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UniStar
NUCLEAR ENERGY

10 CFR 50.4
10 CFR 52.79

May 19, 2010

UN#10-129

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 219, Response to Questions 02.05.01-66 through 69,
Basic Geologic and Seismic Information

Reference: 1) Surinder Arora (NRC) to Robert Poche (UniStar Nuclear Energy), "FINAL RAI 219 RGS2 4162" email dated March 20, 2010

2) UniStar Nuclear Energy Letter UN#10-124, from Greg Gibson to Document Control Desk, U.S. NRC, Response to Request for Additional Information for the Calvert Cliffs Nuclear Power Plant, Unit 3, RAI 219, Questions 02.05.01-63 through 65, Basic Geologic and Seismic Information, dated April 30, 2010.

The purpose of this letter is to respond to the request for additional information (RAI) identified in the NRC e-mail correspondence to UniStar Nuclear Energy, dated March 20, 2010 (Reference 1). This RAI addresses 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 (CCNPP) Unit 3 Combined License Application (COLA), Revision 6.

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Reference 2 submitted the response to Questions 02.05.01-63, 64 and 65, and a provided response date of May 20, 2010 for the response to Questions 02.05.01-66, 67, 68 and 69.

Enclosure 1 provides responses to RAI 219, Questions 02.05.01-66, 67, 68 and 69. These responses include revised COLA content. A Licensing Basis Document Change Request has been initiated to incorporate these changes into a future revision of the COLA.

Enclosure 2 provides a CD with a high resolution copy of Figure 5 (used in the response to Question 02.05.01-67).

There are no regulatory commitments identified in this letter. This letter does not contain any proprietary or sensitive information.

If there are any questions regarding this transmittal, please contact me at (410) 470-4205, or Mr. Wayne A. Massie at (410) 470-5503.

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

Executed on May 19, 2010

Christian Clement ~~Greg Gibson~~

fs Greg Gibson

Enclosures:
1. Response to NRC RAI 219, Questions 02.05.01-66, 67, 68 and 69, Calvert Cliffs Nuclear Power Plant, Unit 3
2. CD with a high resolution copy of RAI 219, Question 02.05.01-67, Figure 5, Calvert Cliffs Nuclear Power Plant, Unit 3

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 enclosure)
Loren Plisco, Deputy Regional Administrator, NRC Region II (w/o enclosure)
Silas Kennedy, U.S. NRC Resident Inspector, CCNPP, Units 1 and 2
U.S. NRC Region I Office

GTG/SJS/mdf

Enclosure 1

Response to NRC RAI 219, Questions 02.05.01-66, 67, 68 and 69,

Calvert Cliffs Nuclear Power Plant Unit 3

RAI 219

Question 02.05.01-66

FSAR, Section 2.5.1.1.4.4.4.5, Hillville fault zone, refers to seismic reflection data to support the presence of the Hillville fault, within 5 miles of CCNPP. In RAI 02.05.01-18, the NRC staff asked for a copy of the seismic line St-M-1 and asked about the fault possibly being captured in the extensive marine seismic data taken in the Chesapeake Bay, to the east of the land-based seismic reflection line.

You responded by providing a segment of the seismic reflection line and an enlarged figure of the LiDAR data. You stated that the fault is seen on the St M-1 seismic reflection data but was not interpreted on the marine seismic reflection in the Chesapeake Bay. The fault is projected to the NW (placing it west, southwest of CCNPP) based on coincidence with an aeromagnetic anomaly. In addition, a structure contour map published by the MD Geological Survey does not show offset on a regional recognized stratigraphic marker, the top of the Piney Point-Nanjemoy Aquifer.

In your response, you stated that you plan no change to the FSAR. Please justify why the response figures and associated discussions should not be a part of the revised FSAR.

Response

The figures and associated discussions provided in response to RAI 02.05.01-18[1] will be incorporated into the FSAR Subsections 2.5.1.1.4.4.4.5 and 2.5.3.2.1. Figure 1 from the response will be added as FSAR Figure 2.5-305. This figure is a reproduction of Figure 15 from Hansen (1978) showing the interpretation of the St-M-1 seismic reflection data. In addition, the existing FSAR Figure 2.5-26 will be replaced by Figure 2 from the RAI 02.05.01-18[1] response.

FSAR Subsections 2.5.1.1.4.4.4.5 and 2.5.3.2.1 will include a discussion of the structure contours of the Piney Point-Nanjemoy Aquifer and the absence of faulting in marine geophysical data along the northwest projection of the fault. Note that the Hillville fault was added to the FSAR Figures 2.5-10 and 2.5-11 as part of the response to RAI 130 Question 02.05.01-47[2].

<u>Reference used in this response</u>:

Hansen, H.J., 1978, Upper Cretaceous (Senonian) and Paleocene (Danian) pinchouts on the south flank of the Salisbury Embayment, Maryland and their relationship to antecedent basement structures: Department of Natural Resources Maryland Geological Survey Report of Investigations No. 29, 36p.

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

2 G. Gibson (UniStar Nuclear Energy) to Document Control Desk (U.S. NRC), "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," Letter UN#09-389, dated October 2, 2009.

COLA Impact

FSAR Section 2.5.1.1.4.4.4.5 and 2.5.3.2.1 are revised as follows: Note that this markup is to the FSAR text as provided in UniStar Nuclear Energy letter UN#09-389[2] dated October 2, 2009.

2.5.1.1.4.4.4.5 Hillville Fault Zone

The Hillville fault zone of Hansen (1978) approaches to within 5 mi (8 km) of the site in the subsurface (Figure 2.5-25, Figure 2.5-26, and Figure 2.5-27). The 26 mi (42 km) long, northeast-striking fault zone is composed of steep southeast-dipping reverse faults that align with the east side of the north-to northeast-trending Sussex-Currioman Bay aeromagnetic anomaly (i.e. SGA, Figure 2.5-11 and Figure 2.5-22) (Hansen, 1986). Based on seismic reflection data collected about 9 mi (15 km) west-southwest of the site, the fault zone consists of a narrow zone of discontinuities that vertically separate basement by as much as 250 ft (76 m) (Hansen, 1978) (Figure 2.5-26 and Figure 2.5-305). With exception of the single seismic reflection profile St. M-1 of Hansen (1978) there are no other data to indicate the down-dip geometry of the fault. The strike of the fault is inferred entirely from the inferred coincidence of the fault with the Sussex Currioman Bay aeromagnetic anomaly (Figure 2.5-11)(Hansen, 1986).

The Hillville fault zone delineates a possible Paleozoic suture zone reactivated in the Mesozoic and Early Tertiary. The fault zone is interpreted as a lithotectonic terrane boundary that separates basement rocks associated with Triassic rift basins on the west from low-grade metamorphic basement on the east (i.e., Sussex Terrane/Taconic suture of Glover and Klitgord, (Glover, 1995a) (Figure 2.5-17) (Hansen, 1986). The apparent juxtaposition of the Hillville fault zone with the Sussex-Currioman Bay aeromagnetic anomaly suggests that the south flank of the Salisbury Embayment may be a zone of crustal instability that was reactivated during the Mesozoic and Tertiary. Cretaceous activity is inferred by Hansen (Hansen, 1978) who extends the fault up into the Cretaceous Potomac Group. The resolution of the geophysical data does not allow an interpretation for the upward projection of the fault into younger overlying Coastal Plain deposits (Hansen, 1978). Hansen (Hansen, 1978), however, used stratigraphic correlations (i.e., "pinchouts") of Coastal Plain deposits from borehole data to speculate that the Hillville fault may have been active during the Early Paleocene.

There is no geologic data to suggest that the Hillville fault is a capable tectonic source. Field and aerial reconnaissance, coupled with interpretation of aerial photography and LiDAR data (see Section ~~2.5.3.1~~ 2.5.1.1.4.4 for additional information regarding the general methodology), conducted during this COL study shows that there are no geomorphic features indicative of potential Quaternary activity along the surface-projection of the Hillville fault zone. A review of geologic cross sections (McCartan, 1989a) (McCartan, 1989b) (Glaser, 2003b) (Glaser, 2003c) show south-dipping Lower to Middle Miocene Calvert Formation and no faulting along projection with the Hillville fault zone. A structure contour map of the top of the Eocene Piney Point-Nanjemoy Aquifer appears undeformed in the vicinity of the Hillville fault, indicating the likely absence of faulting of this regionally recognized stratigraphic marker (Figure 2.5-14). A geologic cross section prepared by Achmad and Hansen (Achmad, 1997) that intersects the Hillville fault, also shows no demonstrable offset across the contact between the Piney Point and Nanjemoy Formations (Figure 2.5-13). Furthermore Quaternary terraces mapped by McCartan (McCartan,1989b) and Glaser (Glaser, 2003b) (Glaser, 2003c) bordering the Patuxent and Potomac Rivers were evaluated for features suggestive of tectonic deformation by interpreting LiDAR data and through field and aerial reconnaissance (Figure 2.5-26, Figure 2.5-27, and Figure 2.5-301). No northeast-trending linear features coincident with the zone of faulting were observed where the surface projection of the fault intersects these Quaternary surfaces. Aerial reconnaissance of this fault zone also demonstrated the absence of linear features coincident or aligned with the fault zone (Figure 2.5-301). The ~~Lastly,~~ interpretation of the detailed stratigraphic profiles collected along Calvert Cliffs and the western side of Chesapeake Bay provide geologic evidence for no expression of the fault where the projected fault would intersect the Miocene-aged deposits (Kidwell, 1997; see Section 2.5.3 for further explanation). Lastly, abundant shallow seismic reflection data acquired and interpreted by Colman (1990) in Chesapeake Bay intersect the northeast projection of the Hillville fault (Figure 2.5-29). Colman (1990) makes no mention of encountering the Hillville fault in their interpretations of the seismic data. Therefore, we conclude that the Hillville fault zone is not a capable tectonic source, and there is no new information developed since 1986 that would require a significant revision to the EPRI model.

2.5.3.2.1 Hillville Fault Zone

The 26 mi (42 km) long Hillville fault (MGS, 1978) approaches to within 5 mi (8 km) of the CCNPP site as shown in Figure 2.5-11, Figure 2.5-26, and Figure 2.5-32. The fault consists of a northeast-striking zone of steep southeast-dipping reverse faults that coincide with the Sussex-Currioman Bay aeromagnetic anomaly (Hansen, 1986). The style and location of faulting are based on seismic reflection data collected about 9 mi (14.5 km) west-southwest of the CCNPP site. Seismic line St M-1 (location shown on Figure 2.5-26) imaged a narrow zone of discontinuities that vertically separate basement by as much as 250 ft (76 m) (MGS, 1978) as shown in Figure 2.5-~~27~~305. It has been interpreted (MGS, 1986) that this offset is part of a larger lithotectonic terrane boundary that separates basement rocks associated with Triassic rift basins on the west from low-grade metamorphic basement on the east. The Hillville fault may represent a Paleozoic suture zone that was reactivated in the Mesozoic and Early Tertiary similar to the Brandywine fault system located to the west of the CCNPP site. Based on stratigraphic correlation (e.g., "pinchouts") between boreholes within Tertiary Coastal Plain deposits, it is speculated (MGS, 1986) that the Hillville fault was last active in the Early Paleocene. However, MGS (1986) concludes that the Upper Paleocene Aquia Formation and Miocene Calvert Formation provide evidence for the absence of deformation upsection. For example, a structure contour map of the top of the Eocene Piney Point-Nanjemoy Aquifer appears undeformed in the vicinity of the Hillville fault, that likely reflects the absence of considerable faulting of this regionally extensive stratigraphic marker (Figure 2.5-14). Lastly, a geologic cross section prepared by Achmad and Hansen (Achmad, 1997) that intersects the Hillville fault shows no demonstrable offset across the contact between the Piney Point and Nanjemoy Formations (Figure 2.5-13).

Field and aerial (inspection by plane) reconnaissance, coupled with interpretation of aerial photography (review and inspection of features preserved in aerial photos) and LiDAR data shows that there are no geomorphic features indicative of potential Quaternary activity along the surface-projection of the Hillville fault zone. Multiple Quaternary fluvial terraces of the Patuxent and Potomac Rivers previously mapped (USGS, 1989c) (USGS, 1989d) (MGS, 1994) (MGS, 2003b) (MGS, 2003c) were evaluated for features suggestive of tectonic deformation using the LiDAR data as shown in Figure 2.5-26. Furthermore, where the Hillville fault would intersect the steep cliffs of Chesapeake Bay, there is direct observation of no faulting in the exposed Miocene strata. This is consistent with cross sections (Kidwell, 1997) (Achmad, 1997) (MGS, 2003b) (MGS, 2003c) that trend oblique to and across the northeast strike of the Hillville fault and do not show a fault as shown in Figure 2.5-13, Figure 2.5-30, and Figure 2.5-33. There is no pre-Electric Power Research Institute (EPRI) or post-EPRI (EPRI, 1986) study of seismicity spatially associated with this feature, or any geomorphic evidence of Quaternary deformation as shown in Figure 2.5-25. Abundant shallow seismic reflection data acquired and interpreted by Colman (1990) in Chesapeake Bay intersect the northeast projection of the Hillville fault (Figure 2.5-29). Colman (1990) makes no mention of encountering the Hillville fault in their interpretations of the seismic data. Thus, based on the absence of geomorphic expression, seismicity, and offset of Miocene to Quaternary surficial deposits, it is concluded that the Hillville fault is not a surface-fault rupture hazard at the CCNPP site.

Figure 2.5-26 is updated as shown and two new figures, Figure 2.5-301 and Figure 2.5-305 are added. Figure 2.5-301 was also submitted with the response to Question 02.05.01-64[3].

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[3] G. Gibson (UniStar Nuclear Energy) to Document Control Desk (U.S. NRC), "Response to Request for Additional Information for the Calvert Cliffs Nuclear Power Plant, Unit 3, RAI 219, Questions 02.05.01-63 through 65, Basic Geologic and Seismic Information," Letter UN#10-124, dated April 30, 2010.

Enclosure 1
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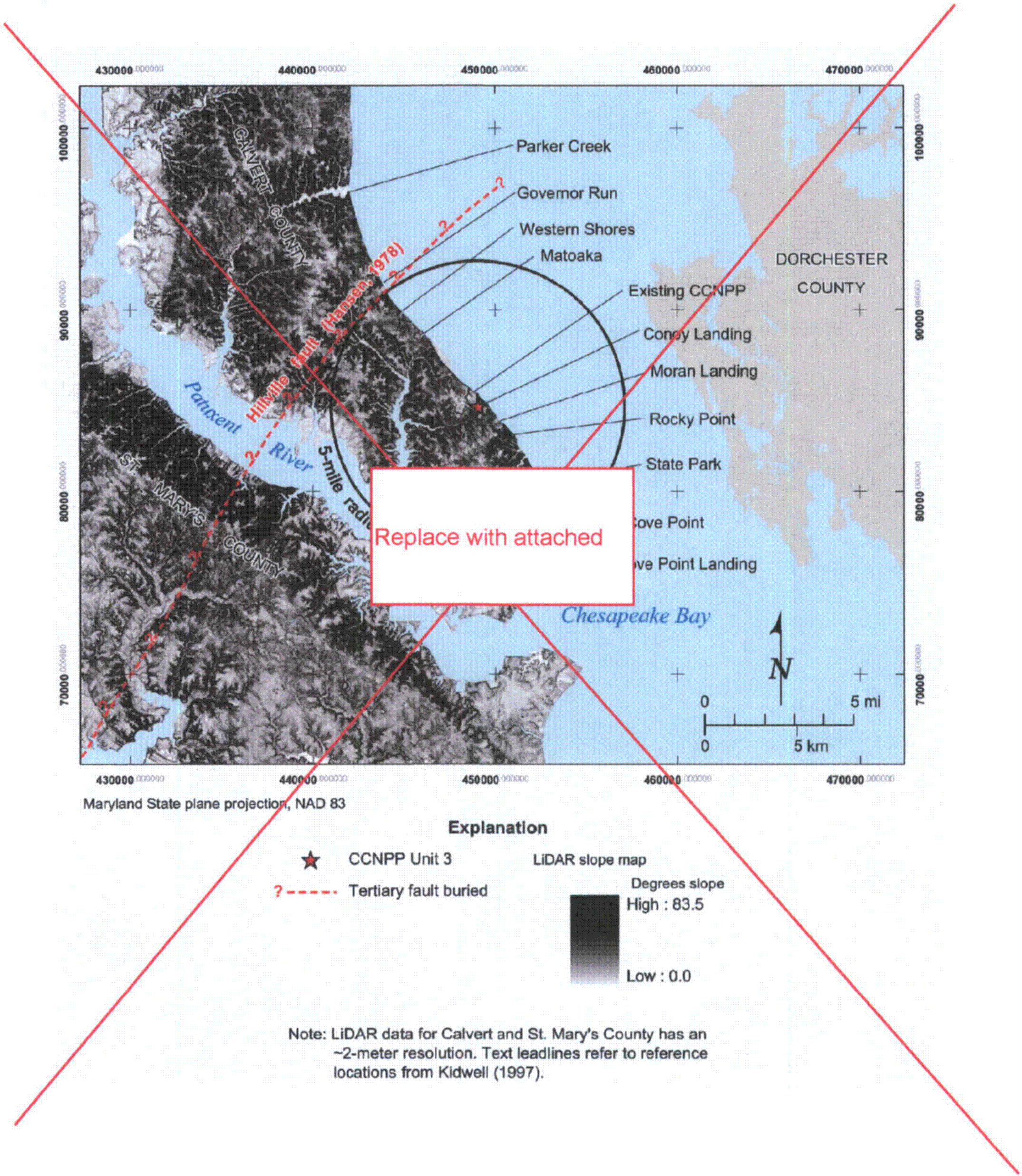
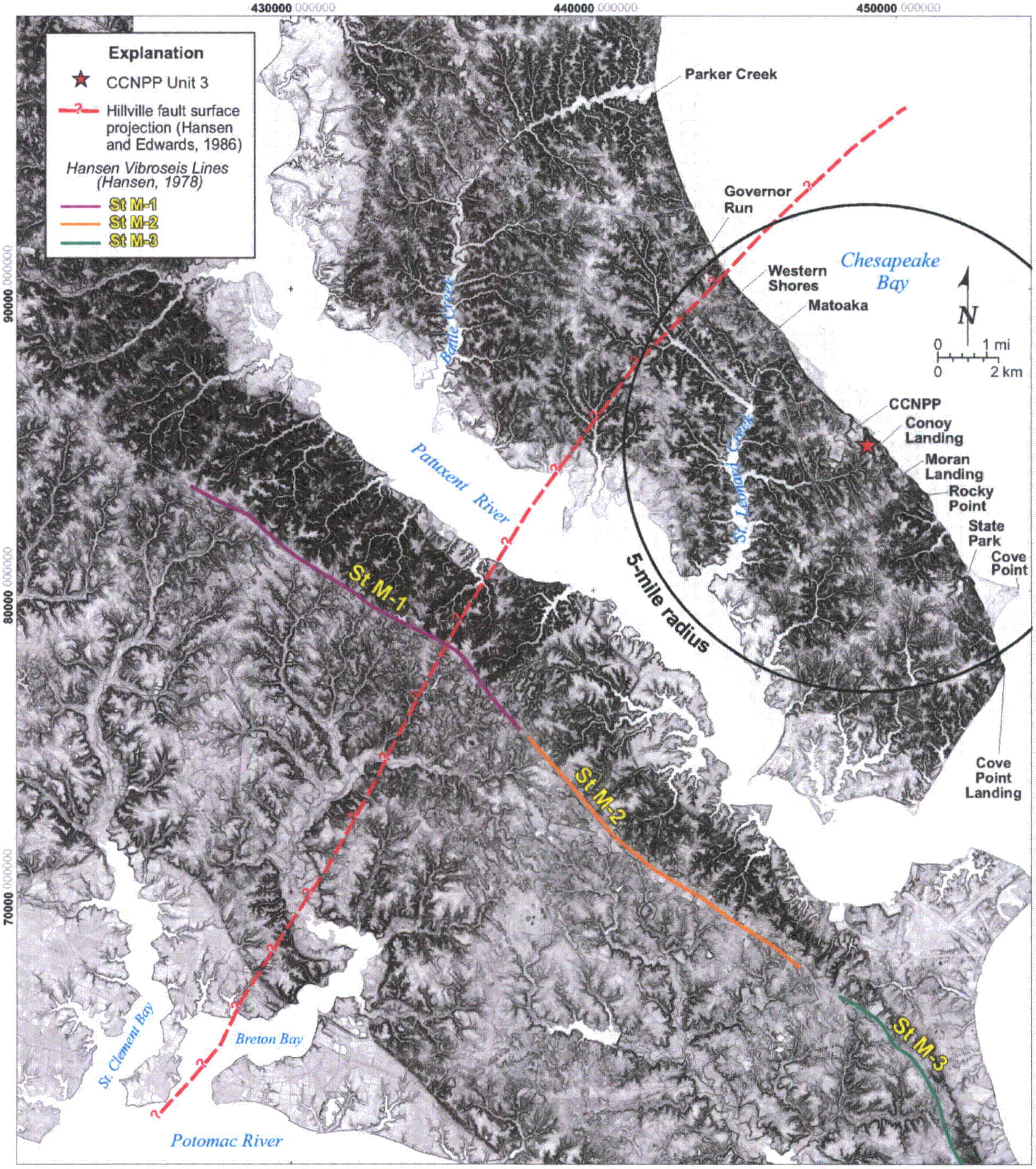
Figure 2.5-26 {LiDAR Data for Calvert and St. Mary's Counties}



Note: LiDAR data for Calvert and St. Mary's County has an ~2-meter resolution. Text leadlines refer to reference locations from Kidwell (1997).

Replacement Figure 2.5-26



Note: LiDAR data for Calvert and St. Mary's County has a resolution of 2 meters.

Figure 2.5-301 {Field and Aerial Reconnaissance Map for CCNPP Unit 3}

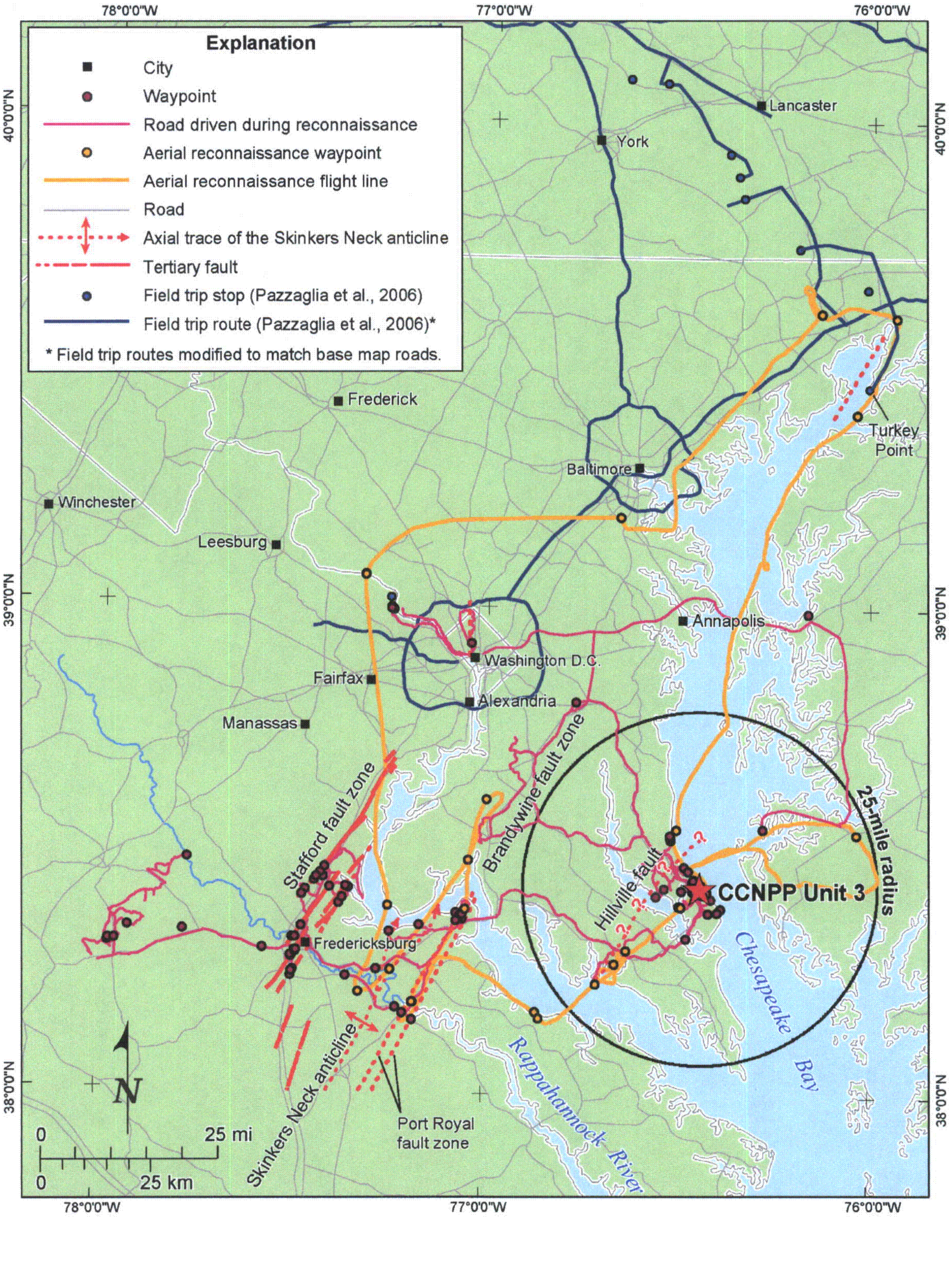
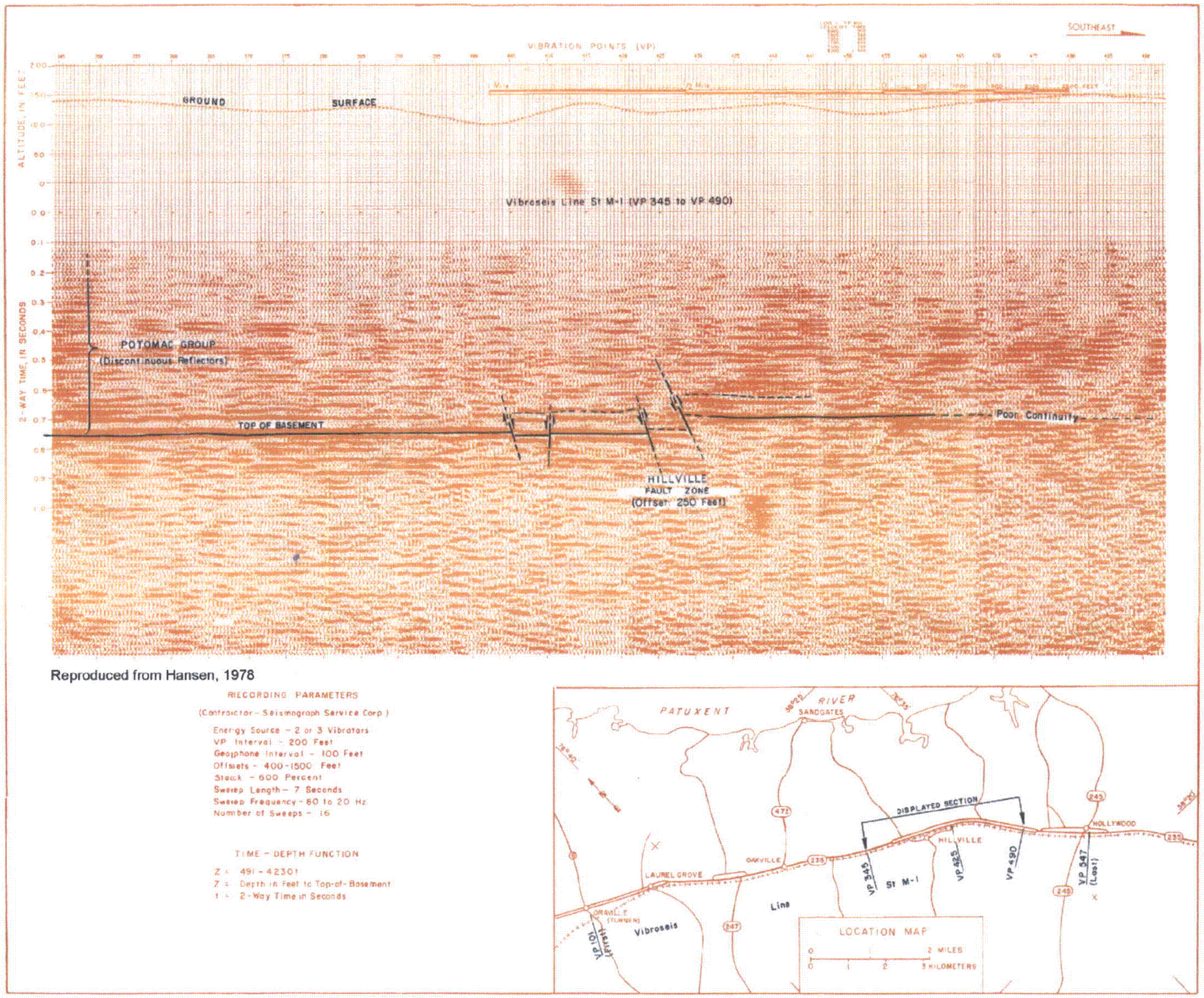


Figure 2.5-305 {Seismic Reflection Line St. M-1 Showing Hillville Fault of Hansen (1978)}



Reproduced from Hansen, 1978

RAI 219

Question 02.05.01-67

In RAI 2.5.1-19 and -48, NRC staff asked for additional information about an unnamed fault in the northern portion of the Chesapeake Bay interpreted by Dr. F. Pazzaglia (Pazzaglia, 1993a, 1993b, 2006)(FSAR Subsection 2.5.1.1.4.4.4.6). You indicated that there was little evidence to support the existence of any fault.

With regard to your RAI response, please address the following issues:

- Older Coastal Plain units more widely exposed and mapped on the SE side of fault (up thrown side) than on the NW side.
- The LiDAR surface map provided in your response is inconclusive because an 8 m elevation difference across the fault would not show in Figure 6 at the scale presented. Furthermore, locating a fault that is "coming ashore" would require examination all along the coast line at a large scale resolution (close in detail). Pazzaglia's dotted line is an approximation of the location of his interpreted fault. This also applies to examination of the bay bathymetry.
- You argue that lack of elevation data for the <u>base</u> of the TP beds precludes corroborating Pazzaglia's 8 m offset. Pazzaglia made his correlation based on the elevation differences of more than one distinct unconformity in Coastal Plain units, both exposed and buried (examined in a trench dug into the Coudon Farm terrace, ~ 3m deep).
- Contrary to your assertion that soil profiles do not correlate across the bay, Pazzaglia does not attempt to correlate the soils located at Coudon's Farm terrace with Turkey Point soils. This is not the basis of his fault interpretation.
- The marine seismic reflection data disclosing paleochannels of the Susquehanna River does not cover the specific area under discussion. However, you pointed out that there are paleochannel segments that are straight. This does not require that the straight eastern Chesapeake Bay coastline must be non-tectonic in origin.
- Susquehanna River channel takes a sharp turn to the south at it's mouth or the head of the bay. This is also supported by the series of submarine paleochannels.
- The bathymetric profile across the bay in Figure 4 indicates a smooth profile but the scale of presentation does not permit close examination of the profile. The offshore location of the fault could be located just off shore from Turkey Point, in the thalweg channel of the Susquehanna River. Newell at al, 2004 interpreted recent river/deltaic deposits along the base of the bay, almost as far south as Annapolis. These deposits could mask a small surface expression of a submarine fault.
- Sea Cliffs on west-facing shorelines of the Elk Neck and Delmarva Peninsulas, along with all streams draining east indicating a tilted block.
- The argument that there have not been subsequent, independent studies to Pazzaglia's does not in itself rule out a fault interpretation.
- In response to RAI 48 b, Part 2, the applicant described the distinction between Higgins' and Pazzaglia's geologic mapping. Higgins's map (Figure 5a) is an earlier interpretation

that does not necessarily refute Pazzaglia's interpretation. NRC staff note that the differences are mostly a matter of breaking out subunits from formerly undifferentiated upland gravel deposits or reinterpreting an informal unit into a distinct stratigraphic formation. Southeast of fault, Pazzaglia breaks out additional units, Bryn Mawr and Perryville Fm, from Higgins' undifferentiated Upland Gravel unit. Northwest of fault, Pazzaglia reinterprets Higgins' Upland gravel as Pensauken Fm.

Please provide a discussion about this potential fault that addresses the above issues.

Response

A more comprehensive description of the hypothesized fault (Pazzaglia, 1993a) (Pazzaglia, 2006) is presented to clarify the inherent uncertainties on the evidence for a fault in the northern part of Chesapeake Bay, Cecil County, Maryland. This response includes a summary of the (1.0) Local Geologic Setting of the area; (2.0) Quaternary geologic mapping and stratigraphic profiles of Pazzaglia (1993a)(1993b)(2006) that form the basis of the hypothesized fault; (3.0) Key arguments in previous RAI responses and new geologic information; and (4.0) Responses for the NRC question issues.

For the CCNPP Unit 3 COL application and previous RAI responses, UniStar has completed several investigative tasks to evaluate the hypothetical fault of Pazzaglia (1993a)(1993b)(2006). These include:

- Conducting an exhaustive literature review;
- Performing field and aerial reconnaissance of the local and regional area;
- Participating in a field trip entitled *Rivers, glaciers, landscape evolution, and active tectonics of the central Appalachians, Pennsylvania and Maryland* (Pazzaglia et al., 2006) lead by F. Pazzaglia (October 18th to 21st 2006). A field trip stop was devoted to addressing the Turkey Point beds and the hypothesized fault;
- Conducting multiple interviews with Dr. Frank Pazzaglia via e-mail, phone and in-person (10/18/2006; 02/13/2007; 3/21/2010);
- Preparing detailed topographic maps using LiDAR data and available bathymetric data to evaluate the onshore and offshore geomorphology; and
- Preparing maps, topographic profiles, and geologic cross sections using available LiDAR, geologic and borehole data developed originally by Pazzaglia (1993a), Higgins (1986)(1990),Benson (2006), and Edwards (1979).

1.0 <u>Local Geologic Setting of the Area</u>

Pazzaglia (1993a) hypothesized a fault in northern Chesapeake Bay near the Elk Neck Peninsula on the basis of geologic mapping and apparent elevation differences within Pleistocene deposits (FSAR Figure 2.5-25 and new Figure 2.5-302). The three key geologic units in the area of the inferred fault include from oldest to youngest: Bryn Mawr Formation, Pensauken Formation, and the Turkey Point beds. A summary of the lithologic characteristics and origin of each unit is presented below based on the findings of Pazzaglia (1993a), Owens (1979), and Higgins (1986)(1990).

The Bryn Mawr Formation consists of a yellow quartzose-rich, well sorted and well-rounded sandy gravel and pebbly sand of fluvial origin. The deposit is extensive across Pennsylvania, Delaware and Maryland, and generally occurs at elevations exceeding 60 m above mean sea level (amsl). In the area of Coudon Farm, the deposit is derived from the Susquehanna River and unconformably overlies Cretaceous Potomac Group. The age of the fluvial deposit is estimated as late to middle Miocene (Pazzaglia, 2006). The distribution of the deposit in the subject area is constrained primarily west of Chesapeake Bay with sporadic remnants rimming the higher elevations of Elk Neck Peninsula (FSAR Figure 2.5-302). Pazzaglia (2006) concludes that the Bryn Mawr Formation was likely deposited during a middle to late Miocene eustatic highstand when erosion was stripping the Appalachians of a deeply weathered regolith.

The Pensauken Formation is a reddish brown, fluvially-derived feldspathic quartz sand to gravelly sand occurring at elevations ranging from 5 to 25 m amsl (FSAR Figure 2.5-302). Unlike the Bryn Mawr Formation, the gravel component is highly variable and includes igneous, sedimentary and metamorphic clasts. The Pensauken Formation is estimated to be Pliocene in age but also may extend into the early Pleistocene (Pazzaglia, 2006). The Pensauken Formation consists of broad and deep paleochannel deposits largely derived from the paleo-Hudson and Delaware Rivers (Figure 1). On the basis of geologic mapping by Owens (1979), Higgins (1986) and Pazzaglia (1993a), the Pensauken Formation is widely observed along the east side of Elk Neck Peninsula within the Elk River watershed supporting a paleo-Delaware-Hudson River origin (Figure 1)(Figure 2)(Pazzaglia, 2006). Pazzaglia (1993a) recognizes three lithofacies within the Pensauken Formation. The basal lithofacies (1 and 2) of the Pensauken are interpreted as sourced from the paleo-Delaware-Hudson River (Figure 1) (Owens, 1979). The upper lithofacies (lithofacies 3) was differentiated from the lower two as being a coarser-grained fluvial facies with both southeasterly and southerly paleoflow orientations, suggesting both a Susquehanna River and paleo-Delaware Hudson source (Pazzaglia, 1993a; 2006). Vertical relief along the base of the Pensauken Formation is highly irregular (up to 40 to 50 feet) based on review of LiDAR-based topographic profiles (as much as 11 m) (Figure 3), as well as previous mapping by Pazzaglia (1993a) and Higgins (1986)(1990).

The Turkey Point beds of Pazzaglia (1993a) are interpreted as early to late Pleistocene fluvial to estuarine deposits believed to be distinct to the Susquehanna River (FSAR Figure 2.5-302). The Turkey Point beds occur at elevations ranging from 18-40 meters and are composed of pebbly sand and silts with laminated silty clay. The beds contain buried and truncated paleosols often used to denote a lithofacies change. Pazzaglia (1993a) subdivides the Turkey Point beds from oldest to youngest into three lithofacies (1-3). On the basis of sedimentary structures, petrography, and multiple unconformities, the Turkey Point beds are interpreted as fluvial and tidal-estuarine in origin, and are interpreted to represent a change from large fluvial depositional systems (i.e. Pensauken Formation) to more quiet water estuarine conditions (Pazzaglia, 1993a). The Turkey Point beds are differentiated, in part, from the underlying Pensauken Formation on the basis of a greater percentage of staurolite (observed more frequently in modern Susquehanna River sediments) and lithologic differences indicating a change in sediment source area. It is important to note that the Turkey Point beds of Pazzaglia (1993a) have not been mapped in detail along the Elk Neck Peninsula (only two localities have been characterized one of which includes Turkey Point and the majority lying east of Elk River) (FSAR Figure 2.5-302).

2.0 Quaternary Geologic Mapping and Stratigraphic Profiles of Pazzaglia (1993a) (1993b)(2006) Forming the Basis of the Hypothesized Fault

Pazzaglia (1993a) represents a regional chronostratigraphic correlation of Coastal Plain and Fall Zone fluvial deposits and generalized reconstruction of post-Oligocene Salisbury Embayment depositional history. On the basis of this information, Pazzaglia speculates on the influence of late Cenozoic isostasy, tectonics, and eustasy. However, this paper and subsequent papers (Pazzaglia, 1993b; Pazzaglia, 2006) do not represent a detailed investigation of any hypothetical faults in the upper Chesapeake Bay. Pazzaglia's interpretation of a fault beneath the Northeast River is based on the observation that there appears to be a vertical elevation difference of the early Pleistocene Turkey Point beds across Chesapeake Bay in Cecil County (FSAR Figure 2.5-302), specifically as below:

> "The Turkey Point beds at Turkey Point, Grove Point, and Betterton lie 6 – 8 m higher than at the mouth of the Susquehanna River...These elevation disparities suggests ~8 m of post-early Pleistocene offset along a northeast-southwest – trending fault beneath the upper Chesapeake Bay."(Pazzaglia, 1993b; p. 1632).

Central to Pazzaglia's interpretation of a fault is the argument that the Turkey Point beds exposed in a 3 m deep trench on Coudon Farm terrace west of Chesapeake Bay correlate with, and are equivalent to, the Turkey Point beds exposed in a sea cliff at Turkey Point, located 10 km to the southeast on the opposite side of the bay (FSAR Figure 2.5-302). The fault interpretation relies on the argument that the depositional base of the Turkey Point beds should lie at a very similar elevation over considerable lateral distances (Figure 2). More specifically, Pazzaglia interprets the Turkey Point beds at the mouth of the Susquehanna River (i.e., Coudon Farm terrace) and at Turkey Point as genetically-related deposits based on petrographic and lithostratigraphic analysis (Pazzaglia 1993a, 1993b). From the petrographic analysis (e.g., an increase in staurolite content) and correlation of interpreted lithologic facies (lithofacies) from these two field exposures, Pazzaglia (1993a, b; 2006) argues that along the Cecil County shorelines, the Turkey Point beds occur as paleo-Chesapeake Bay fluvial and estuarine deposits (all Turkey Point beds are derived from the Susquehanna River). Therefore, the elevations of the base of the Turkey Point beds between Coudon Farm terrace and Turkey Point, Grove Point, and Betterton should be at similar elevations. Pazzaglia interprets the disparity in elevation of the Turkey Point beds between Coudon Farm and Turkey Point and speculates a tectonic fault as a mechanism for producing the apparent southeast-side-up separation. The specific basis or elevation datum for calculating the vertical disparity is not defined by Pazzaglia (1993a; 1993b; 2006).

Pazzaglia (1993a) also discusses the "Near-vertical cliffs of the northeast shore of Chesapeake Bay, exposing the Turkey Point beds and Pensauken Formation up to 30 m amsl, contrast with the poor exposure of these deposits elsewhere, such as eastern Delmarva, where they do not exceed 18 m amsl" (p. 1632) as geomorphic evidence supporting the existence of the hypothetical fault.

During a phone interview on March 21, 2010, F. Pazzaglia clarified how the elevation data, used as a basis for the vertical separation of the Turkey point beds, were collected and what sites were used to estimate the six to eight meters of elevation change. At Turkey Point, the elevation of the exposed section was measured using a Jacobs staff and tape measure that was referenced to a USGS bench mark at the Turkey Point lighthouse. The elevation of the Coudon

Farm terrace was determined to be 60 ft using the U.S. Geological Survey Havre de Grace topographic quadrangle (20 ft contour interval). Note that only these two locations were used to estimate the six to eight meters of vertical separation. The Grove Point and Betterton sites or other localities shown on FSAR Figure 2.5-302 were not systematically measured (Pazzaglia personal communication, 2010). During this interview Pazzaglia also stated that there may be original depositional relief on the base of the Turkey Point beds that could account for the elevation disparity between the Coudon Farms and Turkey Point sites.

3.0 Key Arguments in Previous RAI Responses and New Geologic Information

UniStar compiled existing geologic data within the direct vicinity of the inferred fault to assess if faulting is observable in underlying bedrock and Coastal Plain stratigraphy. In addition, UniStar developed a topographic profile using geologic map boundaries digitized from Pazzaglia (1993a) and Higgins (1990)(1986) to evaluate the elevation variability in the basal contact and surficial expression of the Pensauken Formation upon which the Turkey Point beds unconformably overlie at Turkey Point (Figures 2 and 3). Direct and indirect geologic evidence contradicting the presence of the inferred fault, as well as several key uncertainties that suggest significant natural elevation disparities of the base of the Turkey Point beds, are summarized below.

(1) The Cecil County geologic map, prepared by Higgins (1986)(1990), encompasses the inferred fault of Pazzaglia (1993a) and does not show any on-land northeast-striking fault (Figure 2). Mapping by Higgins (1986) near Indian Falls and Northeast does not show a fault projecting on land and intersecting Paleozoic rocks of the James Run Formation (Figure 2). Higgins (1990) reported unfaulted Cretaceous deposits along a northeast projection of the inferred fault and states: "No irregularities such as local steepening, flattening, or reversal of the dip of the Coastal Plain strata have been found in Cecil County which would indicate that there has been significant post-depositional tectonic movements." (page 123).

(2) A structure contour map of the top of basement developed by Edwards (1979) (FSAR Figure 2.5-303) illustrates the absence of faulting within the Coastal Plain section within a vertical resolution of 50 feet. Motivated by speculations from Higgins (1974) – that the northern Chesapeake Bay magnetic anomaly (see response to RAI 71 Question 02.05.01-19[4]) was created by faulting of Coastal Plain stratigraphy, Edwards (1979) drilled three borings on either side of the magnetic anomaly and compiled existing boring and geophysical data to construct the structure contour map shown in FSAR Figure 2.5-303. The Edwards (1979) work was motivated by a concern that this inferred fault may represent a "capable fault" that "could influence design criteria for a nuclear power plant" (p. 3). It is important to note that the hypothetical fault inferred by Pazzaglia (1993a) is coincident with the fault inferred previously by Higgins (1974) and re-evaluated by Edwards (1979). Based on their findings, Edwards (1979) makes several key statements on the absence of the fault: 1) "A regional map of the basement surface... does not reveal any structural anomalies coincident with the magnetic pattern that could not be explained by relict topographic relief on the pre-Coastal Plain surface" (p. 20); 2) "the stratigraphy at Spesutie Island conforms with an unfaulted, up-dip

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

projection of the palynostratigraphic zones present at Grove Neck (CE-Ec17)" (p. 21); 3) "within the scale of resolution (50 feet) of the data obtained in this project, offset at the base of the Coastal Plain cannot be demonstrated. Thus any fault associated with the shear zone can be dated no younger than Early Cretaceous (pre-Barremian)" (p. 21).

(3) A recent hydrogeologic study performed by the Delaware Geological Survey (Benson, 2006) to establish a new stratigraphic framework for correlating units within the Potomac Formation used geophysical well-log correlations, coupled with fossil pollen and spores, from sedimentary facies of the Potomac Formation in New Castle County, Delaware and Cecil County, Maryland. Benson (2006) relied on the previous borehole data collected by Edwards (1979). The boreholes are re-interpreted and reproduced in Benson (2006) and are used to correlate Potomac strata (fine-grained marker horizons) across the northern part of Chesapeake Bay (Figures 4 and 5). Published geologic cross-sections of Benson (2006) provide a line of evidence that is inconsistent with faulting beneath the northern part of Chesapeake Bay. The geologic cross-section I-I' developed by Benson (2006) is oriented northeast-southwest and intersects Turkey Point on the east and Spesutie Island on the southwest, thus crossing the projection of the inferred fault of Pazzaglia (1993a) (Section #1 on Figures 4 and 5). In addition, cross-section K-K' (not included in this response; see Plate 3 of Benson, 2006) located directly southeast of Turkey Point can be used to develop a new profile that considers the borehole on Spesutie Island on the west with the borehole at Grove Point to the southeast (Section #3 on Figures 4 and 5). The cross sections confirm a regional southeast dip of the Potomac Formation and the absence of west-dipping or flattening bedding east of the inferred fault. In addition, the section shows the entire Coastal Plain stratigraphy down to the bedrock unconformity essentially maintaining uniform thickness. The consistent southeast dipping stratigraphy and absence of anomalous elevation changes across the bay strongly support the absence of faulting hypothesized by Pazzaglia (1993a). Collectively, the cross sections of Benson (2006), structural contour map of Edwards (1979) and mapping of Higgins (1990) strongly support the absence of a large pre-existing structure beneath the northern arm of Chesapeake Bay.

(4) Bathymetric data, compiled in response to RAI 130 Question 02.05.01-48[2], along the projection of the hypothetical fault of Pazzaglia (1993a), illustrates a flat submarine Northeast River channel even at 67 times vertical exaggeration (Figure 6). In addition, much of the slope of the bathymetric surface west of Elk Neck Peninsula exhibits an apparent southeast dip consistent with the grade of the Susquehanna River and inconsistent with the sense of deformation inferred from the hypothesized fault. The interpretation of the bathymetric data therefore supports the absence of a submerged fault scarp of significance. Note that the horizontal cell size of the digital bathymetric data is 30 meters.

(5) There is no obvious fault scarp-morphology along the northeast projection of the hypothetical fault as determined through aerial reconnaissance and review of 'bare earth' topographic data (LiDAR data) (Figure 5).

(6) There is no published information that associates seismicity with the inferred fault; nor are there any earthquake epicenters aligned with the hypothetical fault (FSAR Figure 2.5-10).

(7) Pazzaglia (personal communication; 2010) stated that the contact between the Pensauken Formation and Turkey Point beds is non-planar and may show meters of natural relief. The natural variability in the relief of this contact has not been considered within the estimated 6-8 m of inferred vertical separation.

(8) Elevations of the base of the Turkey Point beds were only measured at two of the nine locations shown on Pazzaglia's map, and therefore there is uncertainty as to the actual natural variability in the range in elevation of the base of the Turkey Point beds across the head of the Chesapeake Bay. A topographic profile was developed along the west side of the Elk River to better assess the natural variability of the base of the Pensauken Formation to provide a proxy by which to estimate possible natural undulations at the base of the Turkey Point beds (Figure 2). As shown in Figure 3, the base of the Pensauken Formation locally is highly undulatory with peaks and valleys separated by as much as 11 m. A similar observation was noted by Higgins (1990), who stated "The base of the Pensauken Formation is irregular... In places along the shores of Elk and Sassafras Rivers, the base of the gravel ranges markedly from 40 to 50 ft (12 to 15 m) above sea level down to or near sea level within a horizontal distance of only a few hundred yards (few hundred meters)" (p. 162).

(9) As noted in response to RAI 130 Question 02.05.01-48[2], the field soil profile descriptions provided in Table 2 of Pazzaglia (1993a) were used in part to support the estimated age of the Turkey Point beds. Examination of the pedologic characteristics of the profiles from Coudon Farm and Turkey Point actually are not that similar. In particular, the clay film development – a strong indicator of relative age – appears to be more pronounced in the Coudon Farm soil profile, suggesting these deposits may be considerably older than the Turkey Point deposits, and thus the lithofacies correlation may not be entirely accurate if these deposits are not time stratigraphic equivalents. Lastly, the fault inferred by Pazzaglia is contingent upon the interpretation of Turkey Point beds of the Coudon Farm terrace at the mouth of the Susquehanna River. As stated previously, this is the only location of Turkey Point beds northwest of the postulated fault. Pazzaglia queries the interpretation of Turkey Point lithofacies 1 and 2 at Coudon Farm terrace (1993a, Table 2B), suggesting a degree of uncertainty regarding the stratigraphic correlation across the bay.

(10) In expert interviews, F. Pazzaglia noted that there is no direct geologic evidence for the hypothesized fault and that the elevation disparities also could be readily explained by original depositional relief (Pazzaglia personal communication, 2010).

4.0 Responses for NRC Question Issues

The response for each NRC issue listed for this question is provided below. Where possible, the information presented in Sections 1.0 through 3.0 is referenced for additional clarification in the separate responses to avoid unneeded redundancy.

- **Older Coastal Plain units more widely exposed and mapped on the SE side of fault (up thrown side) than on the NW side.**

This issue appears to be related to the Potomac Formation mapped on the Elk Neck Peninsula (e.g. Higgins, 1986). Potomac Formation (map unit Kp of Higgins, 1986; "Other Coastal Plain" deposits of Pazzaglia, 1993a) is common on both the Elk Neck Peninsula and the northwest side of the hypothesized fault (e.g. Carpenter Point neck) (Figure 2). The distribution of the Potomac Formation (other Coastal Plain units) likely is more attributable to the land surface area exposed directly below the Fall Zone where Chesapeake Bay begins to impinge on the Fall Zone. There is more surface area for sediments to be deposits directly southeast of this location, thus there appears to be a greater amount of Potomac Formation deposits east of Chesapeake Bay.

The paucity of Quaternary deposits (e.g. Pensauken Formation) along the Northeast River inlet is also reasonably attributable to either original non-deposition (Owens, 1979) or to post-depositional erosion and stripping. The map pattern and distribution of Pensauken Formation is more consistent with deposition from a paleo-Delaware Hudson River flowing along present-day Elk River drainage (Owens, 1979)(Higgins, 1986) (Pazzaglia, 2006) (Figure 1). Thus, the map patterns of the Potomac Formation and Pensauken Formation can be explained readily by non-tectonic processes.

- **The LiDAR surface map provided in your response is inconclusive because an 8 m elevation difference across the fault would not show in Figure 6 at the scale presented. Furthermore, locating a fault that is "coming ashore" would require examination all along the coast line at a large scale resolution (close in detail). Pazzaglia's dotted line is an approximation of the location of his interpreted fault. This also applies to examination of the bay bathymetry.**

The LiDAR surface map provided as Figure 6 from RAI 130 Question 02.05.01-48[2] was evaluated at a large scale in an effort to identify possible fault related features along the coast line of the Northeast River. This figure is reproduced in this response as Figure 5 and is included electronically as a large high resolution version in Enclosure 2. In addition, this figure will be included in the COLA as FSAR Figure 2.5-304.

- **You argue that lack of elevation data for the <u>base</u> of the TP beds precludes corroborating Pazzaglia's 8 m offset. Pazzaglia made his correlation based on the elevation differences of more than one distinct unconformity in Coastal Plain units, both exposed and buried (examined in a trench dug into the Coudon Farm terrace, ~ 3m deep).**

The above NRC statement is referring to the UniStar response to RAI 130, Question 02.05.01-48[2], which reads follows:

> "*Because the absolute elevation of the base of the either the Pliocene Pensauken Formation or the early Pleistocene Turkey Point are specifically not defined by Pazzaglia (1993b; 2006), verification of the declared vertical elevation disparities between these deposits is not possible, and does not provide direct evidence to support the interpretation of a fault.*"

The purpose of this statement was to address the uncertainty in the Pazzaglia (1993a) estimate of the approximate six to eight meter offset of the Turkey Point beds. As discussed previously (Section 3.0), there are multiple lines of evidence to suggest that there is epistemic and aleatory uncertainty in the six to eight meter estimate. For example, a recent interview with Pazzaglia (March 26, 2010 and review of his field notes) indicates that 1) the elevation of the base of the Turkey Point beds is derived from elevation measurements at only two locations: Coudon Farm terrace and Turkey Point; 2) the base of the Turkey Point beds is not planar and may have meters of natural elevation changes, and 3) the elevation difference between the Turkey Point beds can be explained by deposition on an erosional surface with paleo-relief (Pazzaglia personal communication, 2010). In addition, a topographic profile showing the base of the Pensauken Formation, of which the Turkey Point beds are an informal lithofacies, indicates a highly variable basal contact that has as much as 11 m of topographic relief, suggesting that the basal contact of the Turkey Point beds may contain a similar irregular topographic relief (Figure 3).

- **Contrary to your assertion that soil profiles do not correlate across the bay, Pazzaglia does not attempt to correlate the soils located at Coudon's Farm terrace with Turkey Point soils. This is not the basis of his fault interpretation.**

That is correct. As stated above, the basis for the hypothesized fault is the apparent elevation disparity noted at the base of the Turkey Point beds at Coudon Farm with respect to a correlative contact at Turkey Point. However, the pedologic analysis provides a means by which to estimate the age of the deposits at the two sites. The soil profiles and age indicators used to estimate age of the two deposits are not necessarily similar and suggest that the two deposits may not be time-stratigraphic equivalents (see discussion in response to RAI 130 Question 02.05.01-48[2]). Figure 2 from response to RAI 130 Question 02.05.01-48 (FSAR Figure 2.5-302 part b) is intended to show that, based on Pazzaglia's published data (Table 2, Pazzaglia, 1993a), the Turkey Point beds field description correlations are tenuous because the interpreted soil profiles are, in effect, very different. For example, Lithofacies 2 of the Turkey Point beds are quite different across the field property descriptions. Likewise, in Table 2, Pazzaglia (1993a) queries the lithofacies assignments (e.g. Lithofacies 2?) for every lithofacies at the Coudon Farm site except Lithofacies 3. This calls into question the correlation of similar-aged deposits at Turkey Point and Coudon Farms and the inference of the hypothetical fault.

- **The marine seismic reflection data disclosing paleochannels of the Susquehanna River does not cover the specific area under discussion. However, you pointed out that there are paleochannel segments that are straight. This does not require that the straight eastern Chesapeake Bay coastline must be non-tectonic in origin.**

The above statement appears to refer to UniStar's previous response in RAI 71 Question 02.05.01-19[4] that addressed the request to consider the "straight" eastern coastline of the

Chesapeake Bay shown in FSAR Figure 2.5-25. In response to RAI 71 Question 02.05.01-19, we explained that the "straight shore" is actually sinuous and appears straight only on small-scale (less detailed) maps, such as FSAR Figure 2.5-25.

The discussion of the "straight" paleochannels of the Susquehanna River referred to by the statement above read:

> *"The "straight" and partially eroded coastline also could have been carved by these ancient paleochannels of the Susquehanna River. For instance, submarine studies of Susquehanna River paleo-channels south of the "straight" coastline (between the Chesapeake Bay Bridge and the mouth of the Chesapeake Bay) indicate that significant lengths of the submerged ancient paleochannels are linear and form submerged and shallow, fairly straight east-bounding terrace margins, not unlike the exposed feature referred to in the RAI question (Coleman and Halka, 1989; Coleman et al., 1990; Chen et al., 1994; Bratton et al., 2003). Similar observations have been made of the submerged portions of the paleo-Susquehanna River in the northern part of the bay (Newell et al., 2004)."*

The purpose of the above quote text was to point out that the river systems, such as the Susquehanna River, have straight segments unrelated to tectonic processes.

The information that "requires that the straight eastern Chesapeake Bay must be non-tectonic in origin" includes the fact that the eastern Chesapeake Bay coastline in question is arguably not straight and, as discussed in Section 3.0, structure contour maps of the top of basement preclude a major post-Early Cretaceous fault projecting upsection through Coastal Plain deposits (See Figure 4, Figure 5 and FSAR Figure 2.5-303) (Edwards, 1979). Thus, direct evidence provides support for the statement that there is a non-tectonic origin of the non-linear eastern Chesapeake Bay coastline.

- **Susquehanna River channel takes a sharp turn to the south at it's mouth or the head of the bay. This is also supported by the series of submarine paleochannels.**

The southerly bend in the Susquehanna River at the mouth of Chesapeake Bay likely represents a deflection as a result of accumulated fan deposits (now submerged) forming a submarine river delta (Newell, 2004). The river channel turns southeast around Spesutie Island, and then joins the deep channel of the present-day Elk River (Figure 5). Similar southwest deflections are observed elsewhere at or near the Fall Line along several major drainages in the eastern United States and have been attributed to inherited Miocene depositional processes (Figure 1) (Pazzaglia, 2006).

- **The bathymetric profile across the bay in Figure 4 indicates a smooth profile but the scale of presentation does not permit close examination of the profile. The offshore location of the fault could be located just off shore from Turkey Point, in the thalweg channel of the Susquehanna River. Newell at al, 2004 interpreted recent river/deltaic deposits along the base of the bay, almost as far south as Annapolis. These deposits could mask a small surface expression of a submarine fault.**

The above statement is referring to Figure 4 from UniStar's response to RAI 130 Question 02.05.01-48[2]. This response states that

"The cross section (Figure 5a) also includes 30 m cell size bathymetric data from NOAA that shows no warping, scarps, offsets, or deformation of the Chesapeake Bay bottom consistent with the absence of faulting."

We interpret the profile discussed in the statement above is referring to geologic cross section A-A' (included as Figure 6) that illustrates both topography and bathymetry. This profile has a vertical exaggeration of over 67 times intended to "permit close examination of the profile". Any resolvable deflection in the base of the Northeast River should be detected at this scale. The above statement was provided as indirect evidence of the absence of obvious submarine geomorphology that could be associated with the hypothesized fault from Pazzaglia (1993a). However, as the statement above notes, the profile cannot preclude faulting that may be masked by recent river deposits. The above quotation was not intended to preclude faulting within buried fluvial units.

The recent river/deltaic deposits could mask the morphologic expression of a hypothesized submarine fault. However, as discussed in Section 3.0, there is clear evidence that supports the absence of a submarine fault at depth.

- **Sea Cliffs on west-facing shorelines of the Elk Neck and Delmarva Peninsulas, along with all streams draining east indicating a tilted block.**

In response to the above statement, UniStar has completed a careful review of U.S. Geological Survey topographic maps and detailed LiDAR data along the Elk Neck Peninsula (Figure 2 and Figure 5). This inspection revealed that there are both east and west flowing streams on the Elk Neck and Delmarva peninsulas and the drainage divide for the peninsula is located roughly in the center of the peninsula (roughly coincident with the mapping of the Bryn Mawr Formation, Unit Tb) (Figure 2).

Along the west-facing shoreline of the Elk Neck Peninsula there are eleven west-draining creeks from Elk Neck State Park northeast to just north of the town of Northeast Heights, Maryland (Figure 2). For example, the USGS basemap in Figure 2 (Higgins, 1986) shows three creeks flowing into a marsh near Camp Rodney and three creeks draining west to Sandy Cove directly north of Roach Point. On the Delmarva Peninsula (east of the Elk River), there are many large west-flowing drainages including the Bohemia River, Pearce Creek, and Pond Creek. Based on the numerous west-draining creeks along the west-facing shore of Elk Neck peninsula, the drainage pattern does not appear to support a tilted block.

If the Elk Neck Peninsula was a tilted fault block, the above statement insinuates that the drainage divides should be asymmetric (i.e. "all streams draining east"). Following this logic, the drainages along the southeastern margin of the peninsula should be abnormally large when compared to the west flowing drainages. Inspection of the topographic map presented in Figure 2, illustrates that the drainage divide on the Elk Neck Peninsula is largely symmetrical following a trend subparallel to the Northeast and Elk Rivers. This lack of pronounced drainage basin asymmetry does not support the interpretation of a fault block.

- **The argument that there have not been subsequent, independent studies to Pazzaglia's does not in itself rule out a fault interpretation.**

The above statement appears to be referring to UniStar's response to RAI 130 Question 02.05.01-48[2] that read:

"As stated in the above quoted FSAR text, Pazzaglia's interpretation of a fault remains unproven based on analysis of the existing data. Further, Pazzaglia's mapping and correlation (1993a; 1993b, 2006) have not been confirmed by independent studies."

This is true. However, the intention of the statement is to point out that there are no other published reports that show direct geologic evidence for the fault inferred by Pazzaglia (1993a). In fact, as discussed in Section 3.0, Edwards (1979) investigated an inferred bedrock fault at the same location as the fault hypothesized by Pazzaglia (1993a) and concluded that there is enough subsurface borehole data to suggest the absence of post-Early Cretaceous faulting (FSAR Figure 2.5-303). Fundamentally, direct geological evidence to support a fault remains to be identified.

- **In response to RAI 48 b, Part 2, the applicant described the distinction between Higgins' and Pazzaglia's geologic mapping. Higgins's map (Figure 5a) is an earlier interpretation that does not necessarily refute Pazzaglia's interpretation. NRC staff note that the differences are mostly a matter of breaking out subunits from formerly undifferentiated upland gravel deposits or reinterpreting an informal unit into a distinct stratigraphic formation. Southeast of fault, Pazzaglia breaks out additional units, Bryn Mawr and Perryville Fm, from Higgins' undifferentiated Upland Gravel unit. Northwest of fault, Pazzaglia reinterprets Higgins' Upland gravel as Pensauken Fm.**

The above statement regarding the differences between the Higgins (1986) and Pazzaglia (1993a) geologic mapping is correct. For clarity, FSAR Subsection 2.5.1.1.4.4.4.6 will be revised to remove the discussion of Higgins (1986) verses Pazzaglia (1993a) geologic mapping. The FSAR revision will include further discussion of the data and interpretations discussed in Section 1.0 through 3.0 of this RAI question response.

References used in this response:

Benson, 2006. Internal stratigraphic correlation of the subsurface Potomac Formation, New Castle County, Delaware, and adjacent areas in Maryland and New Jersey, Delaware Geological Survey Report of Investigations No. 71, R.N. Benson, 2006.

Coleman, 1990. Ancient channels of the Susquehanna River beneath Chesapeake Bay and the Delmarva Peninsula, Geological Society of America Bulletin, Vol. 102, p. 1268-1279, S.M. Colman, J.P. Halka, C.H. Hobbs, R.B. Mixon, and D.S. Foster, 1990.

Edwards, 1979. New Data Bearing on the Structural Significance of the Upper Chesapeake Bay Magnetic Anomaly; Maryland Geological Survey Report of Investigation No. 30, 44 p. J. Edwards and H. Hansen,1979.

Higgins, 1974. Interpretation of aeromagnetic anomalies bearing on the origin of Upper Chesapeake Bay and river course changes in the central Atlantic seaboard region: Speculations; Geology, v. 2 no. 1, p. 73-76, M.W. Higgins, I. Zietz, and G.W. Fisher, 1974.

Higgins, 1986 Geologic map of Cecil County; Maryland Geological Survey, map scale 1:62,500, M.W. Higgins, and L.B. Conant, 1986.

Higgins, 1990. The geology of Cecil County, Maryland; Maryland Geological Survey, Bulletin 37, p. 183, M.W. Higgins, and L.B. Conant, 1990.

Newell, 2004. Distribution of Holocene sediment in Chesapeake Bay as interpreted from submarine geomorphology of the submerged landforms, selected core holes, bridge borings and seismic profiles; U.S. Geological Survey Open File Report 1235, Newell, W. L., Clark, I., and Bricker, O., 2004.

Owens, 1979. Upper Cenozoic Deposits of the Central Delmarva Peninsula, Maryland and Delaware, U.S. Geological Survey Professional Paper 1067-A, 32 p., J.P. Owens and C.S. Denny, 1979.

Pazzaglia, 1993a. Stratigraphy, petrography, and correlation of late Cenozoic middle Atlantic Coastal Plain deposits: Implications for late-stage passive-margin geologic evolution, Geological Society of America Bulletin, Volume 105, p 1617-1634, F. Pazzaglia, 1993.

Pazzaglia, 1993b. Fluvial terraces of the lower Susquehanna River, Geomorphology, Volume 8,p 83-113, F. Pazzaglia and T. Gardner, 1993.

Pazzaglia, 2006. Rivers, Glaciers, landscape evolution, and active tectonics of the central Appalachians, Pennsylvania and Maryland, Geological Society of America, Field Guide 8. F. Pazzaglia, D. Braun, M. Pavich, P. Bierman, N. Potter Jr., D. Merritts, R. Walker, and D. Germanoski, 2006.

<u>Figures used in this response</u>

Figures 1 – 5 support the above narrative, but are not included in the COLA. Figures 2.5-302, 2.5-303 and 2.5-304 are FSAR figures and follow the COLA Impact section.

Figure 1. Illustrating the evolution of paleo-Hudson and paleo-Delaware Rivers deposition on the Delmarva peninsula and northern part of the Atlantic Coastal Plain (reproduced from Owens and Denny, 1979)

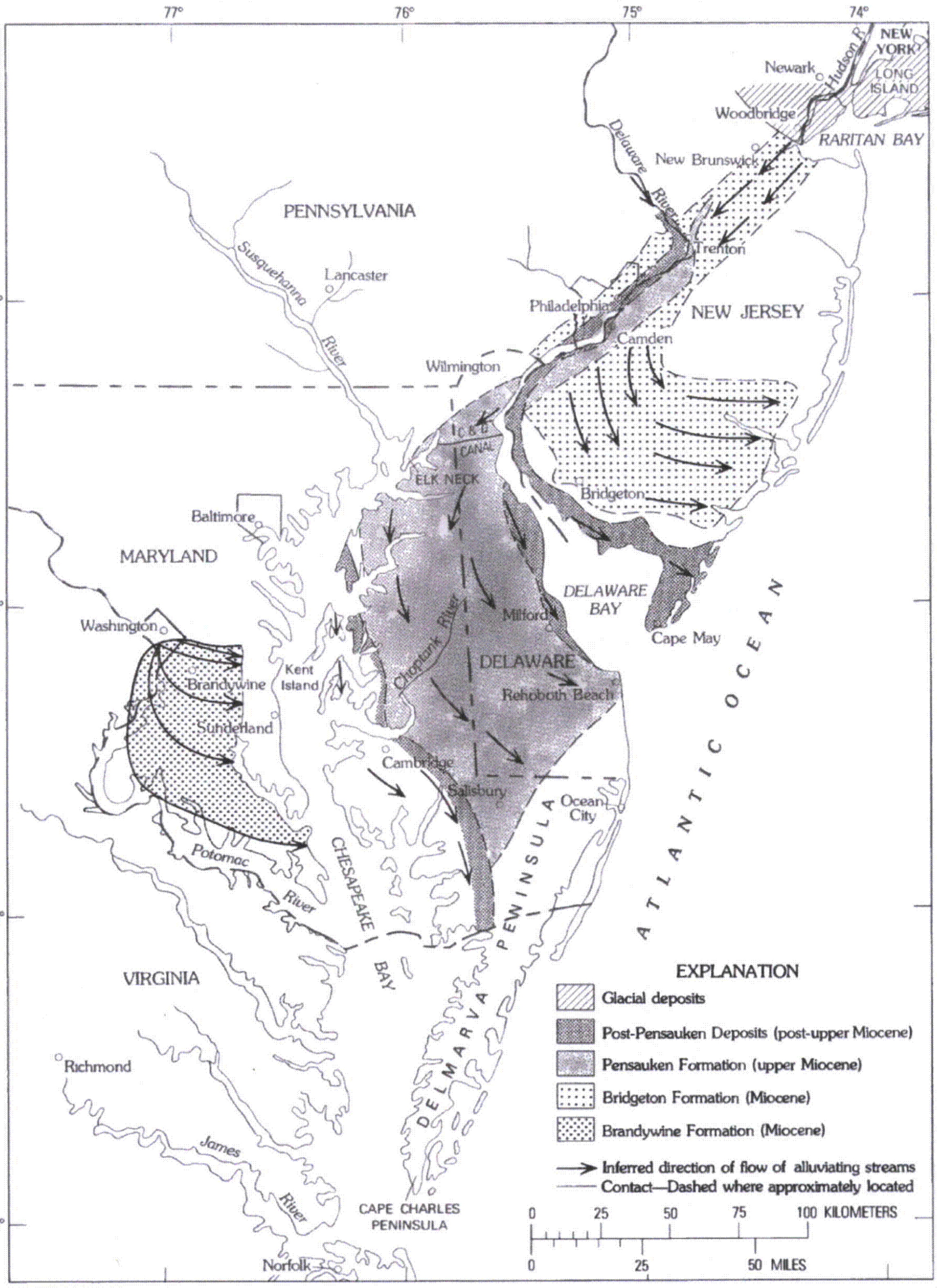
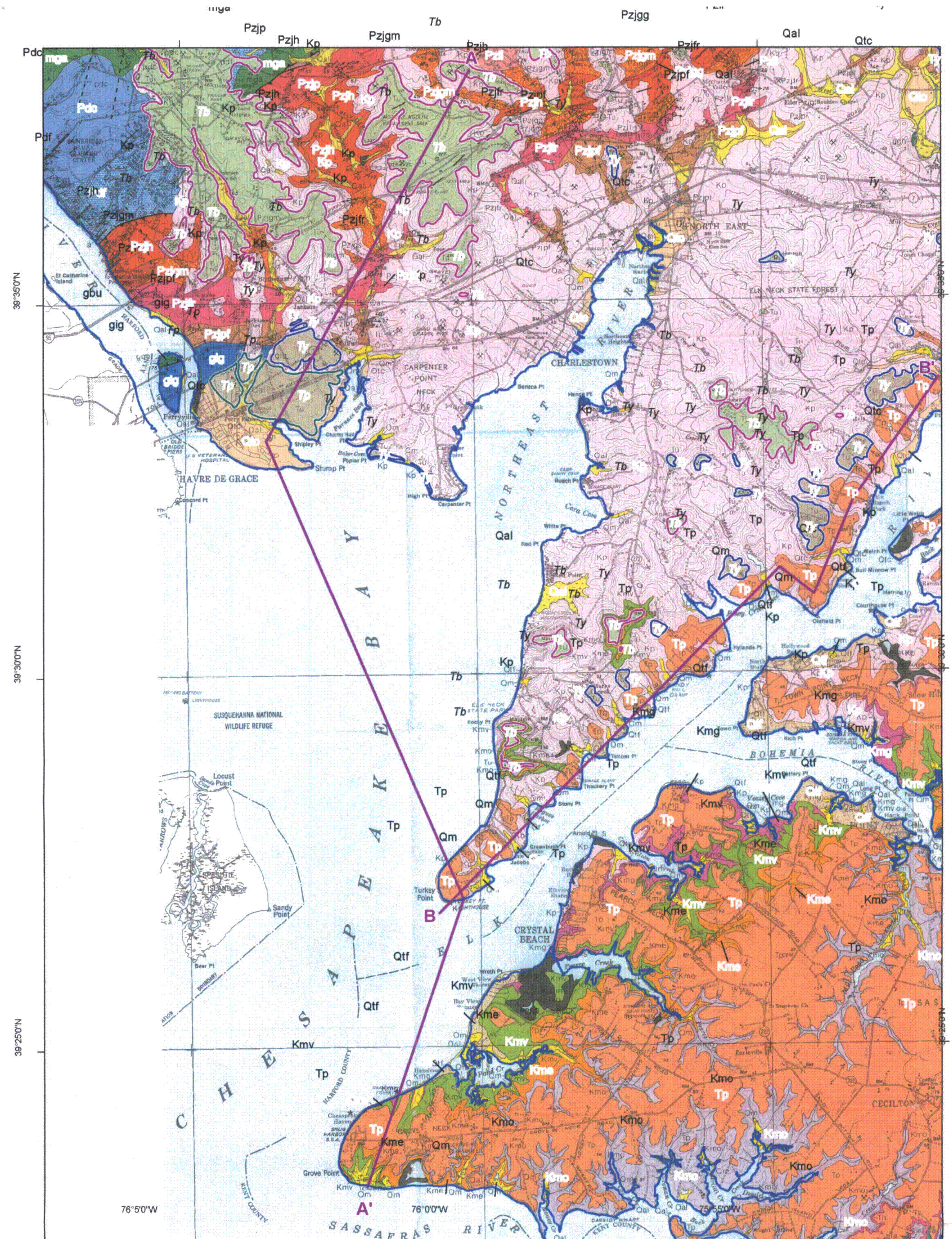
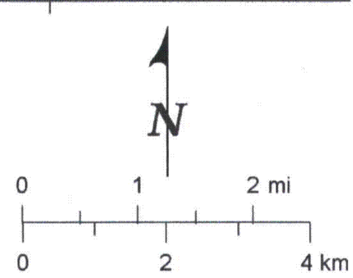


Figure 2a. Comparison of Higgins (1986) and Pazzaglia (1993a) Geologic Mapping





Notes:
1. See Figure 2b for explanation of symbols and units
2. See Figure 6 for cross section A - A'
3. See Figure 4 for cross section B - B'

Figure 2b. Comparison of Higgins (1986) and Pazzaglia (1993a) Geologic Mapping (explanation)

Explanation

Symbols

Cecil County shoreline

A A' Location of cross section

Units by U.S.G.S (by Higgins and Conant, 1986)

SEDIMENTARY ROCKS

- Qm — Tidal marsh deposits
- Qal — Alluvium
- Qtc — Coarse-grained facies, Talbot Formation
- Qtf — Fine-grained facies Talbot Formation
- Tp — Pensauken Formation
- Tu — Upland gravel
- Kmo — Monmouth Group
- Kme — Matawan Group
- Kmv — Merchantville Formation
- Kmg — Magothy Formation
- Kp — Potomac Formation

Units by Pazzaglia (1993b)

- Tb — Bryn Mawr Formation
- Tp — Pensauken Formation
- Ty — Perryville Formation

METASEDIMENTARY ROCKS

- mga — Metagraywake with amphibolite

METAVOLCANIC ROCKS

- Pzjh — Happy Valley Branch Member James Run Formation
- Pzjp — Principio Creek Member, James Run Formation
- Pzjgg — Gilpins Falls Member, greenstone, James Run Formation
- Pzjgm — Gilpins Falls Member, pillow metabasalt, James Run Formation
- Pzjgs — Gilpins Falls Member, chlorite schist James Run Formation
- Pzjl — Little Northeast Creek Member James Run Formation
- Pzjfr — Frenchtown Member James Run Formation
- Pzjpf — Principio Furnace Member, James Run Formation

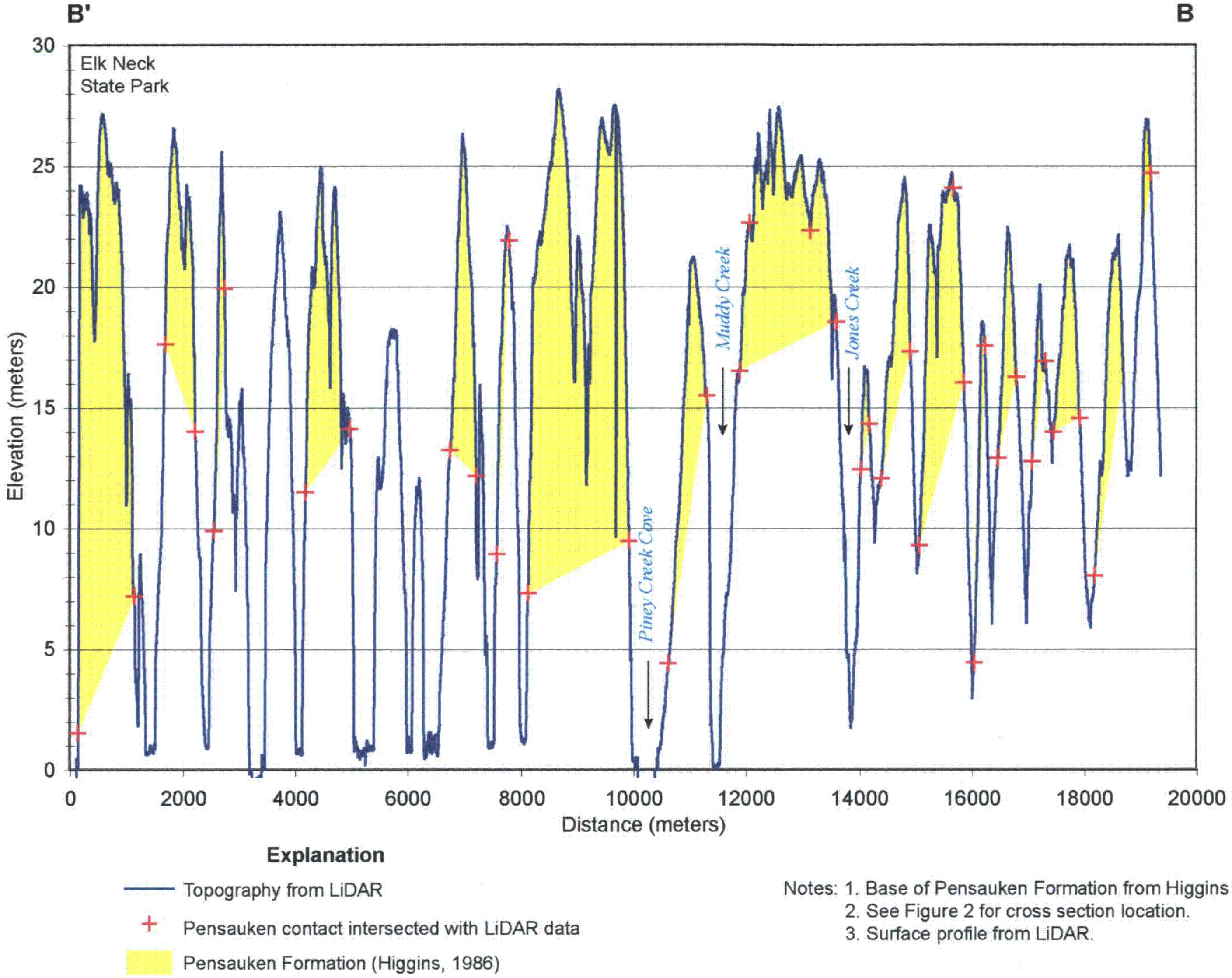
FELSIC PLUTONIC ROCKS

- pdc — Port deposit gneiss: coarse-grained phase
- pdf — Port Deposit gneiss: fine-grained phase
- gig — Gneiss on Garrett Island

MAFIC PLUTONIC ROCKS

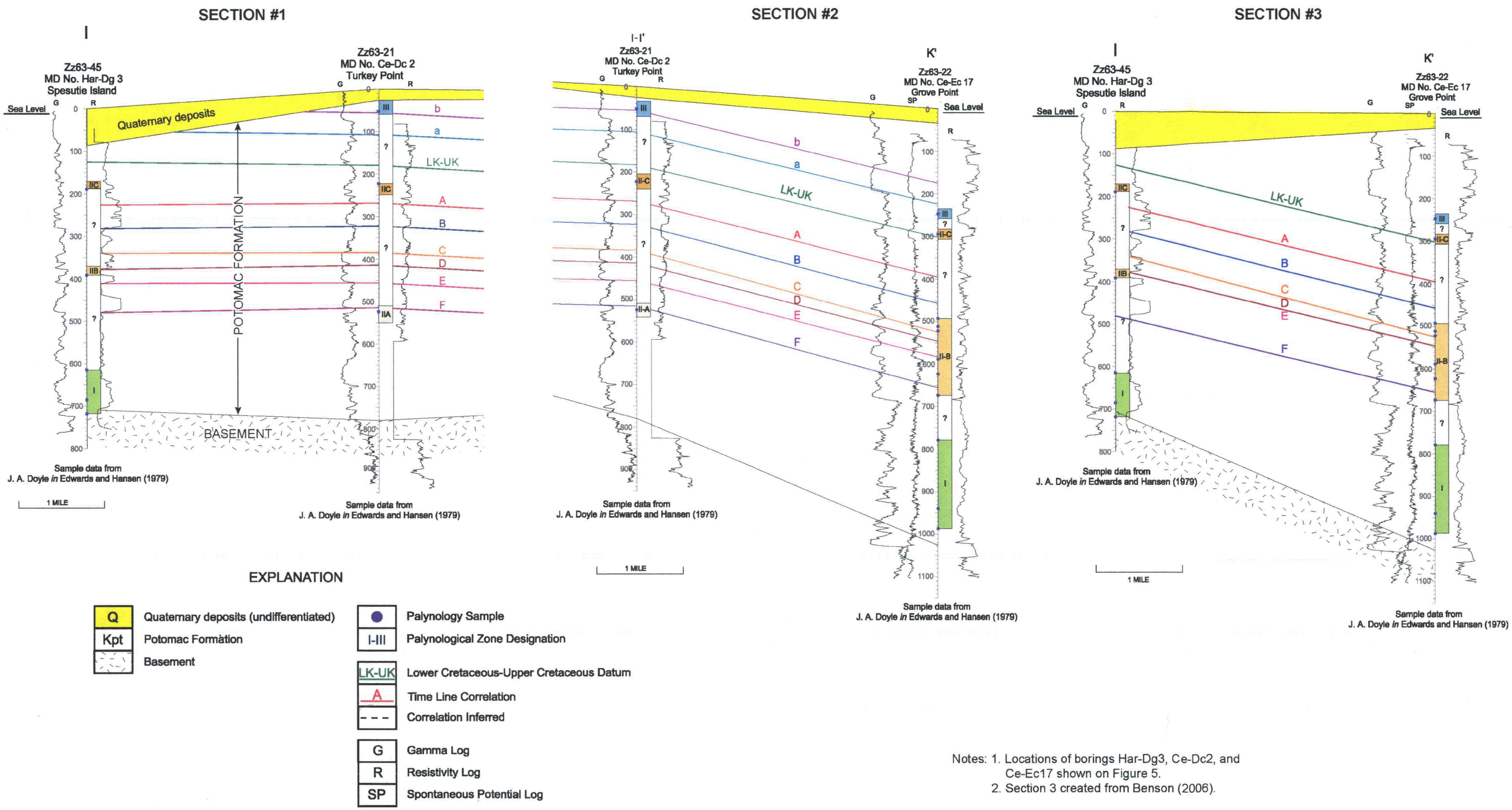
- gbu — Gabbrioc rocks, undifferentiated

Figure 3. Cross section profile B-B' showing base of Pensauken Formation



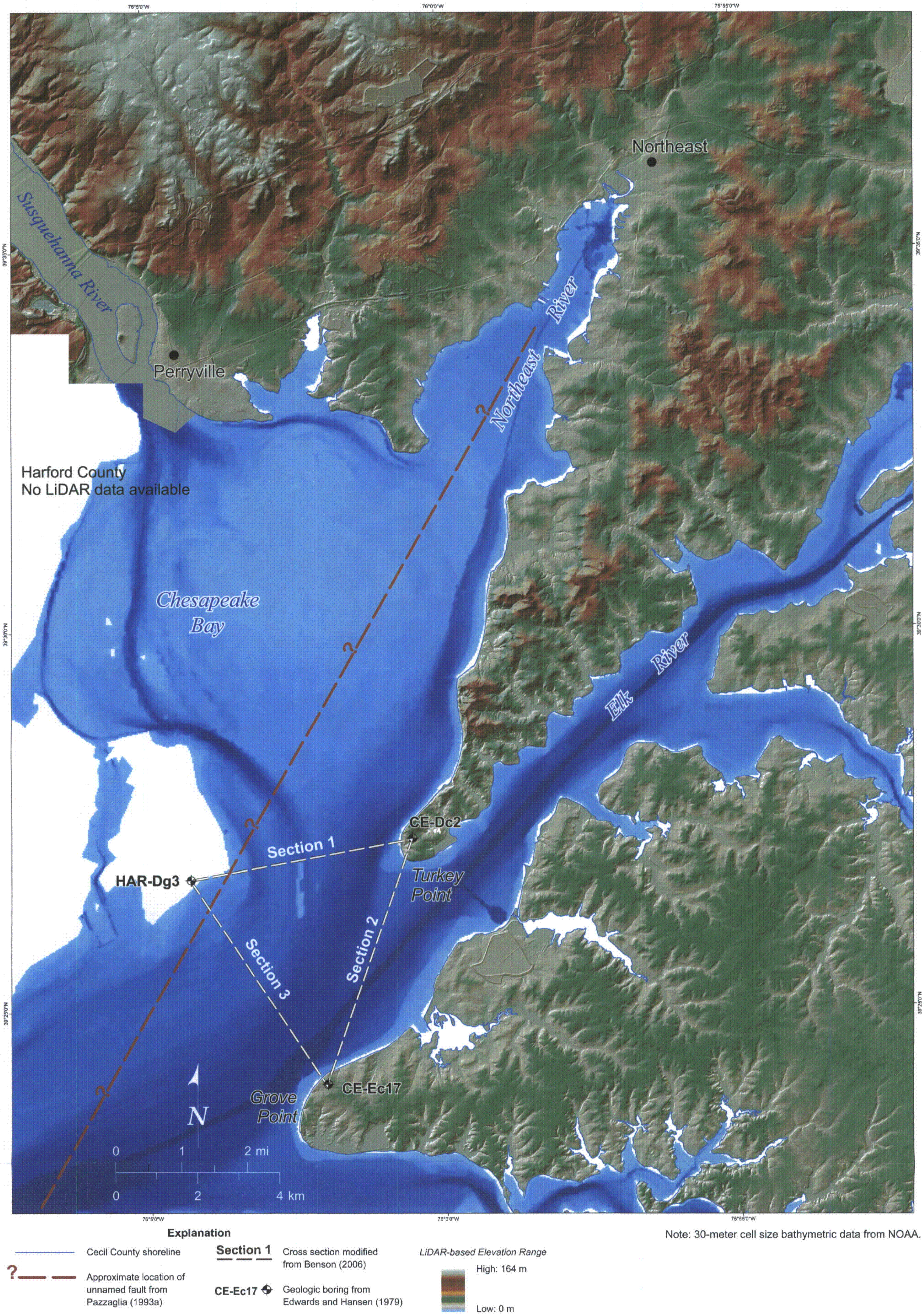
Notes: 1. Base of Pensauken Formation from Higgins (1986).
2. See Figure 2 for cross section location.
3. Surface profile from LiDAR.

Figure 4. Geologic cross sections from Spesutie Island to Turkey Point to Grove Point illustrating unfaulted Potomac Formation (modified from Benson, 2006).



Notes: 1. Locations of borings Har-Dg3, Ce-Dc2, and Ce-Ec17 shown on Figure 5.
2. Section 3 created from Benson (2006).

Figure 5 LiDAR Elevation Showing Trace of Pazzaglia's Fault



Note: 30-meter cell size bathymetric data from NOAA.

COLA Impact

2.5.1.1.4.4.4.6 Unnamed Fault beneath Northern Chesapeake Bay, Cecil County, Maryland

Pazzaglia (1993a) proposed a fault in northern Chesapeake Bay that comes to within 70 mi (113 km) north of the site (Figure 2.5-25 and Figure 2.5-302). On the basis of geologic data and assuming that the bay is structurally controlled, Pazzaglia (1993a) infers a 14 mi (23 km) long, northeast-striking fault with a southeast-side up sense of displacement. ~~Near the mouth of the Susquehanna River, in Maryland, the unnamed fault is interpreted to vertically separate Pleistocene Turkey Point gravels of the Quaternary Pennsauken Formation on the east at elevations higher than a similar gravel deposit mapped on the west side of the Chesapeake Bay. The amount of apparent vertical separation is unconstrained because the base of the gravel unit is not exposed west of the bay; however, estimates of the exposed section provide a minimum of 26 ft (8 m) of vertical separation of the Pleistocene Turkey Point gravels (Pazzaglia, 1993).~~

~~This fault is unconfirmed based on the lack of direct supporting evidence. First, the fault has not been observed as a local discontinuity on land. Second, the correlation of gravels is permissible based on the data, but has not been confirmed by detailed stratigraphic or chronologic studies. Geologic mapping of the area (Higgins, 1986) shows Miocene Upland gravels along the northeast mouth of the Susquehanna River where Pazzaglia (Pazzaglia, 1993) maps the Quaternary Pennsauken Formation.~~

~~There is no geologic data to suggest that this unnamed fault zone is a capable tectonic source. There is no pre-EPRI or post-EPRI seismicity spatially associated with this fault zone. Field and aerial reconnaissance conducted to support CCNPP Unit 3 shows that there are no geomorphic features indicative of potential Quaternary activity along the surface-projection of the unnamed fault; therefore, this fault is not a capable tectonic source.~~

Pazzaglia (1993a) interprets this fault as beneath the Northeast River and northern Chesapeake Bay based on a vertical elevation difference of the early Pleistocene Turkey Point beds across the bay in Cecil County, Maryland (Figure 2.5-302). Specifically:

> "The Turkey Point beds at Turkey Point, Grove Point, and Betterton lie 6 – 8 m higher than at the mouth of the Susquehanna River...These elevation disparities suggests ~8 m of post-early Pleistocene offset along a northeast-southwest – trending fault beneath the upper Chesapeake Bay."(Pazzaglia, 1993a; p. 1632).

Central to the Pazzaglia (1993a) interpretation of a fault is the argument that the Turkey Point beds exposed in a three meter deep trench on Coudon Farm terrace west of Chesapeake Bay correlate with, and are equivalent to, the Turkey Point beds exposed in a sea cliff at Turkey Point, located 10 km to the southeast on the opposite side of the bay (Figure 2.5-302). This fault interpretation assumes that the depositional base of the Turkey Point beds should lie at a very similar elevation over considerable lateral distances. Pazzaglia clarified several key aspects of the fault interpretation during expert interviews. First, he stated that only the Turkey Point and Coudon Farm sites were used to estimate the six to eight meters of vertical separation. Second, he indicated that there may be original depositional relief on the base of the Turkey Point beds, which could account for the elevation disparity between Coudon Farms and Turkey Point.

Despite the information discussed above, the hypothesized fault from Pazzaglia (1993a) is unconfirmed based on evidence that supports the absence of faulting and the lack of direct supporting geologic evidence. First, the hypothetical fault inferred by Pazzaglia (1993a) is coincident with a fault inferred previously by Higgins (1974) that was re-evaluated by Edwards (1979). Motivated by speculations from Higgins (1974) – that the northern Chesapeake Bay magnetic anomaly was created by faulting of Coastal Plain stratigraphy, Edwards (1979) drilled three borings on either side of the magnetic anomaly and compiled existing boring and geophysical data to construct the top-of-basement structure contour map shown in Figure 2.5-303. Based on their findings, Edwards (1979) make several key statements on the absence of a fault, including: "A regional map of the basement surface... does not reveal any structural anomalies... that could not be explained by relict topographic relief on the pre-Coastal Plain surface" (p. 20) and "within the scale of resolution (50 feet) of the data obtained in this project, offset at the base of the Coastal Plain cannot be demonstrated. Thus any fault associated with the shear zone can be dated no younger than Early Cretaceous" (p. 21). Similarly, geologic cross-sections from Benson (2006), developed from the borings of Edwards (1979), provide a line of evidence that is inconsistent with faulting beneath the northern part of Chesapeake Bay. Second, geologic mapping by Higgins (1986) along the northeast on-land projection of the inferred fault of Pazzaglia (1993a) does not show any northeast-striking fault(s) near Indian Falls and Northeast (Figure 2.5-304). Likewise, Higgins (1990) reported unfaulted Cretaceous deposits along a northeast projection of the inferred fault and states: "No irregularities such as local steepening, flattening, or reversal of the dip of the Coastal Plain strata have been found in Cecil County which would indicate that there has been significant post-depositional tectonic movements." (p. 123).

There is no direct geologic evidence to suggest that this unnamed fault zone from Pazzaglia (1993a) is a capable tectonic source. There is no pre-EPRI or post-EPRI seismicity spatially associated with this fault zone. Field and aerial reconnaissance conducted to support CCNPP Unit 3 (Figure 2.5-301) and inspection of detailed 'bare earth' LiDAR data (Figure 2.5-304) shows that there are no geomorphic features indicative of potential Quaternary activity along the surface-projection of the unnamed fault. Based on the sum of published literature (Higgins, 1986)(Higgins, 1990), structure contour maps (Edwards, 1979), field and aerial reconnaissance, and reasonable alternate explanations presented by F. Pazzaglia, it is concluded that this hypothetical fault is not a capable tectonic source.

The following references will be added to FSAR Subsection 2.5.1.3:

Benson, 2006. Internal stratigraphic correlation of the subsurface Potomac Formation, New Castle County, Delaware, and adjacent areas in Maryland and New Jersey, Delaware Geological Survey Report of Investigations No. 71, R.N. Benson, 2006.

Edwards, 1979. New Data Bearing on the Structural Significance of the Upper Chesapeake Bay Magnetic Anomaly; Maryland Geological Survey Report of Investigation No. 30, 44 p. J. Edwards and H. Hansen ,1979.

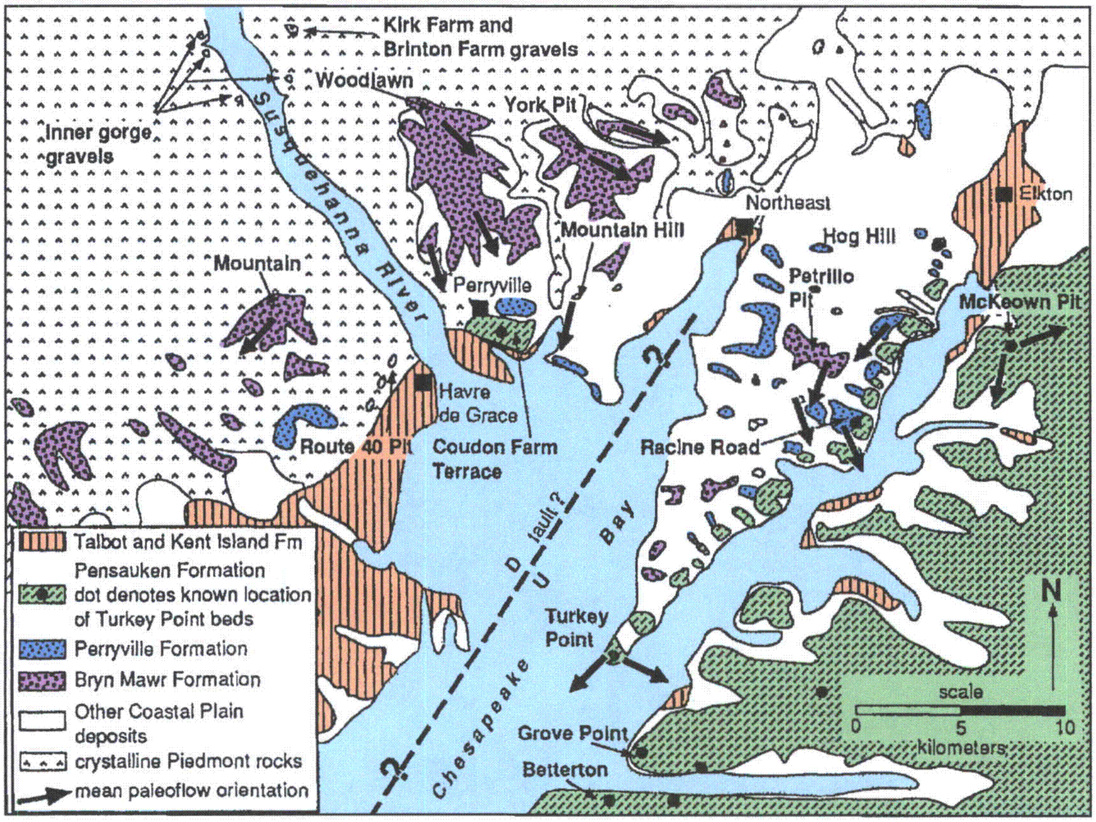
Higgins, 1990. The geology of Cecil County, Maryland; Maryland Geological Survey, Bulletin 37, p. 183, M.W. Higgins, and L.B. Conant, 1990.

Higgins, 1974. Interpretation of aeromagnetic anomalies bearing on the origin of Upper Chesapeake Bay and river course changes in the central Atlantic seaboard region: Speculations; Geology, v. 2 no. 1, p. 73-76, M.W. Higgins, I. Zietz, and G.W. Fisher, 1974.

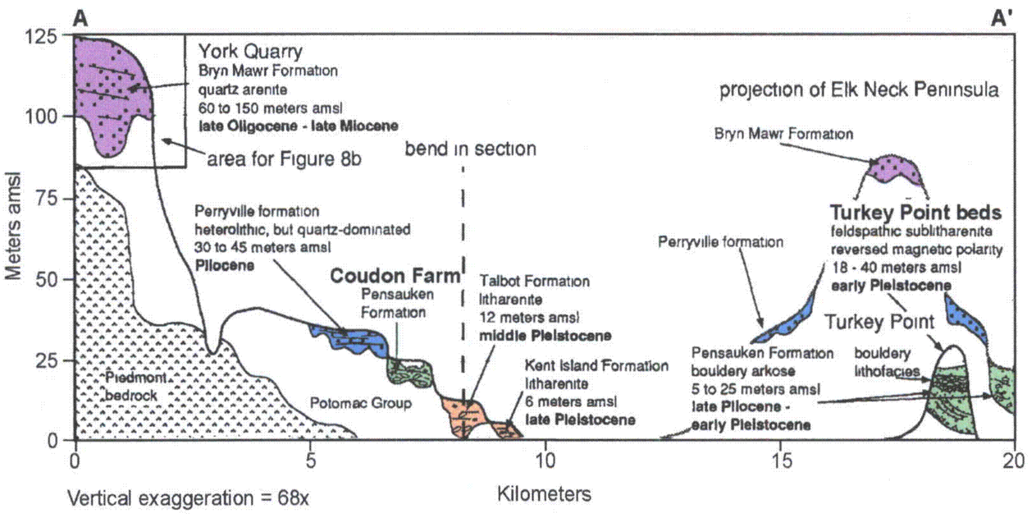
New figures FSAR 2.5-302, 2.5-303 and 2.5-304 will be added to FSAR Section 2.5.

Figure 2.5-302 {(A) Generalized Geologic Map and (B) Schematic Cross Section of the Northern Chesapeake Bay}

A)

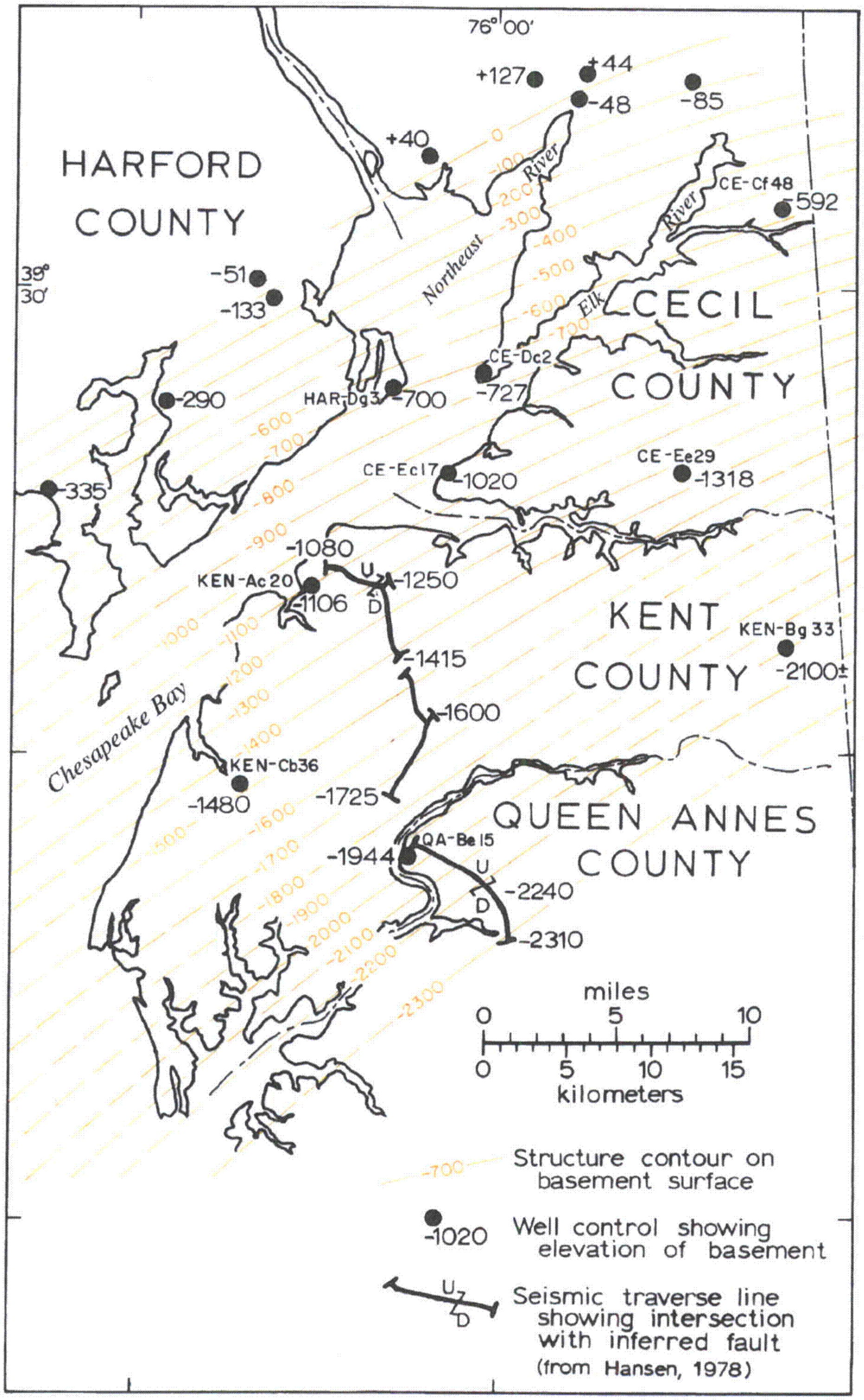


B)



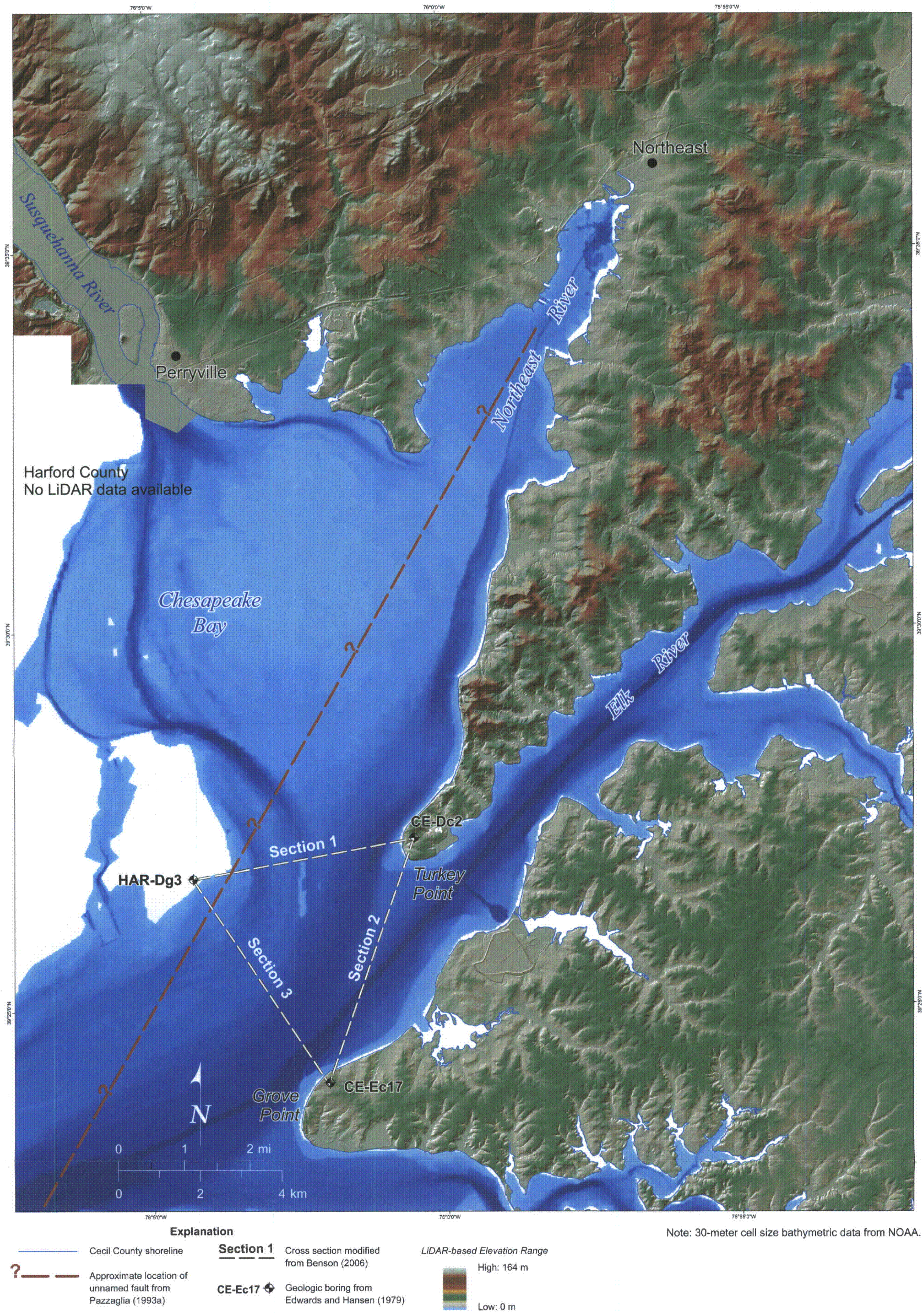
Note: (A) and (B) modified from Pazzaglia (1993a and 1993b).

Figure 2.5-303 {Generalized Top-of-Basement Structure Contour Map of the Northern Chesapeake Bay}



Reproduced from Edwards and Hansen (1979)

Figure 2.5-304 {LiDAR Elevation Showing Trace of Pazzaglia's Fault}



RAI 219

Question 02.05.01-68

FSAR Sections 2.5.1.1.4.4.5.4 Ramapo Fault system and 2.5.1.1.4.4.5.5 Kingston Fault cite Figure 2.5-31 when discussing the Ramapo, Kingston, and New York Bight faults which indicates these faults as circled numbers. In RAI 02.05.01-24 NRC staff asked the applicant to provide a figure that shows the fault lines and map relations that are described in the text. In response the applicant provided 4 additional maps. You also indicated that there would be no change to the FSAR.

NRC staff note that the discussions in the original FSAR about these faults cannot be understood without additional illustrations/maps beyond Figure 2.5-31. The map and cross section of the Kingston fault is needed to understand the uncertainty of the interpretation of a fault in the first place. It is difficult to understand the general geologic setting and relative position of these faults to each other as well. Please explain why you do not plan to include a more illustrative map/figure to support the text.

Response

Several of the figures generated previously in response to RAI 70 Question 02.05.01-24[1] will be added to the FSAR as new figures (Figures 2.5-306, 2.5-307 and 2.5-308). These figures illustrate the geologic setting of the Ramapo, Kingston, and New York Bight faults. These new FSAR figures provide additional fault location information by which one can better understand the general geologic setting, as well as the regional location of the faults with respect to one another. It may be noted that the FSAR Figure 2.5-307 is a reproduction of the geologic map by Stanford (2002) for the Kingston fault and is shown at a larger scale than the original mapping of 1:24,000.

FSAR Subsections 2.5.1.1.4.4.5.4, 2.5.1.1.4.4.5.5, and 2.5.1.1.4.4.5.6 will be revised and will refer to the new FSAR Figures 2.5-306, 2.5-307 and 2.5-308.

<u>Reference used in this response</u>:

Stanford, S.D., 2002, Surficial geology of the Monmouth Junction Quadrangle, Somerset, Middlesex, and Mercer Counties, New Jersey: Department of Environment Protection New Jersey Geological Survey Open-File Map OFM 47, 1 plate, scale 1:24,000.

COLA Impact

FSAR Section 2.5.1.1.4.4.4.5, 2.5.1.1.4.4.5.5, and 2.5.1.1.4.4.5.6 are revised as follows: Note that this markup is to the FSAR text as provided in UniStar Nuclear Energy letter UN#09-389[2] dated October 2, 2009.

2.5.1.1.4.4.5.4 Ramapo Fault System

The Ramapo fault is located in northern New Jersey and southern New York State, approximately 200 mi (320 km) north-northeast of the CCNPP site (Figure 2.5-31, Figure 2.5-216 and Figure 2.5-306). The Ramapo fault is one segment of a system of northeast-striking, southeast-dipping, normal faults that bound the northwest side of the Mesozoic Newark basin (Figure 2.5-10, and Figure 2.5-216), (Drake~~ et al.~~, 1996~~;~~) (Ratcliffe, 1971~~;~~) (Schlische, 1992). Bedrock mapping by Drake et al. (Drake et al., 1996) shows primarily northwest-dipping Lower Jurassic and Upper Triassic Newark Supergroup rocks in the hanging wall and tightly folded and faulted Paleozoic basement rocks in the footwall of the fault. The Ramapo fault proper extends for 50 mi (80 km) from Peapack~~Peakpack~~, NJ to the Hudson River (Ratcliffe, 1971). To the south the Ramapo fault splays into several fault strands and merges with the Flemington Fault zone. On the north side of the Hudson River the fault splays into several northeast- to east-trending faults in Rockland and Westchester Counties, New York.

The Ramapo fault first received significant attention as a potentially capable fault during the licensing process for the Indian Point Nuclear Power Plant ~~nuclear power plant~~ in the late 1970s ~~(Aggarwal and Sykes, 1978)~~ (Aggarwal, 1978). Due to the close proximity of a proposed strand of this fault to the Indian Point plant (several miles at most) and the questions raised regarding the capability of the fault during the licensing process, a considerable amount of research has been conducted to ~~addresses~~address the potential capability of the fault. The vast majority of the research was conducted prior to the development of the EPRI~~-SOG~~ source characterizations (EPRI, 1986~~-1989~~) that are used as the base source model for the CCNPP Unit 3 COLA (see discussion in Section 2.5.2). Therefore, much of this information was known to the EPRI~~-SOG~~ teams and considered by them in the development of the existing source characterizations for the Ramapo fault (~~see~~ ~~Section~~Subsection 2.5.2.2.1). Of the information on the Ramapo fault that has been published since the EPRI~~-SOG~~ study ~~(e.g., Kafka and Miller, 1996; Kafka et al., 1989; Newman et al., 1987; Ratcliffe et al., 1990; Sykes et al., 2008),~~ (Kafka, 1996) (Kafka, 1989) (Newman, 1987) (Ratcliffe, 1990) (Sykes, 2008) none has presented any new information or data that requires updating of the EPRI~~-SOG~~ model. The primary basis for this conclusion is the observation that none of the more recent publications provide conclusive evidence that the Ramapo and related faults are capable structures.

Interest in the Ramapo fault as a potential seismogenic fault was initially driven by the work of seismologists at what is now referred to as the Lamont Doherty Earth Observatory in New Jersey. Largely based on earthquake locations generated from local network data, these researchers noticed a spatial association between earthquakes and the Ramapo fault ~~(e.g., Aggarwal and Sykes, 1978; Kafka et al., 1985; Page et al., 1968)~~ (Aggarwal, 1978) (Kafka, 1985) (Page, 1968). The study of Page et al. (Page, 1968) used the locations of four earthquakes that they located near the Ramapo fault as the basis for concluding that the earthquakes were occurring on the Ramapo fault, and, therefore, the Ramapo was experiencing small slip events. In a later study, Aggarwal and Sykes (Aggarwal, 1978) located 33 earthquakes with magnitudes less than or equal to mb 3.3 that occurred between 1962 and 1977 within the New York - New Jersey region surrounding the Ramapo fault. Based on the locations of these earthquakes, Aggarwal and Sykes (Aggarwal, 1978) also noted a spatial association between the locations of the earthquakes and the Ramapo and related faults. Aggarwal and Sykes (Aggarwal, 1978) described this association as "leav[ing] little doubt that earthquakes in this area occur along preexisting faults" (page 426) (Aggarwal ~~and Sykes~~, 1978). In particular, Aggarwal and Sykes (Aggarwal, 1978) focused on the Ramapo fault: (1) noting that over half of the 32 events plot along the Ramapo fault, and (2) concluding that that Ramapo fault is an active fault with the capability of generating large earthquakes. Aggarwal and Sykes (Aggarwal, 1978) based this conclusion on: (1) the spatial association of seismicity; (2) ~~earthquake~~ focal mechanisms for earthquakes near the Ramapo fault that show high-angle thrust faulting along roughly northeast trending faults, implying a northwest maximum compressive stress direction; and (3) earthquake hypocenters from within 10 km of the Ramapo fault surface trace that align with a dip of approximately 60°.

Despite the strong insistence from earlier authors that there was little doubt the Ramapo fault is active, numerous studies ~~(e.g., Kafka et al., 1985; Quittmeyer et al., 1985; Seborowski et al., 1982; Thurber and Caruso, 1985)~~(Kafka, 1985) (Quittmeyer, 1985) (Seborowski, 1982) (Thurber, 1985) post-dating those of Aggarwal and Sykes (Aggarwal, 1978) and Page et al. (Page, 1968) presented revised analyses of the seismicity that contradict the earlier work and clearly demonstrate that there is considerable uncertainty as to whether or not slip on the Ramapo and related faults is causing the recorded seismicity. Seborowski et al. (Seborowski, 1982) analyzed a sequence of aftershocks in 1980 near the northern end of the Ramapo fault close to ~~Annesville~~Annsville, NY (Figure 2.5-216). Seborowski et al. (Seborowski, 1982) demonstrated that the alignment of these earthquakes and their composite focal mechanism suggest thrusting on a north-northwest trending fault plane. This observation led Seborowski et al. (Seborowski, 1982) to conclude that their observations are not consistent with the conclusion of Aggarwal and Sykes (Aggarwal, 1978) that the Ramapo fault is active because their slip direction and corresponding maximum compressive stress direction is perpendicular to that hypothesized by Aggarwal and Sykes (Aggarwal, 1978).

Quittmeyer et al. (Quittmeyer, 1985) analyzed another earthquake sequence that occurred in 1983 approximately 7 miles from the sequence analyzed by Seborowski et al. (Seborowski, 1982) and also reanalyzed one of the earthquakes used by Aggarwal and Sykes (Aggarwal, 1978) explicitly to address the discrepancy between the expected slip directions, and thus maximum compressive stress directions, of the Aggarwal and Sykes (Aggarwal, 1978) and Seborowski et al. (Seborowski, 1982) studies. Quittmeyer et al. (Quittmeyer, 1985) demonstrated two main points: (1) a composite fault plane solution for the 1983 earthquake sequence indicates thrust faulting along faults striking northwest with a maximum compressive stress direction oriented to the northeast; and (2) the earthquake analyzed by Aggarwal and Sykes (Aggarwal, 1978) has a non-unique fault plane solution that could be consistent with either the results of Aggarwal and Sykes (Aggarwal, 1978) or consistent with the fault plane solution for the 1983 earthquake sequence. Based on these observations, Quittmeyer et al. (Quittmeyer, 1985) hypothesized the maximum compressive stress direction is directed roughly northeaster~~ly~~ and implied that the Ramapo fault is not likely a source of earthquakes within the region.

Kafka et al. (Kafka, 1985) presented a revised and extended seismicity catalog for the New York - New Jersey area surrounding the Ramapo fault region extending from 1974 to 1983. Kafka et al. (Kafka, 1985) described this compilation as an improvement over previous catalogs because the increased robustness of the network during that timeframe provides more accurate earthquake locations and uniform magnitude estimates. During this time period, Kafka et al. (Kafka, 1985) recorded a total of 61 earthquakes, all with magnitudes less than or equal to m_{bLg} 3.0. Assuming that their earthquake catalog is complete down to magnitudes of $m_{bLg} > 2.0$, Kafka et al. (Kafka, 1985) reported that 7 out of 15 earthquakes occur within 10 mi (6 km) of the Ramapo fault. Kafka et al. (Kafka, 1985) describe the remaining earthquakes as occurring around the outside of the Newark basin. Importantly, Kafka et al. (Kafka, 1985) concluded that while "much emphasis was placed on the significance of the Ramapo fault and its relationship to seismicity" (page 1279), the other seismicity occurring throughout the region suggests that "the geologic structures associated with most (if not all) earthquakes in this region are still unknown" (page 1285). In a later publication in which Kafka and Miller (Kafka, 1996) analyze updated seismicity with respect to geologic structures, Kafka and Miller (Kafka, 1996) further discredit the association between seismicity and the Ramapo fault by saying, "...the currently available evidence is sufficient to rule out ... a concentration of earthquake activity along the Ramapo fault" (page 83).

Thurber and Caruso (Thurber, 1985) derived new, one- and three-dimensional crustal velocity models of the upper crust in the region of the northern Ramapo fault to provide better earthquake locations in that area. These new velocity models ~~were~~ are considered improvements over those used in previous studies (e.g., Aggarwal~~ and Sykes~~, 1978). The new models resulted in some changes in depths for the 15 earthquakes examined by Thurber and Caruso (Thurber, 1985). Based on their work, Thurber and Caruso (Thurber, 1985) concluded that: (1) there are significant lateral velocity variations within the region surrounding the Ramapo fault that can impact earthquake locations made using simple velocity models; and (2) "the Ramapo fault proper is not such a salient seismic feature in New York State, unlike the findings of Aggarwal and Sykes" (page 151). As with the Quittmeyer et al. (Quittmeyer, 1985), Seborowski et al. (Seborowski, 1982), and Kafka et al. (Kafka, 1985) studies, these conclusions of Thurber and Caruso (1985) indicate that there is considerable uncertainty surrounding the potential activity of the Ramapo fault.

Primarily triggered by the seismological suggestions that the Ramapo fault is active, geological investigations also were~~ also~~ conducted to look for evidence of Quaternary slip on the Ramapo fault. The primary researcher involved in these efforts was Nicholas Ratcliffe of the U.S. Geological Survey. Ratcliffe and his colleagues' work consisted of detailed geologic mapping, seismic reflection profiling, petrographic analysis, borings and core analysis along much of the Ramapo fault and its corollary northern and southern extension ~~(e.g., Ratcliffe, 1980, 1983, 1992; Ratcliffe and Burton, 1985, 1988; Ratcliffe et al., 1986a; Ratcliffe et al., 1986b; Ratcliffe and Costain, 1985)~~ (Ratcliffe, 1980) (Ratcliffe, 1983) (Ratcliffe, 1985a) (Ratcliffe 1985b) (Ratcliffe 1986a) (Ratcliffe 1986b) (Ratcliffe 1988) (Ratcliffe 1992). Much of Ratcliffe's work was explicitly focused on investigating the potential relationship between the Ramapo fault and the seismicity that had been noted in the surrounding region ~~(e.g., Aggarwal and Sykes, 1978).~~(Aggarwal, 1978). The primary conclusions of the cumulative work of Ratcliffe and his colleagues' with respect to the potential for Quaternary slip on the Ramapo fault are:

- The most recent episodes of slip along the Ramapo fault, as determined from rock core samples taken across the fault, were in a normal sense with some along-strike slip motion (i.e., oblique normal faulting). Ratcliffe and others concluded that the evidence for extension across the fault as the most recent slip and the lack of compression (i.e., thrust faulting), as would be required in the modern day stress field ~~(Zoback and Zoback, 1980; Zoback and Zoback, 1989),~~ (Zoback, 1980) (Zoback, 1989),is evidence that the Ramapo fault has not been reactivated since the latest episode of extension in the Mesozoic.

- The Ramapo fault generally has a dip that is less than that inferred from the earthquake epicenters of Aggarwal and Sykes (Aggarwal, 1978), with the exception of the northernmost end of the fault where the dip measured from borings is approximately 70°. The implication of this observation is that earthquakes near the Ramapo fault hypothesized as being due to slip on the Ramapo fault are more likely occurring within the Proterozoic footwall rocks of the Ramapo fault.

Ratcliffe and his colleagues' results ~~are~~provide additional evidence of the uncertainty with respect to the potential activity of the Ramapo fault because they found positive evidence for a lack of slip along the fault since the Mesozoic.

Most, if not all, of this geologic and seismologic information was known at the time of the EPRI-~~SOG~~ study (EPRI, 1986-~~1989~~) when the seismic source characterizations that are used as the base model for CCNPP Unit 3 were developed (~~see~~ Section 2.5.2). As such, the EPRI-~~SOG~~ characterizations take into account uncertainty in the potential for the Ramapo fault to be a capable fault. For example, some of the EPRI-~~SOG~~ Earth Science Teams explicitly characterized the Ramapo fault, and the probability of activity for the Ramapo fault given by those teams is less than 1.0 (~~see Section~~Subsection 2.5.2.2.1).

Since the research pre-dating the ERPI-~~SOG~~ study, there has been some additional research on the Ramapo fault. However, none of this additional research has provided any ~~additional~~ certainty with respect to the potential for activity of the Ramapo fault. For example, a fieldtrip guidebook of Kafka et al. (Kafka, 1989) for the New York region briefly discusses geomorphic evidence of the Ramapo fault including valley tilting, concentrations of terraces on only one valley side, and tributary offsets as evidence of Quaternary activity along the Ramapo fault. The use of these observations of Kafka et al. (Kafka, 1989) as evidence supporting Quaternary activity of the Ramapo fault should be treated cautiously ~~because:~~ based on the following:

- Kafka et al. (Kafka, 1989) present no data or evidence supporting these observations;
- Some of the noted geomorphic features may be older than Quaternary in age; and
- The observations themselves are not necessarily positive evidence of seismogenic, Quaternary faulting.

Newman et al. ~~(1987; 1983)~~ (Newman, 1987) (Newman, 1983) also presents observations that they interpret as evidence of Quaternary activity along the Ramapo fault. In their studies, Newman et al. (Newman, 1987) (Newman, 1983) ~~(1987; 1983)~~ constructed marine transgression curves based on radiocarbon dating of peat deposits for a series of tidal marsh sites along the Hudson River where it crosses the Ramapo fault. A total of eleven sites were investigated by Newman et al. (Newman, 1987), six of which were within the Ramapo fault zone as it crosses Hudson River. Of the six sites within the Ramapo fault zone, Newman et al. (Newman, 1987) report that three of the sites show a discontinuity in transgression curves that they conclude reflects Holocene normal faulting within the Ramapo fault zone. These observations and conclusions of Newman et al. (Newman, 1987) (Newman, 1983) ~~(1987; 1983)~~ are questionable with respect to the argument for Quaternary faulting along the Ramapo fault because:

- There is considerable uncertainty in the radiocarbon and elevation data used to develop the transgression curves that was not clearly taken into account in testing the faulting or no faulting hypotheses;
- The sense of motion indicated by the transgression curves (normal faulting) is contrary to the current state of stress (reverse faulting is expected);
- Trenching studies across the Ramapo fault have not revealed any evidence of Quaternary faulting (Ratcliffe~~ et al.~~, 1990; Stone~~ and Ratcliffe~~, 1984); and
- If the inferred offsets within the transgression curves are from fault movement, there is no evidence that the movement ~~was accommodated seismically (e.g.,~~ could have been accumulated through a seismic slip).

Finally, in an abstract for a regional Geological Society of America meeting, Nelson (Nelson, 1980) reported the results of pollen analysis taken from a core adjacent to the Ramapo fault near Ladentown, NY (Figure 2.5-216). In the brief abstract Nelson (Nelson, 1980) reports that the pollen history can be interpreted as either a "continuous, complete Holocene pollen profile suggesting an absence of postglacial seismicity along the fault" or as a pollen profile with a reversal, potentially suggesting a disruption of the infilling process caused by faulting. In summarizing his work, Nelson (Nelson, 1980) concludes that, "the pollen evidence is equivocal but certainly not strongly suggestive of seismicity."

More recently, another reanalysis of the seismicity within the region surrounding the Ramapo fault has been conducted by Sykes et al. (Sykes, 2008). ~~Sykes et al. (2008)~~who compiled a seismicity catalog extending from 1677 through 2006 for the greater New York ~~city~~ City – Philadelphia area. This catalog contains 383 earthquakes occurring within parts of New York, Connecticut, Pennsylvania, and New Jersey (Figure 2.5-216). Of these 383 earthquakes, those occurring since 1974 are thought to have the best constraints on location due to the establishment of a more robust seismograph network at that time. Sykes et al. (Sykes, 2008) claim that one of the striking characteristics of their seismicity catalog is the concentration of seismicity within what they refer to as the Ramapo Seismic Zone (RSZ), a zone of seismicity approximately 7.5 mi (12 km) wide extending from the Ramapo fault to the west and from northern New Jersey north to approximately the Hudson River (Figure 2.5-216). The RSZ defined by Sykes et al. (Sykes, 2008) is approximately 200 mi (320 km) from the CCNPP site. All of the instrumentally located earthquakes within the RSZ have magnitudes less than mb 3.0 (Sykes~~ et al.~~, 2008). The only earthquake with mb > 3.0 is the historical mb 4.3

earthquake of 30 October 1783. However, uncertainty in the location of this earthquake is thought to be as much as 100 km (62 mi) (Sykes~~ et al.~~, 2008) raising significant suspicion as to whether the event occurred within the RSZ given the small extent of the RSZ relative to the location uncertainty.

From analyzing cross sections of the earthquakes, Sykes et al. (Sykes, 2008) concluded that the earthquakes within the RSZ occur within the highly deformed middle Proterozoic to early Paleozoic rocks to the west of the Mesozoic Newark basin and not the Ramapo fault proper. Figure 2.5-217 shows the Sykes et al. (Sykes, 2008) seismicity from the box in Figure 2.5-216 plotted along a cross section perpendicular to the Ramapo fault with the range of expected dips for the Ramapo fault (approximately 45° near the south end and 70° near the north end) ~~(Ratcliffe, 1980; Ratcliffe and Burton, 1985). Sykes et al. (2008)~~(Ratcliffe, 1980) (Ratcliffe, 1985a) (Sykes, 2008) specifically noted that, with the exception of three earthquakes with magnitudes less than or equal to mb 1.0 that are poorly located, earthquake hypocenters are almost vertically aligned beneath the surface trace of the Ramapo fault and not aligned with the Ramapo fault at depth (Figure 2.5-217). Instead of associating the earthquakes with the Ramapo fault, Sykes et al. (Sykes, 2008) attributed the observed seismicity within the RSZ to minor slip events on numerous small faults within the RSZ. However, neither Sykes et al. (Sykes, 2008), nor any other researchers ~~(e.g., Kafka et al., 1985; Wheeler, 2005, 2006, 2008; Wheeler and Crone, 2001),~~ (Kafka, 1985) (Wheeler, 2001) (Wheeler, 2005) (Wheeler, 2006) (Wheeler,2008), have identified distinct faults on which they believe the earthquakes may be occurring thus preventing the characterization of any potentially active faults. Also, Sykes et al. (Sykes, 2008) only vaguely described the geometry of the RSZ and did not provide robust constraints on the geometry of the zone, the orientation of the potentially active faults they interpret to exist within the zone, or the maximum expected magnitude of earthquakes within the zone. As such, the Sykes et al. (Sykes, 2008) study presents no new information that suggests changes to the EPRI~~-SOG~~ model are required to adequately represent the potential capability of the Ramapo fault or the Ramapo seismic zone.

A good summary of the current state of knowledge concerning the capability of the Ramapo fault is provided by Wheeler (Wheeler, 2006). While the Wheeler (Wheeler, 2006) paper did not consider the results of the Sykes et al. (Sykes, 2008) study, Wheeler's (Wheeler, 2006) comments accurately describe the current state of knowledge concerning the capability of the Ramapo fault of RSZ. Wheeler (Wheeler, 2006) states that: "No available arguments or evidence can preclude the possibility of occasional small earthquakes on the Ramapo fault or other strands of the fault system, or of rarer large earthquakes whose geologic record has not been recognized. Nonetheless, there is no clear evidence of Quaternary tectonic faulting on the fault system aside from the small earthquakes scattered within and outside the Ramapo fault system"~~.~~ (page 178). The implication for the CCNPP Unit 3 site is that there is no new information to suggest that the EPRI~~-SOG (EPRI, 1986-1989)~~ (EPRI, 1986) characterizations for the Ramapo fault do not adequately capture the current technical opinion with respect to the seismic hazard posed by the Ramapo fault or RSZ.

2.5.1.1.4.4.5.5 Kingston Fault

The Kingston fault is located in central New Jersey, approximately 175 mi (282 km) northeast of the CCNPP site (Figure 2.5-31 and Figure 2.5-306). The Kingston fault is a

7 mi (11 km) long north to northeast-striking fault that offsets Mesozoic basement and is overlain by Coastal Plain sediments (Owens, 1998)(Figure 2.5-307). Stanford (Stanford, 1995) use borehole and geophysical data to interpret a thickening of as much as 80 ft (24 m) of Pliocene ~~Pennauken~~ Pensauken Formation across the surface projection of the Kingston fault (Figure 2.5-308). Stanford (Stanford, 1995) interprets the thickening of the ~~Pennauken~~ Pensauken Formation ~~gravel~~ as a result of faulting rather than fluvial processes. Geologic cross sections prepared by Stanford (Stanford, 2002) do not show that the bedrock- ~~Pennauken~~ Pensauken contact is vertically offset across the Kingston fault (Figure 2.5-308). Therefore, it seems reasonable to conclude that faulting of the ~~Pennauken~~ Pensauken Formation is not required and that apparent thickening of the Pliocene gravels may represent a channel-fill from an ancient pre-Pliocene channel (Figure 2.5-308). ~~Furthermore, Pleistocene glaciofluvial gravels that overlie the fault trace are not offset, thus indicating the fault is not a capable tectonic source (Stanford, 1995).~~ Wheeler (Wheeler, 2006) reports that the available geologic evidence does not exclusively support a fault versus a fluvial origin for the apparent thickening of the ~~Pennauken~~ Pensauken Formation. Wheeler (Wheeler, 2005) assigns the Kingston fault as a Class C feature based on a lack of evidence for Quaternary deformation. Given the absence of evidence for Quaternary faulting and the presence of undeformed Pleistocene glaciofluvial gravels overlying the fault trace, we conclude that the fault is not a capable tectonic feature.

2.5.1.1.4.4.5.6 New York Bight Fault

On the basis of seismic surveys, the New York Bight fault is characterized as an approximately 31 mile (50 km) long, north-northeast-striking fault, located offshore of Long Island, New York (Hutchinson, 1985) (Schwab, 1997a) (Schwab, 1997b) (Figure 2.5-31 and Figure 2.5-306). The fault is located about 208 mi (335 km) northeast of the CCNPP site. Seismic reflection profiles indicate that the fault originated during the Cretaceous and continued intermittently with activity until at least the Eocene. The sense of displacement is northwest-side down and displaces bedrock as much as 357 ft (109 m), and Upper Cretaceous deposits about 236 ft (72 m) (Hutchinson, 1985). High-resolution seismic reflection profiles that intersect the surface projection of the fault indicate that middle and late Quaternary sediments are undeformed within a resolution of 3 ft (1 m) (Hutchinson, 1985) (Schwab, 1997a) (Schwab, 1997b).

The Mesozoic New York Bight basin is located immediately east of the New York Bight fault (Hutchinson et al., 1986) (FSAR Figure 2.5-10). On the basis of seismic reflection data, Hutchinson (1986) interpret the basin to be structurally controlled by block faulting in the crystalline basement accompanied by syn-rift Mesozoic sedimentation. There is no evidence reported by Hutchinson (1986) that the basin bounding faults extend into the overlying Cretaceous sediments. Although not explicitly stated in the published literature (Hutchinson, 1985)(Schwab, 1997a) (1997b), the association of the New York Bight fault along the western edge of the New York Bight basin suggests late Cretaceous through Eocene reactivation of the early Mesozoic basin bounding fault.

Only a few, poorly located earthquakes are spatially associated within the vicinity of the New York Bight fault (Wheeler, 2006) (Figure 2.5-31 and Figure 2.5-306). Wheeler (Wheeler, 2006) defines the fault as a feature having insufficient evidence to demonstrate that faulting is Quaternary and assigns the New York Bight fault as a Class C feature. Based on the seismic reflection surveys of Schwab (Schwab, 1997a)

(Schwab, 1997b) and Hutchinson (1985) and the absence of Quaternary deformation, we conclude that the New York Bight fault is not a capable tectonic source.

New Figures 2.5-306, 2.5-307 and 2.5-308 will be added to the COLA FSAR.

Figure 2.5-306 {Geologic Map of the Ramapo Fault and Vicinity with Seismicity}

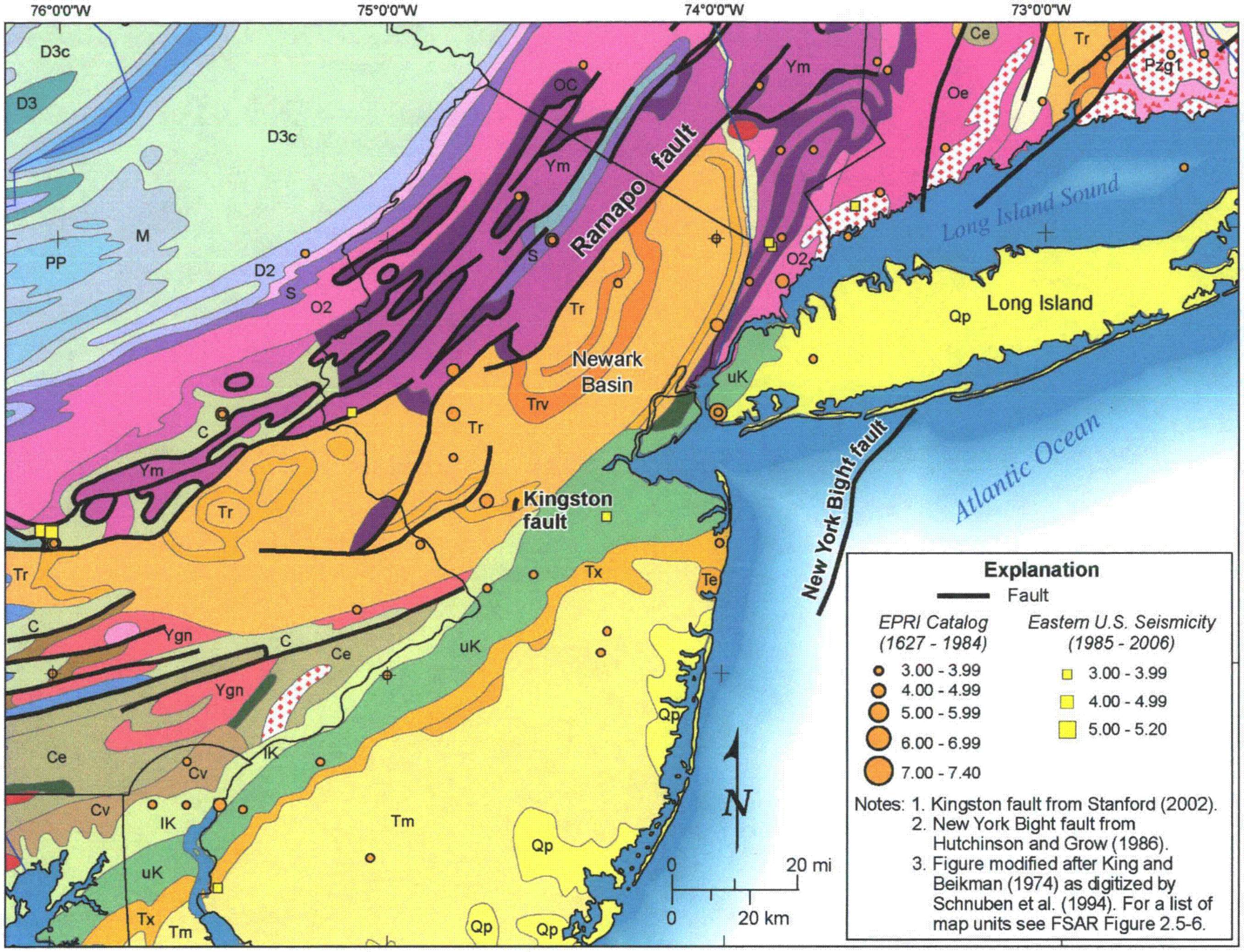
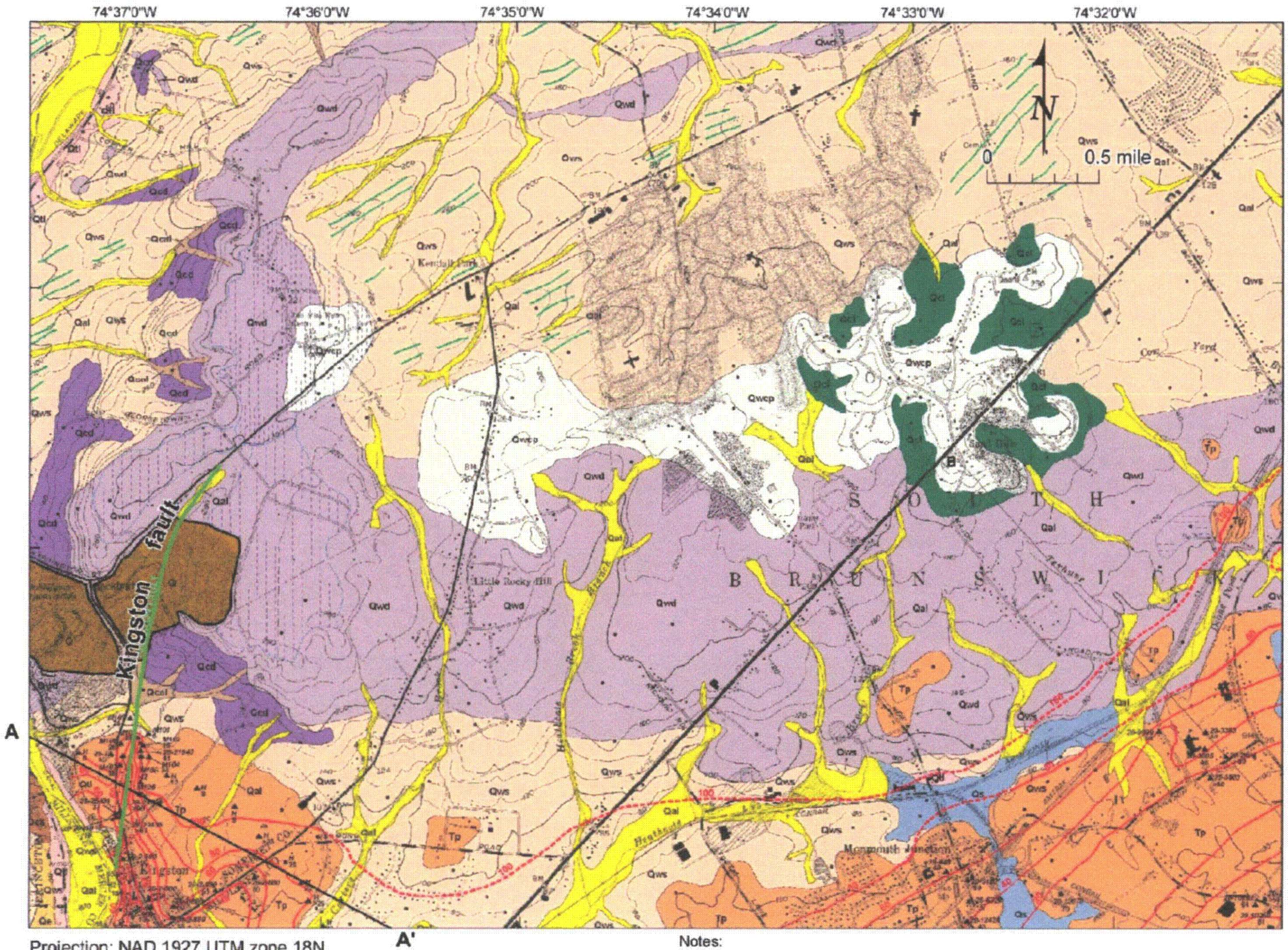


Figure 2.5-307 {Geologic Map of Kingston Fault}



Projection: NAD 1927 UTM zone 18N

Notes:

1. Reproduced from Stanford, 2002, Surficial Geology of the Monmouth Junction Quadrangle, Sommerset, Middlesex, and Mercer Counties, NJ, 1;24,000.

2. See Figure 2.5-308 for the geologic explanation and cross section A - A'.

Figure 2.5-308 {Explanation of Map Units and Cross Section A - A' for the Geologic Map of the Kingston Fault.}

SURFICIAL GEOLOGY OF THE MONMOUTH JUNCTION QUADRANGLE, SOMERSET, MIDDLESEX, AND MERCER COUNTIES, NEW JERSEY

by
Scott D. Stanford
2002

MAP UNITS

Age of unit indicated in parentheses. For units spanning more than one period, principal age is listed first.

Order of map units in list does not necessarily indicate chronologic sequence.

ARTIFICIAL FILL--Sand, silt, clay, gravel; brown, gray, yellowish brown; may include angular fragments of shale, sandstone, and diabase bedrock. May also include demolition debris (concrete, brick, asphalt, glass) and trash. As much as 30 feet thick. Many small areas of fill in urban areas are not shown.

Qal — **ALLUVIUM** (Holocene and late Pleistocene)--Sand, silt, clay, peat; yellowish brown, reddish brown, dark brown, gray; and pebble-to-cobble gravel. Abundant organic matter. Sand is chiefly quartz and shale fragments, with some glauconite and mica. Gravel is quartz, shale fragments, and quartzite with minor diabase and ironstone. As much as 20 feet thick. Deposited in floodplains, channels, and groundwater seepage areas.

Qs — **SWAMP AND MARSH DEPOSITS** (Holocene and late Pleistocene)--Peat and organic silt, sand, and clay; dark brown to black. As much as 10 feet thick.

Qcal — **COLLUVIUM AND ALLUVIUM** (Holocene and late Pleistocene)--Interbedded alluvium and colluvium in headwater valleys. As much as 15 feet thick.

Qaf — **ALLUVIAL FAN DEPOSITS** (Holocene and late Pleistocene)--Sand, silt; brownish yellow, reddish brown, brown; and pebble gravel. Minor amounts of organic matter. As much as 15 feet thick. Forms small fans at mouths of steep streams.

Qe — **EOLIAN DEPOSITS** (late Pleistocene and Holocene)--Fine-to-medium sand, very pale brown to reddish yellow. Sand is chiefly quartz and shale fragments with minor mica in places. As much as 15 feet thick. Forms sand sheets.

Qtl — **LOWER TERRACE DEPOSITS** (late Pleistocene)--Sand and minor silt; reddish brown, yellowish brown, reddish yellow; and pebble gravel. Sand is chiefly quartz and red and gray shale fragments with some glauconite and mica. Gravel is quartz, quartzite, gray and red shale and siltstone, with minor diabase, gneiss, and chert. As much as 30 feet thick. Forms stream terraces with surfaces 5 to 20 feet above the modern floodplain.

Qcl — **LOWER COLLUVIUM** (late Pleistocene)--Sand, silt, minor clay; yellow, yellowish brown, reddish yellow, light gray; some quartz and ironstone pebbles. As much as 15 feet thick, generally less than 10 feet thick. Deposited by downslope movement of Cretaceous sand and clay.

Qcs — **SHALE COLLUVIUM** (late Pleistocene)--Sandy, clayey silt; reddish brown; many angular chips and fragments of shale. As much as 10 feet thick. Deposited by downslope movement of weathered shale. Forms aprons on grade with lower terraces.

Qcd — **DIABASE COLLUVIUM** (middle and late Pleistocene)--Sandy, clayey silt to sandy, silty clay; reddish yellow, brown, gray; some to many angular to subrounded pebbles, cobbles, and small boulders of diabase and gray hornfels, and a few rounded pebbles and cobbles of quartz and quartzite. As much as 25 feet thick. Deposited by downslope movement of weathered diabase, hornfels, and Beacon Hill lag.

Tp — **PENSAUKEN FORMATION** (Pliocene)--Sand, minor silt and clay; yellow to reddish yellow; pebble gravel and minor cobble gravel, particularly at the base of the deposit. Sand is chiefly quartz with some weathered feldspar and minor glauconite and mica. Gravel is chiefly quartz and quartzite with some chert and ironstone, and minor sandstone, mudstone, gneiss, and diabase. Gneiss, diabase, and some sandstone and mudstone, clasts are deeply weathered. Locally iron-cemented. As much as 145 feet thick. In erosional remnants of a dissected river plain.

Qwcp — **WEATHERED COASTAL PLAIN FORMATIONS**--Exposed sand and clay of Coastal Plain bedrock formations. May be overlain by thin, patchy alluvium and colluvium. Quartz, chert, and ironstone pebbles left from erosion of surficial deposits may be present on the surface and in the upper several feet of the formation.

Qws — **WEATHERED SHALE**--Silty clay to sandy silt; reddish brown, pale red, reddish yellow, gray; some to many angular chips and fragments of shale and a few quartz, chert, and ironstone pebbles left from erosion of surficial deposits. As much as 10 feet thick, generally less than 3 feet thick.

Qwd — **WEATHERED DIABASE**--Silty clay to clayey sand; yellow, reddish yellow, light gray; some to many angular to subrounded pebbles, cobbles, and small boulders of diabase. A few quartz, chert, and ironstone pebbles and cobbles left from erosion of surficial deposits may be present on the surface and in the upper several feet. As much as 20 feet thick.

MAP SYMBOLS

Contact--Contacts of alluvium, swamp deposits, and lower terrace deposits are well-defined by landforms and are drawn from 1:12,000 scale aerial stereophotos. Contacts of other units are approximately located based on both landforms and field observation points.

Material observed in hand-auger hole, exposure, or excavation.

Shallow topographic basin--Of probable periglacial origin.

Well or boring--Upper number (italicized) is identifier, lower number is thickness of surficial material, in feet. Identifiers of the form '28-xxxx' are N. J. Department of Environmental Protection well permit numbers. Identifiers of the form 'Mxxx' are monitoring wells filed under permit numbers 28-31109 to 28-31122. Identifiers of the form '28-xx-xxx' are N. J. Atlas Sheet grid locations of entries in the N. J. Geological Survey permanent note collection. Borings identified by 'H' are N. J. Department of Transportation borings from Harper (1984).

Thickness of surficial material--From geophysical survey (D. L. Jagel and D. W. Hall, N. J. Geological Survey, 1995)

Elevation of base of Pensauken Formation--In feet above sea level. Contour interval 20 feet. Dashed where eroded Topography of the base of the Pensauken in the Kingston area shows abrupt thickening along the trace of the Kingston Fault, suggesting fault offset of the Pensauken (Stanford and others, 1995). See section AA'.

Trace of Kingston Fault--From Parker and Houghton (1990).

Bedrock strike ridge--Low ridge parallel to strike of bedrock. Drawn from airphotos.

Beacon Hill lag--Pebbles and cobbles of quartz, quartzite, chert, and ironstone left from erosion of the Beacon Hill Gravel, a late Miocene fluvial deposit that formerly covered the quadrangle above an elevation of 320 feet.

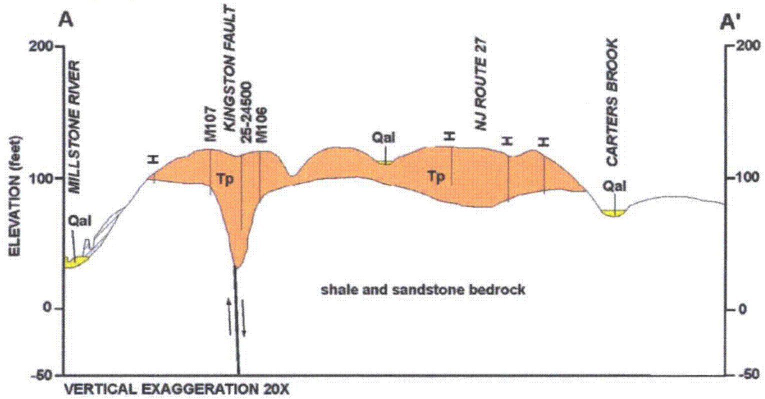
Sparse Beacon Hill lag--Pebbles and cobbles as above, but sparsely distributed.

Pensauken lag--Pebbles and a few cobbles of quartz, quartzite, and chert left from erosion of the Pensauken Formation. Only concentrated lags are mapped; sparsely distributed lag pebbles are widespread below 140 feet in elevation.

Upper terrace lag--Pebbles and a few cobbles of quartz and quartzite left from erosion of upper stream terrace deposits. Marks level of Millstone River in the middle Pleistocene.

Fluvial scarp--Line at top, ticks on slope. Cut into shale. On grade with upper terrace lag. Marks level of Millstone River in the middle Pleistocene.

Q — Quarry--Line marks perimeter of excavated area at time of mapping. Diabase and hornfels outcrop, quarried rock, and stripped surficial material occur within perimeter.



REFERENCES

Harper, D. P., 1984, Geologic compilation map of the Monmouth Junction quadrangle, New Jersey: N. J. Geological Survey Open-File Map 1, scale 1:24,000.

Parker, R. A., and Houghton, H. F., 1990, Bedrock geologic map of the Monmouth Junction quadrangle, New Jersey: U. S. Geological Survey Open-File Report 90-219, scale 1:24,000.

Stanford, S. D., Jagel, D. L., and Hall, D. W., 1995, Possible Pliocene-Pleistocene movement on a reactivated Mesozoic fault in central New Jersey: Geological Society of America Abstracts with Programs, v. 27, no. 1, p. 83.

RAI 219

Question 02.05.01-69

FSAR section 2.5.1.2.6.4 states that "There is no evidence of earthquake-induced liquefaction in the State of Maryland" and cited the Crone and Wheeler papers. In RAI 02.05.01-28 NRC staff pointed out that the Crone and Wheeler database does not support that statement and asked if potential liquefaction features had been investigated as part of the geologic investigation for the site. NRC staff also requested you provide details of any such survey. In RAI 02.05.01-30, NRC staff asked you to provide liquefaction information for the site area along with methods used and a summary of the findings.

In response, you indicated that the investigation for potential liquefaction features done for this COL application included a literature review, discussions with subject matter experts, an aerial and field reconnaissance, and a review of aerial photography. You stated that based on this work there is no liquefaction within 25 miles of CCNPP and within the state of MD. You planned no revision to the FSAR.

NRC staff note that the original statement citing Crone and Wheeler as the basis of the conclusion that there is no earthquake induced liquefaction in the state of MD remains in the FSAR and does not actually support that conclusion.

a. Dr. Martitia Tuttle is a regional expert in paleoliquefaction. Please explain if you reviewed Tuttle publications about potential paleoliquefaction within the state of MD.

b. In figure 4 of the response to this question is an oblique aerial photo of a terrace along the Potomac River. There are two circular features in the foreground that appear as sand blow deposits. Please discuss the origin of these circular features.

c. Please explain why the response to this question is not to be included in a future FSAR revision.

Response

(a.) Dr. Martitia Tuttle is a regional expert in paleoliquefaction. Please explain if you reviewed Tuttle publications about potential paleoliquefaction within the state of MD.

As discussed in responses to RAI 71 Question 02.05.01-04[1] and in the revised FSAR Section 2.5.1.1.4.4 prepared in response to RAI 219 Question 02.05.01-64[3], a comprehensive literature search for publications about potential Quaternary faults and tectonic features (including paleoliquefaction features) within the State of Maryland was performed for this study. No publications authored by Dr. Martitia Tuttle were identified, which discussed paleoliquefaction features within the State of Maryland. Further, Dr. Martitia Tuttle was interviewed by phone on March 22, 2010, when she stated that she was unaware of any paleoliquefaction features within the State of Maryland. Also, previous conversations (by phone and in-person) with paleoliquefaction expert Dr. Steve Obermeier and geologists with the Maryland Geological Survey provided similar findings. As discussed in response to RAI 71 Question 02.05.01-28[1], our literature search found only one study entitled "*Paleoliquefaction Features Along the Atlantic*

Seaboard" by Amick et al. (1990) that searched for paleoliquefaction features in the State of Maryland. Although the NRC funded study focused primarily on Charleston, South Carolina, they also performed a regional paleoliquefaction survey between Cape May, New Jersey and the Georgia/Florida state line, which included portions of the Delmarva Peninsula and Chesapeake Bay. Amick et al. (1990) reported no liquefaction in the Delmarva Peninsula portion of the investigation (Amick et al., 1990) where Quaternary-aged deposits are ubiquitous.

(b.) In figure 4 of the response to this question is an oblique aerial photo of a terrace along the Potomac River. There are two circular features in the foreground that appear as sand blow deposits. Please discuss the origin of these circular features.

The semi-circular features, which appear in Figure 4 of UniStar's response to RAI 71 Question 02.05.01-30[1], were investigated through field and aerial reconnaissance, analysis of aerial imagery, geologic maps, and SSUGRO soil data. A map of the field and aerial reconnaissance was provided in response to RAI 71 Question 02.05.01-04 and will be included in the FSAR as Figure 2.5-301. The area shown in the photograph (Figure 4) is along the eastern shore of Breton Bay, Maryland, along the north side of the Potomac River. This small bay is located where McIntosh Run empties into Breton Bay, approximately 25 miles upstream from where the Potomac River enters into the Chesapeake Bay. The features mentioned in the response to RAI 71 Question 02.05.01-30 occur on a low lying cultivated terrace (3 to 15 feet above sea level). McCartan (1989) mapped this surface as a combination of Undivided Holocene deposits along the water's edge (Unit Qh) and the Pleistocene Maryland Point Formation (Unit Qm – an approximately 70,000 year old fluvial terrace composed of sand, silt, and coarse sand) The Holocene deposits form a slightly lower surface composed of unconsolidated poorly sorted sand and gravel to sandy, silt, and clay formed along the margins of modern waterways and inset against the Qm surface. The United States Department of Agriculture (USDA) - Natural Resources Conservation Services (NRCS) Soil Survey Geographic Database (SSUGRO) indicates that the whitish features shown in Figure 4 correlates with the Evesboro loamy sand that develops on 0 to 8% slopes with occasional ridges, depressions, and steeper slopes along major drainages. To the east and south the Evesboro loamy sand is bounded by Woodstown fine sandy loam forming on old stream surfaces (0 to 2% slopes) and the Othello silty loam (0 to 2% slopes).

To further investigate the semi-circular feature pointed out in the statement above, Google Earth imagery was reviewed that captured this feature at varying months of the year between 1993, 2005, and 2007. Many images viewed from multiple vantage points show that these features have an elongated and curvelinear shape with irregular boundaries defined by light and dark tonal contrasts. Delineation of the tonal features exhibit fluvial geomorphic expressions associated with paleo-sand bars (light-colored features shown in Figure 4) and channels rather than liquefaction-related features. The former channel locations exhibit some meandering characteristics and appear to have been filled in with finer grained material. Where vegetation is stripped and has been replaced by agricultural or grasslands, similar fluvial geomorphic-related features (abandoned meanders and stream channels, sand bars and fluvial depressions) are observed along many of the large low-lying terraces in Maryland. On this basis, coupled with the absence of reported liquefaction features in Maryland from our literature review, other literature reviews (Crone, 2000; Wheeler, 2005 and 2006), and other field studies (Amick, et al., 1990), we interpret these features as paleo-sand bar deposits typically seen in fluvial terraces and not as paleoliquefaction features.

(c.) Please explain why the response to this question is not to be included in a future FSAR revision.

FSAR Section 2.5.1.2.6.4 will be revised as shown below in COLA Impact.

References used in this response:

Amick, D., Gelinas, R., Maurath, G., Cannon, R., Moore, D., Billington, E., and Kemppmen, H., 1990, Paleoliquefaction features along the Atlantic Seaboard, NUREG/CR-5613

Crone, A.J., and Wheeler, R.L., 2000, Data for Quaternary faults, liquefaction features, and possible tectonic features in the Central and Eastern United States, east of the Rocky Mountain front; U.S. Geological Survey Open File Report 00-260.

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

Wheeler, R.L., 2005, Known or suggested Quaternary tectonic faulting, central and eastern United States-New and updated assessments for 2005, U.S. Geological Survey Open-File Report 2005-1336.

Wheeler, R.L., 2006, Quaternary tectonic faulting in the Eastern United States, Engineering Geology, 82, pages 165-186.

COLA Impact

2.5.1.2.6.4 Prior Earthquake Effects

Outcrops are rare within the CCNPP site area. Studies of the CCNPP Unit 1 and 2 excavation, available outcrops and small streams, and extensive exposures along the western shore of Chesapeake Bay have not indicated any evidence for earthquake activity that affected the Miocene deposits. ~~Potential liquefaction features were investigated as part of the CCNPP Unit 3 site investigation, which included a review of existing literature, discussion with researchers familiar with the local Quaternary geology, aerial and field reconnaissance, and review of site vicinity aerial photography (multiple vantages within a 5 mile radius of the site). During the field reconnaissance along the Potomac and Patuxent Rivers, and where outcrops of Quaternary deposits were available, exposures were evaluated for liquefaction-related deformation features. Quaternary fluvial deposits inset into Calvert Cliffs and partially exposed along the west side of Chesapeake Bay were evaluated for liquefaction-related features. No liquefaction features were identified. Several small tributaries intersecting the site were also inspected; however, no suspicious features were identified in the limited exposures available for review. The aerial reconnaissance consisted of traverses across the Potomac, Patuxent and Rappahannock Rivers where Quaternary fluvial terraces (e.g., potentially liquefiable deposits) were inspected for features that could be related to earthquake-induced liquefaction. A similar aerial reconnaissance of the Delmarva Peninsula was performed. There is no evidence of earthquake-induced liquefaction in the State of Maryland (Crone, 2000) (Wheeler, 2005).~~ The findings of a field and aerial reconnaissance (Figure 2.5-301), coupled with literature and aerial photography review, as well as discussions with experts in the assessment of paleoliquefaction in the central and eastern United States, indicate the absence of evidence for paleoliquefaction in Maryland. For example, one study entitled "*Paleoliquefaction Features along the Atlantic Seaboard*" by Amick (1990) searched for paleoliquefaction features in the State of Maryland. This NRC funded study performed a regional paleoliquefaction survey between Cape May, New Jersey and the Georgia/Florida state line, which included portions of the Delmarva Peninsula and Chesapeake Bay. Amick (1990) reported no liquefaction in the Delmarva Peninsula portion of the investigation (Amick, 1990) where Quaternary-aged deposits are ubiquitous. These findings are consistent with Crone (2000) and Wheeler (2005)(2006), which make no reference to paleoliquefaction features in the State of Maryland.

The following reference will be added to Section 2.5.1.3:

Amick, 1990. Paleoliquefaction features along the Atlantic Seaboard, NUREG/CR-5613, D. Amick, R. Gelinas, G. Maurath, R. Cannon, D. Moore, E. Billington, and H. Kemppmen, October, 1990.

Enclosure 2

CD with a high resolution copy of

RAI 219, Question 02.05.01-67, Figure 5,

Calvert Cliffs Nuclear Power Plant, Unit 3