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U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: Duke Energy Carolinas, LLC.
William States Lee III Nuclear Station - Docket Nos. 52-018 and 52-019
AP1000 Combined License Application for the
William States Lee III Nuclear Station Units 1 and 2
Response to Request for Additional Information
(RAI No. 1053)
Ltr# WLG2008.12-07

Reference: Letter from Brian Hughes (NRC) to Peter Hastings (Duke Energy), *Request for Additional Information Letter No. 026 Related To SRP Section 2.5.3 for the William States Lee III Units 1 And 2 Combined License Application*, dated October 2, 2008

This letter provides the Duke Energy response to the Nuclear Regulatory Commission's requests for additional information (RAIs) included in the referenced letter.

Responses to the NRC information requests described in the referenced letter are addressed in separate enclosures, which also identify associated changes, when appropriate, that will be made in a future revision of the Final Safety Analysis Report for the Lee Nuclear Station.

If you have any questions or need any additional information, please contact Peter S. Hastings, Nuclear Plant Development Licensing Manager, at 980-373-7820.

Bryan J. Dolan
Vice President
Nuclear Plant Development

D093
NRO

Enclosures:

1) Duke Energy Response to Request for Additional Information Letter 026, RAI 02.05.03-001
2) Duke Energy Response to Request for Additional Information Letter 026, RAI 02.05.03-002
3) Duke Energy Response to Request for Additional Information Letter 026, RAI 02.05.03-003
4) Duke Energy Response to Request for Additional Information Letter 026, RAI 02.05.03-004
5) Duke Energy Response to Request for Additional Information Letter 026, RAI 02.05.03-005
6) Duke Energy Response to Request for Additional Information Letter 026, RAI 02.05.03-006
7) Duke Energy Response to Request for Additional Information Letter 026, RAI 02.05.03-007
8) Duke Energy Response to Request for Additional Information Letter 026, RAI 02.05.03-008
9) Duke Energy Response to Request for Additional Information Letter 026, RAI 02.05.03-009

AFFIDAVIT OF BRYAN J. DOLAN

Bryan J. Dolan, being duly sworn, states that he is Vice President, Nuclear Plant Development, Duke Energy Carolinas, LLC, that he is authorized on the part of said Company to sign and file with the U. S. Nuclear Regulatory Commission this supplement to the combined license application for the William States Lee III Nuclear Station and that all the matter and facts set forth herein are true and correct to the best of his knowledge.

Bryan J. Dolan

Bryan J. Dolan

Subscribed and sworn to me on December 3, 2008

Phoebe P. Elliott

Notary Public

My commission expires: June 26, 2011

SEAL

xc (w/o enclosures):

Luis Reyes, Regional Administrator, Region II
Loren Plisco, Deputy Regional Administrator, Region II
Thomas Bergman, Deputy Division Director, DNRL
Stephanie Coffin, Branch Chief, DNRL

xc (w/ enclosures):

Brian Hughes, Senior Project Manager, DNRL

Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI Letter No. 026

NRC Technical Review Branch: **Geosciences and Geotechnical Engineering Branch 2 (RGS2)**

Reference NRC RAI Number(s): **RAI 02.05.03-001**

NRC RAI:

FSAR Sections 2.5.3.1.1 and 2.5.3.1.2 (pages 2.5-142 and 2.5-143) indicate that the PSAR for the former Duke Cherokee site contains the most detailed, but unpublished, geologic maps of the Lee site. Information derived from these unpublished geologic maps is used to conclude that no evidence exists for active or geologically recent faulting within the site area, but this important map information is not summarized and presented in the FSAR.

Please summarize pertinent data from the geologic maps of the Cherokee site that are used to conclude that no evidence exists for active faulting in the site area. Please show these geologic data on the Lee site geologic map (existing Figure 2.5.1-220) and the surficial excavation geologic map (existing Figure 2.5.1-229) if they are not already included on those maps.

Duke Energy Response:

The response to this RAI summarizes the Cherokee Nuclear Station (CNS) historic data for the site and clarifies what portions of these data were used to help support the FSAR conclusion that no evidence exists for active faulting in the site area. In addition, this response addresses if any of the historic data are included or can be added to FSAR Figures 2.5.1-220 and 2.5.1-229.

FSAR Section 2.5.3.1.1, which addresses previous Lee Nuclear Site investigations, states: "The results of previous site investigations are presented in the PSAR ... This previous work does not identify the existence of tectonic faulting within the site area." FSAR Section 2.5.3.1.2, which addresses published geologic mapping, states: "The most detailed mapping of the Duke Lee Nuclear Site is the unpublished mapping developed by Duke Power geologists performed as part of the Cherokee nuclear site construction." Thus, the CNS detailed geologic maps are not included in the PSAR, but rather were produced later during CNS construction mapping. These detailed construction maps of the excavation were not used, directly or exclusively, to conclude that no active faults exist at the site given that these were not compiled into a final published map product.

Historic CNS evaluations and pertinent data evaluated as part of Lee COLA investigations include the following documents and project records:

- 1974 CNS Preliminary Safety Analysis Report (FSAR References 2.5.3-201, 2.5.3-202, and 2.5.3-203),
- 1977 Safety Evaluation Report, NUREG-0189, (Reference 1), and
- Construction-derived records including unpublished detailed geologic mapping, zone reports, petrographic analyses, and evaluations.

The Lee COLA relies more on the CNS PSAR than the unpublished construction-derived records to conclude that that no active faults exist at the site. CNS construction began in 1977 and was ultimately cancelled in the early 1980s. Construction-derived records, such as detailed mapping of excavation exposures, were never compiled into final maps and reports. This phase of final compilation was to be completed as part of the CNS FSAR. A review of surviving construction-derived records, specifically the detailed excavation mapping performed at 1:120- and 1:240-scale and supporting zone reports, indicates that these records are consistent with the earlier CNS PSAR findings that no capable tectonic features traverse the site.

Review of CNS historic records and detailed discussions with the Duke Power project geologist who oversaw the CNS construction mapping efforts support this conclusion. A team of consultant expert geologists working with Duke Power provided interim progress reviews and consultations throughout the CNS construction program. This team included Professors Robert Hatcher from the University of Tennessee, Don Secor from the University of South Carolina, and Robert Butler from the University of North Carolina. Professors Hatcher and Secor served as the Duke Power expert geologic review board and Professor Butler served as a consultant to Duke Power's project geologist. This consultant team supported Duke throughout construction and up until CNS project cancellation in the mid-1980s. During this period, the NRC worked closely with Duke Power and its team of geologic consultants in conducting quarterly reviews and acceptance of Duke Power interpretations and findings.

The minor ductile and brittle faults identified during COLA mapping activities at the William States Lee III site are not considered capable tectonic sources. Radiometric dating documented within the CNS PSAR, and later during construction mapping investigations, was performed on intact and disturbed minerals within fault planes or adjacent to fault surfaces (e.g., chlorite along slickenside surfaces). These analyses indicate that minor bedrock adjustments last occurred during the Mesozoic Era. Similar features are common throughout the bedrock of the Piedmont and have been independently evaluated in the foundations of other Piedmont nuclear plant sites.

Independent mapping evaluations performed as part of Lee COLA investigations confirm the conclusions stated in historical CNS evaluations. Specifically, Lee COLA investigations confirm the rock types and cross-cutting relationships that support the age and origin of tectonic deformation. As such, it is our assessment that the CNS evaluations are acceptable for characterizing foundation-level rock. An independent age-dating evaluation of bedrock structures exposed within the Lee site has not been performed as part of the Lee COLA studies.

The site geologic map (0.6 mile radius) presented in FSAR Figure 2.5.1-220 is modified from Nystrom (2004) [FSAR Reference 2.5.3-205]. The scale of this FSAR map does not permit the inclusion of details from 1:240-scale and 1:120-scale construction mapping of rock types and structure internal to the pluton.

The surficial geologic map of the existing excavation presented in FSAR Figure 2.5.1-229 represents mapping of the exposed bedrock surface performed for the Lee COLA. This map does not include results from the unpublished mapping performed during the CNS construction. However, Lee COLA comparison mapping of a portion of the exposed foundation rock in the northern portion of CNS Unit 2 yields similar results, as described above. Integration of all the detailed, unpublished CNS construction-derived final foundation map panels into a single integrated map was to be performed as part of the CNS FSAR. This final foundation map compilation was not completed before cancellation of the CNS project in the mid-1980s.

Considering the small scale of these displacement features in comparison to illustration scales used in the Lee Site Geologic Map (FSAR Figure 2.5.1-220) and Surficial Geologic Map of Existing Excavation (FSAR Figure 2.5.1-229), it is not practical to illustrate the pertinent data from CNS investigations in these FSAR figures. The results of radiometric age dating of on-site and off-site samples used to constrain the age and origin of tectonic deformations are summarized in PSAR Tables 2C-3A through 3C. The results presented in these PSAR summary tables are re-created as follows:

- Table 1A. Radiometric Age Determinations From Slickensides and Shears,
- Table 1B. Radiometric Age Determinations From Undisturbed Site Rocks, and
- Table 1C. Radiometric Age Determinations From Off-Site Rock Samples.

The sample locations corresponding to radiometric age dating results for on-site slickensides and shears (Table 1A), and undisturbed site rocks (Table 1B) are illustrated on Figure 1. Figure 2 illustrates the approximate locations of off-site samples (Table 1C) used to obtain radiometric dates reported in the CNS PSAR.

References:

1. US Nuclear Regulatory Commission, Safety Evaluation Report related to construction of Cherokee Nuclear Station, Units 1, 2, and 3, Duke Power Company, NUREG-0189, Washington, DC, March 1977.

Associated Revision to the Lee Nuclear Station Final Safety Analysis Report:

None

Attachments:

1) Figure 1. Locations of Radiometric Age Determinations for Slickensides and Shears and Undisturbed Rock Samples.
2) Figure 2. Locations of Radiometric Age Determinations for Potassium-Argon Ages of Off-Site Rocks
3) Table 1A. Radiometric Age Determinations From Slickensides and Shears (3 Sheets)
4) Table 1B. Radiometric Age Determinations From Undisturbed Site Rocks (2 Sheets)
5) Table 1C. Radiometric Age Determinations for Off-Site Rock Samples (1 Sheet)

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 1 to RAI 02.05.03-001

Figure 1. Locations of Radiometric Age Determinations for Slickensides and Shears and Undisturbed Rock Samples

Sources: 1) CNS PSAR Table 2C-3A, Radiometric Age Determinations Slickensides and Shears (Duke Power 1974)

2) CNS PSAR Table 2C-3B, Radiometric Age Determinations Undisturbed Site Rocks (Duke Power 1974)

Explanation

B114 — Slickensides and Shears Sample Source Boring Number

GTP7 — Slickensides and Shears Sample Source Test Pit Number

B64 — Undisturbed Site Rocks Source Boring Number

GTP7 — Undisturbed Site Rocks Source Test Pit Number

N

0 200 400 Feet

0 100 Meters

WILLIAM STATES LEE III
NUCLEAR STATION UNITS 1 & 2

Locations of Radiometric Age Determinations from Slickensides and Shears and Undisturbed Site Rock Samples

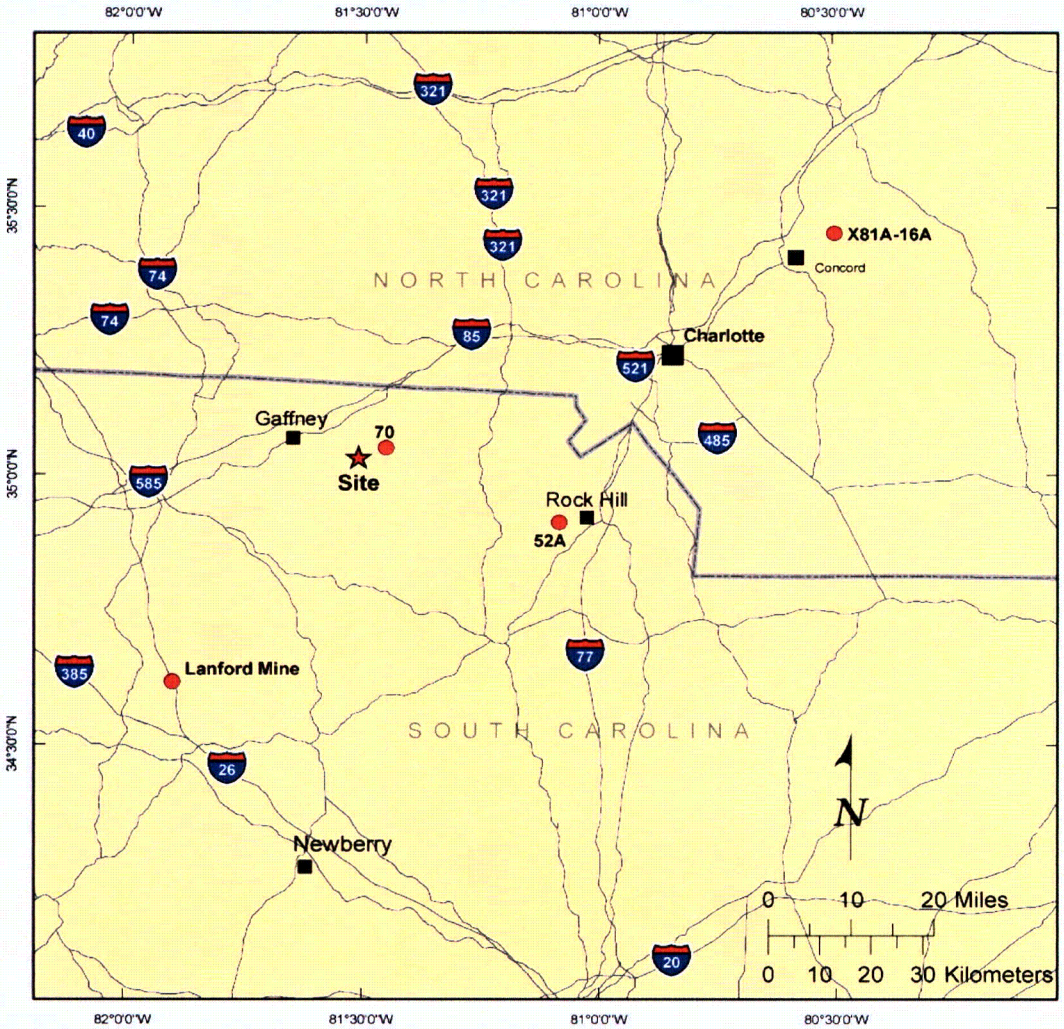
FIGURE 1 Rev 0

1990 RAI Duke Lee Phase 2_NK

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 2 to RAI 02.05.03-001

Figure 2. Locations of Radiometric Age Determinations for Potassium-Argon Ages of Off-Site Rocks



Source: CNS PSAR TABLE 2C-3C Radiometric Age Determinations Potassium-Argon Ages of Off-Site Rocks (Duke Power, 1974)

Explanation

70 Off-site Sample Location

WILLIAM STATES LEE III
NUCLEAR STATION UNITS 1 & 2

Locations of Radiometric Age Determinations of from Off-Site Rock Samples

FIGURE 2 Rev 0

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 3 to RAI 02.05.03-001

Table 1A. Radiometric Age Determinations From Slickensides and Shears

Table 1A. Radiometric Age Determinations From Slickensides and Shears (Sheet 1 of 3)

Rubidium-Strontium Analyses

Sample ID	Sample Material	Rb (ppm)	Sr (ppm)	Rb/Sr	Rb^{87}/Sr^{86}	Apparent Age (millions of yrs.)	Lab
B-51, 76 ft	Biotite and Muscovite from Slickensided Surface on Felsic Gneiss	225.5	146.9	1.535	4.450	225 ± 30	University of North Carolina - Chapel Hill

Potassium-Argon Analyses

Sample ID	Sample Material	K (weight %)	Sample Weight (g)	% Radiogenic Argon	Apparent Age (millions of yrs.)	Lab
BP-7, 59 ft	Biotite Plus Alteration Products from Slickensided Surface on Felsic Gneiss	3.75	0.0187	86.3	252 ± 10	Georgia Institute of Technology
B-28, 106 ft	Chlorite from Slickensided Surface on Mafic Gneiss	0.027	0.0534	24.0	420 ± 50	Georgia Institute of Technology
B-51, 76 ft	Biotite and Muscovite from Slickensided Surface on Felsic Gneiss	5.77	0.1620	76.8	178 ± 30	Florida State University – Tallahassee
B-53, 69 ft	Sericite from Micro-Shear Paralleling Slickenside in Felsic Gneiss	5.954	0.3167	85.5	278 ± 1	University of California – Berkeley
B-114, 70.8 ft	Sericite from Slickensided Surface on Felsic Gneiss	6.90	0.2721	95.9	246 ± 10	Florida State University – Tallahassee

Table 1A. Radiometric Age Determinations From Slickensides and Shears (Sheet 2 of 3)

Potassium-Argon Analyses

Sample ID	Sample Material	K (Weight %)	Sample Weight (g)	% Radiogenic Argon	Apparent Age (millions of yrs.)	Lab
B-114, 71.1 ft	Chlorite from Slickensided Surface on Felsic Gneiss [Note: Apparent age is anomalously old because country rock apparently was included with Chlorite for Argon Analysis.]	0.445	0.8318	57.3	459 ± 40	Florida State University – Tallahassee
B-114, 71.1 ft	Chlorite from Slickensided Surface on Felsic Gneiss [Note: Calculated age has larger analytical error due to small sample size and percent radiogenic argon, but should be more geologically meaningful than the 459 million year date.]	0.445	0.0560	18.0	250 ± 100	Florida State University – Tallahassee
B-119, 98.8 ft	Chlorite from Slickensided Surface on Felsic Gneiss	0.928	0.3002	49.4	261 ± 30	Florida State University – Tallahassee
B-119, 102.5 ft	Chlorite from Slickensided Surface on Felsic Gneiss	0.189	0.7335	28.6	172 ± 50	Florida State University – Tallahassee
B-119, 102.8 ft	Chlorite from Slickensided Surface on Felsic Gneiss	0.105	0.4389	34.7	251 ± 60	Florida State University – Tallahassee

Table 1A. Radiometric Age Determinations From Slickensides and Shears (Sheet 3 of 3)

Potassium-Argon Analyses

Sample ID	Sample Material	K (Weight %)	Sample Weight (g)	% Radiogenic Argon	Apparent Age (millions of yrs.)	Lab
B-139, 86 ft	Chlorite from Slickensided Surface on Felsic Gneiss	2.74	0.2985	77.1	170 ± 20	Florida State University – Tallahassee
B-236, 72 ft	Potassium Feldspar from Shear Zone in Felsic Gneiss	7.540	1.1204	79.1	210 ± 1	University of California – Berkeley
GTP-7, Sta. 15	Partly Weathered Mica and Potassium Feldspar Immediately below Black Slickenside in Saprolite	4.33	0.3094	70.1	166 ± 25	Florida State University – Tallahassee

Modified from Table 2C-3C Sheet 1 of 2, Cherokee Nuclear Station Preliminary Safety Analysis Report (PSAR), vol. 4, Appendix 2C – Geology, prepared by Law Engineering Testing Company for Duke Power Company Project 81, July 1974, Amendment 2 (New) and Amendment 16, 1974. (Reference 2.5.3-202).

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 4 to RAI 02.05.03-001

Table 1B. Radiometric Age Determinations From Undisturbed Site Rocks

Table 1B. Radiometric Age Determinations From Undisturbed Site Rocks (Sheet 1 of 2)

Rubidium-Strontium Analyses

Sample ID	Sample Material	Rb (ppm)	Sr (ppm)	Rb/Sr	Rb^{87}/Sr^{86}	Apparent Age (millions of yrs.)	Lab
B-51, 76 ft	Biotite from Undisturbed Felsic Gneiss behind Slickenside	247.6	43.68	5.669	16.52	291 ± 10	University of North Carolina - Chapel Hill
B64, 120 ft	Biotite from Felsic Gneiss	184.4	40.92	4.516	13.14	277 ± 10	University of North Carolina - Chapel Hill

Potassium-Argon Analyses

Sample ID	Sample Material	K (weight %)	Sample Weight (g)	% Radiogenic Argon	Apparent Age (millions of yrs.)	Lab
BP-7, 59 ft	Biotite from undisturbed felsic gneiss behind slickenside	6.74	0.0433	95.4	296 ± 7	Georgia Institute of Technology
B-28, 106 ft	Hornblende from undisturbed mafic gneiss behind slickenside	0.248	0.4345	84.8	290 ± 9	Georgia Institute of Technology
B-37, 70.5 ft	Whole rock very fine-grained felsic gneiss (metagraywacke?)	1.054	0.8759	88.2	322 ± 2	University of California – Berkeley

Table 1B. Radiometric Age Determinations From Undisturbed Site Rocks (Sheet 2 of 2)

Potassium-Argon Analyses

Sample ID	Sample Material	K (Weight %)	Sample Weight (g)	% Radiogenic Argon	Apparent Age (millions of yrs.)	Lab
B-53, 69 ft	Whole rock felsic gneiss	1.371	0.2697	35.5	362 ± 7	University of California – Berkeley
B-58, 33 ft	Whole rock felsic gneiss	0.931	1.0103	87.9	288 ± 1	University of California – Berkeley
B-236, 72 ft	Whole rock felsic gneiss	4.975	0.5395	92.6	234 ± 1	University of California – Berkeley
GTP-7, Sta. 18	Potassium feldspar and quartz from undisturbed pegmatitic quartz vein crossing a shear zone	8.946	0.1984	87.8	219 ± 1	University of California – Berkeley

Modified from Table 2C-3C Sheet 1 of 2, Cherokee Nuclear Station Preliminary Safety Analysis Report (PSAR), vol. 4, Appendix 2C – Geology, prepared by Law Engineering Testing Company for Duke Power Company Project 81, July 1974, Amendment 2 (New) and Amendment 16, 1974. (Reference 2.5.3-202).

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 5 to RAI 02.05.03-001

Table 1C. Radiometric Age Determinations for Off-Site Rock Samples

Table 1C. Radiometric Age Determinations for Off-Site Rock Samples (Sheet 1 of 1)

Argon Analyses

Sample Designation	Sample Location	Material Analyzed	Potassium (Weight %)	Sample Weight (g)	Percent Radiogenic Argon	Apparent Age (millions of yrs.)	Lab
52A Felsic Gneiss	State Highway 102, 600 ft. N of Junction State Highway 103	Muscovite	7.17	0.1155	95.6	293 ± 9	Georgia Institute of Technology
		Whole Rock	2.00	0.1645	95.1	252 ± 8	
70 Diabase	Dirt Road off State Highway 44, 1 ½ Miles SW of Kings Creek	Whole Rock	0.140	0.4542	64.0	231 ± 10	Georgia Institute of Technology
Lanford Mine	State Highway 49 at I-26, 35 Miles SW of Site	Crushed Diabase	0.216	0.4108	37.4	187 ± 7	Georgia Institute of Technology
		Coarse Crushed Diabase	0.232	0.2556	51.3	182 ± 6	
		Mylonite 1	4.53	0.3039	95.6	151± 4	
		Mylonite 2	1.53	0.1535	74.5	151± 4	
X81A-16A	Near Gold Hill Fault, 0.3 Miles W of Dutch Buffalo Creek Near C.R. 2408, Cabarrus County, NC	Crushed Diabase	0.208	0.3429	>61.1	<244	Georgia Institute of Technology
		Coarse Crushed Diabase	0.215	0.4362	71.4	254± 10	
		Crushed Serpentinized Olivine Diabase	0.217	0.3604	4.6	238± 30	University of California – Berkeley

Modified from Table 2C-3C Sheet 1 of 2, Cherokee Nuclear Station Preliminary Safety Analysis Report (PSAR), vol. 4, Appendix 2C – Geology, prepared by Law Engineering Testing Company for Duke Power Company Project 81, July 1974, Amendment 2 (New) and Amendment 16, 1974. (Reference 2.5.3-202).

Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI Letter No. 026

NRC Technical Review Branch: **Geosciences and Geotechnical Engineering Branch 2 (RGS2)**

Reference NRC RAI Number(s): **RAI 02.05.03-002**

NRC RAI:

In FSAR Sections 2.5.3.1.1 (page 2.5-142) and 2.5.3.1.3 (page 2.5-144), the primary lithologic unit mapped in the Cherokee site excavation, a plutonic rock mass (Zto), is referred to as a granodiorite. However, the excavation geologic map (Figure 2.5.1-229) labels the unit as a meta-granodiorite. In addition, the figure cited in Section 2.5.3.1.3 as showing the western boundary of plutonic rock mass Zto, Figure 2.5.1-218a, is at a scale that barely permits definition of this boundary.

Please be consistent in nomenclature for the foundation rock unit mapped in the excavation in FSAR Sections 2.5.3.1.1 and 2.5.3.1.3 and throughout the FSAR. Please include color schemes shown in the map legend on the geologic map of Figure 2.5.1-229 to clearly indicate lithologic units which are exposed in the excavation. Please consider citing Figures 2.5.1-219a and 2.5.1-219b in Section 2.5.3.1.3 to better illustrate the mapped boundary of plutonic rock mass Zto.

Duke Energy Response:

The Duke Lee site is underlain by a metamorphosed plutonic rock mass. This rock mass has been mapped at various scales by various geologists and, consequently, has been termed differently. Table 1 compares the terminology used by Horton and Dicken (2001) [FSAR Reference 2.5.3-209], Nystrom (2004) [FSAR Reference 2.5.3-205], and Howard (2004) [FSAR Reference 2.5.3-206] to that used in historic Cherokee documents and in the current COL evaluations. When referring to a specific map source, the nomenclature used by that map source is adopted. For example, the 1:24,000-scale map of the Blacksburg South quadrangle by Nystrom (2004) uses the term "metatonalite" to describe the metamorphosed plutonic rocks at the Duke Lee site. Therefore, when describing Nystrom's mapping in FSAR text and figures, the term "metatonalite" is adopted. The preferred nomenclature for this rock mass is "meta-granodiorite," because it is the most abundant rock type (confirmed by petrographic analyses) present within the excavation at the site (FSAR Figure 2.5.1-229). As such, this is the term used in the FSAR text and figures describing current site mapping. It should also be noted that, when referring to this rock mass at the time of its emplacement and prior to subsequent metamorphism, the term "granodiorite" remains appropriate. As detailed below, FSAR Section 2.5.3 has been revised to incorporate consistent use of lithologic nomenclature for the meta-granodiorite pluton at the Duke Lee site.

This RAI suggests that FSAR Figure 2.5.1-229 lacks color schemes depicting the distribution of rock types listed in the figure explanation. As indicated in the response to RAI 02.05.03-003, FSAR Figure 2.5.1-229 (ADAMS Accession No. ML073511086) is complete and correct.

Subsection 2.5.3.1.3 has been revised to cite FSAR Figures 2.5.1-219a and 2.5.1-219b (instead of FSAR Figures 2.5.1-218a and 2.5.1-218b). FSAR Figure 2.5.1-219a shows the western boundary of plutonic rock mass Zto in more detail, thereby better illustrating the items discussed in the text. In addition, a new reference is provided in FSAR Subsection 2.5.3.1.3 to FSAR Figure 2.5.1-226, which shows both the Nystrom (2004) and revised depictions of the western pluton boundary. Note that the revised text for FSAR Subsection 2.5.3.1.1 also includes changes associated with the response to RAI 02.05.03-003.

Associated Revision to the Lee Nuclear Station Final Safety Analysis Report:

FSAR Subsection 2.5.3.1.1

FSAR Subsection 2.5.3.1.3

FSAR Subsection 2.5.3.2

Attachments:

1) Table 1. Lithologic Terminology Describing Site Pluton
2) Mark-up of FSAR Subsection 2.5.3.1.1
3) Mark-up of FSAR Subsection 2.5.3.1.3
4) Mark-up of FSAR Subsection 2.5.3.2

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 1 to RAI 02.05.03-002

Table 1. Lithologic Terminology Describing Site Pluton

Table 1. Lithologic Terminology Describing Site Pluton

	SITE VICINITY (25-mi radius)	SITE AREA (5-mi radius)		SITE (≤ 0.6-mi radius)	
Source:	**Horton and Dicken (2001)**	**Nystrom (2004)**	**Howard (2004)**	**Historic Cherokee Nuclear Station Documents**	**FSAR Evaluations**
Scale:	1:500,000	1:24,000	1:24,000	Multiple scales, including 1:120 and 1:240	1:600
Lithologic unit name:	Metatonalite (Zto)	Metatonalite (Zto)	Metatonalite and volcaniclastic rocks (Zto)	1. Felsic gneiss 2. Mafic gneiss	1. Meta-granodiorite to meta-quartz diorite (tonalite) 2. Meta-diorite (mafic intrusives) 3. Amphibolite (mafic intrusives)
FSAR figure(s):	2.5.1-218a, 2.5.1-218b	2.5.1-219a, 2.5.1-219b, 2.5.1-220*	2.5.1-219a, 2.5.1-219b, 2.5.1-220*, 2.5.1-224	--	2.5.1-229

Notes:

* FSAR Figure 2.5.1-220 combines 1:24,000-scale mapping by Nystrom (2004) and Howard (2004) and uses "undifferentiated intrusive plutonic rocks (Zto)" to describe the pluton.

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 2 to RAI 02.05.03-002

Mark-up of FSAR Subsection 2.5.3.1.1

COLA Part 2, FSAR, Chapter 2, Subsection 2.5.3.1.1, second paragraph, will be revised as follows:

2.5.3.1.1 Previous Lee Nuclear Site Investigations

Detailed geologic mapping and inspection of excavations during construction for Units 1, 2, and 3 of the former Duke Cherokee nuclear site reveal no evidence of active or geologically recent faulting within the site area (Subsection 2.5.1.2 provides additional discussion of site area geology). These excavations did expose minor bedrock shears that are related to mafic intrusions (e.g., meta-diorite and amphibolite rock units) in the meta-granodiorite pluton (e.g., meta-granodiorite to meta-quartz diorite rock units). Most of this minor deformation is associated with the contact between the mafic intrusions and the meta-granodiorite pluton (Figure 2.5.1-229). ~~None of the intrusive mafic bodies are offset by the minor brittle shears, suggesting that the minor brittle shears formed after the emplacement of the granodiorite pluton and during the intrusion of mafic bodies.~~ A more detailed discussion of the minor bedrock features is provided in Subsections 2.5.1.2 and 2.5.4.1.

Note: The above changes include revisions to FSAR Subsection 2.5.3.1.1 described in the response to RAI 02.05.03-003.

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 3 to RAI 02.05.03-002

Mark-up of FSAR Subsection 2.5.3.1.3

COLA Part 2, FSAR, Chapter 2, Subsection 2.5.3.1.3, second paragraph, will be revised as follows:

2.5.3.1.3 Current Geologic Mapping

The existing geologic maps discussed in the preceeding Subsection 2.5.3.1.2 form the basis for the geologic maps presented in Section 2.5.1. Field reconnaissance of the site, site area, and site vicinity included field checks of existing mapping and, where necessary, refinement of previous geologic maps.

A very linear geologic contact at the Lee Nuclear Site was investigated in detail to preclude the presence of a fault. Nystrom (2004, Reference 205) maps at 1:24,000-scale the western margin of a meta-granodiorite pluton at the Lee Nuclear Site as a linear, north-northwest-trending contact (Figures 2.5.1-219a~~8,and~~ 2.5.1-219b, and 2.5.1-226~~8~~). The nature of this contact between the meta-granodiorite pluton and metavolcanic country rock was investigated by means of detailed geologic mapping, compilation and review of borehole information, and geologic logging of six test pits. The results of this investigation demonstrate that this contact is more irregular than mapped by Nystrom (2004, Reference 205), and confirm the intrusive nature of the contact. The more irregular map pattern (Figures 2.5.1-220 and 2.5.1-226) and the intrusive nature of the contact preclude a fault interpretation for the western margin of the pluton.

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 4 to RAI 02.05.03-002

Mark-up of FSAR Subsection 2.5.3.2

COLA Part 2, FSAR, Chapter 2, Subsection 2.5.3.2, third paragraph, will be revised as follows:

There is direct geologic evidence to preclude the presence of northeast- or east-striking faults projecting through the Lee Nuclear Site. The predominant structural grain of the site area, vicinity, and region is oriented northeast. As mapped by Nystrom (2004, Reference 205) and confirmed by reconnaissance mapping, two elongated, north-striking quartzite bodies are located in the western portion of the site area (Figures 2.5.1-219a, 219b and 2.5.1-220). These unfaulted, continuous quartzite beds, oriented at a high angle to the regional structural grain, demonstrate the absence of any northeasterly or easterly striking fault through the Lee Nuclear Site. In addition, the northerly striking western margin of the meta-granodiorite pluton provides an additional strain marker that precludes the presence of any northeasterly or easterly striking faults through the Lee Nuclear Site. The timing of emplacement of this ~~granodiorite~~-pluton is uncertain, but according to Butler (1981, Reference 235), it is likely early Paleozoic or older in age.

Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI Letter No. 026

NRC Technical Review Branch: **Geosciences and Geotechnical Engineering Branch 2 (RGS2)**

Reference NRC RAI Number(s): **RAI 02.05.03-003**

NRC RAI:

Mafic intrusions referred to in FSAR Section 2.5.3.1.1 (page 2.5-142) are not distinguished on the excavation geologic map of Figure 2.5.1-229, although these lithologic units are used to provide a relative age for minor brittle shears in the excavation.

Please include the mafic intrusions on the geologic map of the excavation (existing Figure 2.5.1-229), and incorporate these intrusions into the map color legend.

Duke Energy Response:

Mafic intrusions described in FSAR Section 2.5.3.1.1 are comprised of meta-diorite and amphibolite rock lithologies that are illustrated using dark blue and green colors on the excavation map and map legend for FSAR Figure 2.5.1-229, "Surficial Geologic Map of Existing Excavation."

Review of FSAR Figure 2.5.1-229 (ADAMS Accession No. ML073511086) confirms that the image presented in the FSAR is correct and accurate.

Since submittal of Revision 0 of the FSAR, Duke has concluded that the use of "none" in the following text from FSAR Subsection 2.5.3.1 cannot be positively substantiated.

> "None of the intrusive mafic bodies are offset by the minor brittle shears, suggesting that the minor brittle shears formed after the emplacement of the granodiorite pluton and during the intrusion of mafic bodies."

Accordingly, this statement will be removed from the FSAR text. This does not change the interpretations or findings relevant to the conclusions presented in FSAR Subsection 2.5.3.8.

As part of the response to RAI 02.05.03-002 (Enclosure 2, Attachment 2), FSAR Subsection 2.5.3.1.1, paragraph 2 is revised to more clearly describe rock lithologies, including the mapped mafic intrusions, and to also remove the statement described above.

Reference:

None

Associated Revision to the Lee Nuclear Station Final Safety Analysis Report:

Revisions to FSAR Subsection 2.5.3.1.1 text are included in the response to RAI 02.05.03-002 (Enclosure 2, Attachment 2)

Attachments:

None

Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI Letter No. 026

NRC Technical Review Branch: **Geosciences and Geotechnical Engineering Branch 2 (RGS2)**

Reference NRC RAI Number(s): **RAI 02.05.03-004**

NRC RAI:

FSAR Section 2.5.3.1.3 (page 2.5-144) indicates that "refinement" of previous geologic maps was undertaken during the Lee COL field investigations. However, FSAR Section 2.5.3.1.3 does not indicate what refinements were done other than confirmatory testing, and the "refined" information is not summarized or presented on geologic maps in the FSAR.

Please summarize what refinements were made to previous geologic maps, and present this information on a geologic map if it has not already been included on geologic maps found in the FSAR.

Duke Energy Response:

A summary of mapping activities and associated map refinements are provided in the changes to FSAR Subsection 2.5.3.1.3 and FSAR Figure 2.5.1-226 described in Attachment 1 and Attachment 2.

Associated Revision to the Lee Nuclear Station Final Safety Analysis Report:

FSAR Subsection 2.5.3.1.3

FSAR Figure 2.5.1-226

Attachments:

1) Mark-up of FSAR Subsection 2.5.3.1.3
2) Revision to FSAR Figure 2.5.1-226

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 1 to RAI 02.05.03-004

Mark-up of FSAR Subsection 2.5.3.1.3

COLA Part 2, FSAR, Chapter 2, Subsection 2.5.3.1.3, will be revised as follows:

2.5.3.1.3 Current Geologic Mapping

The existing geologic maps discussed in the preceding Subsection 2.5.3.1.2 form the basis for the geologic maps presented in Subsection 2.5.1. Field reconnaissance of the site (0.6 mile radius), site area (5 mile radius), and site vicinity (25 mile radius) included field checks of existing mapping and, where necessary, refinement of previous geologic maps.

A very linear geologic contact at the Lee Nuclear Site was investigated in detail to preclude the presence of a fault. Nystrom (2004, Reference 205) maps at 1:24,000-scale the western margin of a ~~granodiorite~~metatonalite pluton at the Lee Nuclear Site as a linear, north-northwest-trending contact (Figure 2.5.1-218a and 218b). The nature of this contact between the ~~granodiorite~~metatonalite pluton and metavolcanic country rock was investigated by means of detailed geologic mapping, compilation and review of borehole information, and geologic logging of six test pits. The results of this investigation demonstrate that this contact is more irregular than mapped by Nystrom (2004, Reference 205), and confirm the intrusive nature of the contact. The more irregular map pattern (Figures 2.5.1-220 and 2.5.1-226) and the intrusive nature of the contact preclude a fault interpretation for the western margin of the pluton.

Refinements were made to existing geologic maps at the site vicinity, site area and site scale as well as at the scale of the existing excavation to develop the geologic maps as described in subsection 2.5.1.2.5.5 and presented in Figures 2.5.1-218a,b, 2.5.1-219a,b, 2.5.1-220, 2.5.1-226 and 2.5.1-229 of the FSAR. These modifications reflect new geologic mapping performed as part of this COLA project, as well as efforts to reconcile previous geologic and structural mapping from various sources conducted at varying scales.

The geologic map of the site vicinity (FSAR Figure 2.5.1-218a,b) comprises 1:500,000-scale mapping of South Carolina by Horton and Dicken (2001) [FSAR Reference 308] and 1:500,000-scale mapping of North Carolina by the North Carolina Geological Survey (1998). Geologic contacts and descriptions from these two sources are presented in FSAR Figure 2.5.1-218a,b without modification, but unit colors have been altered for consistency across the South Carolina-North Carolina state border. Fault locations shown on FSAR Figure 2.5.1-218a are slightly modified after 1:500,000-scale mapping by Hibbard et al. (2006) [FSAR Reference 210], such that the faults "snap" to geologic contacts.

The site area geologic map (FSAR Figure 2.5.1-219a,b) comprises 1:24,000-scale mapping by Nystrom (2004) [FSAR Reference 391] and Howard (2004) [FSAR Reference 286], as well as 1:500,000-scale mapping by Horton and Dicken (2001) [FSAR Reference 308]. This geologic mapping is supplemented on FSAR Figure 2.5.1-219a with fold axes from Butler (1981) [FSAR Reference 389] and fault locations slightly modified after 1:500,000-scale mapping by Hibbard et al. (2006) [FSAR Reference 210], such that the faults "snap" to geologic contacts.

The site geologic map (FSAR Figure 2.5.1-220) is modified after 1:24,000-scale geologic mapping by Nystrom (2004) [FSAR Reference 391] and Howard (2004) [FSAR Reference 286], and represents the only FSAR geologic map that incorporates significant revisions to previously published data. As described in FSAR Subsection 2.5.3.1.3, Nystrom (2004) [FSAR Reference 391] maps a metatonalite pluton that underlies much of the site. Nystrom (2004) [FSAR Reference 391] maps a relatively straight western boundary of this pluton (FSAR Figure 2.5.1-219a). The nature of this western pluton boundary was investigated in detail and remapped as part of this COLA project. FSAR Figure 2.5.1-226 and FSAR Subsection 2.5.4.2

present the details of this remapping, and the refined mapping of the western pluton boundary is incorporated into the site geologic map (FSAR Figure 2.5.1-220).

Of particular interest at the site scale is the western boundary of the metatonalite pluton which is the foundation bearing unit as shown on Figure 2.5.1-219a. Nystrom (2002) maps the western margin of the pluton (noted as Zto) as a pronounced linear feature. Field reconnaissance indicated that this boundary is not constrained by actual observation or data although it is shown as a solid line contact on Nystrom, 2002.

To improve the control on the western margin of the pluton, borings from the previous as well as current COLA investigation were evaluated. Previous mapping performed during the original site construction for a cooling water corridor had previously exposed the contact between the pluton and country rock outside of the north western corner of the excavation for Unit 1 as shown on Figure 2.5.1-226 (revised figure from PR). A series of geologic trenches were located along the western margin to confirm this contact.

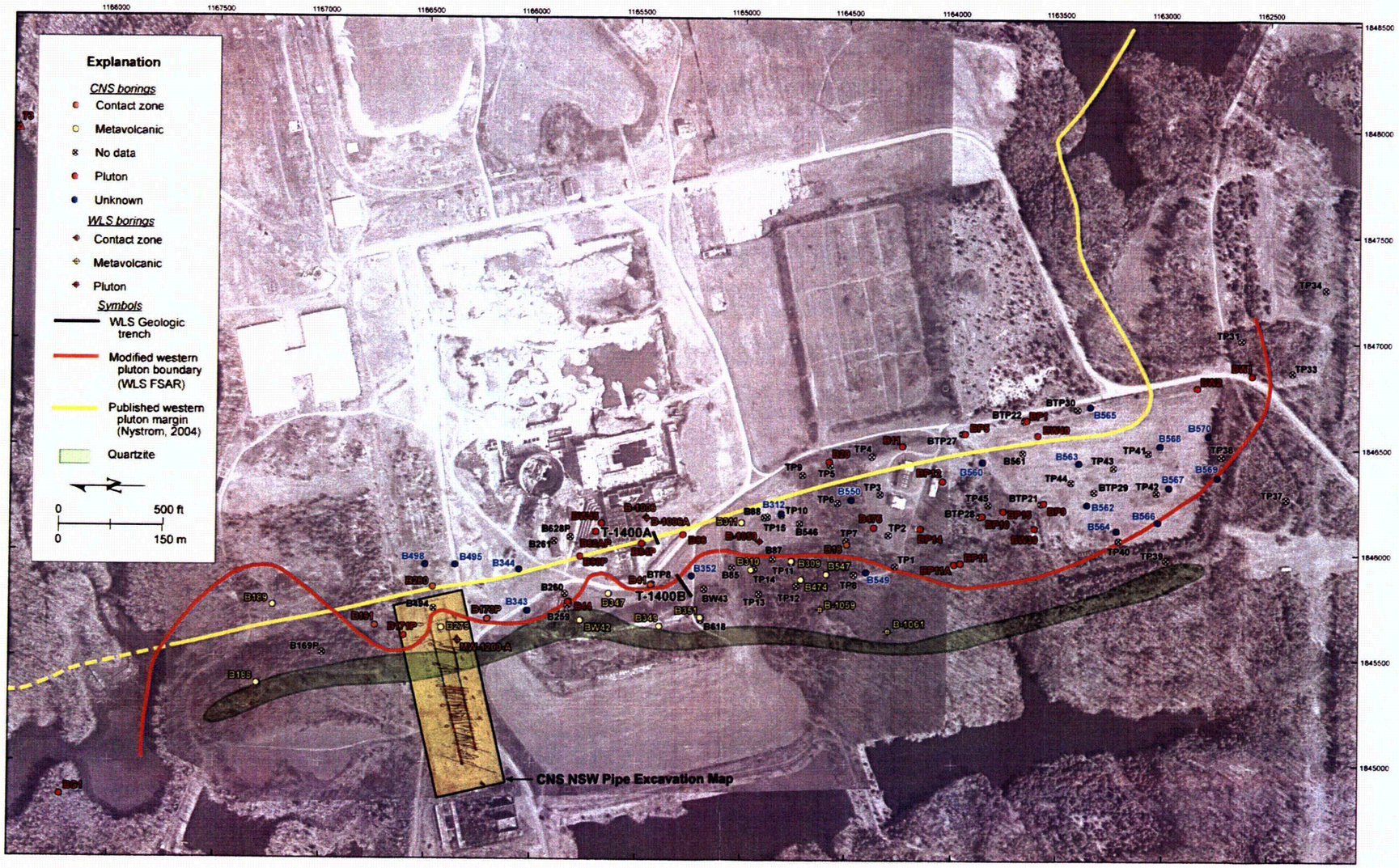
As shown on Figure 2.5.1-226, existing boring and test pits were evaluated to refine the western pluton contact with the metavolcanic country rock. Also, two geologic trenches were excavated to investigate the margin location and nature of the rock lithologies to correlate with the boring log descriptions. The exposed rock in the first trench indicated saprolitic and partially weathered rock indicative of granodiorite and diorite plutonic rock and a second trench was opened about 300 feet to the west. The second trench indicated that the western saprolite lithology was not typical of saprolites of granodiorite or diorite origin and that the fabric was foliated thus suggesting a metamorphic lithology more representative of the metavolcanic country rocks of the region. The borings, geologic trenches, and field reconnaissance as shown on Figure 2.5.1-226 were thus used to refine the geologic map presented as FSAR Figure 2.5.1-220.

At the scale of the excavation, because extensive mapping during the original construction had been performed but was not completed or verified, mapping of the existing exposure was completed. Specifically, the noted rock lithologies were cataloged for correlation with more general nomenclature used in the PSAR. The exposed limits of the excavation were mapped to document the spatial relationship of major lithologic units and structural features observed in the excavation area. FSAR Figure 2.5.1-229 shows the major lithologic units and structural features within the Old Unit 2 and 3 areas and limited areas bordering the Old Unit 1 area. Also shown on this map are the limits of available exposure for mapping.

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 2 to RAI 02.05.03-004

Revision to FSAR Figure 2.5.1-226



WLS COL 2.5-1

WILLIAM STATES LEE III
NUCLEAR STATION UNITS 1 & 2

Field Investigation Data Used to Constrain Western Pluton Boundary

FIGURE 2.5.1-226 Rev 1

Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI Letter No. 026

NRC Technical Review Branch: **Geosciences and Geotechnical Engineering Branch 2 (RGS2)**

Reference NRC RAI Number(s): **RAI 02.05.03-005**

NRC RAI:

FSAR Section 2.5.3.1.5 (page 2.5-145) states an interpretation by Talwani (2006) that two earthquakes, which occurred near Bennettsville, South Carolina, in September 2006 and exhibited body wave magnitudes (mb) of 3.5 and 3.7, may have been spatially related to the Eastern Piedmont fault system (EPFS) as defined by Hatcher and others (1977). FSAR Section 2.5.3.1.5 concludes that the two earthquakes cannot be positively correlated with the EPFS. The EPFS is not labeled on any map in the FSAR, although Figure 2.5.1-209 is referred to as showing the location of this fault system; faults which comprise the EPFS are not specified; and age of the fault system is not stated. Consequently, any potential correlation of the September 2006 earthquakes with the EPFS fault system cannot be assessed.

FSAR Section 2.5.3.1.5 (page 2.5-145) also states an interpretation by Benson (1992) that these two earthquakes were spatially correlated with a small Mesozoic extensional basin lying beneath Coastal Plain deposits, but no discussion regarding this potential correlation is presented in this FSAR section.

Please locate the EPFS on the appropriate map, indicate which faults make up this fault system, and document the age of the EPFS with due consideration of information published in 2006 by Nystrom suggesting possible reactivation and post-Miocene displacement along the EPFS. Please discuss in more detail the suggested spatial correlation of the September 2006 earthquakes with the EPFS and the logic for concluding that there is no correlation between these earthquakes and the fault system. Please also discuss in more detail the suggested spatial correlation between the two earthquakes and the Mesozoic basin that lies beneath Coastal Plain sediments.

Duke Energy Response:

FSAR Subsection 2.5.3.1.5 describes two minor earthquakes that occurred near Bennettsville, South Carolina on September 22 and 25, 2006. These minor earthquakes are given specific mention in the FSAR only because they post-date compilation of the seismicity catalog update performed for this COLA project.

Duke Energy has modified FSAR Figures 2.5.1-209 and 2.5.1-210 to clearly label the Eastern Piedmont fault system (EPFS). The EPFS comprises an extensive array of mostly dextral strike-slip faults that bound the Alleghanian metamorphic core of the Southern Appalachians, and is defined as a related series of polyphase deformed cataclastic zones of varying thickness and dip (Hatcher et al. 1977 [FSAR Reference 2.5.3-223], Hatcher et al. 2007 [Reference 3]). These faults are expressed in South Carolina as magnetic anomalies and limited outcrops and exposures. The EPFS in South Carolina includes the Towaliga, Augusta, Modoc, Belair, Davis Pond, and other named and unnamed faults.

The timing of movement on the EPFS is largely constrained to the Paleozoic Era. Hatcher et al. (1977) [FSAR Reference 2.5.3-223] indicate that the EPFS cuts the ~400 million year old (m.y.) Clouds Creek granite in South Carolina, but in turn cut by the 269 m.y. Siloam granite in Georgia and by Mesozoic diabase dikes in South Carolina. There is evidence, however, for minor, localized reactivation of the EPFS in central South Carolina. In a 2006 abstract, Nystrom [Reference 6] suggests potential localized Cenozoic reactivation of the Augusta and Davis Pond faults, two components of the EPFS in South Carolina, west and west-southwest of Columbia, South Carolina. Nystrom (2006) [Reference 6] implies 30 ft. of up-to-the-south brittle offset of the Piedmont-Upper Cretaceous contact across the Augusta fault south of Monetta, South Carolina. Additionally, Nystrom (2006) [Reference 6] suggests 20 ft. of up-to-the-north brittle offset across the Davis Pond fault south of Batesburg, South Carolina. Howard et al. (2005) [Reference 4] suggest minor, brittle cross-faulting of Mesozoic to Cenozoic age in the Saluda Dam spillway near Irmo, South Carolina. Taken together, these data indicate that slip on the EPFS is largely constrained to the Paleozoic Era, but that minor, localized Mesozoic to Cenozoic reactivation may have occurred within South Carolina.

As noted in FSAR Subsection 2.5.3.1.5, these two minor earthquakes are located in the vicinity of the EPFS (Hatcher et al. 1977) [FSAR Reference 2.5.3-223] and an extensional basin mapped by Benson (1992) [FSAR Reference 2.5.3-221]. Given the lack of focal mechanism data for these events and given the large positional uncertainties associated with these two earthquakes and with geologic structures mapped beneath the Coastal Plain, positive correlation of these earthquakes with a specific tectonic feature is not established. The small magnitudes of these earthquakes (magnitudes 3.5 and 3.7) indicate small rupture areas, on the order of <0.5 km2 (Brune 1970 [Reference 1], Brune 1971 [Reference 2], Mahdyiar 1987 [Reference 5]). Therefore, these minor earthquakes need not have occurred on a large, regional structure. As such, Talwani (2006) [FSAR Reference 2.5.3-222] states that "the [two September 2006] earthquakes lie in the vicinity of the EPFS" as mapped by Hatcher et al. (1977) [FSAR Reference 2.5.3-223], but does not explicitly attribute these two earthquakes to the EPFS.

In a paper published after Talwani's (2006) [FSAR Reference 2.5.3-222] assessment and after preparation of the FSAR, Hatcher et al. (2007) [Reference 3] present revised geologic mapping of the southern and central Appalachians, including the EPFS. Revised FSAR Figure 2.5.1-210 shows the location of the two minor earthquakes relative to Hatcher et al.'s (2007) [Reference 3] revised mapping of the EPFS. Compared with earlier (Hatcher et al. 1977) [FSAR Reference 2.5.3-223] mapping of the EPFS, Hatcher et al.'s (2007) [Reference 3] revised mapping indicates the presence of shorter, more localized EPFS fault strands in the vicinity of the September 2006 minor earthquakes. Whereas available data do not preclude the possibility that these earthquakes occurred on the EPFS, there are no data (such as focal mechanisms or alignment of aftershocks) demonstrating that the EPFS produced these minor earthquakes.

Benson's (1992) [FSAR Reference 2.5.3-221] mapping of extensional basins predates the occurrence of the two minor earthquakes in 2006. Therefore, Benson (1992) [FSAR Reference 2.5.3-221] does not correlate the locations of these minor earthquakes with the basin. FSAR Subsection 2.5.3.1.5 does, however, describe the observation that the minor earthquakes occurred in the general vicinity of Benson's (1992) [FSAR Reference 2.5.3-221] basin. Hatcher et al. (2007) [Reference 3] also map an extensional basin beneath the Coastal Plain in the vicinity of the 2006 earthquakes that is nearly coincident with Benson's (1992) [FSAR Reference 2.5.3-221] interpretation. However, given the large positional uncertainties associated with the two

earthquakes and with the extensional basins mapped beneath the Coastal Plain, positive correlation of these earthquakes with this specific basin is not possible. Whereas available data do not preclude the possibility that these earthquakes occurred on a fault or faults associated the extensional basin, there are no data (such as focal mechanisms or alignment of aftershocks) demonstrating that these basin-related structures produced these minor earthquakes.

References:

1. Brune, J.N., "Tectonic Stress and the Spectra of Seismic Shear Waves from Earthquakes," Journal of Geophysical Research 75 (26):4,997-5,009, 1970.
2. Brune, J.N., "Correction to Brune (1970)," Journal of Geophysical Research 76(20):5,002, 1971.
3. Hatcher, R.D. Jr., Bream, B.R., and Merschat, A.J., "Tectonic Map of the Southern and Central Appalachians: A Tale of Three Orogens and a Complete Wilson Cycle," in 4-D Framework of Continental Crust, Geological Society of America Memoir 200, ed. R.D. Hatcher Jr., M.P. Carlson, J.H. McBride, and J.R. Martinez Catalan, p. 595-632, 2007.
4. Howard, C.S., Charlton, J.E., and McCarney, K.J., "New Geologic Synthesis of the Dreher Shoals and Carolina Terranes, Lake Murray and Saluda Dam, Columbia, SC," Geological Society of America Abstracts with Programs, Southeastern Section 54th annual meeting, 2005.
5. Mahdyiar, M. "A Nomograph to Calculate Source Radius and Stress Drop from Corner Frequency, Shear Velocity, and Seismic Moment," Bulletin of the Seismological Society of America 77 (1):264-265, 1987.
6. Nystrom, P.G. Jr., "Late Cretaceous-Cenozoic Brittle Faulting Beneath the Western South Carolina Coastal Plain: Reactivation of the Eastern Piedmont Fault System," Geological Society of America Abstracts with Programs, Southeastern Section 55th annual meeting, 2006.

Associated Revision to the Lee Nuclear Station Final Safety Analysis Report:

FSAR Figure 2.5.1-209

FSAR Figure 2.5.1-210

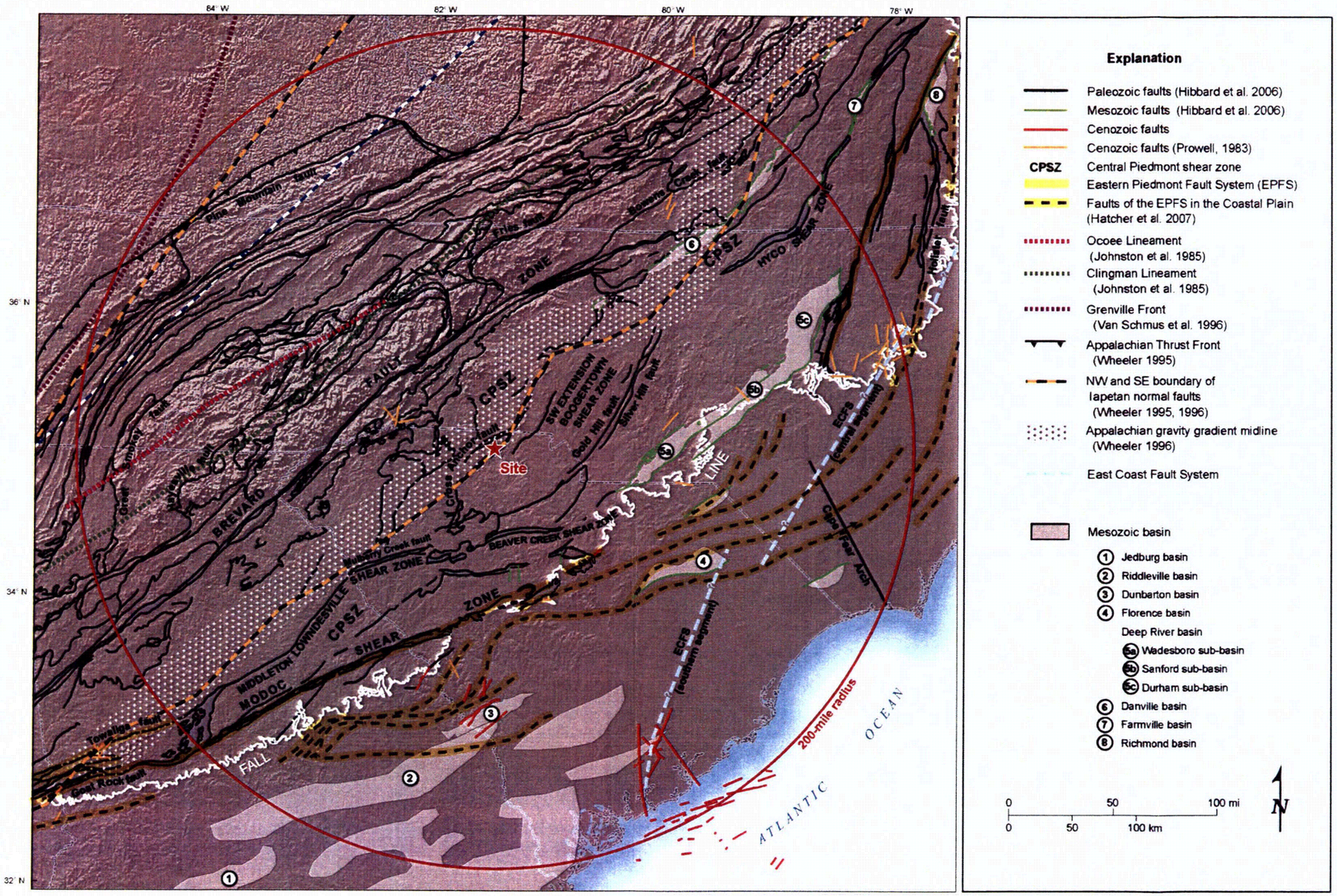
Attachments:

1) Revision to FSAR Figure 2.5.1-209
2) Revision to FSAR Figure 2.5.1-210

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 1 to RAI 02.05.03-005

Revision to FSAR Figure 2.5.1-209



WLS COL 2.5-1

WILLIAM STATES LEE III
NUCLEAR STATION UNITS 1 & 2

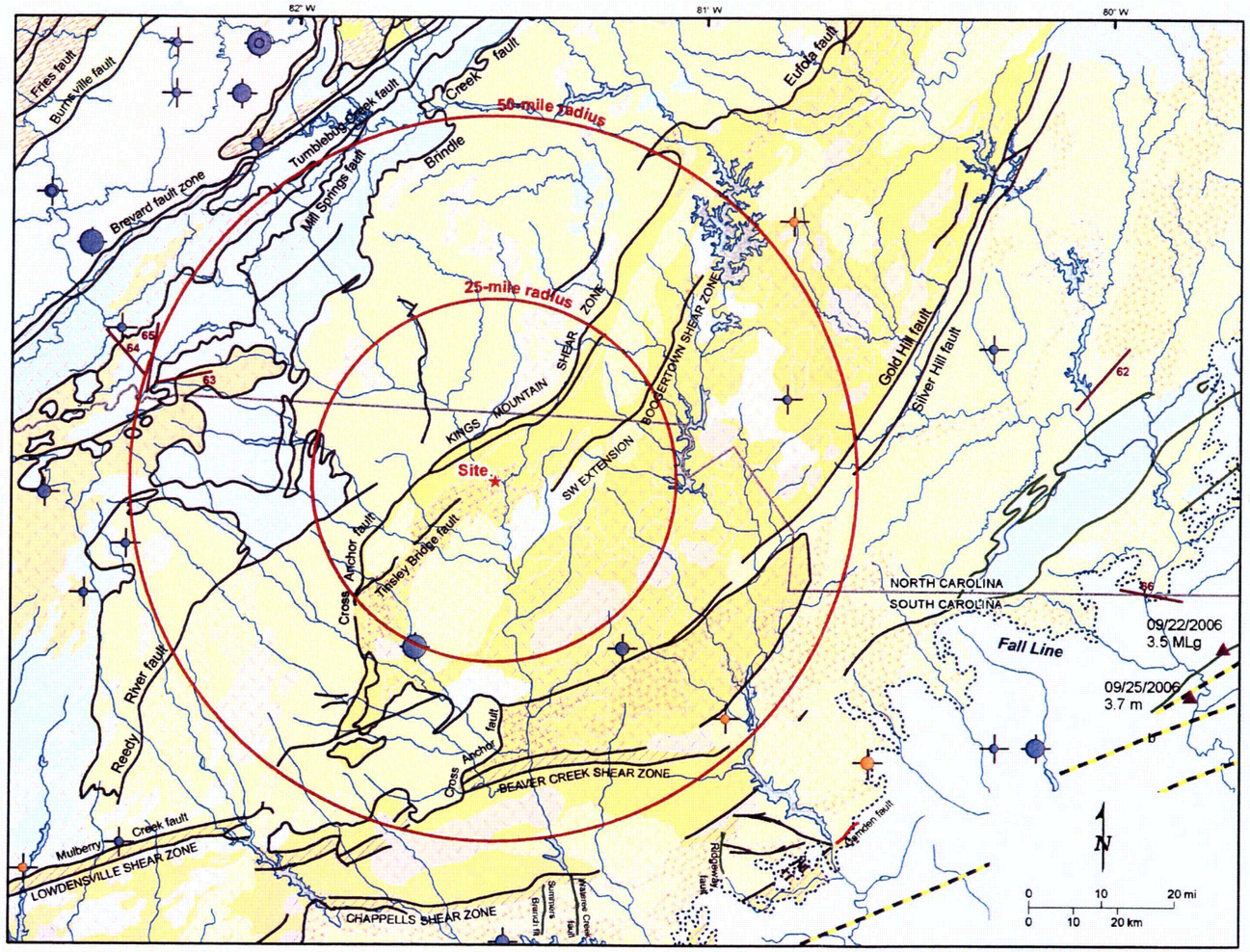
Site Region Tectonic Features

FIGURE 2.5.1-209 Rev 1

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 2 to RAI 02.05.03-005

Revision to FSAR Figure 2.5.1-210



Explanation

Earthquake Epicenters
(by estimated body wave magnitude, Emb)

EPRI Catalog Main Events (1627 - 1984)
- 3.11 - 3.49
- 3.50 - 3.99
- 4.00 - 4.49
- 4.50 - 4.99

Eastern US seismicity (1985 - 2005)
- 3.00 - 3.49
- 3.49 - 3.99

Faults
- Paleozoic
- Cenozoic
- Mesozoic fault
- Cenozoic fault (Prowell, 1983)
- Eastern Peidmont Fault System (modified after Hatcher et al. 2007)

Lithotectonic Units (Hibbard et al. 2006)
- Plutonic rocks of unknown origin (felsic)
- Plutonic rocks of unknown origin (mafic)
- Mesozoic rift basins
- Carboniferous to Permian plutonic rocks (felsic)
- Middle Devonian Carboniferous plutonic rocks
- Silurian and Devonian sedimentary and plutonic rocks (felsic)
- Silurian and Devonian sedimentary and plutonic rocks (mafic)
- Middle Ordovician to Lower Silurian plutonic rocks
- Neoproterozoic to Cambrian metavolcanic rocks
  - Intrusive, felsic
  - Volcanic, felsic
  - Intrusive, mafic
  - Volcanic, mafic
- Neoproterozoic to Lower Paleozoic magmatic sequences
  - Intrusive, mafic
  - Volcanic, mafic
  - Volcanic, felsic
- Neoproterozoic to Lower Paleozoic metasediments
- Neoproterozic to Lower Paleozoic metasedimentary rocks
- Lower to Middle Ordovician metamorphic rocks
  - Intrusive, felsic
- Neoproterozoic to Lower Paleozoic clastic metasedimetary rocks
- Lower Paleozoic passive margin sequence
- Proterozoic magmatic and sedimentary rocks
- Proterozoic Grenville basement
  - Orthogneiss

WLS COL 2.5-1

WILLIAM STATES LEE III NUCLEAR STATION UNITS 1 & 2

Tectonic Features and Seismicity Within 50 Miles of the Site

FIGURE 2.5.1-210 **Rev 1**

Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI Letter No. 026

NRC Technical Review Branch: **Geosciences and Geotechnical Engineering Branch 2 (RGS2)**

Reference NRC RAI Number(s): **RAI 02.05.03-006**

NRC RAI:

In FSAR Section 2.5.3.1.6 (page 2.5-146), a northeast-trending, linear topographic ridge that is 7.2 km (4.5 mi) long is described as resulting from erosion of resistant quartzite layers by London Creek based on information derived from aerial reconnaissance and field studies. This linear feature is located approximately 3.2 km (2 mi) northwest of the site and parallels the predominant northeastern trend of regional tectonic structures.

Please summarize the information gleaned from aerial reconnaissance and field investigations which led to the conclusion that this feature is non-tectonic in origin and the result of erosion although it parallels the northeastern trend of tectonic structures in the region.

Duke Energy Response:

The northeast-trending topographic lineament described in FSAR Subsection 2.5.3.1.6 comprises three roughly collinear and subparallel smaller ridges (Figure 1). From southwest to northeast these include:

- A 1.5-mi- (2.4-km-) long, north-facing ridge with roughly 100 ft of local relief. This ridge is capped by erosion resistant quartz pebble metaconglomerate (Nystrom 2004) [FSAR Reference 2.5.3-205]. Spencer Branch flows southwestward along the northern base of this ridge.
- A 0.8-mi- (1.3-km-) long, north-facing ridge with roughly 70 ft of local relief. Erosion resistant quartz pebble metaconglomerate caps this ridge also (Nystrom 2004) [FSAR Reference 2.5.3-205]. An unnamed tributary of London Creek flows along the northern base of this ridge.
- A 2.2-mi- (3.5-km-) long, north-facing ridge with roughly 100 ft of local relief. Along much of its length, this ridge is capped by erosion resistant fine- to medium-grained quartzite (Nystrom 2004) [FSAR Reference 2.5.3-205]. London Creek flows northeast along base of this ridge. The lineament terminates northeastward at the Broad River and is not expressed in the topography northeast of the river.

Collectively, these three collinear ridges form "Lineament 1" shown in FSAR Figure 2.5.1-221. This lineament is expressed in 1:40,000-scale color-infrared stereo aerial photography, 1:20,000-scale black-and-white stereo aerial photography, and 10-ft contour interval topographic maps and shaded relief images of the site area.

There is no evidence suggesting a tectonic origin for this lineament. Previous geologic maps identify no faults associated with this lineament (Butler 1981 [FSAR Reference 2.5.3-235],

Nystrom 2004 [FSAR Reference 2.5.3-205], Hibbard et al. 2006 [FSAR Reference 2.5.3-210]). Likewise, geologic field reconnaissance performed as part of this COLA project did not recognize any evidence for faulting associated with this lineament, but does confirm the presence of quartzite on the northeastern ridge.

Instead, Duke Energy favors an erosional origin for this lineament. Lineament 1 results from the combination of erosion-resistant, northwest-elongated, ridge-top quartzite and quartz metaconglomerate stringers with local stream erosion. Other examples of quartzite-topped erosional ridges are found within the site area, most notably at McKowns Mountain and the unnamed ridge 1/3-mi to its east (Figure 1).

Appendix 2C of the Preliminary Safety Analysis Report (PSAR 1974) [FSAR Reference 2.5.3-202] Project 81 prepared for the former Duke Cherokee nuclear site describes a geologic investigation of McKowns Mountain (called "McGowan Mountain" in the PSAR) and the ridge to its east. This investigation included logging and geologic interpretation of six test pits excavated on McKowns Mountain and the ridge to its east [FSAR Reference 2.5.3-202]. This PSAR study concludes that "the absence of shearing in the pits indicates that the orientation of the ridges probably is not the result of cumulative offset and shearing" (p. 2C-II-4) and "the anomalous orientation of the quartzite ridges [likely] reflects an original sedimentary condition" (p. 2C-II-4). In other words, McKowns Mountain and the ridge to its east are not tectonic in origin.

By analogy to McKowns Mountain and the ridge to its east, and based on the lack of evidence for faulting associated with Lineament 1, we conclude that Lineament 1 is not tectonic in origin. Instead, our preferred interpretation is that Lineament 1 formed as the result of localized stream erosion and erosion-resistant, ridge-forming quartzite and quartz metaconglomerate stringers.

Associated Revision to the Lee Nuclear Station Final Safety Analysis Report:

None

Attachments:

1) Figure 1. Northeast-Trending Topographic Lineament

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 1 to RAI 02.05.03-006

Figure 1. Northeast-Trending Topographic Lineament

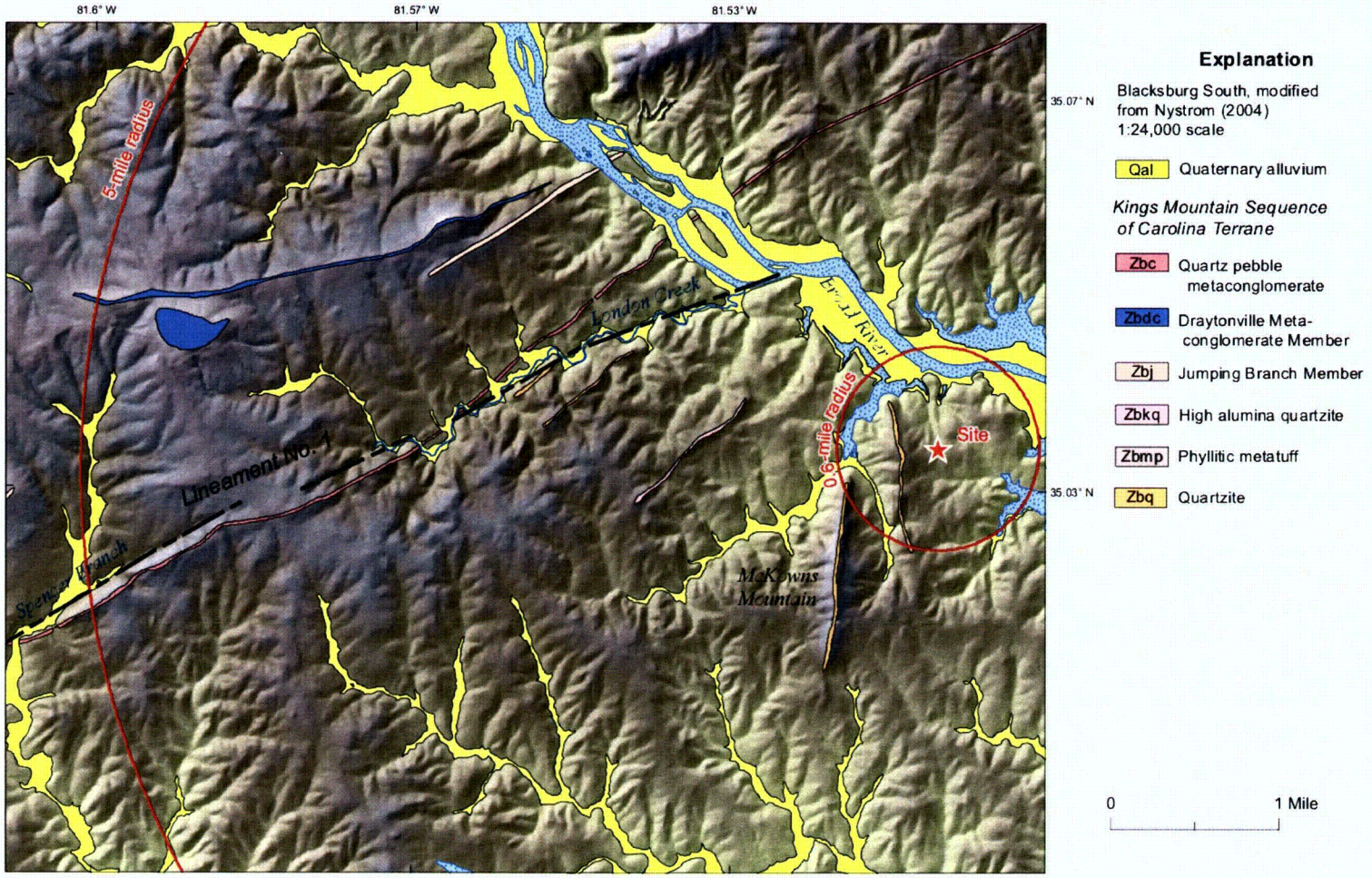


Figure 1. Northeast-trending Topographic Lineament

Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI Letter No. 026

NRC Technical Review Branch: **Geosciences and Geotechnical Engineering Branch 2 (RGS2)**

Reference NRC RAI Number(s): **RAI 02.05.03-007**

NRC RAI:

In FSAR Section 2.5.3.1.6 (pages 2.5-145 and 2.5-146), two bullets state that 1:20,000-scale black and white and 1:40,000-scale color infrared aerial photographs (dated 1959 and 1994, respectively) cover the "majority" of the site area.

Please qualify what part, if any, of the site area was not covered by the aerial imagery to ensure that a careful assessment of potential geomorphic features indicative of tectonic deformation was undertaken.

Duke Energy Response:

The wording of FSAR Subsection 2.5.3.1.6 will be updated to more clearly describe the completeness of the aerial imagery. As shown on Figure 1, 1:20,000-scale black and white stereo aerial photographs cover the entire site area (5-mile radius) and beyond. Figure 2 indicates that the 1:40,000-scale color infrared photographs cover roughly 90 percent of the site area, with only the southernmost portion of the site area not covered. Taken together, these sets of aerial photographs allow for assessment of potential geomorphic features indicative of tectonic deformation within the site area and beyond, as described in the FSAR.

Associated Revision to the Lee Nuclear Station Final Safety Analysis Report:

FSAR Subsection 2.5.3.1.6

Attachments:

1) Figure 1. Index Map for 1959 USDA Black & White Stereo Aerial Photography (1:20,000 scale) Reviewed for the Project
2) Figure 2. Index Map for 1994 USGS NAPP Color IR Stereo Aerial Photography (1:40,000 scale) Reviewed for the Project
3) Mark-up of FSAR Subsection 2.5.3.1.6

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 1 to RAI 02.05.03-007

Figure 1. Index Map for 1959 USDA Black & White Stereo Aerial Photography (1:20,000 scale) Reviewed for the Project

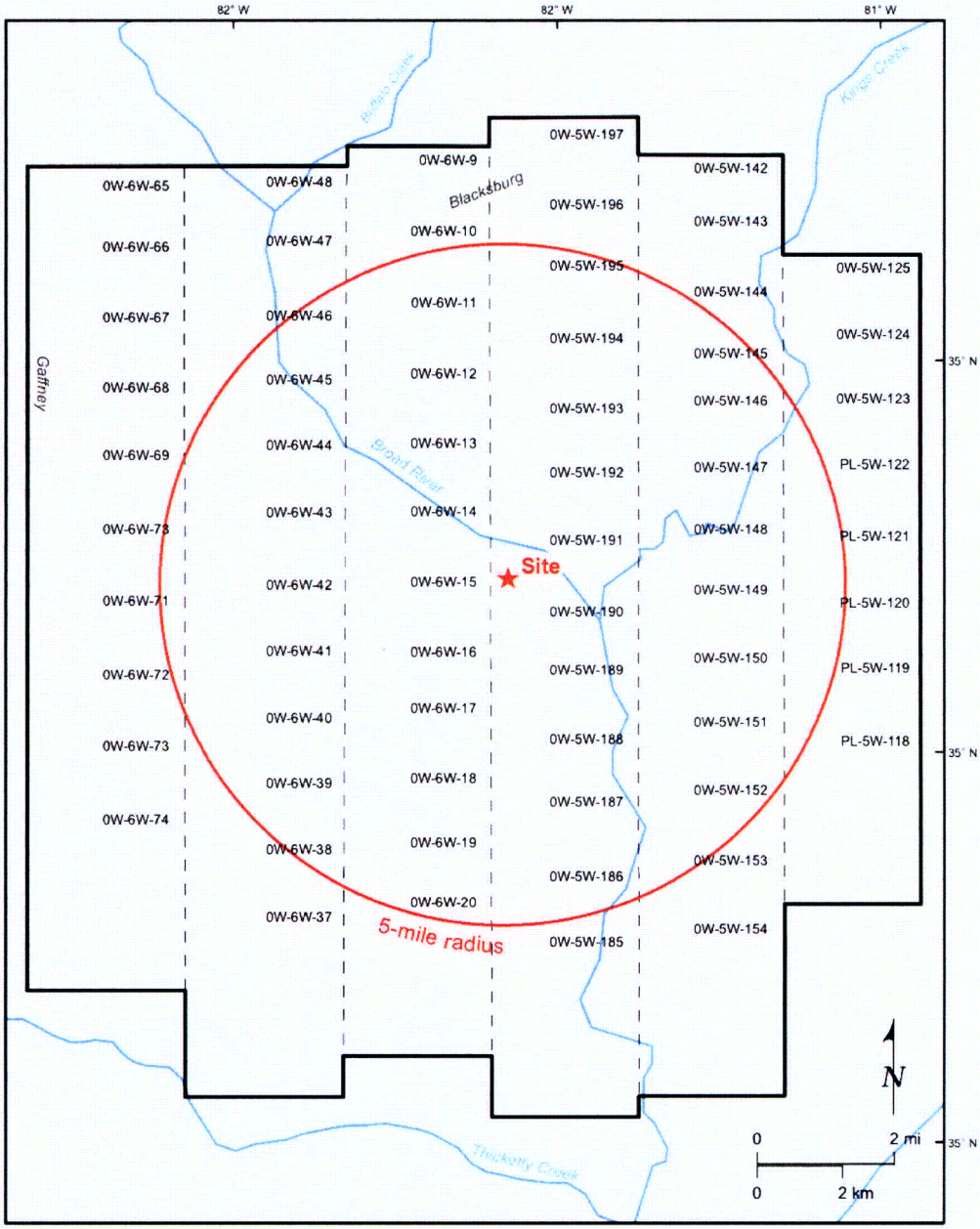


Figure 1. Index Map for 1959 USDA Black & White Stereo Aerial Photography (1:20,000 scale) Reviewed for the Project.

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 2 to RAI 02.05.03-007

Figure 2. Index Map for 1994 USGS NAPP Color IR Stereo Aerial Photography (1:40,000 scale) Reviewed for the Project

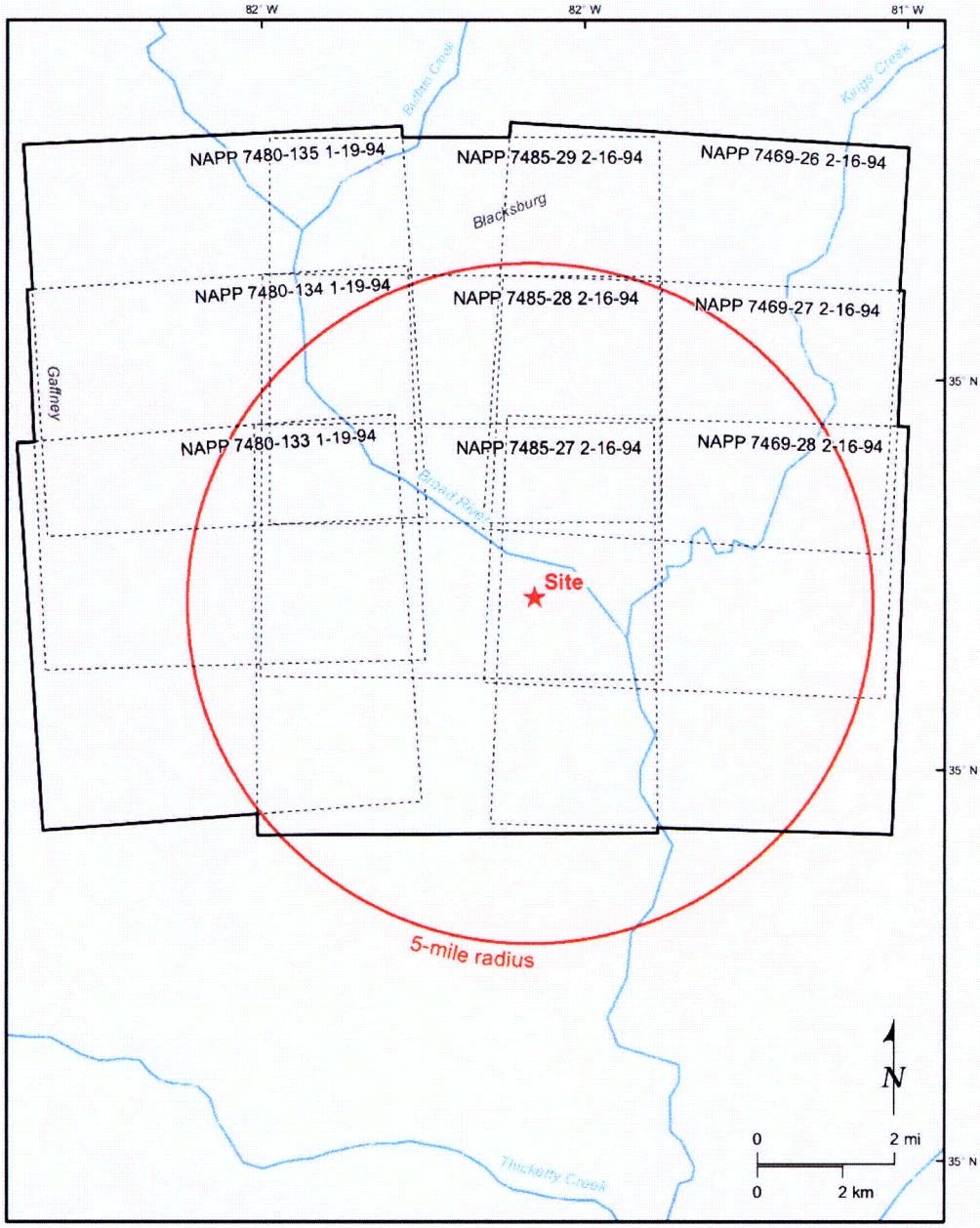


Figure 2. Index Map for 1994 USGS NAPP Color IR Stereo Aerial Photography (1:40,000 scale) Reviewed for the Project.

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 3 to RAI 02.05.03-007

Mark-up of FSAR Subsection 2.5.3.1.6

COLA Part 2, FSAR, Chapter 2, Subsection 2.5.3.1.6, will be revised as follows:

2.5.3.1.6 Current Aerial and Field Reconnaissance

Aerial photography, satellite imagery, and topographic maps of varying scales and vintages reveal no evidence of geomorphic features indicative of the potential for tectonic surface deformation (e.g., faulting or warping) within the site area. Imagery reviewed as part of this license application includes:

- 1:20,000-scale, black and white, stereo aerial photographs from the U.S. Department of Agriculture (1959) covering the ~~majority of the~~entire site area and beyond.
- 1:40,000-scale, color-infrared, stereo aerial photographs from the USGS (1994) covering the majority of the site area.
- Landsat satellite imagery of varying color bands covering the site vicinity and beyond.
- Shaded relief topographic imagery with 100-foot (30-m) grid spacing covering the site vicinity and beyond.

Review of aerial photography reveals a linear topographic feature within the Lee Nuclear Site area that, because of its orientation parallel to the predominant regional structural grain and its proximity to the site, was investigated in detail to assess its origin. This approximately 4.5-mi.-long, linear feature is located approximately 2 mi. northwest of the site, and strikes approximately N55°E with a steeper slope facing to the northwest (shown as "Lineament No. 1" on Figure 2.5.1-221). London Creek flows northeastward along much of the length of the northwestern base of the ridge, before joining with the Broad River near the southernmost tip of Ninety-Nine Islands. The lineament, which is most easily recognized on the 1:40,000-scale USGS photography, terminates northeastward at the Broad River and is not expressed in the topography northeast of the river. Field reconnaissance and previous geologic mapping by Nystrom (2004, Reference 205) reveal that resistant, northeast-striking quartzite layers core this linear ridge. The linear topographic expression of this ridge is the result of erosion by London Creek (and the erosion resistance of the quartzite layers) and is assessed to be non-tectonic in origin.

Field and aerial reconnaissance inspections reveal no evidence for surface rupture, surface warping, or the offset of geomorphic features indicative of active faulting within the site area.

Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI Letter No. 026

NRC Technical Review Branch: **Geosciences and Geotechnical Engineering Branch 2 (RGS2)**

Reference NRC RAI Number(s): **RAI 02.05.03-008**

NRC RAI:

FSAR Section 2.5.3.2 (pages 2.5-146 through 2.5-147) discusses five bedrock faults of proposed Paleozoic age which are mapped within the site vicinity. The Brindle Creek fault is not included, even though a segment of this structure appears to occur in the site vicinity (Figure 2.5.1-120). There is no concise summary of information in the FSAR from the references cited that documents a Paleozoic age for these structures in either FSAR Section 2.5.3.2 or FSAR Section 2.5.3.4 (Ages of Most Recent Deformation). Also, it is not obvious from the text or cited figures how these structures relate to regional boundaries of lithotectonic terranes, including the Charlotte terrane of the Carolina Zone in which the site lies.

Please provide a summary of published evidence for the proposed Paleozoic age of the faults discussed, including the Brindle Creek fault. Please prepare a figure to illustrate how these structures relate to regional boundaries of lithotectonic terranes, including the Charlotte terrane of the Carolina Zone in which the Lee site is located.

Duke Energy Response:

Portions of six faults occur within 25 mi. of the Duke Lee site. FSAR Subsection 2.5.1.1.2.4.2 and Table 2.5.3-201 present information regarding the timing of activity for these structures, with the exception of the Brindle Creek fault. This RAI response provides additional information and clarification regarding timing constraints on these six faults.

Whether or not the Brindle Creek fault extends into the site vicinity is the matter of debate. Some maps of the area depict a small segment of the Brindle Creek fault within the 25 mi. radius of the site (Hibbard et al. 2006 [FSAR Reference 2.5.3-210], Hatcher et al. (2007) [Reference 1]), whereas others depict a different geometry in which the Brindle Creek fault trace is completely located outside of the site vicinity (Merschat and Hatcher 2007 [Reference 2]). While the Brindle Creek fault is recognized in North Carolina as a low-angle fault with an extensive mylonite zone, the mapping of this structure in South Carolina is speculative (Bream 2002 [Reference 3]). For the Lee COLA we have adopted the fault mapping of Hibbard et al. (2006) [FSAR Reference 2.5.3-210], which shows a small portion of the Brindle Creek fault within the site vicinity. According to Hatcher et al. (2007 [Reference 1]), the following lines of evidence are used to map the Brindle Creek fault:

- The fault separates areas with different stratigraphy,
- The fault separates areas with different detrital zircon age distributions,
- The fault separates areas with different mafic and ultramafic rocks, and

- The fault separates areas with different age and character of plutons.

The Brindle Creek fault is interpreted as an early Paleozoic unconformity that was activated as a mylonitic fault in the late Paleozoic during the Alleghanian orogeny (Dennis 2007 [Reference 4]) or as a Neoacadian (early Mississippian) thrust (Hatcher et al. 2007 [Reference 1]). No evidence exists to support an age younger than Late Paleozoic for this feature. The Kings Mountain shear zone is part of the central Piedmont shear zone, and thus separates the Piedmont zone to the northwest from the Charlotte Terrane of the Carolina Zone to the southeast (Hibbard et al. 2002[FSAR Reference 2.5.3-234]) (Revised FSAR Figure 2.5.1-218a – Attachment 5). Located farther west, the Brindle Creek fault is within the Piedmont Zone.

To summarize the available timing information for faults within the site vicinity:

Kings Mountain shear zone: Deformation of this mylonitic shear zone is overprinted by semi-brittle cleavage. Pegmatite dikes in North Carolina intruded parallel to the semi-brittle cleavage and some have been ductiley deformed. Hence, the dikes are interpreted as syn- to post-kinematic and their Rb-Sr whole rock isochron age of 352 ± 10 Ma indicates that the late-stage semi-brittle deformation occurred in the Late Devonian (Horton 1981[FSAR Reference 2.5.3-225]). Furthermore, an unnamed granite with a 326 ± 3 Ma U-Pb upper-intercept age cuts and is undeformed by the Central Piedmont suture in South Carolina south of the intersection of the Kings Mountain shear zone and the Tinsley Bridge faults (Dennis and Wright 1995 [Reference 5]).

Tinsley Bridge fault: Mylonitic deformation occurred after peak metamorphic conditions (Dennis 1995 [FSAR Reference 2.5.3-229]). The fault is cut by the undeformed Pacolet granite with a whole rock Rb/Sr age of 383 ± 5 Ma (Dennis 1995 [FSAR Reference 2.5.3-229]).

Boogertown shear zone: The northeastern end of the Boogertown shear zone is mapped terminating into an unsheared granitic pluton (Milton 1981 [Reference 6], Hibbard et al. 2006 [FSAR Reference 2.5.3-210]). This pluton is undated, but the youngest plutons within the Carolina Zone are generally 300-265 Ma (Hatcher et al. 2007 [Reference 1]).

Brindle Creek fault: In North Carolina, a granite found only in the hanging-wall of the Brindle Creek fault has a concordant zircon ion-microprobe weighted mean 206Pb/238U age of 366 ± 3 Ma (Giorgis et al. 2002 [Reference 7]). These field relations were interpreted to indicate that the Brindle Creek fault was active after the intrusion of the granite, and thus is Devonian or younger in age (Giorigis et al., 2002 [Reference 7]). In North Carolina, migmatitic, high-temperature deformation is spatially associated with the Brindle Creek fault (Giorgis et al. 2002 [Reference 7]). Metamorphic rims on migmatitic rocks in the immediate footwall of the Brindle Creek fault yield ion-microprobe U-Pb ages of ~350 Ma, probably correlative with emplacement of the Brindle Creek hanging-wall (Merschat and Kalbas 2002 [Reference 8]).

Reedy River fault and unnamed fault north of Gaffney: Little is known about these structures and both have been omitted from some maps (e.g., Hatcher et al. 2007 [Reference 1], Merschat et al. 2005 [Reference 9]). They are mapped as thrusts and presumably related to Paleozoic tectonic events.

References:

1. Hatcher, R. D., Bream, B. R., and Merschat, A. J., 2007, Tectonic Map of the Southern and Central Appalachians: A Tale of Three Orogens and a Complete Wilson cycle, in Hatcher, R. D., Carlson, M. P., McBride, J. H., and Martinez Catalan, J. R., eds., 4-D Framework of Continental Crust: Geological Society of America Memoir 200, p. 595-632.
2. Merschat, A. J., Hatcher, R. D., 2007, The Cat Square Terrane: Possible Siluro-Devonian Remnant Ccean Basin in the Inner Piedmont, Southern Appalachians, USA, in Hatcher, R. D., Carlson, M. P., McBride, J. H., and Martinez Catalan, J. R., eds., 4-D Framework of Continental Crust: Geological Society of America Memoir 200, p. 553-565.
3. Bream, B.R., 2002, The Southern Appalachian Inner Piedmont: New Perspectives Based on Recent Detailed Geologic Mapping, Nd Isotopic Evidence, and Zircon Geochronology, in Hatcher, R.D., Jr., and Bream, B.R., eds., Inner Piedmont Geology in the South Mountains-Blue Ridge Foothills and the Southwestern Brushy Mountains, Central-Western North Carolina: North Carolina Geological Survey, Carolina Geological Society Annual Fieldtrip Guidebook, p. 45–63.
4. Dennis, A. J., 2007, Cat Square Basin, Catskill Clastic Wedge: Silurian-Devonian Orogenic Events in the Central Appalachians and the Crystalline Southern Appalachians: Geological Society of America Special Paper 433, p. 313-329.
5. Dennis, A. J., Wright, J. E., 1995, Mississippian (ca. 326-323 Ma) U-Pb Crystallization for Two Granitoids in Spartanburg and Union Counties, South Carolina, in Dennis et al., eds., Geology of the Western Part of the Carolina Terrane in Northwestern South Carolina, CGS Fieldtrip Guidebook v. 37, p. 43-47.
6. Milton, D. J., 1981, The Northern Termination of the Kings Mountain Belt, in Horton, J. W., Butler, J. R., Milton, D. M., eds., Geological Investigations of the Kings Mountain Belt and Adjacent Areas in the Carolinas: Carolina Geological Society Field Trip Guidebook, p. 1-5.
7. Giorgis, S. D., Mapes, R. W., Bream, B. R., 2002, The Walker Top Granite: Acadian Granitoid or Eastern Inner Piedmont Basement? in Hatcher, R. D. and Bream, B. R., eds., Inner Piedmont Geology in the South Mountains-Blue Ridge Foothills and the Southwestern Brushy Mountains, Central-Western North Carolina: North Carolina Geological Survey, Carolina Geological Society Annual Fieldtrip Guidebook, p. 33-43.
8. Merschat, A. J., Kalbas, J. L., 2002, Geology of the Southwestern Brushy Mountains, North Carolina Inner Piedmont: A Summary and Synthesis of Recent Studies, in Hatcher, R. D. and Bream, B. R., eds., Inner Piedmont Geology in the South Mountains-Blue Ridge Foothills and the Southwestern Brushy Mountains, Central-Western North Carolina: North Carolina Geological Survey, Carolina Geological Society Annual Fieldtrip Guidebook, p. 101-126.
9. Merschat, A. J., Hatcher, R. D., Davis, T. L., 2005, The Northern Inner Piedmont, Southern Appalachians, USA: Kinematics of Transpression and SW-Directed Mid-Crustal flow: Journal of Structural Geology, v. 27, p. 1252-1281.

Associated Revision to the Lee Nuclear Station Final Safety Analysis Report:

FSAR Subsection 2.5.3.2

FSAR Subsection 2.5.3.4

FSAR Subsection 2.5.1.1.2.4.2

FSAR Table 2.5.3-201

FSAR Figure 2.5.1-218a

Attachments:

1) Mark-up of FSAR Subsection 2.5.3.2
2) Mark-up of FSAR Subsection 2.5.3.4
3) Mark-up of FSAR Subsection 2.5.1.1.2.4.2
4) Revised FSAR Table 2.5.3-201
5) Revised FSAR Figure 2.5.1-218a

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 1 to RAI 02.05.03-008

Mark-up of FSAR Subsection 2.5.3.2

COLA Part 2, FSAR, Chapter 2, Subsection 2.5.3.2, will be revised as follows:

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

As shown in Figure 2.5.1-218 and discussed in Subsection 2.5.1.1.2.4, ~~five~~ six bedrock faults of Paleozoic age are mapped within the site vicinity. These ~~five~~ six faults are:

- Kings Mountain shear zone, including the Blacksburg shear zone and the Kings Creek shear zone.
- Tinsley Bridge fault.
- Southwestern extension of the Boogertown shear zone
- Brindle Creek thrust fault.
- Reedy River thrust fault.
- Unnamed fault north of Gaffney.

No deformation or geomorphic features suggestive of potential Quaternary activity are reported in the literature for these five faults. Aerial and field reconnaissance and interpretation of aerial photographs and satellite imagery show that no geomorphic features indicative of Quaternary activity exist along any of the mapped fault traces. These ~~five~~ six features are discussed in 2.5.1.1.12.4.2, summarized in Table 2.5.3-201 and described below.

- Kings Mountain shear zone. The northeast-striking Kings Mountain shear zone (Reference 210) in the Lee Nuclear Site vicinity is a zone of mylonitic deformation (References 224, 225, 226, 227, and 228) and considered part of the Central Piedmont shear zone separating the Carolina and Piedmont Zones (Figure 2.5.1.-218a) (Reference 224). The sense of motion on the Kings Mountain shear zone is uncertain, but structural data suggest that the zone is a steeply northwest-dipping reverse fault (Reference 224). Deformation of this mylonitic shear zone is overprinted by semi-brittle cleavage. Pegmatitic dikes in North Carolina intruded parallel to the semi-brittle cleavage and some have been ductile deformed. Hence, the dikes are interpreted as syn- to post-kinematic and their Rb-Sr whole rock isochron age of 352 ± 10 Ma indicates that the late-stage semi-brittle deformation occurred in the Late Devonian (Reference 224). Furthermore, an unnamed granite with a 326 ± 3 Ma U-Pb upper-intercept age cuts and is undeformed by the central Piedmont shear zone in South Carolina south of the intersection of the Kings Mountain shear zone and the Tinsley Bridge faults (Reference 238).
- Tinsley Bridge fault. The Tinsley Bridge fault (Figure 2.5.1-210) is a zone of retrograde mylonite with apparent down-to-the-northwest sense of slip and is less than 20 mi. in length (Reference 229). ~~Cross-cutting relationships constrain the age of most recent movement on the Tinsley Bridge fault to the late Paleozoic~~Mineral assemblages in the mylonite indicate that deformation on the Tinskey Bridge fault occurred after peak metamorphic conditions (Reference 229). The fault is cut by the undeformed Pacolet granite with a whole rock Rb/Sr age of 383 ± 5Ma (Reference 229).
- Southwest extension of the Boogertown shear zone. The northeast-striking Boogertown shear zone (Figure 2.5.1-210) ~~marks the~~is sometimes interpreted as a terrane boundary ~~between the Kings Mountain belt and the Charlotte belt~~ (Reference 225 and 230). The northeastern end of the Boogertown shear zone is mapped terminating into an unsheared granitic pluton (References 244 and 210). This pluton is undated, but the youngest plutons within the Carolina Zone are generally 300-265 Ma (Reference 241). There is no evidence

to suggest post-Paleozoic motion on the southwest extension of the Boogertown shear zone.

- Brindle Creek thrust fault. The Brindle Creek thrust was recognized in North Carolina as a low-angle fault with an extensive mylonite zone, but authors have indicated that the mapping of this structure in South Carolina is speculative (Reference 236). In North Carolina, a granite found only in the hanging-wall of the Brindle Creek fault (and hence older than movement on the structure) has zircons with a weighted $^{206}Pb/^{238}U$ ion mircorprobe age of 366 ± 3 Ma (Reference 239). These field relations were interpreted to indicate that the Brindle Creek fault was active after the intrusion of the granite, or is Devonian or younger in age. In North Carolina, migmatitic, high-temperature deformation is spatially associated with the Brindle Creek fault (Reference 239). Metamorphic rims on migmatitic rocks in the immediate footwall of the Brindle Creek fault yield ion-microprobe U-Pb ages of ~350 Ma, probably correlative with emplacement of the Brindle Creek hanging-wall (Reference 243).
- Reedy River thrust fault. The Reedy River thrust fault is a northeast-striking structure in the Inner Piedmont (References 208, 231, 232, and 233) (Figure 2.5.1-210). There is no evidence to suggest post-Paleozoic motion on the Reedy River thrust fault.
- Unnamed fault north of Gaffney. In their tectonostratigraphic compilation map of the Appalachians, Hibbard et al. (2006, Reference 210) suggest that this approximately 20-mi.-long, northerly striking fault records up-to-the-east displacement and Goldsmith et al. (Reference 240) indicate it is a northwest-vergent thrust fault. Horton and Dicken (2001, Reference 209) do not include this fault in their compilation of South Carolina Piedmont and Blue Ridge geology. There is no evidence to suggest post-Paleozoic motion on the unnamed fault North of Gaffney.

There is direct geologic evidence to preclude the presence of northeast- or east-striking faults projecting through the Lee Nuclear Site. The predominant structural grain of the site area, vicinity, and region is oriented northeast. As mapped by Nystrom (2004, Reference 205) and confirmed by reconnaissance mapping, two elongated, north-striking quartzite bodies are located in the western portion of the site area (Figures 2.5.1-219 and 2.5.1-220). These unfaulted, continuous quartzite beds, oriented at a high angle to the regional structural grain, demonstrate the absence of any northeasterly or easterly striking fault through the Lee Nuclear Site. In addition, the northerly striking western margin of the granodiorite pluton provides an additional strain marker that precludes the presence of any northeasterly or easterly striking faults through the Lee Nuclear Site. The timing of emplacement of this granodiorite pluton is uncertain, but according to Butler (1981, Reference 235), it is likely early Paleozoic or older in age.

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 2 to RAI 02.05.03-008

Mark-up of FSAR Subsection 2.5.3.4

COLA Part 2, FSAR, Chapter 2, Subsection 2.5.3.4, will be revised as follows:

2.5.3.4 Ages of Most Recent Deformations

The ~~five~~ six faults mapped in the Lee Nuclear Site vicinity (i.e., the Kings Mountain shear zone, the Tinsley Bridge fault, the southwest extension of the Boogertown shear zone, the Brindle Creek thrust, the Reedy River thrust fault, and the unnamed fault north of Gaffney) have not been active since Paleozoic time (References 224 and 229), although Garihan et al. (1993, Reference 230) suggest the possibility that the Kings Mountain shear zone may have experienced localized Mesozoic reactivation.

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 3 to RAI 02.05.03-008

Mark-up of FSAR Subsection 2.5.1.1.2.4.2

COLA Part 2, FSAR, Chapter 2, Subsection 2.5.1.1.2.4.2, will be revised as follows:

2.5.1.1.2.4.2 Regional Paleozoic Tectonic Structures

The Lee Nuclear Site region encompasses portions of the Coastal Plain, Piedmont, Blue Ridge, Valley and Ridge, and Appalachian Plateau physiographic provinces (Figure 2.5.1-201). Rocks and structures within these provinces are often associated with thrust sheets that formed during convergent Appalachian orogenic events of the Paleozoic Era. Tectonic structures of this affinity also exist beneath the sedimentary cover of the Coastal Plain province. These types of structures are shown on Figure 2.5.1-209 and Figure 2.5.1-210, and include the following:

- Sutures juxtaposing allochthonous (tectonically transported) rocks with autocthonous (non-transported North American crust) rocks.
- Regionally extensive Appalachian thrust faults and oblique-slip shear zones.
- Numerous smaller structures that accommodated Paleozoic deformation within individual belts or terranes.

The majority of these structures dip eastward, initially at a steep angle that becomes shallower as they approach the basal Appalachian decollement. The Appalachian orogenic crust is relatively thin across the Valley and Ridge province, Blue Ridge province, and western part of the Piedmont province and the Coastal Plain province. Below the decollement are rocks that form the North American basement complex. These basement rocks contain northeast-striking, Late Precambrian to Cambrian normal faults that formed during the Iapetan rifting that preceded the deposition of Paleozoic sediments.

Researchers observe that much of the sparse seismicity in eastern North America occurs within the North American basement below the basal decollement. Therefore, seismicity within the Appalachians may be unrelated to the abundant, shallow thrust sheets mapped at the surface (Reference 267). For example, seismicity in the Giles County seismic zone, located in the Valley and Ridge province, is occurring at depths ranging from 3 to 16 mi. (see Subsection 2.5.1.1.3.2.3) (References 265 and 371), which is generally below the Appalachian thrust sheets and basal decollement (Reference 265).

Paleozoic faults within 200 mi. of the Lee Nuclear Site are shown on Figures 2.5.1-209 and 2.5.1-210, and selected features are described as follows:

Kings Mountain Shear Zone (Central Piedmont Shear Zone). The northeast-striking Kings Mountain shear zone is a zone of mylonitic deformation that separates the Inner Piedmont terrane from the Carolina terrane, and is considered part of the larger Central Piedmont shear zone (References 236, 296, and 297). The Kings Mountain shear zone comprises smaller, localized shear zones, including the Blacksburg and Kings Creek shear zones. At its nearest point, the Kings Mountain shear zone is located 5 mi. north of the Lee Nuclear Site (Figure 2.5.1-210). The sense of motion on the Kings Mountain shear zone is unclear, but structural data suggest that the zone is a steeply northwest-dipping reverse fault (Reference 236). On the basis of field relationships, Horton (1981) (Reference 236) estimates a Mississippian age for the latest significant movement on the Kings Mountain shear zone.

Brindle Creek Thrust Fault. The Brindle Creek thrust was recognized in North Carolina as a low-angle fault with an extensive mylonite zone, but authors have indicated that the mapping of this structure in South Carolina is speculative (Reference 236). According to Hatcher et al. (Reference 241), the following lines of evidence are used to map the Brindle Creek fault:

- The fault separates areas with different stratigraphy,

- The fault separates areas with different detrital zircon age distributions,
- The fault separates areas with different mafic and ultramafic rocks, and
- The fault separates areas with different age and character of plutons.

The fault is interpreted as an early Paleozoic unconformity that was activated as a mylonitic fault in the late Paleozoic during the Alleghanian orogeny (Reference 237) or as a Neoacadian (early Mississippian) thrust (Reference 241).

Tinsley Bridge Fault. The Tinsley Bridge fault is a less than 20-mi.-long zone of retrograde mylonite with ~~apparent down-to-the-~~northwest-vergent sense of slip (Reference ~~298~~240). At its nearest point, the Tinsley Bridge fault is located 5 mi. southwest of the Lee Nuclear Site (Figure 2.5.1-210). Cross-cutting relationships constrain the age of most-recent movement on the Tinsley Bridge fault to the late Paleozoic (Reference 298).

Cross Anchor Fault. The greater than 60-mi.-long Cross Anchor fault is mapped by Hibbard et al. (2006) (Reference 260) as a thrust fault of variable strike. At its nearest point, the Cross Anchor fault is located approximately 10 mi. west of the Lee Nuclear Site (Figure 2.5.1-210). West (1998) (Reference 297) interprets the Cross Anchor fault as the Carolina-Inner Piedmont terrane boundary. Cross-cutting and structural relationships indicate that the Cross Anchor fault is Paleozoic (325 Ma) and may be part of the Central Piedmont shear zone (Reference 297).

Southwest Extension of the Boogertown Shear Zone. The northeast-striking Boogertown shear zone marks the boundary between the Kings Mountain belt and the Charlotte Belt (Reference 236). At its nearest point, this shear zone is located 8 mi. east of the Lee Nuclear Site (Figure 2.5.1-210).

Reedy River Thrust Fault. The Reedy River thrust fault is a northeast-striking structure in the Inner Piedmont (References 260, 299, and 300). At its nearest point, the Reedy River thrust fault is located 18 mi. west-northwest of the Lee Nuclear Site (Figure 2.5.1-210).

Gold Hill-Silver Hill Shear Zone. The Gold Hill-Silver Hill shear zone is a dextral strike-slip shear zone located approximately 30 mi. south of the Lee Nuclear Site (Figure 2.5.1-210). Based upon structural correlations with the Deal Creek shear zone and cross-cutting relationships with intrusive igneous bodies, West (1998) (Reference 297) constrains motion on this shear zone to between approximately 400 and 325 Ma.

Beaver Creek-Lowdensville Shear Zone. The Beaver Creek shear zone is located approximately 40 mi. south of the Lee Nuclear Site (Figure 2.5.1-210), and correlates westward with the dextral strike-slip Lowdensville shear zone (Reference 297). Evidence suggesting dextral strike-slip motion for this shear zone includes feldspar porphyroclasts with tails, shear bands from orthogneiss sheets, and rotated quartz-filled gash veins. Cross-cutting relationships with the mesoscopically undeformed Newberry granite indicates that motion on the Beaver Creek-Lowdensville shear zone occurred prior to 415Ma (Reference 297).

Modoc Shear Zone. The Modoc shear zone is a region of high ductile strain separating the Carolina terrane (Carolina Slate and Charlotte belts) from amphibolite facies migmatitic and gneissic rocks (Reference 301). The northeast-trending Modoc zone dips steeply to the northwest and is traced through the Piedmont from central Georgia to central South Carolina based on geological and geophysical data. The Modoc shear zone appears to continue northeastward to North Carolina beneath the Coastal Plain, as demonstrated by geologic mapping and aeromagnetic data (Figure 2.5.1-206). At its nearest point, the Modoc shear zone is about 75 mi. south of the Lee Nuclear Site. The Modoc shear zone contains fabrics characterized by brittle and ductile deformation produced by ductile shear during an early phase

of the Alleghanian orogeny approximately 315 Ma (References 302, 303, 304, and 305). There is no evidence for post-315 Ma slip on the Modoc shear zone.

Hatcher et al. (1977) (Reference 306) suggest that the Modoc shear zone, the Irmo shear zone, and the Augusta fault are part of the proposed eastern Piedmont fault system, an extensive series of faults and splays extending from Alabama to Virginia. Aeromagnetic, gravity, and seismic reflection data indicate that the Augusta fault zone continues northeastward in the crystalline basement beneath the Coastal Plain province sediments.

Brevard Fault Zone. The northeast-trending Brevard fault zone extends for over 400 mi. from Alabama to Virginia (References 260 and 307). At its nearest point, the Brevard fault zone is located approximately 55 mi. northwest of the Lee Nuclear Site (Figure 2.5.1-210). The Brevard fault zone separates the Blue Ridge province to the west from the Piedmont province to the east. Diabase dikes preclude post Jurassic slip on the Brevard fault and cooling age histories indicate that no slip has occurred on the Brevard fault since the late Paleozoic (Reference 226).

Chappells Shear Zone. Horton and Dicken (2001) (Reference 308) and Hibbard et al. (2006) (Reference 260) map the 60-mi.-long Chappells shear zone as an approximately northeasterly-trending, 2-mi.-wide zone of ductile deformation. At its nearest point, the Chappells shear zone is located approximately 57 mi. south of the Lee Nuclear Site (Figure 2.5.1-210). Post-Paleozoic slip on the Chappells shear zone is precluded by cross-cutting relationships with the late Paleozoic (309 Ma; Reference 309) Winnsboro pluton.

Other Paleozoic Faults. Other Paleozoic faults are present in the site region, most are located northwest of the site and are oriented parallel to the regional structural grain. These include, but are not limited to, the Eufola, Seneca, Pine Mountain, Tumblebug Creek, Bowens Creek, and Fries faults.

No seismicity is attributed to these Paleozoic faults, and published literature does not indicate that any of these faults offset late Cenozoic deposits or exhibit a geomorphic expression indicative of Quaternary deformation. In addition, Crone and Wheeler (2000) (Reference 310) and Wheeler (2005) (Reference 311) do not show any of these faults to be potentially active Quaternary faults. Therefore, these Paleozoic structures in the site region are not considered to be capable tectonic sources. No new information has been published since 1986 on any Paleozoic fault in the site region that would cause a significant change in the EPRI seismic source model.

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 4 to RAI 02.05.03-008

Revised FSAR Table 2.5.3-201

TABLE 2.5.3-201

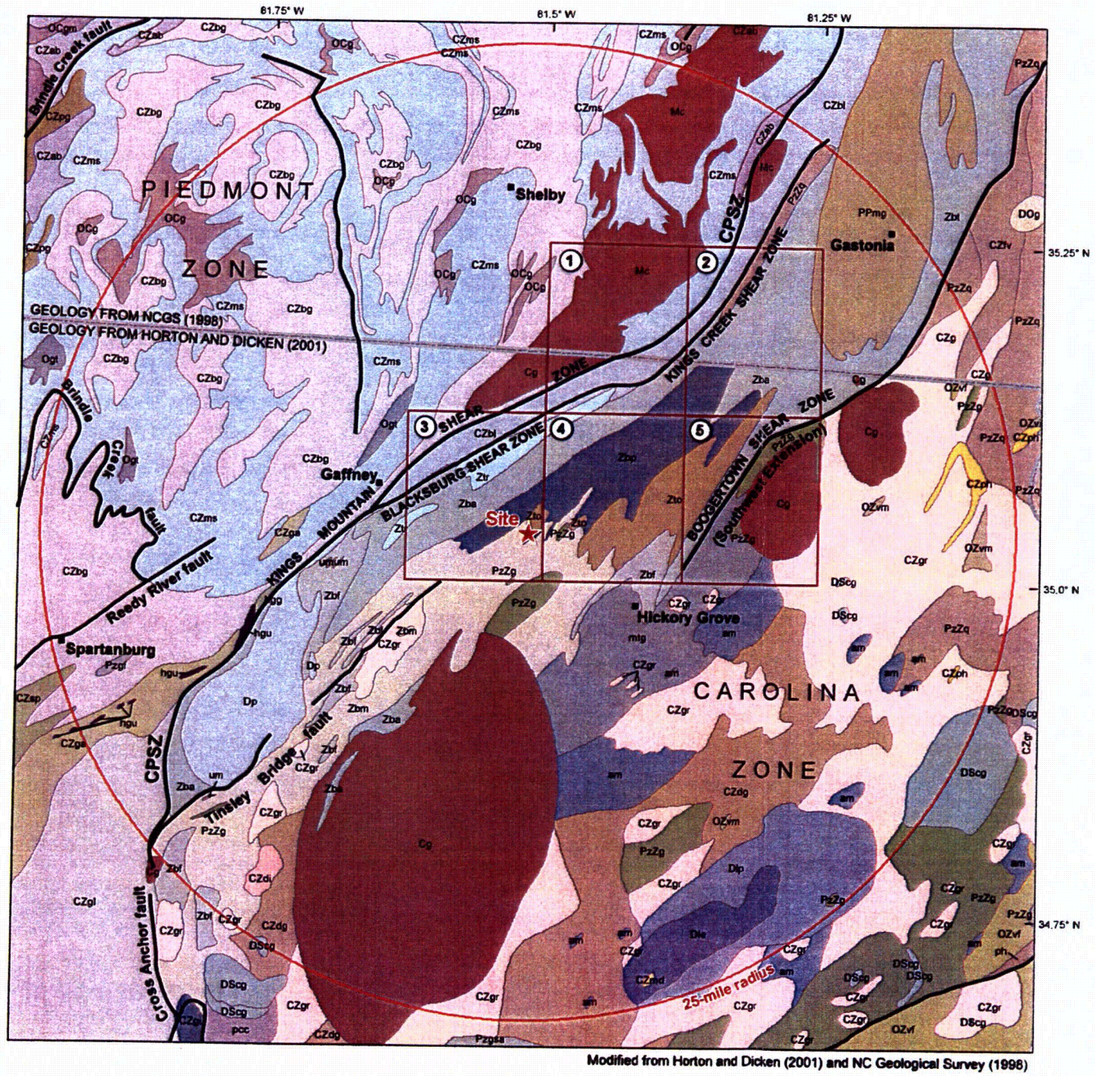
SUMMARY OF BEDROCK FAULTS MAPPED WITHIN SITE VICINITY

Feature Name	Distance from Site	Mapped Length	Strike Orientation	Reference(s)	Assigned Age	Evidence for Age
Kings Mountain shear zone	~5 mi.	>70 mi.	NE	Garihan et al. (1993) (Reference ~~230~~232) Hibbard et al. (2006) (Reference ~~210~~211) Horton (1981a, 1981b) (References ~~224~~225 and ~~225~~226) West et al. (1998) (Reference ~~228~~229)	Paleozoic (possibly Mesozoic)	Syn- to post-kinematic dikes have Rb/Sr isochron age of 325 Ma; Cut by a 326 Ma granite
Tinsley Bridge fault	~6 mi.	~20 mi.	NE	Dennis (1995) (Reference ~~228~~230) Hibbard et al. (2006) (Reference ~~210~~211)	Paleozoic	Cut by 383 Ma granite
Brindle Creek thrust fault	~11 mi.	>100 mi.	NE, variable	Hibbard et al. (2006) (Reference 210) Hatcher et al. (2007) (Reference 242) Giorgis et al. (2002) (Reference 239)	Paleozoic	Cuts a 366 Ma granite; Fault-related migmatites have ~350 Ma age
SW extension of Boogertown shear zone	~8 mi.	~12 mi.	NE	Hibbard et al. (2006) (Reference ~~210~~211) Horton et al. (1981b) (Reference ~~225~~226) Maybin and Nystrom (1997) (Reference ~~230~~231)	Paleozoic	Cut by an undated pluton (Pluton mapped as Ordovician to Devonian)
Reedy River thrust fault	>10 mi.	>100 mi.	NE	Hibbard et al. (2006) (Reference ~~210~~211) Horton and Dicken (2001) (Reference ~~209~~210) Maybin and Nystrom (1997, 2002) (References ~~230~~231 and ~~233~~234) Nystrom (2001) (Reference ~~232~~233)	Paleozoic	
Unnamed fault north of Gaffney	>12 mi.	20 mi.	N	Hibbard et al. (2006) (Reference ~~210~~211) Goldsmith et al. (1988) (Reference 240)	Paleozoic	

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 5 to RAI 02.05.03-008

Revised FSAR Figure 2.5.1-218a



(See figure 2.5.1-218b for explanation)

WLS COL 2.5-1

Modified from Horton and Dicken (2001) and NC Geological Survey (1998)

WILLIAM STATES LEE III
NUCLEAR STATION UNITS 1 & 2

Site Vicinity Geologic Map

FIGURE 2.5.1-218a Rev F

Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI Letter No. 026

NRC Technical Review Branch: **Geosciences and Geotechnical Engineering Branch 2 (RGS2)**

Reference NRC RAI Number(s): **RAI 02.05.03-009**

NRC RAI:

FSAR Section 2.5.3.6 (page 2.5-149) states that data are presented throughout Section 2.5.1 documenting that there is no evidence for capable tectonic sources within the Lee site vicinity. However, these important data are not adequately summarized in FSAR Section 2.5.3.6.

Please summarize the pertinent data from FSAR Section 2.5.1 which documents the conclusion that no capable tectonic sources exist in the site vicinity.

Duke Energy Response:

A summary of tectonic features is provided in FSAR Subsection 2.5.3.2, and this section has been revised in response to NRC RAI 02.05.03-008. FSAR Subsection 2.5.3.6 will be revised to now reference Subsection 2.5.3.2 for the summary and data reinforcing the conclusion that no tectonic activity exists within the site vicinity.

Associated Revision to the Lee Nuclear Station Final Safety Analysis Report:

FSAR Subsection 2.5.3.6

Attachments:

1) Mark-up of FSAR Subsection 2.5.3.6

Lee Nuclear Station Response to Request for Additional Information (RAI)

Attachment 1 to RAI 02.05.03-009

Mark-up of FSAR Subsection 2.5.3.6

COLA Part 2, FSAR, Chapter 2, Subsection 2.5.3.6, will be revised as follows:

2.5.3.6 Characterization of Capable Tectonic Sources

Based on reviews of updated geologic, seismic, and geophysical data from published literature, interviews with expert earth scientists, and the COL investigations, no evidence for capable tectonic sources is identified within the Lee Nuclear Site vicinity. These data are presented in detail throughout Subsection 2.5.1, and are summarized in 2.5.3.2. This interpretation is consistent with investigations performed for the former Cherokee nuclear site. The Tinsley Bridge fault and the Kings Mountain shear zone are the nearest mapped faults to Lee Nuclear Site (located approximately 5 mi. away at their nearest points), and have not been active since Paleozoic time (Reference 224 and 229), although Garihan et al. (1993, Reference 231) suggest the possibility that the Kings Mountain shear zone may have experienced localized Mesozoic reactivation.