showed no faults within a 5 mile (8 km) radius of the site. More recent references (MODNR, 2007) confirm that there are no faults within a 5 mile (8 km) radius of the site. Both references also identified only three faults in or close to the site vicinity: the Kingdom City Fault, Mineola Fault, and the Cuba Fault.

The Kingdom City Fault and the Mineola Fault lie within the 25 mile (40 km) radius of the Callaway Plant Unit 1, and the Cuba Fault mapped northern limit just outside the site vicinity (25 mile (40 km) radius) which are all described in Section 2.5.1.1.1.4.2.2. No other fault has been identified in the site vicinity since then (MODNR, 2007). These faults are considered inactive, are not capable tectonic sources, and are not considered capable of generating earthquakes and/or ground deformation and shaking.

The locations for these three faults are shown in Figure 2.5-14, and each of them is described below (AmerenUE, 2004 and MODNR, 2007).

- **Kingdom City Fault** (see No. 48 in Missouri on Figure 2.5-14) is proposed to trend east-northeast in Township 49 North, Range 9 West, Callaway County, Missouri. Based on data from well log No. 26595 in the Missouri Geological Survey and Water Resources well log files, it is a reverse fault and cuts the St. Peter Formation twice, displacing it 300 feet. On the basis of surrounding well information, the southeast side was downthrown.

  MODNR (2007) does not describe this fault by this name but uses Fox Hollow Fault – Monocline, for a more complex structure revealed by additional mapping. The structure is referred as a monocline because no definite fault plane was discovered and because the stratigraphic displacement can be accounted for by dip alone. However, it is probable that faulting and fracturing accompany the folding. The monocline is uplifted to the east relative to the west. South of Fox Hollow the structure's strike bends to the south and changes from a monocline to a fault.

- **Mineola Fault** (see No. 52 in Missouri on Figure 2.5-14) is located in the southwestern portion of Township 48 North, Range 6 West, Montgomery County, Missouri on the flank of the Mineola Dome. This is the closest reported geologic structure (fault or fold) to the site, at approximately 12 miles (19 km). Interpretation of well log data from the Missouri Geological Survey and Water Resources files (1974) indicates that 200 feet of downward displacement to the southwest.

  MODNR (2007) describes the fault as Mineola structure-Mineola dome, first mapped as a pronounced anticline in the vicinity of Mineola, with a N. 75° E. trend, and 10° to 20° dips on both flanks; the dips are generally steeper on the south limb. Later work showed the structure to be closed with a short north south axis. It is asymmetrical with a steep south southwest dip and more gentle north northeast dip. An additional closure was mapped and pointed to a number of closed anticlines or domes striking N. 70° W. in an en echelon pattern from the Mineola area to the Browns Station anticline in Boone County. The Mineola dome brings Cotter (lower Ordovician) rocks to the surface in Loutre Creek, where they are surrounded by rocks ranging in age from Middle Ordovician (St. Peter) to Pennsylvanian (Cherokee Group).

- **Cuba Fault** (see No. 10 in Missouri on Figure 2.5-14) passes 3 miles west of Cuba, Missouri, across Crawford and Gasconade counties to Township 43 North, Range 7 East in Osage County, Missouri (McQueen, 1943 in AmerenUE, 2004). Fox (1954 in

AmerenUE, 2004) proposed that the fault extends to the south and possibly joins the Crooked Creek Structure (see No. 9 in Missouri on Figure 2.5-14). Current work refutes Fox's concept. James A. Martin and James H. Williams of the Missouri Geological Survey and Water Resources accompanied James W. Smith of Dames & Moore in verifying the position of the fault essentially as mapped by McQueen (1943 in AmerenUE, 2004).

The Cuba Fault is downthrown on the east side with a vertical displacement from 125 to 150 feet (McCracken, 1971 in AmerenUE, 2004). As Pennsylvanian strata may be cut by the fault, the age of the last movement is Pennsylvanian or younger.

MODNR (2007) describes the fault essentially north-south in direction with a slight trend to the northwest. It is downthrown to the northeast with a vertical displacement of from 125 to 150 feet. The upthrown side is broadly arched exposing rocks of Ordovician age as old as Gasconade Dolomite in places. The downthrown side is synclinal and probably controls the occurrence of fire clay in the Owensville, Rosebud and Gerald fire clay districts. In places the fault may be replaced by folding. It appears to die out in Osage County, and is expressed by silicified Roubidoux Sandstone in the east bank of the Meramec River, as well as by displacements of the Roubidoux and Gasconade formations.

2.5.3.1.3 Current Seismicity Data

The earthquake epicenters shown in Figure 2.5-14 indicate no earthquakes within the 25 mile (40 km) radius of the Callaway site. The site is located in a region that has experienced only infrequent minor earthquake activity, with the closest epicentral location (3.0 to 3.9 mb) situated approximately 38 miles (61 km) southwest of the Callaway Plant Unit 1 site, west of Cole County. Besides the latter there has been only one more cataloged earthquake within 50 miles (80 km) of the Callaway Plant Unit 1 site, this one (3.0 to 3.9 mb) approximately 45 miles (72 km) south-southeast of the, south of Gasconade County. Section 2.5.2 provides a full discussion on the seismicity analysis for the Callaway Plant site.

2.5.3.1.4 Current Shear Wave Reflection Seismic Studies

Interpreted shear wave reflection seismic sections (Bay Geophysical, 2008) are displayed in Figure 2.5-37. In this figure interpreted seismic sections are identified by the correlation of the Graydon Chert Conglomerate and the Snyder Creek events traced across each seismic profile. The Graydon Chert Conglomerate is highlighted in orange and the Snyder Creek event is highlighted in yellow on each of the seismic figures.

The minimal vertical time shift noted in Reflection Lines REF-1, REF-2 and REF-3 have not been interpreted as significant offsets within the Snyder Creek event that could be attributed to faulting. These offsets do not appear above or below the Snyder Creek, and in consideration of area geology, post-depositional movements are not likely their cause. It is probable that apparent offsets could be a result of lenticular facies, erosion remnants, or a depositional feature within the Snyder Creek Formation (noted in Line REF-2 in Figure 2.5-37). Other apparent offsets may be the result of low fold (low statistical redundancy) that occurs at the line ends of seismic reflection data and thus reducing the confidence of the interpreted apparent offsets. These offsets show minimal vertical time shift above the Snyder Creek event, and no evidence above the Graydon Chert Conglomerate event.

2.5.3.1.5 Current Field Reconnaissance

Existing information referenced in 2.5.3.1.1 was supplemented by study of aerial photography and field reconnaissance within a 5 miles (8 km) radius of the site. Field reconnaissance of the site was conducted by geologists in teams of two. Details of these field activities are presented in Section 2.5 Appendix B and in Callaway Plant Unit 2 FSAR Section 2.5.1.2.4. Geologic studies to determine the site structural characteristics have been performed utilizing data obtained from site borings, excavation mapping and geophysical surveys. In addition, bedrock exposures were observed and described throughout the site area. Dip and strike measurements were taken on bedding planes and joints where possible.

A remote imagery interpretation, followed by a detailed ground truthing investigation, yielded no evidence of paleo-liquefaction in the area of the site. Most of the area around the site has been impacted by agricultural activities or is wooded which might mask such features on remote imagery; however, no such features were found in non-developed areas along water bodies either -- areas where paleo-liquefaction features would tend to be more prevalent if they exist at all in the area. No paleo-liquefaction features were found in the area of the site, thus eliminating such features as a geologic hazard which could impact on the safety-related facilities of the proposed plant.

In addition, the USGS recently completed a compilation of all Quaternary faults, liquefaction features, and possible tectonic features in the central and eastern U.S. (Crone, 2000; Wheeler, 2005; Tuttle, 2005). USGS findings all are in accordance with the reported liquefaction for the site region, where the closest reported indication to paleo-liquefaction is referred to in Crone, 2000 and Tuttle, 2005, listed within the St. Louis–Cape Girardeau liquefaction features, 70 miles southeast from the site. These liquefaction features were found along the Cache, Cuivre, Femme, Osage Creek, Meramec, and Missouri Rivers.

A remote imagery interpretation, followed by a detailed ground truthing investigation, yielded no evidence of faulting. The ground truthing work led to observations of small deformations (less than five (5) feet) – all associated with slumping or consolidation and contained within Ordovician rocks, which are pre-Middle Devonian in age (over 350 million years old). No long linear features indicative of strike slip movement or evidence of normal or thrust features were found. No surface faulting features were found in the area of the site that represent a geologic hazard which could impact the safety-related facilities of the proposed plant.

A thorough search for faulting or evidence of faulting was made throughout the site area. No major geologic structures or faults in the site area have been identified that have the potential to affect construction and operation of the plant. }

2.5.3.2 Geological Evidence, or Absence of Evidence, for Surface Deformation

{ As discussed in previous Section 2.5.3.1, investigations for this site have not revealed any faults, active or inactive, within 5 miles (8 km) of the site, with the exception of minor, inactive displacements associated with slump features found in Ordovician deposits.

Folds shown in Callaway Plant Unit 2 FSAR Figures 2.5-8, 2.5-15, 2.5-32 and 2.5-33 are all pre-Pennsylvanian, preceding the deposition of the Graydon Conglomerate. Descriptions are provided in the Section 2.5.1.2.4.1.}

2.5.3.3 Correlation of Earthquakes with Capable Tectonic Sources

{No reported historical earthquake epicenters have been associated with bedrock faults within the 25 miles (40 km) radius of the Callaway Plant Unit 2 Site vicinity.

The site is located in a region that has experienced only infrequent minor earthquake activity, with the closest epicentral location (3.0 to 3.9 mb) situated approximately 38 miles (61 km) southwest of the Callaway Plant Unit 1 site, west of Cole County. Additionally there has been only one more cataloged earthquake within 50 miles (80 km) of the Callaway Plant Unit 1 site, this one (3.0 to 3.9 mb) approximately 45 miles (72 km) south-southeast of the, south of Gasconade County. Section 2.5.2 provides a full discussion on the seismicity analysis for the Callaway Plant site.

Based on this information, there are no significant hazard potential faults within a 25 mile (40 km) radius of the Callaway Plant Unit 2 Site shown in Figure 2.5-14 }

2.5.3.4 Ages of Most Recent Deformations

{ As presented in Callaway Plant Unit 2 FSAR, Section 2.5.3.1 and 2.5.3.2, there are no faults within the 5 mile site area and postulated geologic structures (slump and folds) do not exhibit evidence of Quaternary activity. Based on a review of available published geologic literature, field and aerial reconnaissance, and interpretation of aerial photography in Callaway Plant Unit 1 FSAR (AmerenUE, 2004) and in the present report, structures on site are constrained to the Pennsylvanian and do not appear to affect Pleistocene deposits.}

2.5.3.5 Relationship of Tectonic Structures in the Site Area to Regional Tectonic Structures

{No faulting is known to exist within 5 miles (8 km) of the site, and no historic epicenters within 38 miles (61 km)}.

2.5.3.6 Characterization of Capable Tectonic Sources

{Based on previous discussions in Sections 2.5.3.1 through 2.5.3.4, there are no capable tectonic sources within 25 miles (40km) of the Callaway Plant Unit 2 site.}

INSERT 'J' to FSAR Section 2.5.3

Surface Faulting

(amended FSAR page 2-946 through 2-950)

2.5.3.7 Designation of Zones of Quaternary Deformation in the Site Region

{There are no zones of Quaternary deformation within the Callaway Plant Unit 2 site area. Preliminary geologic investigations of the site have not revealed any evidence of faulting affecting Pennsylvanian or younger deposits (Graydon Conglomerate Formation as well as Quaternary glacial and post-glacial deposits).

In addition, the USGS recently completed a compilation of all Quaternary faults, liquefaction features, and possible tectonic features in the central and eastern U.S. (Crone, 2000; Wheeler, 2005; Tuttle, 2005; USGS, 2000). Their findings indicate that the closest reported indication to paleo-liquefaction is referred to in Crone, 2000 and Tuttle, 2005, listed within the St. Louis–Cape Girardeau liquefaction features, 70 miles southeast from the site. These liquefaction features were found along the Cache, Cuivre, Femme Osage Creek, Meramec, and Missouri Rivers.}

2.5.3.8 Potential for Tectonic or Non-Tectonic Deformation at the Site

{The potential for tectonic deformation at the site is negligible. This is based on:

1. A remote imagery interpretation, followed by a detailed ground truthing investigation, yielded no evidence of paleo-liquefaction or faulting in the site area.
2. There is no Quaternary deformation in the site vicinity, and the closest reported indication to paleo-liquefaction is referred to in Crone, 2000 and Tuttle, 2005, listed within the St. Louis–Cape Girardeau liquefaction features, 70 miles southeast from the site.
3. The site is located in a region that has experienced only infrequent minor earthquake activity, with the closest epicentral location (3.0 to 3.9 mb) situated approximately 38 miles (61 km) southwest of the Callaway Plant Unit 1 site, west of Cole County. Besides the latter there have been only one more cataloged earthquake within 50 miles (80 km) of the Callaway Plant Unit 1 site, this one (3.0 to 3.9 mb) approximately 45 miles (72 km) south-southeast of the, south of Gasconade County.
4. Interpreted seismic sections (Bay Geophysical, 2008), displayed in Figure 2.5-37, and discussed in 2.5.3.2, reported that the minimal vertical time shift noted in REF-1, REF-2 and REF-3 have not been interpreted as significant offsets within the Snyder Creek event that could be attributed to faulting. These offsets do not appear above or below the Snyder Creek event that along with area geology and eliminate post-depositional movements as their cause. Other apparent offsets may be the result of low fold (low statistical redundancy) that occurs at the line ends of seismic reflection data and thus reducing the confidence of the interpreted apparent offsets. These offsets show minimal vertical time shift above the Snyder Creek event, and no evidence above the Graydon Conglomerate event.
5. Folds shown in Callaway Plant Unit 2 FSAR Figures 2.5-8, 2.5-15, 2.5-32 and 2.5-33 are all pre-Pennsylvanian, preceding the deposition of the Graydon Conglomerate. Descriptions are provided in the Section 2.5.2.4.1.

6. The detailed mapping of the excavations for Callaway Plant Unit 1 revealed no evidence of folding or faulting, or any other feature that would adversely affect the safety of the plant (Dames & Moore 1980).
7. The interpretation of aerial photography for Callaway Plant Unit 1 (AmerenUE, 2004).

Collectively, these data support the interpretation for the absence of any Quaternary surface faults or capable tectonic sources within the site area. In addition, there is no evidence of non-tectonic deformation at the site, such as glacially induced faulting, collapse structures, growth faults, salt migration, or volcanic intrusion.}

2.5.3.9 References

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Wheeler, 2005. Known or Suggested Quaternary Tectonic Faulting, Central and Eastern United States—New and Updated Assessments for 2005, U.S. Geological Survey, Open-File Report 2005-1336, Wheeler, 2005.}

Supplement to FSAR 2.5; Documentation of Geologic Field Studies Performed

FSAR Section 2.5B Pages	Description
B2.5-1 through B2.5-70	New Appendix 2.5B describing geologic field studies performed.

FSAR Appendix 2.5

This appendix contains a description of the site area paleo-liquefaction and surface faulting investigation program that are the basis for discussion in relevant sections of 2.5.

{FSAR 2.5 APPENDIX B

SITE AREA PALEO-LIQUEFACTION AND SURFACE FAULTING INVESTIGATION PROGRAM

To complement the references in the literature that consider paleo-liquefaction and surface faulting in the area of the Callaway Plant site, a specific field investigation program was conducted during the general field investigations as part of the overall development of the project. This investigation program consisted of a number of steps, including an on-the-ground inspection and reconnaissance (ground truthing) during late June-early July of 2007 of all areas where evidence on remote imagery suggests some type of anomaly which could not be interpreted directly. Each anomaly was visited, logged, photographed if questionable and documented to define the conditions at each anomaly, with an eye toward assessing the impact of the anomaly on the safety-related facilities of the proposed plant.

Work Plan

The work plan implemented for this program consisted of a number of steps as outlined below:

- Identify remote imagery, specifically aerial and satellite images, available for the area of the site.

- Analyze and interpret the aerial and satellite images to identify features on the ground surface that are anomalous and not explainable by observation on the remote imagery and could be postulated as being related to historic or prehistoric earthquakes or tectonic activity.

- Create a remote image that shows all of the anomalous features to be used as a field working document and later as a basis for documentation purposes. The remote image with the labeled anomalous features is used as a guide by the field geologists as an aid to find the anomalous feature in the field.

- Assign a label and longitude and latitude co-ordinates to the anomalous features using tools available from the imagery supplier.

- Using the remote image along with the labels and co-ordinates, a team of geologists arranges to visit each anomalous feature with the aid of a portable GPS unit to ground truth the anomaly.

- During the visit to the anomalous feature, the team of geologists records electronically the actual location of the feature with the portable GPS unit.

- The anomalous feature is observed, discussed by the team, logged with a written description, interpreted as (a) a non-geologic feature or (b) a geologic feature that is not associated with an earthquake or tectonics, e.g., a landslide or slump or (c) a feature that could be postulated as being derived from an earthquake (such as a paleo-liquefaction feature) or (d) a tectonic feature such as fold, monocline or a fault. Photographs are taken to supplement the logs if necessary for future referencing.

- In addition, the location of anomalous features observed during the field reconnaissance, but not observed on the remote imagery, are identified and logged as above for features observed on the remote imagery.

- The results of the ground truthing work are then re-interpreted in the office together with the remote imagery and any literature that is available for the area of the feature. This step also involves a peer review of the interpretation of the anomaly.

- The results are then analyzed with respect to the possibility as to whether any of the features are offer evidence as a geologic hazard that could affect the safety-related facilities of the proposed plant. If so, they are documented and referred to in the appropriate FSAR sections 2.5.1 through 2.5.5.

Summary of the Geology of the Site Area

To implement this Work Plan, it is necessary to understand the geology of the area. The geology of the area around the site is fully described in Section 2.5.1.2 and the stratigraphy and lithology of rock formations observed are described in Section 2.5.1.2.3.3. The rocks are of Ordovician age, including the St. Peter Formation, the underlying Cotter-Jefferson City Dolomite and the underlying Roubidoux and Gasconade Formations, also of Ordovician age. These rock units are illustrated on the Site Stratigraphic Column, Figure 2.5-10.

Paraphrasing text in Section 2.5.1.2.3.3.4, the St. Peter Formation is present in the site area in the form of isolated depression fillings on the eroded Cotter-Jefferson City surface. The depressions reflect ancient buried karst (paleokarst) features that developed during a period of uplift and erosion that occurred in Ordovician time, approximately 425 million years ago. The St. Peter Formation is white, fine grained, sugary sandstone, generally cross-bedded and friable. On exposed surfaces, it weathers yellowish brown and becomes resistant to erosion as a result of secondary cementation. The St. Peter Formation can be observed in numerous locations throughout the site area with patchy distribution in the site area. Surface exposures are typically rounded in form and in all cases appear to be isolated depression fillings.

The Cotter-Jefferson City formations underlie the entire site area and crop out in the rugged terrain surrounding the plant site. These formations appear as prominent bluffs along the sides of the Missouri River. The Cotter Formation lies conformably on the underlying Jefferson City Formation. Because it is difficult, however, to differentiate between the two formations, they are often designated as a combined unit.

The Cotter-Jefferson City is typically a light gray dolomite, fine grained, thin bedding planes, becoming numerous and closely spaced in some zones. Dark gray and white banded chert is present in thin layers. Siltstone and sandstone beds are present at some locations.

The Roubidoux Formation underlies the Cotter-Jefferson City formations. It consists of sandstone, dolomitic sandstone, and cherty dolomite. In central Missouri, it is predominantly quartzose sandstone. The sandstone is composed of fine to medium grained quartz sand that characteristically is subrounded and frosted. Gray and brown colors are predominant on weathered surfaces, but the color of the fresh sandstone is commonly light yellow, tan, or red at the surface and white in the subsurface. The dolomite in the Roubidoux is finely crystalline, light gray to brown in color, and thinly to thickly bedded. Individual beds contain brown to gray, banded, oolitic sandy chert.

The outcrops investigated during this program include the stratigraphic profile between the St. Peter Formation and the Roubidoux Formation.

Work Plan Implementation

Recognizing the stratigraphy in the area of the site, the above Work Plan was implemented firstly with remote imagery work in the office, secondly with field work and finally with office work to finish the effort over the course of several months.

The initial remote imagery work culminated with the production of Figure 2.5B-1 which is a satellite image showing the area around the site, overlaid with all of the anomalous features located remotely as well as those added during the field work. The anomalous features are classified as either a Potential Paleo-Liquefaction Feature (L-Feature) or a Potential Surface Fault Feature (G-Feature).

An anomalous feature was considered to be a Potential Paleo-Liquefaction Feature (L-Feature) if it was viewed remotely as being circular or linear or a line of circular features (sand blows, sand boils, dikes, etc) much like the interpretations in Al-Shukri, 2000.

An anomalous feature was considered to be a Potential Surface Fault Feature (G-Feature) if it appears on the remote image as a non-manmade photo-linear such as a natural change in color or type of vegetation, an alignment of abrupt changes in stream pathways, a sag pond or alignment of ponds that could be viewed as sag ponds, an alignment of springs as evidenced by vegetative color changes, linear topographic features inconsistent with the dominant pattern of topographic features in the area of the site,

The field work activities defined in the Work Plan were performed in late June and early July 2007, by a team of geologists. The work was accomplished in the field using a combination of four-wheel drive vehicles and hiking. USGS Quadrangle Maps, the satellite imagery and the portable GPS Units were used for determining locations. Log books and digital cameras were used for logging and documenting the anomalous features.

Results of the Program

As mentioned above, Figure 2.5B-1 depicts a large scale satellite image showing the (a) the Potential Paleo-Liquefaction Features and (b) the Potential Surface Fault Features.

The results are summarized on two tables --Table 2.5B-1, which is a summary of the Potential Paleo-Liquefaction Features (L-Features), and Table 2.5B-2, which is a summary of the Surface Fault Features (G-Features). Each table includes a label for the feature, its longitude and latitude and a summary of the field observations at each feature.

During the field work, digital photographs were taken of most of the L-Features and the G-Features for purposes of documentation and future reference. The photos of the G-Features are provided on Figure Nos. 2.5B-2 through 2.5B-52. Photos of the L-Features are provided in Figure Nos. 2.5B-53 through 2.5B-82.

Potential Paleo-Liquefaction Features

As indicated on Table 2.5B-1, most of the L-Features were determined to be associated with agricultural activities. For example, the circular features are most often circular hay bales. Linear features are usually a line of hay bales and several drainage features are man-made ditches. All of the L-Features are interpreted as being derived from man's activities (hay harvesting/farming, roads, accesses, clearings, gardens, constructions, graveyard), and surface water processes (runoff water erosion features, and pond water features). No indication of paleo-liquefaction was observed.

It is recognized that much of the area around the site has been impacted by agricultural activities or is wooded which might mask such features on remote images, but, on the other hand, no such features were found in non-developed areas along water bodies either -- areas where paleo-liquefaction features would tend to be more prevalent if they exist at all in the area.

These findings are in accordance with the reported liquefaction for the site region, where the closest reported indication of paleo-liquefaction is referred to in Crone, 2000 and Tuttle, 2005 as being in the St. Louis–Cape Girardeau area, 70 miles southeast from the site. These liquefaction features were found along the Cache, Cuivre, Femme Osage Creek, Meramec, and Missouri Rivers.

Potential Surface Fault Features

The descriptions of Potential Surface Fault Features are provided on Table 2.5B-2. As seen on the table, sixty (60) G-Features (Figures 2.5B-2 through 2.5B-52) were investigated in the field which included finding and confirming the location (longitude and latitude co-ordinates, observing the feature, interpreting the stratigraphy, lithology and mineralogy of the rocks at the feature, preparing written logs and, finally, photographing the feature. None of the features yielded evidence of faulting. Some of the features as described on Table 2.5B-2 are slump features associated with old landslides or consolidation. None showed evidence of faulting. These slump and/or consolidation type features are tabulated below and more fully on Table 2.5B-2 and on their respective photos:

Feature	Latitude	Longitude	Brief Description of Feature
G23/G24	38°43'17.28"N	91°46'54.23"W	Slump feature on one side of road cut. Deformation as much as 43 inches.
	38°43'21.68"N	91°46'55.00"W	
G39	38°42'30.44"N	91°47'14.56"W	Slump feature that resulted in facies change.
G43	38°43'21.32"N	91°48'9.97"W	Convolute structure attributed to slumping or lateral compression

None of the above listed features is tectonically derived and none indicates evidence of faulting.

Conclusions

The conclusions emanating from this Site Area Paleo-Liquefaction and Surface Faulting Investigation Program are summarized as follows:

1. A remote imagery interpretation, followed by a detailed ground truthing investigation, yielded no evidence of paleo-liquefaction in the area of the site. Most of the area around the site has been impacted by agricultural activities or is wooded which might mask such features on remote imagery; however, no such features were found in non-developed areas along water bodies either -- areas where paleo-liquefaction features would tend to be more prevalent if they exist at all in the area.

   No paleo-liquefaction features were found in the area of the site, thus eliminating such features as a geologic hazard which could impact on the safety-related facilities of the proposed plant.

2. A remote imagery interpretation, followed by a detailed ground truthing investigation, yielded no evidence of faulting. The ground truthing work led to observations of small deformations (less than five (5) feet) – all associated with slumping or consolidation and contained within

Ordovician rocks, which are pre-Middle Devonian in age (over 350 million years old). No long linear features indicative of strike slip movement or evidence of normal or thrust features were found.

No surface faulting features were found in the area of the site that represents a geologic hazard which could impact the safety-related facilities of the proposed plant.

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Table 2.5B-1 Potential Paleo-Liquefaction Features(L-Features) Summary Page 1 of 5			
Feature Label	LOCATION		FIELD DESCRIPTION OF FINDINGS (prepared based on field notes and photos)
	LATITUDE	LONGITUDE	
L1	38°46'26.18"N	91°46'23.22"W	Blocked. Area looks to be used for cattle grazing. Hay field. No evidence of paleo-liquefaction.
L2	38°46'3.68"N	91°46'20.27"W	Wheat field. No evidence of circular feature or change in soil color. No evidence of paleo-liquefaction.
L3	38°45'58.98"N	91°47'24.60"W	Feature present is a depression (E to W) in a Silty/Clay (dark yellowish brown) soil. No evidence of paleo-liquefaction.
L4	38°50'12.48"N	91°46'50.15"W	Oval cut/fill small corn field. No evidence of paleo-liquefaction.
L5	38°49'58.96"N	91°46'48.18"W	Grooves in hay field. Leveled high ground in the middle of a bean field. No evidence of spot circular features along this path. No evidence of paleo-liquefaction.
L6	38°49'12.81"N	91°45'57.56"W	Hay bales/Hay field. No evidence of paleo-liquefaction.
L7	38°49'5.35"N	91°45'57.27"W	Hay bales/Hay field. No evidence of paleo-liquefaction.
L8	38°48'18.96"N	91°45'3.93"W	Drains running down hill to mid field drainage. No evidence of paleo-liquefaction.
L9	38°47'44.82"N	91°45'45.46"W	Drainage area of wheat field, draining to small pond. No evidence of paleo-liquefaction.
L10	38°47'58.38"N	91°45'57.11"W	Drainage toward wooded area. No evidence of paleo-liquefaction.
L11	38°47'43.00"N	91°44'58.07"W	Clearing for power pole line. No evidence of paleo-liquefaction.
L12	38°47'38.73"N	91°45'7.71"W	House/warehouse. No evidence of paleo-liquefaction.
L13	38°47'4.65"N	91°44'38.16"W	Hay field. Blocked access to top of hill. No evidence of paleo-liquefaction.
L14	38°46'53.79"N	91°44'37.45"W	Hay field. Blocked access to top of hill. No evidence of paleo-liquefaction.

Table 2.5B-1 Potential Paleo-Liquefaction Features (L-Features) Summary Page 2 of 5			
Feature Label	LOCATION		FIELD DESCRIPTION OF FINDINGS (prepared based on field notes and photos)
	LATITUDE	LONGITUDE	
L15	38°46'36.32"N	91°42'59.75"W	Hay bales in hay field. No evidence of paleo-liquefaction.
L16	38°46'45.67"N	91°43'8.82"W	Hay bales in hay field. No evidence of paleo-liquefaction.
L17	38°46'56.74"N	91°42'46.20"W	Hay bales in hay field. No evidence of paleo-liquefaction.
L18	38°47'4.02"N	91°43'6.94"W	Hay bales/lines in hay field. No evidence of paleo-liquefaction.
L19	38°47'17.38"N	91°43'13.30"W	Hay bales/lines in hay field. No evidence of paleo-liquefaction.
L20	38°45'52.74"N	91°42'38.79"W	Depression in field, once harvested for hay. The lines are along lower areas. No evidence of paleo-liquefaction.
L21	38°45'26.63"N	91°43'10.10"W	Farmed field with no evidence of circular features. No evidence of paleo-liquefaction.
L22	38°44'20.57"N	91°42'24.93"W	Clear areas between trees in wooded forest area. No evidence of paleo-liquefaction.
L23	38°42'21.68"N	91°45'14.19"W	Potato crop, circular features relate to harvest. No evidence of paleo-liquefaction.
L24	38°42'8.16"N	91°47'11.88"W	Wheat field, linear features are in direction of cropping. No evidence of paleo-liquefaction.
L25	38°42'23.32"N	91°47'7.14"W	Concrete pads in potato fields. No evidence of paleo-liquefaction.
L26	38°42'49.31"N	91°49'15.96"W	Graveyard. No evidence of paleo-liquefaction.
L27	38°42'28.60"N	91°50'17.00"W	Hay field/hay bales. No evidence of paleo-liquefaction.
L28	38°43'54.73"N	91°48'47.81"W	Access road from gate to tree. No evidence of paleo-liquefaction.
L29	38°44'3.68"N	91°48'48.73"W	Hay bales/ hay field. No evidence of paleo-liquefaction.
L30	38°43'21.11"N	91°46'7.97"W	Farmed field, linear features associated with ditch and circular features not evident, checked for soil color changes and none found. No evidence of paleo-liquefaction.
L31	38°43'39.05"N	91°45'46.63"W	Farmed field. Dark yellowish brown Silty/Clay soil. No evidence of soil type change of circular features. No evidence of paleo-liquefaction.
L32	38°42'47.61"N	91°43'12.33"W	Upper edge of "pond like" depression. No evidence of paleo-liquefaction.
L33	38°42'56.58"N	91°43'9.33"W	Crop related circular feature. Not visible now. No evidence of paleo-liquefaction.

Table 2.5B-1 Potential Paleo-Liquefaction Features (L-Features) Summary Page 3 of 5			
Feature Label	LOCATION		FIELD DESCRIPTION OF FINDINGS (prepared based on field notes and photos)
	LATITUDE	LONGITUDE	
L34	38°42'50.86"N	91°42'38.51"W	Linear features are drainage in bottom of hill towards the SW and then to the Missouri River. No evidence of paleo-liquefaction.
L35	38°43'42.38"N	91°42'24.86"W	Hay field not in use. No evidence of circular features. No evidence of paleo-liquefaction.
L36	38°43'48.14"N	91°44'35.22"W	Pine tree forest and junk yard. No evidence of paleo-liquefaction.
L37	38°43'42.69"N	91°45'31.81"W	Farmed field. Dark yellowish brown Silty/Clay soil. No evidence of soil type change of circular features. Similar to L31. No evidence of paleo-liquefaction.
L38	38°44'14.35"N	91°50'1.53"W	Drainage pattern running to ditch and then to creek. No evidence of paleo-liquefaction.
L39	38°44'32.50"N	91°50'43.46"W	Drainage lines to center of field. No evidence of paleo-liquefaction.
L40	38°44'52.48"N	91°50'27.18"W	Linear feature is an access road in the middle of bean field. Appears to be drainage patterns. No evidence of paleo-liquefaction.
L41	38°44'51.39"N	91°50'44.63"W	Drainage in low areas of bean field. Appears to be drainage patterns. No evidence of paleo-liquefaction.
L42	38°45'11.29"N	91°50'31.51"W	Appears to be drainage patterns. Corn field. No evidence of paleo-liquefaction.
L43	38°45'19.55"N	91°49'7.36"W	Hay bales/hay field. No evidence of paleo-liquefaction.
L44	38°44'58.53"N	91°46'37.48"W	No evidence of linear fracture type feature. Lineament matches the alignment of two signal poles. No evidence of paleo-liquefaction.
L45	38°44'55.97"N	91°46'20.68"W	Features are grooves from farming (bean crop). No evidence of paleo-liquefaction.
L46	38°45'16.90"N	91°44'32.31"W	Hay bales/hay field. No evidence of paleo-liquefaction.
L47	38°45'57.84"N	91°50'40.06"W	Linear and circular features are hay bales (spots and aligned). By the house there is a pond. No evidence of paleo-liquefaction.
L48	38°46'24.79"N	91°48'3.60"W	Soil is Silty/Clay. Wheat farmed field. No indication of feature. No evidence of paleo-liquefaction.

Table 2.5B-1 Potential Paleo-Liquefaction Features (L-Features) Summary Page 4 of 5			
Feature Label	LOCATION		FIELD DESCRIPTION OF FINDINGS (prepared based on field notes and photos)
	LATITUDE	LONGITUDE	
L49	38°46'10.59"N	91°47'58.03"W	Soil is Silty/Clay. Wheat farmed field. No indication of feature. No evidence of paleo-liquefaction.
L50	38°46'41.14"N	91°47'2.57"W	Linear features are groups and drainage patterns in farm field. No evidence of paleo-liquefaction.
L51	38°46'50.96"N	91°46'20.03"W	Linear features are groups and drainage patterns in farm field. No evidence of paleo-liquefaction.
L52	38°47'10.40"N	91°46'16.38"W	No evidence of circular features. Wheat farmed field, moderate to dark yellowish brown Silty/Clay soil. Similar to L54. No evidence of paleo-liquefaction.
L53	38°47'8.77"N	91°45'56.56"W	Corn field. Dark yellowish brown silty/clay soil. No evidence of paleo-liquefaction.
L54	38°47'11.24"N	91°46'49.56"W	No evidence of circular features. Wheat farmed field, moderate to dark yellowish brown Silty/Clay soil. No evidence of paleo-liquefaction.
L55	38°46'20.03"N	91°52'30.18"W	No indication of circular features. No evidence of paleo-liquefaction.
L56	38°47'7.88"N	91°51'50.84"W	Cut is on the side of a meandering creek. No evidence of paleo-liquefaction.
L57	38°47'53.08"N	91°50'17.71"W	Linear features are groups and drainage patterns in farm field. No evidence of paleo-liquefaction.
L58	38°49'6.03"N	91°48'29.08"W	Hay field/hay bales. No evidence of paleo-liquefaction.
L59	38°49'42.34"N	91°48'24.79"W	Hay field, no active harvesting. No evidence of paleo-liquefaction.
L60	38°49'51.63"N	91°48'9.63"W	Hay field, no active harvesting. No evidence of paleo-liquefaction.
L61	38°46'58.50"N	91°49'1.04"W	Different Clay soil color. Linear features are grayish gray to light gray Clay, and surrounding Clay is moderate yellowish to moderate brown. No evidence of paleo-liquefaction.

Table 2.5B-1 Potential Paleo-Liquefaction Features (L-Features) Summary Page 5 of 5			
Feature Label	LOCATION		FIELD DESCRIPTION OF FINDINGS (prepared based on field notes and photos)
	LATITUDE	LONGITUDE	
L62	38°47'6.96"N	91°47'59.17"W	No evidence of feature (circular) on the ground. Soil is Clay, dark to moderate yellowish brown (Evidence of being a corn field/crop). No evidence of paleo-liquefaction.
L63	38°47'22.12"N	91°47'38.03"W	Cardboard, trees, and junk cars. Material associated with construction of lake. No evidence of paleo-liquefaction.
L64	38°47'28.67"N	91°45'49.47"W	Hay fields/rows.

Table 2.5B-2 Potential Surface Fault Features (G-Features) Summary Page 1 of 8			
Feature Label	LOCATION		FIELD DESCRIPTION OF FINDINGS (prepared based on field notes and photos)
	LATITUDE	LONGITUDE	
G1	38°50'46.97"N	91°52'28.70"W	Sequence on both sides of road shows no sign of faulting or visible offset.
G2	38°50'27.11"N	91°48'34.43"W	Approximately 10 ft of calcareous shale, medium to medium dark gray; on top there is a dark yellowish orange limestone with white chert; rapid reaction to HCl. No indication of faulting.
G3	38°48'58.83"N	91°48'19.98"W	Similar limestone as observed at G2 with sub horizontal /horizontal layering; grayish to gray shale is not calcareous; the grayish red shale pockets are calcareous. Clay pockets observed in "auger" lens type shape, 8 inches x 1.5 ft; very thin chert layer; discontinuous. No evidence of faulting;
G4	38°47'7.51"N	91°53'17.18"W	Thin bedded, very hard, yellowish gray shale with alluvial material, dark reddish brown, silty clay. No indication of any faulting in either the shale or alluvium; joints do not penetrate into upper layer. Pale bluish green thin coating and very thin dark brown veins; positive reaction to HCl. No indication of faulting.
G5	38°47'0.62"N	91°53'27.65"W	Thin bedded, very hard, yellowish gray shale with alluvial material, dark reddish brown, silty clay. No indication of any faulting in either the shale or alluvium; joints do not penetrate into upper layer. Pale bluish green thin coating and very thin dark brown veins; positive reaction to HCl. No indication of faulting from G4 to G5.
G6	38°44'1.99"N	91°49'9.24"W	Thin bedded calcareous sandstone; slow reaction to HCl. Light olive gray to pale olive, very hard, layers range from 1 inch to 4 inches with ripple marks. No indication of faulting.
G7	38°43'16.05"N	91°48'7.95"W	Yellowish gray, very hard, limestone. Slow reaction to HCl, convolute structure, layering horizontal on top is a grayish limestone with closely spaced thin chert layers, not continuous. No indication of faulting.

Table 2.5B-2 Potential Surface Fault Features (G-Features) Summary Page 2 of 8			
Feature Label	LOCATION		FIELD DESCRIPTION OF FINDINGS (prepared based on field notes and photos)
	LATITUDE	LONGITUDE	
G8	38°42'32.22"N	91°47'37.21"W	Very hard dolomite, nonreactive to HCl, yellowish gray. Thin layer of shale, nonreactive to HCl, includes a lens of breccia (6 ft x 2 ft) that does not penetrate into the shale layer. Dolomite just above the shale layers shows gentle folding, intra-layered. No evidence of faulting.
G9	38°42'37.68"N	91°44'34.64"W	Quarry wall with no evidence of faulting. Minor shear zones, interpreted as non-tectonic; they are confined by overlaying light brownish gray dolomite (~6 ft thick). Below this top dolomite there is a light greenish gray dolomite with greenish gray shale. None of the three reacts to HCl.
G10	38°47'44.88"N	91°52'41.36"W	4 inch to 6 inch thick layers of limestone, dark yellowish orange to grayish orange, positive reaction to HCl. On top there is an approximately 10 inch layer of grayish green shale, nonreactive to HCl. Above continues same limestone as below but layering is 1 inch to 2 inches thick. No evidence of faulting.
G11	38°47'42.54"N	91°52'46.48"W	G11 is at western end of outcrop. Fossiliferous limestone, dark yellowish brown to dark yellowish orange. Bottom and top of sequence is an overlain by a 4 ft thick massive layer. No evidence of faulting
G12	38°47'39.00"N	91°51'53.71"W	Crest of anticline with open fractures (10°). Axis of anticline is approximately N15°E with flanks (10°) towards the NW and SE. Limestone is pale yellowish brown to moderate yellowish brown, reactive to HCl. There are thin layers of shaley material nonreactive to HCl. No evidence of faulting.
G13	38°47'25.85"N	91°51'42.25"W	Thinly layered fossiliferous limestone, siltstone, and shale. Siltstone is nonreactive to HCl. Limestone is yellowish gray as well as siltstone. Shale is pale yellowish green. Convolute structures on top of siltstone. No evidence of faulting.

Table 2.5B-2 Potential Surface Fault Features (G-Features) Summary Page 3 of 8			
Feature Label	LOCATION		FIELD DESCRIPTION OF FINDINGS (prepared based on field notes and photos)
	LATITUDE	LONGITUDE	
G14	38°46'42.47"N	91°50'47.55"W	Thin Layered Limestone with thin shale layers. Slow reaction to HCl in all layers. Bottom of sequence is finer grained (silty), top is sandier and with ripple marks and undulated top surfaces. Top is 1 inch to 1.5 inch thick layer and bottom is an average of 2.5 inches thick with a 12 inch thick layer. Grayish green shale and limestone is light to very light gray in bottom layers and pale yellowish orange to grayish orange in top layers (sandier). No evidence of faulting.
G15	38°42'35.00"N	91°50'8.20"W	G15 is an outcrop approximately 100 ft from access road. Massive Sandstone, approximately 10 ft thick and 250 ft long, dissected by intermittent ditch that runs forward to the west, to access road. Non reactive to HCl. Pale yellowish brown to yellowish gray. Very friable. No evidence of faulting.
G16	38°44'29.77"N	91°50'7.35"W	Light olive gray Limestone, slow reaction to HCl, very hard. No evidence of faulting. Outcrops between G16 and G17 in access road do not show evidence of faulting. Multiple isolated outcrops. *Note: Features G16 and G17 are captured on Figure 2.5B-17*
G17	38°44'36.89"N	91°50'6.33"W	Sub horizontal to horizontal layering across the access road. No evidence of faulting. *Note: Features G16 and G17 are captured on Figure 2.5B-17.*
G18	38°42'57.17"N	91°50'12.72"W	All part of a sequence of limestone, reactive to HCl; Bottom of sequence is 1.5 ft of thinly bedded very hard, fine grained limestone, followed by 2 ft of massive coarser grained limestone. Top of sequence is 3 ft of the coarser grained limestone, grayish orange, very hard. Bottom three layers are light olive gray. No evidence of faulting.
G19	91°50'12.72"W	91°50'11.59"W	Description same as that for G-18.
G20	38°42'51.31"N	91°50'13.00"W	Top 2 sequences in layer No.1 are similar to G18-G19. A slump structure on top of unit 1 with listric type deformation on both ends, completely healed. Interpreted as derived from slope movement and not tectonically derived. A 20' long outcrop with no evidence of faulting between G19 and G20.

Table 2.5B-2 Potential Surface Fault Features (G-Features) Summary Page 4 of 8			
Feature Label	LOCATION		FIELD DESCRIPTION OF FINDINGS (prepared based on field notes and photos)
	LATITUDE	LONGITUDE	
G21	38°42'48.68"N	91°50'16.28"W	Same sequence as outcrop at G20 but layer No.1 is more massive and thicker (5 ft). Bottom layer is also thicker (5 ft). No evidence of faulting.
G22	38°42'46.48"N	91°50'17.12"W	End of outcrop between G18 and G22. No evidence of faulting.
G23	38°43'17.28"N	91°46'54.23"W	No evidence of faulting exists but there is evidence of an old non-tectonic offset with 43 inches of vertical deformation. "Hanging wall" is to the south but does not continue completely to the other side of road, where its effect is not evident. Rock is a limestone, very hard, yellowish gray, alternates with layers between 1 inch to 2 inches thick and layers 2.5 inch to 3 inch thick. Alteration exists in six zones from a more massive bottom layers to top of sequence, thin layered, reactive to HCl with grain size in the very fine sand to silt range, fracture surface N40º/80ºS.
G24	38°43'21.68"N	91°46'55.00"W	Description same as that for G23.
G25/G26	38°48'0.33"N	91°48'24.18"W	G25/G26 is near Thunderbird Lakes. Outcrop is limestone with rapid reaction to HCl; hard, dark yellowish orange 1 ft to 3 ft thick layers. No evidence of faulting is present. Outcrops are intermittent.
G27	38°49'22.88"N	91°48'54.57"W	G27 is in a rock quarry. No evidence of faulting on any of the outcrops around the quarry. Several pictures taken. Also, inspected cut toward the east to point G28.
G28	38°49'28.08"N	91°48'34.25"W	Location of Feature is on access road from gate to tree at quarry in G27. No evidence of faulting.
G29	38°50'38.72"N	91°48'18.48"W	Light brown, very hard limestone with rapid reaction to HCl. No evidence of faulting.
G30	38°43'15.16"N	91°41'28.49"W	Outcrop (quarry face) on side of Route 94. No evidence of faulting.

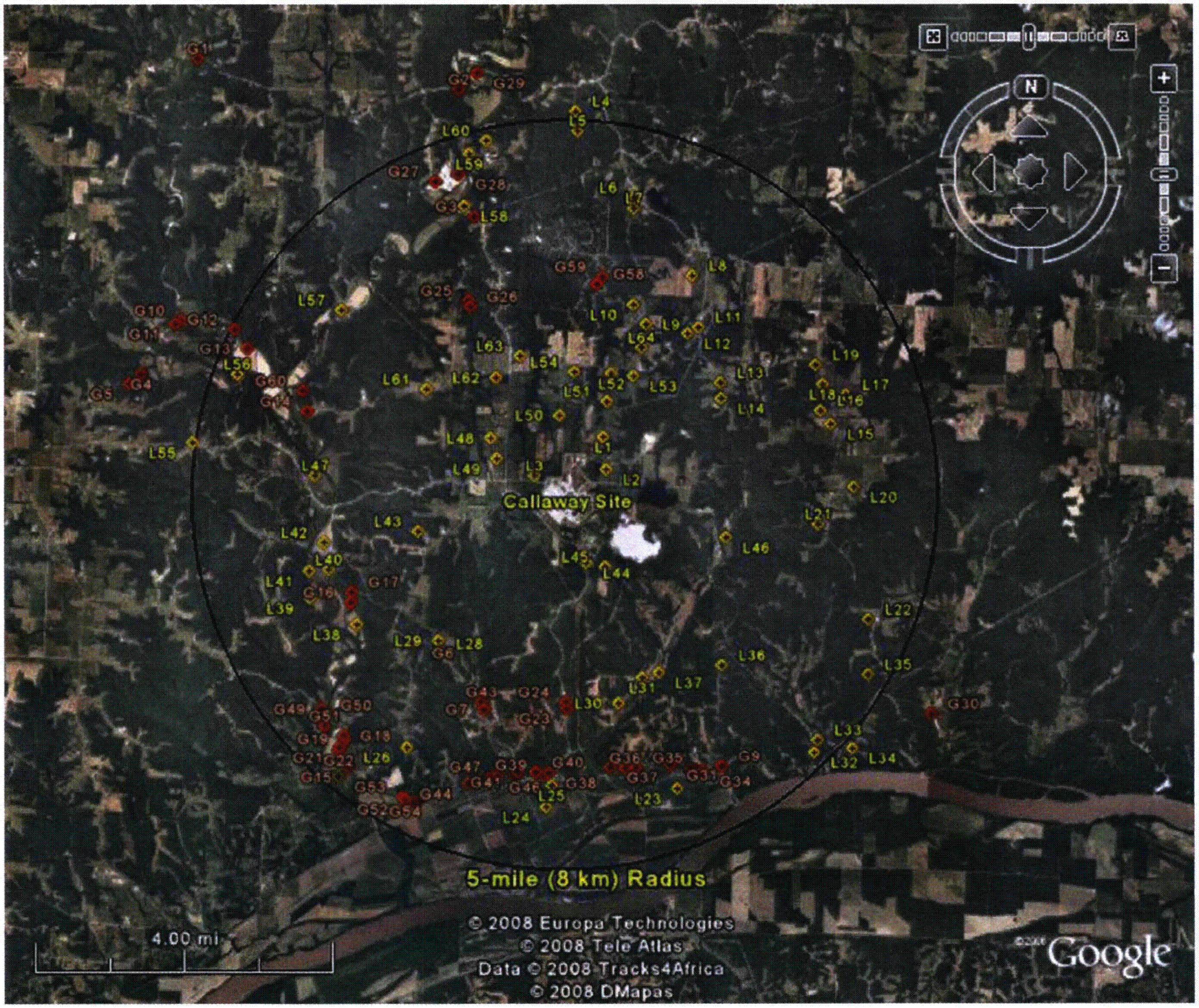
Table 2.5B-2 Potential Surface Fault Features (G-Features) Summary Page 5 of 8			
Feature Label	LOCATION		FIELD DESCRIPTION OF FINDINGS (prepared based on field notes and photos)
	LATITUDE	LONGITUDE	
G31	38°42'38.05"N	91°45'20.79"W	Outcrop along Katy Trail. Layer No.1 pale red, very hard dolomite. One ft to 1.5 ft thick individual layers. Layer No.2 is very light gray. Silty sized grains with slow reaction to HCl. Bottom consists of 8 inch thick layer with 1 inch thick layering followed on top by layers 4 inches thick, 2 ft thick and 3 inches thick. Layer No.3 very light gray limestone with rapid reaction to HCl, thickening upward layer from <1 inch to 6 inches. No evidence of faulting. Layer No.4 repeated No.3 with sequence same thickness and character. No evidence of faulting in stretch from G31 to G32.
G32	38°42'35.49"N	91°45'2.54"W	No evidence of faulting between layer No.4 and top. Limestone is less resistant to weathering and stuck out only in upper layers. No evidence of faulting in stretch from G32 to G33.
G33	38°42'34.86"N	91°44'58.06"W	East of G33 layer dips slightly to the east. No evidence of offset between layering. No evidence of faulting in stretch from G33 to G34.
G34	38°42'33.93"N	91°44'51.42"W	Same as G33. No evidence of faulting. *Note: Features G34, G35 and G36 are captured on Figure 2.5B-33*
G35	38°42'36.03"N	91°45'51.81"W	G35 is toward the west along trail on the levee. No evidence of faulting. *Note: Features G34, G35 and G36 are captured on Figure 2.5B-33*
G36	38°42'35.62"N	91°46'1.46"W	No evidence of faulting, several spots of vegetation. No evidence of faulting in stretch from G35 to G36. *Note: Features G34, G35 and G36 are captured on Figure 2.5B-33.*

Table 2.5B-2 Potential Surface Fault Features (G-Features) Summary Page 6 of 8			
Feature Label	LOCATION		FIELD DESCRIPTION OF FINDINGS (prepared based on field notes and photos)
	LATITUDE	LONGITUDE	
G37	38°42'36.12"N	91°46'14.80"W	Top of sequence above layer No.4 detailed at G31. Grayish orange pink limestone. Slow reaction to HCl. Thin layered 1 inch to 6 inches seems like western flank of an open anticline. Layer No.5 includes an exotic block of pale yellowish brown to grayish orange dolomite with a very slow reaction to HCl; very hard. Block shows shear and slickensided surface. Shows "brecciated" characteristics, folded and fractured. Layer No. 6 is more massive 2 ft to 3 ft thick individual layers and more resistant. To the west there is a stretch of discontinuous outcrop with opened rock surface not showing signs of faulting.
G38	38°42'31.86"N	91°47'9.92"W	Same description as G37. This location is to the west of G37. No signs of faulting.
G39	38°42'30.44"N	91°47'14.56"W	Facies change in outcrop interpreted to be associated with slumping or ancient settlement. The facies change appears is N45°/vertical, healed with numerous brecciated fragments. These fragments are opaline, quartz, and similar to rocks in both side of the feature. Covered with vegetation. Layer No.1 is pale yellowish brown to grayish orange, very hard, calcareous, very fine sandstone, slow reaction to HCl. Layer No. 2 is very pale orange, hard calcareous, very fine sandstone, slow reaction to HCl. Sequence on the west end of the structure is similar to described in G31and G37 combined layers of No.1 to No.6. No evidence of faulting.
G40	38°42'32.23"N	91°47'21.58"W	Outcrop is near G-39. No evidence of faulting in this outcrop.
G41	38°42'32.33"N	91°47'37.13"W	Outcrop is near G-39. No evidence of faulting in this outcrop.
G42	38°42'31.50"N	91°47'37.86"W	Pale olive shale and siltstone in bottom, nonreactive to HCl, very hard, visible 2.5 ft thick layer, thin bedded. Top layers pale yellowish orange to grayish orange Limestone, hard, slow reaction to HCl. On south end of outcrop there is a small (6 ft) anticline, E to W trending, with flanks dipping 25° toward N and S. No evidence of faulting.

Table 2.5B-2 Potential Surface Fault Features (G-Features) Summary Page 7 of 8			
Feature Label	LOCATION		FIELD DESCRIPTION OF FINDINGS (prepared based on field notes and photos)
	LATITUDE	LONGITUDE	
G43a & G43b	38°43'21.32"N	91°48'9.97"W	Bottom is yellowish gray, very hard Limestone. Moderate reaction to HCl. Feature includes convolute structure that does not penetrate into the overlying layer. Top layer is grayish orange calcareous sandstone, positive reaction to HCl with no evidence of convolute structure. Feature interpreted as being derived from ancient settlement or slumping. Non-tectonic. No evidence of faulting.
G44	38°42'24.07"N	91°48'21.43"W	Complete sequence of layering (Layer No.1 thru layer No.6). No evidence of faulting. *Note: Features G44, G45 and G46 are captured on Figure 2.5B-42.*
G45	38°42'28.35"N	91°48'2.91"W	Upper layer No.6 seems to have two more, coarsening upward layers (~8 ft each) of the same as below, but not possible to sample. No evidence of faulting. *Note: Features G44, G45 and G46 are captured on Figure 2.5B-42.*
G46	38°42'28.62"N	91°47'59.96"W	Same description as that for G45. *Note: Features G44, G45 and G46 are captured on Figure 2.5B-42.*
G47	38°42'29.10"N	91°47'55.72"W	"Standing Rock", very fine sandstone, friable, outcrop partially covered with vegetation. No evidence of faulting.
G48	38°42'31.03"N	91°47'40.93"W	Cave above Katy Trail, extends ~50' to the north, roof is very fine sandstone, friable. It looks like it developed in brecciated material; very fine sandstone matrix and gravel sized sub angular fragments of chert material. No evidence of faulting.
G49	38°43'15.50"N	91°50'32.55"W	150 ft of outcrop with no visible evidence of faulting.
G50	38°43'11.23"N	91°50'30.48"W	Top of outcrop is 40 ft above. Bottom unit is thin layered (1 inch to 3 inch), yellowish gray limestone, top is 3 inch to 6 inch layered, very hard, grayish red, non reactive to HCl. No evidence of faulting.
G51	38°43'3.66"N	91°50'29.90"W	Same description as that for G50.

Table 2.5B-2 Potential Surface Fault Features (G-Features) Summary Page 8 of 8			
Feature Label	LOCATION		FIELD DESCRIPTION OF FINDINGS (prepared based on field notes and photos)
	LATITUDE	LONGITUDE	
G52	38°42'13.01"N	91°49'17.66"W	Base of sequence is 25 ft from location point, towards the north and consists of approximately of 35 ft of very hard calcareous sandstone, with bottom third part a very hard; very light gray, slow reaction to HCl, carbonaceous, massive to thickly bedded (1 ft to 2 ft). No evidence of faulting. Note: Features G52 and G53 are captured on Figure 2.5B-48.
G53	38°42'14.51"N	91°49'19.59"W	Same description as that for G52. *Note: Features GG52 and G53 are captured on Figure 2.5B-48.*
G54	38°42'11.50"N	91°49'17.13"W	No evidence of faulting. Interbedded carbonaceous sandstone and limestone. Slow reaction to HCl for the sandstone but rapid reaction for massive limestone. *Note: Features G54, G55, G56, G57 are captured on Figure 2.5B-49.*
G55	38°42'11.65"N	91°49'13.93"W	No evidence of faulting. *Note: Features G54, G55, G56, G57 are captured on Figure 2.5B-49.*
G56	38°42'11.63"N	91°49'9.21"W	Sequence is similar to that described in G54. No evidence of faulting. *Note: Features G54, G55, G56, G57 are captured on Figure 2.5B-49.*
G57	38°42'13.00"N	91°49'3.77"W	Sequence is similar to that described in G54. No evidence of faulting. *Note: Features G54, G55, G56, G57 are captured on Figure 2.5B-49.*
G58	38°48'12.54"N	91°46'30.04"W	Limestone outcrop. No evidence of faulting.
G59	38°48'17.69"N	91°46'24.90"W	Rocks along the creek are intact; show no sign of faulting. Rocks comprising floor of creek are very hard, light olive gray, limestone with an abundant calcite overgrowth. The other type is a weathered limestone, moderately hard, dark yellowish orange. Both have a rapid reaction to HCl.
G60	38°46'56.61"N	91°50'51.80"W	Layer No.1, light brown, very hard Limestone, rapid reaction to HCl. 1 inch to 3 inch thick undulating layers. Layer No.2 is similar to No.1 but massive (grain size). Layer No.3 is light olive gray, fine grained limestone with rapid reaction to HCl; 3 inch to 1inch (average 5 inch) thick layers. No evidence of faulting.}

Figure 2.5B-1
Satellite Image of Site Area
showing L and G features



Potential Surface Fault Feature

Potential Paleo-liquefaction Feature

Figure 2.5B-2
Feature Label G1

Figure 2.5B-3
Feature Label G2

Figure 2.5B-4
Feature Label G3

Figure 2.5B-5
Feature Label G4

Figure 2.5B-6
Feature Label G5

Figure 2.5B-7
Feature Label G6

Figure 2.5B-8
Feature Label G7

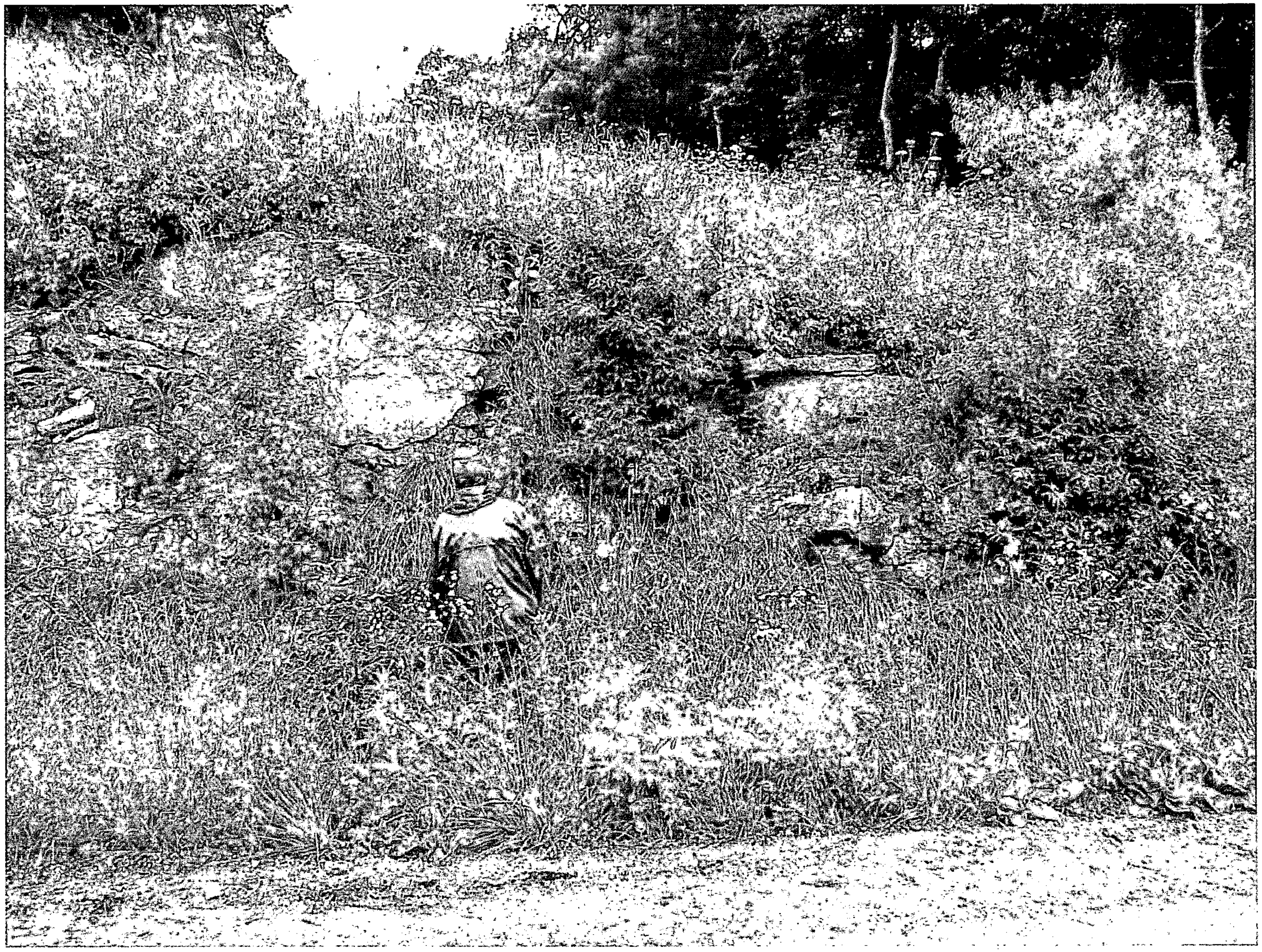


Figure 2.5B-9
Feature Label G8

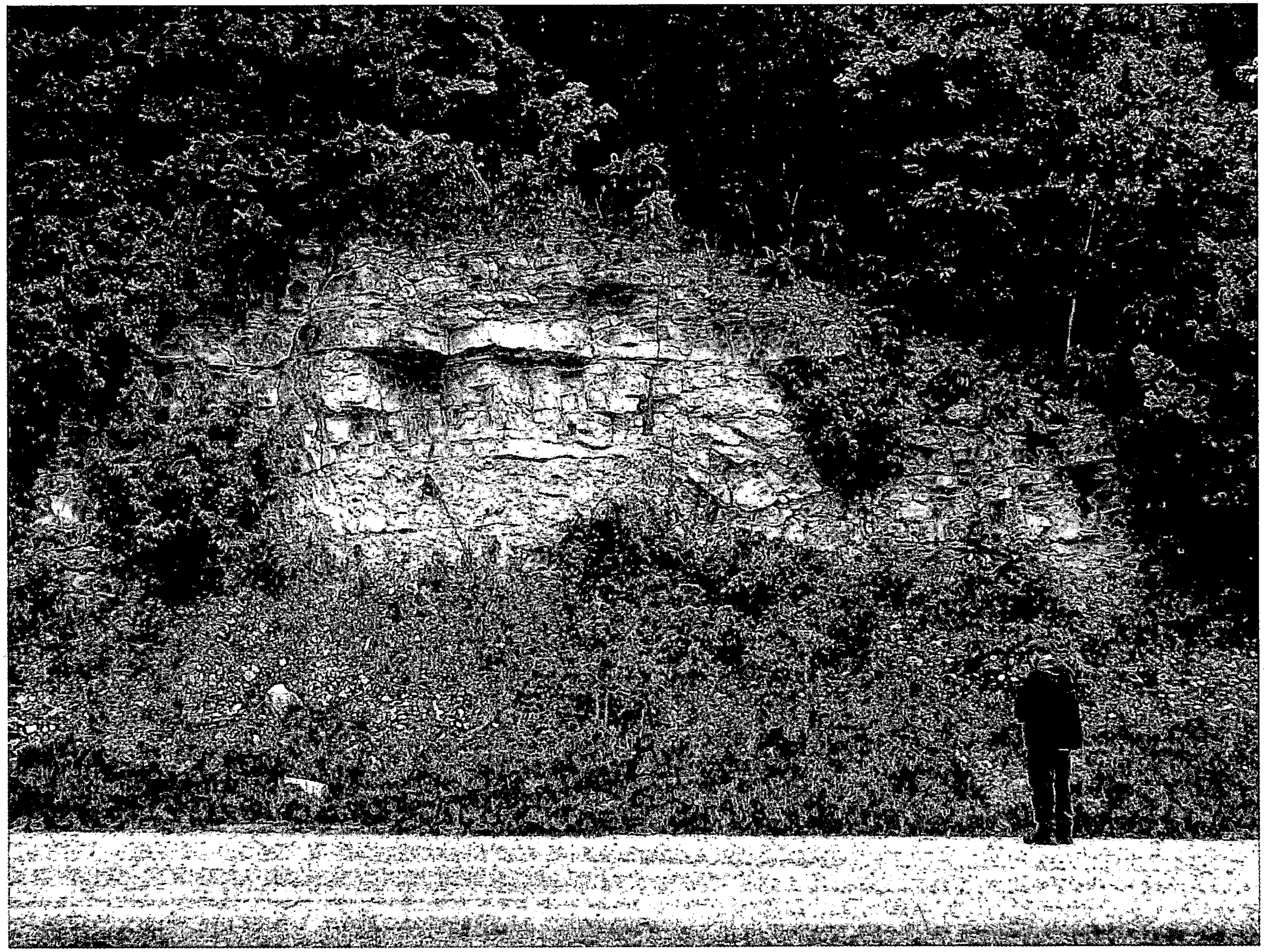


Figure 2.5B-10
Feature Label G9

Figure 2.5B-11
Feature Label G10

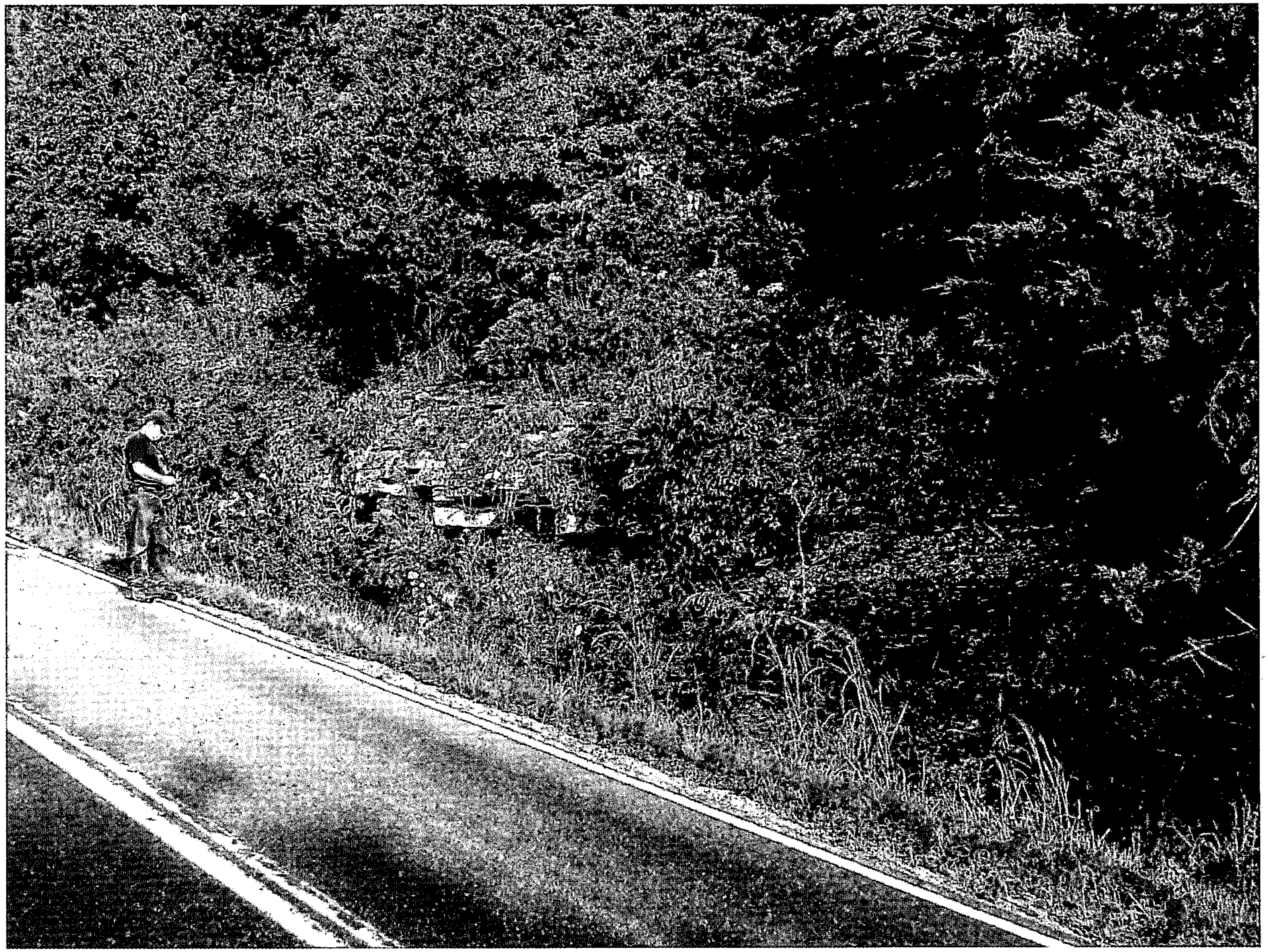


Figure 2.5B-12
Feature Label G11

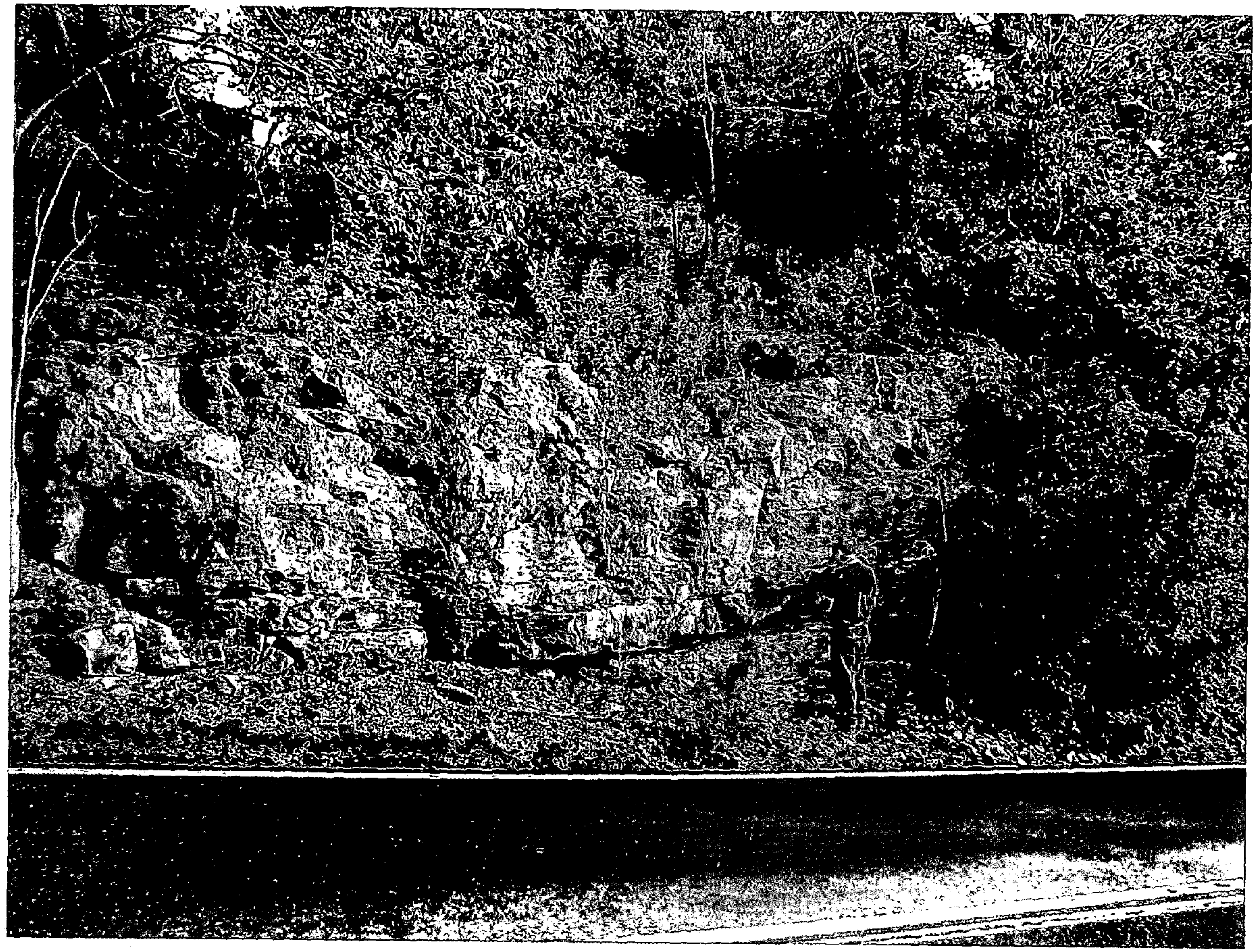


Figure 2.5B-13
Feature Label G12

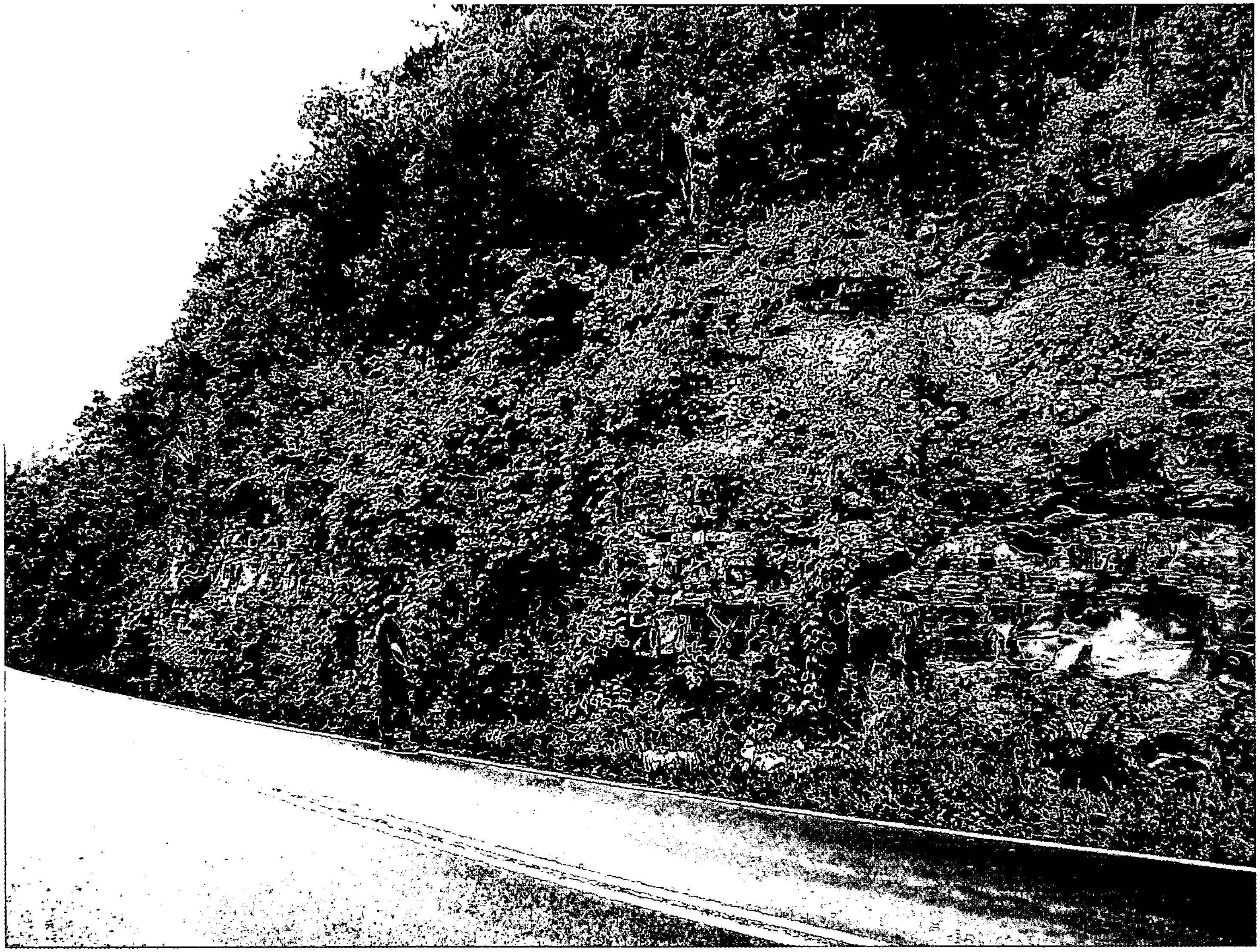


Figure 2.5B-14
Feature Label G13

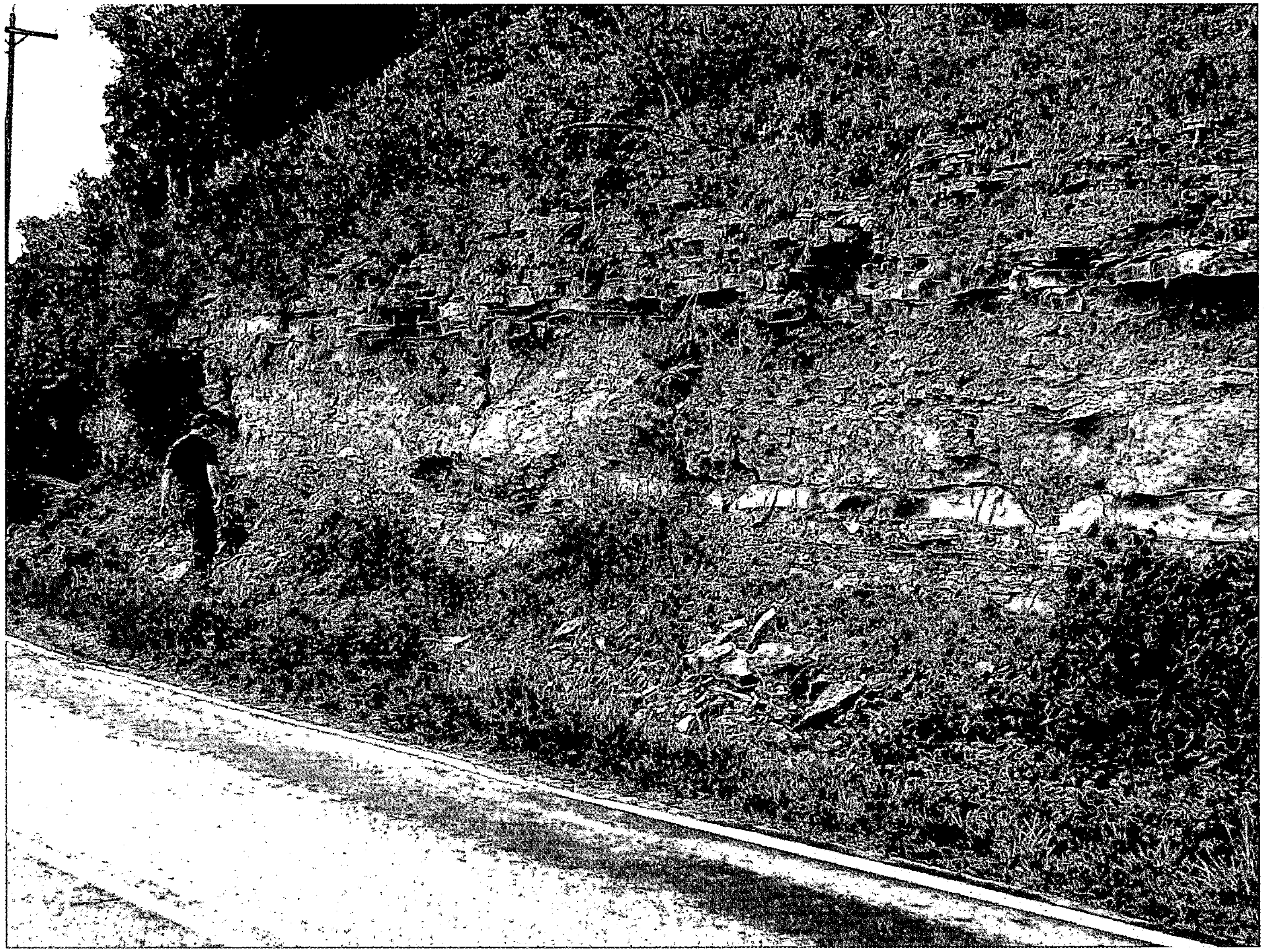


Figure 2.5B-15
Feature Label G14

Figure 2.5B-16
Feature Label G15

Figure 2.5B-17
Feature Label G16/G17

Figure 2.5B-18
Feature Label G18

Figure 2.5B-19
Feature Label G19

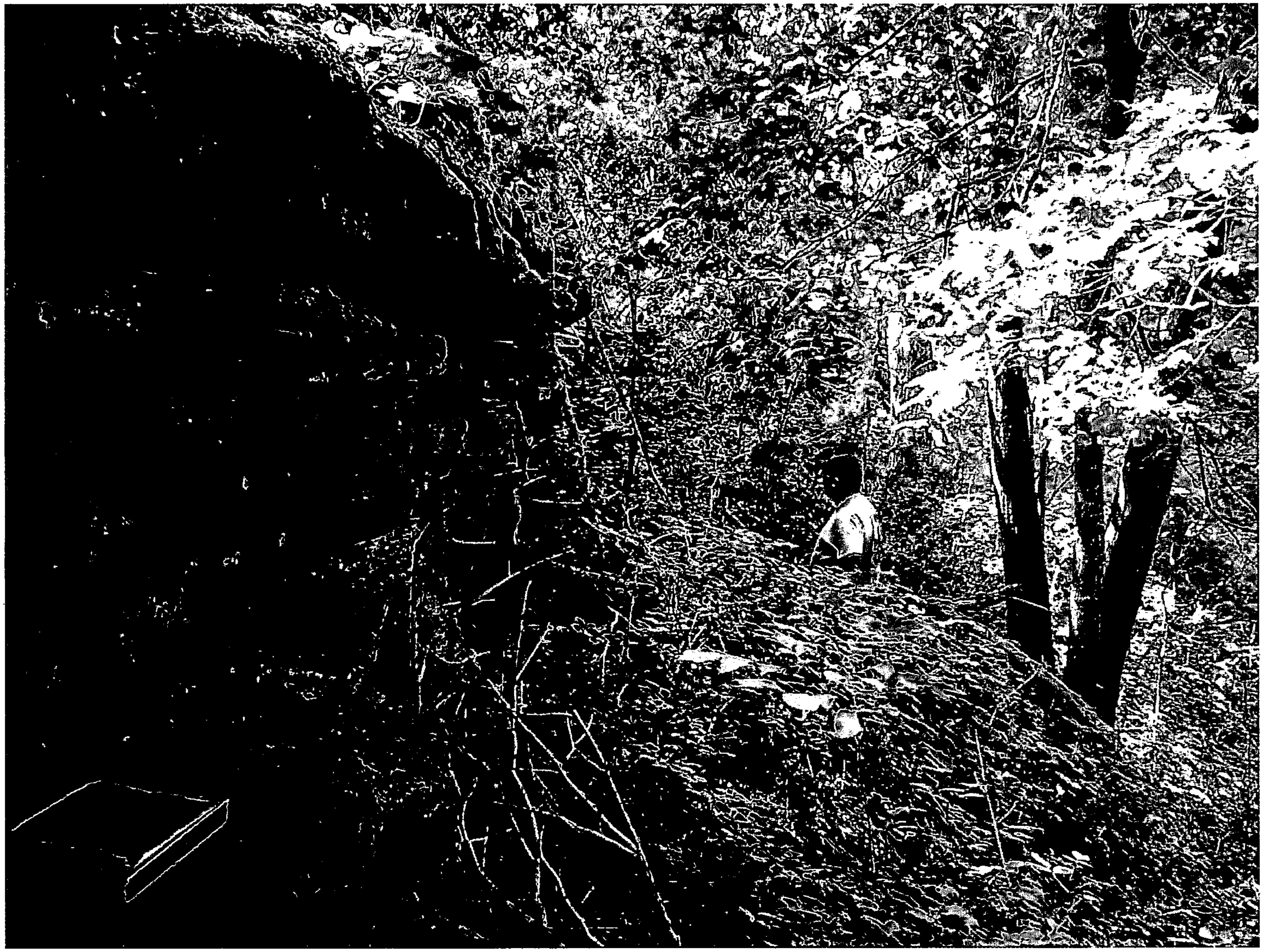


Figure 2.5B-20
Feature Label G20

Figure 2.5B-21
Feature Label G21

Figure 2.5B-22
Feature Label G22

Figure 2.5B-23
Feature Label G23

Figure 2.5B-24
Feature Label G24

Figure 2.5B-25
Feature Label G25/G26

Figure 2.5B-26
Feature Label G27

Figure 2.5B-27
Feature Label G28

Figure 2.5B-28
Feature Label G29

Figure 2.5B-29
Feature Label G30

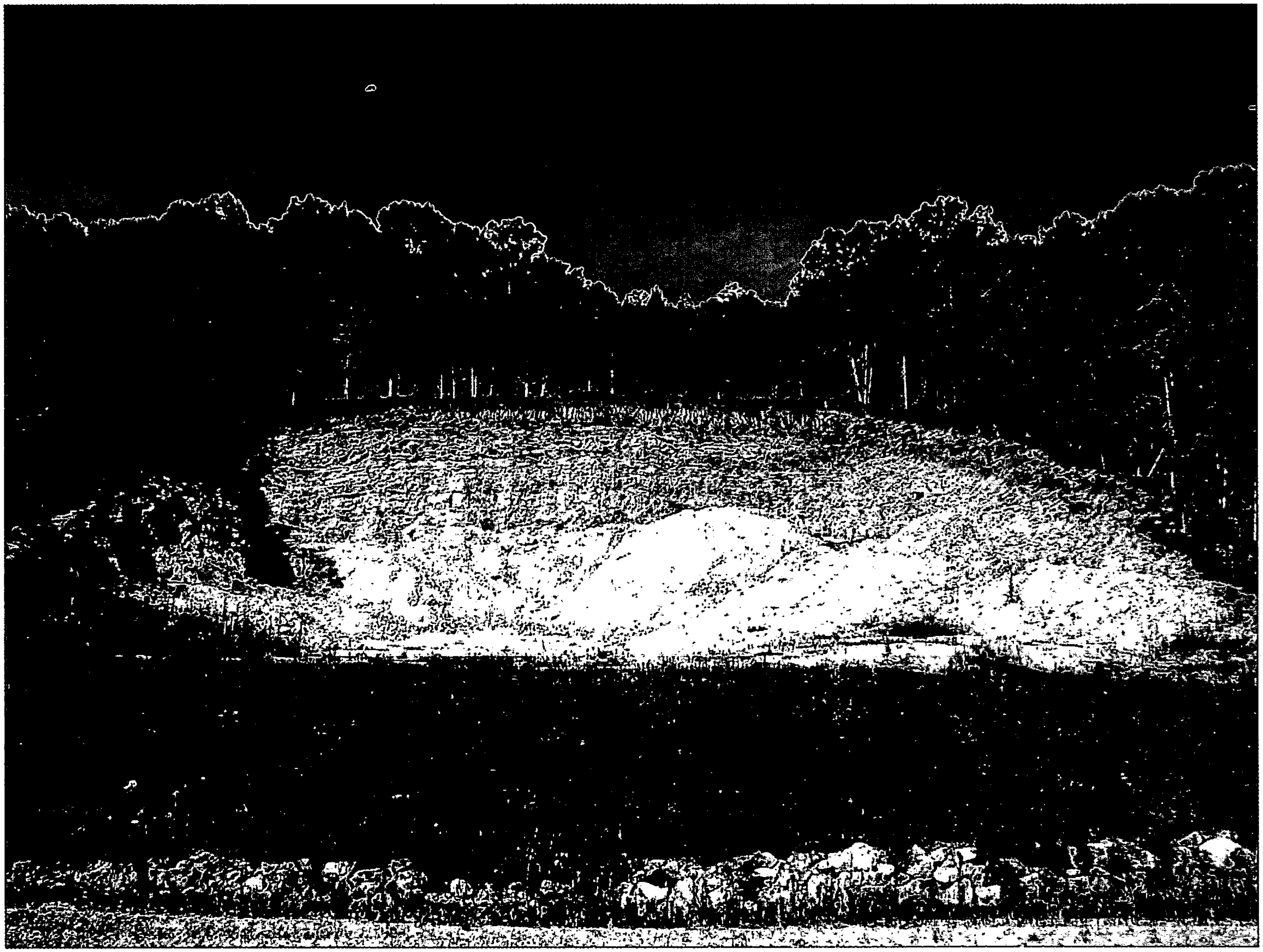


Figure 2.5B-30
Feature Label G31

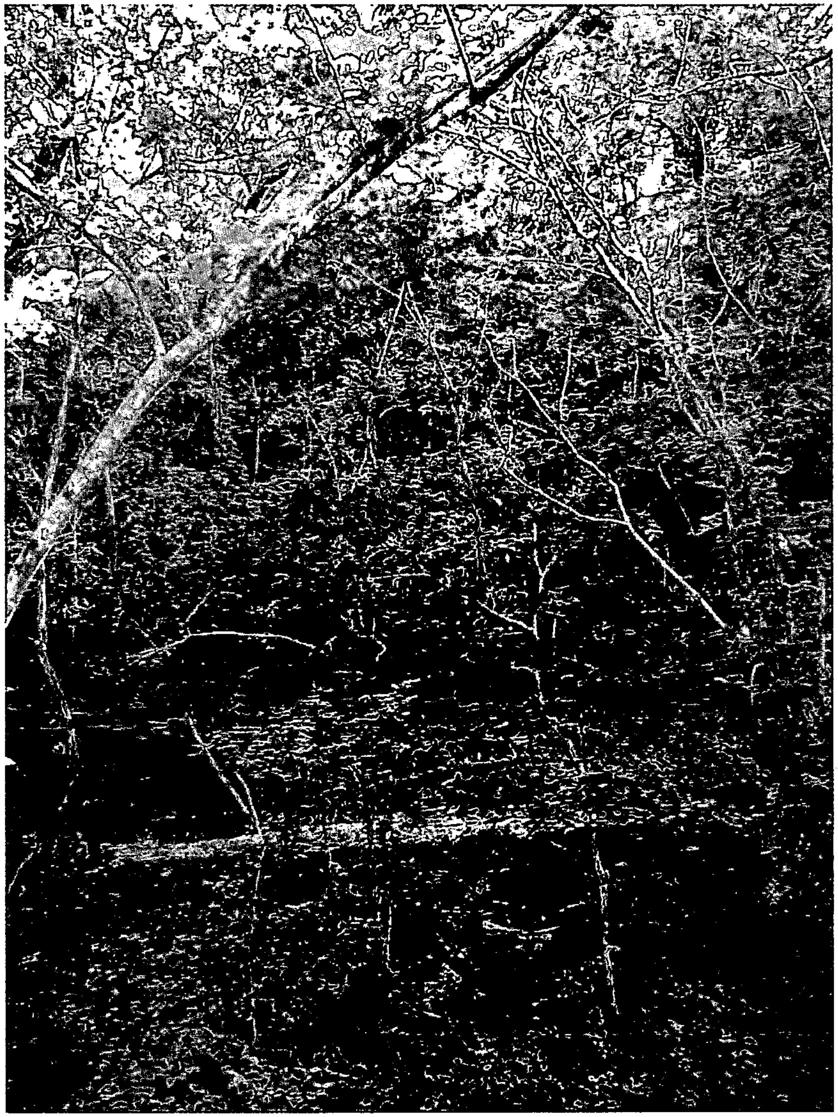


Figure 2.5B-31
Feature Label G32

Figure 2.5B-32
Feature Label G33

Figure 2.5B-33
Feature Label G34/G35/G36

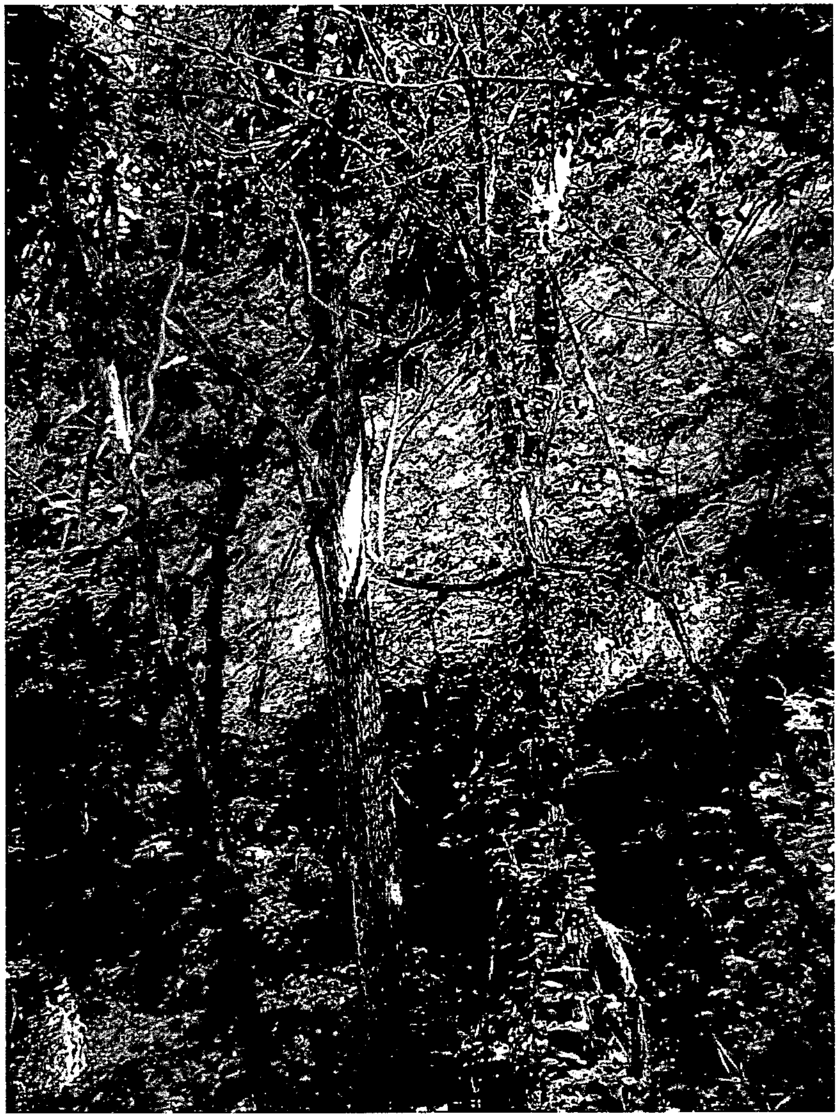


Figure 2.5B-34
Feature Label G37

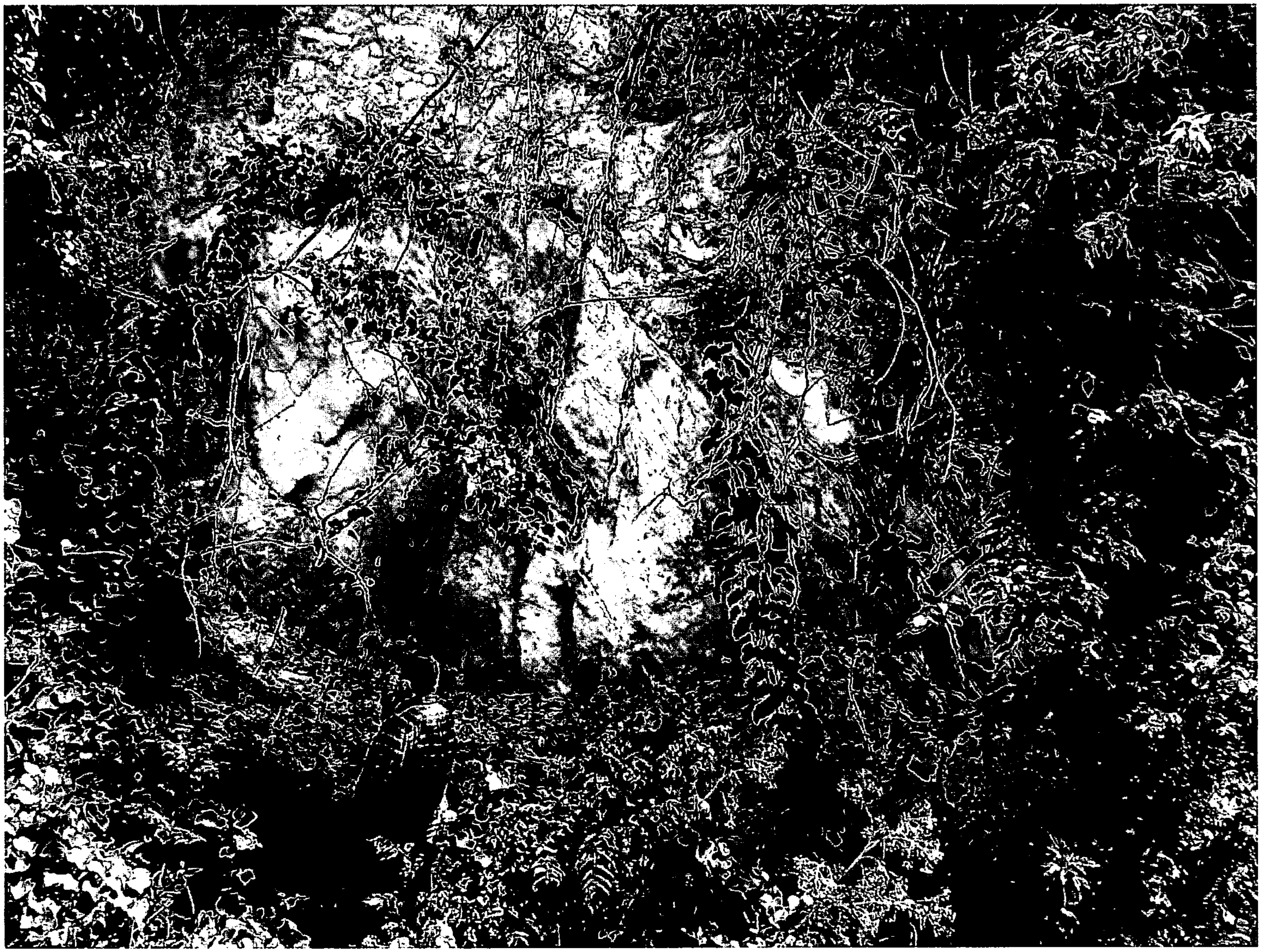


Figure 2.5B-35
Feature Label G38

Figure 2.5B-36
Feature Label G39

Figure 2.5B-37
Feature Label G40

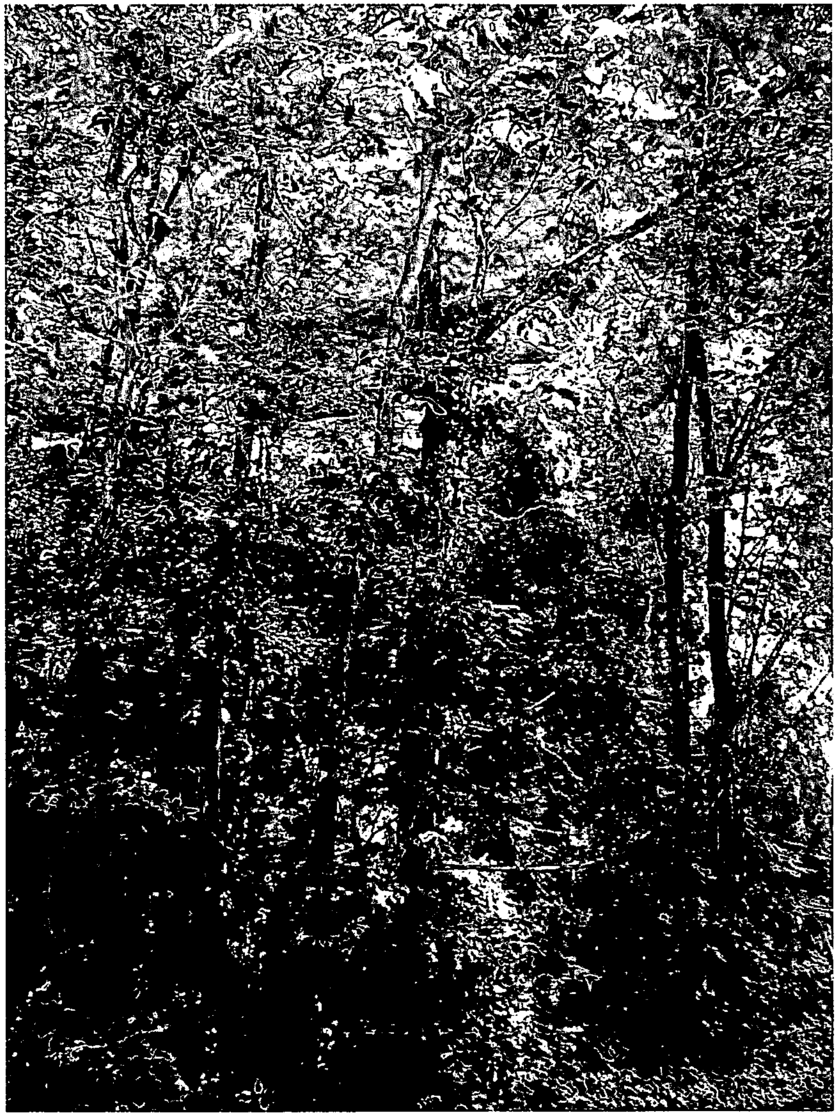


Figure 2.5B-38
Feature Label G41

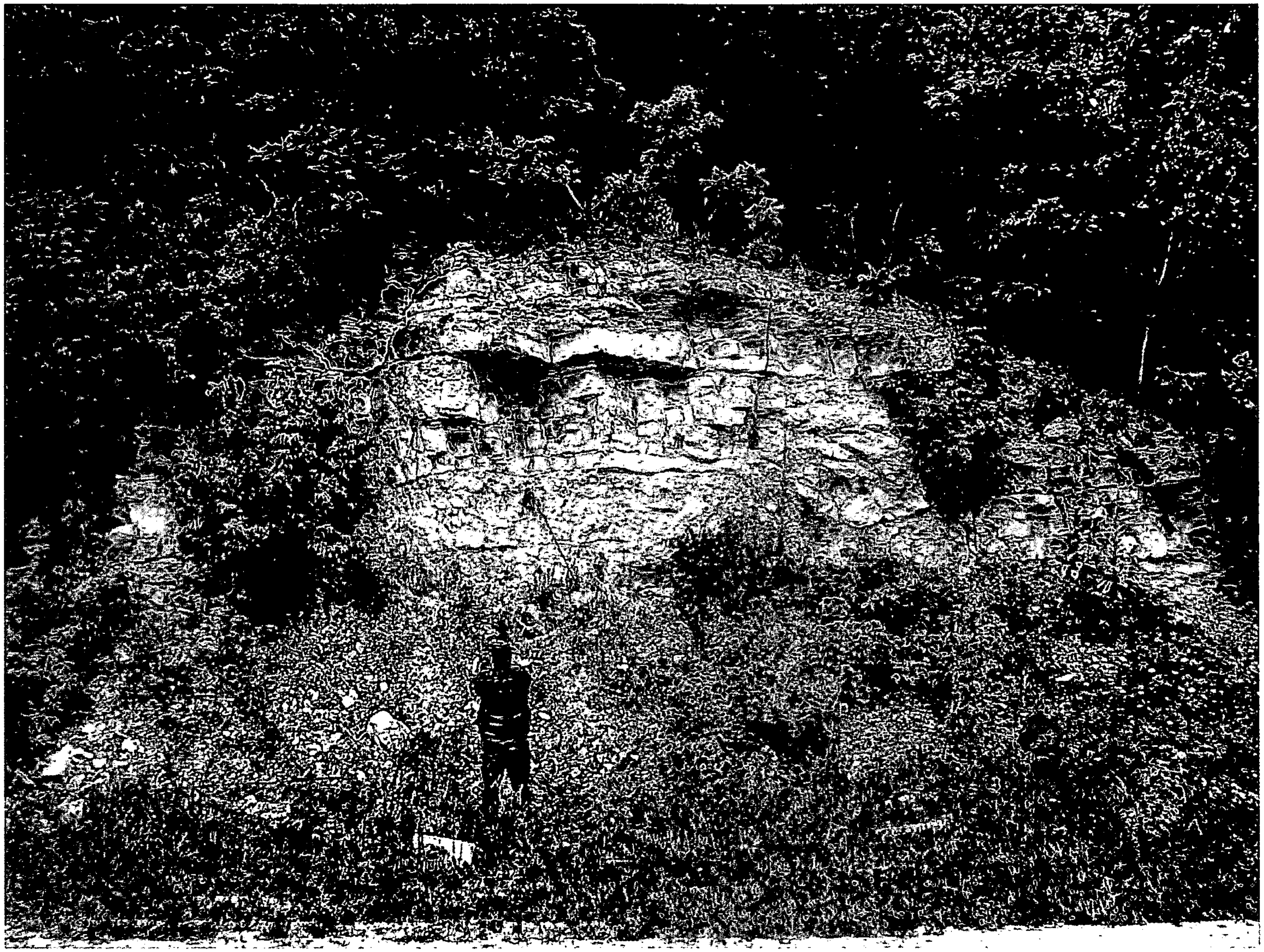


Figure 2.5B-39
Feature Label G42

Figure 2.5B-40
Feature Label G43a

Figure 2.5B-41
Feature Label G43b

Figure 2.5B-42
Feature Label G44/G45/G46

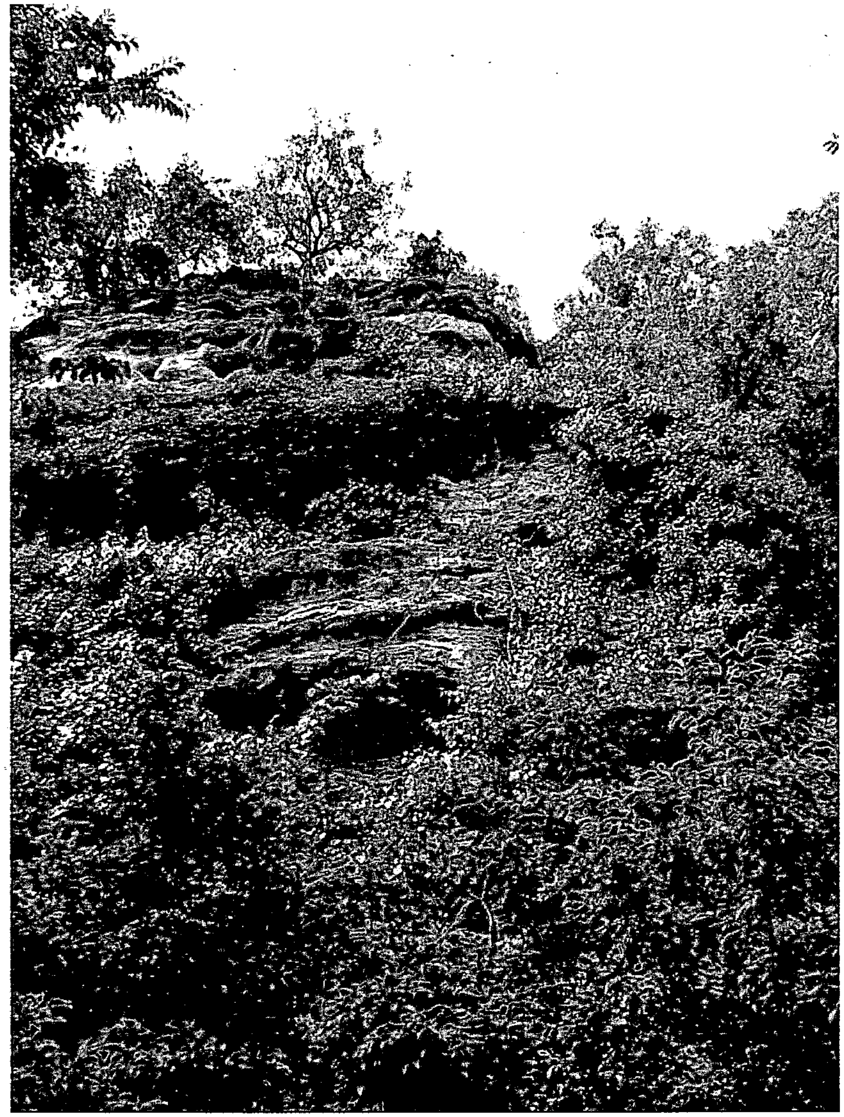


Figure 2.5B-43
Feature Label G47

Figure 2.5B-44
Feature Label G48

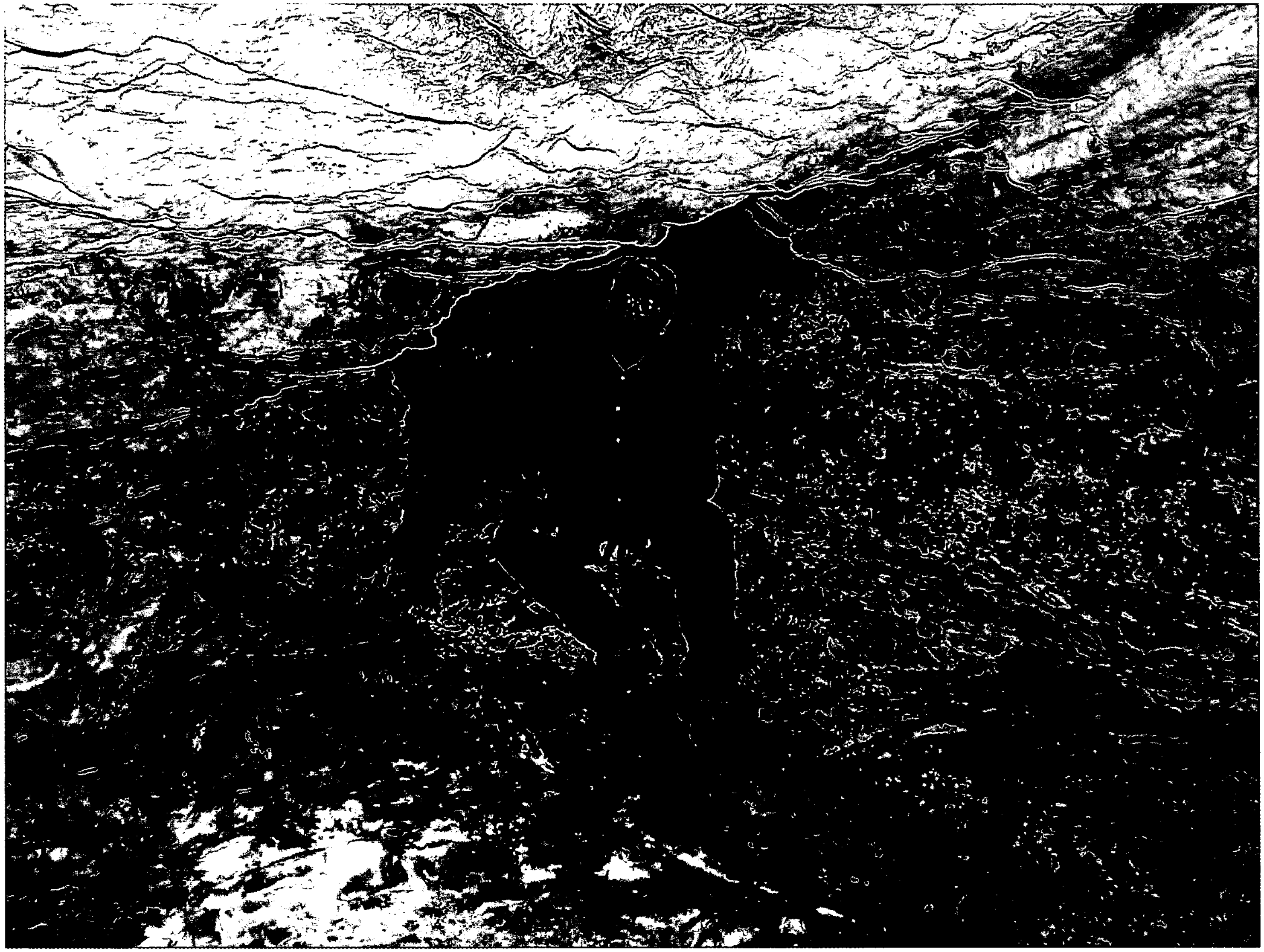


Figure 2.5B-45
Feature Label G49

Figure 2.5B-46
Feature Label G50

Figure 2.5B-47
Feature Label G51

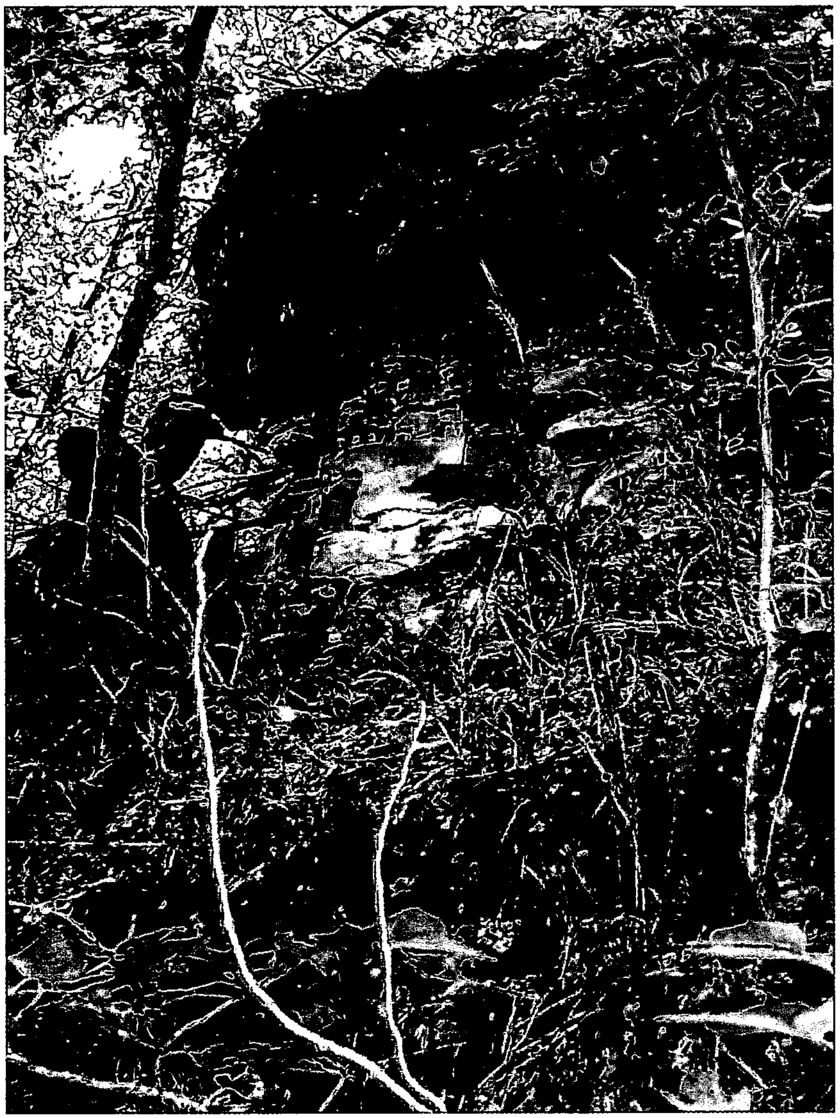


Figure 2.5B-48
Feature Label G52/G53

Figure 2.5B-49
Feature Label G54/G55/G56/G57

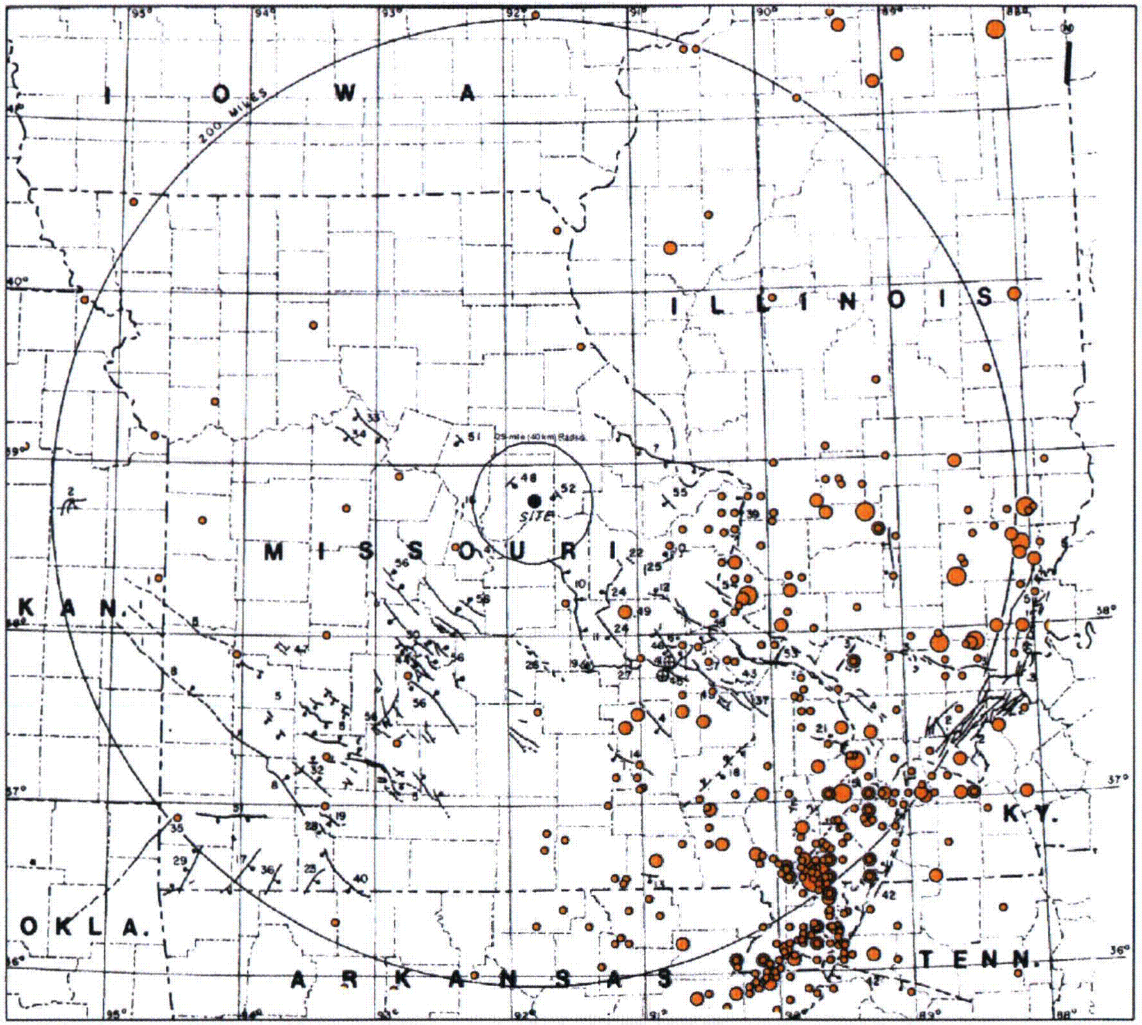
Figure 2.5B-50
Feature Label G58

Figure 2.5B-51
Feature Label G59

Figure 2.5B-52
Feature Label G60

Updated Selected
FSAR 2.5
Figures

FSAR Page Affected	Description
2-852	Section 2.5 LOF update to reflect new Figures 2.5-144, 2.5-145, 2.5-146, 2.5-147, 2.5-148, 2.5-149, 2.5-150 and 2.5-151.
2-1170, 1180, 1181, 1182, 1183, 1184, 1185, 1195, 1196, 1197, 1198, 1199, 1200, 1205, 1206, 1207, 1208, 1250	Updated figures 2.5-14, 2.5-24, 2.5-25, 2.5-26, 2.5-27, 2.5-28, 2.5-29, 2.5-39, 2.5-40, 2.5-41, 2.5-42, 2.5-43, 2.5-44, 2.5-49, 2.5-50, 2.5-51, 2.5-52, and 2.5-94 with legend information.
2-1299A, 1299B, 1299C, 1299D, 1299E, 1299F, 1299G, 1299H	New Figures 2.5-144, 2.5-145, 2.5-146, 2.5-147, 2.5-148, 2.5-149, 2.5-150, and 2.5-151 associated with FSAR 2.5.1 and FSAR 2.5.2 updates.



LIST OF FEATURES BY STATE:

ILLINOIS:
1. Centralia Fault
2. Fluorspar Area Complex
3. Rough Creek Lineament
4. St. Genevieve
5. Wabash Valley

MISSOURI:
1. Aptus Fault
2. Aquilla Fault
3. Big River Fault System
4. Black Fault
5. Bolivar-Mansfield
6. Cabanne Fault
7. Cap au Gres Faulted Flexure
8. Chesapeake Fault
9. Crooked Creek Structure
10. Cuba Fault
11. Cuba Graben
12. Ditch Creek Fault System
13. Doniphan Fault
14. Ellington Fault
15. English Hill Fault
16. Fox Hollow Fault
17. Greasy Creek Fault
18. Greenville Fault
19. Highlandville Fault
20. Idalia Fault
21. Jackson Fault
22. Jeffriesburg Fault
23. Lampe Fault
24. Leasburg Fault
25. Moselle Fault
26. Newburg Fault
27. Palmer Fault System
28. Ponce de Leon Fault
29. Pineville Fault
30. Red Arrow Fault
31. Ritchey Fault
32. Sac River Fault
33. Saline City Fault
34. Salt Fork Fault
35. Seneca Fault
36. Shell Knob-Eagle River Structure
37. Simms Mountain
38. Ste. Genevieve Fault System
39. St. Louis Fault

MISSOURI (Continuation):

40. Ten O'Clock Run Fault
41. Wardsville Fault
42. Mississippi Valley
43. Avon Diatremes (dikes)
44. Decaturville Structure
45. Dent Branch Structure
46. Furnace Creek Structure
47. Weaubleau Creek Structure Associated faults
48. Kingdom City Fault
49. Anthonies Mill Fault
50. Catawissa Fault
51. Browns Station Fault
52. Mineola Fault
53. Ste. Mary's Fault
54. Unnamed Fault (Jefferson County)
55. Unnamed Fault (St. Charles County)
56. Unnamed Fault (Lake of the Ozarks Region)

KANSAS:
1. Chesapeake Fault
2. Worden Fault

KENTUCKY:
1. Reelfoot Lake Fault

LEGEND

Earthquakes by Magnitude, mb

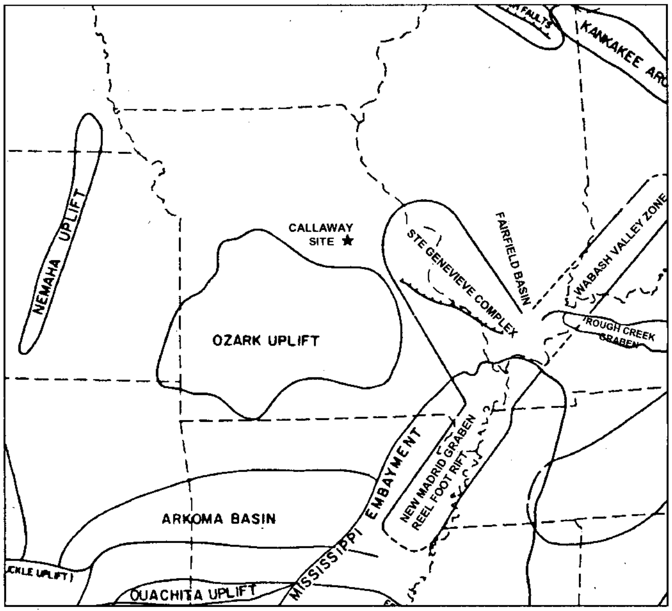
- 3.00000 - 3.90000
- 3.90001 - 4.90000
- 4.90001 - 5.90000
- 5.90001 - 6.90000
- 6.90001 - 7.90000

0 50 100 Miles

References: Figure 2.5-13 and Table 2.5-3, Callaway Plant Unit 1 FSAR (AmerenUE, 2004

Figure 2.5-14	Rev. 0
Regional Faulting	
CALLAWAY PLANT UNIT 2 FSAR	

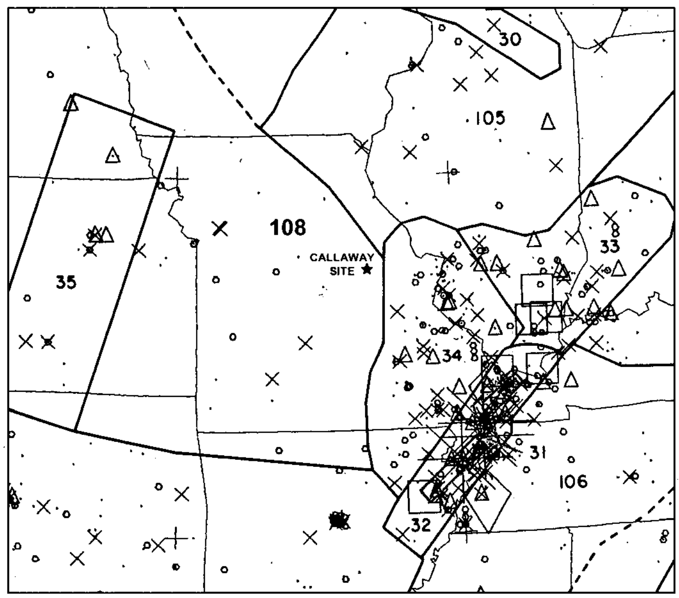
Figure 2.5-24—{Tectonic and Seismic Source Zones Interpretation by Weston Geophysical Corporation}



Tectonic Features

Seismic Source Zones:

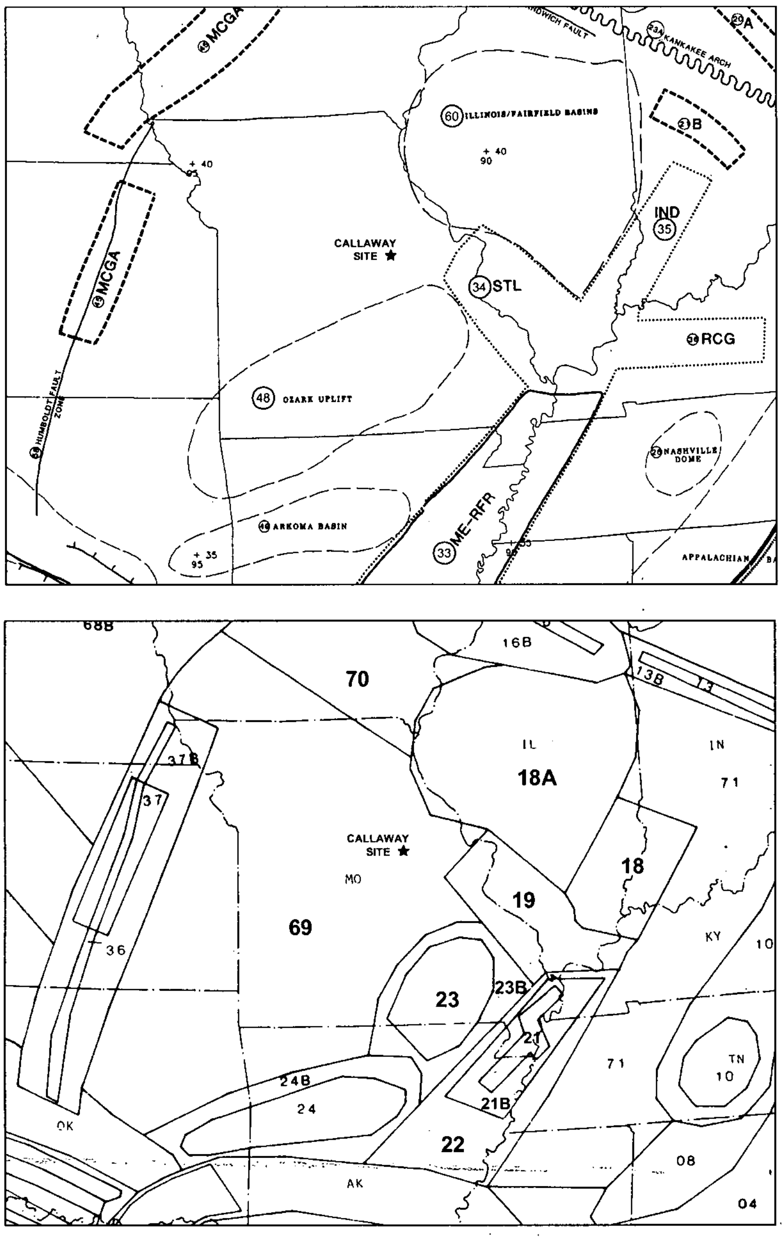
31. New Madrid Fault Zone
32. Reelfoot Rift
33. Indiana Arm
34. St. Louis Arm
105. North Central
108. Great Plains



Seismic Source Zones

Reference: Modified from EPRI (1986), VOLUME 5

Figure 2.5-25—{Tectonic and Seismic Source Zones Interpretation by Dames & Moore}



Tectonic Features

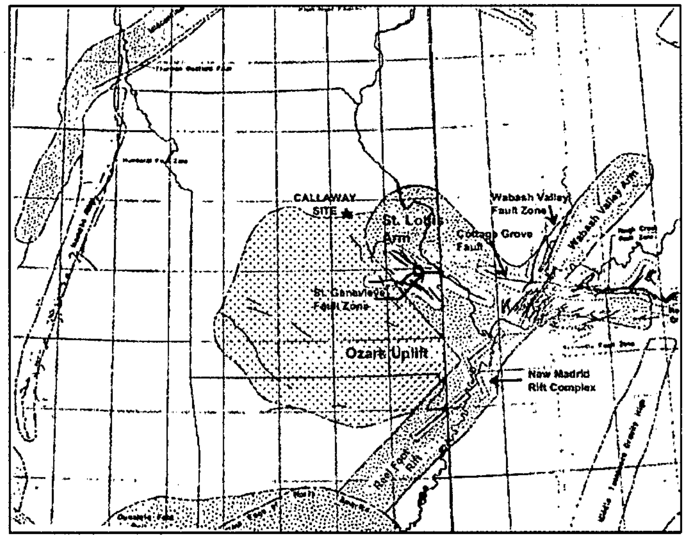
Seismic Source Zones

Seismic Source Zones:

18. Southern Illinois/ Southern Indiana/ Fairfield Basin
18A. Illinois Basin
19. St. Louis Arm
21. New Madrid Comparison Zone
21B. New Madrid Count Zone
22. Reelfoot Rift
23. Eastern Ozarks
23B. Default (Regional Source)
36. Midcontinent Province
70. Wisconsin - Michigan Block

Reference: Modified from EPRI (1986), VOLUME 6

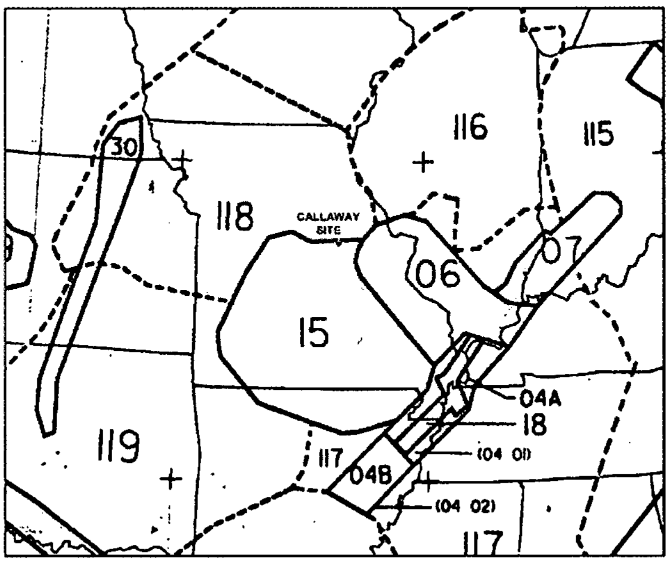
Figure 2.5-26—{Tectonic and Seismic Source Zones Interpretation by Law Engineering Testing Company}



Tectonic Features

Seismic Source Zones:

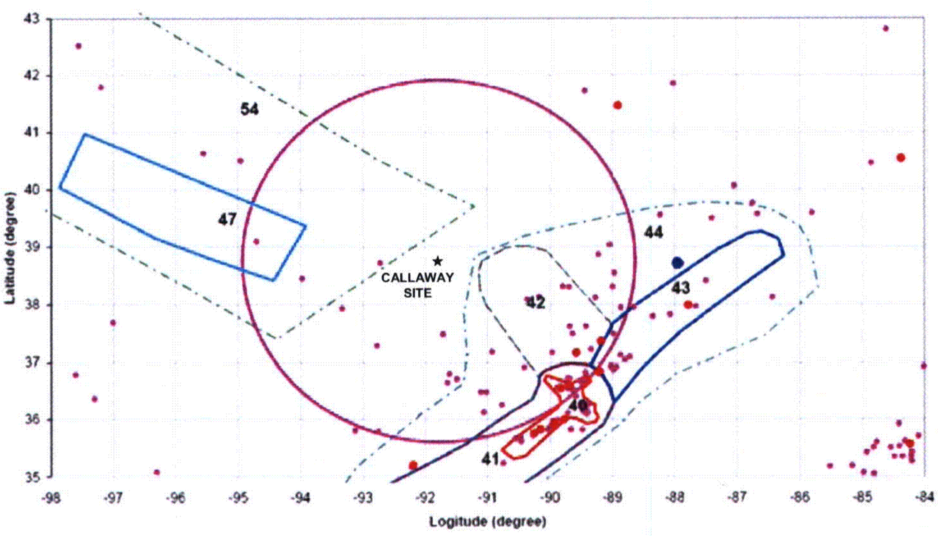
04A. Reelfoot Rift
06. St. Louis Arm of the New Madrid Rift Complex
07. Wabash Valley Arm
15. Ozark Uplift
18. Postulated Faults in Reelfoot Rift
114. Wisconsin Block
116. Illinois Block
117. Mississippi Embayment
118. Missouri Block
119. Eastern Mid-Continent



Seismic Source Zones

Reference: Modified from EPRI (1986), VOLUME 7

Figure 2.5-27—{Tectonic and Seismic Source Zones Interpretation by Woodward-Clyde Consultants}



• M = 3 - 4	● M = 4 - 5	● M >= 5

Reference: Modified from EPRI (1986), VOLUME 8

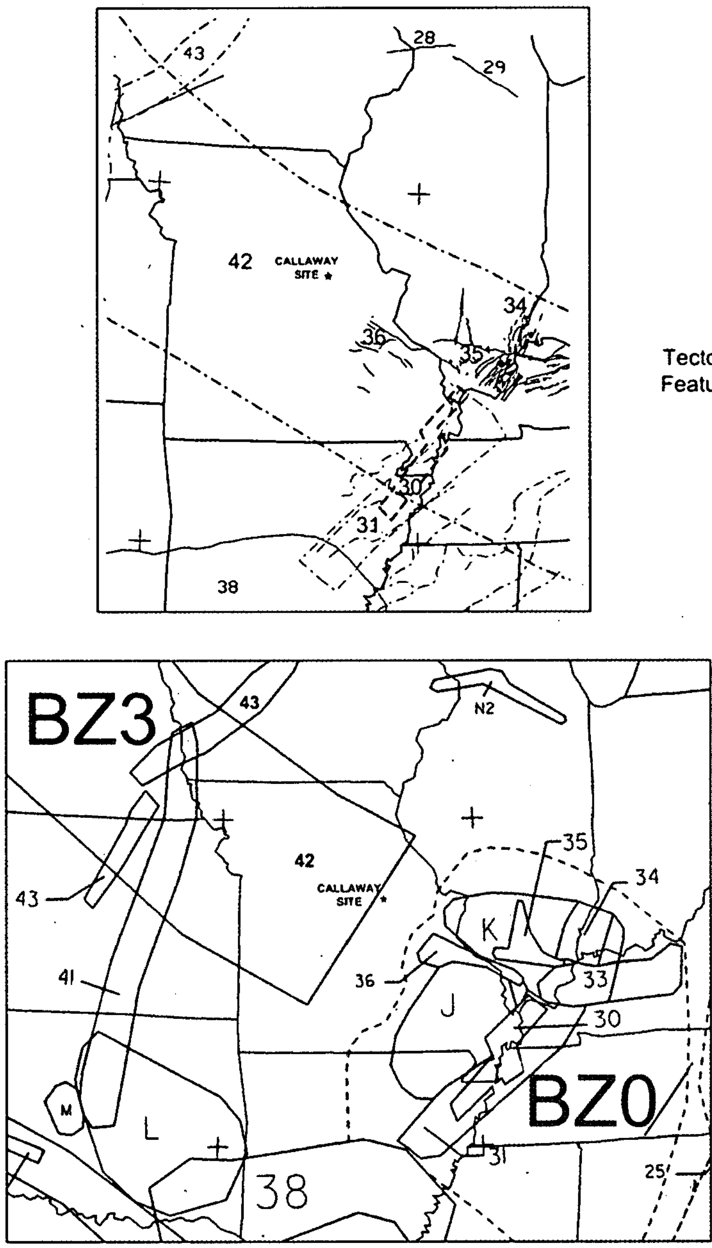
Seismic Source Zones:

40. Central Reelfoot Rift
41. Reelfoot Rift
42. St. Louis Arm, New Madrid Rift
43. South Indiana Arm, New Madrid Rift
44. New Madrid Loading Zone
47. Kansas/Nebraska offset of Mid-Continent Geophysical Anomaly
54. Great Plains Crustal Block

Figure 2.5-28—{Tectonic and Seismic Source Zones Interpretation by Bechtel Group, Inc.}

Seismic Source Zones:

30. New Madrid
31. Reelfoot Rift
36. Ste. Genevieve
42. TN-MT Trend
J. Ozark Area
K. South Illinois Area
B20. Background Zone O
B23. Background Zone 3

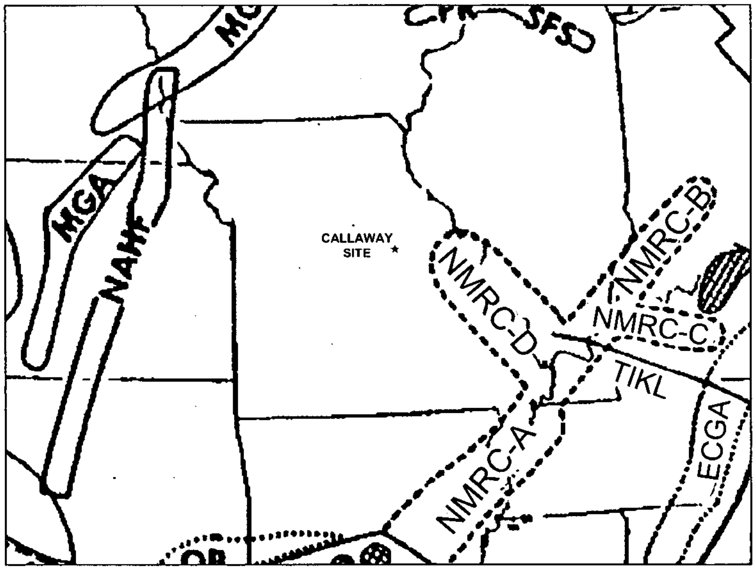


Tectonic Features

Seismic Source Zones

Reference: EPRI (1986), VOLUME 9

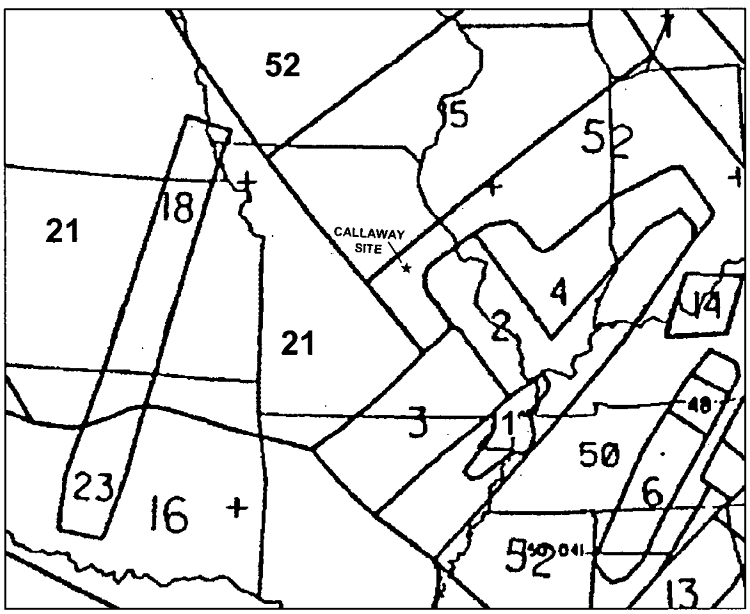
Figure 2.5-29—{Tectonic and Seismic Source Zones Interpretation by Rondout Associates, Inc.}



Tectonic Features

Seismic Source Zones:

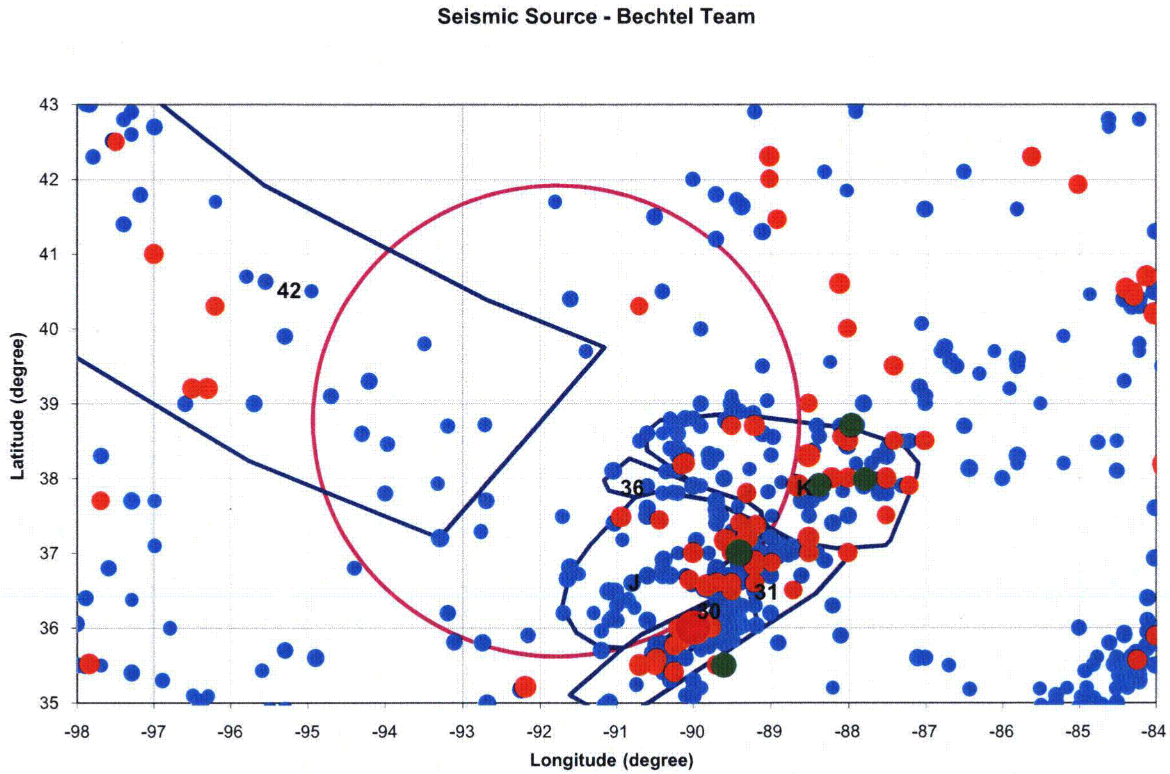
1. New Madrid
2. New Madrid Rift Complex
3. Ozark Uplift
4. Southern Illinois
15. Northern Illinois
21. Great Plains
52. Pre-Grenville Pre-Cambrian Craton (Background Zone)



Seismic Source Zones

Reference: EPRI (1986), VOLUME 10

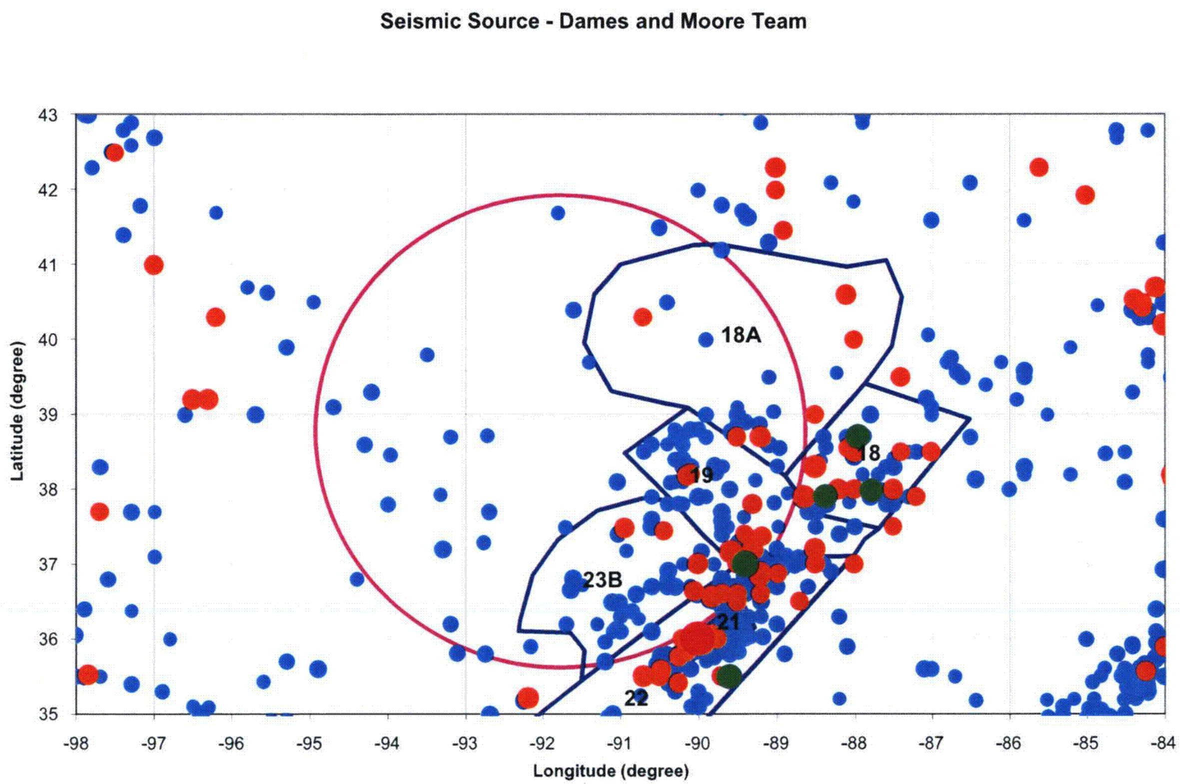
Figure 2.5-39—{Bechtel Group EPRI Source Zones}



NOTES:
The list of seismic sources can be found in Table 2.5-12.
The size of the color dots represents the magnitude of earthquakes.
Sky blue represents earthquakes with magnitude between m_b 3.0 and m_b 4.0.
Orange represents earthquakes with magnitude between m_b 4.0 and m_b 5.0.
Green represents earthquakes with magnitude between m_b 5.0 and m_b 6.0.
Red represents earthquakes with magnitude greater than m_b 6.0.
The pink line represents the area of interest: 200 miles (320 km) radius from the Callaway Plant Site.

FSAR: Section 2.5

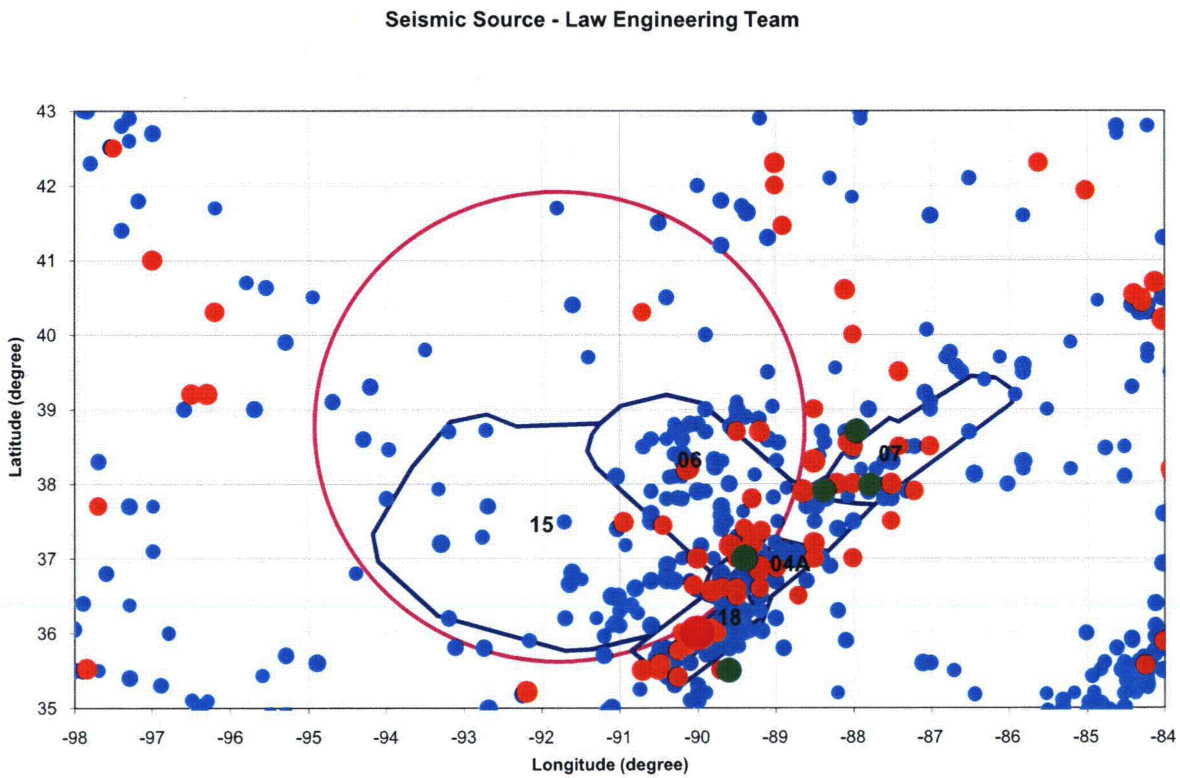
Figure 2.5-40—{Dames & Moore EPRI Source Zones}



NOTES:
The list of seismic sources can be found in Table 2.5-13.
The size of the color dots represents the magnitude of earthquakes.
Sky blue represents earthquakes with magnitude between m_b 3.0 and m_b 4.0.
Orange represents earthquakes with magnitude between m_b 4.0 and m_b 5.0.
Green represents earthquakes with magnitude between m_b 5.0 and m_b 6.0.
Red represents earthquakes with magnitude greater than m_b 6.0.
The pink line represents the area of interest: 200 miles (320 km) radius from the Callaway Plant Site.

FSAR: Section 2.5

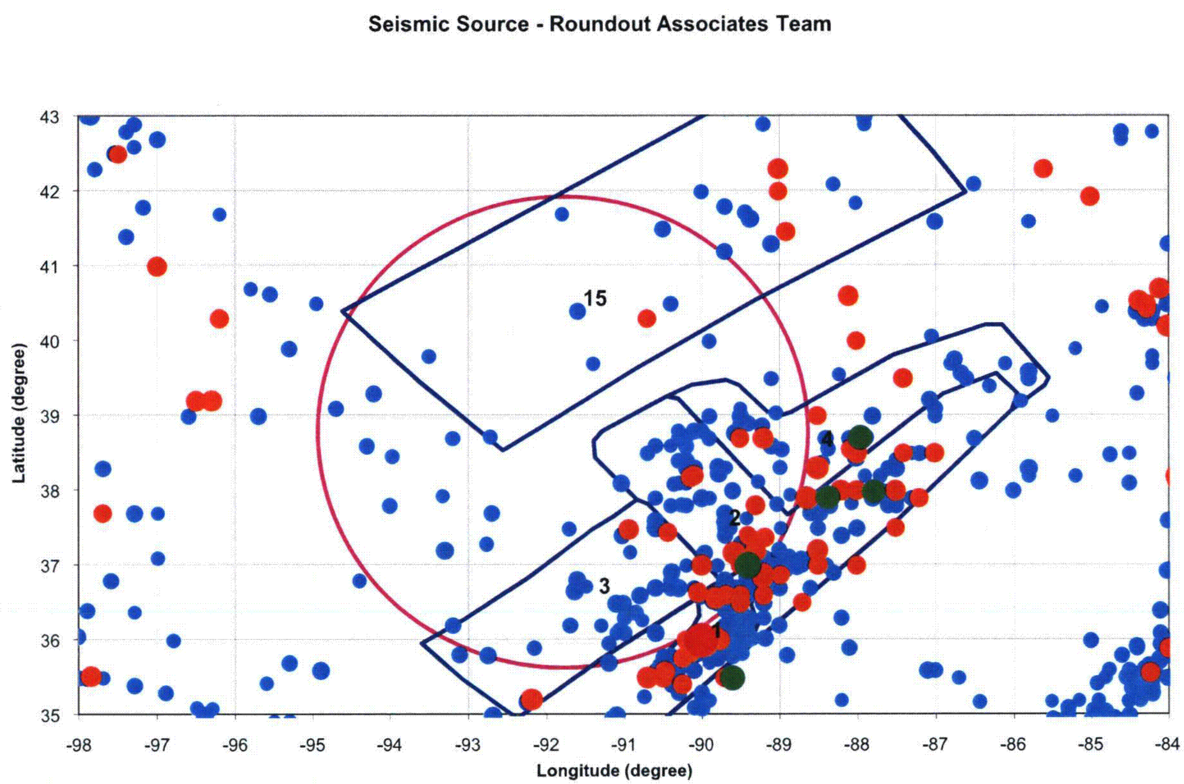
Figure 2.5-41—{Law Engineering EPRI Source Zones}



NOTES:
The list of seismic sources can be found in Table 2.5-14.
The size of the color dots represents the magnitude of earthquakes.
Sky blue represents earthquakes with magnitude between m_b 3.0 and m_b 4.0.
Orange represents earthquakes with magnitude between m_b 4.0 and m_b 5.0.
Green represents earthquakes with magnitude between m_b 5.0 and m_b 6.0.
Red represents earthquakes with magnitude greater than m_b 6.0.
The pink line represents the area of interest: 200 miles (320 km) radius from the Callaway Plant Site.

FSAR: Section 2.5

Figure 2.5-42—{Rondout EPRI Source Zones}



NOTES:

The list of seismic sources can be found in Table 2.5-15.

The size of the color dots represents the magnitude of earthquakes.

Sky blue represents earthquakes with magnitude between m_b 3.0 and m_b 4.0.

Orange represents earthquakes with magnitude between m_b 4.0 and m_b 5.0.

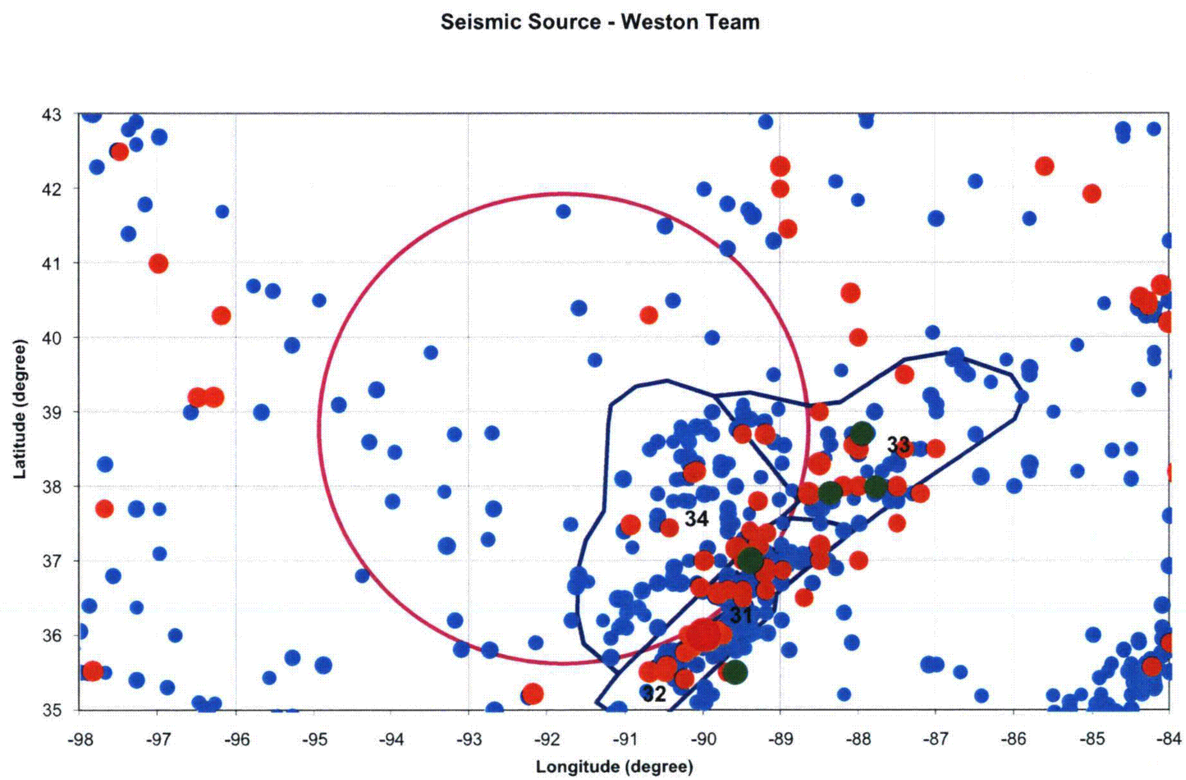
Green represents earthquakes with magnitude between m_b 5.0 and m_b 6.0.

Red represents earthquakes with magnitude greater than m_b 6.0.

The pink line represents the area of interest: 200 miles (320 km) radius from the Callaway Plant Site.

FSAR: Section 2.5

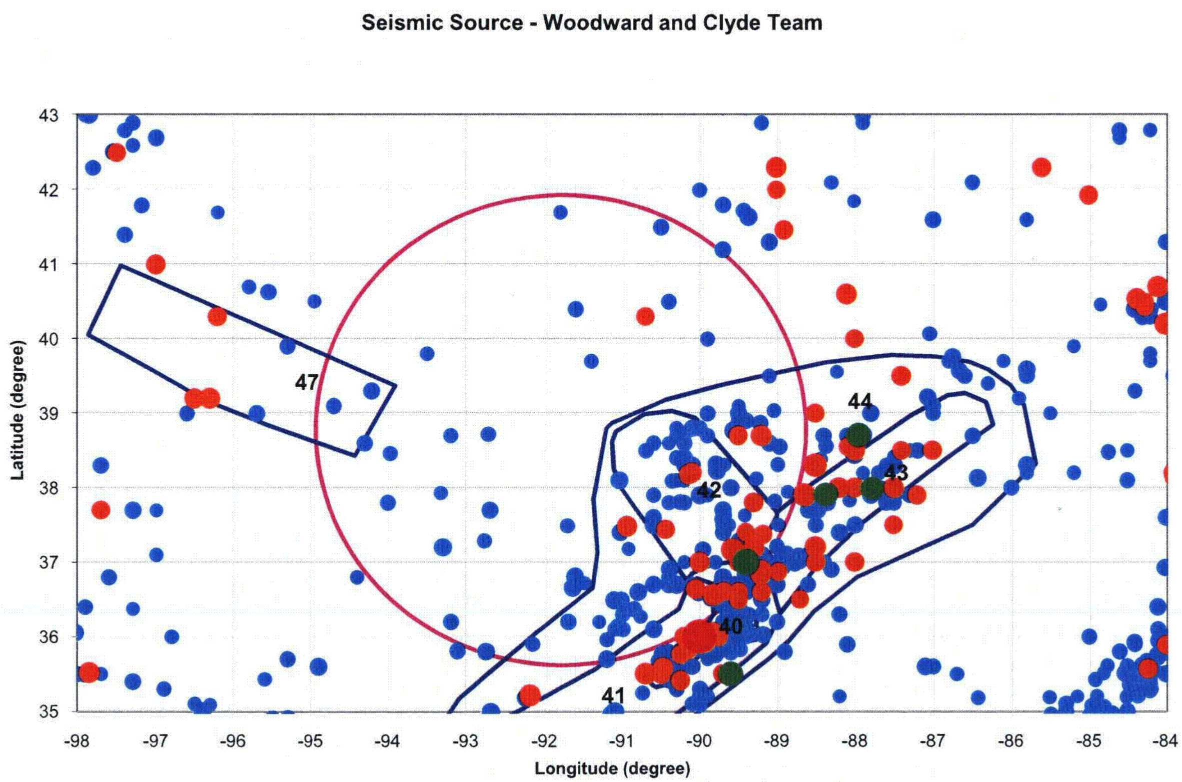
Figure 2.5-43—{Weston Geophysical EPRI Source Zones}



NOTES:
The list of seismic sources can be found in Table 2.5-16.
The size of the color dots represents the magnitude of earthquakes.
Sky blue represents earthquakes with magnitude between m_b 3.0 and m_b 4.0.
Orange represents earthquakes with magnitude between m_b 4.0 and m_b 5.0.
Green represents earthquakes with magnitude between m_b 5.0 and m_b 6.0.
Red represents earthquakes with magnitude greater than m_b 6.0.
The pink line represents the area of interest: 200 miles (320 km) radius from the Callaway Plant Site.

FSAR: Section 2.5

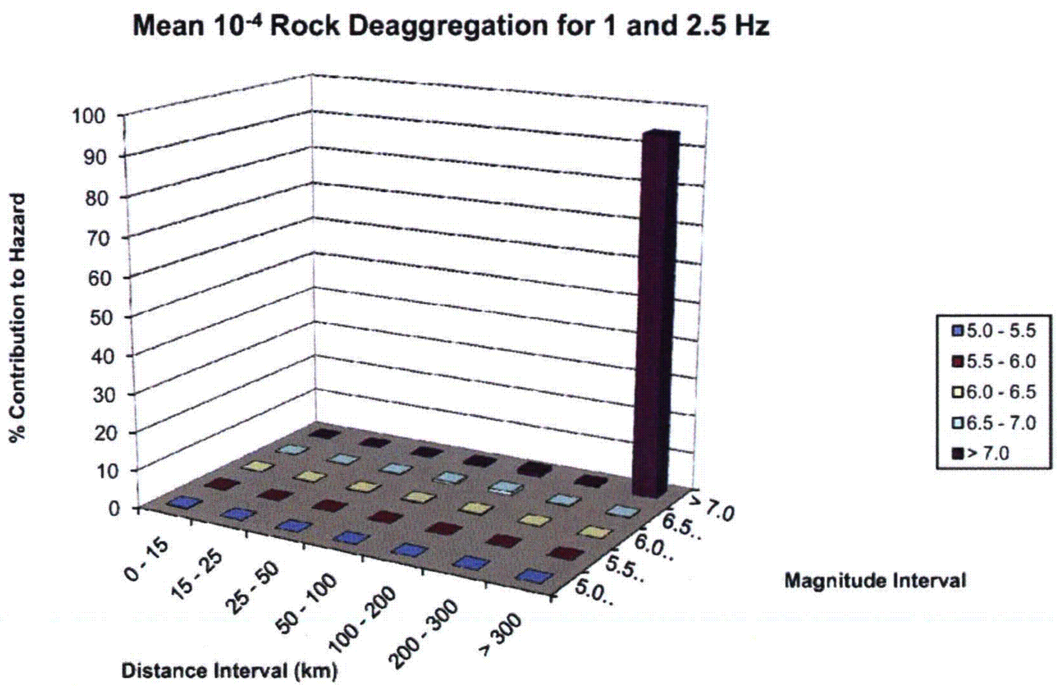
Figure 2.5-44—{Woodward-Clyde Consultants EPRI Source Zones}



NOTES:
The list of seismic sources can be found in Table 2.5-17.
The size of the color dots represents the magnitude of earthquakes.
Sky blue represents earthquakes with magnitude between m_b 3.0 and m_b 4.0.
Orange represents earthquakes with magnitude between m_b 4.0 and m_b 5.0.
Green represents earthquakes with magnitude between m_b 5.0 and m_b 6.0.
Red represents earthquakes with magnitude greater than m_b 6.0.
The pink line represents the area of interest: 200 miles (320 km) radius from the Callaway Plant Site.

FSAR: Section 2.5

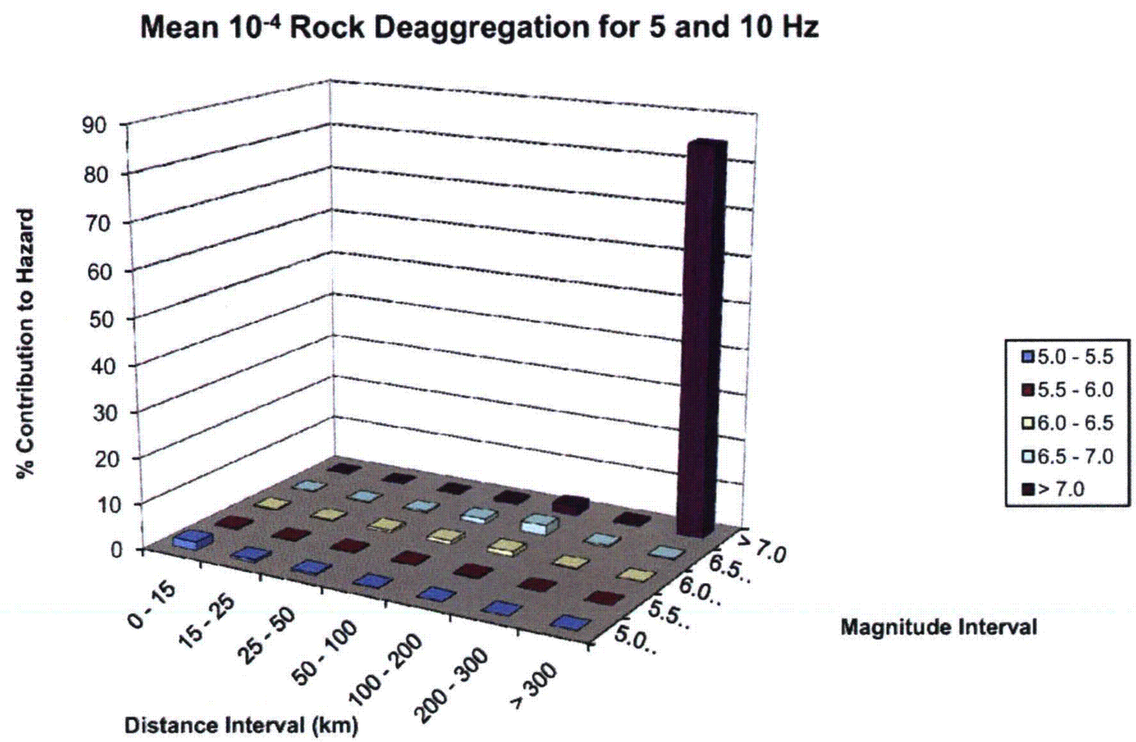
Figure 2.5-49—{Mean 1E-4 Rock Deaggregation for 1 and 2.5 Hz}



NOTE:
Hazard from events farther than 300 km is plotted in the > 300 km bins.
These contributions are from the New Madrid Characteristic Earthquake.

FSAR: Section 2.5

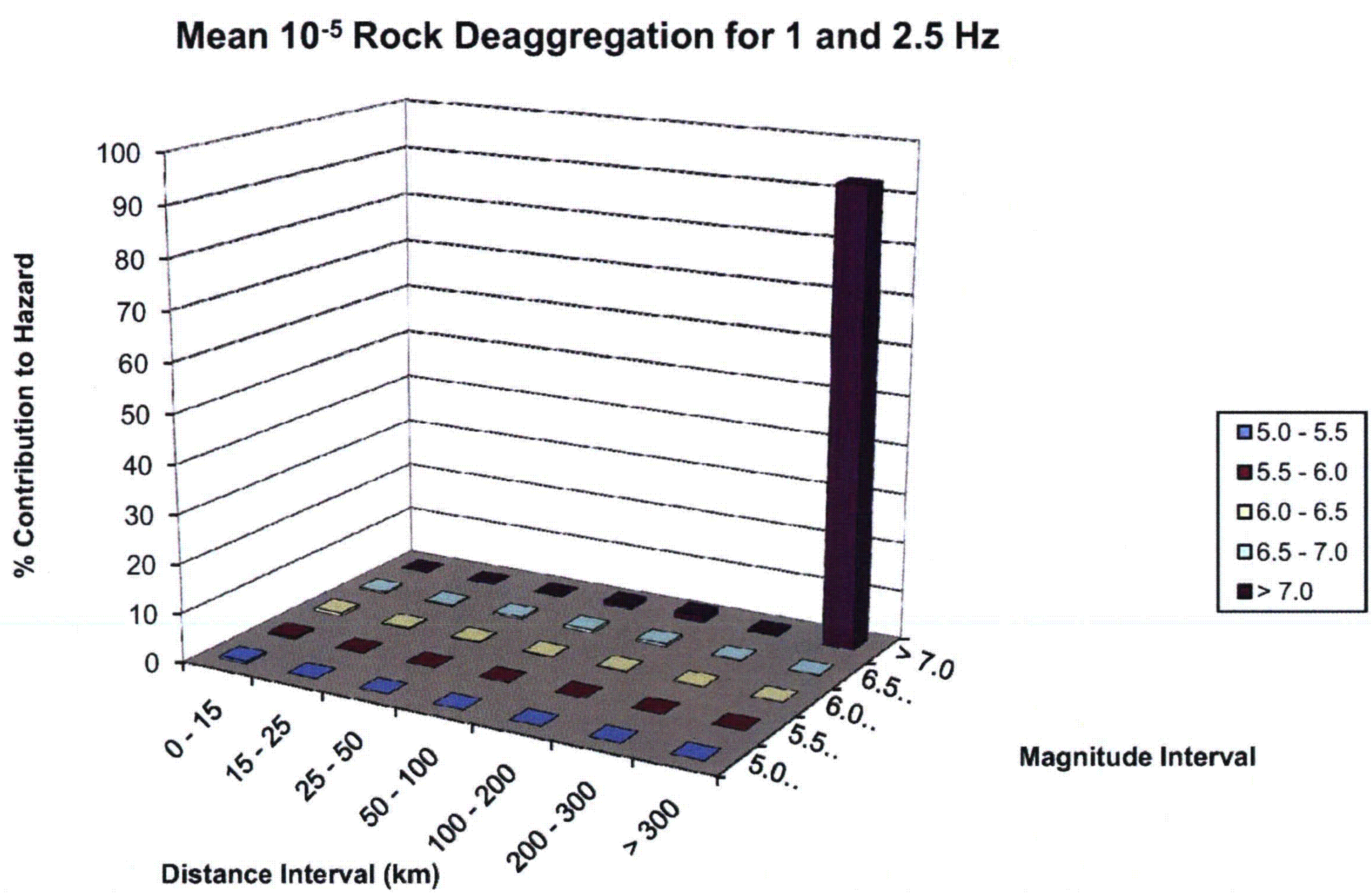
Figure 2.5-50—{Mean 1E-4 Rock Deaggregation for 5 and 10 Hz}



NOTE:
Hazard from events farther than 300 km is plotted in the > 300 km bins.
These contributions are from the New Madrid Characteristic Earthquake.

FSAR: Section 2.5

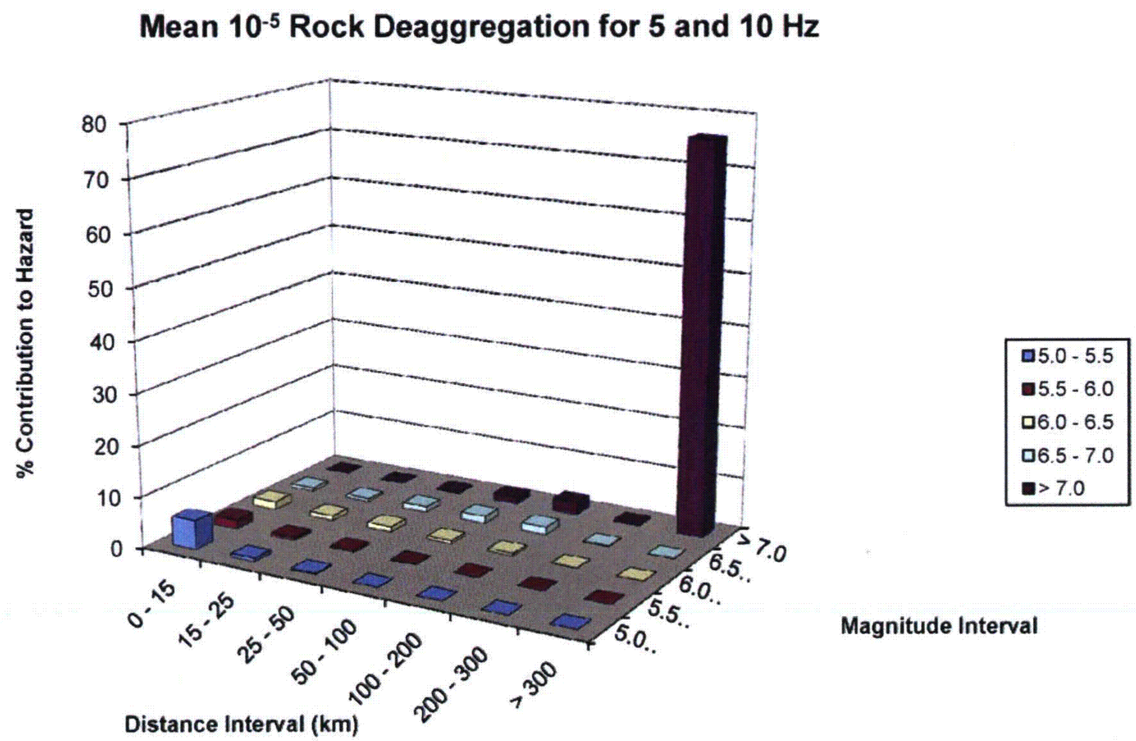
Figure 2.5-51—{Mean 1E-5 Rock Deaggregation for 1 and 2.5 Hz}



NOTE:
Hazard from events farther than 300 km is plotted in the > 300 km bins.
These contributions are from the New Madrid Characteristic Earthquake.

FSAR: Section 2.5

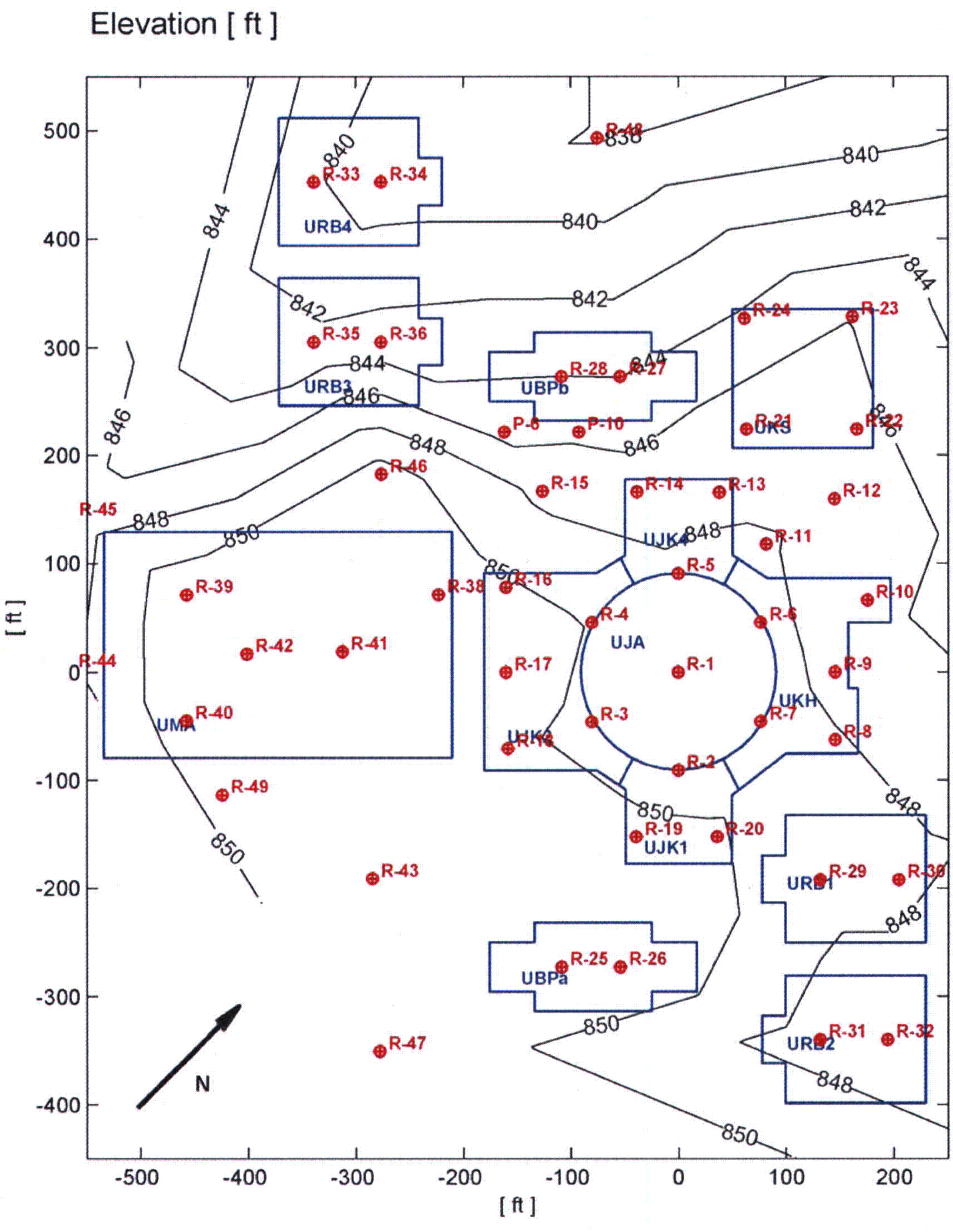
Figure 2.5-52—{Mean 1E-5 Rock Deaggregation for 5 and 10 Hz}



NOTE:
Hazard from events farther than 300 km is plotted in the > 300 km bins.
These contributions are from the New Madrid Characteristic Earthquake.

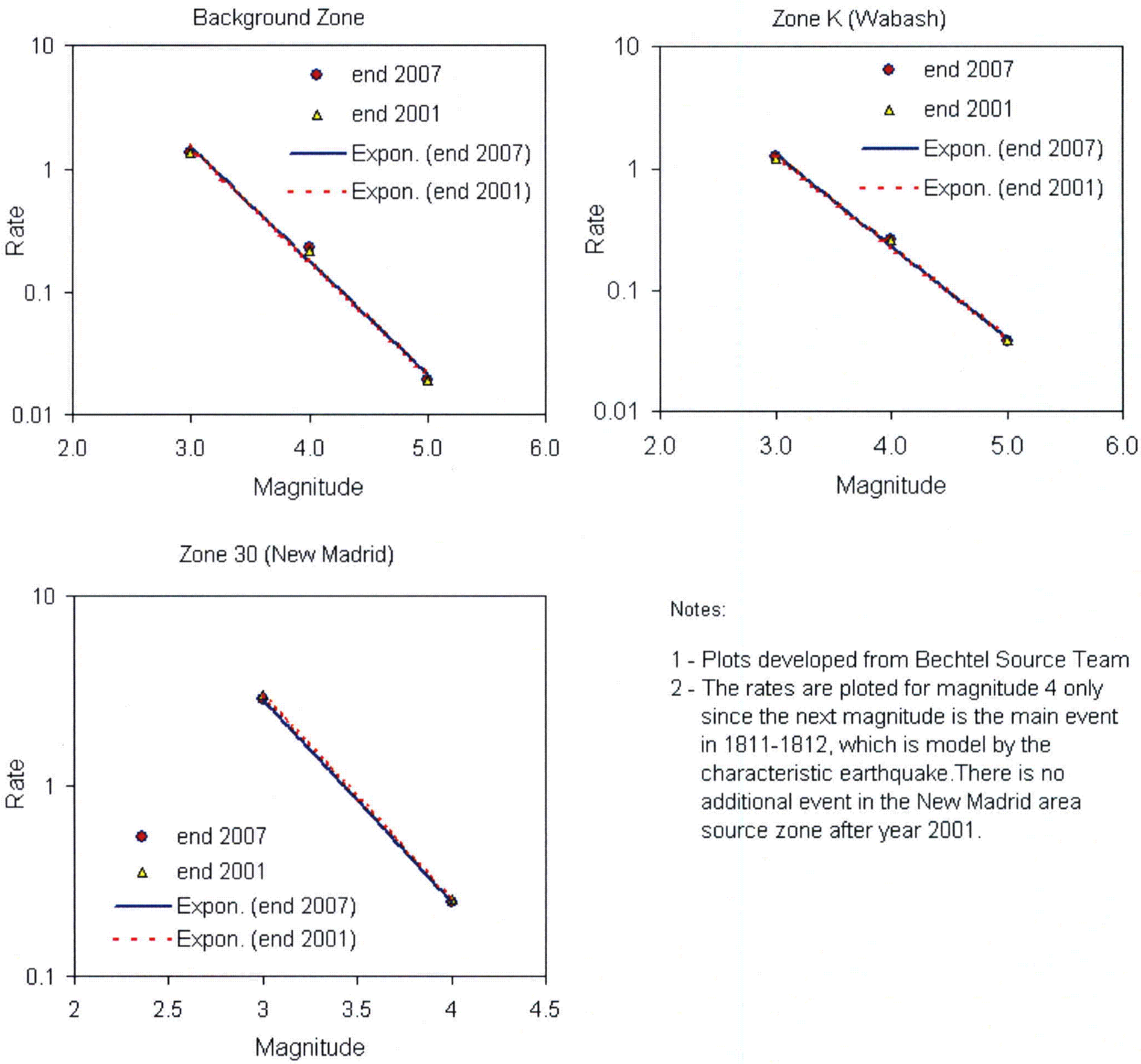
FSAR: Section 2.5

Figure 2.5-94—{Surface Elevation Contours}



NOTE: Refer to Figure 2.5-88 for building designation legend.

Figure 2.5-144
{Comparison of G-R Parameters for the Seismic Source Zones of Background, Wabash Valley, and New Madrid between the 2001 USGS Seismic Catalog and the 2007 USGS Updated Catalog}



Notes:

1 - Plots developed from Bechtel Source Team
2 - The rates are ploted for magnitude 4 only since the next magnitude is the main event in 1811-1812, which is model by the characteristic earthquake.There is no additional event in the New Madrid area source zone after year 2001.

Figure 2.5-145
{Comparison of Uniform Hazard Response Spectra (UHRS) at hard rock for the Callaway Unit 2 Site between the 2001 USGS Seismic Catalog and the 2007 USGS Updated Catalog}

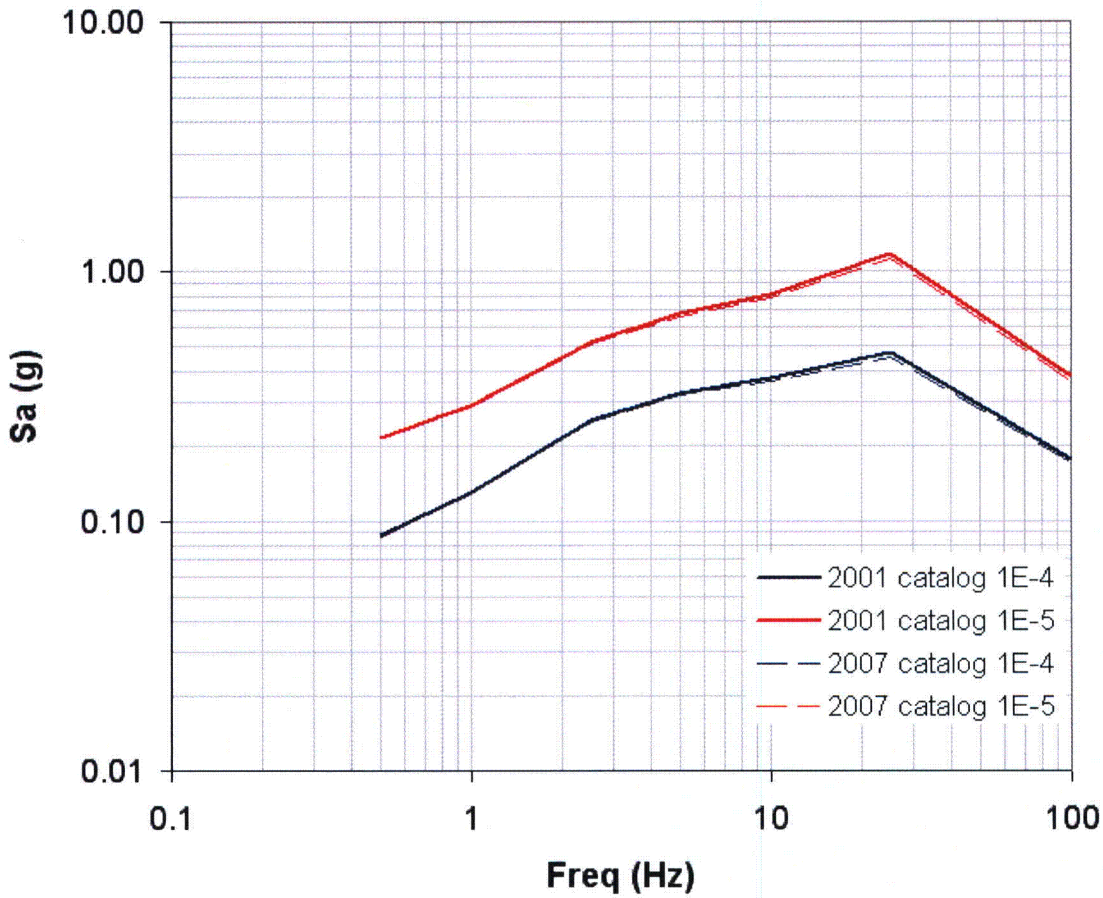
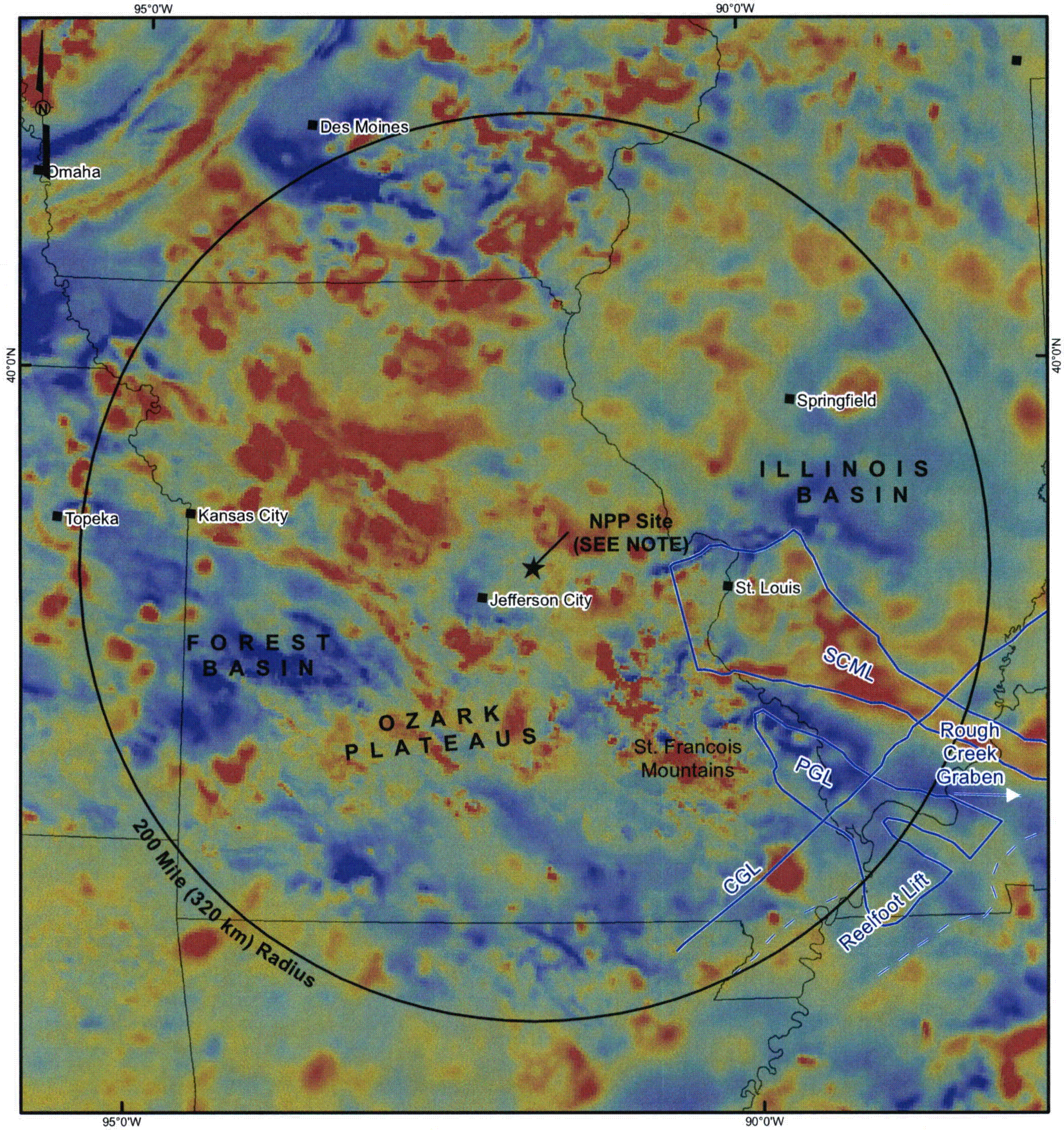


Figure 2.5-146, {Regional Magnetic Anomaly Map}



LEGEND

Aeromagnetics

High : 6012.16

0

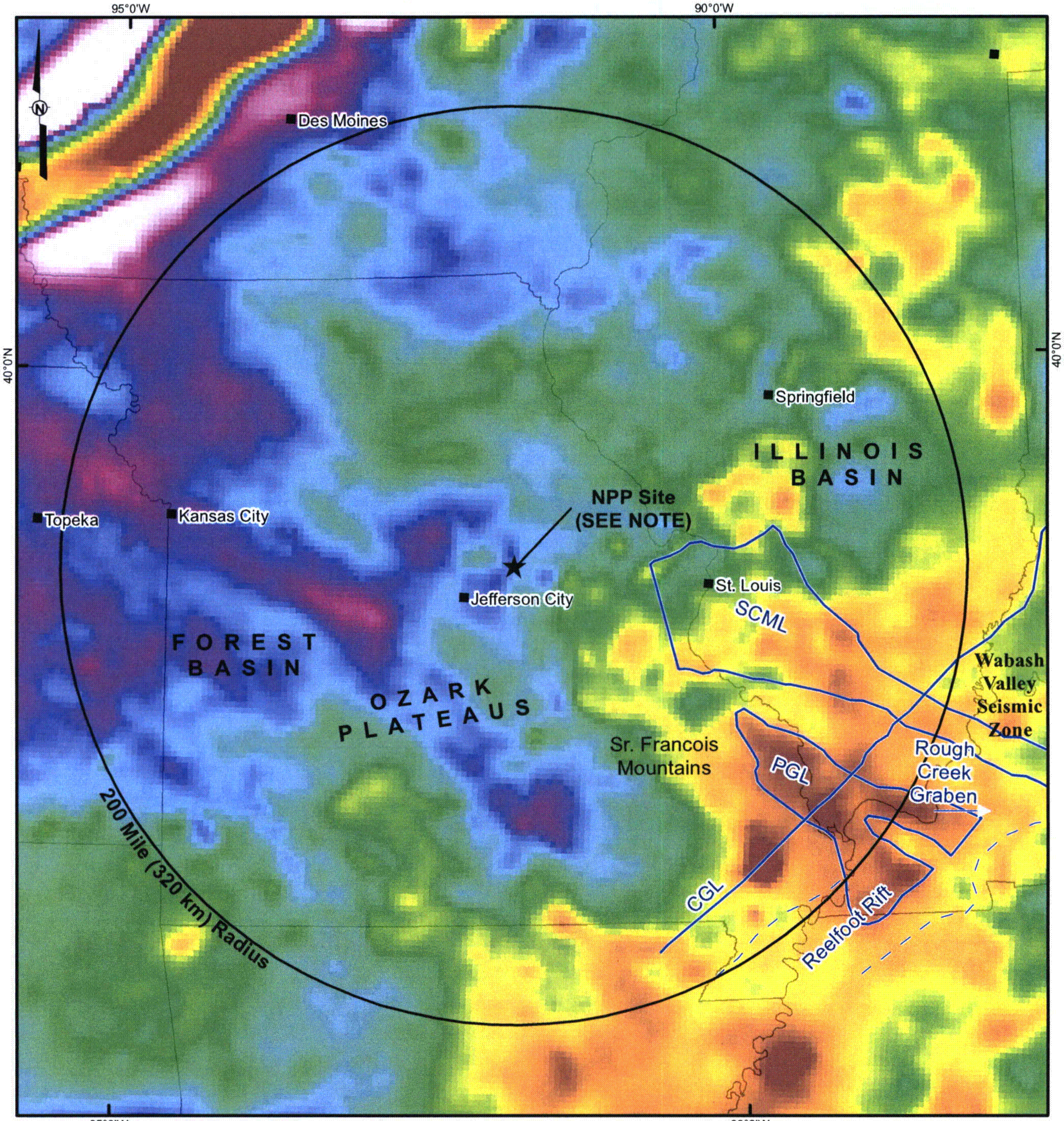
Low : -3086.11

CGL - Commerce Geophysical Lineament
PGL - Paducah Gravity Lineament
SCML - South-Central Magnetic Lineament

NOTE:
REFERENCE CENTER POINT OF PLANT SITE IS DEFINED AT THE MIDPOINT BETWEEN EXISTING REACTOR FOR CALLAWAY UNIT 1 AND PROPOSED CALLAWAY UNIT 2.

REFERENCE:
- USGS, 2002.
- Kolata, 1997.

Figure 2.5-147, {Regional Gravity Anomaly Map}



LEGEND

Gravity Anomaly

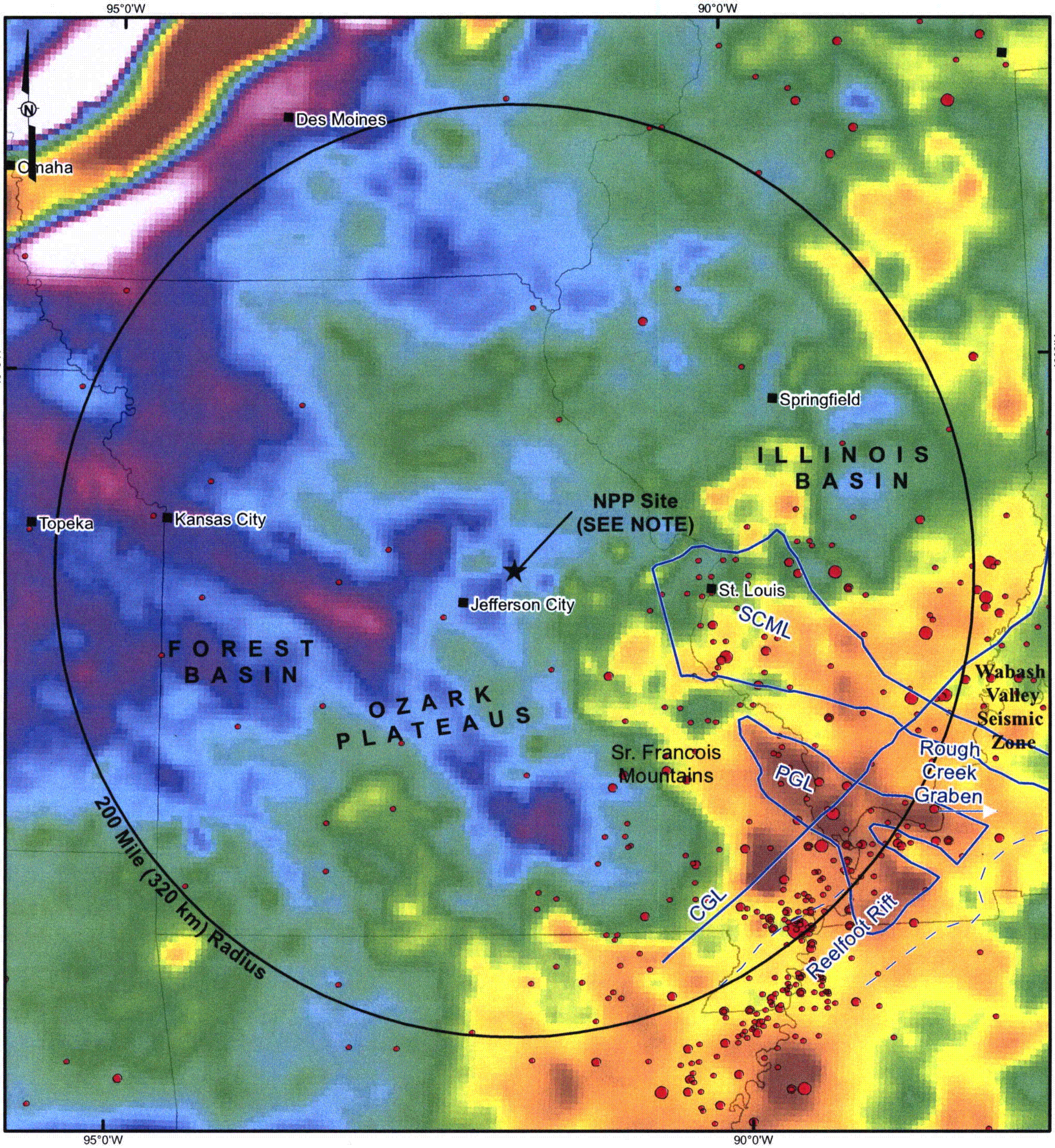
0 - High : 65.6537

Low : -112.67

CGL - Commerce Geophysical Lineament
PGL - Paducah Gravity Lineament
SCML - South-Central Magnetic Lineament

NOTE:
REFERENCE CENTER POINT OF PLANT SITE IS DEFINED AT THE MIDPOINT BETWEEN EXISTING REACTOR FOR CALLAWAY UNIT 1 AND PROPOSED REACTOR FOR CALLAWAY UNIT 2.
REFERENCE:
• Kucks, 1999.

Figure 2.5-148, {Regional Gravity Anomaly Map with Earthquake Overlays}



0 50 100 Miles

LEGEND

Gravity Anomaly

0 - High : 65.6537

Low : -112.67

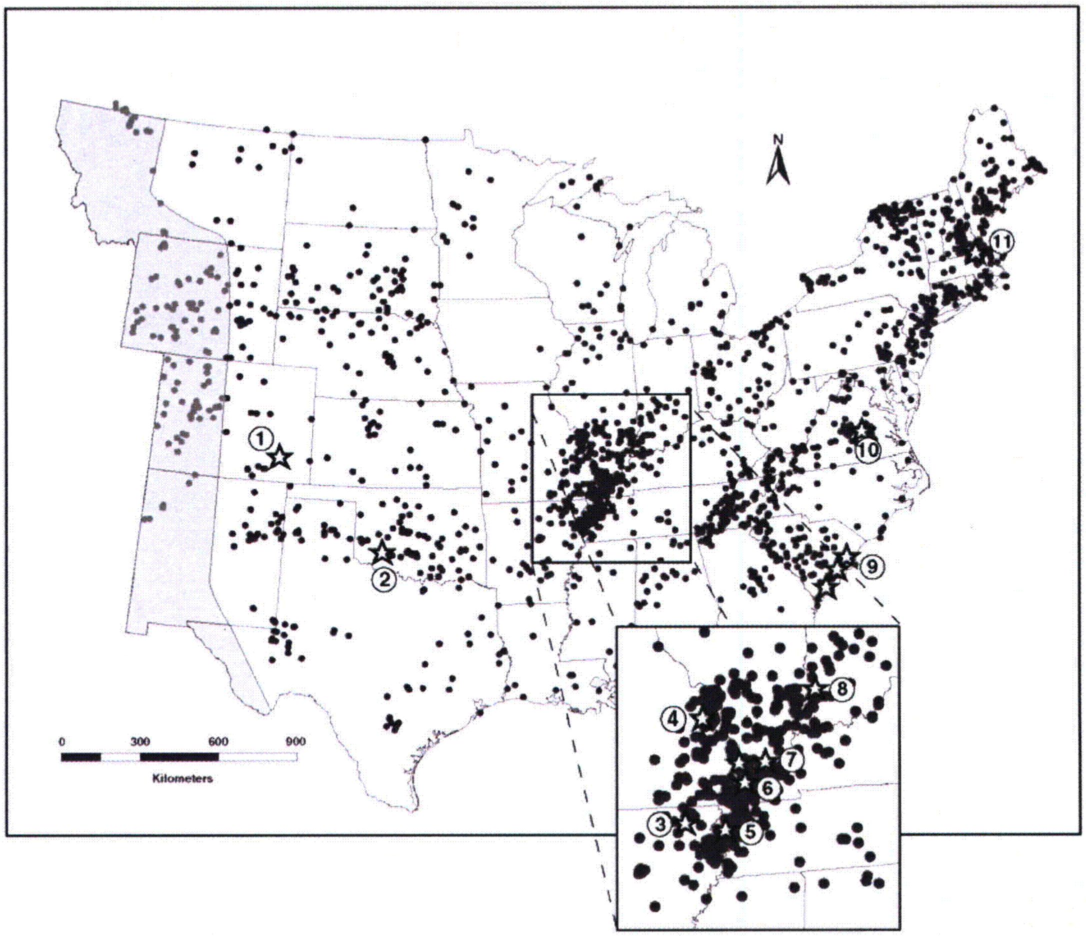
Earthquakes
by Magnitude, mb
(USGS 2002 Catalog)

- 3.0 - 3.9
- 4.0 - 4.9
- 5.0 - 5.9
- 6.0 - 6.9
- 7.0 - 7.9

CGL - Commerce Geophysical Lineament
PGL - Paducah Gravity Lineament
SCML - South-Central Magnetic Lineament

NOTE:
REFERENCE CENTER POINT OF PLANT SITE IS DEFINED AT THE MIDPOINT BETWEEN EXISTING REACTOR FOR CALLAWAY UNIT 1 AND PROPOSED REACTOR FOR CALLAWAY UNIT 2.
REFERENCE:
- Kucks, 1999.
- USGS, 2002.

Figure 2.5-149, {Quaternary Class "A" Features in the CEUS}



LEGEND.

1. - Cheraw fault, Colorado
2. - Meers fault, Oklahoma
3. - Western Lowlands liquefaction features, Missouri- Arkansas
4. - St. Louis-Cape Girardeau liquefaction features, Missouri-Illinois
5. - Reelfoot scarp and New Madrid seismic zone, Missouri-Arkansas-Tennessee
6. - Thebes Gap area, Missouri
7. - Fluorspar Area fault complex, Illinois-Kentucky
8. - Wabash Valley liquefaction features, Indiana-Illinois
9. - Charleston-Bluffton-Georgetown liquefaction features, South Carolina-North Carolina
10. - Central Virginia seismic zone
11. - Newbury liquefaction features, Massachusetts.

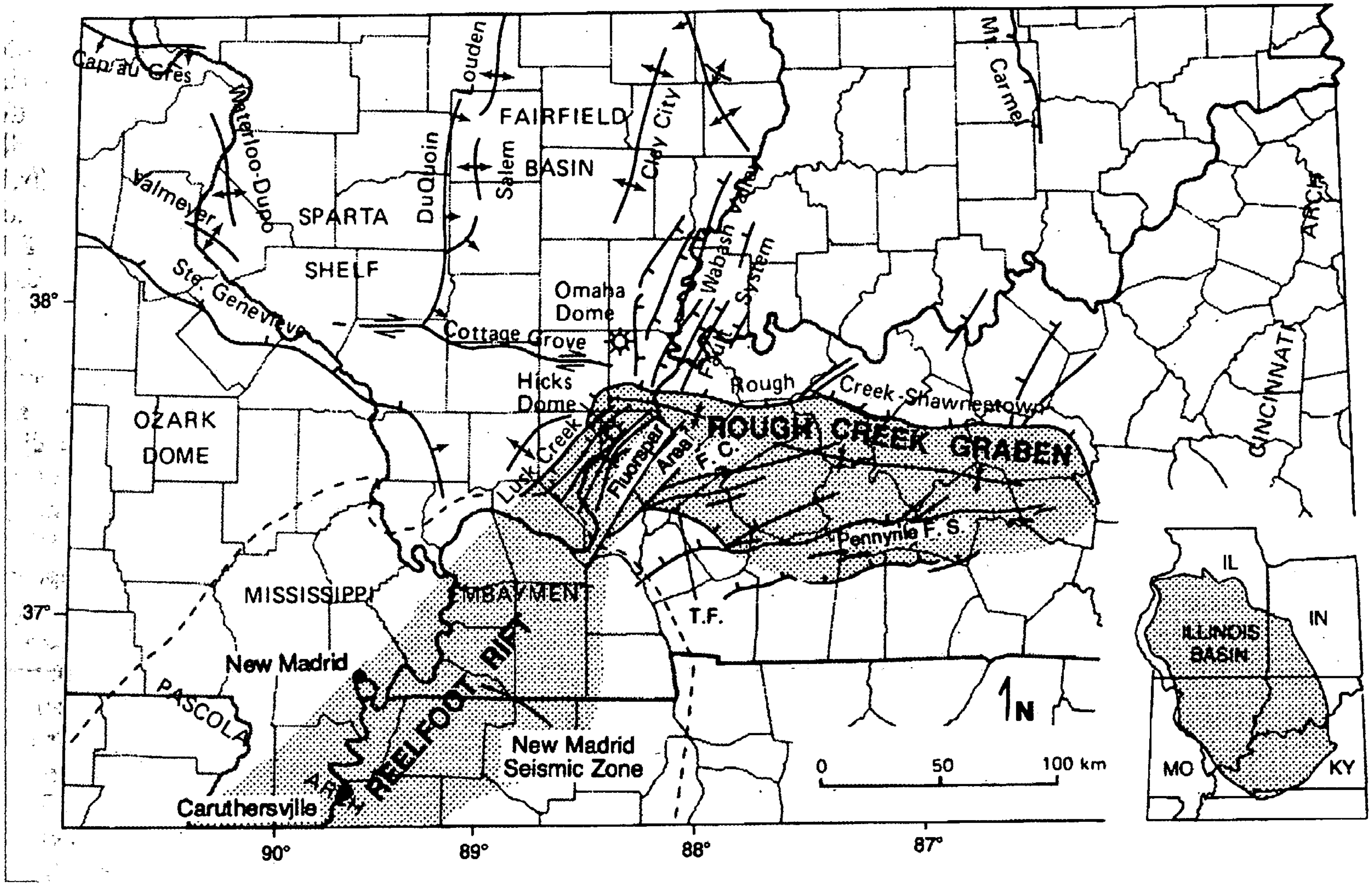
NOTE: Solid dots are historical earthquakes of mb 3.0 or greater; seismicity catalog provided by C. Mueller, USGS.

REFERENCE: Crone, 20000

Figure 2.5-A **Rev. 0**

Quaternary Class "A" Features in the CEUS

CALLAWAY PLANT UNIT 2 FSAR

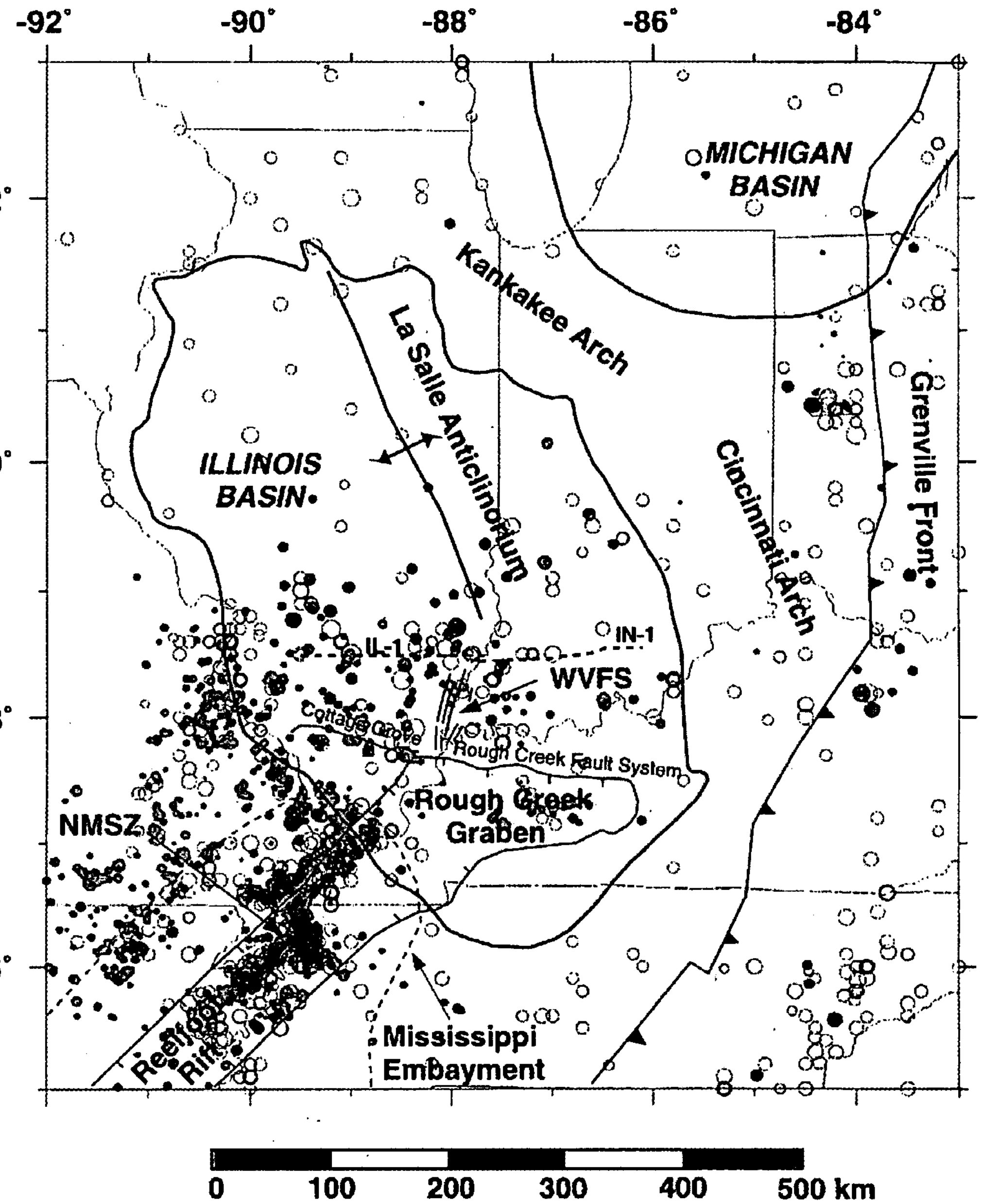


Reference: Kolata, 1997

Figure 2.5-B **Rev. 0**

Major Structural Features in the Southern Illinois Basin

CALLAWAY PLANT UNIT 2 FSAR



REFERENCE: Bear, 1997

Figure 2.5-C **Rev. 0**

Structural Features and Seismicity of the Central US

CALLAWAY PLANT UNIT 2 FSAR