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UniStar
NUCLEAR ENERGY

10 CFR 50.4
10 CFR 52.79

October 2, 2009

UN#09-389

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: UniStar Nuclear Energy, NRC Docket No. 52-016
Response to Request for Additional Information for the Calvert Cliffs Nuclear Power Plant, Unit 3,
RAI No. 130, Basic Geologic and Seismic Information and
RAI No. 134, Basic Geologic and Seismic Information

References:
1) John Rycyna (NRC) to Robert Poche (UniStar Nuclear Energy), "RAI No 130 RGS 2821.doc" email dated July 28, 2009.
2) John Rycyna (NRC) to Robert Poche (UniStar Nuclear Energy), "RAI No 134 RGS 2961.doc" email dated August 5, 2009.
3) Greg Gibson (UniStar Nuclear Energy) Letter UN#09-347 to Document Control Desk (NRC), Response to Request for Additional Information for the Calvert Cliffs Nuclear Power Plant, Unit 3, RAI Nos. 130 and 134, Basic Geologic and Seismic Information, dated August 17, 2009.
4) Greg Gibson (UniStar Nuclear Energy) Letter UN#09-152 to Document Control Desk (NRC), Response to Request for Additional Information for the Calvert Cliffs Nuclear Power Plant, Unit 3, RAI No. 71, Basic Geologic and Seismic Information, RAI No. 72, Vibratory Ground Motion, dated April 15, 2009.
5) Greg Gibson (UniStar Nuclear Energy) Letter UN#09-227 to Document Control Desk (NRC), Response to Request for Additional Information for the Calvert Cliffs Nuclear Power Plant, Unit 3, RAI No. 71, Basic Geologic and Seismic Information, RAI No. 72, Vibratory Ground Motion, dated May 1, 2009.

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The purpose of this letter is to respond to the requests for additional information (RAIs) identified in the NRC e-mail correspondence to UniStar Nuclear Energy, dated July 28, 2009 (Reference 1) and August 5, 2009 (Reference 2). These RAIs address the Basic Geologic and Seismic Information as discussed in Section 2.5.1 of the Final Safety Analysis Report (FSAR), as submitted in Part 2 of the Calvert Cliffs Nuclear Power Plant, Unit 3 Combined License Application (COLA), Revision 5. Reference 3 provided a schedule for the expected response dates for Questions 02.05.01-33 through 02.05.01-61.

Enclosure 1 provides our responses to RAI No. 130, Questions 02.05.01-33 through 02.05.01-56. Enclosure 2 provides our responses to RAI No. 134, Questions 02.05.01-57 through 02.05.01-61. The revised COLA content associated with the responses to these RAIs is consolidated in Enclosure 3 as a replacement for FSAR Section 2.5.1, Basic Geologic and Seismic Information. For clarity, Enclosure 3 also includes changes that were associated with the submitted responses to RAI 71 and RAI 72 (References 4 and 5).

A Licensing Basis Document Change Request has been initiated to incorporate these changes into a future revision of the COLA.

The responses to the identified questions do not include any new regulatory commitments. Our responses to RAI No. 130, Questions 02.05.01-33 through 02.05.01-56 and RAI No. 134, Questions 02.05.01-57 through 02.05.01-61 do not contain any sensitive or proprietary information.

If there are any questions regarding this transmittal, please contact me at (410) 470-4205, or Mr. Michael J. Yox at (410) 495-2436.

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

Executed on October 2, 2009

Greg Gibson

Enclosures:
1) Response to NRC Request for Additional Information, RAI No. 130, Basic Geologic and Seismic Information, Questions 02.05.01-33 through 02.05.01-56, Calvert Cliffs Nuclear Power Plant Unit 3
2) Response to NRC Request for Additional Information, RAI No. 134, Basic Geologic and Seismic Information, Questions 02.05.01-57 through 02.05.01-61, Calvert Cliffs Nuclear Power Plant Unit 3
3) Proposed Changes to Final Safety Analysis Report Section 2.5.1, Basic Geologic and Seismic Information

cc: Surinder Arora, NRC Project Manager, U.S. EPR Projects Branch
Laura Quinn, NRC Environmental Project Manager, U.S. EPR COL Application
Getachew Tesfaye, NRC Project Manager, U.S. EPR DC Application (w/o enclosures)
Loren Plisco, Deputy Regional Administrator, NRC Region II (w/o enclosures)
Silas Kennedy, U.S. NRC Resident Inspector, CCNPP, Units 1 and 2
U.S. NRC Region I Office

GTG/VWH/ms

Enclosure 1

Response to NRC Request for Additional Information, RAI No. 130, Basic Geologic and Seismic Information, Questions 02.05.01-33 through 02.05.01-56, Calvert Cliffs Nuclear Power Plant Unit 3

RAI No. 130

Question 02.05.01-33

In the Calvert Cliffs Nuclear Power Plant (CCNPP) Unit 3 FSAR, Section 2.5.1.1.1.1, p 2.5-11, the text states, "In the site region and vicinity, geomorphic surface expression is a useful criterion for mapping the contacts between Pliocene and Quaternary units as shown in Figure 2.5-5 and Figure 2.5-6." The figures do not show the contact between Quaternary and Pliocene units nor do they show how geomorphic surface expression correlates with geology. Please clarify or provide another illustration that shows the contact.

Response

FSAR Figure 2.5-5 is intended to illustrate the regional geology within the 200-mile radius of the CCNPP site. The figure is too generalized to illustrate the geomorphic expression of the Pliocene-Quaternary contact. The references to FSAR Figure 2.5-5 and Figure 2.5-6 will be deleted from the subject sentence in FSAR Section 2.5.1.1.1.1, Coastal Plain Physiographic Province, in a future revision of the COLA. On a more local scale, McCartan (1989b) has mapped the contacts between Pliocene and Quaternary units in St. Mary's County partly on the basis of geomorphic expression. Additional information is provided in the response to RAI 130, Question 02.05.01-49.

Reference:

McCartan, 1989b. Geologic Map of St. Mary's County, Maryland: Maryland Geological Survey map, Scale 1:62,500, L. McCartan, 1989.

COLA Impact

FSAR Section 2.5.1.1.1.1, Coastal Plain Physiographic Province, will be revised as shown in Enclosure 3 in a future revision of the COLA.

Question 02.05.01-34

CCNPP Unit 3 FSAR Section 2.5.1.1.2 describes the regional geologic history beginning with the Grenville orogeny (Precambrian Eon) and ending with the Cenozoic Era. The NRC staff has identified the following information needs for this FSAR section:

a. The geologic history descriptions contained in FSAR Section 2.5.1.1.2 do not cover the entire area within the 200 mile radius of the site. The region covered is essentially limited to the southeastern North American margin. Please revise and further develop the geologic history sections (Sections 2.5.1.1.2.1 through 2.5.1.1.2.8) such that lithotectonic units or geologic terranes are defined by their structural boundaries (suture zones and/or large, regional fault systems) and illustrated in sufficient details. Please include the geology of the entire area within the 200 mile radius of CCNPP.

b. A frequently cited reference for most of FSAR Section 2.5.1.1.2, the geologic history section, is Fichter, 2000, which is a web site that seems to be for a student course and not peer reviewed, published geologic literature. Please justify your use of this web site rather than peer reviewed, published geologic literature.

c. In Figure 2.5-5, “Regional Geologic Map 200 Mile Radius,” the map does not have the Grenville terranes labeled as discussed in text. There are several colored units on the map within the 200 mile radius that do not have any identification. In Figure 2.5-6, “Regional Geologic Map 200-Mile (320-km) Radius Explanation,” the explanation is a mix of geologic age units with stratigraphic units of unidentified age, and with lithologic type with no age or terrane identity. Please revise Figure 2.5-5 to more directly support the discussion of the regional geologic history, and organize the legend (Figure 2.5-6).

d. Specifically for FSAR Section 2.5.1.1.2.1, Grenville Orogeny: Provide a discussion of Grenville massifs within the 200 mile radius of the site including: Reading Prong, Honey Brook Upland, Mine Ridge, Grenville massifs within the Baltimore Terrane, and the non-Laurentian, Grenville-aged Brandywine Terrane massifs such as those provided in Faill, 1997 and GSA Special Paper 330, 1999.

e. Specifically for FSAR Section 2.5.1.1.2.4, Taconic Orogeny: The FSAR text is taken from an introduction section of the Bledsoe and Marine paper, the topic of which is unrelated to the discussion topic in the FSAR. Provide citations from the original research to support the discussion in the text.

f. FSAR Section 2.5.1.1.2.5, Acadian Orogeny, states, "The Acadian orogeny ended the largely quiescent environment that dominated the Appalachian Basin during the Silurian, as vast amounts of terrigenous sediment from the Acadian Mountains were introduced into the basin and formed the Catskill clastic wedge in Pennsylvania and New York as shown in Figure 2.5-5, Figure 2.5-6, and Figure 2.5-8." These figures do not define or illustrate the Catskill clastic wedge. Please define the Catskill wedge and its significance within the Acadian orogeny and illustrate with appropriate scale maps.

g. FSAR Section 2.5.1.1.2.7 describes the Early Mesozoic Extensional Episode (Triassic Rifting). The CCNPP site is located within the extended continental crust with many Triassic rift basins in the surrounding region and vicinity. In FSAR Section 2.5.1.1.4.1, Plate Tectonic Evolution of the Atlantic Margin (p 2.5-28), a completely different version of Mesozoic history is described. Section 2.5.1.1.4.1 is part of the geologic history for the site region and the information in that section needs to be integrated with Section 2.5.1.1.2.7 so that redundant or conflicting presentation of information is resolved and all the pertinent scientific literature is adequately covered. Please revise both Sections 2.5.1.1.2.7 and 2.5.1.1.4.1 to integrate a single Mesozoic historical description and to include the latest research, along with appropriate regional maps and cross sections.

h. FSAR Section 2.5.1.1.2.8 describes the Cenozoic History for the region. The CCNPP sits on Cenozoic Coastal Plain sediments within the current passive margin tectonic setting. Please revise the text in this FSAR section to provide more details about the current state of stress in the eastern North American continental margin.

Response

Information needs a-h are addressed in the following and the re-write of FSAR Section 2.5.1.1.2, Regional Geologic History, and FSAR Section 2.5.1.1.4, Regional Tectonic Setting. The area within a 200-mile radius of the CCNPP site includes Maryland, Delaware, and portions of New Jersey, Pennsylvania, West Virginia, Virginia, and North Carolina. This area encompasses a small part of the southern Appalachian orogen, most of the central Appalachian orogen and a small transition zone between the central and northern Appalachian orogen as shown in Figure 2.5-200 provided in Enclosure 3. Much of the bedrock geology of the area is covered by Coastal Plain sediments, obscuring geologic structures and lithotectonic terranes potentially significant to the CCNPP site. A new base map of tectonostratigraphic terranes was developed for FSAR Figure 2.5-9, as shown in Enclosure 3, and was revised to cover the entire area within a 200-mile radius of the site and is based on a 1991 compilation by Horton et al (Horton, 1991). While this depiction of tectonostratigraphic terranes is somewhat more dated than the information from Faill, 1997a, 1997b, and 1998 along with Hatcher, 2005, the extent of Horton's 1991 lithotectonic terranes covers the entire 200-mile radius of the CCNPP site, including important units buried on the continental margin. The revised information provides a comprehensive basis for discussion of the geologic history of the region around the CCNPP site.

The tectonostratigraphic terranes presented in the revised FSAR Figure 2.5-9 are exposed as either geologic terranes defined by structural boundaries or buried terranes identified from drilling or inferred from magnetic, gravity or seismic surveys. Each of the described tectonostratigraphic terranes, characterized by distinct lithologic, metamorphic, structural, gravimetric or magnetic signatures, played a role in the development of the eastern edge of the North American continental margin that exists today. The tectonostratigraphic terranes provide a means of describing crustal elements and their behavior through time, from the Mesoproterozoic to the present.

References:

Faill, 1997a. A Geologic History of the North-Central Appalachians, Part 1, Orogenesis from the Mesoproterozoic through the Taconic Orogeny, Journal of Science, Volume 297, p 551–619, R. Faill, 1997.

Faill, 1997b. A Geologic History of the North-Central Appalachians, Part 2, The Appalachian basin from the Silurian through the Carboniferous, Journal of Science, Volume 297, p 729-761, R. Faill, 1997.

Faill, 1998. A Geologic History of the North-Central Appalachians, Part 3, The Allegheny Orogeny, American Journal of Science, Volume 298, p 131–179, R. Faill, February 1998.

Hatcher, 2005. Regional Geology of North America-Southern and Central Appalachians: Encyclopedia of Geology, Elsevier Publishers, London, p 72-81, R. Hatcher (Jr), 2005.

Horton, 1991. Preliminary Tectonostratigraphic Terrane Map of the Central and Southern Appalachians, U.S. Geological Survey Miscellaneous Investigations Series Map I-2163, J. Horton, A. Drake, D. Rankin, and R. Dallmeyer, 1991.

COLA Impact

FSAR Section 2.5.1.1.2, Regional Geologic History, and Section 2.5.1.1.4, Regional Tectonic Setting, will be revised as shown in Enclosure 3 in a future revision of the COLA.

Question 02.05.01-35

In CCNPP Unit 3 FSAR Section 2.5.1.1.3, Regional Stratigraphy (p. 2.5-18), the text states, "...generalized stratigraphy within a 200 mi (322 km) radius of the CCNPP site is shown on Figure 2.5-5 and Figure 2.5-6." The regional stratigraphy is not illustrated in these figures. Please provide an illustration of regional stratigraphy that supports the discussion in Section 2.5.1.1.3.

Response

Illustrations of regional stratigraphy from the Precambrian to the Cenozoic are provided and will be included in the FSAR along with descriptive text. The revised figures are included as Figures 2.5-209 through 2.5-213 in the proposed revision to FSAR Section 2.5.1 as shown in Enclosure 3.

COLA Impact

FSAR Section 2.5.1.1.3, Stratigraphy, will be revised as shown in Enclosure 3 in a future revision of the COLA.

Question 02.05.01-36

CCNPP Unit 3 FSAR Section 2.5.1.1.3 describes the regional stratigraphy. The NRC staff has identified the following information needs for this section:

a. CCNPP Unit 3 FSAR Section 2.5.1.1.3.1.1, Pre-Cretaceous Basement Rock (p. 2.5-18), states, "The non-marine and marine sediments deposited in the Coastal Plain Physiographic Province overlie what are most likely foliated metamorphic or granitic rocks, similar to those cropping out in the Piedmont approximately 50 mi (80 km) to the northwest (Figure 2.5-5 and Figure 2.5-6)." A description of the crystalline rock found in several local basement boreholes is not integrated with the nearby, exposed portion of the Piedmont province immediately to the west of the site and with the locations of several buried Mesozoic rift basins in the site vicinity and region. Also, these crystalline rocks are not part of the Coastal Plain section. Please develop a more integrated discussion of the buried portion of continental margin.

b. On p. 2.5-19 of FSAR Section 2.5.1.1.3.1.1, the text states, "Because of the depth of Coastal Plain sediments, the basement rock type beneath the CCNPP site must be inferred based on surrounding borings and geophysical data." The existence of a Triassic basin beneath the site is important for the regional and vicinity tectonic setting for the site and perhaps for the site response evaluation. Please provide a more detailed development of the regional Mesozoic rift basin regime as it relates to the CCNPP site.

c. In Section 2.5.1.1.3.1.2, Cretaceous Stratigraphic Units (p. 2.5-19), the text states, "In Stafford, Prince William, and Fairfax counties in Virginia Lower Cretaceous Potomac Formation sediments were deposited unconformably on a narrow belt of Ordovician Quantico Slate and on the Cambrian Chopawamsic Formation (Mixon, 2000)." The text also states, "The Lower Cretaceous Potomac Group overlies a complex suite of basement rocks that includes strata as young as Triassic. Jurassic units appear to be missing north of the Norfolk Arch (Hansen, 1978) (Figure 2.5-12). The undulatory and east-dipping basement surface that underlies the Coastal Plain resulted from a combination of downwarping, erosion, and faulting. This has led to local variations in the slope of the bedrock surface." This information is part of the description of Paleozoic crystalline rock that is buried below the Coastal Plain section and not part of Cretaceous stratigraphy. Please integrate this information with the text in the FSAR Section 2.5.1.1.3.1.1, Pre-Cretaceous Basement Rock.

d. Also in Section 2.5.1.1.3.1.2 (p. 2.5-20), the text describes the tectonic evolution of the Salisbury Embayment to begin early in the Cretaceous period and to continue intermittently throughout the Cretaceous and Tertiary periods. This topic is actually discussing young tectonic movements on the continental margin. Please integrate this information with the discussion in FSAR Section 2.5.1.1.4.1.3, Cenezoic Passive Margin Flexural Tectonics (p 2.5-31).

Response

a. Hansen and Edwards (Hansen, 1986) contains descriptions of the lithologies of samples for various wells in Maryland that penetrated the Coastal Plain sediments to the underlying pre-Cretaceous basement. FSAR Section 2.5.1.1.3.1.1, Pre-Cretaceous Basement Rock, is intended to provide lithologic information on the lithologies encountered in a limited number of borings that characterize the surface beneath the Coastal Plain sedimentary sequence.

The relatively small core samples obtained from these borings do not permit a definitive correlation with a unique metamorphic rock unit outcropping in the Piedmont to the west. However, the three distinct belts of crystalline rock interpreted by Hansen and Edwards, shown in FSAR Figure 2.5-11, are based on borehole samples and regional geophysical data and can be associated with broad regional geologic terranes. A paragraph will be added to FSAR Section 2.5.1.1.3.2.1 to provide a discussion of the crystalline rocks encountered in several borings that penetrated Coastal Plain sediments into the underlying igneous or metamorphic rocks. FSAR Section 2.5.1.1.3.1.1 will be revised to refer to the discussion added to Section 2.5.1.1.3.2.1 and to incorporate a discussion of Mesozoic rocks within the Middle Belt and Outer Belt of the pre-Cretaceous Basement.

Reference:

Hansen, 1986. The Lithology and Distribution of Pre-Cretaceous basement rocks beneath the Maryland Coastal Plain, Department of Natural Resources Maryland Geological Survey Report of Investigations No. 44, p 27, H. Hansen and J. Edwards Jr, 1986.

b. Several authors have various interpretations of the occurrence of Mesozoic basins beneath the Atlantic Coastal Plain. These interpretations are often based on sparse, widely-spaced borehole data and geophysical data with variable degrees of resolution as discussed in the response to RAI 71, Question 02.05.01-26[1]. The FSAR will be revised to address this part of RAI 130, Question 02.05.01-36, as shown in the proposed revision to Section 2.5.1.1.4.4.3, Mesozoic Tectonic Structures, provided in Enclosure 3 and as discussed in the response to RAI 130, Question 02.05.01-43, Part b.

c. FSAR Section 2.5.1.1.3.1.1, Pre-Cretaceous Basement Rock and FSAR Section 2.5.1.1.3.1.2, Cretaceous Stratigraphic Units, will be revised to incorporate the requested information.

d. FSAR Section 2.5.1.1.4.1.3, Cenozoic Passive Margin Flexural Tectonics, will be revised to incorporate the requested information.

COLA Impact

FSAR Section 2.5.1.1.3, Stratigraphy, and FSAR Section 2.5.1.1.4, Regional Tectonic Setting, will be revised as shown in Enclosure 3 in a future revision of the COLA.

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[1] G. Gibson (UniStar Nuclear Energy) Letter UN#09-152 to Document Control Desk (NRC), "Response to Request for Additional Information for the Calvert Cliffs Nuclear Power Plant, Unit 3, RAI No. 71, Basic Geologic and Seismic Information, RAI No. 72, Vibratory Ground Motion" dated April 15, 2009.

Question 02.05.01-37

CCNPP Unit 3 FSAR Section 2.5.1.1.3.2 describes the regional stratigraphy under the heading Piedmont Physiographic Province (p 2.5-23).

a. Please provide a discussion of Piedmont geologic stratigraphy organized by lithotectonic terrane rather than physiographic province.

b. Please provide a more complete justification to support your statements about the stratigraphy of the crystalline, metamorphic rock within 200 miles of the site, including a discussion and evaluation of more recent interpretations available in current research.

c. In FSAR Section 2.5.1.1.3.2, the text states, ". . .the second is a set of Early Mesozoic (Triassic) age sedimentary rocks deposited locally in down-faulted basins within the crystalline rocks . . . ." Please revise the discussion of these rocks with respect to their own lithotectonic unit within the Mesozoic Rift basins in the regional geology.

d. FSAR Section 2.5.1.1.3.2.1, Crystalline Rocks (Late Precambrian and Paleozoic) states, "The rocks belong to a number of northeast-trending belts that are defined on the basis of rock type, structure and metamorphic grade (Bledsoe, 1980) . . . ." Please provide citations of the original work for these geologic terranes including more recent interpretations and conceptual models based on published, peer-reviewed research.

e. Please revise FSAR Figure 2.5-9 to include the 200 mile radius of the site, including the portions of the Central and Northern Appalachian and New England terranes that fall within the 200 mile radius.

f. In FSAR Section 2.5.1.1.3.2.1.1, Goochland-Raleigh Belt, Spears, 2002 is cited. This citation to an annual conference in Virginia does not appear to be a complete reference. Please provide a complete citation.

g. In FSAR Section 2.5.1.1.3.3, Blue Ridge Physiographic Province (p 2.5-26), please provide additional details and references about litho/stratigraphic information from the various geologic terranes within the 200 mile radius of the site.

h. In FSAR Section 2.5.1.1.3.4, Valley and Ridge Physiographic Province (p. 2.5-26), please provide additional details and references about litho/stratigraphic information from the various geologic formations within the province.

Response

a, b, c, g, and h:

The area within a 200-mile (322-kilometer) radius of the CCNPP site encompasses a small part of the southern Appalachian orogen, most of the central Appalachian orogen and a small transition zone between the central and northern Appalachian orogen as shown in FSAR Figure 2.5-200 provided in Enclosure 3. Based on publications by numerous investigators and evolving concepts in plate tectonics, the Appalachian orogen is recognized as a complex amalgamation of tectonostratigraphic terranes representing a sequence of events that took place across the surface of an earlier Earth. The conceptual model proposed by Hatcher (1987) included in this FSAR as Figure 2.5-8, is over 20 years old yet still summarizes the sequence of events and some of the major tectonostratigraphic terranes represented in the rock units within a 200-mile radius of the CCNPP site.

An important aspect of Appalachian geology that can confuse investigators who try to describe the stratigraphy of the region is that the usual means of describing a stratigraphic assemblage is to summarize the lithologic and depositional characteristics of rock units from basement to surface. This approach generally represents the order in which the rocks were deposited or emplaced. From an evolving synthesis of local and regional studies of the exposed basement rocks of the Appalachian orogen, an understanding is emerging of the multiple episodes of extension and collision, the latter involving brittle and ductile thrusting and faulting, interspersed with magmatic and metamorphic overprinting. The complexity of the timing and distribution of terranes, tectonic events and depositional environments involved in the Appalachian orogeny is what makes Appalachian stratigraphy difficult to synthesize.

The pre-Silurian stratigraphic units as they relate to the development and movement of the tectonostratigraphic terranes are described and illustrated in FSAR Figure 2.5-9. Silurian and later units are described in a more traditional manner with reference to the geologic map illustrated in FSAR Figure 2.5-5 and described in FSAR Figure 2.5-6.

FSAR Figure 2.5-9 is based on a synthesis by Horton (1991). Horton's recognition of the boundaries of the tectonostratigraphic terranes is valid, though his interpretation of the provenance and geologic history of each terrane reflects the understanding at the time almost twenty years ago. The organization of the stratigraphic discussion in this FSAR section incorporates more recent understandings of the provenance and history of the pre-Silurian tectonostratigraphic terranes that became a part of the North American continental margin by the end of the Allegheny orogeny. The more recent understanding of pre-Silurian tectonostratigraphic terranes in the southern and northern Appalachians has been recently summarized by Hatcher (2007) and Hibbard (2007). Therefore, the characterization of the tectonostratigraphic terranes that follows differs from Horton, 1991.

References:

Hatcher, 1987. Tectonics of the southern and central Appalachian internides, Annual Reviews of Earth and Planetary Science, Volume 15, 9337-362, R. Hatcher, 1987.

Horton, 1991. Preliminary Tectonostratigraphic Terrane Map of the Central and Southern Appalachians, U. S. Geological Survey Miscellaneous Investigations Series Map I-2163, J. Horton, A. A. Drake, D. Rankin and R. Dallmeyer, 1991.

Hibbard, 2007. A Comparative Analysis of Pre-Silurian Crustal building Blocks of the Northern and the Southern Appalachian Orogen, American Journal of Science, Volume 307, p. 23-45, J. P. Hibbard, C. R. van Staal and D. W. Rankin, 2007.

Hatcher, 2007. Tectonic map of the southern and central Appalachians: A tale of three orogens and a complete Wilson cycle, in Hatcher, R. D., Jr. 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, R. D. Hatcher (Jr), B. R. Bream and A. J. Merchat, 2007.

d. The FSAR text has been revised to address the questions in RAI 130. Since the discussions of Appalachian geology are now focused on lithostratigraphic terranes rather than lithotectonic belts, references to Bledsoe (1980) have been deleted.

e. FSAR Figure 2.5-9 has been revised to show the 200-mile radius, the site location and the terranes in the portions of the Central and Northern Appalachian and New England that fall within the 200 mile radius. The revised figure is modified from Horton and others, 1991, and is part of the proposed COLA revision associated with the response to RAI 130, Question 02.05.01-34 shown in Enclosure 3.

Reference:

Horton, J.W., Drake, A.A., Rankin, D.W., and Dallmeyer, R.D., 1991, Preliminary Tectonostratigraphic Terrane Map of the Central and Southern Appalachians, U.S. Geological Survey, Miscellaneous Investigation Series Map I-2163.

f. The citation for Spears, 2002, has been corrected.

Reference:

Spears, 2002. Geology of the central Virginia Piedmont between the Arvonia syncline and the Spotsylvania high-strain zone, Thirty-Second Annual Virginia Geological Field Conference Guidebook, Charlottesville, Virginia, October 11-13, Virginia Division of Mineral Resources, p 36, D. Spears and C. Bailey, 2002.

COLA Impact

FSAR Section 2.5.1.1.3, Stratigraphy, will be revised as shown in Enclosure 3 in a future revision of the COLA.

Question 02.05.01-38

CCNPP Unit 3 FSAR Section 2.5.1.1.4.1.1, Late Proterozoic and Paleozoic Plate Tectonic History, states, "Suturing events that mark the welding of continents to form supercontinents and rifting events that mark the breakup of supercontinents to form ocean basins have each occurred twice during this interval." This statement does not reflect the most current conceptual models for the eastern continental margin. From Late Proterozoic through the end of the Paleozoic there are 5 major collisions with at least one continental rifting (Rodinia) (Faill, 1997a, 1997b, and 1998). Please revise the discussion in this section to include the most up to date tectonic evolution models reflected in the professional literature.

Response

The statement within FSAR Section 2.5.1.1.4.1.1 describes the observation that there have been two complete cycles of collision and rifting (i.e., Wilson cycles) along the eastern margin of present day North America since late Precambrian time. The statement was not intended to imply that there have been only two collisional events as is implied by the RAI question. The FSAR text will be revised to clarify this point and describe the cycles in additional detail.

COLA Impact

FSAR Section 2.5.1.1.4.1.1, Late Proterozoic and Paleozoic Plate Tectonic History, will be revised as shown in Enclosure 3 in a future revision of the COLA.

Question 02.05.01-39

CCNPP Unit 3 FSAR Section 2.5.1.1.4.1.3 discusses aspects of Cenozoic Passive Margin Flexural Tectonics, including the development and evidence of the continental margin arches and embayments.

a. On page 2.5-31 the text states, "Margin-parallel variations in the amount of uplift and subsidence have created arches (e.g., South New Jersey and Norfolk Arches) and basins or embayments (e.g., Salisbury Embayment) along the Coastal Plain and Continental Shelf (Figure 2.5-12)." Provide an explanation of margin parallel uplift/subsidence creating arches that are perpendicular to the margin. Please substantiate the most recent thought on these features with citations to original work.

b. On page 2.5-32, the text states, "It is suggested (Pazzaglia, 1994) that low rates of contractional deformation on or near the hinge zone documented on Cenozoic faults may be a second-order response to vertical flexure and horizontal compressive stresses." Please provide additional details about this interpretation and the significance for potential seismogenic faults.

c. On page 2.5-32 the text states, "Subsequent studies performed during the North Anna ESP study demonstrates that the fall lines (Weems, 1998) are erosional features and not capable tectonic sources (NRC, 2005) (Section 2.5.1.1.4.4.5.1)." Please provide pertinent details and summarize conclusions from the North Anna work, especially as it relates specifically to CCNPP.

Response

a. As discussed in FSAR Section 2.5.1.1.4.1.3 and shown in FSAR Figure 2.5-12, the Atlantic margin of North America is characterized by a series of alternating regions with thicker sedimentary sections and thinner sedimentary sections referred to as embayments and arches, respectively. Also as discussed in Section 2.5.1.1.4.1.3, the processes responsible for the formation and maintenance of the arches and embayments are not well understood and not universally agreed upon. Most researchers acknowledge that the basic cause of the contrasting stratigraphic thicknesses above the embayments and arches is differential subsidence that likely began occurring during establishment of the embayments in the mid-Cretaceous and continued through the Tertiary (e.g., Barosh, 1990; Olsson, 1978; Poag, 1997; Ward and Powars, 2004; Wyer and Watts, 2006). While in the most basic sense this differential subsidence is gravity driven and reflects a flexural response of the lithosphere to loading, there is no one clear explanation for what controls the pattern of subsidence. In addition, it is not evident that the apparent arches and embayments of the Atlantic margin have a common causative mechanism. Several of the more commonly cited causes for the differential subsidence are:

- Sub-perpendicular block faults and zones of weakness (e.g., transform fault zones from opening of the Atlantic) along the margin, potentially involved in wrench faulting, that allow for differential subsidence (Barosh, 1986; Brown, 1978; Brown et al., 1972; Olsson, 1978; Powars et al., 1992; Sheridan, 1974; Ward and Powars, 2004);
- Apparent increased subsidence due to stratigraphic thickening of Chesapeake Bay impact related breccia along near the proposed Norfolk arch (Poag, 1997); and

- Variations in the elastic thickness of the lithosphere (i.e., variations in the ability of the lithosphere to resist flexure) caused by compositional variability, preexisting crustal weaknesses and structures, amount of crustal thinning during rifting, and thermal structure of the lithosphere (Austin et al., 1990; Wyer and Watts, 2006).

As part of the effort in preparing Section 2.5.1, available new information and data was reviewed that could motivate a revision to the EPRI SOG model. Through this extensive review, it was determined that there are no capable tectonic sources within the CCNPP Unit 3 site region. Thus, the mechanism that created the arches/embayments has either ceased or is an aseismic process.

b. The statement within the FSAR regarding the relationship between the low rates of contractional deformation and flexure is based on the work of Pazzaglia and Gardner (1994). Through simple one-dimensional elastic beam models, Pazzaglia and Gardner (1994) demonstrate that the paired epeirogenic uplift of the Appalachian Piedmont and subsidence of the Salisbury Embayment can be explained by the flexural response of the lithosphere to erosional unloading in the Appalachians, deposition within the coastal plain and offshore regions, and eustasy. Pazzaglia and Gardner (1994) propose that the transition from flexural induced uplift to subsidence occurs across a convex-up flexural hinge that is physiographically manifested as the Fall Line. Pazzaglia and Gardner (1994) explicitly conclude that flexural isostasy is the first order cause of uplift and subsidence across the Appalachians and coastal plain and thus is the first order case of the Fall Line.

   The comment within the FSAR that is the subject of the RAI question restates a minor hypothesis also presented by Pazzaglia and Gardner (1994). They hypothesize that there may be secondary tectonic processes that contribute to the steeper gradient observed across the Fall Line. Pazzaglia and Gardner (1994) do not explicitly state what tectonic processes they would propose, but they imply that the tectonic process they are referring to is faulting. Pazzaglia and Gardner (1994) provide very limited discussion of this hypothesis, provide no information hypothesizing when such tectonic processes may have been active, and present essentially no evidence to support the existence of faults along the Fall Line.

   FSAR Sections 2.5.1.1.4.1.3 and 2.5.1.1.4.4.5.1 also describe the work of Weems (1998) where he identified several fall lines (alignments of steep river gradients) coincident with the Fall Line further south of the Pazzaglia and Gardner (1994) study region. Weems (1998) hypothesized that the fall lines may be due to tectonic faulting active within the last 2 Ma. Weems' (1998) work explicitly raises the issue of whether there is faulting associated with the Fall Line, and, as discussed in FSAR Section 2.5.1.1.4.1.3 and 2.5.1.1.4.4.5.1, studies performed for the Dominion Nuclear application for an Early Site Permit (ESP) at the North Anna site have demonstrated that the fall lines are erosional features and do not represent capable tectonic features (Dominion Nuclear, 2006; NRC, 2005).

   Based on the lack of information demonstrating fault control of the Fall Line, the lack of information demonstrating Quaternary activity of potential faults along the Fall Line, and the conclusion that fall lines in some areas are erosional features, it was concluded that there is no hazard implication for the CCNPP site from the hypothesis of Pazzaglia and Gardner (1994) that tectonic processes may be a secondary control on the Fall Line.

c. A clear and succinct summary of the issues regarding the potential capability of the fall lines identified by Weems (1998) and their resolution as addressed in the North Anna ESP and associated RAIs is presented within the NRC's Safety Evaluation Report (SER) for the North Anna site (NRC, 2005). As described in FSAR Section 2.5.1.1.4.1.3 and 2.5.1.1.4.4.5.1, these efforts were used as the basis to conclude that the fall lines presented by Weems (1998) are erosional features and not capable faults that need to be considered for the CCNPP site. However, as part of the effort in preparing Section 2.5.1, available new information and data was reviewed that might motivate a revision to the conclusion that the fall lines were erosional features. This review did not uncover any new information of data suggesting a revision to the conclusion was needed.

The following text is taken from Section 2.5.1.3.1 of the SER for the North Anna site (NRC, 2005) and provides a summary of the pertinent information for the CCNPP site with respect to potential capability of the fall lines identified by Weems (1998) and their resolution as addressed in the North Anna ESP.

The applicant also identified the seven fall lines across the Piedmont and Blue Ridge provinces of North Carolina as another potential Quaternary tectonic feature. Weems identified these seven fall lines (Weems, 1998), which are based on the alignment of short stream segments with anomalously steep gradients. Because other studies of potential tectonic features in the CEUS do not include the seven fall lines identified by Weems, the applicant concluded that they do not represent a capable tectonic source. In its response to RAI 2.5.1-3, the applicant stated that Weems does not present direct credible evidence for a tectonic origin of the fall lines. The applicant stated that the fall lines described by Weems are not defined by formal, consistently applied criteria, and thus are not as well defined and laterally continuous as depicted. In particular, Weems selectively correlated different features to form a laterally continuous fall line, while in other cases similar features are not correlated. The applicant also stated that, based on its evaluation of the stratigraphic, structural, and geomorphic relations across and adjacent to the fall zones, differential erosion resulting from variable bedrock hardness is a more plausible explanation than Quaternary tectonism. As part of its response to RAI 2.5.1-3, the applicant presented a detailed analysis of geologic and geomorphic data to support its conclusion that the fall lines are not tectonic features. This analysis shows that Weems postulated three hypotheses for the origins of the fall lines in the Blue Ridge and Piedmont provinces:

(1) variable erosion across linear belts of rocks of varying hardness

(2) late Cenozoic climatic and sea level fluctuations, producing "waves" of headwater-retreating nick points that are expressed as fall zones and fall lines

(3) localized neotectonic uplift along fall lines

Weems rejected the first two hypotheses, stating that control of fall lines by rock hardness "is true only locally and occurs as a consequence of uplift." He also stated that climatic control does not adequately explain the observed patterns of fall lines. Weems concluded that tectonic uplift "is the dominant cause of the existing Piedmont fall lines" because neither differential rock erosion, nor regional creation of nick points by climate-driven changes in fluvial patterns, could "adequately explain the observed patterns." The applicant concluded that Weems adopted a tectonic interpretation primarily because the alternative interpretations were less compelling, and not because of direct evidence supporting a tectonic origin. The applicant also found that it was unable to reproduce Weems' delineation of individual fall zones or his correlations of fall zones as laterally *continuous fall lines. In summary, the applicant found that Weems' model for the lateral continuity of fall lines for hundreds of miles along trend in the Blue Ridge and Piedmont provinces is based on subjective assessments of some steep stream reaches as anomalous fall zones.*

To further assess the claims made by Weems, the applicant conducted geomorphic analyses of the Tidewater and Central Piedmont fall lines because these two features lie within the North Anna site vicinity. Concerning the Tidewater fall line, the applicant found that a profile of Pliocene marine sand shows no deformation across the Tidewater fall line at the Rappahannock River. The applicant also found that a very strong correlation exists between variations in rock type and gradient changes in the South Anna River profile that strongly suggests that the Tidewater fall line formed as a result of variable erosion across rocks of varying hardness. Concerning the Central Piedmont fall line, the applicant found that the increased gradients along the Rapidan and Rappahannock Rivers as they exit the Culpeper Basin are associated with Jurassic igneous rocks and Paleozoic metamorphic rocks, not Triassic basin sediments as stated by Weems. The applicant stated that the observed gradient as the streams leave the basin is explained by differential erosion of bedrock without invoking tectonic deformation along the Central Piedmont fall line.

Based on the evidence cited by the applicant in response to this RAI, in particular the applicant's evaluation of the stratigraphy and structural relations associated with the fall zones, the staff concludes that the applicant has accurately characterized the seven fall lines as nontectonic features. The staff concurs with the applicant's interpretation that differential erosion resulting from variable bedrock hardness is a more plausible explanation than Quaternary tectonism for the fall lines. The staff notes that evidence for the existence of the seven fall lines as a Quaternary tectonic feature is based solely on the work of Weems and that other geologists have not made this inference" (pages 2-163 to 2-165) (NRC, 2005).

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COLA Impact

The COLA FSAR will not be revised as a result of this response.

Question 02.05.01-40

In CCNPP Unit 3 FSAR Figure 2.5-23 (p. 2.5-336), which is referred to in FSAR Section 2.5.1.1.4.4.2, Paleozoic Tectonic Structures, there are several overlapping interpretations of fault lines and it is difficult to understand what the double lines mean with respect to the discussion in text. Please simplify and integrate aspects of the figure with the discussion in the text in Section 2.5.1.1.4.4.2.

Also, in FSAR Section 2.5.1.1.4.4.2, the text states, "The northeast-striking Little North Mountain Fault Zone [LNMF] is located within the eastern Valley and Ridge Physiographic Province of western Virginia, eastern Maryland, and southern Pennsylvania (Figure 2.5-16 and Figure 2.5-23)." The LNMF is not actually identified on Figure 2.5-16. Please revise the figure to clearly show the LNMF.

Response

The above question requests a simplification to the FSAR Figure 2.5-23 and an integration of aspects of the figure with the discussion in the text Section 2.5.1.1.4.4.2, Paleozoic Tectonic Structures.

The discussion in FSAR Section 2.5.1.1.4.4.2 highlights the principal tectonic structures and seismicity within the 200-mile radius. As discussed in Section 2.5.1.1.4.4.2.1, Appalachian Structures, the major Paleozoic structures of the Appalachian Mountains within the site region (200-mile radius) include the Little North Mountain-Yellow Breeches fault zone, Hylas shear zone, Mountain Run-Pleasant Grove fault system, Brookneal shear zone, and the Central Piedmont shear zone. These structures bound lithotectonic units as defined in recent literature (Horton, 1991) (Glover, 1995b) (Hibbard, 2006) (Hibbard, 2007). FSAR Figures 2.5-16, 2.5-17, and 2.5-19 illustrate the distribution of these lithotectonic units and the interpreted down-dip geometry of these structures discussed in the FSAR text. As presented in the FSAR text, these figures should be used in concert with FSAR Figure 2.5-23. The purpose of FSAR Figure 2.5-23 is to illustrate the available regional data on one figure throughout the site region including seismicity, physiography, detailed fault traces, and principal tectonic structures. The NRC staff is correct that many of the mapped fault traces by Hibbard (2006) are complex. The mapping by Hibbard provides an understanding of the complexity of Paleozoic faults in the site region. However, the major Paleozoic faults (e.g., principal tectonic structures) shown on FSAR Figure 2.5-16 are highlighted on FSAR Figure 2.5-23 as green faults. To further emphasize these principal fault traces, FSAR Figure 2.5-23 has been revised to further emphasize the mapped location of these structures.

As requested by the NRC staff, FSAR Figure 2.5-16 has been revised to clearly label the Little North Mountain fault.

References:

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Horton, 1991. Horton, J.W., Drake, A., Rankin, D., and Dallmeyer, R., Preliminary Tectonostratigraphic Terrane Map of the Central and Southern Appalachians, U.S. Geological Survey Miscellaneous Investigations Series Map I-2163, 1991.

COLA Impact

FSAR Figure 2.5-16 and 2.5-23 will be revised, as shown in Enclosure 3, in a future revision of the COLA.

Question 02.05.01-41

The following questions apply to CCNPP Unit 3 FSAR Section 2.5.1.1.4.4.2.1, Appalachian Structures.

a. On page 2.5-42, the text states, "The Hylas shear zone also locally borders the Mesozoic Richmond basin and appears to have been reactivated during Mesozoic extension to accommodate growth of the basin (Figure 2.5-10)." Since the fault was reactivated during Mesozoic time please address this structure in the Mesozoic section rather than in the section about Paleozoic structures. Please provide additional citations including more recent interpretations about this tectonic structure based on published literature.

b. On page 2.5-42, the text states, "Subsequent studies performed during the North Anna ESP (Dominion, 2004a) on the activity of the Everona-Mountain Run fault system indicate that this fault system is not a capable tectonic source (Section 2.5.1.1.4.4.5.2)." Please summarize in FSAR Section 2.5.1.1.4.4.2.1 or 2.5.1.1.4.4.5.2 the pertinent details from that document. Also, please clarify the name and extent of the fault; is it the Mountain Run Pleasant Grove system or is it the Everona Mountain Run fault system?

c. On page 2.5-42, the text states, "The Brookneal shear zone is located within the Piedmont in Virginia and probably extends beneath the Coastal Plain across Virginia and Maryland to within about 50 mi (80 km) of the site (Figure 2.5-16 and Figure 2.5-23)." This feature is not labeled on Figure 2.5-16. Please revise figure to identify the Brookneal shear zone.

d. On page 2.5-42, the text states, "Southwest of the site region, the Mesozoic Danville basin locally coincides with the Brookneal shear zone, suggesting that portions of the Paleozoic fault may have been reactivated as normal faults in the Triassic period." Please provide more information about how this correlation was determined and provide a reference for this interpretation.

e. On page 2.5-43, the text states, "The fault [Spotsylvania] juxtaposes terranes of different affinity, placing continental rocks of the Goochland terrane to the east against volcanic arc rocks of the Chopawamsic terrane to the west." Please provide more details about this structure. What is the likely geologic age for movement on this fault? How is it genetically linked with the Central Piedmont suture?

Response

a. The Hylas shear zone and evidence for Mesozoic reactivation is addressed in the revision to FSAR Section 2.5.1.1.4.4.3, Mesozoic Tectonic Structures, as part of the response to RAI 130, Question 02.05.01-43. The text addresses potential Mesozoic and early Tertiary reactivation of the northern Hylas shear zone (bounding structure for the northern Taylorsville basin) as responsible for the Brandywine, Port Royal, and Skinker's Neck faults in Section 2.5.1.1.4.4.4, Tertiary Tectonic Structures. That clarification is discussed in the response to RAI 130, Question 02.05.01-46. As requested, Section 2.5.1.1.4.4.2.1, Appalachian Structures, has been revised to provide additional citations from the peer reviewed literature.

   Additional published papers evaluating the Hylas shear zone (also called Hylas zone, Hylas mylonite zone, and Hylas fault zone) subsequent to the one currently cited (Bobyarchick and

Glover, 1979, or Bobyarchick, 1979 in the FSAR text) include Bobyarchick (1988), Gates and Glover (1989) and Hibbard et al. (2006). Gates and Glover (1989) refine the likely dates of dextral faulting of the Hylas zone (ceased prior to ca. 240 Ma) and further describe the ductile, brittle-ductile transitional, and brittle strain features of the shear zone. Bobyarchick (1988) discusses the Hylas zone as part of a regional kinematic framework of Alleghanian ductile strike-slip faults representing late Paleozoic reactivation of sutures and thrust faults as rightlateral strike-slip faults that sole into subhorizontal detachment faults at upper- to mid-crustal depths. Hibbard et al. (2006) shows the connectivity of the Hylas shear zone with other rightlateral ductile fault zones to the southeast such as the Nutbush Creek fault, Lake Gordon shear zone, and Hollister fault. The mapping of Hibbard et al. (2006) is a compilation of previously published mapping (e.g., Virginia Division of Mineral Resources, 1993) plus additional mapping presented in meeting abstracts and field trip guide books, and thus represents the best recently published map showing the Hylas shear zone and its structural relationship with adjacent features (Figure 2.5-23). Based on a detailed review of the published literature to prepare FSAR Section 2.5.1 and a subsequent literature search to respond to this RAI question, no publications were found subsequent to Bobyarchick and Glover (1979) that suggest seismic, geomorphic, or geologic evidence that the Hylas shear zone has been active in the Quaternary Period (e.g., Crone and Wheeler, 2000; Wheeler, 2006).

b. The response to this question is divided into two parts:

1. Please clarify the name and extent of the fault; is it the Mountain Run-Pleasant Grove system or is it the Everona-Mountain Run fault system.
2. Please summarize in FSAR Sections 2.5.1.1.4.4.2.1 or 2.5.1.1.4.4.5.2 the pertinent details from the Dominion (2004a) report.

Part b.1 is addressed first to clarify terminology, and Part b.2 discusses the Dominion (2004a) report.

<u>Part b.1:</u>

This part of the question refers to the last two sentences of paragraph 6 of FSAR Section 2.5.1.1.4.4.2.1:

In northern Virginia, about 70 mi (113 km) west of the site, the Everona fault was identified within Tertiary, and possibly early Quaternary, debris flow deposits (Pavlides et al., 1983) (Pavlides, 1986). Subsequent studies performed during the North Anna ESP (Dominion, 2004a) on the activity of the Everona-Mountain Run fault system indicate that this fault system is not a capable tectonic source (Section 2.5.1.1.4.4.5.2).

These sentences introduce the term "Everona fault" for the first time in the FSAR document, then introduce the term "Everona-Mountain Run fault system" in a way that is confusing.

The text in paragraph 6 of FSAR Section 2.5.1.1.4.4.2.1 and the corresponding labeled fault in FSAR Figure 2.5-23 describe the Mountain Run-Pleasant Grove fault system. The specific name "Mountain Run-Pleasant Grove fault system" is not found in the literature, but is used informally in the FSAR document to describe the generally northeast-striking, southeast dipping zone of faults within the CCNPP site region (200-mile radius) that approximately form the boundary between rocks of the Piedmont province (consisting of metamorphosed mélange and island arcrelated rocks exotic to ancestral North America) and rocks of the Blue Ridge and Valley and Ridge provinces (consisting of metamorphosed continental margin deposits of ancestral North America, or Laurentia) as defined and described by Pavlides (1989), Mixon et al. (2000), and Hibbard et al. (2006). This thrust system extends the entire length of the Southern and Central Appalachian Orogen and at the orogenic scale it is called the "Hollins Line – Pleasant Grove fault system" based on the fault names near either end (Hibbard et al., 2007). Major components of this thrust fault system developed prior to about 450 Ma (Pavlides, 2000). From southwest to northeast, the faults within the site region include, but are not limited to, the Bowens Creek fault, Mountain Run fault, Pleasant Grove fault, and Huntingdon Valley fault (Hibbard et al., 2006; Horton et al., 1991). This system is shown at regional scale juxtaposing the Potomac terrane of the Piedmont province against various terranes of the Blue Ridge and Valley and Ridge province in FSAR Figure 2.5-16 and revised FSAR Figure 2.5-9 (Horton et al., 1991).

In contrast, the "Everona-Mountain Run fault system" is not industry recognized. The Mountain Run fault zone is a ~75-mile (~120-kilometer) long, broad (up to 4-5 km wide) fault zone containing sheared rocks, phyllonites, mylonites, breccias, and phyllites having fish-scale structure (Pavlides, 1994; Pavlides, 2000). The Mountain Run fault zone as commonly named extends from the south-eastern margin of the Culpeper basin southeastward to at least the small Scottsdale basin near Scottsdale, Virginia (Horton et al., 1991) (FSAR Figure 2.5-16 and revised FSAR Figure 2.5-9). The fault zone dips southeast and is developed within mélange rocks of the Potomac terrane (including the Mine Run Formation) of the Piedmont province, although locally the zone of shearing extends across the tectonostratigraphic terrane boundary and involves the Blue Ridge (continental margin)-affiliated True Blue Formation strata (Pavlides, 1994; Pavlides et al., 1989; Mixon et al., 2000). A simplified geologic map of this fault zone and cross sections within the Fredericksburg 30' x 60' Quadrangle (Mixon et al., 2000) are reproduced as Figures 1 and 2.

Within the Mountain Run fault zone, near the western edge of the Fredericksburg quadrangle, is the Everona fault. The Everona fault was named by Crone and Wheeler (2000) (or Crone, 2000 in the FSAR text) as part of their investigation of possible Quaternary faults in the Central and Eastern United States. The Everona fault is the name given to a "small" northeast-striking, northwest-dipping brittle fault within the Mountain Run fault zone that offsets crystalline basement of the True Blue Formation (Blue Ridge province) over a late Cenozoic gravel deposit as described in an outcrop near the town of Everona (Pavlides et al., 1983; Manspeizer et al., 1989; Pavlides, 1994; Crone and Wheeler, 2000). The location of the outcrop exposure is indicated in Figure 1. Based on interpretation from the literature, the term "Everona fault" as used by Crone and Wheeler (2000) pertains only to the single, temporary exposure documented during grading on private property documented by Pavlides et al. (1983), and does not specifically refer to a fault with clear mapped fault length. Mixon et al. (2000) do show a bedrock fault trace defining the western margin of the Mountain Run fault zone running approximately through the Everona fault exposure (Figure 1), although in cross section this fault is shown to dip southeast with the rest of the Mountain Run fault zone (Figure 2). According to Pavlides et al., (1983) and Pavlides (1986), the fault exposure near Everona is a part of the wider Mountain Run fault zone.

The terms "Everona-Mountain Run fault system" and "Everona-Mountain Run fault zone" are inconsistent with the naming conventions used by other authors.

To clarify and avoid future confusion, the FSAR text will be modified to use the terms "Mountain Run-Pleasant Grove fault system" when discussing the early Paleozoic lithotectonic boundary fault system, and the term "Mountain Run fault zone" when discussing Mesozoic and potential Cenozoic tectonic features. The "Everona fault" will be clearly defined as the exposure of a brittle fault within the Mountain Run fault zone seen locally near the town of Everona, Virginia, consistent with the interpretation of Pavlides et al. (1983) and the mapping of Mixon et al. (2000).

Please refer to the response to RAI 130, Question 02.05.01-51 for revision to FSAR Section 2.5.1.1.4.4.5 discussing the Everona fault.

<u>Part b.2:</u>

The NRC staff requests a summary of the pertinent details of the North Anna ESP (Dominion, 2004a) that indicate the "Everona-Mountain Run" fault system is not a capable tectonic source. In response to this question, the text will be revised to clearly state that the new information presented by Dominion (2004a) addresses the activity of two geomorphic features in the Mountain Run fault zone that previous investigations suggested were formed by Tertiary or Quaternary activity: the Mountain Run scarp and the Kelly's Ford scarp (Pavlides, 1986; Pavlides, 1994; Crone and Wheeler, 2000; Pavlides, 2000). These scarps are indicated on Figure 1. The new information gathered for the North Anna ESP application (Dominion, 2004a) does not directly address other major faults within the Mountain Run-Pleasant Grove fault system, nor does it directly address the specific fault exposure near Everona. The pertinent details in Dominion (2004a) that address the origin of the Mountain Run scarp and Kelly's Ford scarp, and by extension the activity of the Mountain Run fault zone, are summarized in paragraph 5 of FSAR Section 2.5.1.1.4.4.5.2. That paragraph states:

> *Field and aerial reconnaissance, and geomorphic analysis of deposits and features associated with the fault zone, recently performed for the North Anna ESP provide new information on the absence of Quaternary faulting along the [Everona-]Mountain Run fault zone (Dominion, 2004a). In response to NRC comments for the North Anna ESP, geologic cross sections and topographic profiles were prepared along the Mountain Run fault zone to further evaluate the inferred tectonic geomorphology coincident with the fault zone. The results of the additional analysis were presented in the response to an NRC Request for Additional Information (RAI) (Dominion, 2004a) and are summarized below:*
>
> - *There is no consistent expression of a scarp along the Mountain Run fault in the vicinity of the Rappahannock River. The northwest-facing Kelly's Ford scarp is similar to a northwest-facing scarp along the southeastern valley margin of Mountain Run; both scarps were formed by streams that preferentially undercut the southeastern valley walls, creating asymmetric valley profiles.*
> - *There is no northwest-facing scarp associated with the Mountain Run fault zone between the Rappahannock and Rapidan Rivers. Undeformed late Neogene colluvial deposits bury the Mountain Run fault zone in this region, demonstrating the absence of Quaternary fault activity.*

- *The northwest-facing "Mountain Run" scarp southwest of the Rappahannock River alternates with a southeast-facing scarp on the opposite side of Mountain Run valley; both sets of scarps have formed by the stream impinging on the edge of the valley.*

The relevant new figures generated for the North Anna ESP application by Dominion (2004a) that address the scarps include a map and nine profiles; these figures are reproduced here as Figures 3 to 8. Figure 3 (corresponding to Figure 1 of Dominion (2004a)) shows the section of the geologic map by Mixon et al. (2000) that includes the Mountain Run and Kelly's Ford scarps, and the locations of the profiles with simplified geology across the Mountain Run fault zone along and between the two scarps. Figures 5 to 8 show the nine profiles. Profile A (upper profile in Figure 5) crosses the Kellys Ford scarp, and profiles G, H, and I (Figure 8) cross the Mountain Run scarp. Profiles B through F cross the Mountain Run fault zone between the two geomorphic features.

The main findings of Dominion (2004a) are two-fold: (1) the scarp locations correlate with reaches where streams impinge on valley margins, suggesting that fluvial erosion and not neotectonic faulting is the principal geomorphic process, and (2) unfaulted Tertiary deposits appear to overlie key faults within the Mountain Run fault zone between the identified scarps. In support of the first finding, Dominion (2004a) showed that the northwest-facing scarps identified as potential tectonic geomorphic features coincide with areas where streams have impinged on the southeast side of the valley (e.g., profiles A, G). Southeast-facing scarps are present locally along Mountain Run where the stream has impinged on the northwest valley margin, with no associated faulting (e.g., profile I). There are no scarps coincident with the Mountain Run fault zone where there are no streams flowing parallel to it (e.g., profiles C-F). Thus, lateral cutting of the stream channel combined with lithologic variations in erosion resistance explain the morphology of the scarps well, and tectonically recent faulting is not required. In support of the second finding of Dominion (2004a), profiles C through F (Figures 6 and 7) cross the Mountain Run fault zone where it crosses a broad, northwest-facing slope mantled by late Neogene colluvial deposits (unit QTc in Figure 3). Along this portion of the Mountain Run fault, which is located between the two identified scarps, the western margin of the Mountain Run fault zone is mapped as a dashed line through the QTC unit. The profiles, however, show no suggestion of a scarp associated with the fault, and there is no geologic or geomorphic indication (e.g., truncation of the unit or a scarp on the surface of the unit) supporting the interpretation that the QTc unit is offset by the fault.

Based on their analysis, Dominion (2004a) concluded that the Mountain Run and Kelly's Ford scarps are fluvial features and were not created by late Cenozoic tectonic displacements along the Mountain Run fault zone. Regarding the broader Mountain Run fault zone, the North Anna ESP SSAR (Dominion, 2006) concluded that the information on timing of displacement of the Mountain Run fault zone and associated faults was available and incorporated into the EPRI seismic source models in 1986, and no new significant information has been gathered since 1986 regarding the activity of the Mountain Run fault zone.

In summary, the new information gathered for the North Anna ESP application does not directly address other major faults within the Mountain Run-Pleasant Grove fault system, nor does it directly address the specific fault exposure near Everona. As part of the response, FSAR Section 2.5.1.1.4.4.2.1 will be revised to clarify the basis for the determination that the Mountain Run-Pleasant Grove fault system is not considered to be a capable tectonic source. Included in the revision will be reference to sections in the FSAR on the Mesozoic tectonics (Section 2.5.1.1.4.4.3) and Quaternary tectonics (2.5.1.1.4.4.5) where the Mountain Run fault zone and Everona fault are discussed.

c. As requested FSAR Figure 2.5-16 has been revised to identify the Brookneal shear zone. Please refer to the revised version of Figure 2.5-16 as provided in Enclosure 3.

d. The FSAR text cited in the RAI question refers to the spatial relationship between the Mesozoic Danville basin and the Brookneal shear zone, and speculated that portions of the Brookneal shear zone may have reactivated as normal faults to accommodate Triassic rifting. Further review of map data (e.g., Hibbard et al., 2006; Horton et al., 1991) and summary papers (e.g., Swanson, 1986; Schlische, 1993; 2003) suggests that the Danville basin overlies the Brookneal shear zone, but the basin margin appears to overlie the fault as a depositional contact and is not cut by the fault. Therefore, the Brookneal shear zone probably was not reactivated during Triassic rifting. The Danville basin is mentioned in the literature as having formed by Mesozoic reactivation of Paleozoic faults (e.g., Swanson, 1986). However, Swanson (1986) states that the Stony Ridge fault—a probable extension of the Chatham fault—is, "the dominant preexisting structural control for the development of the Danville basin." The Chatham fault is located northwest of the Brookneal shear zone and between the Brookneal shear zone and the Mountain Run-Pleasant Grove fault system. The northeastern end of the Chatham fault zone—as shown by Hibbard et al. (2006) and Horton et al. (1991)—coincides approximately with the northeast end of the Danville basin.

In response to this section of the RAI question, the text for FSAR Section 2.5.1.1.4.4.2.1 will be revised and clarified that the cross-cutting relationship between the Danville basin and the Brookneal shear zone is unfaulted. Revised text for FSAR Section 2.5.1.1.4.4.3, Mesozoic Tectonic Structures, will include a brief discussion of the Danville basin as part of the response to the RAI 130, Question 02.05.01-43.

e. As discussed in FSAR Section 2.5.1.1.4.4.2.1, the Spotsylvania fault is a dextral-reverse fault that juxtaposes terranes of different affinity.

The Spotsylvania fault juxtaposes Proterozoic continental rocks of the Goochland terrane to the east against early Paleozoic (Ordovician) volcanic island arc (and successor basin) rocks of the Chopawamsic terrane to the west (Glover et al., 1995; Hibbard et al., 2006). Kinematic analysis of mylonites across the Spotsylvania fault near the James River suggests dextral transpression, with fault-normal shortening and at least 80 to 300 km of right-lateral movement (Bailey et al., 2004). The geologic age of movement on this fault is commonly thought to be late Paleozoic, coincident with the Allegheny orogeny (Pratt et al., 1988). As mentioned in the FSAR text, Cenozoic movement on the fault is ruled out by negligible vertical deformation of a pre- to early Cretaceous erosion surface as analyzed by Dames and Moore (1977b).

The Central Piedmont suture / shear zone is a region of ductile deformation and brittle faults that mark the boundary between various terranes that were accreted to Laurentia during the Paleozoic (Hibbard et al., 1998; Hibbard, 2000). The shear zone as most commonly described joins rocks of the Piedmont terrane or domain on the west to Neoproterozoic to Cambrian magmatic arc rocks of the Carolina domain on the east (Hibbard, 2000). Hibbard et al. (2006), in their attempt to capture first-order tectonic events across and along the Appalachian Orogen, clearly associate the Spotsylvania fault with the Central Piedmont shear zone as it forms a continuous western boundary for the Piedmont terrane. Separate faults within the Central Piedmont shear zone as shown by Hibbard et al. (2006) include, from southwest to northeast, the Lowndesville shear zone, Kings Mountain shear zone, Eufola fault, Hyco shear zone, and the Spotsylvania fault (Horton et al., 1991; Hibbard et al., 1998; Hibbard et al., 2006). Only the eastern portion of the Hyco shear zone is located within the 200-mile site region. The lateral continuity of the Spotsylvania fault mylonites with the Hyco shear zone mylonites was recognized by Bailey et al. (Bailey, 2004).

The Central Piedmont shear zone is believed to have been active during the late Paleozoic Alleghanian orogeny as a thrust fault, with variable components of right-lateral offset (Bobyarchick, 1988; Hibbard et al., 1998; Hibbard, 2000). The Alleghanian right-lateral oblique movement on the Spotsylvania fault (Bailey et al., 2004) is consistent with this style of tectonic movement. The timing of accretion of the Carolina terrane to Laurentia, although uncertain, was probably Late Ordovician to Silurian (Hibbard, 2000) rather than during earlier or later Paleozoic orogenic events. The earlier age for the accretion of the Carolina terrane relative to the timing of the Central Piedmont shear zone suggests that the Central Piedmont shear zone is not a suture but rather a fault that offsets the suture (Hibbard, 2000). The Late-Paleozoic accretionary history of the Goochland terrain likewise is uncertain (Glover et al., 1995; Bailey et al., 2004; Hibbard et al., 2007).

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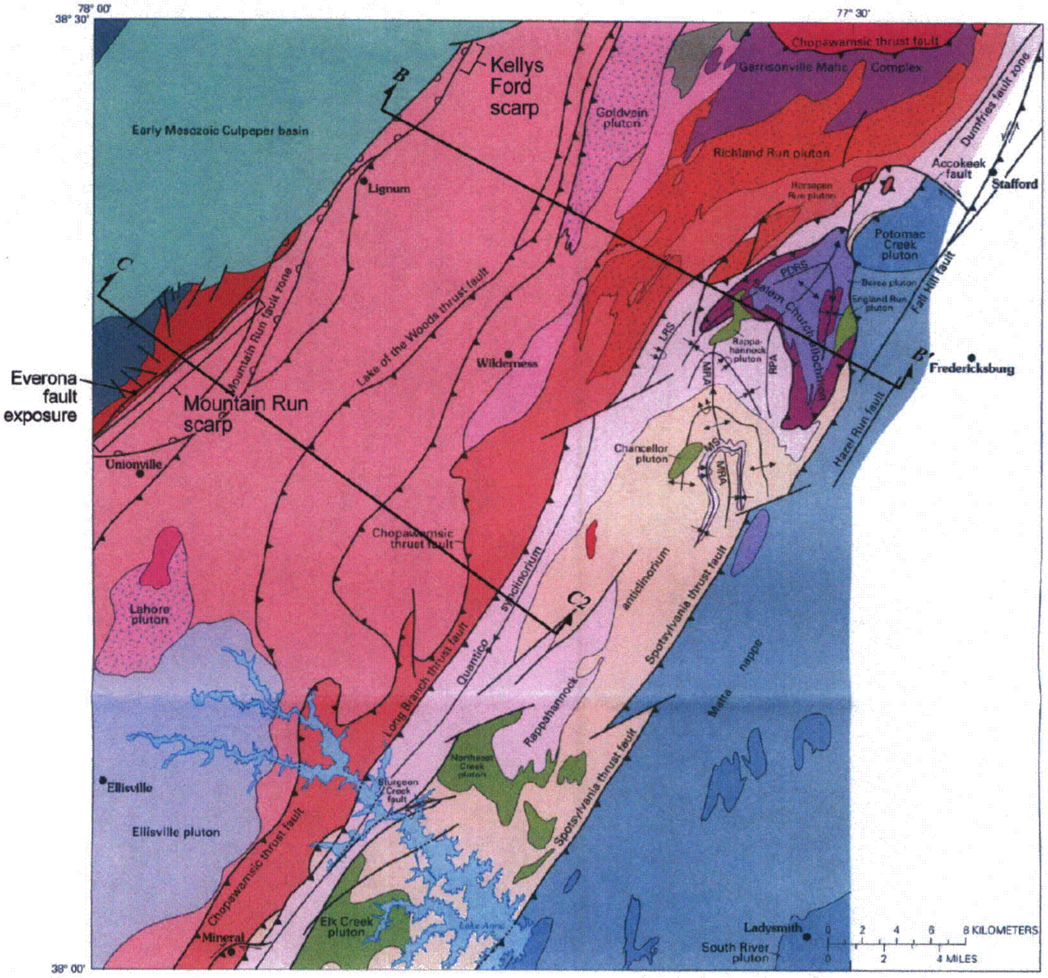
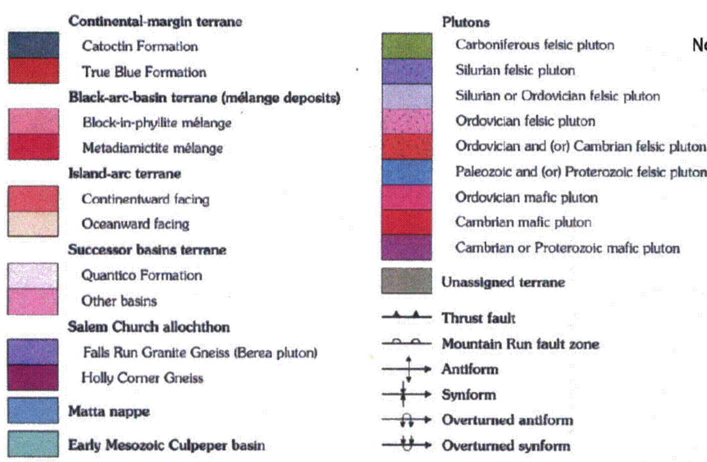
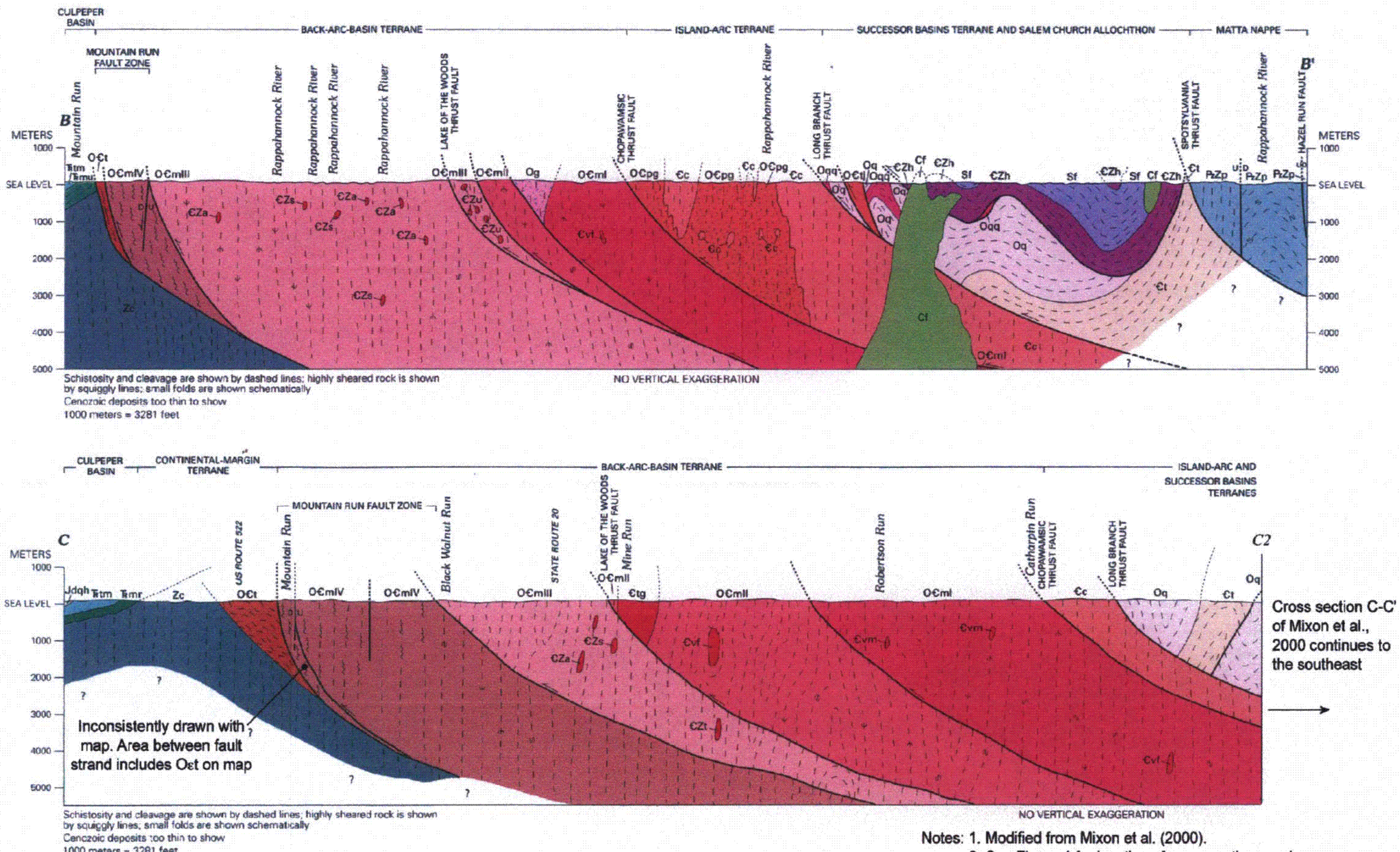


EXPLANATION



Notes:
1. Modified from Mixon et al. (2000).
2. The Mountain Run fault zone is in the northwest portion of the map and separates mélange deposits of the Piedmont province against continental margin rocks of the Blue Ridge province and strata of the Early Mesozoic Culpeper basin.
3. The Everona fault exposure, Mountain Run scarp, and Kellys Ford scarp are indicated.
4. Locations of cross sections B-B' and C-C2 are also shown.

Question 02.05.01-41 Figure 1 – Simplified Tectonostratigraphic Map of the Fredericksburg 30' x 60' Quandrangle Map by Mixon et al. (2000)



Notes: 1. Modified from Mixon et al. (2000).
2. See Figure 1 for location of cross sections and simplified tectonostratigraphic unit descriptions.

Question 02.05.01-41 Figure 2 – Cross Sections from Mixon et al. (2000). Top is entire Cross Section B-B' from Mixon, et al. (2000); Lower is a Portion of Cross Section C-C', with the Western End Labeled C2 to Distinguish it from the C' Location in Mixon et al. (2000)

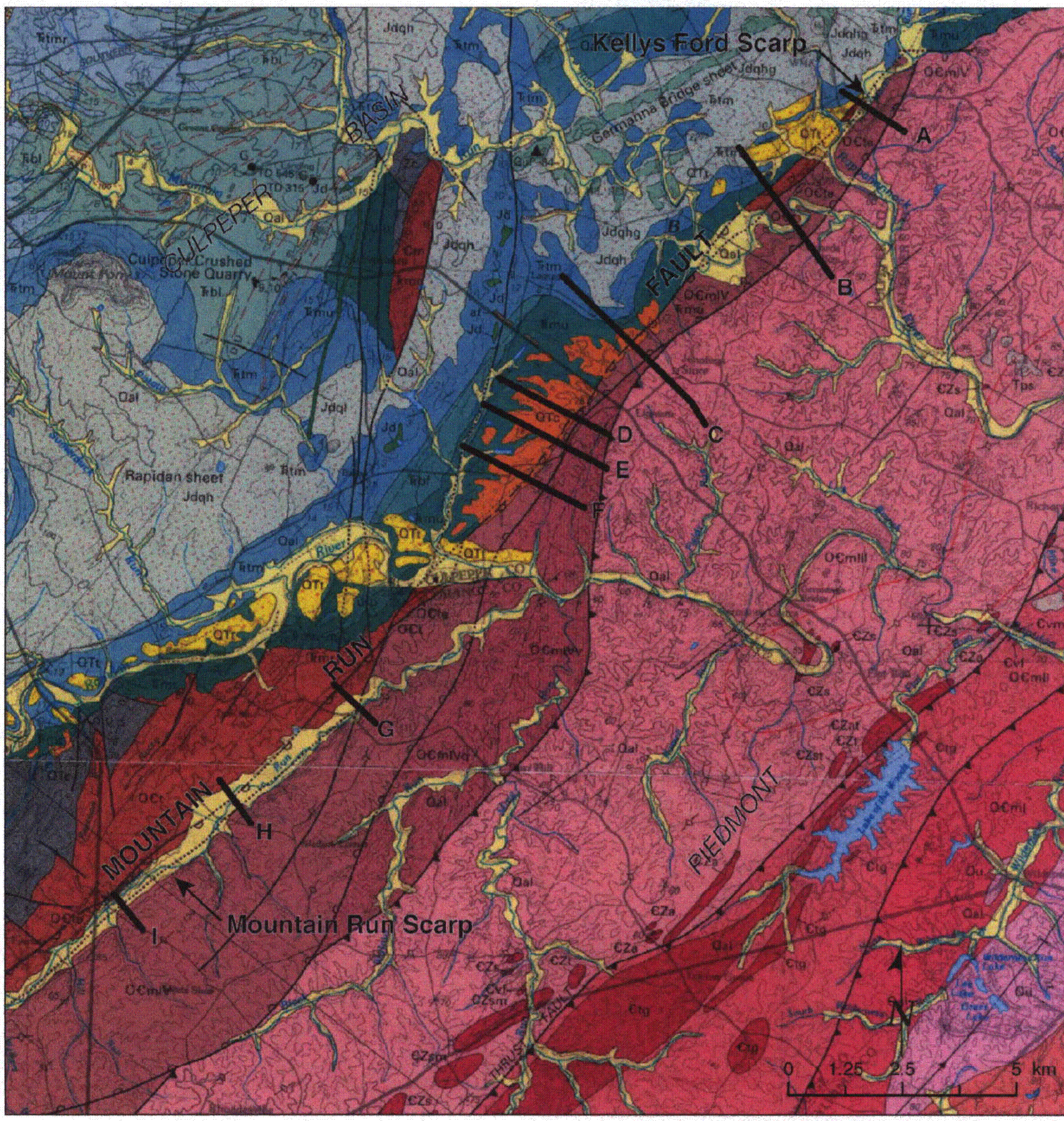


Figure 1. Geologic map of the Mountain Run Fault Zone (taken from Mixon et al., 2000). Profiles constructed across the fault, and illustrated in Figures 3-11, are indicated by black lines labeled A-I.

Question 02.05.01-41 Figure 3 – Portion of the Fredericksburg 30' x 60' Quadrangle Geologic Map by Mixon et at. (2000) Showing the Locations of Profiles A through I. This is a Reproduction of Figure 1 in Dominion (2004a).

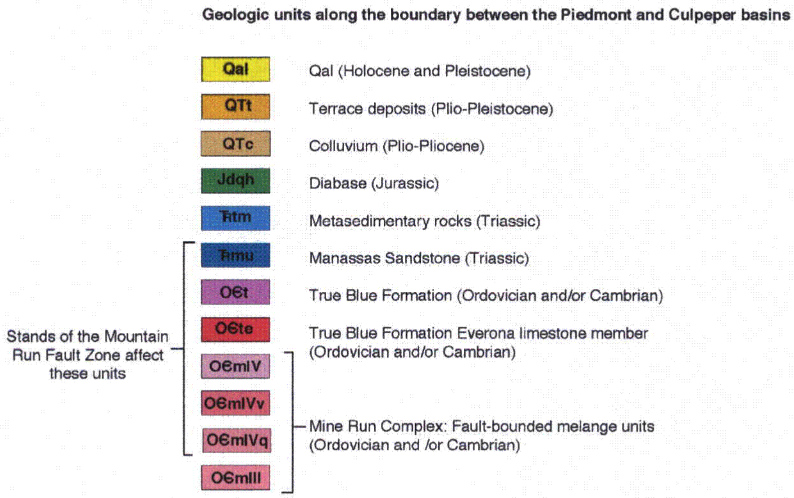


Figure 2. Geologic map units of Mixon et al. (2000) crossed by Profiles A through I (Figures 3-11; see text for discussion).

Question 02.05.01-41 Figure 4 – Explanation to Accompany the Map in Figure 3. This is a Reproduction in Dominion (2004a).

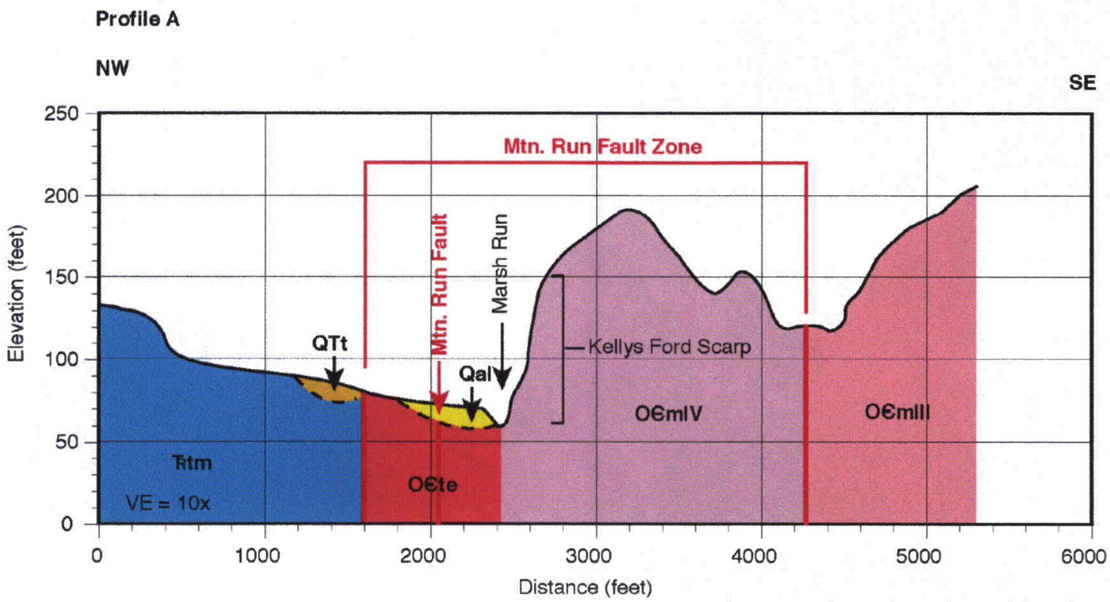


Figure 3. Profile A (see Figure 1 for profile location. Geology from Mixon et al. (2000).

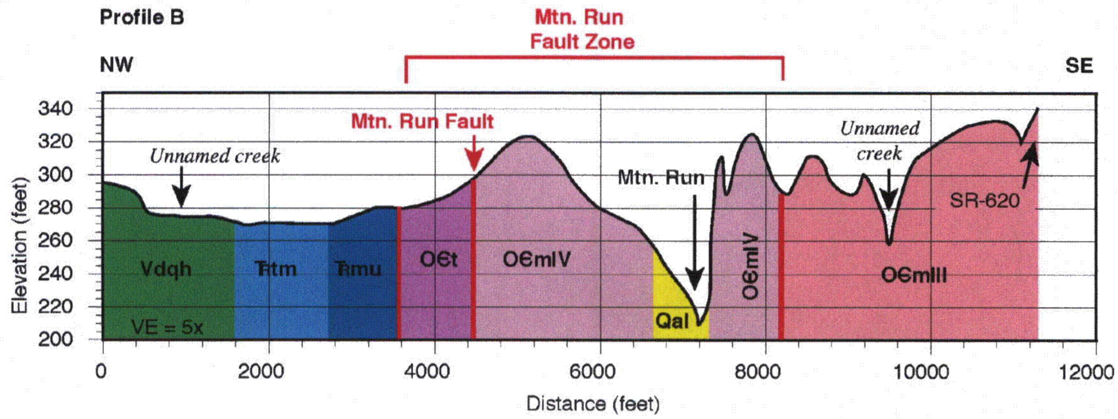


Figure 4. Profile B (see Figure 1 for location). Geology from Mixon et al. (2000).

Question 02.05.01-41 Figure 5 – Profiles A and B across the Mountain Run Fault Zone. This is a Reproduction of Figures 3 and 4 in Dominion (2004a)

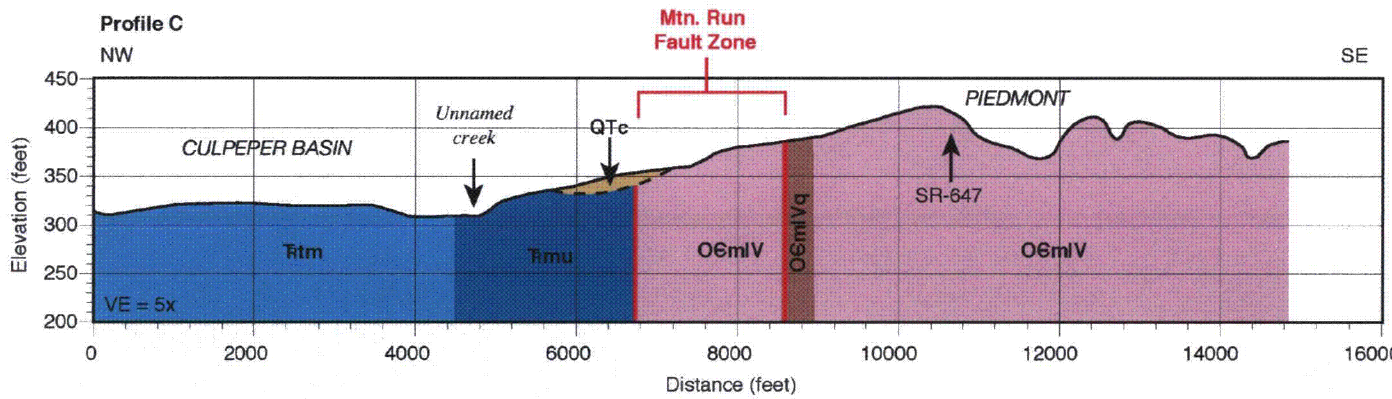


Figure 5. Profile C (see Figure 1 for location). Geology from Mixon et al. (2000).

Question 02.05.01-41 Figure 6 – Profile C across the Mountain Run Fault Zone. This is a Reproduction of Figure 5 in Dominion (2004a)

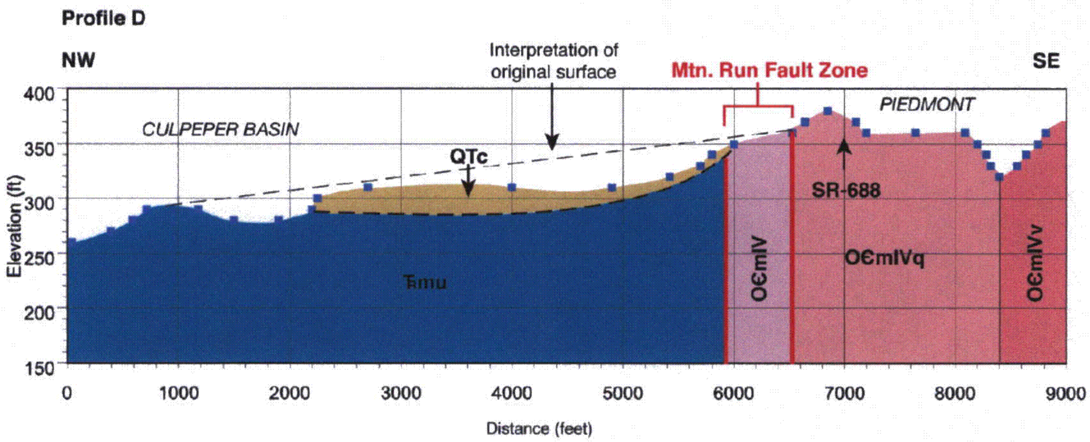


Figure 6. Profile D (see Figure 1 for location). Geology from Mixon et al. (2000). Dashed line shows interpretation of original undissected slope from the Piedmont to Culpeper Basin.

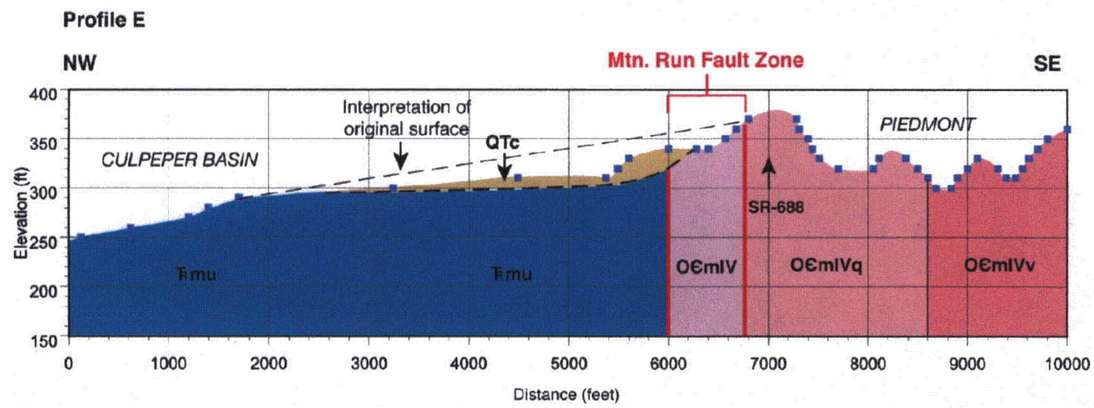


Figure 7. Profile E (see Figure 1 for location). Geology from Mixon et al. (2000). Dashed line shows interpretation of original undissected slope from the Piedmont to Culpeper Basin.

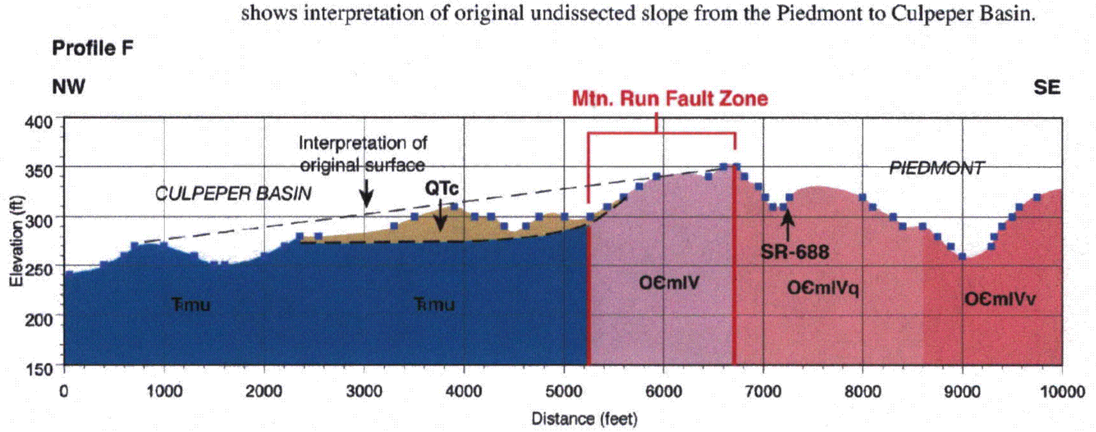


Figure 8. Profile F (see Figure 1 for location). Geology from Mixon et al. (2000). Dashed line shows interpretation of original undissected slope from the Piedmont to Culpeper Basin.

Question 02.05.01-41 Figure 7 – Profiles D, E, and F across the Mountain Run Fault Zone. This is a Reproduction of Figures 6, 7, and 8 in Dominion (2004a).

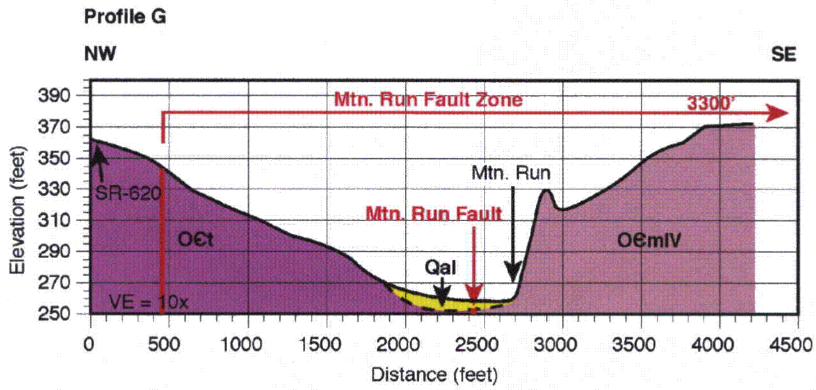


Figure 9. Profile G (see Figure 1 for profile location). Geology from Mixon et al. (2000).

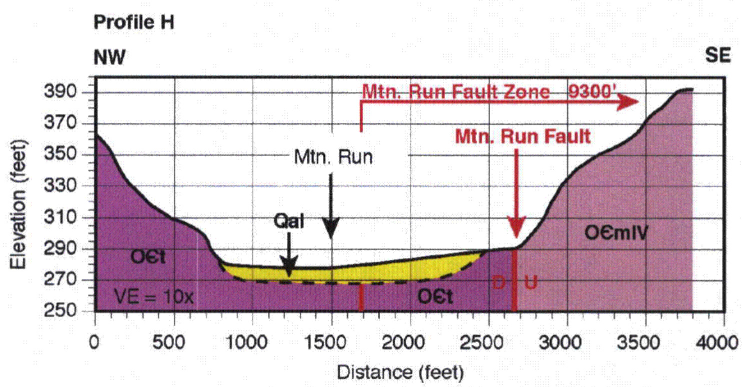


Figure 10. Profile H (see profile across the Mountain Run Fault. See Figure 1 for profile location. Geology from Mixon et al. (2000).

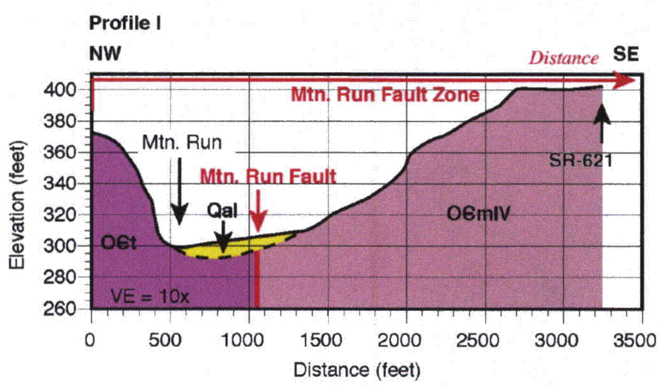


Figure 11. Profile I (see Figure 1 for profile location). Geology from Mixon et al. (2000).

Question 02.05.01-41 Figure 8 – Profiles G, H, and I across the Mountain Run Fault Zone. This is a Reproduction of Figures 9, 10, and 11 in Dominion (2004a)

COLA Impact

FSAR Section 2.5.1.1.4.4.2, Paleozoic Tectonic Structures, will be revised, as shown in Enclosure 3, in a future revision of the COLA. Additionally, FSAR Figure 2.5-16 will be revised, as discussed above, as part of the change associated with the response to RAI 130, Question 02.05.01-40.

Question 02.05.01-42

In CCNPP Unit 3 FSAR Section 2.5.1.1.4.4.2.2, Coastal Plain Structures (p. 2.5-43), the text states, "The western fault zone coincides with the margins of the Sussex Terrane of Horton (Horton, 1991) (Figure 2.5-16 and Figure 2.5-17)."

a. The western and eastern fault zones are not indicated on either figure. The Sussex Terrane is barely discernable on Figure 2.5-16. Please revise the figures to support the text.

b. The text also states on p 2.5-43, "The eastern fault zone is shown to extend from coastal North Carolina to southern Delaware, trending north along the eastern part of southern Chesapeake Bay before branching into two splays that trend northeast across the Delmarva Peninsula (Figure 2.5-16 and Figure 2.5-23)." This aspect of the fault is not indicated on either figure. Please revise the figures. In addition, provide a citation for this interpretation.

Response

FSAR Figure 2.5-16 has been revised to label the western and eastern fault zones referenced in the FSAR text on the Glover and Klitgord (1995) map inset; where the eastern fault zone splays on the Glover and Klitgord (1995) map inset, both splays are labeled. FSAR Figure 2.5-16 has also been revised to label the western fault zone referenced in the FSAR text on the Horton et al. (2001) map inset. The Sussex Terrane has been labeled on the Horton et al. (2001) map inset of FSAR Figure 2.5-16.

On FSAR Figure 2.5-23, the eastern fault zone splay is shown on the existing figure as the easternmost plotted Taconic suture beneath the Coastal Plain, which is mapped through Virginia Beach, VA. The interpretation of the eastern fault zone comes from Glover and Klitgord (1995) (FSAR Figure 2.5-16).

Reference:

Glover, L., III, and Klitgord, K.D., 1995, E-3 Southwestern Pennsylvania to Baltimore Canyon Trough: Geological Society of America Centennial Continent/Ocean Transect #19.

COLA Impact

FSAR Figure 2.5-16 will be revised, as shown in Enclosure 3, in a future COLA revision.

Question 02.05.01-43

The following questions apply to CCNPP Unit 3 FSAR Section 2.5.1.1.4.4.3, Mesozoic Tectonic Structures.

a. In CCNPP Unit 3 FSAR Section 2.5.1.1.4.4.3, Mesozoic Tectonic Structures, the text states (p 2.5-44), "These Mesozoic rift basins, also commonly referred to as Triassic basins, exhibit a high degree of parallelism with the surrounding structural grain of the Appalachian orogenic belt. The parallelism generally reflects reactivation of pre-existing Paleozoic structures (Ratcliffe, 1986)." There are several more recent publications about Eastern United States rift basins, such as Schlische, 2003, in The great rift valleys of Pangea in eastern North America, Columbia Univ. Press, pp 21-64; Schlische and Withjack, 2005, GSA Bulletin, v 117, no. 5/6, pp 823-832; Faill, 2003, GSA Bulletin, v.115, pp 406-421; Schlische et al, 2003, AGU Monograph 136, pp. 33-59; Withjack et al, 1998, AAPG Bulletin, v 82, no 54, pp 817-835. Please provide a discussion of the recent research in this area.

b. The text states (p 2.5-44), "The geometry and continuity of buried rift basins beneath the Coastal Plain and Continental Shelf is not clear, but the recognition and interpretation of these basins have expanded since the EPRI (1986) study. In addition to the identification of new basins since 1986, several alternative geometries have been proposed for the site region (Figure 2.5-10 and Figure 2.5 16) (Horton, 1991) (Benson, 1992) (Klitgord, 1995) (Withjack, 1998) (LeTourneau, 2003)." The evidence for and against interpreting rift basin structure beneath the CCNPP is not adequately developed. This is an important part of the site characterization because there are many rift basins around the site. There is not a single section in the FSAR, supported by figures (maps and or cross sections), that adequately addresses the issue of whether a rift basin exists beneath the CCNPP. Please provide additional discussion of this issue. Further, specific faults have not been identified in this section. Subsurface geometry of the boundary faults for any of these structures and whether or not they lie beneath the site may impact the site response analysis. Please provide additional discussion of the faults associated with the basins.

Response

a. As stated in the above RAI question, the NRC has identified several recent publications pertaining to rift basins and has requested these publications be discussed in the FSAR (e.g., Schlische and Withjack, 2005; Faill, 2003; Withjack, 2005; Schlische et al. 2003 and Withjack et al. 1998). Seminal papers by Withjack et al., (1998) and Schlische (2003) are discussed in the FSAR Section 2.5.1.1.3.1.2 and later in Section 2.5.1.1.4.4.3.

   The tectonic framework for Mesozoic rifting and rift basins for the CCNPP site is summarized in Schlische (2003) and further refined in later papers (Schlische et al. 2003; Withjack et al. 2005). The salient points of these papers as discussed in FSAR Section 2.5.1.1.3.1.2 and Section 2.5.1.1.4.4.3 include: 1) rifting across the eastern Atlantic margin began by the Late Triassic, 2) the Mesozoic rift basins in the site region are predominately halfgrabens, 3) fault systems bordering the rift basins often consist of reactivated structures (e.g., reactivated Paleozoic faults), and 4) the recognition of widespread inversion structures during the rift-to-drift transition marked a significant change from extension to contraction in the site region (Withjack et al., 1998; Schlische et al. 2003; Withjack et al. 2005). Most of these key points are summarized in the existing FSAR text in Section 2.5.1.1.4.1.2, but this section will be revised to incorporate the additional references noted in RAI 130, Question

02.05.01-43. The response to RAI 130, Question 02.05.01-54 provides additional discussion of new literature regarding Mesozoic rifting.

Other topics are summarized by Schlische (2003) and include discussions of how rift basins and their bounding faults develop through time (e.g., fault growth, basin stratigraphy, and subsidence rates). These later topics have little bearing on the location of basins relative to the site. Based on a review, there are no additional data presented in the recent literature that may be used to better delineate buried basins near the CCNPP Unit 3 site.

Schlische (2003) also discusses several points regarding the development of Mesozoic rift basins, including: a) Do the "large suite of structures contained in eastern North America" reflect a changing stress field or a uniform stress field reactivating variably oriented Paleozoic structures?; b) Are the major basin-bounding fault systems syn-depositional or post-depositional?; and c) What caused the major stratigraphic changes in exposed Mesozoic basins? These topics provide limited insight into the seismogenic potential of the basin-bounding faults in the CCNPP 200-mile site region. The recent paper by Faill (2003) and subsequent discussion (Schlische and Withjack, 2005), and reply paper (Faill, 2005) focus on the discussion of the Birdsboro Basin and the finer points of basin evolution. Specifically, Faill (2003) proposes that the Barboursville, Culpeper, Gettysburg, and Newark basins originally formed as a single elongate depositional trough named the Birdsboro basin (FSAR Figure 2.5-10). The paper's focus is the formation and filling of the composite Birdsboro basin, but it provides no new information on the basin-bounding faults (e.g., down-dip geometry). The discussion (Schlische and Withjack, 2005) and reply (Faill, 2005) argue over whether or not the basin-bounding faults were active before or after basin filling, yet provide no new evidence for Quaternary activity of the boundary faults. Although these papers advance the understanding of the Mesozoic basins, there is no new information that relates directly to the seismic hazard at the CCNPP Site, such as identification of a new basin, revision of a basin's geometry close to the Site, or evidence for Quaternary fault activity.

The need to incorporate the most up-to-date literature requested by the NRC is noted and the above references will be included in the revised FSAR text (See response b below).

b. The response to this RAI question has three subparts:

1. Provide additional discussion of whether a rift basin exists beneath the CCNPP;
2. Provide a discussion of the boundary faults and whether or not they lie beneath the Site; and
3. Please provide additional discussion of the faults associated with the basins.

Part b.1:

Additional discussion about the presence or absence of a rift basin beneath the CCNPP Unit 3 site was provided in the response to RAI 71, Question 2.5.1-26[2]. This response has been incorporated into the proposed revision of FSAR Section 2.5.1.1.4.4.3, Mesozoic Tectonic Structures, as shown in Enclosure 3.

[2] G. Gibson (UniStar Nuclear Energy) Letter UN#09-152 to Document Control Desk (NRC), "Response to Request for Additional Information for the Calvert Cliffs Nuclear Power Plant, Unit 3, RAI No. 71, Basic Geologic and Seismic Information, RAI No. 72, Vibratory Ground Motion" dated April 15, 2009.

Part b.2:

The request by NRC staff to provide additional discussion regarding the boundary faults of Mesozoic basins and whether or not they lie beneath the CCNPP site was answered as part of the response to RAI 71, Question 02.05.01-26[3]. Portions of this response and new text have been incorporated into the revised FSAR text for Section 2.5.1.1.4.4.3.

Part b.3:

FSAR Section 2.5.1.1.4.4.3 has been revised to include further discussion of the Mesozoic basins within the CCNPP Unit 3 site region, nearby basin bounding faults, and recent literature. The response to RAI 130, Question 02.05.01-54 provides further discussion and revisions to pertinent FSAR sections regarding Mesozoic rifting and rift basins.

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[3] G. Gibson (UniStar Nuclear Energy) Letter UN#09-152 to Document Control Desk (NRC), "Response to Request for Additional Information for the Calvert Cliffs Nuclear Power Plant, Unit 3, RAI No. 71, Basic Geologic and Seismic Information, RAI No. 72, Vibratory Ground Motion" dated April 15, 2009.

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COLA Impact

FSAR Section 2.5.1.1.4.4.3, Mesozoic Tectonic Structures, will be revised as shown in Enclosure 3 in a future revision of the COLA.

Question 02.05.01-44

In CCNPP Unit 3 FSAR Section 2.5.1.1.4.4.4, Tertiary Tectonic Structures, the text states, "The 35-million year old Chesapeake Bay impact crater is a 56 mi (90 km) wide, complex peak-ring structure defined by a series of inner and outer ring faults, some of which penetrate the Proterozoic and Paleozoic crystalline basement rocks (Powars, 1999)."

Please provide some illustration of the ring faults and their basement geometry. Provide a discussion about the potential for impact crater faults to become seismogenic within the host tectonic regime.

Response

The response to this RAI is addressed in two parts:

a. Provide illustrations of the ring faults and their basement geometry; and

b. Provide a discussion of potential for impact crater faults to become seismogenic.

Each of these issues is discussed below.

a. The inner and outer ring faults that are mentioned in the FSAR passage quoted in the RAI question are compaction related growth faults (Figure1) (Poag et al., 2004). Seismic profiles are used to partly delineate the outer and inner rims of the Chesapeake Bay impact structure (CBIS)(Figure 2). The location of these growth faults as mapped by Poag and Norris (2005) on the Chickahominy Formation horizon (an Upper Eocene marine clay capping impact generated breccia) are presented in Figures 2 and 3. Figure 3 displays an outer ring fault imaged in the York River, whereas Figure 4 shows series of faults located near the inner ring of the CBIS. The growth faults mentioned in the FSAR passage are generally not genetically related to faults within the Proterozoic and Paleozoic crystalline basement rocks that formed at the time of impact (Poag et al., 2004; Powars and Bruce, 1999). The FSAR text will be modified to more clearly make this distinction.

   The interpreted seismic profiles show the locations of faults within the impact structure synimpact, basement involved faults (e.g., faults offsetting the crystalline basement), growth faults, and faults accommodating slip between syn-impact displaced megablocks (e.g., faults separating large slump blocks within the pre-impact sediments near the peak ring) (Poag and Norris, 2005). The inner and outer ring growth faults discussed in the RAI question generally occur within the impact breccia and post-impact sediments as shown in Figures 3 and 4.

b. As described in FSAR Section 2.5.2, a comprehensive review of available geologic, seismologic, and geophysical information and data was conducted to determine whether or not there was any new information or data developed since the EPRI-SOG study (EPRI, 1986) that would motivate revising the seismic source characterizations used for the CCNPP FSAR. Also, as described in Section 2.5.2, this review was conducted following the guidance of NRC Regulatory Guide 1.165 (NRC, 1997). As part of this review (see FSAR Sections 2.5.1.1.4.4 and 2.5.1.1.4.4.4) the Chesapeake Bay impact crater was identified as a geologic feature that was not known of at the time of the EPRI-SOG study and should thus be evaluated with respect to its seismogenic potential. The review of available geologic, seismologic, and geophysical information and data conducted as part of the preparation of the CCNPP FSAR led to the conclusion stated in FSAR Section 2.5.1.1.4.4.4 that the impact crater and its related tectonic structures and faults are not capable seismic sources. A detailed discussion of this evaluation is presented within the response to RAI 71, Question 02.05.01-13[4].

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[4] G. Gibson (UniStar Nuclear Energy) Letter UN#09-227 to Document Control Desk (NRC), "Response to Request for Additional Information for the Calvert Cliffs Nuclear Power Plant, Unit 3, RAI No. 71, Basic Geologic and Seismic Information, RAI No. 72, Vibratory Ground Motion" dated May 1, 2009.

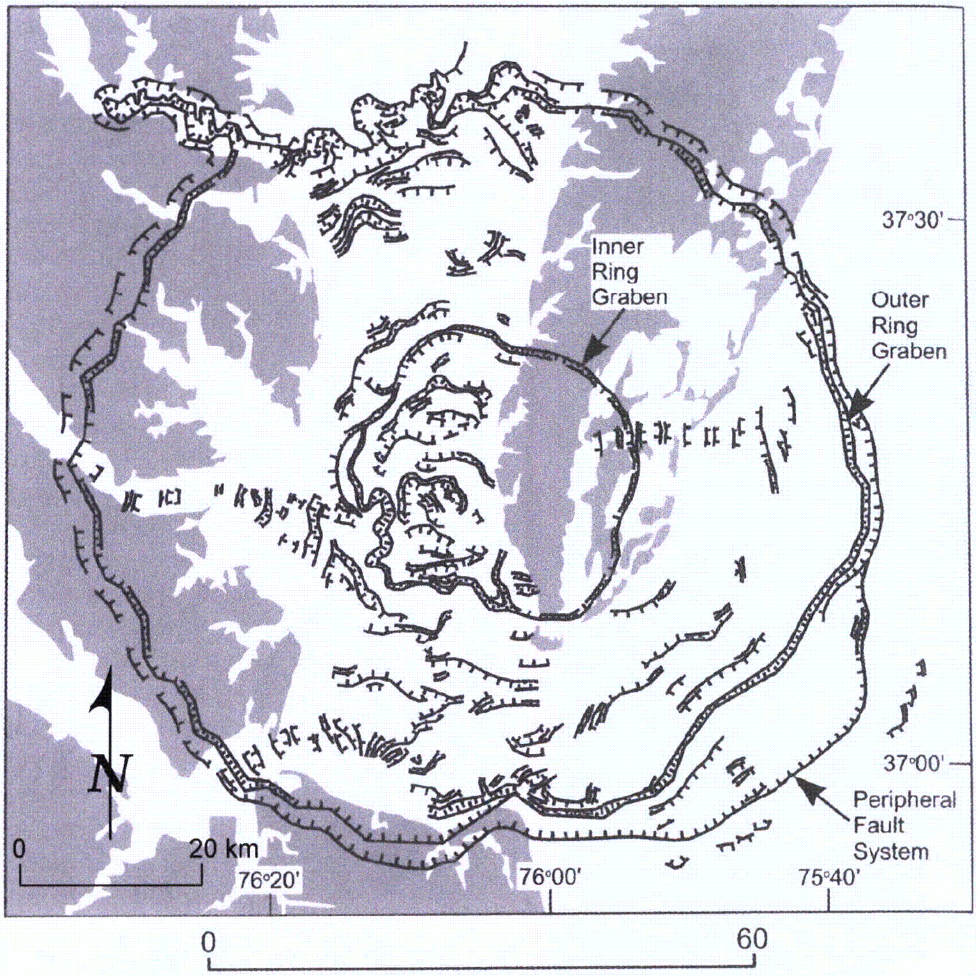
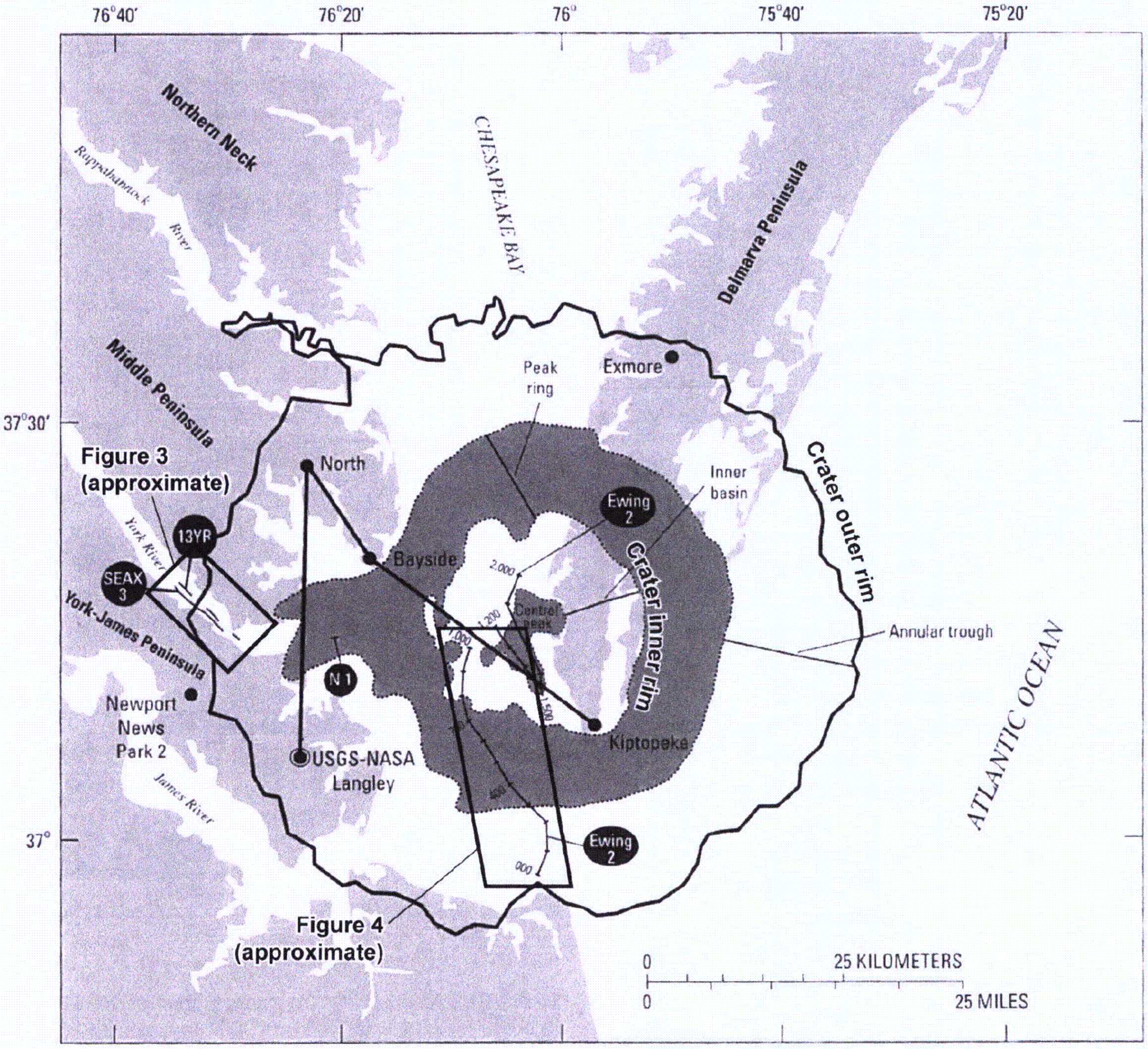
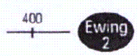


Fig. 7.11. Horizontal distribution of concentric ring-grabens and additional normal faults that offset upper and lower bounding reflections of Chickahominy Formation (mapped on upper surface of Chickahominy Formation). Outer ring-graben marks location of crater outer rim; inner ring-graben marks wall of inner basin. All these faults also extend into postimpact sedimentary section above Chesapeake Bay crater.

Question 02.05.01-44 Figure 1 – Location of Inner and Outer Ring Growth Faults of the Chesapeake Bay Impact Structure Modified from Figure 7.1.1 of Poag et al. (2004)



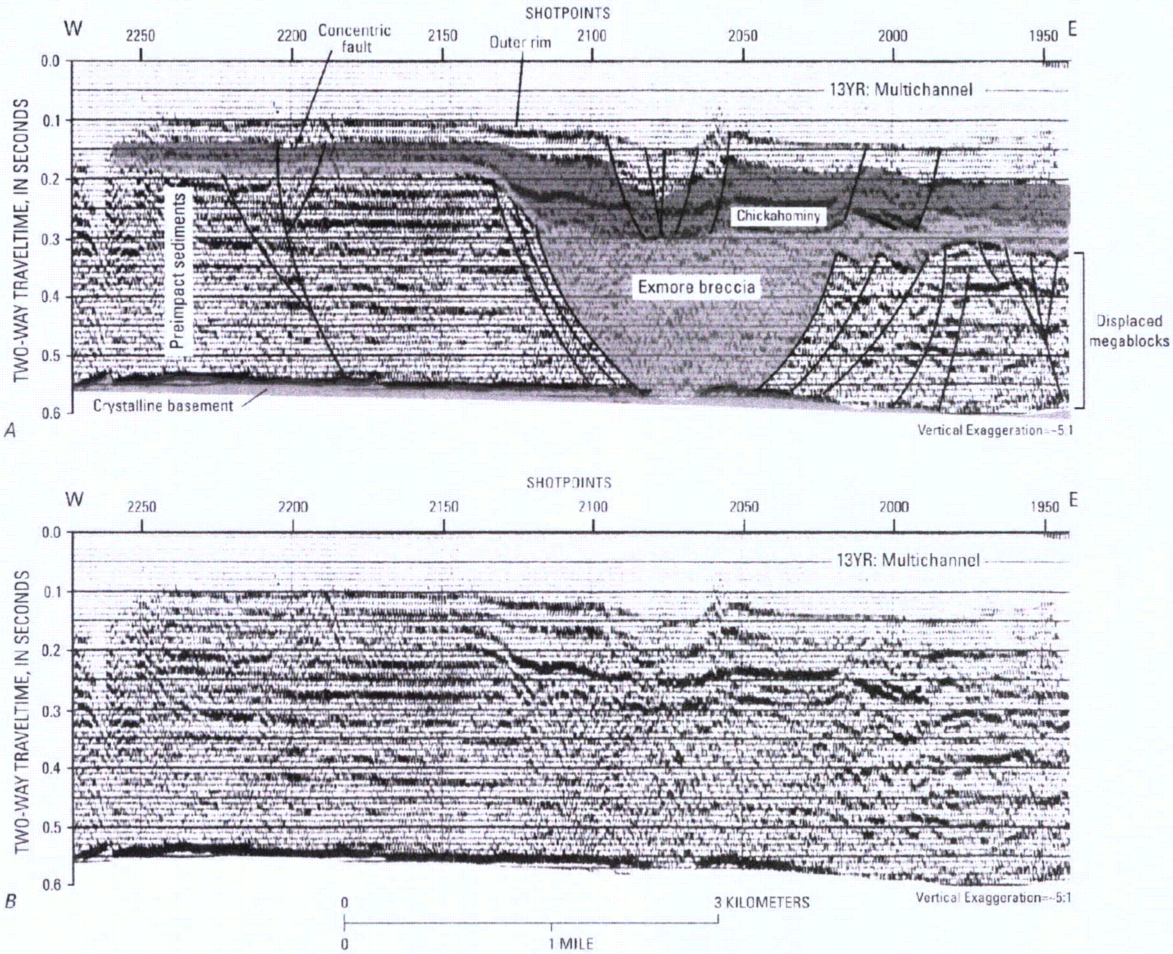
EXPLANATION



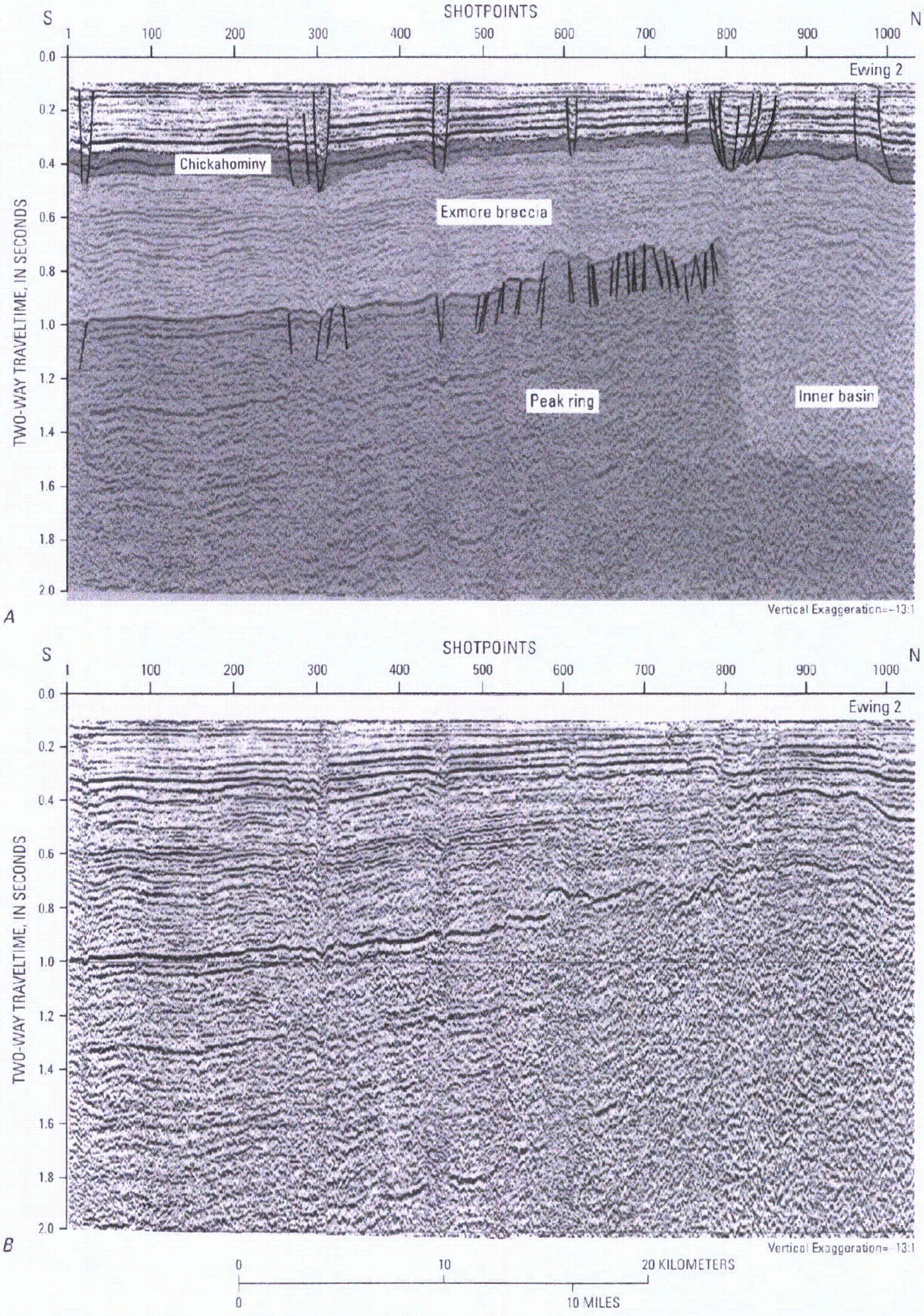
Trackline for seismic-reflection profile; numbered ticks indicate shotpoints; circled label indicates profile name (derived from the ship name) and number


Line connecting four coreholes for which geophysical logs are compared in figure F18

Question 02.05.01-44 Figure 2 – Regional Map Showing the Outer and Inner Rims of the Chesapeake Bay Impact Structure, Corehole Locations, Tracklines for Seismic-Reflection Profiles. Modified from Figure 1 of Poag and Norris (2005)



Question 02.05.01-44 Figure 3 – Segment of Multichannel Seismic-Reflection Profile 13YR Collected by Teledyne Exploration Co. for Texaco Inc., and Exxon Exploration Co. in 1986 in the York River. A. Interpreted Segment of Multichannel Profile 13YR. B. Uninterpreted version of A. Modified from Figure 9 of Poag and Norris (2005)



Question 02.05.01-44 Figure 4 – Segment of Two-Channel Seismic-Reflection Profile Ewing 2 Collected in 1998 by the USGS in Collaboration with the Lamont-Doherty Earth Observator. The profile segment crosses the inner rim of the Chesapeake Bay impact structure. A. Interpreted segment of two-channel profile Ewing 2, B. Uninterpreted version of A. Modified from Figure 13 of Poag and Norris (2005)

COLA Impact

FSAR Section 2.5.1.1.4.4.4, Tertiary Tectonic Structures, will be revised as shown in Enclosure 3 in a future revision of the COLA.

Question 02.05.01-45

In CCNPP Unit 3 FSAR Section 2.5.1.1.4.4.4.1, Stafford Fault of Mixon, et al., the text states (p 2.5-46), "The Stafford fault (#10 on Figure 2.5-31) approaches within 47 mi (76 km) southwest of the site (Figure 2.5-25)." Figure 2.5-31 only shows numerical points on a regional map and doesn't show the traces of the several faults that comprise the Stafford fault system.

a. In Figure 2.5-31, the numbered features from the legend are faults yet it is unclear what map feature (a line, a triangle or a filled circle) the numbers are identifying. Does #8 identify a triangle, a line or a filled circle? Why is the Stafford fault system of Marple a line and the Stafford fault system of Mixon a number (10)? Please provide clarification.

b. Figure 2.5-25 has traces for the Stafford fault but the individual faults are not identified. Please provide a more detailed map of these tectonic features that supports the various discussions in the text. Include the fault geometry information such as movement direction and dip orientation. Describe the evidence supporting the interpretation of these faults. Provide more explanation about the surficial geologic units that are involved with the determination of age of faulting.

c. On page 2.5-46, the text states, "Detailed drilling, trenching, and mapping in the Fredericksburg region by Dames and Moore (DM, 1973) showed that the youngest identifiable fault movement on any of the four primary faults comprising the Stafford fault system was pre-middle Miocene in age" (>16.4 Ma). Please provide more details about how this conclusion was made.

d. The discussion about the Stafford fault system states (3rd paragraph, p. 2.5-46), "Both offsets suggest southeast-side-down displacement (Mixon, 1978)." A previous statement about the Stafford fault system indicated the faults were transpressional faults and dipping to the northwest (1st paragraph, 3rd sentence, p 2.5-46). Please resolve the change in interpretation to a down-to-southeast (and implied normal faulting). What stresses are thought to be responsible for the formation of the fault system active until the late Tertiary period?

e. The text states (p. 2.5-46), "Geomorphic analyses (structure contour maps and topographic profiles) of upland surfaces capped by Neogene marine deposits and topographic profiles of Pliocene and Quaternary fluvial terraces of the Rappahannock River near Fredericksburg, Virginia, indicate that these surfaces are not visibly deformed across the Stafford fault system (Dominion, 2004a)." Please provide more details from the Dominion, 2004a study that resolved uncertainty of movement history on the faults, and support the discussion with illustrations of some of these data and discuss how the final interpretations were drawn.

Response

a. Figure 2.5-31 uses white filled circles with a number to label features discussed in the text as part of the Crone and Wheeler (2001), Wheeler (2005) and Wheeler (2006) papers. As discussed in FSAR Section 2.5.1.1.4.4.5, these papers provided a comprehensive literature review of sites where potential Quaternary tectonic activity has been previously documented or interpreted along the East Coast. Each label, marked by a filled circle with a number in it, identifies either a filled triangle, for smaller features (i.e. shorter faults) that appear as basically a point on the map at this scale, or a line for longer (10s of kms) features. The few long features mapped with lines (the East Coast Fault system, the Stafford fault of Marple [2004] and the Fall Lines of Weems) each have distinctive symbology identified clearly in the explanation. The filled orange dots or solid yellow squares represent pre- and post-1986 earthquakes. The white filled circle numbered 8 is identifying a yellow triangle that is located at the exposure of the Upper Marlboro faults. The Stafford fault system of Mixon (number 10) is a triangle because the faults are reasonably short and, as discussed above, would appear at this scale as features smaller than the triangle marking their location. As discussed in FSAR Section 2.5.1.1.4.4.4.1, while the Stafford fault system of Mixon (number 10) is a set of northwest-dipping thrust faults deforming Tertiary coastal plain deposits near Stafford, Virginia, the Stafford fault of Marple (number 16) is a hypothetical fault drawn on the basis of river geometry, without rock offset or deformation along its length.

b. Several faults are identified as part of the Stafford fault system mapped near the Potomac River in Virginia. As discussed in Section 2.5.1.1.4.4.4.1, the faults of the Stafford fault system strike roughly N35°E (Figure 1). From northwest to southeast they are the Dumfries, the Fall Hill, the Hazel Run, the Brooke and its northern extension, the Tank Creek, and an unnamed fault located ~2 miles (3 km) southeast of the Hazel Run fault (Figure 1). They dip steeply to the northwest and offset Cretaceous and Tertiary units down-to-the-southeast, indicating thrust or reverse movement, though some right-lateral kinematic indicators have been found as well. As discussed below, the majority of faulting occurred after the deposition of the Paleocene Aquia Formation and before the deposition of the Miocene Calvert Formation. However, minor Pliocene faulting or deformation is recorded in two exposures.

The Dumfries fault is a 28 mile (45 km) long, northeast-striking, northwest-dipping, rightlateral thrust juxtaposing the Lower Cretaceous Potomac Formation and the Upper Ordovician Quantico Formation (Mixon et al. 1972; Mixon and Newell, 1977; Mixon et al., 2005). Structure contour maps of the base of the Potomac indicate that the unit thins abruptly to the north across the structure and the Dumfries fault marks the up dip limit of the Paleocene Aquia Formation (Figure 2) (Mixon et al., 1977, Mixon & Newell, 1978; 1982). As reported in, Mixon and Newell (1978) a trench excavated near the southern end of the fault revealed thrust and right-lateral kinematic indicators (striations, etc.) in the fault gouge juxtaposing the Cretaceous and Paleozoic units (Trench 1 of Figure 1).

A boring revealed that the vertical separation of the base of the Cretaceous section was roughly 110 ft (33.5 m) (Figure 5) (Mixon and Newell, 1978). The Dominion study (2004a) study found that the top of the Miocene Calvert Formation was undeformed in a transect across the Dumfries fault, indicating that the timing of the Dumfries fault activity was post-Cretaceous and pre-Miocene (See response to RAI 130 Question 45 part e below).

The *Fall Hill* fault is about 12 miles (19 km) long and used to be well exposed in roadcuts in Fredericksburg Virginia but has been obscured by recent roadwork (Mixon et al., 2000). The base of the Cretaceous Potomac Formation is offset roughly 100 feet (30 m) across the Fall Hill fault (Mixon and Newell, 1978) (Figure 5). The Paleocene Aquia Formation is thinned across the fault (Figure 3, Mixon and Newell, 1977). Structure contours of the base of the Aquia Formation indicate 40-50 ft (12-15 m) of displacement on this structure since early Paleocene time (Mixon and Newell, 1972; Mixon et al., 2005). A trenching study across the structure indicated that the Potomac and Aquia Formations were faulted by high-angle northwest dipping thrusts and a low-angle southeast-dipping thrust, while the upland gravels (interpreted as the Pliocene sandy gravel unit, Tps) overlying these units were undeformed

(Mixon and Newell, 1982; Mixon et al., 2000; Trench 2 of Figure 1; Figure 4). While "considerable debate" exists about a potential 1 inch (2.5 cm) offset in the base of the Pliocene Tps above one of the faults exposed at the northwestern end of this trench (Mixon and Newell, 1982), every other fault in the trench terminates in the unfaulted Tps (or upland gravel) contact (Figure 4)(Mixon and Newell, 1982; Mixon et al., 2000). Former roadcut exposures indicated that the base of a Rappahannock river terrace gravel was offset by 11-14 inches (28-36 cm) (see 14 in. Pliocene Terrace Offset in Figure 1) (Mixon and Newell, 1978). However, the age of the gravel is uncertain. It was originally cited as late Pliocene or early Pleistocene (Mixon and Newell, 1978), but it may be equivalent to the Yorktown Formation, which is early and middle (?) Pliocene in age (Mixon and Newell, 1982). Most recent publications indicate these gravels are "of probable Pliocene age" (Mixon et al., 2005) and speculate the offset unit is the upper Pliocene Bacons Castle Formation (Mixon et al., 2000). Faulting is not traceable into the terrace gravel (Mixon and Newell, 1978). Mixon and Newell (1978) also reported that the Thornburg scarp, a Pliocene paleoshoreline, crosses the Fall Hill fault and is undeformed by it. In recent geologic mapping, the Fall Hill fault is shown as dotted or "concealed" where its trace intersects Upper Pleistocene and younger units (e.g., Mixon et al., 2005). The Dominion (2004a) study found that the Pliocene marginal-marine sandy gravel unit (Tps) was undisrupted across the fault (see also response to part e below). Hence, deformation on the Fall Hill fault most likely ended in the Pliocene.

The *Hazel Run* fault is approximately 10 miles (16 km) long and juxtaposes Paleozoic bedrock against the Cretaceous Potomac Formation with northwest-side up displacement (Figure 1). The base of the Potomac and the Aquia Formation are offset across the structure, 120 and 61 ft (37 and 19 m), respectively, indicating repeated faulting in the Cretaceous to Paleocene (Figure 5, A-A'). Borings across the fault indicate the middle-to-late Miocene Calvert Formation has not been faulted or warped across the fault, and thus, that faulting was pre-middle Miocene in age (see point labeled Borings on Figure 1 for location) (Mixon and Newell, 1978). Near the Rappahannock River, several Pliocene and younger units also bury the Hazel Run fault (Dominion, 2004a). Evidence on the Hazel Run fault indicates that deformation along the fault ended in the Miocene. However, an outcrop located 1500 ft (457 m) southeast of the Hazel Run fault (between the Hazel Run and unnamed faults, see 18" Pliocene Offset on Figure 1 for location) reportedly exposes an unmapped northwest-dipping thrust fault (Mixon and Newell, 1978). The fault offsets the base of upland gravels (Miocene or Pliocene age, but probably equivalent to the Pliocene Tps unit (e.g., Mixon et al. 2000)) 18 inches (46 cm) with west-side-up displacement (Mixon and Newell, 1978). Again, faulting was not traceable up into the gravel (Mixon and Newell, 1982). Though Mixon and Newell (1978, 1982) reported this work, they have not reported visiting the outcrop or confirmed the findings of the original workers (PEPCO, 1973 as cited in Mixon and Newell, 1982). The relationship of this outcrop to the Hazel Run fault is unclear.

The 25 mile (40 km) long Brooke fault zone has been referred to as a monocline because it defines a roughly 1 mi (1.6 km) wide zone of flexure and faulting over which there is a consistent down to the southeast sense of displacement on vertical to steep northwest-dipping faults (Figure 1). Its northern extension, the Tank Creek fault, offsets the Potomac Formation. In addition, the Paleocene Aquia Formation thins to the northwest across the Brooke and Tank Creek faults (Figure 3), and the Paleocene to lower Eocene Marlboro Clay and Nanjemoy Formations are missing northwest of these structures (Mixon and Newell, 1982; Figure 1, Figure 5, B-B'). No faulting younger than early Miocene is indicated (Mixon et al., 2000).

The 8 mile (13 km) long unnamed fault represents the updip limit of the Paleocene Aquia Formation at the southern end of the fault system and offsets structure contours of the top of the Cretaceous Potomac Formation (Mixon et al. 2005) (Figure 1). It is located 1.5 miles (2.4 km) southeast of the Hazel Run fault. A borehole and exposures in a manmade pit located 3000 ft (914 m) apart were used to draw the cross-section shown in Figure 5 (the unnamed fault is labeled as the Brooke fault in A-A'). It is unclear how much of the apparent offset in the base of the upland gravel (40 ft (12 m)) may be related to faulting on this structure, rather than depositional variation. For example, the Miocene Calvert Formation is thicker on the northwest side of this structure, contrary to what would be expected from Miocene thrust faulting (Figure 5). The Pleistocene units along the Rappahannock River are unfaulted by this structure (Mixon et al., 2000, Dominion 2004a).

In summary, the structures are northwest-dipping, southeast-vergent thrust faults (Figure 5). The structures displace Cretaceous Potomac Formation and the Paleocene Aquia Formation thins across these structures, indicating Paleocene faulting. The Paleocene to lower Eocene Marlboro Clay and Nanjemoy Formations have been erosionally removed on the upthrown side of the Brooke fault, further indicating early Tertiary faulting (Figure 5). Most evidence indicates that faulting ceased during the Miocene, including (1) borings across the Hazel Run fault that indicate the Miocene Calvert Formation and overlying gravels have not been deformed (Mixon and Newell, 1978); (2) the Miocene Calvert Formation is undeformed across the Dumfries fault (Dominion, 2004a), and (3) a latest Miocene shoreline (the Thornburg scarp) is not offset by the faults of the Stafford fault system (Mixon and Newell, 1978). However, there are two instances that indicate the Calvert Formation, or younger deposits have been faulted. The first is based on an outcrop southeast of the Hazel Run fault where the base of the upland gravels (Miocene or Pliocene) have been offset 18 inches (46 cm) (Mixon and Newell, 1978). The second is an outcrop on the Fall Hill fault where the base of the Pliocene (?) age Rappahannock River terrace deposit is offset 11-14 inches (28-36 cm) (Figure 1, Mixon and Newell, 1978). In neither case is faulting traceable upward into the younger (Miocene or Pliocene) units (Mixon and Newell, 1978), nor does either case require Quaternary faulting on the Stafford fault system. As discussed in FSAR Section 2.5.1.4.5.4.1, the Stafford fault system is not considered a capable tectonic source, and there is no new information that would require a significant revision to the EPRI (1986) seismic source model.

c. Mixon and Newell, (1978; 1982) and the CCNPP FSAR reference a study conducted as part of a site investigation in the 1970's that may contain geologic information about the Stafford fault system. The Dames and Moore (1973) reference is Supplement Geologic Data for the North Anna Power Station, while the PEPCO (1976) is entitled Geologic Investigation of the Stafford fault zone. However, the full details of this study are apparently in the PEPCO (1976) reference, which was not available from the NRC reading room. Summaries provided in the Mixon and Newell (1978; and 1982) references indicate only that boreholes were drilled on either side of the Hazel Run fault and that the Fall Hill fault trench (Trench 2 on Figure 1; Figure 4) was investigated as part of this study. These summaries do not discuss work conducted on the remaining 2 of the "four primary faults", hence the FSAR will be revised according. However, the pre-middle Miocene age assessment for faulting is based upon the boreholes comparing the deposits on either side of the Hazel Run fault (Mixon and Newell, 1978; 1982). The resulting age assessment for faulting (pre-middle Miocene) is based primarily on the fact that the Calvert Formation appears at the same elevation on either side of the fault. Hence, faulting is older than the age of the Calvert Formation, or middle and lower Miocene.

d. On northwest-dipping structures, southeast-side-down displacement (or thrusting) is consistent with contractional strain, or compressional stress. A maximum horizontal compressive stress oriented generally east-southeast - west-northwest is required to produce the northeast-trending reverse faults associated with the Stafford fault system. This stress state is likely related to the 'ridge push' forces on the passive margin (Withjack et al., 2005) and is similar to the present-day stress field of east-northeast - west-southwest maximum horizontal compression (Zoback and Zoback, 1989b). No normal faulting is implied.

e. The North Anna study (Dominion, 2004a) examined the geometry of the following units to determine whether they were deformed across strands of the Stafford fault system (1) the Pliocene Tps unit, a marginal-marine sand; (2) the Miocene Calvert Formation; and (3) Pliocene and Quaternary terraces of the Rappahannock River (Mixon et al., 2000). The study examined the elevations of the tops of these units in transects across the Dumfries, Fall Hill, Hazel Run, Brooke, and unnamed faults and found that the Miocene and younger units appear to be undeformed across the structures. The Dominion (2004a) work is paraphrased and a summary of their description of the structure contour maps and transects across each fault (Figures 7, 8, and 9) are provided.

   A map of the elevation of the apparent top of the Pliocene sand and gravel unit, Tps, surface was constructed by contouring the elevations of ridges or peaks that expose Tps (Figure 6) (Dominion, 2004a). The elevations from topographically high locations were used to best estimate the fullest stratigraphic extent of the Tps, which has been erosionally removed along stream valleys. However, the upper surface of this unit is not exposed within the study area (i.e., its contact with the overlying unit), so this is a best estimate of the top of Tps. The elevation contours of the top of the Pliocene Tps unit cross-cut at high angles the strands of the Stafford fault system, and indicate that the apparent top of the Tps surface is undeformed by the Stafford fault system (Figure 6).

   The Miocene Calvert Formation is also undeformed where it crosses the Dumfries fault (Dominion, 2004a). Along a linear transect across the Dumfries fault, maximum elevations of the Calvert Formation define a planar, unfaulted surface dipping gently to the southeast with a dip of 0.4° (Figure 7). This planar Miocene surface was interpreted by Dominion (2004a) to indicate that the Dumfries has not been active since the Miocene.

   Several terraces along the south bank of the Rappahannock River were examined for evidence of deformation where they intersected the Stafford fault system (Figure 8) (Dominion, 2004a). The elevation of three Pliocene and Pleistocene terrace surfaces were examined across the Hazel Run fault and one Pleistocene terrace was examined across the unnamed fault (Figure 8). In the four transects, the reconstructed Pliocene and Pleistocene surfaces were planar and undeformed, indicating faulting on these structures had ceased by Pliocene time (Figure 9).

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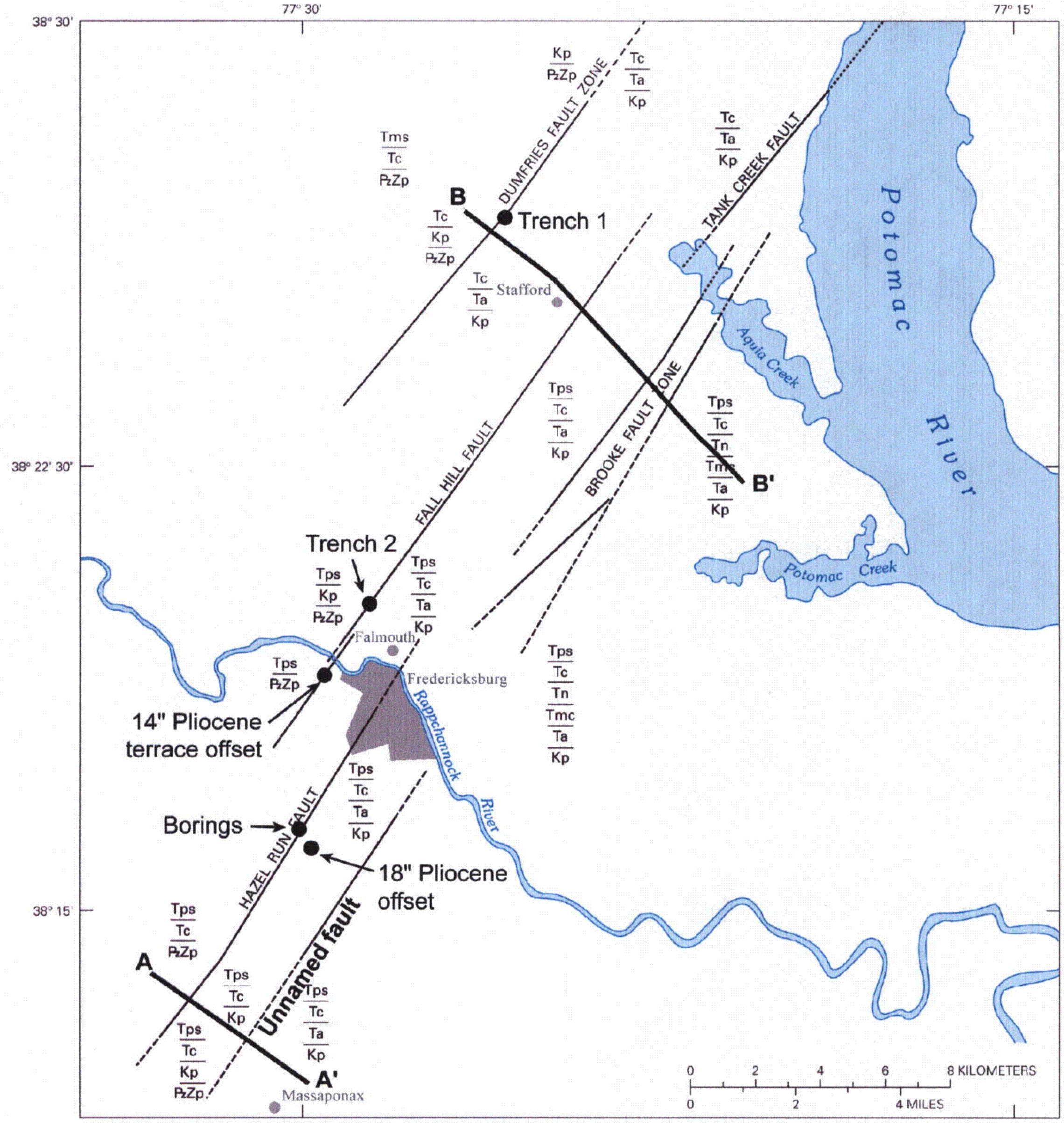
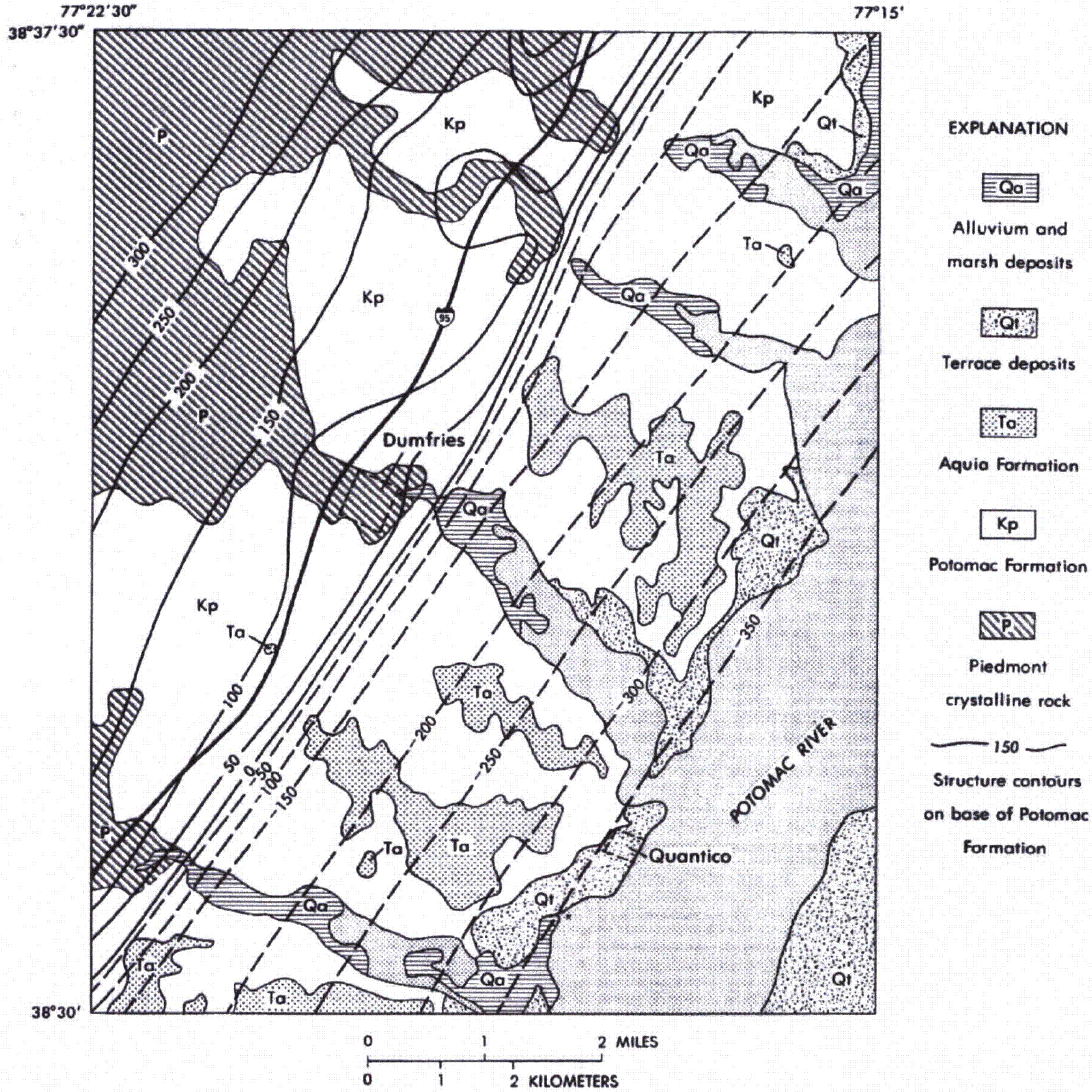


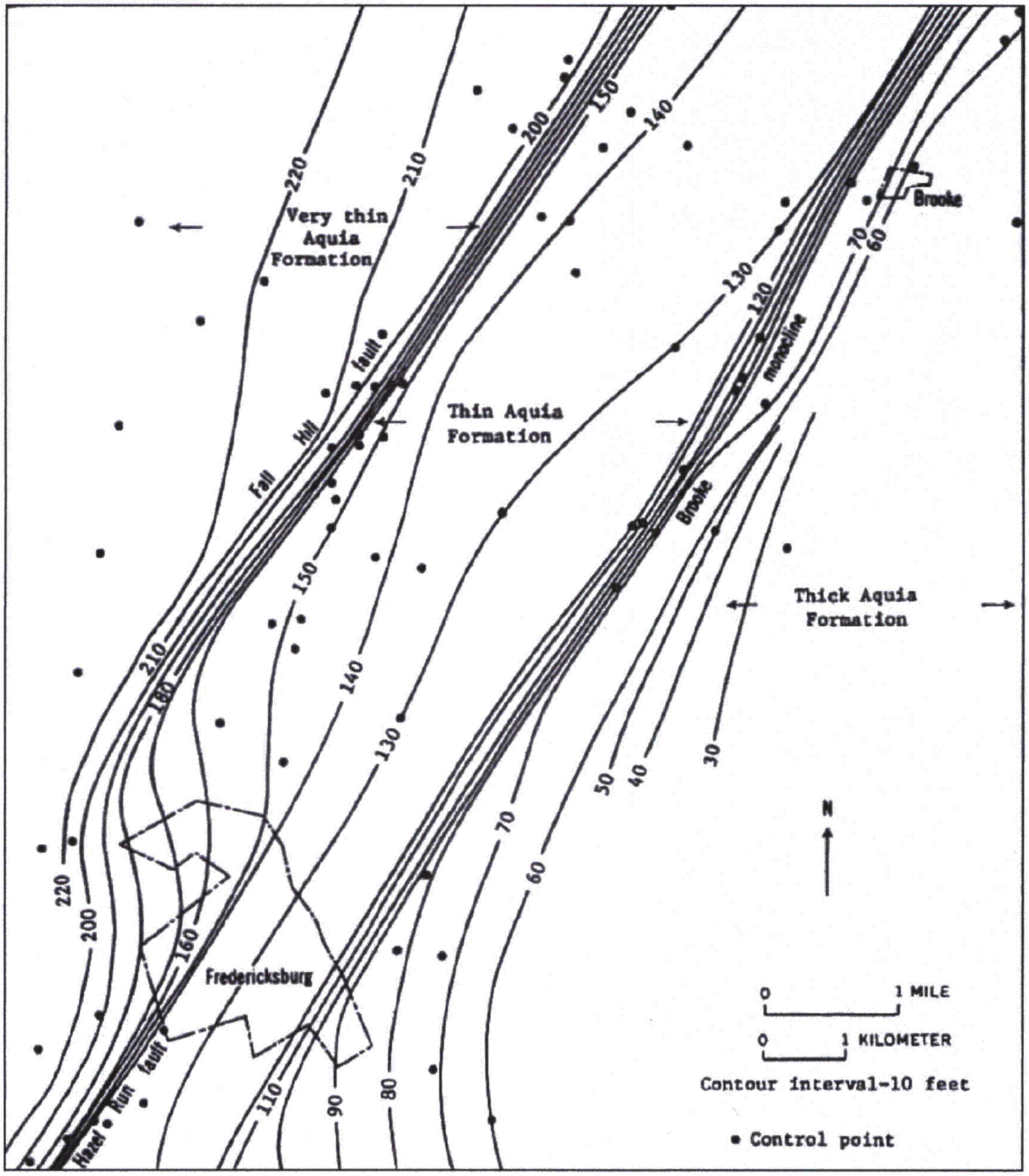
EXPLANATION

Tps	Pliocene sand and gravel	Ta	Aquia Formation (upper Paleocene)
Tms	Miocene sand and gravel	Kp	Potomac Formation (Lower Cretaceous)
Tc	Calvert Formation (lower and middle Miocene)	PzZp	Piedmont rocks (Neoproterozoic and lower Paleozoic)
Tn	Nanjemoy Formation (lower Eocene)	——	Fault—Dashed where inferred; dotted where concealed
Tmc	Marlboro Clay (upper Paleocene)		

Question 02.05.01-45 Figure 1 – Map of the Stafford Fault System and Variation in Stratigraphy Observed in Outcrops. Down-to-the-east Displacement of Coastal Plain Beds by High-angle Reverse Faults Preserves Thicker and More Complete Sections on the Southeastern Side of Structures. Dots Indicate Locations Discussed in Text. From Mixon and Newel (1982); Mixon et al. (2000, 2005)



Question 02.05.01-45 Figure 2 – Structure Contours (Feet) of the Base of the Cretaceous Potomac Formation (Top of Basement) and Geology in the Quantico Quadrangle, Virginia. The Steep Northeast-trending, Southeast-dipping Gradient Delineates the Dumfries Fault Zone. From Mixon and Newell (1982)



Question 02.05.01-45 Figure 3 – Structure Contours (Feet) of the Base of the Paleocene Aquia Formation in the Fredericksburg Area. From Mixon and Newell (1977)

Question 02.05.01-45 Figure 4 – Sketch of South Wall of Trench across Fall Hill Fault, near Falmouth, Virginia. Modified from Pepco (1976), as reported in Mixon and Newell (1982), and Mixon et al. (2005)

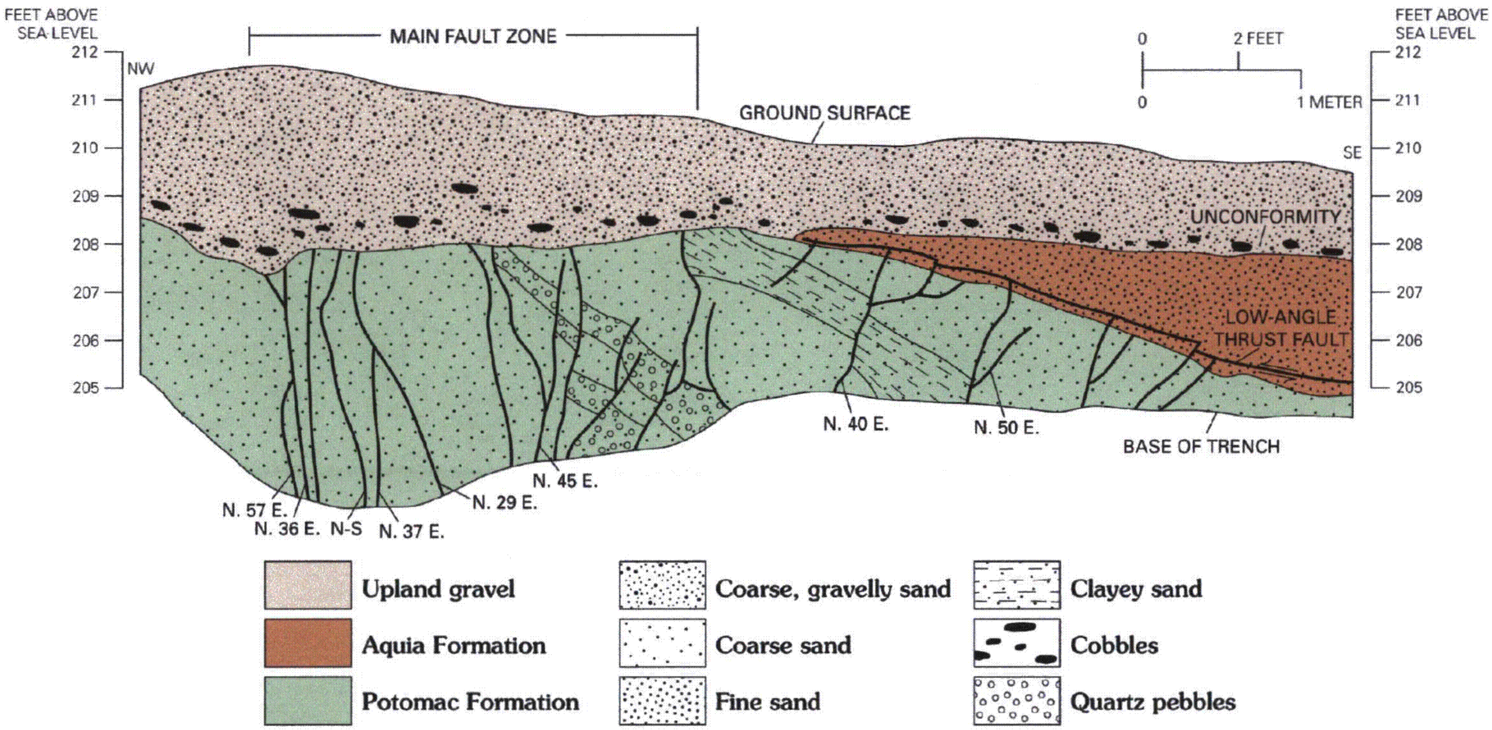
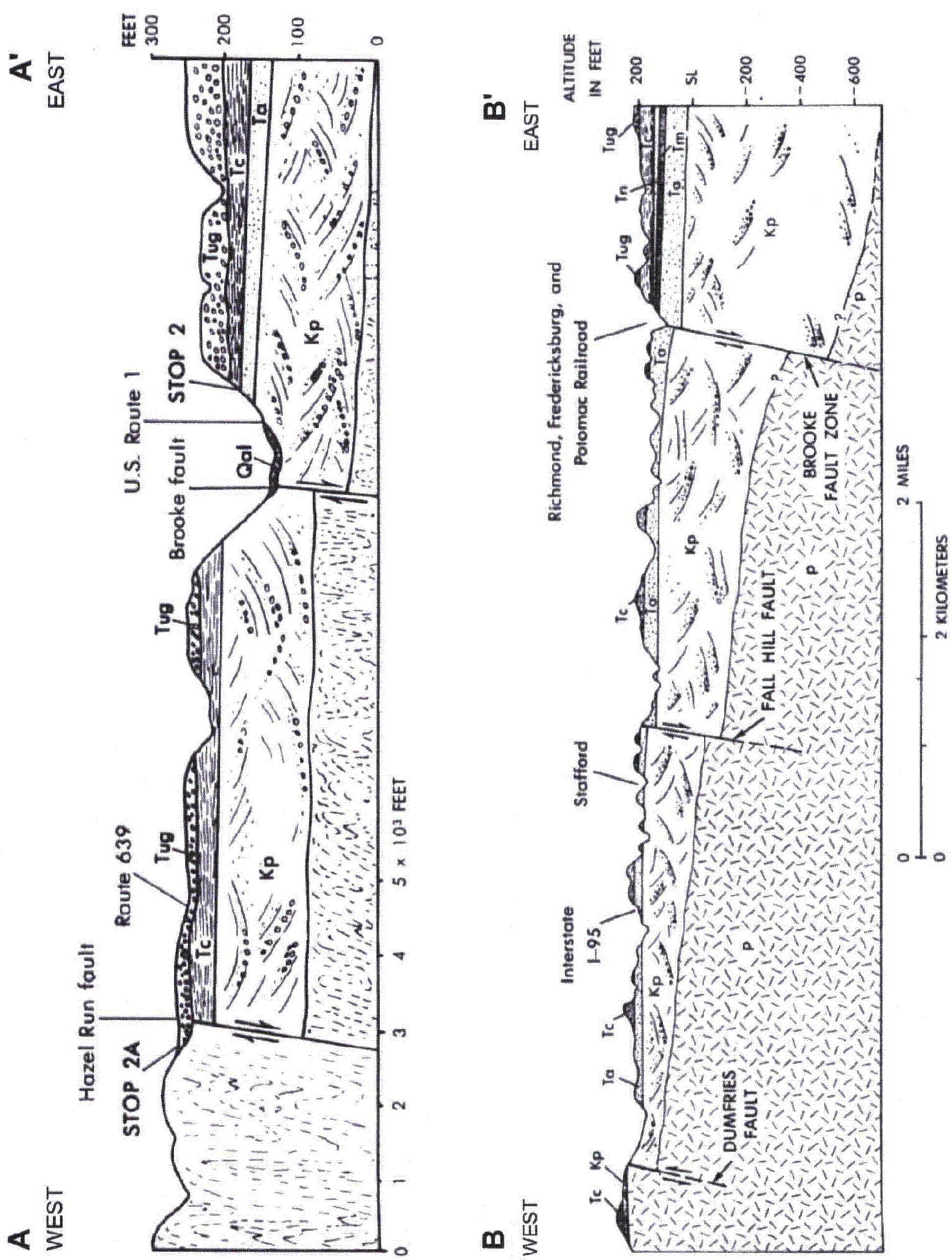
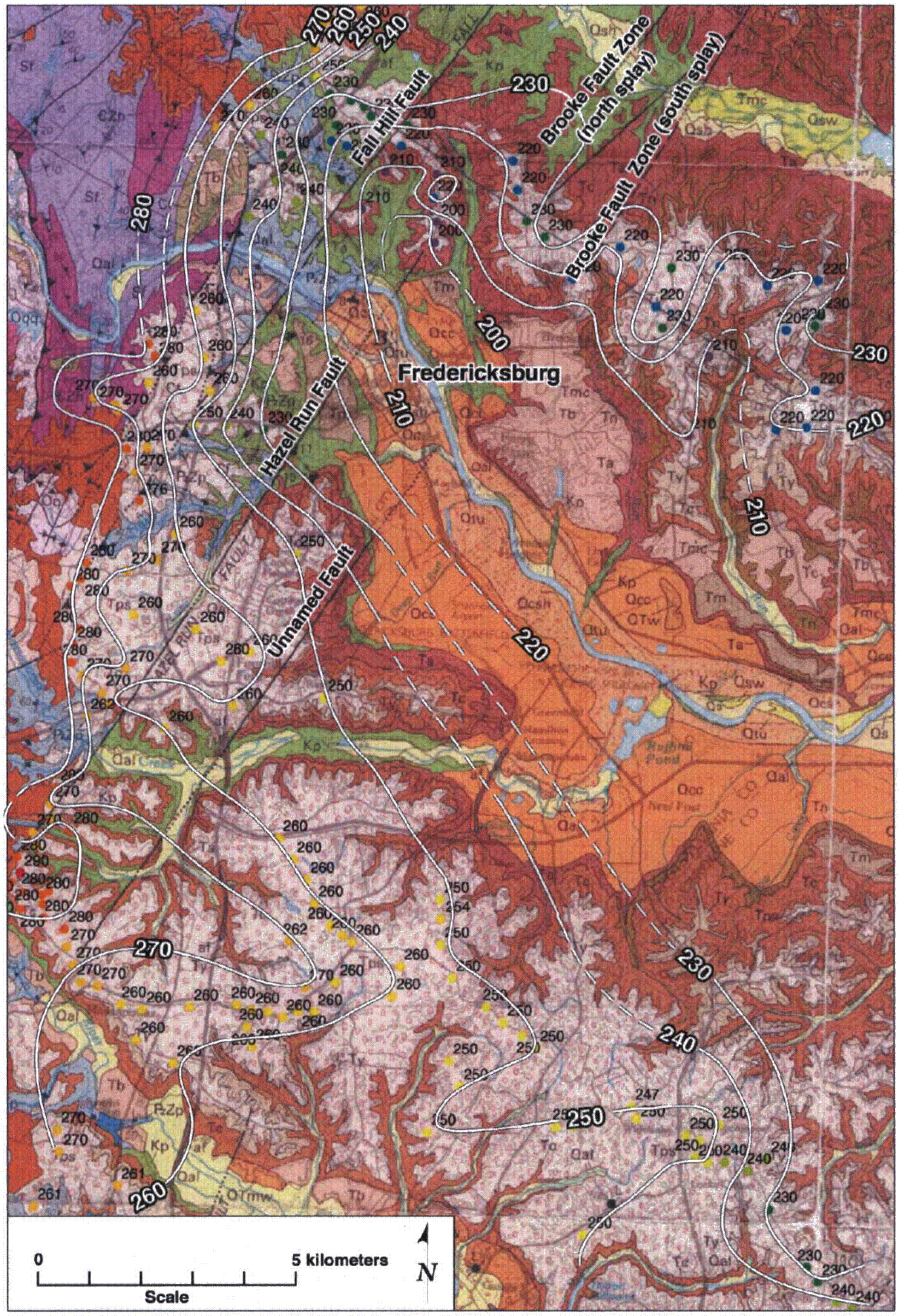


Figure 3.—Sketch of south wall of trench across Fall Hill fault, Falmouth, Va., approximately 2 mi south of Stafford quadrangle. Modified from Potomac Electric Power Company (1976). Nearby outcrop and borehole data show that the same high-angle reverse and vertical faults shown here, offset top of basement rock by as much as 120 ft.

Enclosure 1
UN#09-389
Page 63

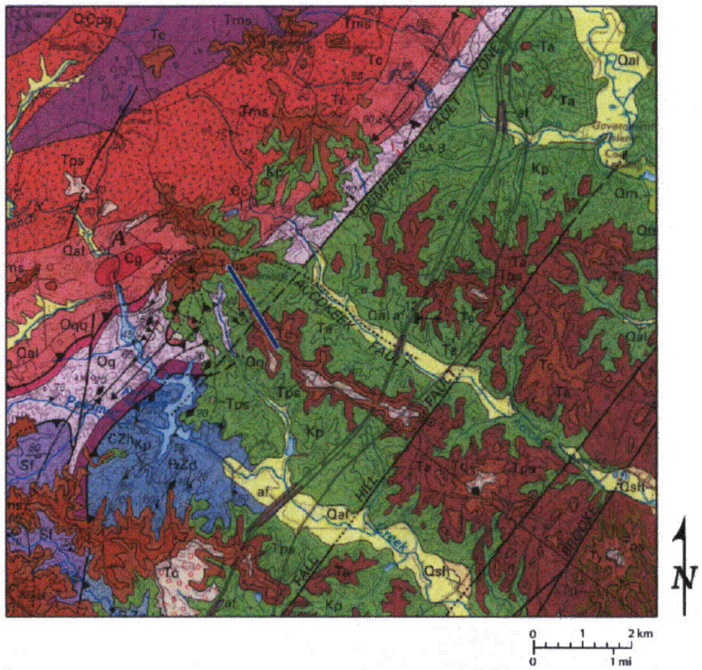


Question 02.05.01-45 Figure 5 – Generalized Cross Sections across the Stafford Fault System, from Mixon and Newell (1982). Kp, Potomac Formation; Ta, Aquia Formation, Tm, Marlboro Clan; Tn, Nanjemoy Formation; Tc, Calvert and/or Choptank Formations; Tug, Upland Gravel; Qal, Alluvium. Note that Eastern Fault (Brooke Fault) in the Southern Cross Section (A-A') is Referred to by Later Authors and this Response as Unnamed.

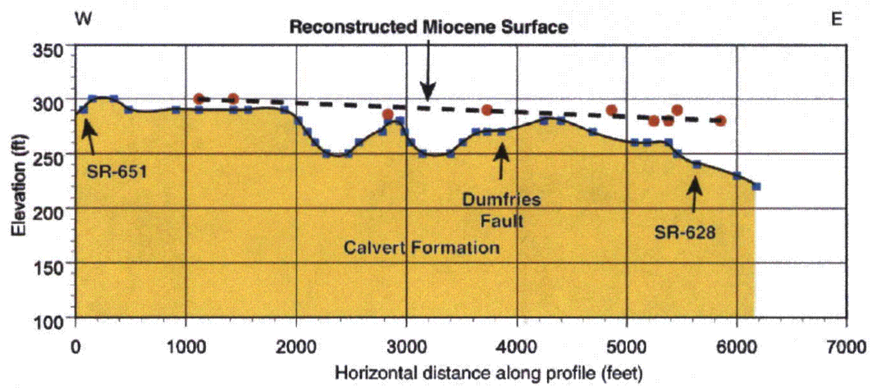


Question 02.05.01-45 Figure 6 – Structure Contour Map of the Upper Surface of the Pliocene Sand and Gravel Unit (Tps) in the Vicinity of Fredericksburg, Virginia, from Dominion (2004a). Geologic Base from Mixon et al. (2000). Contours (10-foot Interval) were Hand-Modified from Machine Generated Contours.

A)



B)

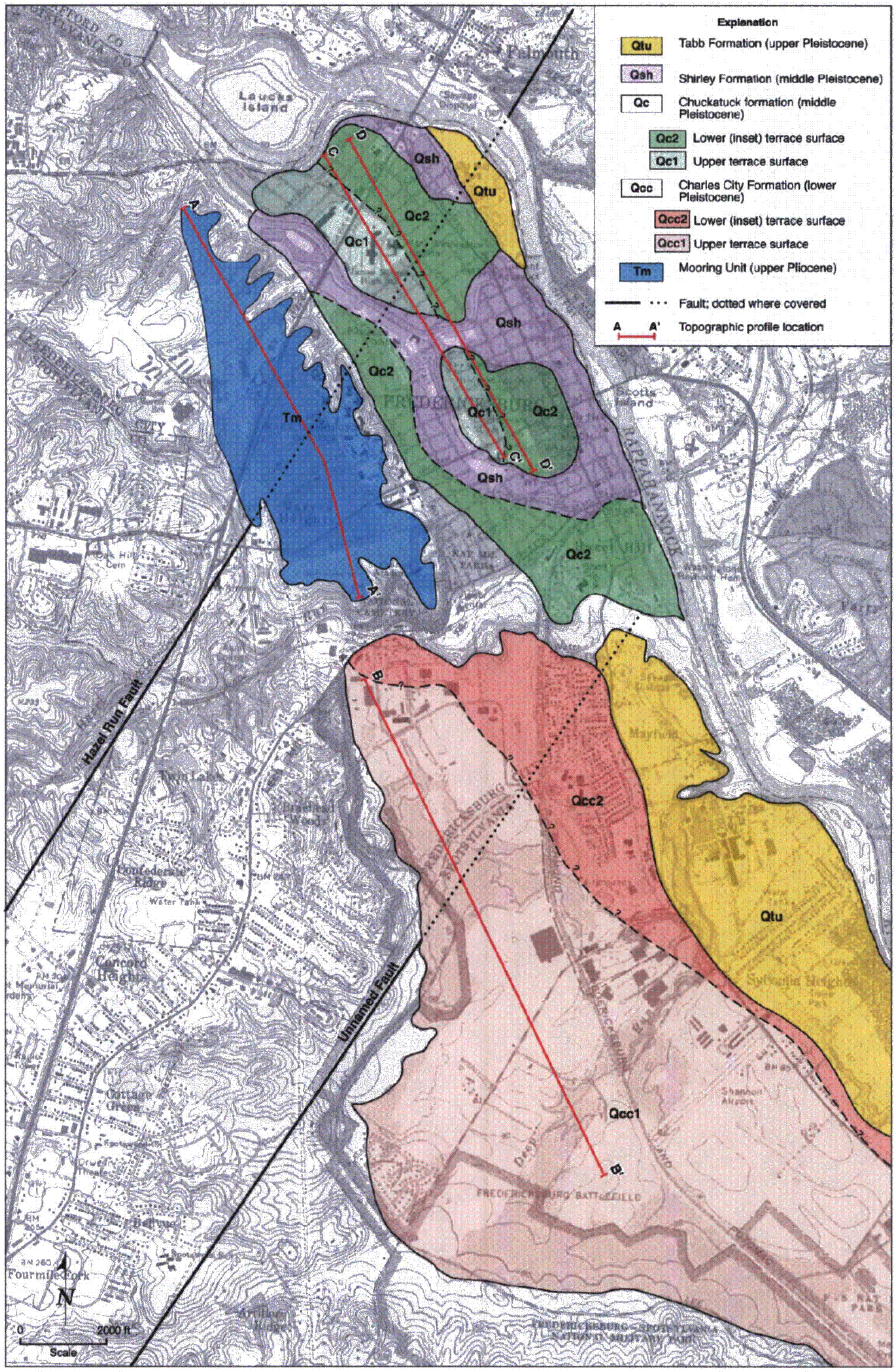


Explanation

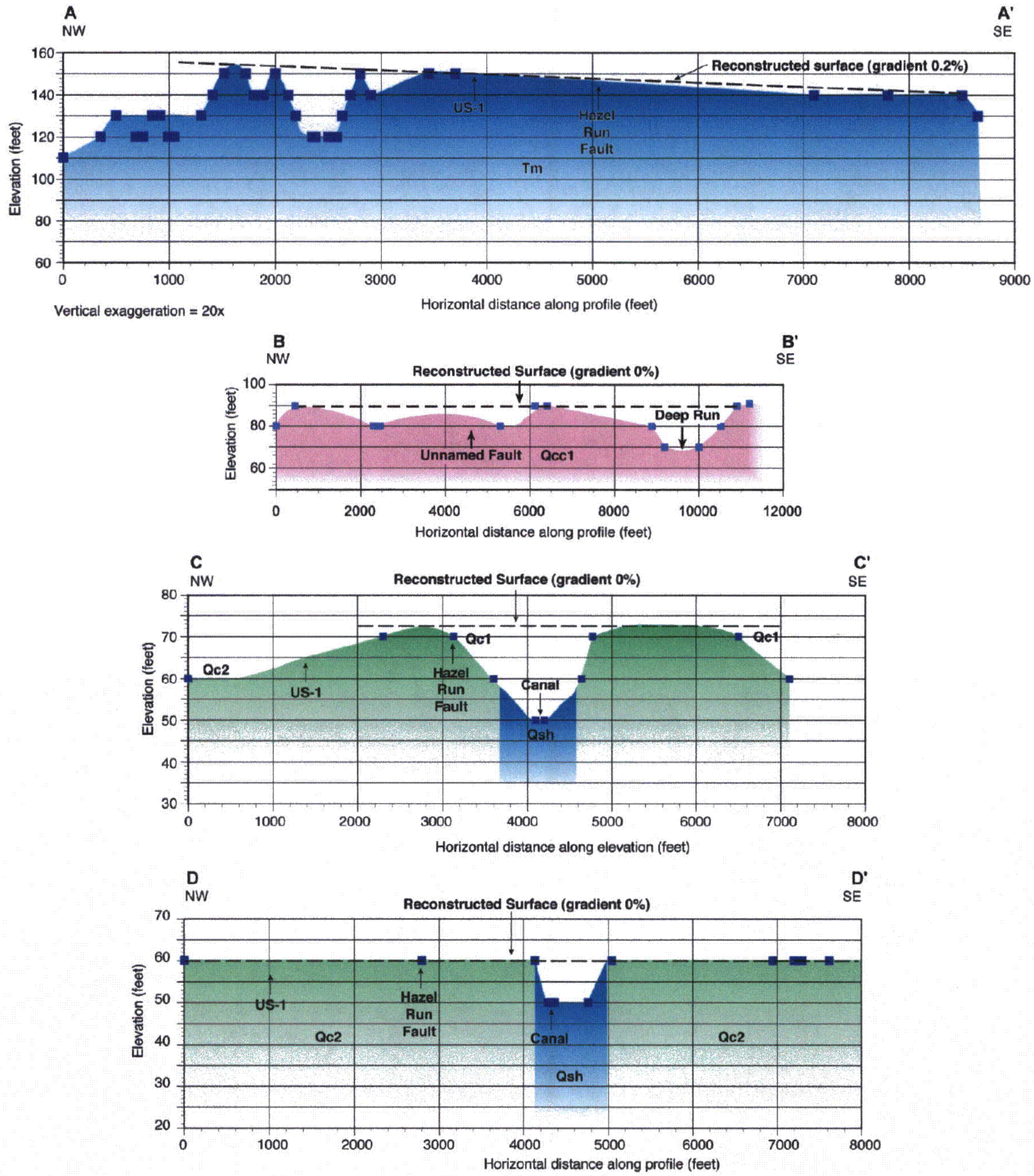
- Projected elevations
- Profile elevation (from topographic map)

Figure 2. Profile of the Calvert Formation (Tc) across the Dumfries Fault. A) Profile location (blue line) and local geology from Mixon et al. (2000). B) Topographic profile points (blue squares) with elevations of upper summit surface underlain by the Calvert Formation (red dots) projected onto the profile. Dashed line shows reconstructed Miocene surface. Note uniform gradient of reconstructed Miocene surface across the Dumfries Fault.

Question 02.05.01-45 Figure 7 – Profile of the Miocene Calvert Formation (Tc) across the Dumfries Fault, from Dominion (2004a). A) Profile Location (Blue Line) and Local Geology from Mixon et al. (2000). B) Topographic Profile Points (Blue Squares) with Elevations of Upper Summit Surface Exposing the Calvert Formation (Red Dots) Projected onto the Profile. Dashed Line Shows Reconstructed Miocene Surface. Not Uniform Gradient (0.4 Degrees) of Reconstructed Miocene Surface across the Dumfries Fault.



Question 02.05.01-45 Figure 8 – Map of Terraces along the Rappahonnock River at Fredericksburg, Virginia (Southwest Bank), from Dominion (2004a). Geology from Mixon et al. (2000). Red Lines Show Location of Topographic Profiles Presented in Figure 9.



Question 02.05.01-45 Figure 9 – Profiles of Undeformed Terrace Surfaces across the Hazel Run and Unnamed Faults, from Dominion (2004a). See Figure 8 for Locations. Geology from Mixon et al. (2000). Blue Squares Represent Points where Profile Cross a Contour Line on the Topographic Base Map. The Black Dashed Lines Indicate the Reconstructed Terrace Surface. A-A': Upper Pliocene Moorings Unit, B-B': Lower Pleistocene Charles City Formation, C-C' Lower Terrace Surface of the Middle Pleistocene Chuckatuck Formation, D-D': Upper Terrace Surface of the Middle Pleistocene Chuckatuck Formation.

COLA Impact

FSAR Section 2.5.1.1.4.4.4.1, Stafford Fault of Mixon,et al., will be revised as described in Enclosure 3 in a future revision of the COLA.