FPL.

L-2012-001
10 CFR 52.3

January 3, 2012

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D.C. 20555-0001

Re: Florida Power & Light Company
Proposed Turkey Point Units 6 and 7
Docket Nos. 52-040 and 52-041
Response to NRC Request for Additional Information Letter No. 041
(eRAI 6024) SRP Section: 02.05.01 - Basic Geologic and Seismic Information

Reference:

1. NRC Letter to FPL dated October 20, 2011, Request for Additional Information Letter No.041 Related to SRP Section 02.05.01 - Basic Geologic and Seismic Information for the Turkey Point Nuclear Plant Units 6 and 7 Combined License Application
2. FPL Letter to NRC dated November 18, 2011, Response and Response Schedule to NRC Request for Additional Information Letter No. 041 (eRAI 6024) SRP Section: 02.05.01 - Basic Geologic and Seismic Information
3. FPL Letter to NRC dated December 20, 2011, Revised Response Schedule to NRC Request for Additional Information Letter No. 041 (eRAI 6024) SRP Section: 02.05.01 - Basic Geologic and Seismic Information

Florida Power & Light Company (FPL) provides, as attachments to this letter, its responses to the Nuclear Regulatory Commission's (NRC) Request for Additional Information (RAI) RAI 02.05.01-1, RAI 02.05.01-3, RAI 02.05.01-5, RAI 02.05.01-7, RAI 02.05.01-8, RAI 02.05.01-11, RAI 02.05.01-12, RAI 02.05.01-13, RAI 02.05.01-14, RAI 02.05.01-15, RAI 02.05.01-16, RAI 02.05.01-17, RAI 02.05.01-18, RAI 02.05.01-19, RAI 02.05.01-20, RAI 02.05.01-21, RAI 02.05.01-23, RAI 02.05.01-24, RAI 02.05.01-25, RAI 02.05.01-26, RAI 02.05.01-27, RAI 02.05.01-28, RAI 02.05.01-30, RAI 02.05.01-31, and RAI 02.05.01-32 provided in Reference 1. FPL provided a schedule for the responses to RAI 02.05.01-1, RAI 02.05.01-3, RAI 02.05.01-5, RAI 02.05.01-7, RAI 02.05.01-8, RAI 02.05.01-11, RAI 02.05.01-12, RAI 02.05.01-13, RAI 02.05.01-14, RAI 02.05.01-15, RAI 02.05.01-16, RAI 02.05.01-17, RAI 02.05.01-18, RAI 02.05.01-19, RAI 02.05.01-20, RAI 02.05.01-21, RAI 02.05.01-23, RAI 02.05.01-24, RAI 02.05.01-25, RAI 02.05.01-26, RAI 02.05.01-27, RAI 02.05.01-28, RAI 02.05.01-30, RAI 02.05.01-31, and RAI 02.05.01-32 in Reference 2. FPL provided a revised schedule for the responses in Reference 3. The attachments identify changes that will be made in a future revision of the Turkey Point Units 6 and 7 Combined License Application (if applicable).



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NRO

If you have any questions, or need additional information, please contact me at 561-691-7490.

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

Executed on January 3, 2012

Sincerely,

William Maher
Senior Licensing Director – New Nuclear Projects

WDM/RFB

Attachment 1: FPL Response to NRC RAI No. 02.05.01-1 (eRAI 6024)
Attachment 2: FPL Response to NRC RAI No. 02.05.01-3 (eRAI 6024)
Attachment 3: FPL Response to NRC RAI No. 02.05.01-5 (eRAI 6024)
Attachment 4: FPL Response to NRC RAI No. 02.05.01-7 (eRAI 6024)
Attachment 5: FPL Response to NRC RAI No. 02.05.01-8 (eRAI 6024)
Attachment 6: FPL Response to NRC RAI No. 02.05.01-11 (eRAI 6024)
Attachment 7: FPL Response to NRC RAI No. 02.05.01-12 (eRAI 6024)
Attachment 8: FPL Response to NRC RAI No. 02.05.01-13 (eRAI 6024)
Attachment 9: FPL Response to NRC RAI No. 02.05.01-14 (eRAI 6024)
Attachment 10: FPL Response to NRC RAI No. 02.05.01-15 (eRAI 6024)
Attachment 11: FPL Response to NRC RAI No. 02.05.01-16 (eRAI 6024)
Attachment 12: FPL Response to NRC RAI No. 02.05.01-17 (eRAI 6024)
Attachment 13: FPL Response to NRC RAI No. 02.05.01-18 (eRAI 6024)
Attachment 14: FPL Response to NRC RAI No. 02.05.01-19 (eRAI 6024)
Attachment 15: FPL Response to NRC RAI No. 02.05.01-20 (eRAI 6024)
Attachment 16: FPL Response to NRC RAI No. 02.05.01-21 (eRAI 6024)
Attachment 17: FPL Response to NRC RAI No. 02.05.01-23 (eRAI 6024)
Attachment 18: FPL Response to NRC RAI No. 02.05.01-24 (eRAI 6024)
Attachment 19: FPL Response to NRC RAI No. 02.05.01-25 (eRAI 6024)
Attachment 20: FPL Response to NRC RAI No. 02.05.01-26 (eRAI 6024)
Attachment 21: FPL Response to NRC RAI No. 02.05.01-27 (eRAI 6024)
Attachment 22: FPL Response to NRC RAI No. 02.05.01-28 (eRAI 6024)
Attachment 23: FPL Response to NRC RAI No. 02.05.01-30 (eRAI 6024)
Attachment 24: FPL Response to NRC RAI No. 02.05.01-31 (eRAI 6024)
Attachment 25: FPL Response to NRC RAI No. 02.05.01-32 (eRAI 6024)

cc:
PTN 6 & 7 Project Manager, AP1000 Projects Branch 1, USNRC DNRL/NRO
Regional Administrator, Region II, USNRC
Senior Resident Inspector, USNRC, Turkey Point Plant 3 & 4

**NRC RAI Letter No. PTN-RAI-LTR-041**

**SRP Section: 02.05.01 - Basic Geologic and Seismic Information**

QUESTIONS from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

**NRC RAI Number: 02.05.01-1 (eRAI 6024)**

FSAR Section 2.5.1.1.1.1.1.1, "Florida Peninsula Physiographic Sub provinces" passage, describes general karst dissolution for Florida to be due to an epigenic, sub aerial process of downward flow of slightly acidic groundwater (weak carbonic acid). The FSAR also provides a classification of Florida sinkhole types and a Florida Geological Survey ranking of sinkhole risk based on aerial density of known sinks.

The staff notes that relatively recent studies have recognized a different class of potentially potent carbonate dissolution and karst development in coastal areas that has been linked to mixing disequilibria at freshwater-brine interfaces. Several examples have been identified within the Caribbean region (FSAR Ref 263; and Smart et al., 2006[a];Mylroie and Carew, 2003[b]).

In order for the staff to determine if the information presented in the FSAR represents an up-to-date and accurate characterization of regional and local limestone formation conditions and in support of 10 CFR 100.23 please address the following:

Discuss any evidence for or against the potential for karst dissolution associated with such fresh-water/brine interfaces in southern Florida, within the site region. Specifically consider the presence of any known water-filled passages and/or potential linking to sub-sea springs that may have formed at current or past fresh-water/brine interfaces based on local and regional stratigraphic studies including the subsurface evaluations completed for this application. Discuss how fresh water/brine zones of dissolution would be expected to migrate in response to sea level changes

[a] Smart, P.L., Beddows, P.A., Coke, J., Doerr, S., Smith, S., and Whitaker, F.F., 2006, Cave development on the Caribbean coast of the Yucatan Peninsula, Quintana Roo, Mexico, in Harmon, R.S., and Wicks, C., eds, Perspectives on karst geomorphology, hydrology, and geochemistry – A tribute volume to Derek C. Ford and William B. White: Geological Society of America Special Paper 404, p. 105–128.

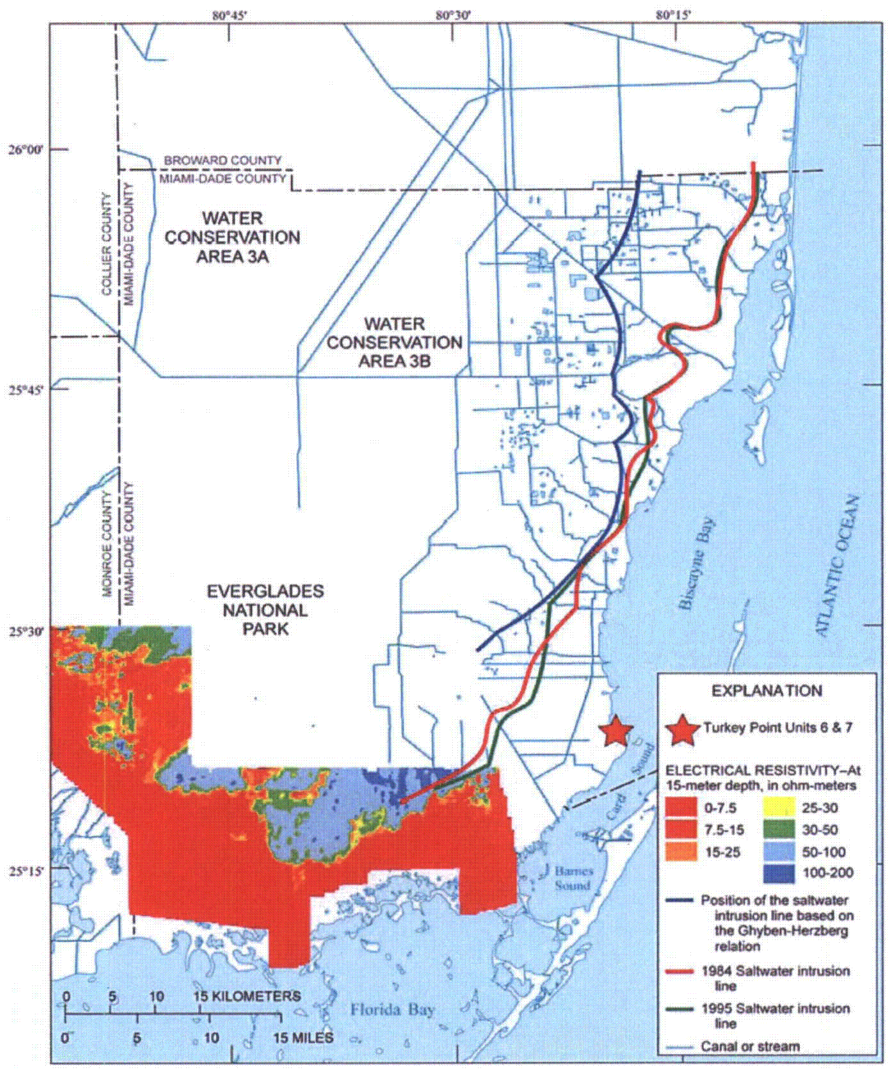
[b] Mylroie, J. E., and Carew, J. L. 2003. Karst development on carbonate islands. *Speleogenesis and Evolution of Karst Aquifers*, V.1 Issue 2

http://www.speleogenesis.info/archive/publication.php?PubID=21

**FPL RESPONSE:**

The freshwater/saltwater interface at the base of the Biscayne Aquifer is located approximately 6 to 8 miles inland of Turkey Point Units 6 & 7, as shown on FSAR Figure 2.4.12-207. The migration of saltwater inland along the base of the aquifer occurs along the entire coastal zone and is the result of the aquifer's high permeability and the lowering of inland groundwater levels from groundwater pumpage and surface drainage.

As shown on FSAR Figure 2.4.12-207, the position of the freshwater/saltwater interface was relatively consistent between 1984 and 1995 and in fact provisional data from the USGS (USGS, 2009) showing the 2008 freshwater/saltwater interface in southeast Florida indicates a similar pattern. Current literature (Moore, 2010, Evans and Lizarralde, 2003, Langevin, 2003, Langevin, 2001, and Smart et al., 1988) indicate that carbonate dissolution associated with the mixing of freshwater and saltwater occurs predominantly at groundwater discharge sites or seafloor discharge zones. Dissolution occurs when the two fluids of different salinities combine, even though both fluids are initially saturated with calcium carbonate (Land and Paull, 2000). Two possible mechanisms for such carbonate dissolution in southeastern Florida and within the site region are surface water release to Biscayne Bay through drainage canal discharge (point sources) and submarine groundwater discharge (SGD) from the Biscayne Aquifer. Both of these mechanisms are discussed in the following section.




FSAR Figure 2.4.12-207 Location of Freshwater-saltwater Interface.

Note: Differences in line location do not necessarily indicate movement of the saltwater intrusion line; differences may be due to interpretation, method, or data availability (Langevin, 2001).

Regional Studies: "Sub-Sea Springs": Canals

Under natural conditions and prior to anthropogenic activity, the freshwater/saltwater interface in southeastern Florida extended close to the coastline and freshwater discharged from springs on the floor of Biscayne Bay. In the late nineteenth century construction of flood control levees, drainage canals, and urbanization changed the freshwater/saltwater interface. Canals were first dug through the Everglades to drain water from the area south of Lake Okeechobee to enable agriculture to develop (FSAR 2.5.1 Reference 267).

By the late 1920s, major canals were constructed and rivers in the transverse glades were modified to connect Lake Okeechobee with the Gulf of Mexico and Atlantic Ocean (FSAR Figure 2.4.1-207). The West Palm Beach, Hillsborough, North New River, South New River, and Miami (River) Canals connect Lake Okeechobee with Biscayne Bay and the Atlantic Ocean (FSAR 2.5.1 Reference 267 and Godfrey, 2006). In the 1930's government-initiated flood control measures including levee construction and drainage channel modification were implemented.

The U.S. Congress authorized the Central and Southern Florida Flood Control Project (C&SF project) in 1948 with a mandate to provide flood protection, water supply, prevention of saltwater intrusion, and protection of fish and wildlife resources (FSAR 2.5.1 Reference 267 and Godfrey, 2006). The state of Florida formed the Central and Southern Florida Flood Control District in 1949, which later became the South Florida Water Management District (SFWMD), to work with the C&SF project. The C&SF project adopted a water management plan for Lake Okeechobee and three water conservation areas (WCA 1, 2 and 3) to provide flood protection, provide water supply and limit saltwater intrusion during drought periods. As part of the water management plan, the Everglades Agricultural Area (EAA) was also drained for agricultural development (FSAR 2.5.1 Reference 267).

By the 1970s, gated control structures were installed at the coastal end of the primary drainage canals to discharge excess water during the wet season and impede the landward movement of saltwater during the dry season. Secondary controls on the inland reaches of canals were installed to regulate flow eastward, control inland and agricultural flooding, and maintain higher water levels in the surficial aquifer system where appropriate. Surface-water pump stations in the EAA were added to regulate water levels for agricultural purposes, and new municipal well fields were either constructed or expanded. The final phase of canal development of the Everglades-South Dade conveyance system in the 1980s was constructed to meet agricultural water-supply needs, control flooding, and mitigate saltwater intrusion (FSAR 2.5.1 Reference 267).

The increased surface water discharge from the Everglades to Biscayne Bay and the Atlantic Ocean through the drainage canals has probably had an impact on coastal groundwater hydrology. Many factors contribute to the possible dissolution of the carbonate material at the coastline because of surface water discharge in the vicinity of the canals. Some of these factors potentially include, the rate of discharge from the canals when they are open, the amount of rainfall, tidal fluctuations, hurricanes, and droughts etc. However, to the best of FPL's knowledge, within the site region there are no documented dissolution features in the available scientific literature at this time to support dissolution from surface water discharge from the canals at the coastal discharge points.

Regional Studies: "Sub-Sea Springs": Submarine Groundwater Discharge (SGD)

Submarine groundwater discharge (SGD) is the exchange of groundwater between land and sea and is comprised of terrestrial water mixed with seawater that has infiltrated coastal aquifers. SGD is defined as the "phenomenon that forces groundwater to flow from beneath the seafloor into the overlying ocean regardless of its composition-whether fresh, recirculated seawater, or a combination of both" (Reich et al., 2009 and Moore, 2010).

Two possible modes of SGD include shoreline flow (the subterranean estuary), and deep pore water upwelling (DPU), both of which are discussed below.

- Shoreline Flow SGD

  Shoreline flow to the sea occurs when fresh groundwater flows through an aquifer that is driven by an inland hydraulic head. As the shoreline flow nears the sea, it encounters the saltwater that has infiltrated from the ocean. The density of freshwater is lower than saltwater and therefore it tends to flow above the saltwater. The freshwater flowing toward the sea encounters an irregular interface where mixing of the fluids is driven by diffusion and dispersion enhanced by ocean forces (i.e., tidal pumping, waves setup, storms, buoyancy and thermal gradients). This freshwater/saltwater circulation pattern and mixing is similar to surface estuaries, leading to the term subterranean estuaries. Tidal forces operating in a mixed medium may enhance dispersion along the freshwater/saltwater interface and the permeability and preferential flow paths may be changed by chemical reactions within the aquifer. Precipitation of solids can restrict or block some paths, while dissolution will enlarge existing paths or open new ones (Moore, 2010).

  Two possible examples of shoreline flow SGD are the freshwater springs along Biscayne Bay and the karst on the Yucatan Peninsula of Mexico. Freshwater springs along Biscayne Bay existed prior to the lowering of surface water and groundwater levels in southeastern Florida. However, while many shoreline springs still exist in the bay, salinity levels of 8 to 31 g/L indicate that the water quality is outside the range for drinking water, and discharge rates from these springs is low (Cunningham and Florea, 2009). In the Yucatan Peninsula, Mexico, flank margin caves form along the margin of the discharging freshwater lens as a result of freshwater/saltwater mixing. The mixing of fresh and salt water, even if both are saturated with respect to $CaCO_3$, results in a mixture that is undersaturated with respect to $CaCO_3$. This is because freshwater discharges are high on the Yucatan carbonate platform, as it is fed by allogenic recharge from the North American continent. In the Bahamas, caves form partly due to the mixing of fresh and salt water and partly due to the presence of organics in the water, which allows oxidation to produce $CO_2$ that drives carbonate dissolution. This carbonate dissolution results in anoxic conditions in the mixing zone of the freshwater lens and complex oxidation/reduction reactions involving sulfur produce acids that lead to further dissolution (FSAR 2.5.1 Reference 263).

- Deep Pore Water Upwelling (DPU)

  Deep pore water upwelling (DPU) takes place beyond the shoreline on the continental shelf through advection of water through deeper permeable shelf sediments and rocks driven by buoyancy and pressure gradients. An example of DPU is offshore submarine springs. In this case, the flow may be driven by an inland hydraulic head through highly permeable formations or by the large-scale cyclic movement of water due to thermal gradients. Two examples of submarine springs are Crescent Beach Spring and Red Snapper Sink (Moore, 2010). Crescent Beach Spring is located about 4 kilometers (2.5 miles) east of Crescent Beach, Florida and is considered a first-order magnitude spring with a flow rate of >40 $m^3/s$. It is located at a depth of 18 meters (59 feet) in the Atlantic Ocean and erosion of confining strata to a depth of 38 meters (125 feet) at the mouth of the vent has enabled direct hydrologic communication of groundwater with coastal bottom waters (Moore, 2010). The Red Snapper Sink is located about 42 kilometers (26 miles) off Crescent Beach and is incised about 127 meters (417 feet) into the continental shelf at a water depth of 28 meters (99 feet). Divers investigating the site observed that seawater was flowing into small caves at the base of the hole, indicating possible recharge and that the water in the bottom of the hole was similar in salinity and sulfate content to ambient seawater. According to Moore (2010), Red Snapper Sink was similar to Crescent Beach Spring before the piezometric head was lowered along the coast and preservation of the feature suggests that a spring was active at this site in the recent past.

Another example of DPU, are the blue holes of the Bahamas. The blue holes, which reach depths exceeding 100 meters (328 feet), are entrances to underwater caves along offshore fracture systems in the Bahamas. Investigations into groundwater-seawater circulation in some of the holes offshore of Andros Island indicate a brackish mixture within the caves that readily dissolves aragonite but not the calcite, producing secondary porosity. The depletion of calcium in the saline groundwater indicates precipitation of calcite cement. Bacterial processes possibly due to SGD also play a significant role in driving carbonate dissolution in the Bahamas (Moore, 2010 and Smart et al., 1988).

Local Studies: "Water-Filled Passages"

As described in FSAR Section 2.5.1.2.4 two preferential secondary porosity flow zones, an upper and a lower zone are identified within the Biscayne Aquifer beneath the site. The upper secondary porosity flow zone is located approximately at the boundary between the Miami and Key Largo Limestones from approximately -25 to -35 feet NAVD 88 and is considered to represent a laterally continuous relatively thin layer of secondary porosity consisting of touching-vugs. The lower zone is located within the Fort Thompson Formation from approximately -65 to -75 feet and is not considered to be a laterally persistent layer but rather isolated pockets of moldic porosity within the layer. The two zones of secondary porosity were identified at the site following review of the Units 6 & 7 subsurface investigation data (FSAR 2.5.1 Reference 708) and supplemental data (Dames and Moore 1971 and 1975; HDR, 2009).

The potential origin of the touching-vug porosity within the upper zone of secondary porosity is solution enlargement and original reef structure. Recent studies by Cunningham et al. (FSAR 2.5.1 References 404 and 723) suggest vuggy porosity is common within the Biscayne Aquifer (Miami and Key Largo limestones and Fort Thompson Formation) and that typical solution features associated with the touching-vug porosity include solution-enlarged fossil molds up to pebble size, molds of burrows or roots, irregular vugs surrounding casts of burrows or roots, and bedding plane vugs. The potential origin of the lower zone of secondary porosity is moldic porosity or separate-vug porosity (Lucia, 1995) resulting from dissolution of in-situ bivalve shells.

Whether these two preferential secondary porosity flow zones can be classified as "water-filled passages" is unclear as the definition of a "water-filled passage" is ambiguous. Also unclear is the lateral extent of these zones as evidence derived from the subsurface investigation data beyond the Units 6 & 7 site area are not definitive.

Sea Level Changes and Migration of Freshwater/Saltwater Carbonate Dissolution

When sea level rises (for example, glacial retreat), increases in ocean hydrostatic head results in the saltwater interface migrating inland especially if the water table is held constant. Conversely, as sea level retreats or during periods of high freshwater head (for example, glacial advance) the decrease in ocean hydrostatic head causes the saltwater interface to migrate seaward. In the zone of diffusion between the freshwater and saltwater interface the diluted saltwater flows seaward. When the freshwater head is low, the freshwater and saltwater contact in the lower part of the aquifer moves inland while diluted saltwater in the zone of diffusion continues its seaward flow (Wait and Callahan, 1965).

A small level of sea level rise will have little to no impact to the freshwater/saltwater zone migration with respect to the site because the site is already in the freshwater/saltwater interface.

This response is PLANT SPECIFIC.

**References:**

Cunningham, K., and Florea, L.J., "The Biscayne Aquifer of Southeastern Florida" Caves and Karst of the USA. In Arthur N. Palmer (editor). Huntsville: National Speleological Society, pp.196-199, 2009.

Dames & Moore, *Geohydrologic Conditions Related to the Construction of Cooling Ponds, Florida Power & Light Company, Steam Generating Station, Turkey Point, Florida for Brown & Root, Inc.,* pp. 101, July 23, 1971.

Dames & Moore, *Floridan Aquifer Water Supply Investigation, Turkey Point Area, Dade County Florida,* 1975.

Evans, R.L., and Lizarralde, D., Geophysical evidence for karst formation associated with offshore groundwater transport: An example from North Carolina, Geochemistry Geophysics Geosystems, American Geophysical Union, v. 4, no. 8, pp. 1-9, 2003.

HDR Engineering, Inc., Florida Power and Light Company: Turkey Point Exploratory Drilling and Aquifer Performance Test Program, pp. 351, August 19, 2009.

Godfrey, M.C. (with contribution by Theodore Catton), *River of Interests: Water Management in South Florida and the Everglades, 1948–2000*, U.S. Army Corps of Engineers, June 2006.

Land, L.A., and Paull, C.K., Submarine karst belt rimming the continental slope in the Straits of Florida, Geo-Marine Letters, v. 20, pp. 123-132, 2000.

Langevin, C. D., Simulation of Submarine Ground Water Discharge to a Marine Estuary: Biscayne Bay, Florida, Ground Water, v. 41, no. 6., pp. 758-771, 2003.

Langevin, C.D., Simulation of Ground-Water Discharge to Biscayne Bay, Southeastern Florida, Water-Resources Investigations Report 00-4251, U.S. Geological Survey, 2001.

Lucia, F. J., Rock-Fabric / Petrophysical classification of Carbonate Pore Space for Reservoir Characterization. AAPG bulletin, v.79, no. 9, pp. 1275-1300, September 1995.

Moore, W. S., The Effect of Submarine Groundwater Discharge on the Ocean, Annual Review of Marine Science, v. 2, pp. 59-88, 2010.

Reich, C.D., Swarzenski, P.W., Greenwood, J.W., and Wiese, D.S., Investigation of coastal hydrogeology utilizing geophysical and geochemical tools along the Broward County coast, Florida: U.S. Geological Survey Open-File Report 2008-1364, p. 21, plus apps. A-C., 2009.

Smart, P.L., Dawans, J.M., and Whitaker, F., Carbonate dissolution in a modern mixing zone, Nature, v. 335, pp. 811-813, 1988.

U.S. Geological Survey, *Manual Water-level Measurements in the Homestead, FL Area, as of March 2009, Groundwater conditions in Southern Florida.* Available at http://www.sflorida.er.usgs.gov/edl_data/text/hstd_gov.html, accessed May 22, 2009.

Wait, R.L., and Callahan, J.T., Relations of Fresh and Salty Ground Water along the Southeastern U.S. Atlantic Coast, National Ground Water Association, v. 3, issue 4, pp. 3-17, 1965.

**ASSOCIATED COLA REVISIONS:**

None

**ASSOCIATED ENCLOSURES:**

None

**NRC RAI Letter No. PTN-RAI-LTR-041**

**SRP Section: 02.05.01 - Basic Geologic and Seismic Information**

QUESTIONS from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

**NRC RAI Number: 02.05.01-3 (eRAI 6024)**

FSAR 2.5.1.1.3.4 discusses the "Quaternary Tectonic History" of the TPNPP region. However, additional, detailed, information is needed to evaluate the Quaternary tectonic history of the site region.

In order for the staff to determine if the information presented in the FSAR represents an up-to-date and accurate characterization of the Quaternary tectonic history of the site region and in support of 10 CFR 100.23 please address the following:

a) Identify and locate features of Quaternary, tectonic deformation in the site region (such as Walkers Cay fault, Santaren Anticline, Straits of Florida normal faults).

b) Summarize all Quaternary tectonic features in the site region, and update Figure 2.5.1-202 to depict all Quaternary active tectonic features in the entire site region.

c) Please revise the text to eliminate the duplicate paragraphs in this section.

**FPL RESPONSE:**

a) Identify and Locate features of Quaternary, tectonic deformation

The features listed in the RAI (the Walkers Cay fault, Santaren Anticline and Straits of Florida normal faults) are not considered to be Quaternary tectonic deformation structures (tectonically active after ~2.5 Ma). They are all considered primarily Tertiary tectonic features, as discussed in FSAR Subsection 2.5.1.1.1.3.2.

A summary of the Walkers Cay fault is provided in FSAR Subsection 2.5.1.1.1.3.2.2. While one seismic section depicts a splay of the Walkers Cay fault extending to the seafloor (Figure 2.5.1-277), most interpretations indicate that the structure has minimal offset on strata younger than Miocene in age (FSAR Figures 2.5.1-275, and -276). A more detailed discussion of the age of faulting is also provided in RAI Response 02.05.01-14.

The Santaren Anticline is also discussed in FSAR Subsection 2.5.1.1.1.3.2.2. This fold initiated in the Late Cretaceous, reached a maximum expression in the early Cenozoic (before 20 Ma), and experienced differential compaction in the late Cenozoic (FSAR 2.5.1 Reference 501). Detailed stratigraphic analysis has indicated that after 20 Ma, the fold uplift rate is negligible (0.03 mm/yr) and that most strata younger than 15 Ma maintain constant bed thickness over the fold crest (FSAR 2.5.1 Reference 479). One Quaternary bed does thin slightly across the top of the structure (Bed M3 in FSAR Figure 2.5.1-278, FSAR 2.5.1 Reference 479), but the uncertainty in this analysis does not permit the assessment of Quaternary age to this variation in stratigraphy. The possibility that this minor stratigraphic variation in the Quaternary section is nontectonic further prevents consideration of this feature as representing Quaternary tectonic deformation. A more detailed discussion of this is provided in RAI Response 02.05.01-15.

The Straits of Florida normal faults are discussed in FSAR Subsection 2.5.1.1.1.3.2.2. These Eocene faults accommodated thickening and deformation in the foreland of the collision of the Greater Antilles arc with the southern boundary of the North American plate. Available interpretations of seismic data indicate that these structures were active in the Eocene and that Miocene and younger strata show no deformation or southward-thickening characteristic of this tectonic event (FSAR 2.5.1 References 221 and 482). These structures and other geomorphic features of the Straits of Florida are discussed further in the Response to RAI 02.05.01-16

b) Summarize all Quaternary tectonic features in the site region and update Figure 2.5.1-202

Potential zones of Quaternary tectonic deformation within the site region may be located on Cuba. Several faults designated as 'active' by Cotilla-Rodriquez et al. (2007) (FSAR 2.5.1 Reference 494) have portions located within the site region, including the Cochinos, Habana-Cienfuegos, Hicacos, and Las Villas structures (FSAR Table 2.5.1-204). However, this 'active' designation does not meet the definition of a capable tectonic source set forth in RG 1.208. Published geologic evidence regarding timing of latest movement on these and other structures associated with Cuba, such as the Pinar and Nortecubana faults, is lacking, and age assessment is highly uncertain. However, these structures are discussed within FSAR Subsection 2.5.1.1.1.3.2.4.

Figure 2.5.1-202 depicts the tectonic elements of the Northern Caribbean-North American plate boundary. The Walkers Cay fault, Santaren Anticline, and Straits of Florida normal faults are not a part of this active plate boundary system and thus will not be added to FSAR Figure 2.5.1-202. However, these Tertiary tectonic features are all depicted on FSAR Figure 2.5.1-229, Regional Tectonic Features.

c) Revise text to eliminate duplicate paragraphs

The last three paragraphs of FSAR Subsection 2.5.1.1.3.4 includes duplicate information. These paragraphs will be eliminated. The mark-up of the revised subsection is shown below.

This response is PLANT SPECIFIC.

**References:**

None

**ASSOCIATED COLA REVISIONS:**

The following paragraph will be inserted after the third paragraph of Subsection 2.5.1.1.3.3. Tertiary Tectonic History, immediately preceding the section "Opening of the Cayman Spreading Center and Trough" in a future revision of the FSAR:

**Within the site region, the effects of the collision of the Greater Antilles arc with the Bahama Platform led to the development of faulting in northern Cuba and in the Straits of Florida during Eocene time. The Walkers Cay fault and Santaren Anticline were also active at this time, though deformation continued into the Miocene on these structures.**

The following sentence will be added to the end of the second paragraph of FSAR Subsection 2.5.1.1.3.4 and the last three paragraphs of FSAR Subsection 2.5.1.1.3.4 will be deleted in a future revision of the FSAR:

Present day tectonic features of the northern Caribbean region are shown in (Figure 2.5.1-202). The Nortecubana fault system, sometimes interpreted as a suture between the northwestern Caribbean Plate and the North America Plate, is more aptly described as the fold-and-thrust belt from the collision. The collision-and-suture process proceeded from northwest to southeast, beginning at 60 Ma and ending at 40 Ma. **The portions of Cuba within the site region are far (>300 kilometers) from the active plate boundary between the Caribbean and North American plates, and exhibit low to moderate seismicity.**

West of 71° W, the Cayman Trough separates the current Caribbean-North America Plate boundary into two subparallel, predominantly left-lateral strike-slip features, the Oriente and Septentrional faults on the north, and the Swan Islands-Walton-Duanvale-Enriquillo-Plantain Garden fault system on the south. These accommodate a relative plate motion of about 20 millimeters/year, which appears to be about equally divided between the two features (References 358, 652, and 643).

~~Within the site region, the Quaternary Period is characterized by sedimentary deposition in both marine and terrestrial environments. On the Florida Platform, the Pleistocene Anastasia formation and the Miami Limestone were deposited. The Miami Limestone grades into the Key Largo Limestone, which is a shallow shelf-margin coral reef deposit. Within the submerged areas of the Straits of Florida and the Bahama Banks, Neogene sedimentation is dominated by basinal carbonates and slope deposits of peri-platform oozes intercalcated with turbidites and often controlled by ocean current activity and sea level changes (Reference 228).~~

~~Present day tectonic features of the northern Caribbean region are shown in (Figure 2.5.1-202). The Nortecubana fault system, sometimes interpreted as a suture between the northwestern Caribbean Plate and the North America Plate, is more aptly described as the fold-and-thrust belt from the collision. The collision-and-suture process proceeded from northwest to southeast, beginning at 60 Ma and ending at 40 Ma.~~

~~West of 71° W, the Cayman Trough separates the current Caribbean-North America Plate boundary into two subparallel, predominantly left-lateral strike-slip features, the Oriente and Septentrional faults on the north, and the Swan Islands-Walton-Duanvale-Enriquillo-Plantain Garden fault system on the south. These accommodate a relative plate motion of about 20 millimeters/year, which appears to be about equally divided between the two features (References 358, 652, and 643).~~

**ASSOCIATED ENCLOSURES:**

None

**NRC RAI Letter No. PTN-RAI-LTR-041**

**SRP Section: 02.05.01 - Basic Geologic and Seismic Information**

QUESTIONS from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

**NRC RAI Number: 02.05.01-5 (eRAI 6024)**

FSAR Section 2.5.1.2.4, the "Dissolution Features" passage, states that potential hydrostatic stress mechanisms to initiate sinkhole collapse are unlikely at the site area because the water table is presently near the surface and is not expected to fall or rise greatly. The staff notes that there may be a change in hydrostatic stress during dewatering at the site during construction, thus more discussion is needed to evaluate the potential of sinkhole collapse.

In order for the staff to evaluate dissolution potential, and in support of 10 CFR 100.23, please discuss the potential for initiation of sinkhole collapse during site construction or during a potential rise in sea-level during the planned lifetime of Units 6 & 7.

**FPL RESPONSE:**

The potential for initiation of sinkhole collapse during site construction will be mitigated using a dewatering system that will consist of a reinforced diaphragm wall and grout plug. The deepest excavation level at the Turkey Point Units 6 & 7 site is El. –35 feet NAVD 88 (i.e., extending 35 feet below the ground water level) (FSAR Subsection 2.5.4.5.4, Revision 3).

Power block excavations are primarily open cuts, with temporary ground support provided by a reinforced concrete diaphragm wall surrounding each power block excavation area. The reinforced diaphragm walls resist lateral earth and hydrostatic pressures while providing a barrier to ground water flow. The reinforced diaphragm walls are seated at approximately El. –60 feet NAVD 88, just below the most competent portion of the Fort Thompson Formation. Tiebacks to provide resistance to the lateral earth and hydraulic pressures are installed based on the final design that includes embedment, spacing, and other details, as applicable. The completed reinforced diaphragm walls effectively impede any overturning or sliding on the lean concrete fill, provided as a sub-basemat for Category I seismic structures, confined within the walls (FSAR Subsection 2.5.4.5.4, Revision 3).

FSAR Subsection 2.5.4.6.2 (Revision 3) discusses the pumping rates that are required for dewatering each unit and describes how these rates can be reduced significantly by installing a grout plug between approximately El. -35 feet NAVD 88 and the bottom of the diaphragm wall at approximately El. -60 feet. With the grout plug installed, the seepage can be controlled during excavation using sumps and discharge pumps.

Based on the above engineering and construction concepts, FPL anticipates a limited potential for water table fluctuation due to construction dewatering. Therefore, once construction has been completed, the potential for initiation of sinkhole collapse during the planned lifetime of Turkey Point Units 6 & 7 due to a potential rise in sea level is very low to nonexistent. Because the groundwater in the Biscayne aquifer in the area of Turkey Point Units 6 & 7 contains saline to saltwater (FSAR Subsection 2.4.12.1.2.1, Revision 3), a potential rise in sea level during the life of the plant is not likely to lead to freshwater discharge at the site, and therefore it is not likely that sinkhole collapse could occur.

This response is PLANT SPECIFIC.

**References:**

None

**ASSOCIATED COLA REVISIONS:**

None

**ASSOCIATED ENCLOSURES:**

None

**NRC RAI Letter No. PTN-RAI-LTR-041**

**SRP Section: 02.05.01 - Basic Geologic and Seismic Information**

QUESTIONS from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

**NRC RAI Number: 02.05.01-7 (eRAI 6024)**

FSAR Section 2.5.1.1.1.2.1.1, "Holocene Stratigraphy of the Florida Peninsula" states that hurricanes complicate the preservation of Pleistocene and Holocene deposits on the east and west coasts of the Florida Peninsula by eroding these deposits and depositing them elsewhere. In order for the staff to evaluate the Holocene geologic record at the site and in support of 10 CFR 100.23 please address the following:

a) Within the context of the Holocene sedimentary record at the site discuss the nature and extent of paleostorm deposits.

b) Provide a discussion that compares and contrasts deposits of Hurricane Andrew or other historical hurricanes, and any paleostorm deposits preserved in the Holocene stratigraphy, with potential tsunami deposits at the site.

c) Provide a figure or a map that illustrates these deposits.

**FPL RESPONSE:**

a) The Holocene section at the Units 6 & 7 site is classified as wetland soils belonging to the saprist (muck) group. Saprist soils are generally defined as those in which two-thirds or more of the material is decomposed, and less than one-third of plant fibers are identifiable (FSAR 2.5.1 Reference 276). Eighty-eight (88) borings were drilled and sampled (standard penetration test (SPT) samples in soil, continuous coring in rock) as part of the Units 6 & 7 subsurface investigation. The description of the Holocene section (i.e. muck) in the soil borings across the Turkey Point Units 6 & 7 site (FSAR 2.5.1 Reference 708), describes the thickness, color, hardness, and the presence of organic, silt, roots, and shell fragment contents (Table 1). The muck soils were sampled at the site every 2.5 feet using the SPT geotechnical sampling method. The muck soils are classified under the Unified Soil Classification System (USCS) in accordance with ASTM D2488-06 instead of the Troels-Smith sediment classification system. Modifiers such as trace, few, little, some and mostly were used to provide an estimate of the percentage of gravel, sand and fines (silt or clay size particles) or other materials such as organics (muck) or shells (Table 2). In general, the thickness of the muck ranges from 0 feet to 12.2 feet (0.2 to -8.2 feet Elevation NAVD 88). Muck is ubiquitous across the site and appears to be thicker in the areas of the surficial dissolution features, which act as sediment traps. Color ranges from black to light gray, dark grayish brown to light brownish gray and dark olive brown to light olive brown. Mottled coloration is also noted in the muck. The consistency of the muck is very soft-to-soft. Fibrous internal structure occurs within organic soils in eight of the site borings: B-614, B-625, B-626, B-702, B-715, B-725, B-727, and B-729. The organic content of the muck was estimated to vary from some to mostly (Tables 1 and 2, FSAR 2.5.1 Reference 708).

Although the muck description in FSAR Subsection 2.5.1.1.1.2.1.1 includes silt, only one sample from boring B-601 (DH) contains "mostly silt." Trace to some sand is noted in three borings: B-617, B-623, and B-723. Neither the sand nor the silt can be correlated across the site as continuous stratigraphic units. However, fine-grained calcareous material appears to overlie the muck in six borings: B-736, B-738, B-802, B-810, B-812, and B-813. Laboratory tests indicate that this marl-like material is a fat clay to sandy fat clay (rather than a silt as described in the field) that is light/dark gray to light/dark grayish brown, very soft, moist to wet, with some fine grained sand and strong hydrochloric acid reaction (Table 1 and FSAR 2.5.1 Reference 708). This type of marl forms when the ground surface is flooded for several months each year in the summer followed by a number of dry months during the winter (hydroperiod). During the hydroperiod, the microalgae (periphyton) grow on the water surface. The precipitation of the microalgae from the calcium bicarbonate saturated water creates marl (Li, 2001).

The conclusion that there are no tsunami deposits at the site is based on the interpretation of the soil boring log data (FSAR 2.5.1 Reference 708). The marl and muck are interpreted to have formed in an anaerobic tidal environment as indicated by the color (i.e. mottled and wide range of gray to brown coloration), softness, and wetness descriptions (Table 1). The presence of shells and roots is indicative of a calm low energy environment of deposition with little to no wave action enabling plants and organisms to have time to be productive. Lastly, the presence of silt in only one of the 88 borings and sand in nine of the 88 borings drilled at the Units 6 & 7 site is not conclusive evidence of either a paleostorm or a tsunami deposit at the site.

In conclusion, the Holocene muck, as described on the Units 6 & 7 boring logs, contains no sedimentary or sedimentological indicators of either paleostorm or paleostunami deposits (FSAR 2.5.1 Reference 708). The geotechnical boring logs for the Turkey Point Units 6 & 7 site indicate that geologic conditions are uniform (FSAR Figures 2.5.1-231 and 2.5.1-232) and show no evidence of interruption by a tsunami-like event. The site exploration data do not indicate the presence of erosional channels that are filled with poorly sorted, angular, or subangular siliciclastics containing exotic fragments or coral rubble that might have been deposited by paleotsunamis or topographically high areas with potential paleotsunami overwash deposits (FSAR Figure 2.5.1-348).

**Table 1. Descriptions of Muck at the Turkey Point Units 6 & 7 Site**

| Boring ID | GS Elevation (ft) | Muck top | | Muck bottom | | Muck Description | Internal Structure (when described in the log) | Modifiers on Silt and Sand (when described in the log) |
|---|---|---|---|---|---|---|---|---|
| | | Elevation (ft) | Depth (ft) | Elevation (ft) | Depth (ft) | | | |
| B-601 (DH) | -1.4 | -1.4 | 0 | -3.9 | 2.5 | MUCK, very dark gray, very soft, wet, **mostly silt**, some organics, trace shells, weak HCL Rx | - | 50 to 100% silt |
| B-602 | -1.4 | -1.4 | 0 | -4.5 | 3.1 | MUCK, dark gray, very soft, wet, roots, mostly organic, 2.5 ft firm | - | - |
| B-603 | -1.4 | -1.4 | 0 | -4.7 | 3.3 | MUCK, light gray, to black, very soft, wet, mostly organics, trace roots, trace shell fragments | - | - |
| B-604 (DH) | -1.5 | -1.5 | 0 | -4.5 | 3 | MUCK, dark grayish brown, very soft, moist, organics | - | - |
| B-605 | -1.7 | -1.7 | 0 | -4.2 | 2.5 | MUCK, very dark gray, very soft, moist, mostly organics | - | - |
| B-606 | -1.4 | -1.4 | 0 | -4.4 | 3 | MUCK, light brownish gray, very soft, wet, organic, trace shell fragments, 2.5 ft-black, soft | - | - |
| B-607 | -1.5 | -1.5 | 0 | -4 | 2.5 | MUCK, light brownish gray to dark olive brown to black, very soft, wet, organic, trace roots and shell fragments, no HCL Rx | - | - |
| B-608 (DH) | -1.5 | -1.5 | 0 | -6 | 4.5 | MUCK: no recovery, 3.5 ft-very dark brown, very soft, wet, organics | - | - |
| B-609 | -1.5 | -1.5 | 0 | -3.5 | 2 | MUCK, very pale brown to very dark gray, very soft, wet, mostly organic, strong HCL Rx | - | - |
| B-610 (DH) | -1.4 | -1.4 | 0 | -4.2 | 2.8 | MUCK, pinkish gray to black, very soft, wet, mostly organic, strong HCL Rx | - | - |
| B-611 | -1.5 | -1.5 | 0 | -3.5 | 2 | MUCK, very pale brown, mottled, dark gray, very soft, moist, weak HCL Rx | - | - |
| B-612 | -1.5 | -1.5 | 0 | -4.5 | 3 | MUCK, grayish brown, very soft, wet, no HCL Rx | - | - |

**Table 1. Descriptions of Muck at the Turkey Point Units 6 & 7 Site**

| Boring ID | GS Elevation (ft) | Muck top | | Muck bottom | | Muck Description | Internal Structure (when described in the log) | Modifiers on Silt and Sand (when described in the log) |
|---|---|---|---|---|---|---|---|---|
| | | Elevation (ft) | Depth (ft) | Elevation (ft) | Depth (ft) | | | |
| B-613 | -1.4 | -1.4 | 0 | -4.8 | 3.4 | MUCK, black, very soft, wet, strong, HCL Rx, mostly organics | - | - |
| B-614 | -1.5 | -1.5 | 0 | -5.3 | 3.8 | MUCK, black, very soft, wet, **fibrous**, strong HCL Rx, 2.8 ft-soft | fibrous | - |
| B-615 | -1.5 | -1.5 | 0 | -6 | 4.5 | MUCK, dark brown, very soft, wet, strong HCL Rx | - | - |
| B-616 | -1.2 | -1.2 | 0 | -8.2 | 7 | MUCK, very dark gray, very soft, wet, mostly organics, weak HCL Rx, 2.5 ft-trace shell fragments, weak HCL Rx | - | - |
| B-616 | -1.2 | -10.7 | 9.5 | -12.2 | 11.0 | MUCK, brown, firm, wet, with limestone fragments, mostly organics | - | - |
| B-617 | -1.4 | -1.4 | 0 | -3.4 | 2 | MUCK, pale brown, very soft, wet, **few fine grained sand**, mostly organic, strong HCL Rx | - | 5 to 10% fine grained sand |
| B-618 | -1.4 | -1.4 | 0 | -4.4 | 3 | MUCK, very dark grayish brown, very soft, wet, trace peat | - | - |
| B-619 | -1.7 | -1.7 | 0 | -5.2 | 3.5 | MUCK, very dark grayish brown, very soft, wet, mostly organic | - | - |
| B-620 (DH) | -1.5 | -1.5 | 0 | -4.5 | 3 | MUCK, light gray, to grayish brown, very soft, wet, strong, HCL Rx, mostly organics | - | - |
| B-621 | 0.2 | 0.2 | 0 | -5.9 | 6.1 | MUCK, very dark gray, very soft, dry, mostly organic, strong HCL Rx | - | - |
| B-622 | 0.2 | 0.2 | 0 | -5.4 | 5.6 | MUCK, light brownish gray, to very dark gray, very soft, moist, mostly organic, strong HCL Rx | - | - |
| B-623 | -1.3 | -1.3 | 0 | -5 | 3.7 | MUCK, light brownish gray to very dark gray, wet, mostly organic, strong HCL Rx | - | - |

**Table 1. Descriptions of Muck at the Turkey Point Units 6 & 7 Site**

| Boring ID | GS Elevation (ft) | Muck top | | Muck bottom | | Muck Description | Internal Structure (when described in the log) | Modifiers on Silt and Sand (when described in the log) |
|---|---|---|---|---|---|---|---|---|
| | | Elevation (ft) | Depth (ft) | Elevation (ft) | Depth (ft) | | | |
| B-624 | -1.4 | -1.4 | 0 | -4.4 | 3 | MUCK, light olive brown to very dark grayish brown, very soft, wet, organic, strong HCL Rx | - | - |
| B-625 | -1.4 | -1.4 | 0 | -4.2 | 2.8 | MUCK, black, very soft, wet, strong HCL Rx, mostly organic, **fibrous** | fibrous | - |
| B-626 | -1.6 | -1.6 | 0 | -5.1 | 3.5 | MUCK, black, very soft, wet, no HCL Rx, **fibrous** | fibrous | - |
| B-627 | -1.3 | -1.3 | 0 | -4.2 | 2.9 | MUCK, light brownish gray to very dark brown, very soft, wet, organic, trace shell fragments | - | - |
| B-628 | -1.5 | -1.5 | 0 | -5.3 | 3.8 | MUCK, light brownish gray, very soft to soft, wet, strong HCL Rx, mostly organic, shell fragments | - | - |
| B-629 | -1.1 | -1.1 | 0 | -4.6 | 3.5 | MUCK, brown, very soft, wet, organics, trace shell fragments, strong HCL reaction, 2.5 ft-black | - | - |
| B-630 | -1.5 | -1.5 | 0 | -4.5 | 3 | MUCK; no recovery | - | - |
| B-631 | -1.2 | -1.2 | 0 | -4.8 | 3.6 | MUCK, very dark gray, wet, very soft, mostly organic, strong HCL Rx | - | - |
| B-632 | -1.6 | -1.6 | 0 | -5.1 | 3.5 | MUCK, very dark grayish brown, very soft, wet, strong HCL Rx | - | - |
| B-633 | -1.5 | -1.5 | 0 | -4.5 | 3 | MUCK, very dark grayish brown, very soft, wet, strong HCL Rx, organics, trace shell fragments | - | - |
| B-634 | -0.7 | -0.7 | 0 | -5.2 | 4.5 | MUCK, very dark gray, very soft, wet, **trace fine grained sand**, trace shell fragments, strong HCL Rx, 2.5 ft-soft, weak HCL Rx | - | <5% fine grained sand |

**Table 1. Descriptions of Muck at the Turkey Point Units 6 & 7 Site**

| Boring ID | GS Elevation (ft) | Muck top | | Muck bottom | | Muck Description | Internal Structure (when described in the log) | Modifiers on Silt and Sand (when described in the log) |
|---|---|---|---|---|---|---|---|---|
| | | Elevation (ft) | Depth (ft) | Elevation (ft) | Depth (ft) | | | |
| B-635 | -0.9 | -0.9 | 0 | -2.9 | 2 | Sandy FAT CLAY, very dark gray to very pale brown, very soft, wet, some fine grained sand, trace organics, strong HCL Rx | - | - |
| B-635 | -0.9 | -2.9 | 2 | -4.1 | 3.2 | MUCK, very dark gray, very soft, wet, trace shell fragments, mostly organic, weak HCL Rx | - | - |
| B-636 | -1.1 | -1.1 | 0 | -4.8 | 3.7 | MUCK, black to gray, very soft, moist, mostly organic, strong HCL Rx | - | - |
| B-637 | -0.2 | -0.2 | 0 | -4.2 | 4 | MUCK, very dark grayish brown, very soft, moist, strong HCL Rx | - | - |
| B-639 | -1.4 | -1.4 | 0 | -4.4 | 3 | MUCK, black, very soft, wet, organic, trace shells | - | - |
| B-701 (DH) | -1.1 | -1.1 | 0 | -4 | 2.9 | MUCK, olive gray to black, very soft, wet, mostly organic, strong HCL Rx | - | - |
| B-702 | -1.2 | -1.2 | 0 | -4.6 | 3.4 | MUCK, very dark grayish brown, very soft, wet, strong HCL Rx, **fibrous** | fibrous | - |
| B-703 | -1.3 | -1.3 | 0 | -4.6 | 3.3 | MUCK, very dark grayish brown, very soft, wet, organics, strong HCL Rx, 2.5 ft-soft | - | - |
| B-704 (DH) | -1.4 | -1.4 | 0 | -4.5 | 3.1 | MUCK, greenish brown, very soft, wet, strong HCL reaction, mostly organics, 2.4 ft-grayish brown to dark grayish brown, soft | - | - |
| B-705 | -1.3 | -1.3 | 0 | -4.2 | 2.9 | MUCK, very dark brown, very soft, wet | - | - |
| B-706 | -1.2 | -1.2 | 0 | -4.4 | 3.2 | MUCK, brown to very pale brown, very soft, moist, organics, strong HCL Rx | - | - |
| B-707 | -1.8 | -1.8 | 0 | -3.8 | 2 | MUCK, light brownish gray to very dark gray, very soft, mostly organic, strong HCL Rx | - | - |

**Table 1. Descriptions of Muck at the Turkey Point Units 6 & 7 Site**

| Boring ID | GS Elevation (ft) | Muck top | | Muck bottom | | Muck Description | Internal Structure (when described in the log) | Modifiers on Silt and Sand (when described in the log) |
|---|---|---|---|---|---|---|---|---|
| | | Elevation (ft) | Depth (ft) | Elevation (ft) | Depth (ft) | | | |
| B-708 (DH) | -1.4 | -1.4 | 0 | -3.9 | 2.5 | MUCK, dark gray brown to black, moist, mostly organic, strong HCL Rx | - | - |
| B-709 | -1.3 | -1.3 | 0 | -4.6 | 3.3 | MUCK, very dark brown, very soft, moist, organic | - | - |
| B-710 (DH) R | -1.3 | -1.3 | 0 | -3.8 | 2.5 | MUCK, dark grayish brown, to black, very soft, wet, organics, strong HCL Rx | - | - |
| B-711 | -1.1 | -1.1 | 0 | -4.1 | 3 | MUCK, grayish brown to light gray, very soft, wet, strong, HCL Rx, mostly organic, 2.5 ft-dark grayish brown | - | - |
| B-712 | -1.1 | -1.1 | 0 | -4.2 | 3.1 | MUCK, very dark grayish brown, very soft, moist, mostly organic, strong HCL Rx | - | - |
| B-713 | -1.1 | -1.1 | 0 | -3.6 | 2.5 | MUCK, dark grayish brown to pale brown, very soft, wet, mostly organic | - | - |
| B-714 | -1 | -1 | 0 | -4.4 | 3.4 | MUCK, olive brown, very soft, wet, strong HCL Rx, mostly organic | - | - |
| B-715 | -0.9 | -0.9 | 0 | -4.4 | 3.5 | MUCK, black, very soft, wet, strong HCL Rx, **fibrous** | fibrous | - |
| B-716 | -1.1 | -1.1 | 0 | -4.1 | 3 | MUCK, light brownish gray, very soft, wet, mostly organic, trace shell fragments, strong HCL Rx | - | - |
| B-717 | -1.1 | -1.1 | 0 | -4.7 | 3.6 | MUCK, dark grayish brown, very soft, wet, mostly organic | - | - |
| B-718 | -1.2 | -1.2 | 0 | -4.3 | 3.1 | MUCK, brown to very dark grayish brown, very soft, wet, organic, strong HCL Rx, trace shells, 2.5 ft-very dark gray to black | - | - |

**Table 1. Descriptions of Muck at the Turkey Point Units 6 & 7 Site**

| Boring ID | GS Elevation (ft) | Muck top | | Muck bottom | | Muck Description | Internal Structure (when described in the log) | Modifiers on Silt and Sand (when described in the log) |
|---|---|---|---|---|---|---|---|---|
| | | Elevation (ft) | Depth (ft) | Elevation (ft) | Depth (ft) | | | |
| B-719 | -1.1 | -1.1 | 0 | -4.1 | 3 | MUCK, light brownish gray to very dark gray, very soft, wet, mostly organic, strong HCL Rx | - | - |
| B-720 (DH) | -0.9 | -0.9 | 0 | -3.9 | 3 | MUCK, gray, very soft, moist organics, trace roots, strong HCL Rx | - | - |
| B-721 | -1.5 | -1.5 | 0 | -5 | 3.5 | MUCK, very dense, gray, very soft, wet, mostly organic, strong HCL Rx, 2.5 ft- very dark brown to dark yellowish brown | - | - |
| B-722 | -1 | -1 | 0 | -3.5 | 2.5 | MUCK, light brownish gray to very dark gray, very soft, dry to wet, mostly organic, strong HCL Rx | - | - |
| B-723 | -1 | -1 | 0 | -5 | 4 | MUCK, very dark grayish brown, very soft to soft, wet, **trace fine grained sand**, strong HCL Rx | - | <5% fine grained sand |
| B-724 | -0.7 | -0.7 | 0 | -5.3 | 4.6 | MUCK, very dark grayish brown, very soft, wet, strong HCL Rx, mostly organic | - | - |
| B-725 | -1 | -1 | 0 | -4.5 | 3.5 | MUCK, dark grayish brown, very soft, wet, strong HCL Rx, mostly organic, **fibrous** | fibrous | - |
| B-726 | -1.4 | -1.4 | 0 | -4.7 | 3.3 | MUCK, dark olive brown, very soft, wet, strong HCL Rx | - | - |
| B-727 | -1.3 | -1.3 | 0 | -5.3 | 4 | MUCK, black, very soft, wet, strong HCL Rx, **fibrous** | fibrous | - |
| B-728 | -1.4 | -1.4 | 0 | -4.5 | 3.1 | MUCK, black, very soft, wet, strong HCL Rx | - | - |
| B-729 | -1.2 | -1.2 | 0 | -4.5 | 3.3 | MUCK, very dark gray, very soft, wet, organics, strong HCL Rx, **fibrous**, 2.5 ft-soft | fibrous | - |

| Table 1. Descriptions of Muck at the Turkey Point Units 6 & 7 Site | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Boring ID | GS Elevation (ft) | Muck top | | Muck bottom | | Muck Description | Internal Structure (when described in the log) | Modifiers on Silt and Sand (when described in the log) |
| | | Elevation (ft) | Depth (ft) | Elevation (ft) | Depth (ft) | | | |
| B-730 | -1 | -1 | 0 | -5 | 4 | MUCK, light brownish gray to black, very soft, wet, strong HCL Rx, trace shell fragments, mostly organic | - | - |
| B-731 | -1.5 | -1.5 | 0 | -4 | 2.5 | MUCK, light gray to very dark gray, very soft, wet, mostly organic, strong HCL Rx | - | - |
| B-732 | -1 | -1 | 0 | -4.5 | 3.5 | MUCK, light gray to light brownish gray, very soft, moist to wet, strong HCL Rx, some organics, 2.5 ft-very dark grayish brown | - | - |
| B-733 | -1 | -1 | 0 | -3.5 | 2.5 | MUCK, no recovery | - | - |
| B-734 | -0.6 | -0.6 | 0 | -2.6 | 2 | Sandy LEAN CLAY, very dark grayish brown, very soft, moist, strong HCL Rx | - | - |
| B-734 | -0.6 | -2.6 | 2 | -4.6 | 4 | MUCK, black to grayish brown, very soft, wet, no to strong HCL Rx | - | - |
| B-735 | -0.8 | -0.8 | 0 | -4.5 | 3.7 | at 0 ft MUCK, no recovery, 2.4 ft-MUCK black, very soft, wet, organics | - | - |
| B-736 | -0.5 | -0.5 | 0 | -2.5 | 2 | FAT CLAY with sand, dark grayish brown, very soft, moist, fine grained sand, strong HCL Rx | - | - |
| B-736 | -0.5 | -2.5 | 2 | -4.5 | 4 | MUCK, black, very soft, wet, **few sand**, organics, weak HCL Rx | - | 5 to 10% sand |
| B-737 | -0.6 | -0.6 | 0 | -5.1 | 4.5 | MUCK, light brownish gray, mottled, very dark gray and black, very soft, wet, **little fine grained sand**, trace shell fragments, strong HCL Rx, 2.5 ft-very dark gray, weak HCL Rx | - | 15 to 25% fine grained sand |
| B-738 | 0.1 | 0.1 | 0 | -1.9 | 2 | Sandy FAT CLAY, very dark grayish brown, very soft, moist, fine sand, strong HCL Rx | - | - |

**Table 1. Descriptions of Muck at the Turkey Point Units 6 & 7 Site**

| Boring ID | GS Elevation (ft) | Muck top | | Muck bottom | | Muck Description | Internal Structure (when described in the log) | Modifiers on Silt and Sand (when described in the log) |
|---|---|---|---|---|---|---|---|---|
| | | Elevation (ft) | Depth (ft) | Elevation (ft) | Depth (ft) | | | |
| B-738 | 0.1 | -1.9 | 2 | -4.4 | 4.5 | MUCK, very dark grayish brown, soft, wet, organics, strong HCL Rx | - | - |
| B-739 | -1.6 | -1.6 | 0 | -4.6 | 3 | MUCK, light brownish gray, to dark grayish brown, very soft, wet, strong, HCL Rx, mostly organic | - | - |
| B-802 | -1.5 | -1.5 | 0 | -3.5 | 2 | Sandy FAT CLAY, light gray, very soft, wet, **some fine grained sand**, trace organics, strong HCL Rx | - | 30 to 45% fine grained sand |
| B-802 | -1.5 | -3.5 | 2 | -4.8 | 3.3 | MUCK, dark gray to light gray, very soft, moist, fine grained sand, trace shell fragments, strong HCL Rx | - | - |
| B-805 | -1.6 | -1.6 | 0 | -4.1 | 2.5 | MUCK, dark grayish brown, very soft, wet, strong HCL Rx, organics | - | - |
| B-806 | -0.4 | -0.4 | 0 | -4.9 | 4.5 | MUCK, very dark gray, very soft, wet, mostly organic, strong HCL Rx | - | - |
| B-807 | -0.7 | -0.7 | 0 | -4.2 | 3.5 | MUCK, very dark gray, very soft, wet, mostly organic, strong HCL Rx | - | - |
| B-808 | -1 | -1 | 0 | -4.4 | 3.4 | MUCK, light gray to grayish brown, very soft, moist to wet, strong HCL Rx, 2.8 ft-dark gray | - | - |
| B-809 | -1.3 | -1.3 | 0 | -4.3 | 3 | MUCK, very dark gray, very soft, moist, mostly organic, strong HCL Rx, trace shell fragments | - | - |
| B-810 | -1.2 | -1.2 | 0 | -3.2 | 2 | FAT CLAY with sand, light brownish gray, very soft, wet, **some fine grained sand**, trace organics, strong HCL Rx | - | 30 to 45% fine grained sand |
| B-810 | -1.2 | -3.2 | 2 | -4.3 | 3.1 | MUCK, dark gray, soft, moist, mostly organic, strong HCL Rx | - | - |

**Table 1. Descriptions of Muck at the Turkey Point Units 6 & 7 Site**

| Boring ID | GS Elevation (ft) | Muck top | | Muck bottom | | Muck Description | Internal Structure (when described in the log) | Modifiers on Silt and Sand (when described in the log) |
|---|---|---|---|---|---|---|---|---|
| | | Elevation (ft) | Depth (ft) | Elevation (ft) | Depth (ft) | | | |
| B-811 | -1.4 | -1.4 | 0 | -5.3 | 3.9 | MUCK, black, very soft, wet, strong, HCL Rx | - | - |
| B-812 | -1.4 | -1.4 | 0 | -2.9 | 1.5 | Sandy FAT CLAY, very pale brown, very soft, wet, **some fine grained sand,** trace organics, trace shell fragments, strong HCL Rx | - | 30 to 45% fine grained sand |
| B-812 | -1.4 | -2.9 | 1.5 | -4.1 | 2.7 | MUCK, very dark gray, soft, wet, mostly organic, trace shell fragments, strong HCL Rx | - | - |
| B-813 | -1.3 | -1.3 | 0 | -3.3 | 2 | Sandy FAT CLAY, dark gray, to gray, very soft, wet, some sand, trace shell fragments, fine grained sand, trace shells, strong HCL Rx | - | - |
| B-813 | -1.3 | -3.3 | 2 | -4.8 | 3.5 | MUCK, very dark gray, very soft, wet, trace shell fragments, mostly organic, weak HCL Rx | - | - |
| B-814 | 9 | 9 | 0 | 4.5 | 4.5 | Poorly Graded Sand with gravel (Spoil Material) | - | - |
| B-814 | 9 | 4.5 | 4.5 | -3.2 | 12.2 | Poorly Graded Gravel (Spoil Material) | - | - |
| B-814 | 9 | -3.2 | 12.2 | -6.1 | 15.1 | MUCK, black, very soft, wet, strong HCL Rx, mostly organic | - | - |

Source: FSAR 2.5.1 Reference 708
Note: Rx denotes "reaction

**Table 2. Modifiers**

| MODIFIERS | |
|---|---|
| Approximate Percentage (%) | Modifiers |
| <5% | TRACE |
| 5 to 10% | FEW |
| 15 to 25% | LITTLE |
| 30 to 45% | SOME |
| 50 to 100% | MOSTLY |

Source: FSAR 2.5.1 Reference 708

b) During the 20th Century, several powerful hurricanes (intensity greater than three on the Saffir-Simpson Scale) affected Miami-Dade Counties: Key West Hurricane (1919), The Hurricane of 1926/Fort Lauderdale and Miami Areas (1926), Palm Beach Hurricane (1928), Labor Day Hurricane (1935), Hurricane Donna (1960), Hurricane Cleo (1964), Hurricane Betsy (1965), Hurricane Andrew (1992), Hurricane Opal (1995), and Hurricane Charley (2004). Due to the resulting destruction and loss of life, Hurricane Andrew is well documented in the scientific literature. Swiadek (1997) discusses the damages from Hurricane Andrew to coastal mangroves in Southern Florida. High wind velocities and storm surges are associated with Hurricane Andrew. The high winds and storm surges caused shoreline erosion, which in turn affected the mangroves. Three factors minimized the impacts of the storm surge: 1- the keys in Biscayne National Park acted as an offshore breakwater; 2-the Bahamas Islands and carbonate shoals limited the fetch of hurricane-force winds, and, 3-the continental shelf in southeastern Florida is very narrow (Swiadek, 1997).

From late August through mid-September 1992, Swiadek (1997) evaluated sedimentary deposits due to shoreline erosion caused by Hurricane Andrew. A widespread layer of mud and muddy sand, up to 50 centimeters thick, was deposited in the subtidal banks on the west coast of Florida. A grayish mud layer 20 to 50 centimeters thick was deposited in protected off-shore depressions and interior bays on the west coast. A tan to brownish sedimentary layer, up to 50 centimeters thick, was deposited in the depressions along the western margin of Biscayne Bay on the east coast. A grayish mud layer, up to 50 centimeters thick, was deposited on the east side of Biscayne Bay (Swiadek, 1997).

According to Swiadek (1997), the waters receding from mangrove swamps on the west coast formed ebb deltas along tidal channels and on Cape Sable. On the east coast, from Soldier Key to Elliot Key, vegetation was removed; however, the limestone surface was not affected (Swiadek, 1997).

Generally, the physical attributes of sedimentary deposits that appear to favor a modern or paleostorm origin are (FSAR 2.5.1 Reference 890):

- Moderately thick (average >30 centimeters) sand bed composed of numerous subhorizontal planar lamination organized into multiple lamina sets.
- Maximum bed thickness is near the shore.
- Landward thinning of the deposit is usually abrupt.

- Abundant shell fragments organized in laminations.
- Storm deposits fill in topographic lows and the upper surface is relatively uniform in elevation alongshore (FSAR 2.5.1 Reference 890).

The Holocene deposits at the Turkey Point Units 6 & 7 site do not contain any of the above indicators of paleostorm deposits. There are no moderately thick sand beds and there is no indication of abrupt thinning of sand deposits landwards. In addition, there are no abundant shell fragments deposited in laminations.

c) Since there are no paleostorm or tsunami deposits preserved at the site, there are no data from which a map can be generated

This response is PLANT SPECIFIC.

**References:**

Li, Y. *Calcareous Soils in Miami-Dade County*, Fact Sheet SL 183, Soil and Water Science Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, 2001.

Swiadek, J. W., *The Impacts of Hurricane Andrew on Mangrove Coasts in Southern Florida: A Review*, Journal of Coastal Research, v. 13, no. 1, pp. 242-245, 1997.

**ASSOCIATED COLA REVISIONS:**

The fifth paragraph in FSAR Subsection 2.5.1.2.2 will be replaced with the following paragraphs in a future revision of the FSAR:

**The Holocene section at the Units 6 & 7 site is classified as wetland soils belonging to the saprist (muck) group. Saprist soils are generally defined as those in which two-thirds or more of the material is decomposed, and less than one-third of plant fibers are identifiable (Reference 276). Eighty-eight (88) borings were drilled and sampled (standard penetration test (SPT) samples in soil, continuous coring in rock) as part of the Units 6 & 7 subsurface investigation. The description of the Holocene section (i.e. muck) in the soil borings across the Turkey Point Units 6 & 7 site (Reference 708), describes the thickness, color, hardness, and the presence of organic, silt, roots, and shell fragment contents. The muck soils were sampled at the site every 2.5 feet using the SPT geotechnical sampling method. The muck soils are classified under the Unified Soil Classification System (USCS) in accordance with ASTM D2488-06 instead of the Troels-Smith sediment classification system. Modifiers such as trace, few, little, some and mostly were used to provide an estimate of the percentage of gravel, sand and fines (silt or clay size particles) or other materials such as organics (muck) or shells. In general, the thickness of the muck ranges from 0 feet to 12.2 feet (0.2 to -8.2 feet Elevation NAVD 88). Muck is ubiquitous across the site and appears to be thicker in the areas of the surficial dissolution features, which act as sediment traps. Color ranges from black to light gray, dark grayish brown to light brownish gray and dark olive brown to light olive brown. Mottled coloration is also noted in the muck. The consistency of the muck is very soft-to-soft. Fibrous internal structure occurs within organic soils in eight of the**

**site borings: B-614, B-625, B-626, B-702, B-715, B-725, B-727, and B-729. The organic content of the muck was estimated to vary from some to mostly (Reference 708). Only one sample from boring B-601 (DH) contains "mostly silt." Trace to some sand is noted in three borings: B-617, B-623, and B-723. Neither the sand nor the silt can be correlated across the site as continuous stratigraphic units. However, fine-grained calcareous material appears to overlie the muck in six borings: B-736, B-738, B-802, B-810, B-812, and B-813. This marl-like material is described as a fat clay to sandy fat clay (rather than a silt as described in the field) that is light/dark gray to light/dark grayish brown, very soft, moist to wet, with some fine grained sand and strong hydrochloric reaction (Reference 708). This type of marl forms when the ground surface is flooded for several months each year in the summer followed by a number of dry months during the winter (hydroperiod). During the hydroperiod, the microalgae (periphyton) grow on the surface water. The precipitation of the microalgae from the calcium bicarbonate saturated water creates marl (Reference 905).**

~~The surface of the site consists of approximately 2 to 6 feet (0.6 to 1.8 meters) of organic soils called muck. The muck comprises recent light gray calcareous silts with varying amounts of organic content. The surface elevations for the top of the organic soil ranged from +0.2 to 1.8 feet (0.06 to 0.55 meters) MSL (Figures 2.5.1-334 and 2.5.1-337).~~

The following reference will be added to FSAR Subsection 2.5.1.3 in a future revision of the FSAR.

**905. Li, Y. *Calcareous Soils in Miami-Dade County*, Fact Sheet SL 183, Soil and Water Science Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, 2001.**

**ASSOCIATED ENCLOSURES:**

None

**NRC RAI Letter No. PTN-RAI-LTR-041**

**SRP Section: 02.05.01 - Basic Geologic and Seismic Information**

QUESTIONS from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

**NRC RAI Number: 02.05.01-8 (eRAI 6024)**

FSAR Section 2.5.1.1.5, "Tsunami Geologic Hazard Assessment," Section 2.5.1.2.1, "Site Physiography and Geomorphology," and Section 2.5.1.2.4, "Site Geologic Hazards," state that an extensive review of scientific literature resulted in no evidence of Quaternary seismically induced or landslide-generated tsunami deposits within the 200-mile radius of the Units 6 & 7 site region. The FSAR adds that sampling performed as part of the subsurface investigations at the Turkey Point site encountered about 1 meter (3 feet) of organic muck overlying Pleistocene and older carbonate strata and that the muck is the dominant surficial sediment type varying in thickness across the site from 2 to 6 feet (0.6 to 1.8 meters). FSAR Figure 2.5.1-332 shows the organic muck section as Holocene. Finally, the FSAR states that examination of Units 6 & 7 has provided no evidence of known tsunami deposits. In light of the foregoing conclusion, the staff notes that the FSAR does not provide an analysis of the Holocene section (muck layers) in the site vicinity with respect to paleo-tsunami or paleo-storm surge events and core data regarding the muck layers is absent from the FSAR.

In order for the staff to understand the Holocene geologic setting of the TPNPP and in support of 10 CFR 100.23 please address the following questions:

a) Provide justification for your conclusion that there are no tsunami deposits at the site with a detailed presentation of the Holocene section, including how it varies across the site in terms of thickness and internal structure.

b) Discuss the organic sediment ("muck") and included silt layers within an appropriate framework for the description of biogenic deposits, such as the Troels-Smith sediment classification system. Provide sufficient detail to illustrate how you evaluated silt layers as either potential storm or tsunami-derived sources.

**FPL RESPONSE:**

The information requested in Parts a and b of this RAI is found in the response for RAI 02.05.01-7 part a.

This response is PLANT SPECIFIC.

**References:**

None

**ASSOCIATED COLA REVISIONS:**

None

**ASSOCIATED ENCLOSURES:**

None

**NRC RAI Letter No. PTN-RAI-LTR-041**

**SRP Section: 02.05.01 - Basic Geologic and Seismic Information**

QUESTIONS from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

**NRC RAI Number: 02.05.01- 11 (eRAI 6024)**

FSAR Section 2.5.1.1.1.3.2 "Principal Tectonic and Structural Features" states that the site region has generally recorded only sedimentary processes since Mesozoic rifting, with the exception of tectonic activity associated with the collision of the Greater Antilles Arc with the Bahamas Platform during Cretaceous to Eocene time. The staff notes that this suggests that there has been no tectonic activity in the site region since the end of the Eocene (~34 Ma). However, the north coast of Cuba, the Walkers Cay fault, the Santaren Anticline, and the Straits of Florida normal faults all occur within the site region and show evidence for post-Eocene tectonic activity.

In order for the staff to fully understand site region specific geology, and in support of 10 CFR 100.23, please address the following: Update this discussion to clarify the timing and location of all tectonic features in the site region and place into the regional tectonic setting.

**FPL RESPONSE:**

This RAI mentions four structures or groups of structures: the Walkers Cay fault, the Santaren Anticline, the Straits of Florida normal faults and structures along the north coast of Cuba. Each is addressed below, with a brief discussion of their activity and regional tectonic setting.

As discussed in FSAR Subsection 2.5.1.1.1.3.2.2., the Walkers Cay fault was active in the Miocene. Because of its distance from Cuba, it is difficult to consider the Greater Antilles collision a likely tectonic setting for the fault. Sheridan et al. (1988) (FSAR 2.5.1 Reference 307) indicate that the Walkers Cay may represent a reactivation of buried Mesozoic normal faults within the basement of the Bahama platform. As noted in the Response to RAI 02.05.01-14, the unlithified character of the uppermost strata and the location on the slope of the northern edge of Little Bahama Bank could indicate that gravity-driven processes play a role in the latest development of the Walkers Cay fault.

The Santaren Anticline is located along the southern margin of the Bahama Platform and was active up until the Miocene (see FSAR Subsection 2.5.1.1.1.3.2.2.). As discussed in the FSAR and Response to RAI 02.05.01-15, the Santaren Anticline does not have a clear tectonic mechanism, though some authors interpret it as related to the collision of the Greater Antilles Arc with the Bahamas platform (FSAR 2.5.1 Reference 501, p. 479).

As described in FSAR Subsection 2.5.1.1.1.3.2.2, the Straits of Florida normal faults were active in the Eocene, and acted to thin the overthickened wedge of foreland material shed off the colliding Greater Antilles arc ( FSAR 2.5.1 Reference 221, p. 482). These structures were active in the Eocene and show very little (if any) evidence for younger deformation (Figure 2.5.1-209). In summary, these faults are not post-Eocene in age and are clearly related to the collision of the Greater Antilles arc.

Some structures in northern Cuba do exhibit potential post-Eocene deformation. For example, small-scale maps indicate the Pinar fault crosscuts strata as young as lower to middle Miocene (Pushcharovskiy et al., 1988). Though the preponderance of evidence indicates that the majority of structures in northern Cuba were active during the Eocene (e.g., FSAR Figure 2.5.1-248), rare younger deformation may represent either the waning effects of this collision, or the reactivation of older structures caused by stresses transmitted from the distant plate boundary (which migrated from central Cuba to southernmost Cuba from the Miocene to Recent).

In summary, the statement in the FSAR indicates that generally no tectonic deformation has occurred since the Eocene in the site region outside of the greater Antilles arc collision. The Santaren Anticline and Walkers Cay fault are structures that were active as recently as the Miocene and have uncertain relationships with the regional tectonic setting, and the specifics of those uncertainties are further addressed in RAI Responses 02.05.01-14 and 15. Hence, they are rare exceptions to that general rule, and are described as such in the FSAR. The structures along the coast of Cuba and the Straits of Florida normal faults are both predominantly Eocene in age and obviously related to the collision of the Greater Antilles arc with the Bahamas platform. Hence, these structures are consistent with the statement in the FSAR.

This response is PLANT SPECIFIC.

**References:**

Pushcharovskiy, Y., Borkowska, M., Hamor, G., Suarez, J., Velinov, I. (eds.), *Geologic Map of Cuba* (Mapa Geológico de Cuba), 1:250,000 Scale (40 Sheets), Academy of Sciences of Cuba, Institute of Geology and Paleontology, 1988.

**ASSOCIATED COLA REVISIONS:**

None

**ASSOCIATED ENCLOSURES:**

None

**NRC RAI Letter No. PTN-RAI-LTR-041**

**SRP Section: 02.05.01 - Basic Geologic and Seismic Information**

QUESTIONS from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

**NRC RAI Number: 02.05.01-12 (eRAI 6024)**

FSAR Section 2.5.1.1.1.3.2.1, "Structures of the Florida Peninsula and Platform" states that occasional variations in pre-Miocene stratigraphy recorded in boreholes due to erosion-based paleo-topography or karst have sometimes been interpreted as possible faulting; for example, the queried fault in Figure 2.5.1-234 (between wells Park W-2404 and Gulf W-3510) appears to displace the base of the Long Key and Arcadia Formations at approximately 100 m and coincides with nearly a doubling in thickness of the Long Key Formation on the downthrown (southern) side. The staff notes that the fault juxtaposes the Long Key Formation against the Arcadia Formation and the Arcadia Formation against the Avon Park Formation. Cunningham et al., 1998 (Reference 373) also provides a structural contour map of the top of the Arcadia formation and a map of net thickness of Miocene-to-Pliocene siliciclastic sand that appears to be consistent with faulting (Figure 17 of Cunningham et al., 1998).

In order for the staff to fully understand site region geology and in support of 10 CFR 100.23, please address the following:

a) Substantiate your interpretation with specific evidence that the stratigraphic relations across the queried fault shown in Figure 2.5.1-234 and depicted in Reference 373 are a result of paleo-topographic or karst processes, rather than tectonic offset.
b) If the queried fault is indeed a fault, please discuss the timing and spatial extent of faulting and update the FSAR discussion accordingly.

**FPL RESPONSE:**

a) Substantiate your interpretation with specific evidence that the stratigraphic relations across the queried fault shown in Figure 2.5.1-234 and depicted in Reference 373 are a result of paleo-topographic or karst processes, rather than tectonic offset.

The queried fault on FSAR Figure 2.6.1-234 was presumably interpreted because of the change in elevation of the Arcadia formation. However, because no discussion of the queried structure was presented in Cunningham et al. (1998) (FSAR 2.5.1 Reference 373, hereafter referred to as Cunningham et al. (1988)), it is uncertain if that assumption is correct. Nonetheless, the Everglades Park well W-2404 drilled the top of the Arcadia northeast of the queried fault at a depth of approximately 125 meters, while to the southwest the Gulf Oil well W-3510 drilled the top of the Arcadia at a depth of approximately 225 meters. FPL interpreted Figure 2.5.1-234 to indicate that in the Everglades Park well the Long Key formation is roughly 100 meters thick (though with an intervening limestone), while it is a little more than 125 meters thick in the Gulf well (also with intervening carbonates). FPL interprets a corresponding 25-30% increase in thickness across the queried structure.

The primary evidence that this approximately 100 meters of relief on the Arcadia could be related to paleotopography is that similar or greater amounts of relief are seen on the top of the Arcadia in southern Florida, without invoking tectonic faults (FSAR 2.5.1 Reference 373). In Cunningham et al's (1998) Figure 4, the top of the Arcadia formation varies by more than 150 meters in elevation, and by as much as 75 meters in adjacent wells (see Figure 1). The slope needed to accomplish the vertical offset seen between the Everglades Park and Gulf Oil well would only be 0.3°. This low slope is reasonable for normal sedimentary deposition in the region and the data do not require the interpretation of an intervening fault.

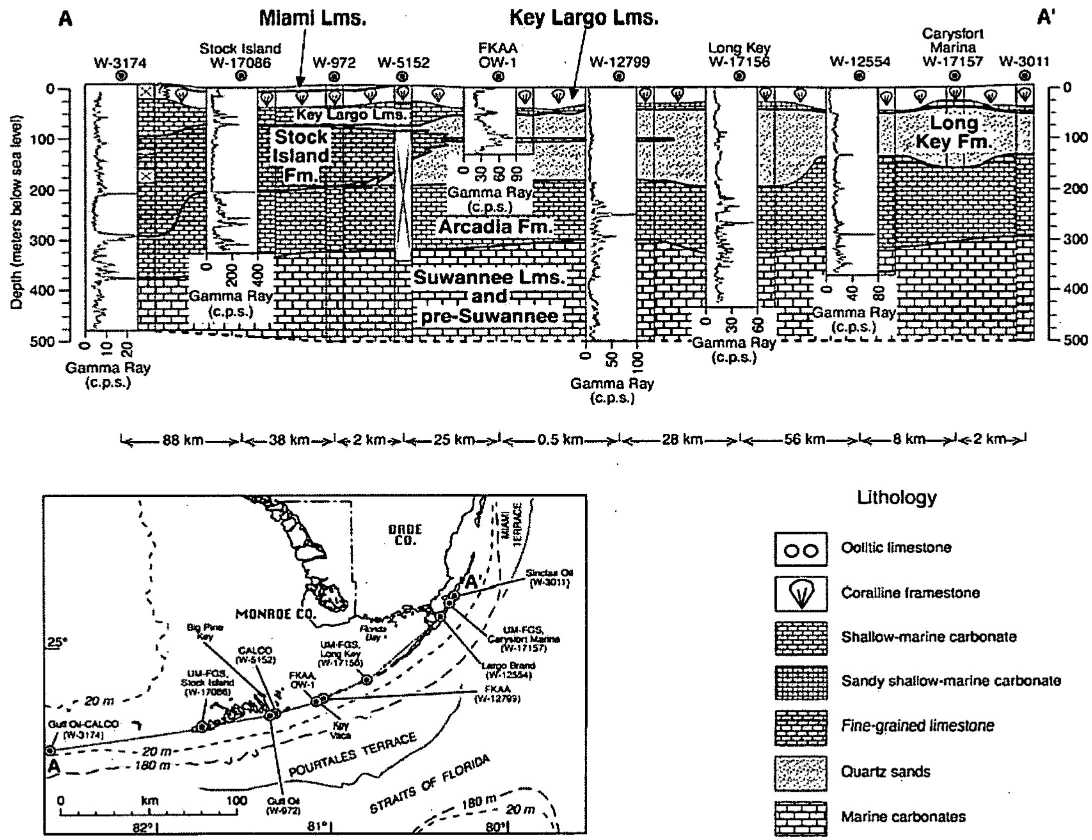
b) If the queried fault is indeed a fault, please discuss the timing and spatial extent of faulting and update the FSAR discussion accordingly.

If the variation in elevation of the Arcadia formation is related to faulting, the relationships in Figure 2.5.1-234 indicate the fault is older in age than the Upper Miocene to Pliocene Long Key Formation. The queried depiction of this fault in Figure 17 of Cunningham et al. (1998) indicates that it could be as much as 55 km long. Since only two borings define the geometry of this fault, the uncertainties in the geometry of this structure are large. Farther east, closer to the Turkey Point site, boring data were not interpreted by Cunningham et al., (1988) as indicating the presence of a fault.

The uncertainties associated with interpreting the relief on the top Arcadia formation between the Gulf and Park wells as fault-related include the following:

- The fault is queried in Cunningham et al (1998).
- No discussion of the reasoning for the queried structure are presented in Cunningham et al. (1998).
- The stratigraphy in the two wells that demarcate the potential fault was interpreted from cuttings only, no logs or core (see Figure 2).
- Recovery or available cuttings for the Arcadia formation in the Gulf well was apparently less than 20% (FSAR Figure 2.5.1-234).
- It appears that this fault is drawn on the basis of 2 wells in an area of very low well density (Figure 2).

Based upon the great uncertainties associated with this fault, the existence of this postulated structure is not substantiated by the available, albeit sparse, data.



Location of cross-section (A-A') in Florida Keys.

Figure 1 - Stratigraphic Cross Section Along the Florida Keys with More Than 150 meters in Relief on the Top of the Arcadia Formation (from a high of approximately 150 meters in W-12554 to a low of 300 meters in W-3174) (FSAR 2.5.1 Reference 373)

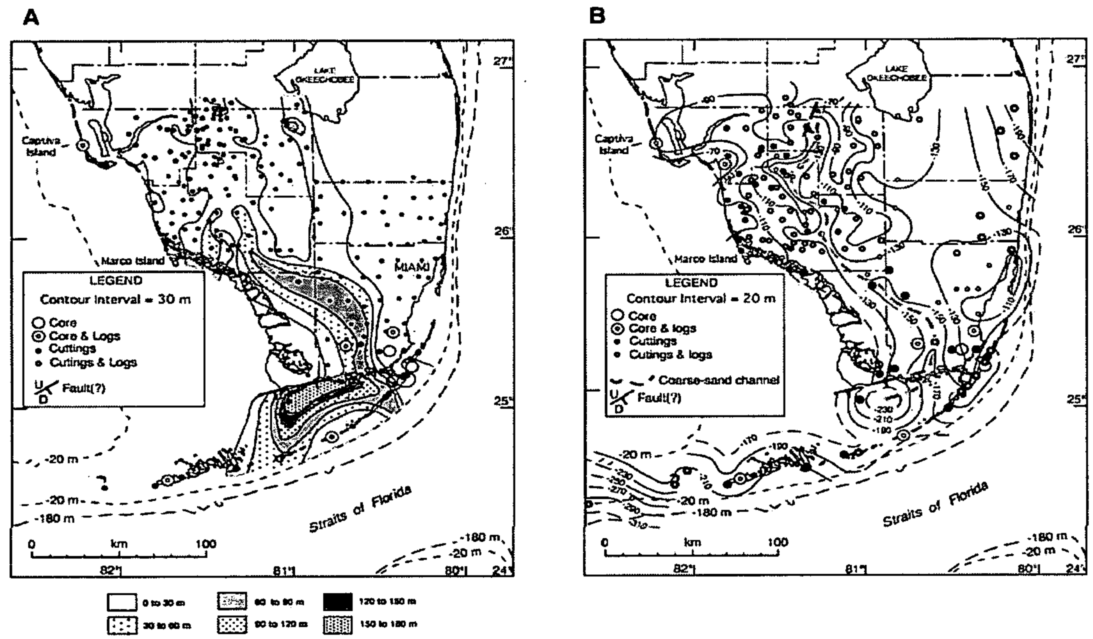



Figure 2 - Contoured Well Data for Southern Florida (FSAR 2.5.1 Reference 373)

This response is PLANT SPECIFIC.

**References:**

None

**ASSOCIATED COLA REVISIONS:**

None

**ASSOCIATED ENCLOSURES:**

None

**NRC RAI Letter No. PTN-RAI-LTR-041**

**SRP Section: 02.05.01 - Basic Geologic and Seismic Information**

QUESTIONS from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

**NRC RAI Number: 02.05.01-13 (eRAI 6024)**

FSAR Section 2.5.1.1.1.3.2.2 states with respect to Mesozoic Normal Faults of the Bahamas Platform, that the basement of the Bahamas Platform is depicted as a series of fault blocks with syn-tectonic Triassic to Jurassic strata, draped by undeformed Cretaceous strata. However, the staff notes that in FSAR Figure 2.5.1-264, Lower Cretaceous strata are faulted.

In order for the staff to evaluate the site region geology and in support of 10 CFR 100.23, please clarify the age of latest movement in light of faulted lower Cretaceous strata.

**FPL RESPONSE:**

The discussion of Mesozoic Normal Faults of the Bahamas Platform in FSAR Section 2.5.1.1.1.3.2.2 notes that normal faults cutting Cretaceous strata have been identified, but concludes that "More commonly, the basement of the Bahama Platform is depicted as a series of fault blocks with syn-tectonic Triassic to Jurassic strata, draped by undeformed Cretaceous strata." Such undeformed Cretaceous strata are depicted in FSAR Figures 2.5.1-262, -263, and -272 (western Straits of Florida), FSAR Figure 2.5.1-268 (western Bahama Bank), FSAR Figure 2.5.1-269 (northwest Bahama Bank), and FSAR Figure 2.5.1-270 (southeast Bahama Plateau), all of which are discussed in Section 2.5.1.1.1.3.2.2. The FSAR notes exceptions to the rarely faulted Bahama Platform are "generally associated with...the Tertiary Cuban orogen".

Lower Cretaceous strata (Albian-Aptian) are interpreted as faulted in Figure 2.5.1-264, but upper Cretaceous strata (Cenomanian to Conacian and Santorinian to Lower Paleocene) strata are unfaulted, consistent with the statement in the FSAR. The statement in Subsection 2.5.1.1.1.3.2.2 of the FSAR will be revised to provide clarification.

In preparation for this RAI response, Figure 2.5.1-270 was found to have the wrong reference cited. The reference in the notes to FSAR Figure 2.5.1-270 will be revised.

This response is PLANT SPECIFIC.

**References:**

None

**ASSOCIATED COLA REVISIONS:**

The second paragraph of FSAR Subsection 2.5.1.1.1.3.2.2 will be revised as shown below in a future revision of the FSAR:

As described above, the openings of the Gulf of Mexico and Atlantic Ocean led to the development of Mesozoic normal faults that extended the basement beneath the Florida and Bahama Platforms. No detailed maps of the entire subsurface Bahama Platform exist, but limited mapping of such faults has been done in conjunction with large-scale seismic surveys. For example, Austin et al. (Reference 432) identify seven normal faults cutting a

Cretaceous horizon in the Exuma Sound, and a seismic line in the Straits of Florida identified several minor normal faults cutting a Cretaceous horizon (Figure 2.5.1-274). More commonly, the basement of the Bahama Platform is depicted as a series of fault blocks with syn-tectonic Triassic to Jurassic strata, draped by undeformed **lower** Cretaceous strata (Figure 2.5.1-243).

The notes for FSAR Figure 2.5.1-270 will be revised as shown below in a future revision of the FSAR:

Notes:

(a) Seismic line OBC-8B, C, 48-trace, 24-fold; four air guns of 6000 cubic inches total volume, fired at 500 psi in 25-second intervals; data not deconvolved or migrated.

(b) Interpretation of line OBC-8B, C Identification of reflectors seaward of escarpment is based on correlation with DSDP Site 99. Modified from: Reference ~~794~~ **687**

Reference 2.5.1- 794 in FSAR Subsection 2.5.1.3 will be revised as shown in a future revision of the FSAR:

794. Schlager, W., Buffler, R**.,** **Angstadt, D.,** and Phair, R. "32. Geologic History of the Southeastern Gulf of Mexico," *Initial Reports DSDP, 77*, Buffler, R., Schlager, W., Bowdler, J., Cotillon, P., Halley, R., et al., Washington, U.S. Government Printing Office, pp. 715-738, 1984.

**ASSOCIATED ENCLOSURES:**

None

**NRC RAI Letter No. PTN-RAI-LTR-041**

**SRP Section: 02.05.01 - Basic Geologic and Seismic Information**

QUESTIONS from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

**NRC RAI Number: 02.05.01-14 (eRAI 6024)**

FSAR Section 2.5.1.1.1.3.2.2, "Bahamas Platform Tectonic and Structural Features" states with respect to Walkers Cay Fault, that although strata above the Oligocene horizon have been interpreted as both faulted and unfaulted, Harwood and Towers (1988) indicated that the Walkers Cay fault has minimal effect on middle Miocene and younger strata. In addition the FSAR states that because of the minor deformation of Miocene and younger strata, the Walkers Cay fault is concluded to be a Tertiary structure, and consequently, not a capable tectonic structure.

In order for the staff to understand the geologic setting of the TPNPP site and In support of 10 CFR 100.23 please address the following:

1) Label Walkers Cay fault on FSAR figure 2.5.1-276.
2) Explain the basis for Harwood and Towers (1988) conclusion within the limits of resolution for marine seismic reflection data.
3) Discuss the earlier interpretation of fault offset to the sea floor in light of the Austin et al 1988 a and b papers.
4) Discuss site-survey profiles LBB-17 and LBB-18 of ODP Leg 101, which show the Walkers Cay fault displacing the seafloor(see Austin et al., 1988 *a* and *b).*

   a. Austin, J. A., Jr., Schlager, W., et al, 1988, Proceedings of the Ocean Drilling Program, Scientific Results (1988) 101: 455-472. Paper number 29, by the "Leg 101 Scientific Party." Copyright 1988, Ocean Drilling Program.

   b. Austin, J. A., Jr., Schlager, W., et al., 1988, Proceedings of the Ocean Drilling Program, Scientific Results (1988) 101: 455-472. Paper number 26, by Austin et al." Copyright 1988, Ocean Drilling Program.

**FPL RESPONSE:**

<u>1) Label Walkers Cay fault on FSAR figure 2.5.1-276</u>

The interpreted faults on the seismic section of FSAR Figure 2.5.1-276 have been labeled on the revised Figure 2.5.1-276 shown in the Associated COLA Revisions section of this response. Labels requested as a part of RAI 02.05.01-18 have also been added.

<u>2) Explain the basis for Harwood and Towers (1988) conclusion within the limits of resolution for marine seismic reflection data.</u>

Harwood and Towers (1988) (FSAR 2.5.1 Reference 476, hereafter referred to as Harwood and Towers (1988)) concluded that the "Walkers Cay fault is visible on seismic profiles LBB 5, 6, 13, and 15, with a minor splay on LBB 18 (FSAR 2.5.1 Reference 476, Figure 6), but throughout the area it has only a minimal effect on sediments younger than middle Miocene" (FSAR 2.5.1 Reference 476, p. 266). They also state that in their study, "seismic sedimentologic features are recognizable to a resolution of better than 10 meters" (FSAR

2.5.1 Reference 476, p. 263). Thus, the basis for their conclusion is that throughout the area, they can not observe disturbances in post-middle Miocene strata that are appreciably larger than the resolution limit of the seismic data (~10 meters).

3) Discuss the earlier interpretation of fault offset to the sea floor in light of the Austin et al 1988 a and b papers.

Based upon seismic reflection data, Mullins and Van Buren (1981) (FSAR 2.5.1 Reference 474) identify a structure north of Little Bahama Bank called the Walkers Cay fault. As mapped, the fault is a 33-kilometer-long structure that strikes north-northeast (FSAR Figure 2.5.1-175). Mullins and Van Buren (1981) (FSAR 2.5.1 Reference 474, hereafter referred to as Mullins and Van Buren (1981)) interpret a Late Oligocene reflector to be offset by as much as 75 to 100 m (NLBB-2 on FSAR Figures 2.5.1-275, 276). However, Mullins and Van Buren (1981) also show a few short, but continuous, reflectors above the fault in the younger section. This indicates that any fault activity was decreasing to negligible after the Late Oligocene.

Mullins and Van Buren (1981) do not interpret the Walkers Cay fault as offsetting sea floor, they simply speculate that faulting above the top of NLBB-2 may extend "possibly even to the seafloor" (FSAR 2.5.1 Reference 474, p. 226). This does not conflict with the findings of later seismic studies (summarized below), which generally concluded that whereas some splays of the Walkers Cay fault may reach the seafloor, the majority of late Oligocene to Miocene and younger beds are only minimally disturbed.

4) Discuss site-survey profiles LBB-17 and LBB-18 of ODP Leg 101, which show the Walkers Cay fault displacing the seafloor(see Austin et al., 1988 *a* and *b*).

Austin et al. (1988b) (FSAR 2.5.1 Reference 785) imaged the Walkers Cay fault in profile LBB-18 with seismic sequences A through G (Enclosure 02.05.01-14A). For comparison, the authors correlate the F/G boundary to the uppermost Albian NLBB 3/4 boundary of Van Buren and Mullins (1983)(FSAR 2.5.1 Reference 791). In this line, Austin et al. (1988b) (FSAR 2.5.1 Reference 785, hereafter referred to as Austin et al. (1986b)) indicate that the entire section, from the top of sequence G to the seafloor, is offset by the Walkers Cay fault, although reflector offset near the seafloor is imperceptible. Regarding profile LBB-17 (FSAR Figure 2.5.1-346), however, Austin et al. (1988b) state that sequence G was offset, but that "Sequences A-F do not appear to be offset, but thickening of sequences A-E across the upward continuations of the fault trace implies continuing differential subsidence across the feature" (FSAR 2.5.1 Reference 785, p. 395). Indeed, in FSAR Figure 2.5.1-346, Austin et al. (1988b) interpret the presence of a monocline in the upper stratigraphy. Austin et al. (1988a) is not cited in the FSAR, however, it cites the same seismic data and interpretations for LBB-18 and reaches the same conclusions. Austin et al. (1988a) does not discuss LBB-17.

Additionally, Austin et al.'s (1988b) profile LBB-13 shows clear offset in three relatively narrow zones at the top of an Early Cretaceous bed (unit G on FSAR Figure 2.5.1-277), with the majority of displacement occurring on the westernmost fault splay. Moving upsection along this splay, displacements appear to become smaller and spread over a greater width. In latest early Miocene and younger beds (above unit D on FSAR Figure 2.5.1-277), displacements are minimal to imperceptible. This is consistent with a decrease in slip with time.

Harwood and Towers (1988) also examined these seismic profiles, focusing on sedimentologic development of the carbonate slope. In their analysis, they state the "Walkers Cay fault is visible on seismic profiles LBB 5, 6, 13, and 15, with a minor splay on LBB 18 (FSAR 2.5.1 Reference 476, Figure 6), but throughout the area it has only a minimal effect on sediments younger than middle Miocene" (FSAR 2.5.1 Reference 476, p. 266). This statement indicates that the relationships described by Austin et al. (1988b) for profiles LBB-17 and LBB-13, in which younger sediments are not offset or are only minimally offset, is more frequently observed than the apparent offset of the seafloor interpreted in profile LBB-18. In summary, the bulk of seismic reflection data indicate that displacement along the Walkers Cay fault progressively diminished to minor or imperceptible levels after the Late Oligocene to Miocene.

It should also be noted that drill cores taken from Site 627 locally characterized the upper 181.4 meters of seafloor as generally unlithified, composed of oozes with occasional layers of floatstone and packstone (Austin et al., 1986). These sediments display evidence of gravity-driven soft-sediment deformation (such as inclined laminations and upward fining) characteristic of turbidite sequences. As such, it is also possible that some of the uppermost displacement interpreted across the Walkers Cay fault is related to gravitational collapse instead of tectonic activity.

In preparation for this RAI response, FSAR 2.5.1 Reference 785, (Austin et al., 1988b) was found to have the incorrect title. A revised version of this reference will be provided.

This response is PLANT SPECIFIC.

**References:**

Austin, J.A., Jr., Schlager, W., Palmer, A. A., et al., 1986, Proceedings of the Ocean Drilling Program, Initial Results (Part A), 101: 111-212.

Austin, J. A., Jr., Schlager, W., et al, 1988a, Proceedings of the Ocean Drilling Program, Scientific Results (1988) 101: 455-472. Paper number 29, by the "Leg 101 Scientific Party." Copyright 1988, Ocean Drilling Program.

**ASSOCIATED COLA REVISIONS:**

The second and third paragraphs of FSAR Subsection 2.5.1.1.1.3.2.2 will be revised as shown below in a future FSAR revision:

For example, Austin et al. (Reference ~~432~~ **785**) identify seven normal faults cutting a Cretaceous horizon in the Exuma Sound, and a seismic line in the Straits of Florida identified several minor normal faults cutting a Cretaceous horizon (Figure 2.5.1-274). More commonly, the basement of the Bahama Platform is depicted as a series of fault blocks with syn-tectonic Triassic to Jurassic strata, draped by undeformed Cretaceous strata (Figures 2.5.1-264 and 2.5.1-243).

Walkers Cay Fault

"The Walkers Cay fault is mapped just north of Little Bahama Bank (approximately 198 miles or 320 kilometers from the Units 6 & 7 site) (Figure 2.5.1-229) in a series of seismic reflection profiles (Reference 474). However, different seismic studies have depicted different geometries for the estimated trace of the fault and its location should be considered uncertain. Originally, the youngest offset on the structure was interpreted as the top of a seismic sequence correlated as Oligocene, with 75 to 100 meters (250 to 330 feet) of offset (Reference 474) (Figure 2.5.1-275). Later work with a more detailed seismic study indicated that the youngest sequence offset by the fault is the top of an Early Cretaceous (Albian) shallow water carbonate platform~~, and that~~**; the observation of** overlying strata thicken**ing** across the trace of the fault~~, indicating~~ **was variously interpreted as evidence of** continuing differential subsidence (Reference ~~432~~ **785) or the result of regional tilting (Reference 476)** (Figure 2.5.1-346 **and Figure 6 from Reference 476**). However, some seismic profiles indicate that the Walkers Cay fault, or a similar normal fault, may extend to the seafloor (Figures 2.5.1-276 and 2.5.1-277).

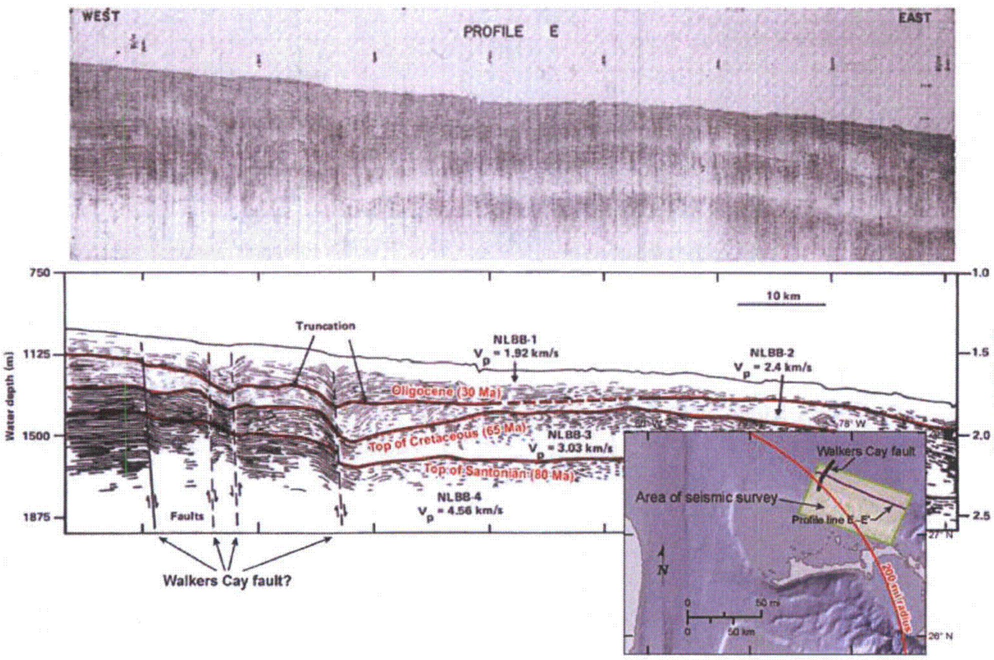
Regional summaries assign a Cretaceous to middle Tertiary age for this structure and interpret it as indicating some late-stage reactivation of Mesozoic normal faults cutting basement (Reference 307). While strata above the Oligocene horizon have been interpreted as both faulted and unfaulted (e.g., References 474 and ~~432~~ **785**), Harwood and Towers (Reference 476) indicate that the Walkers Cay fault has only a minimal effect on middle Miocene and younger strata. **This is also supported by a detailed examination of the data presented by Austin et al. (Reference 785). Seismic reflection line LBB-13 shows clear offset in three relatively narrow zones at the top of an Early Cretaceous bed (Figure 2.5.1-277, unit G), with the majority of displacement occurring on the westernmost fault splay. Moving upsection along this splay, displacements appear to become smaller and spread over a greater width. In latest early Miocene and younger beds (above unit D), displacements are minimal to imperceptible. The same trend is visible in seismic line LBB-17, with clearly defined offsets in unit G covered by a wider zone of folding, capped by minimal offset in unit D and above.** Because of the **transition to** minor **(or imperceptible)** deformation of Miocene and younger strata**, FPL concludes that displacement on the Walkers Cay fault has been diminishing over time, and it was last active in the Miocene**. ~~the Walkers Cay fault is concluded to be a Tertiary structure, and thus,~~ **Therefore, it is** not considered a capable tectonic structure.

Reference 2.5.1-785 in FSAR Subsection 2.5.1.3 (References) will be revised as shown below in a future revision of the FSAR:

785. Austin, J. A., ~~et al.,~~ **Ewing, J. I., Ladd, J. W., Mullins, H. T., and Sheridan, R. E.,** ~~"Boreholes at Great Isaac and Site 626 and the History of the Florida Straits,"~~ **"Seismic Stratigraphic Implications of ODP Leg 101 Site Surveys,"** Proceedings of the Ocean Drilling Program, Scientific Results, v. 101, Austin, J., et al. (eds.), p. ~~425-437,~~ **391-424,** 1988.

FSAR Figure 2.5.1-276 will be replaced with the following revised figure in a future revision of the FSAR:

**Figure 2.5.1-276 Seismic Line and Interpretation across the Walkers Cay Fault**




Source: Reference 791

**ASSOCIATED ENCLOSURES:**

None

**NRC RAI Letter No. PTN-RAI-LTR-041**

**SRP Section: 02.05.01 - Basic Geologic and Seismic Information**

QUESTIONS from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

**NRC RAI Number: 02.05.01-15 (eRAI 6024)**

FSAR Section 2.5.1.1.1.3.2.2 states, with respect to the Santaren Anticline, that stratigraphic analysis (References 477 and 479) used to infer Pliocene or potential Quaternary activity on the structure, suggests this structure is Tertiary in age and predominantly active during the Eocene, with diminishing activity throughout the Miocene. The staff notes that References 477, 479, and 501 present evidence that the Santaren Anticline (within the 200 mi radius of the site) is cored by a thrust fault and is undergoing present-day shortening.

In order for the staff to determine the potential for activity on this structure and in support of 10 CFR 100.23 please address the following questions:

a) In light of evidence for ongoing deformation (References 477, 479, and 501), discuss the present day rates of shortening calculated across the anticline (see also Masaferro et al, 1999).

b) Plot regional seismicity on a close-up view of the Santaren Anticline and comment whether the Santaren Anticline is a capable tectonic structure.

c) Provide a discussion regarding the possibility that the Santaren Anticline and the Nortecubana fault system are linked.

[a] Masaferro, J.L., Poblet, J., Bulnes, M., Eberli, G.P., Dixon, T.H., and McClay, K., 1999, Palaeogene-Neogene/present day(?) growth folding in the Bahamian foreland of the Cuban fold and thrust belt: Journal of the Geological Society of London, v. 156, Part 3, 617–631.

**FPL RESPONSE:**

<u>a) In light of evidence for ongoing deformation (References 477, 479, and 501), discuss the present day rates of shortening calculated across the anticline (see also Masaferro et al, 1999)</u>

Based on seismic reflection, gravity, and magnetic data collected from the southwest edge of the Bahama Platform, Ball et al. (1985) (FSAR 2.5.1 Reference 501, hereafter referred to as Ball et al. (1985)) interpret subsurface geology and structures associated with the northern edge of the Bahama-Cuba collision zone. Ball et al. (1985) identify the Santaren anticline as an approximately 10-km-wide, 70-km-long, northwest-trending structure (FSAR Figure 2.5.1-343) that may be cored by a southwest-dipping thrust fault. The fold is "inferred to be a hanging-wall anticline at the northern limit of the Cuban fold-thrust belt formed in the late Cretaceous" (FSAR 2.5.1 Reference 501, p. 1275). As part of their analysis, Ball et al. (1985) resolve regional thinning of Upper Cretaceous beds from north to south across the Santaren anticline, with the largest magnitude of thinning occurring off the anticline's southern flank within uppermost Cretaceous and lower Cenozoic carbonate beds. They conclude "these thinning relationships indicate that the structure was initiated during the Late Cretaceous and that maximum topographic relief occurred in the early Cenozoic. Late Cenozoic expression could be a result of differential compaction of thick, semiconsolidated sediments on the structure's flanks" (FSAR 2.5.1 Reference 501,

p. 1,285-1,287). Moreover, Ball et al. (1985) indicate "the [Santaren anticline] appears to have been formed in the Late Cretaceous and early Cenozoic" (FSAR 2.5.1 Reference 501, p. 1,292). Ball et al. (1985) do not suggest that the Santaren anticline is currently undergoing shortening. Ball et al. (1985) do not present evidence for or describe a fault in the core of the Santaren anticline, but merely show a postulated fault as a dashed line on their Figure 9B with no further explanation given.

Masaferro (1997) and Masaferro et al. (2002) (FSAR 2.5.1 References 477 and 479, respectively, hereafter referred to as Masaferro (1997) and Masaferro et al. (2002)) provide a more detailed stratigraphic analysis of the Santaren anticline, based primarily on seismic reflection data and well logs acquired during the Ocean Drilling Project (ODP). Masaferro et al. (2002) use the geometries and inferred ages of growth strata associated with the Santaren anticline to model the temporal variability in sedimentation and fold-growth rates since Late Oligocene time. They conclude that the geometry of Santaren anticline growth strata results from the interplay between sedimentation and tectonic fold uplift, and that sedimentation and fold-growth rates have been highly variable over time. In other words, the "evolution of the Santaren anticline consists of cycles that involved tectonically active periods separated by interruptions in which the tectonic activity fell to zero" (FSAR 2.5.1 Reference 479, p. 21). Furthermore, their analysis suggests that the preponderance of tectonic growth of the Santaren anticline occurred prior to 20 Ma (i.e., prior to bed "E" in their figure 4C). Since that time, the average fold uplift rate is approximately 0.03 mm/yr. Masaferro et al. (2002) conclude that, for the time period 6.2 Ma to present, "there were many lapses within this [time period] during which no tectonic uplift occurred" (FSAR 2.5.1 Reference 479, p. 21) and that the greatest fold uplift rate since approximately 6.2 Ma occurred during or just before deposition of beds K2 and K3, which are assigned Late Miocene age. Since deposition of beds K2 and K3, Santaren anticline fold uplift rates have been at or near zero.

Masaferro et al. (2002) do not suggest that the Santaren anticline currently is undergoing shortening. What they do suggest is that the anticline has experienced episodic tectonic growth and sedimentation since at least Oligocene time, with the most recent episode interpreted as having occurred in the early Quaternary (beds M2-M3, with a fold uplift rate of 0.05 mm/yr. However, as Masaferro et al. (2002) state, the uncertainties associated with their methodology for estimating fold uplift rate are "hardly quantifiable" and therefore "error bars associated with these values have been omitted...for clarity" (FSAR 2.5.1 Reference 479, p. 18). In other words, based on the information presented in Masaferro et al. (2002), it is not possible to assess whether the very low apparent fold uplift rates since Late Miocene time are distinguishable from zero. It is likely that a fold uplift rate of 0.05 mm/yr is not detectable with the resolution of the method.

Masaferro et al. (2002) is largely a continuation of the work performed in Masaferro et al. (1999) (FSAR 2.5.1 Reference 426, hereafter referred to as Masaferro et al. (1999)). The latter concluded that the post-mid-Eocene strata of the Santaren Anticline recorded uplift; once this conclusion was reached, it was the basis for the former to call these strata "growth strata" and determine the relative contribution of sedimentation versus fold growth over time. However, the conclusion of post-mid-Eocene uplift is subject to the same resolution issues that Masaferro et al. (2002) is subject to, as both papers use the same methods and calculations to determine decompaction, crestal relief, shortening, etc. Masaferro et al. (1999) admit that the error associated with their work in "hardly quantifiable", and suggest an error of 10% might be appropriate. They then proceed to build a case for modern-day uplift based on the fact that crestal relief over time must have increased, as a horizontal line cannot be fit to the data in their figure 13. However, an interpretation of no uplift is only prevented by their assumed error of 10%; at 14%, such an interpretation is possible. Even if their error were only 12.2%, the data would allow for no uplift since 20 Ma. However, Masaferro et al. (1999) offer no explanation as to why 10% is a suitable error, and by 2002 Masaferro et al. have completely abandoned the estimation of these same errors.

b) Plot regional seismicity on a close-up view of the Santaren Anticline and comment whether the Santaren Anticline is a capable tectonic structure

The Phase 2 earthquake catalog developed for the Turkey Point Units 6 & 7 project indicates that there is only one earthquake within 40 km of the Santaren anticline. This Mw 3.26 earthquake occurred on 06/02/1990 and is located approximately 8 km northwest of the northwestern-most mapped point along the Santaren anticline fold axis. As suggested in FSAR Subsection 2.5.1.1.1.3.2.2, it is possible that the Santaren anticline is rooted in Jurassic evaporates and fine-grained deposits and that the prolonged period of intermittent fold growth potentially is non-seismogenic deformation related to salt diapirism or gravity slides. While salt diapirism has not been documented at the location of the Santaren anticline, evidence for this non-tectonic process associated with Jurassic evaporates is found within the Cuban fold and thrust belt about 50 kilometers northeast near the southeast corner of Cay Sal Bank (p. 1277 of Ball et al. 1985) and about 75 kilometers south at Punta Allegre, Cuba (p. 1275 of Ball et al. 1985). Hanson et al. (1999) indicate that regional deformation due to salt diapirism can span tens to hundreds of millions of years and the time scales of shale diapirism is determined by the duration of high fluid pressures, which may be transient.

In their description of previous studies of the Santatren anticline, Masaferro et al. (2002) acknowledge that Ball et al. (1985) suggested the possibility that the Santaren anticline may be cored by a fault. Masaferro et al. (2002), however, provide no further discussion of this postulated fault, nor do any faults appear in their interpreted cross sections of the Santaren anticline. Thus, even if the Santaren anticline currently is undergoing shortening at a very low rate, it is not clear that this shortening is accommodated by a seismogenic structure capable of producing vibratory ground motion or tectonic surface deformation. The absence of seismicity near this structure would indicate that it is not a capable tectonic structure (see Figure 1).

c) Provide a discussion regarding the possibility that the Santaren Anticline and the Nortecubana fault system are linked

Both structures are discussed in the FSAR as being spatially and temporally associated with the northern reaches of the Cuban orogeny, and as such, it is likely they were both genetically associated with the same driving forces. Additionally, the Santaren Anticline appears to be on trend with the eastern portion of the Nortecubana fault. The fact that there is no detailed mapping for the Nortecubana fault makes it difficult to speculate on whether or not it may have at one time been structurally linked to the Santaren Anticline.

The seismic catalog can however provide some insight into modern-day associations. As discussed in the FSAR, seismicity along the Nortecubana fault is concentrated near its intersection with the Oriente fault and substantially decreases westward into the site region

(FSAR Subsection 2.5.1.1.1.3.2.4). Seismicity in the vicinity of the Santaren Anticline, discussed in part (b) of this RAI, is sparse. There is only one event that is on-trend with the anticline, and that event is to the west. There are no recorded earthquakes or mapped structures in the ~20 mile gap between the Santaren Anticline and the Nortecubana fault (see Figure 1).

Given the lack of data suggesting a structural link between these features, FPL has no reason to conclude that the Santaran Anticline and the Nortecubana fault are linked.

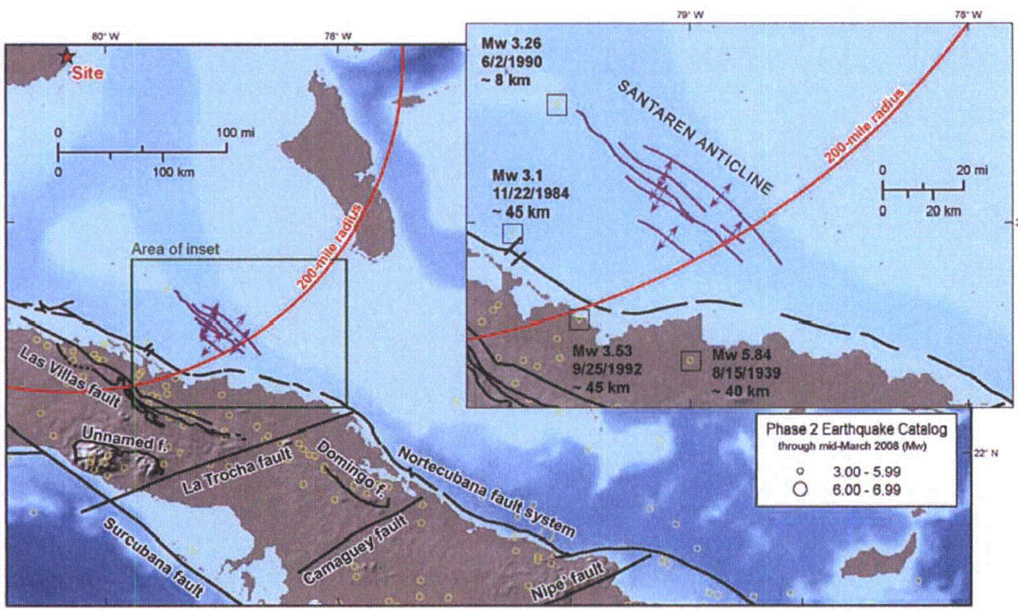



Figure 1 - Regional Seismicity Plotted on a Map of the Nortecubana Fault and Santaren Anticline.

Sources: Base bathymetric map from British Oceanographic Data Center, 2008 (FSAR 2.5.1 Reference 822). Mapping of the Santaren Anticline from Masaferro et al., 1997 (FSAR 2.5.1 Reference 477). Mapping of Cuban faults from Cotilla-Rodriguez et al., 2007 (FSAR 2.5.1 Reference 494); French and Schenk, 2004 (FSAR 2.5.1 Reference 492); Hall et al., 2004 (FSAR 2.5.1 Reference 770); Iturralde-Vinent, 1994 (FSAR 2.5.1 Reference 440); Kerr et al., 1999 (FSAR 2.5.1 Reference 443); and Pardo, 2009 (FSAR 2.5.1 Reference 439).

This response is PLANT SPECIFIC.

**References:**

Hanson, K.L., Kelson, K.I., Angell, M.A., and Lettis, W.R., 1999, Techniques for Identifying Faults and Determining Their Origins, Nuclear Regulatory Commission Report NUREG/CR-5503, 463 pp.

**ASSOCIATED COLA REVISIONS:**

None

**ASSOCIATED ENCLOSURES:**

None

**NRC RAI Letter No. PTN-RAI-LTR-041**

**SRP Section: 02.05.01 - Basic Geologic and Seismic Information**

QUESTIONS from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

**NRC RAI Number: 02.05.01-16 (eRAI 6024)**

FSAR Section 2.5.1.1.1.3.2.2 states, with respect to the Straits of Florida Normal Faults, that middle to late Eocene to early middle Miocene strata were deposited uniformly over most of the southern Straits of Florida and that similarly; continuous, unfaulted strata drape the edges of the Florida and Bahamas Platforms along the Straits of Florida. The staff needs more details with respect to the timing and location of the Straits of Florida Normal Faults.

In order for the staff to completely understand the geologic setting of the TPNPP site and in support of 10 CFR 100.23, Provide a discussion of the structural and stratigraphic evidence for the location and timing of deformation along the Mitchell, Pourtales, and Miami escarpments, the Las Villas and the Sierra de Jatibonico fault zones, and other tectonic features present in the bathymetry of subsurface of the Straits of Florida within the site region, including those located offshore northern Cuba, and in light of references such as Uchupi, 1966[a] and Malloy and Hurley, 1970[b] .

[a] Uchupi, E., 1966, Shallow structure of the Straits of Florida, Science, New Series, Vol 153, no.3735, pp.529-531, published by AAAS.

[b] Malloy and Hurley, 1970, Geomorphology and Geologic Structure: Straits of Florida, Geological Society of America Bulletin, v. 81, p. 1947-1972, 19 figs., July 1970

**FPL RESPONSE:**

Provide a discussion of the structural and stratigraphic evidence for the location and timing of deformation along the Mitchell, Pourtales, and Miami escarpments

As described in FSAR Subsection 2.5.1.1.1.3.2.2, deformation within the Straits of Florida is characterized by a series of short, steep normal faults in the western straits southwest of Turkey Point (Case and Holcombe, 1980) (FSAR 2.5.1 Reference 480) (FSAR Figure 2.5.1-229). Based on an interpretation of seismic reflection data, these faults are mapped in Paleocene and Eocene strata and are overlain by undeformed Miocene and younger strata. This faulting is interpreted as syn-tectonic deformation of the Cuban foreland basin during its collision with the Florida-Bahama Platform (Schlager et al. 1984; Angstadt et al. 1985) (FSAR References 2.5.1-794, p. 482). The undeformed Miocene and younger strata overlying these faults are interpreted to indicate that subsidence of the straits had largely ceased with a change in tectonic regime. The short, steep normal faults that accommodated the formation of the Straits of Florida in the Paleocene and Eocene are distinct from the small-scale escarpments addressed in this RAI.

Uchupi (1966) presents results of a seismic survey conducted throughout the Straits of Florida and suggests that "the steepness of the slopes flanking the Miami and Pourtales terraces along their seaward sides, and the presence of drag folds along the slope south of Pourtales Terrace, suggest that these features may be fault-line scarps. If faulting produced the slopes flanking the terraces, it probably occurred in Miocene or post-Miocene time, as the cores of both terraces consist of Lower Miocene limestones" (Uchupi, 1966, p. 531). However, the seismic survey did not provide any direct evidence of faulting beneath these features.

Malloy and Hurley (1970) present mapping of the Straits of Florida based on bathymetry and seismic reflection data, but were more equivocal in their interpretation of the Pourtales and Mitchtell escarpments. A seismic reflection profile of the Mitchell escarpment shows possible faulting, but Malloy and Hurley (1970) state that whatever faulting may have occurred, it is doubtful that displacements are of regional tectonic significance. Moreover, Malloy and Hurley (1970) state "there is evidence of features that may be normal faults on the southern side of the Southern Straits [of Florida]. It is by no means obvious that any of these faults have any regional tectonic significance. In fact, there is no need to postulate extensive faulting here" (Malloy and Hurley, 1970. p. 1968).

According to Malloy and Hurley (1970), seismic reflection data across the Pourtales escarpment show "the near-flat strata of the terrace possibly in fault contact with consolidated strata dipping locally 7° (apparent) to the south," however, they go on to state that "the Pourtales escarpment may not represent a fault scarp, but an original sedimentary feature associated with sediments deposited against the steeper face of the old reef front. It would seem that such relationships should be expected in this region" (Malloy and Hurley, 1970. p. 1968). Indeed, Uchupi et al. (1971) (FSAR 2.5.1 Reference 428, hereafter referred to as Uchupi et al. (1971)) also suggest that such escarpments are commonly formed along the Bahamas and Gulf of Mexico through carbonate accretion by Mesozoic reefs. Detailed seismic mapping by Eberli et al. (2002) also indicate that these relationships are typical and related to the edge of carbonate banks. Denny et al. (1994) (FSAR 2.5.1 Reference 221) also describe seismic reflection lines that cross the Pourtales escarpment showing no evidence of shallow faulting.

In summary, the majority of the data collected in the study of the Mitchell, Pourtales, and Miami escarpments provide no basis for concluding that these features are the product of fault activity. Instead, Malloy and Hurley (1970) and Uchupi et al. (1971) suggest that these escarpments are sedimentary features common to the Bahamas and Gulf of Mexico.

<u>Provide a discussion of the structural and stratigraphic evidence for the location and timing of deformation along the Las Villas and the Sierra dė Jatibonico fault zones, and other tectonic features present in the bathymetry of subsurface of the Straits of Florida within the site region, including those located offshore northern Cuba</u>

The seismic mapping campaign conducted by Malloy and Hurley (1970) could not extend to within 12 n.m. of Cuba, and they were therefore unable to analyze the Las Villas and Sierra de Jatibonico fault zones. They summarized Khudoley's (1967) work documenting the location and extent of these faults, and concluded that "it is certainly most probable that there are extensive faults adjacent to Cuba, particularly along the Sierra de Jatibonico and Las Villas scarps...it is by no means obvious that any of these faults have any regional tectonic significance" (Malloy and Hurley, 1970, p. 1968).

To the best of our knowledge, there have been no subsequent detailed studies of the Las Villas or Sierra de Jatibonico fault zones. This is typical for Cuban faults, which is why Garcia et al. (2008) (FSAR 2.5.1 Reference 490) used areal source zones rather than fault sources when characterizing the seismic potential of Cuban faults. Those details that are known are presented in Section 2.5.1.1.1.3.2.4 of the FSAR, "Cuba," which includes a discussion of the Las Villas fault.

The Sierra de Jatibonico fault zone is not discussed in the FSAR. In Khudoley's (1967) outline of Cuban geology, the presence and extent of this fault zone is mentioned, although timing is not. According to Hatten et al. (1988), the Sierra de Jatibonico fault zone is a vertical suture with a component of right-lateral slip that separates the Zueleta and Remedios Units. Each of those units is capped by middle Eocene sediments containing high-angle faults with a component of right-lateral slip. Assuming that faulting within each unit was contemporaneous with movement on the Sierra de Jatibonico fault, that provides a minimum age of last activity. Pardo (2009) (FSAR 2.5.1 Reference 439) also dates the youngest units in the Jatibonico belt (approximately the same as the Remedios Unit from Hatten et al., 1988) as middle Eocene.

This response is PLANT SPECIFIC.

**References:**

Eberli, G.P., Anselmetti, F.S., Kroon, D., Sato, T., and Wright, J., *The chronostratigraphic significance of seismic reflections along the Bahamas Transect, Marine Geology*, 185, p. 1-17, 2002.

Hatten, C.W., Somin, M., Millan, G., Renne, P., Kistler, R.W., and Mattinson, J.M., *Tectonostratigraphic units of central Cuba, Eleventh Caribbean Geological Conference Symposium Volume*, Barbados, BWI, p. 35:1-13, 1988.

Khudoley, K.M., , Principal features of Cuban geology, *American Association of Petroleum Geologists Bulletin*, v. 51, no. 5, pp. 668-677 1967.

Malloy, R.J. and Hurley, R.J., *Geomorphology and geologic structure: Straits of Florida, Geological Society of America Bulletin*, v. 81, p. 1947-1972, 1970.

Uchupi, E., Shallow Structure off the Straits of Florida, Science, v. 153, no. 3735, p. 529-531, 1966.

**ASSOCIATED COLA REVISIONS:**

The following text will be inserted after the ninth paragraph of FSAR Subsection 2.5.1.1.1.3.2.4 , preceding the discussion of the Pinar fault in a future revision of the FSAR:

***Sierra de Jatibonico fault***

**The Sierra de Jatibonico fault is a 1-2 km-wide zone that parallels the trend of Cuba along its 450 km length. Both Khudoley (Reference 906) and Hatten et al. (Reference 907) describe the fault as being vertical at the surface but gradually flattening at depth, reaching a minimum dip of 55°S. Hatten et al. (Reference 907) state that there is a component of right-lateral displacement along the fault, whereas Pardo (Reference 439) only cites the throw of 1500 meters.**

**There are no studies that document fault activity or seismicity along the Sierra de Jatibonico fault zone. Mapping by Hatten et al. (Reference 907) shows that the fault juxtaposes the Zueleta and Remedios Units, each of which is capped by middle**

**Eocene sediments containing high-angle faults with a component of right-lateral slip. Pardo (Reference 439) also dates the youngest units in the Jatibonico belt (approximately the same as the Remedios Unit from Hatten et al., (Reference 907)) as middle Eocene. Assuming that faulting within each unit was contemporaneous with movement on the Sierra de Jatibonico fault, that provides a minimum age of last activity.**

The following references will be added to FSAR Subsection 2.5.1.3, References in a future revision of the FSAR:

**906.** **Hatten, C.W., Somin, M., Millan, G., Renne, P., Kistler, R.W., and Mattinson, J.M., *Tectonostratigraphic units of central Cuba, Eleventh Caribbean Geological Conference Symposium Volume,* Barbados, BWI, pp. 35:1-13, 1988.**

**907.** **Khudoley, K.M.,, Principal features of Cuban geology, *American Association of Petroleum Geologists Bulletin*, v. 51, no. 5, pp. 668-677, 1967.**

**ASSOCIATED ENCLOSURES:**

None

**NRC RAI Letter No. PTN-RAI-LTR-041**

**SRP Section: 02.05.01 - Basic Geologic and Seismic Information**

QUESTIONS from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

**NRC RAI Number: 02.05.01-17 (eRAI 6024)**

FSAR Figures 2.5.1-342, -343, and -344 illustrate isopach and structure contour maps of the Key Largo Limestone and Fort Thompson Limestone stratigraphic units. The staff notes, however, that additional information is needed on the maps to understand the nature of the Key Largo and Fort Thompson limestone units.

In order for the staff to evaluate depositional structures or potential tectonic deformation in the bearing layer formation within the site area and in support of 10 CFR 100.23, please address the following:

a) Indicate the elevation on the structure contour maps and thickness values on the isopachs.

b) Indicate thin areas on the isopachs and low areas on structure contours.

c) Plot the location of cross section lines A, B, C, and D on the isopach and structure contour maps.

d) Provide a structure contour for the Key Largo formation.

e) The FSAR describes the Fort Thompson Formation as vuggy, and solution riddled. In light of this characteristic in the underlying Fort Thompson, discuss the implication of the numerous closed circles shown on the Key Largo isopach.

**FPL RESPONSE:**

The updated Figures 2.5.1-342, 343, and 344 and Figure 1 are provided below. Upon review of these maps, it was discovered that the FSAR Figure 2.5.1-342 "Isopach of the Site: Key Largo Limestone" had an incorrect figure (that did not match the title) and as part of this response the correct figure is provided. The original figure shown on Figure 2.5.1-342 is necessary and is provided below as Figure 1. This Figure (Structure Contour Map: Top of Key Largo Limestone) has been updated and will remain in the FSAR with a new Figure number.

a) The updated elevation values on the structure contour maps and updated thickness values on the isopach maps for the respective Figures 2.5.1-342, 343, and 344 and Figure 1 are provided below.

b) As shown on the updated Figure 2.5.1-342, the thickness of the Key Largo Formation ranges from about 15 to 30 feet with a minimum thickness of about 15 feet. As shown on Figure 2.5.1-344, the thickness of the Fort Thompson Formation ranges from about 60 to 70 feet.

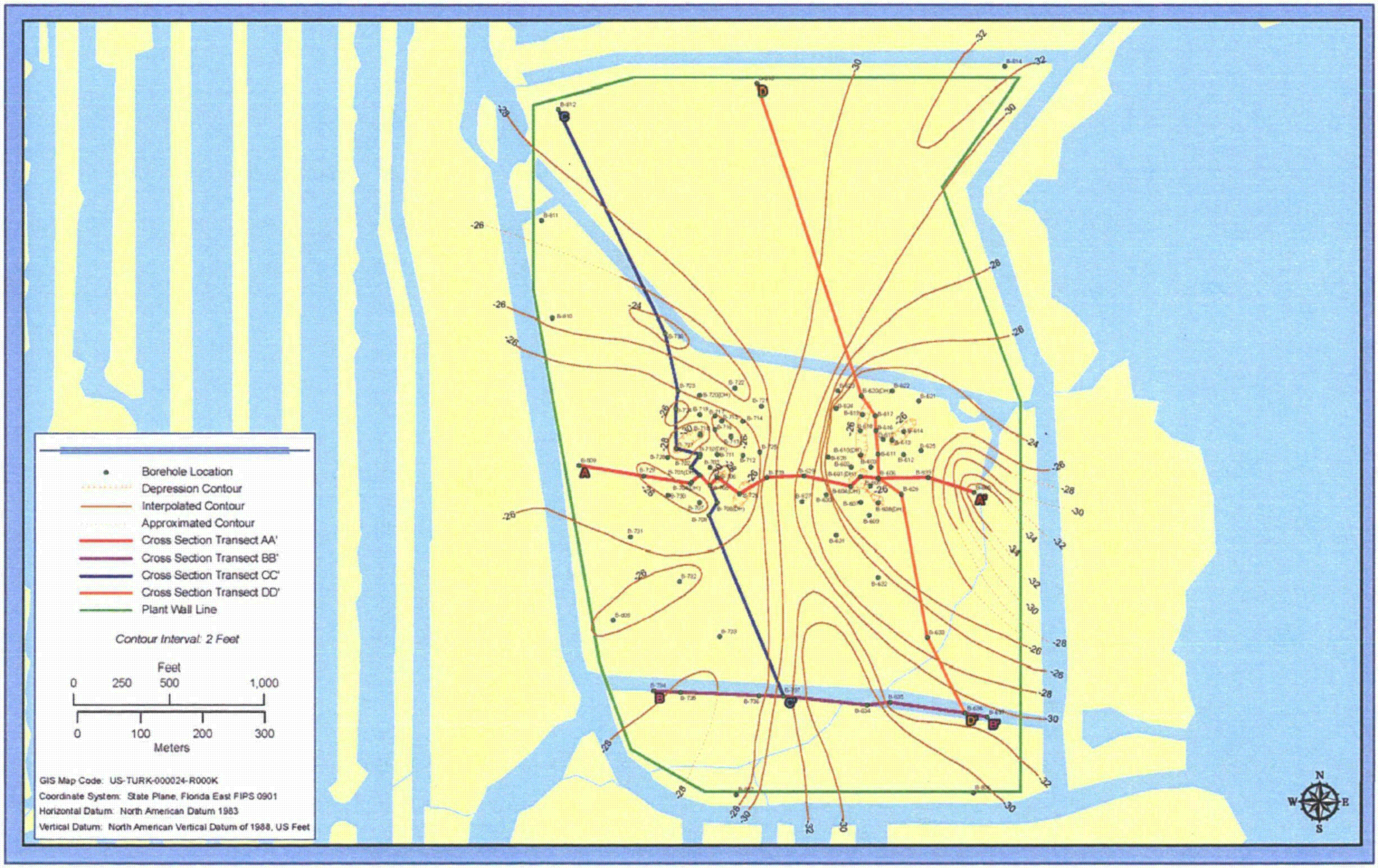
As shown on Figure 1, the top of the Key Largo Formation ranges in elevation from about -25 to -35 feet NAVD 88, with a minimum elevation of -35 feet NAVD 88. As shown on the updated Figure 2.5.1-343, the top of the Fort Thompson Formation ranges in elevation from about -45 to -55 feet NAVD 88, with a minimum elevation of about -55 feet NAVD 88.

c) The location of cross section lines A, B, C, and D are plotted on the updated Figures 2.5.1-342, 343, and 344 and Figure 1.

d) The updated structure contour map for the Key Largo Formation is provided in this response as Figure 1 and will be a new figure, Figure 2.5.1-349, in a future revision of the FSAR. The updated isopach map for the Key Largo Formation is provided as FSAR Figure 2.5.1-342.

e) The possible implication of the "closed" circles in the structure contour map of the Key Largo Limestone are slight depressions that could be interpreted to be forming in a shallow patch reef environment during sea level fluctuation

Figure 1. Structure Contour Map: Top of Key Largo Limestone




Source: FSAR 2.5.1 Reference 708

This response is PLANT SPECIFIC.

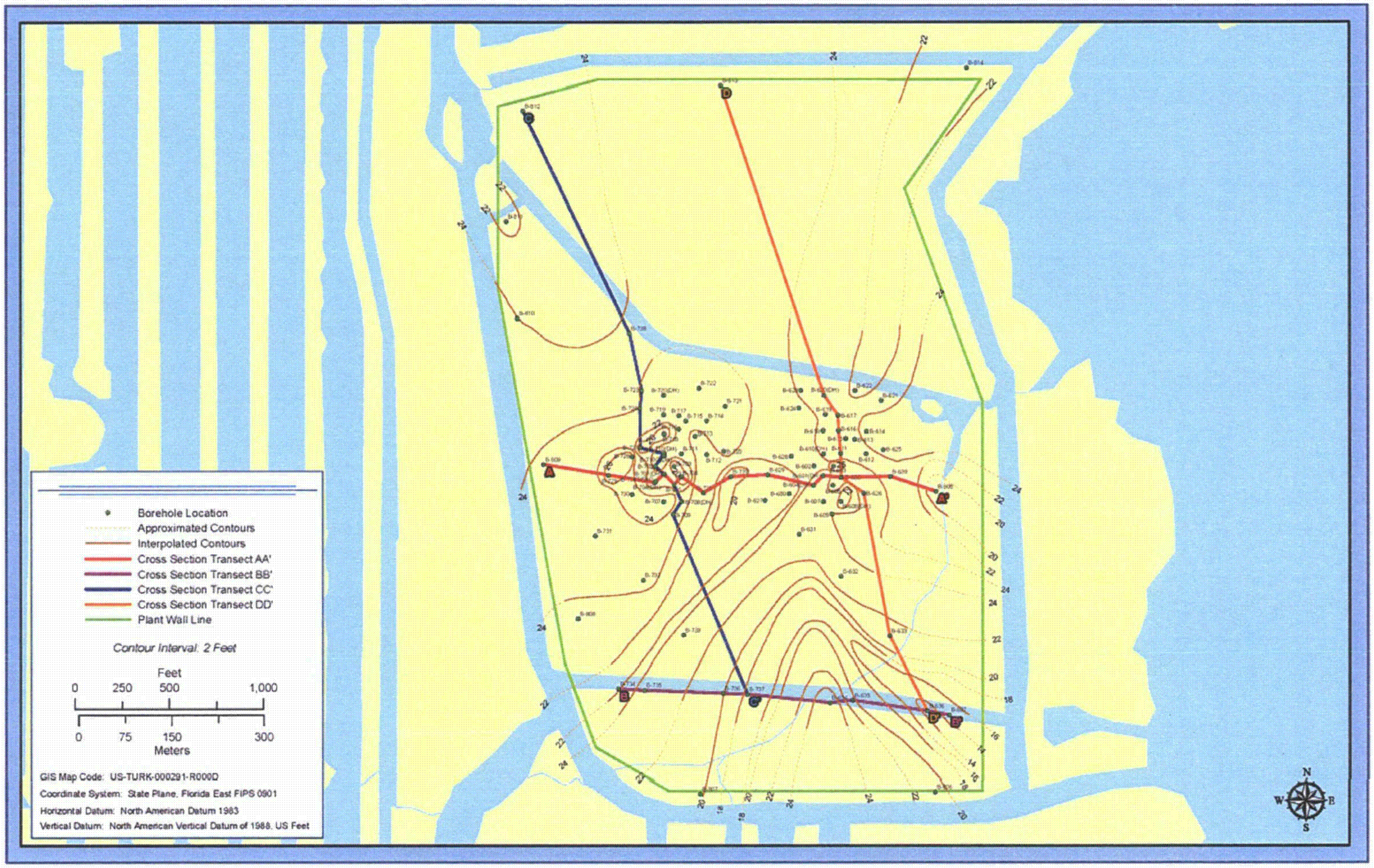
**References:**

None

**ASSOCIATED COLA REVISIONS:**

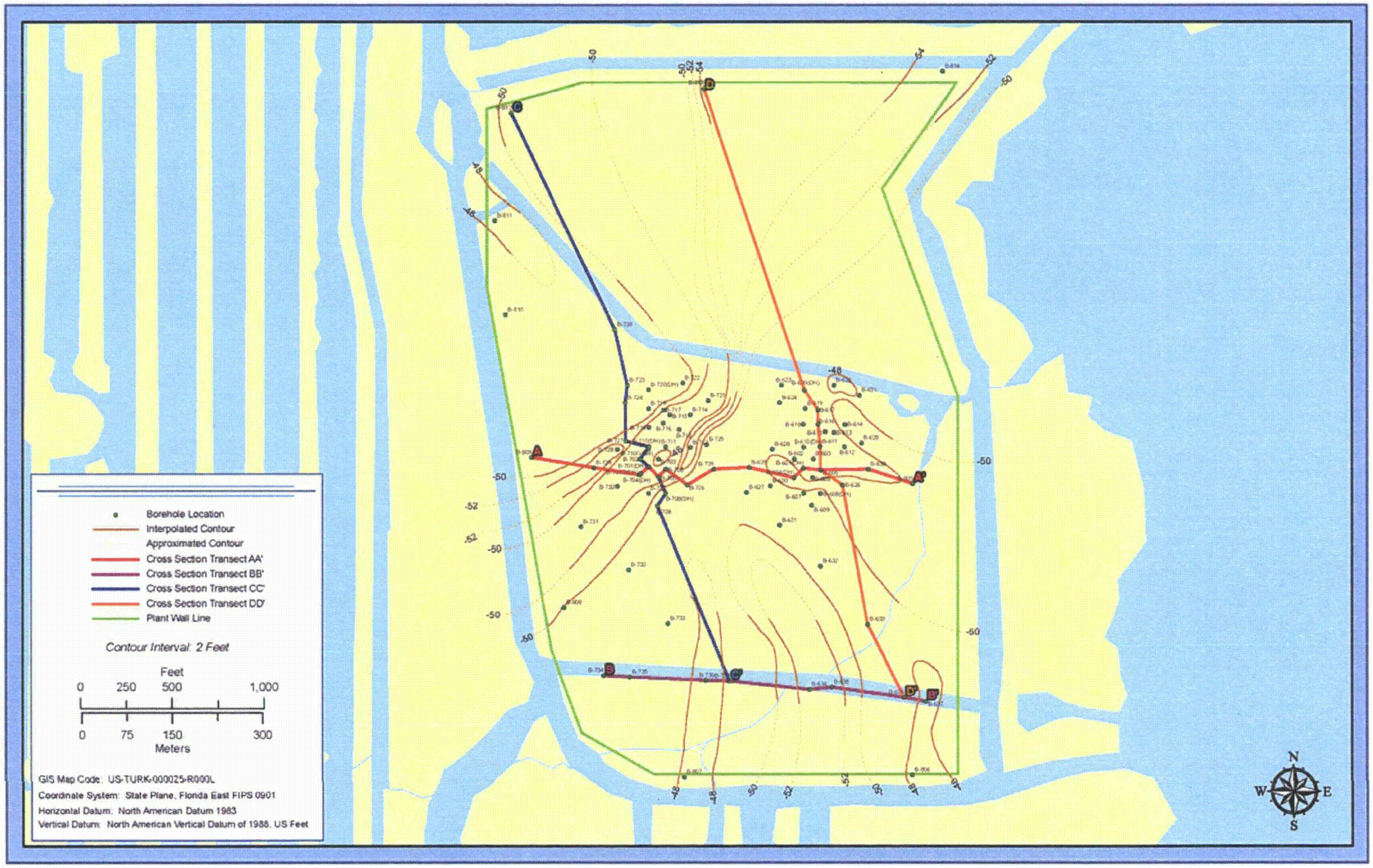
The FSAR Subsection 2.5.1 Figures 2.5.1-342, 343, and 344 will be replaced and one new figure, Figure 2.5.1-349, will be added in a future revision of the FSAR.

Figure 2.5.1-342 Isopach of the Site: Key Largo Limestone



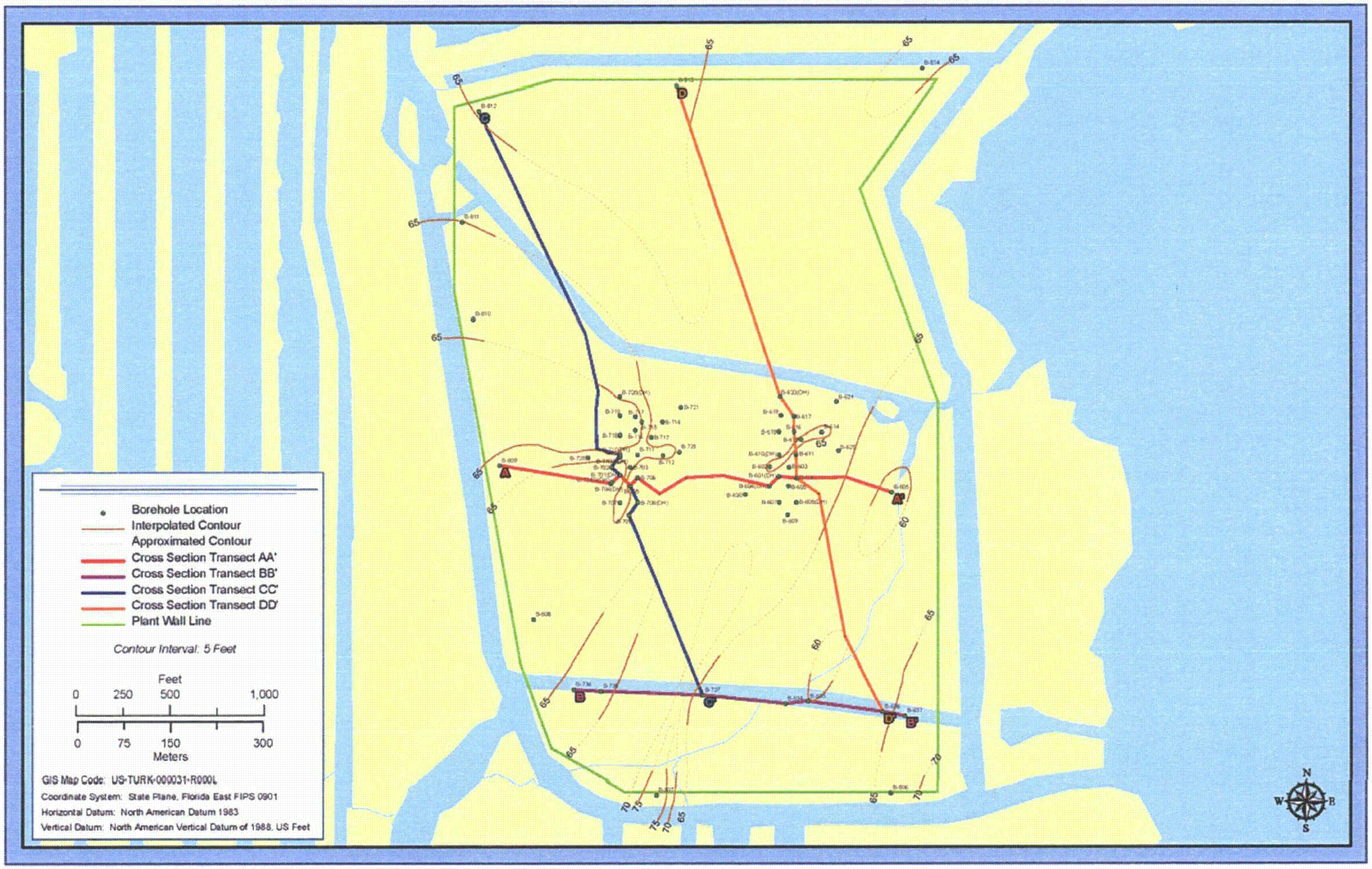

Source: Reference 708

Figure 2.5.1-343 Structure Contour Map: Top of Fort Thompson Formation



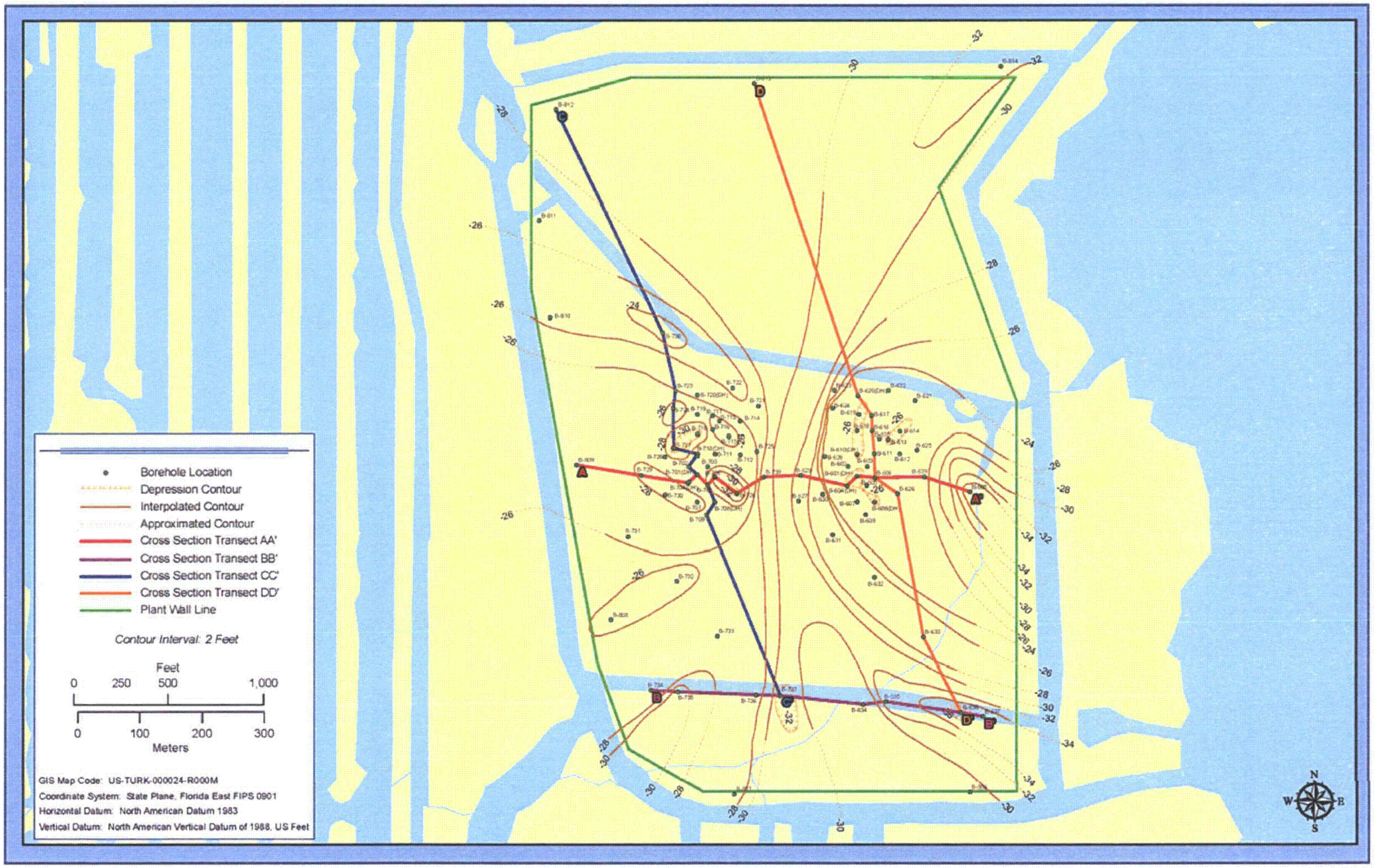

Source: Reference 708

Figure 2.5.1-344 Isopach of the Site: Fort Thompson Formation




Source: Reference 708

Figure 2.5.1-349 Structure Contour Map: Top of Key Largo Limestone




Source: Reference 708

**ASSOCIATED ENCLOSURES:**

None

**NRC RAI Letter No. PTN-RAI-LTR-041**

**SRP Section: 02.05.01 - Basic Geologic and Seismic Information**

QUESTIONS from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

**NRC RAI Number: 02.05.01-18 (eRAI 6024)**

FSAR Figures 2.5.1-274 through 278 and 280, 281, and 287 shows annotated seismic sections, however the staff notes that more information is needed in order to evaluate the relative ages of deformation shown in these seismic cross sections.

In order for the staff to fully understand the regional site geology area and in support of 10 CFR 100.23, please indicate the ages and formation names, if known, of the various sedimentary strata on these figures. Please clarify what is the interpreted depth to faulted strata.

**FPL RESPONSE:**

Figure 2.5.1-274

The seismic line in Figure 2.5.1-274 is from FSAR 2.5.1 Reference 785.

Schalger et al. (1988) (FSAR 2.5.1 Reference 432, hereafter referred to as Schalger et al. (1988)) identified eleven prominent seismic sequence boundaries above a target horizon, which they interpreted to be a buried shallow-water carbonate platform, with an Albian-Cenomanian age. Sheridan et al. (1981) (FSAR 2.5.1 Reference 424) had hypothesized that this platform could be mid-Cretaceous. The only age information provided by Schlager et al. (1988) is for the 8/9 boundary, which is the only well-sampled part of the section at site 626. They correlate the debris flows and turbidites sampled there with the Great Abaco Member of the Blake Ridge Formation, which would mean sequence 9 is composed of middle Miocene deposits. Schlager et al. (1988) note that consistent fault offset is only seen at the sequence 1/2 boundary. One of these faults is interpreted to almost reach the 2/3 boundary, which lies at a depth of 1.74 kilometers beneath sea level and roughly 940 meters beneath the seafloor (assuming a mean water depth of 800 meters, see Table 5 and Figure 13 from Schlager et al., 1988). This faulting occurred between the deposition of mid-Cretaceous and middle Miocene sequences.

The annotated revised figure is presented in the Associated COLA Revisions section.

Figure 2.5.1-275

FSAR Figure 2.5.1-275 shows a seismic section from Van Buren and Mullins (1983) (FSAR 2.5.1 Reference 791, hereafter referred to as Van Buren and Mullins (1983)) depicting the Walker's Cay fault and four seismic sequences NLBB-1 (youngest) through NLBB-4 (oldest).

Van Buren and Mullins (1983) interpret layer NLBB-4 as shallow-water platform interior carbonates, which they correlate to the ~80 Ma boundary between Santonian and Campanian limestones. This is also the top of sequence BP-4 from Shipley et al. (1978), which contained Santonian to mid-Cenomanian strata.

Van Buren and Mullins (1983) correlate layer NLBB-3 with the top of sequence BP-3 of Shipley et al. (1978), containing Campanian to Maestrictian sediments (~65 Ma according to Van Buren and Mullins (1983), figure 6).

Layer NLBB-2 is interpreted as fine-grained periplatform oozes and submarine slide/sedimentary gravity deposits. Van Buren and Mullins (1983) correlate the unconformity at the top of this layer with the late Oligocene drop in sea level (~30 Ma), which would mean it corresponds to the Paleocene to late-Oligocene sequence BP-2 of Shipley et al. (1978).

Layer NLBB-1 is interpreted as fine-grained periplatform oozes and sediment gravity flow deposits, which is consistent with core samples. Van Buren and Mullins (1983) date this layer as Late Oligocene to recent, but don't formally compare to results from Shipley et al. (1978). Van Buren and Mullins (1983), Figure 6 shows NLBB-1 corresponding to BP-1 from Shipley et al. (1978), though.

Depth to faulted strata is not discussed by Van Buren and Mullins (1983). The base of NLBB-1 is clearly offset, but the upper half of the thickness of the Late Oligocene to recent sedimentary package has continuous, apparently unfaulted, reflectors, even in the region where Van Buren and Mullins (1983) tentatively dashed a continuation of the fault plane. Using the scale provided in the figure, the depth to the top of faulted NLBB-2 looks to be ~1175 meters below sea level (~175 meters beneath sea floor). Stratigraphy drilled in ODP Hole 627B indicate that at similar water depths this depth beneath sea floor corresponds to seismic sequence D, within early Miocene debris flows (Austin et al., 1986a).

The revised annotated figure is presented in the Associated COLA Revisions section.

Figure 2.5.1-276

Figure 2.5.1-276 is also taken from Van Buren and Mullins (1983) and uses the same stratigraphy as Figure 2.5.1-275. Depth to faulted strata is difficult to discern, as much of the faulting in this figure is speculative (drawn with dashed lines). The westernmost fault is drawn with the most certainty; depth to the top of faulted layer NLBB-2 is ~1150 meters below sea level (~150 m beneath sea floor). Again using stratigraphy from the ODP Hole 627B as comparison, this depth to faulted strata would fall within seismic Sequence C, early to middle Miocene debris flows (Austin et al., 1986a and 1988) (FSAR 2.5.1 Reference 785).

The revised annotated figure is presented in the Associated COLA Revisions section.

Figure 2.5.1-277

Austin et al. (1988) (FSAR 2.5.1 Reference 785, hereafter referred to as Austin et al. (1988) identify seven seismic stratigraphic sequences that they label A through G (top to bottom). Comparing with other studies, Austin et al. (1988) indicate that the F/G boundary corresponds to the NLBB-3/4 boundary of Van Buren and Mullins (1983), marking the top of the uppermost Albian shallow-water platform carbonates sampled at Site 627 (Austin et al., 1986a). Above this, seismic sequence boundary C/D is correlated with the boundary between latest early Miocene debris flows and Early Paleocene to Early Miocene limestone at Site 627 (Austin et al., 1986a). Based on depth and seismic velocity comparisons, the

C/D boundary of Austin et al. (1986a, 1988) would correspond to the NLBB-1/2 boundary from Van Buren and Mullins (1983).

Faulting in seismic sequences A-C is imperceptible, therefore, the base of C appears to be the depth at which faulted strata are found. The depth to the bottom of sequence C (meters below sea level) is contoured in figure 8 of Austin et al. (1988), which shows the base of sequence C shallowing along LBB-13 from ~1300 m in the east to ~1160 meters in the west. Figure 11 from Austin et al. (1988) contours the thickness of sequences A-C; along LBB-13 these sequences range from 250-300 meters thick.

The revised annotated figure is presented in the Associated COLA Revisions section.

Figure 2.5.1-278

FSAR Figure 2.5.1-278 shows a portion of a seismic line crossing the Santaren anticline published in Masaferro et al., (2002) (FSAR 2.5.1 Reference 479, hereafter referred to as Masaferro et al. (2002)). The authors correlated strong reflectors in their data to reflectors identified by Eberli et al. (1997) (FSAR 2.5.1 Reference 385, hereafter referred to as Eberli et al. (1997)) further to the northwest. Eberli et al. (1997) dated their reflectors using biostratigraphic indicators collected from ODP Leg 166 boreholes, and Masaferro et al. (2002) adopt these ages when dating the key layers from C-M (bottom to top). Intermediate layers (C1, G1, etc.) are undated.

The ages of layers C-M are identified on the figure. They are: C – 23.7 Ma; D – 23.2 Ma; E – 19.2 Ma; F – 16.0 Ma; G – 15.1 Ma; H – 12.2 Ma; I – 10.1 Ma; J – 9.0 Ma; K – 6.2 to 8.7 Ma; L – 5.6 Ma; M – 3.6 Ma. Individual formations are not identified, instead, the authors rely on the general characterization provided Ball et al. (1985) (FSAR 2.5.1 Reference 501) and Eberli et al. (1997), who identify the entire sequence as mixed pelagic/hemipelagic sediments intermittently interrupted by platform-derived carbonates with varying amounts of clay.

Bed E (19.2 Ma) is the first layer that overlaps, rather than onlaps, the Santaren anticline, and represents a transition to much lower fold growth rates. After deposition of bed L (5.6 Ma), fold uplift rates are essentially zero.

The revised annotated figure is presented in the Associated COLA Revisions section.

Figures 2.5.1-280 and 281

Figures 2.5.1-280 and 281 are seismic lines from offshore Cuba shown in Echevarria-Rodriquez et al., (1991) (FSAR Reference 497, hereafter referred to as Echevarria-Rodriquez et al., (1991)). In both figures, the authors use roman numerals to designate seismic horizons of Tertiary, Upper Cretaceous and Upper Jurassic age. They do not trace these horizons, but we have presented a best effort at doing so in the attached annotated figure. Figure 2.5.1-280, which depicts seismic line A-A', indicates that faults tip out just below the seismic horizon labeled "Tertiary sediments." In Figure 2.5.1-281, seismic line B-B' has several faults, the youngest of which tips out below the Upper Cretaceous seismic horizon. No other stratigraphic information for these seismic lines is presented in Echeviarria-Rodriquez et al. (1991).

The revised annotated figure is presented in the Associated COLA Revisions section.

Figure 2.5.1-287

Moretti et al. (2003) (FSAR 2.5.1 Reference 484, hereafter referred to as Moretti et al. (2003)) identify seismic reflectors A-M (bottom to top). These reflectors were correlated to the known lithostratigraphy of north-central and western Cuba using existing and newly-acquired analysis of samples from western Cuba. The authors note that some ages presented are hypothetical, and correlation to seismic reflectors is open to debate.

Groups A-C are interpreted as Jurassic synrift clastic deposits. Group A is correlated to the San Cayetano Formation, and is thought to have been deposited 210-160 Ma. Group B is dated from 160-152 Ma, and includes the upper San Cayetano Formation along with the Francisco Formation. Group C is simply dated as Oxfordian, and is associated with the San Cayetano Formation based on source-rock potential.

Groups D-F are interpreted as middle Oxfordian to Hauteverian postrift regional platform carbonates. Group D is divided in two. The lower section (D1) is correlated with the Jagua Formation, which is known to form the base of this carbonate platform in western Cuba. The suggested age is upper Oxfordian. The authors correlate the upper section (D2) with the Kimmeridgian San Vicente Formation. Group E is thought to be composed of the Americano, Artemisa, and Cifuentes formations, which span upper Kimmeridgian to Tithonian time. The authors suggest Group F comprises the Tumbadero, Sumidero, and Ronda formations, spanning Berriasian to Hauteverian time.

Groups G-J are interpreted as middle Cretaceous Bahama Channel deposits. Group G is correlated with the Aptian-Albian-Early Cenomanian Pons and Carmita formations by comparing onshore and offshore drill core data. Group H is correlated with the Cenomanian/Turonian Angelica Formation based on new onshore drill core analysis. The authors propose that Group J is composed of Paleocene sediments.

Groups I-M are not discussed in the text, but figure 2 from Moretti et al. (2003) associates these groups with relative ages. Group I is thought to be late Cretaceous, groups J, K, and L span the Paleogene, and Group M is Neogene.

Numerous normal faults cut Upper Jurassic and older horizons. One offshore normal fault tips out within Group M Miocene-Pleistocene strata, within ~0.12 seconds of the seafloor (two way travel time). To the south, several faults associated with the Cuban thrust belt are depicted, but the seismic horizons are not traced near these structures. In the text, however, the authors describe this thrusting as Eocene in age (FSAR 2.5.1 Reference 484).

The revised annotated figure is presented in the Associated COLA Revisions section

This response is PLANT SPECIFIC.

**References:**

Austin, J. A., Schlager, W., Palmer, A. A., et al., *Proceedings Initial reports ODP Leg 101*, Chapter 6 Site 627: Southern Blake Plateau, pp. 111-212, 1986a.

Echevarria-Rodriguez, G., Hernandez-Perez, J., Lopez-Quintero, J., Lopez-Rivera, R., Rodriguez-Hernandez, J., Sanchez-Arango, R., Socorro-Trujillo, R., Tenreyro-Perez, and

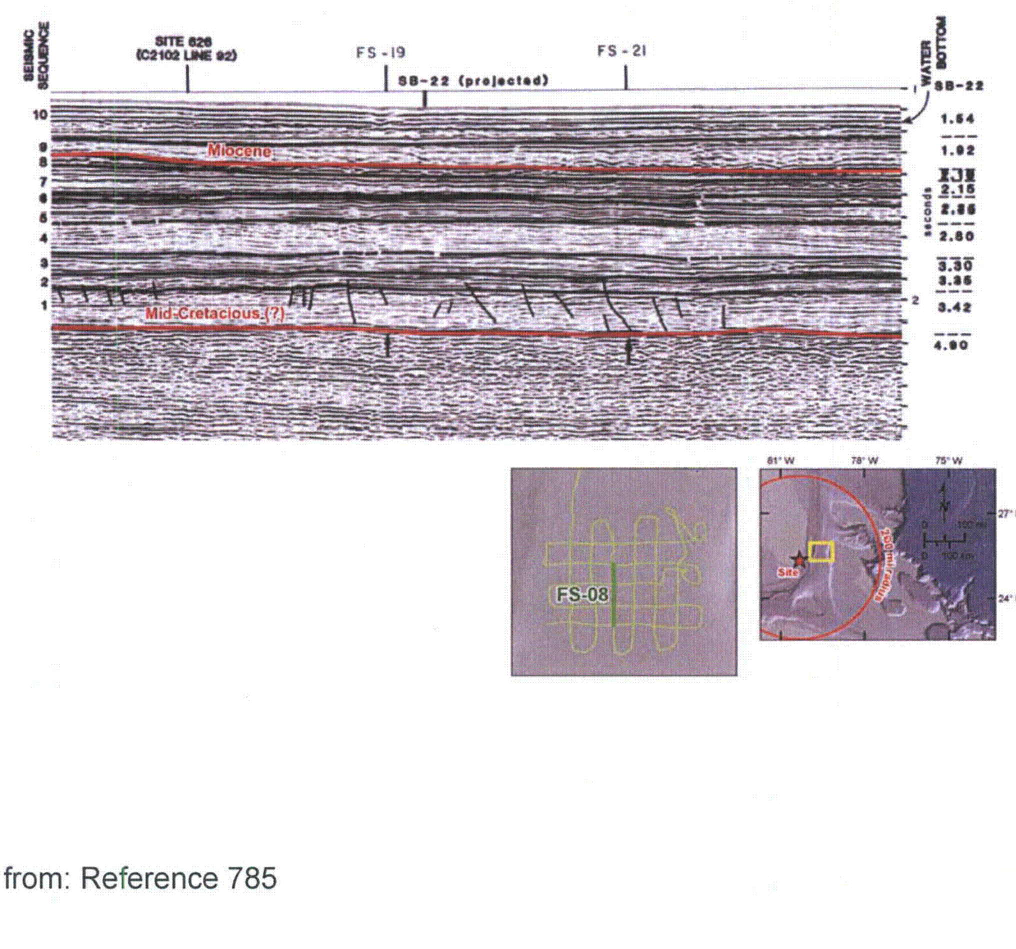
Yparraguirre-Pena, J., "Oil and Gas Exploration in Cuba," *Journal of Petroleum Geology*, v. 14, no. 3, pp. 259-274, 1991.

Shipley, T.H., Buffler, R.T., and Watkins, J.S., *Seismic stratigraphic and geologic history of Blake Plateau and adjacent western Atlantic continental margin, American Association of Petroleum Geologists Bulletin,* v. 62, pp. 792-812, 1978

**ASSOCIATED COLA REVISIONS:**

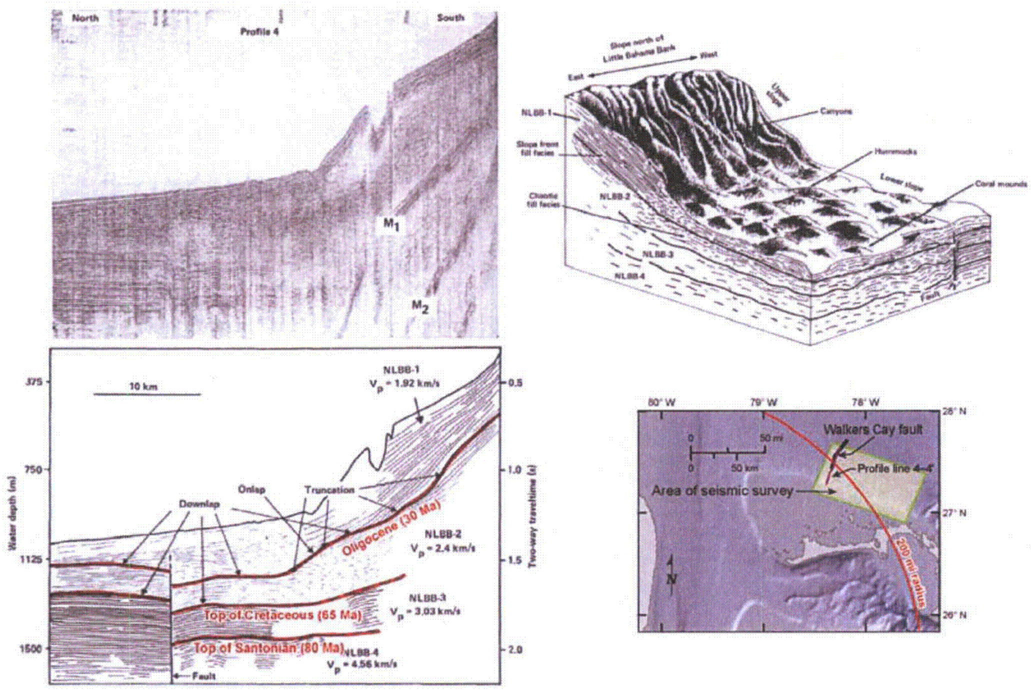
FSAR Figures 2.5.1-274, 275, 276, 277, 278, 280, 281, and 287 will be replaced with the revised figures shown below in a future revision of the FSAR.

**Figure 2.5.1-274 Interpreted Versions of the Southern Half of Profile FS-08 in the Straits of Florida**



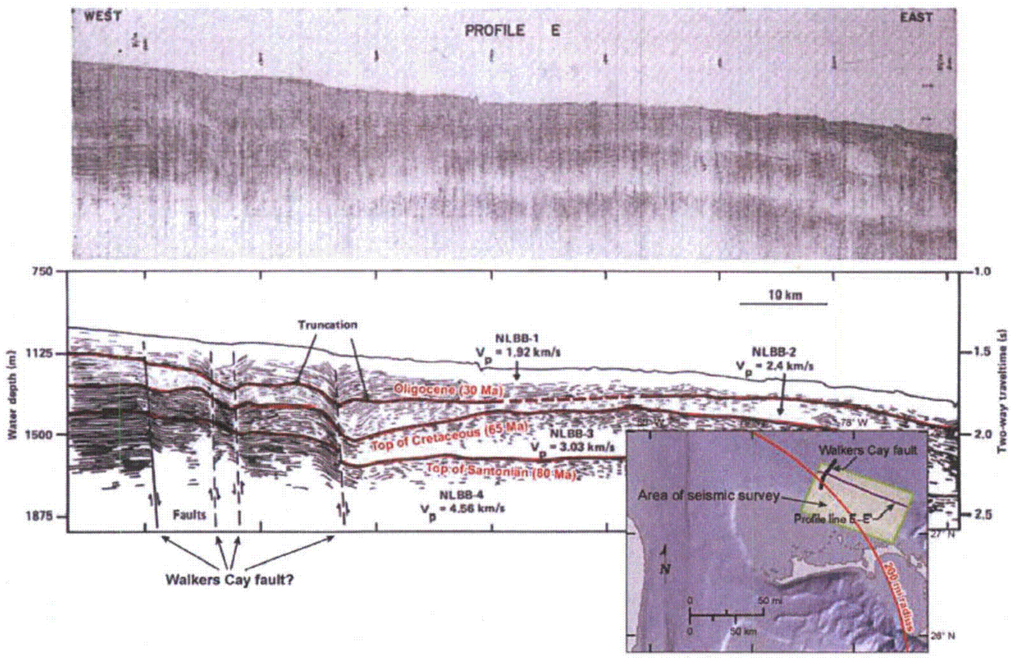

Modified from: Reference 785

**Figure 2.5.1-275 Seismic Line and Interpretation across the Walkers Cay Fault**



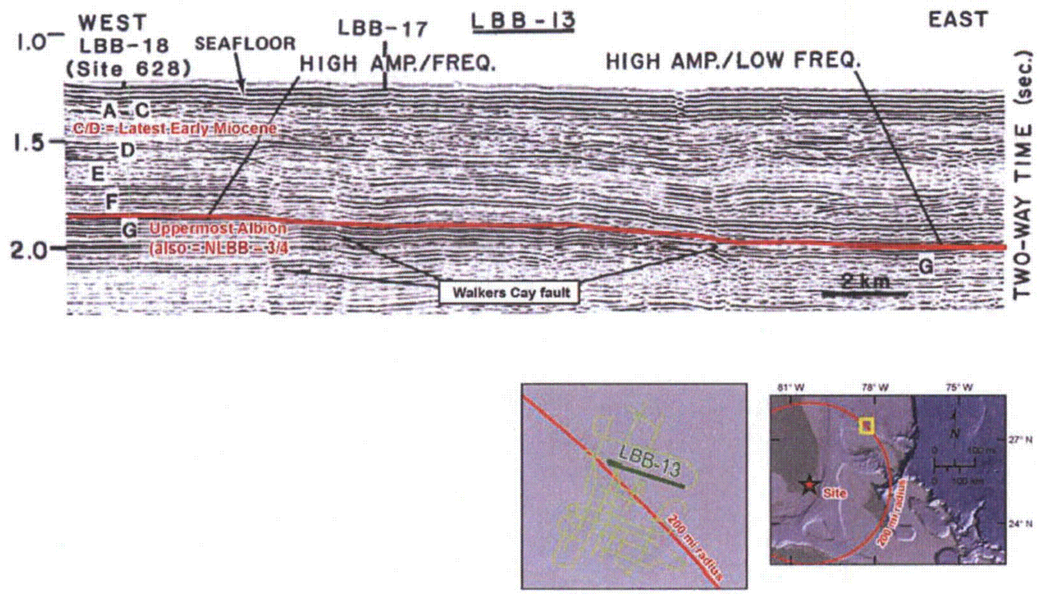

Modified from: Reference 791

**Figure 2.5.1-276 Seismic Line and Interpretation across the Walkers Cay Fault**



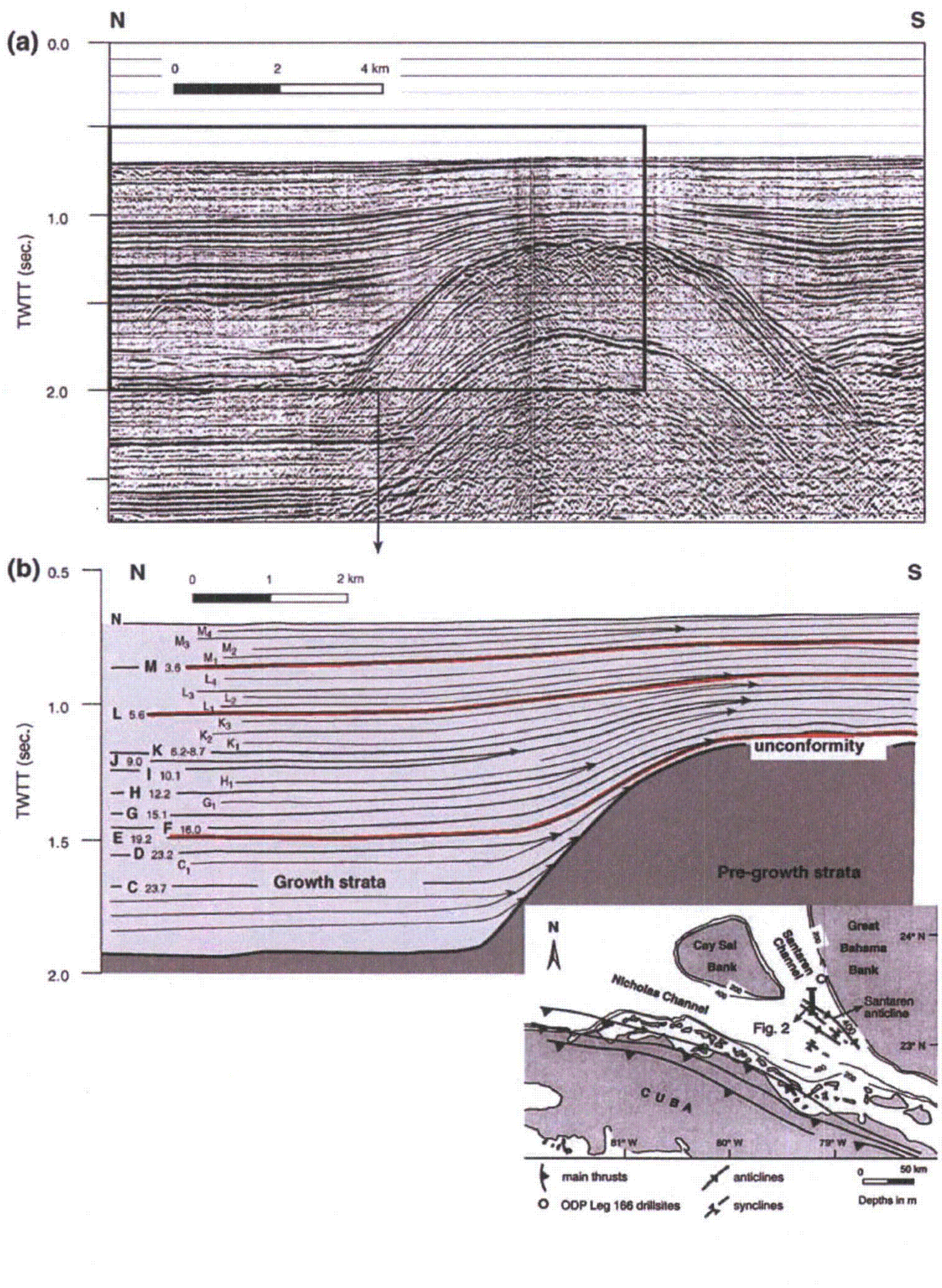

Source: Reference 791

**Figure 2.5.1-277 Seismic Line along Edge of Little Bahama Bank and Walkers Cay Fault**



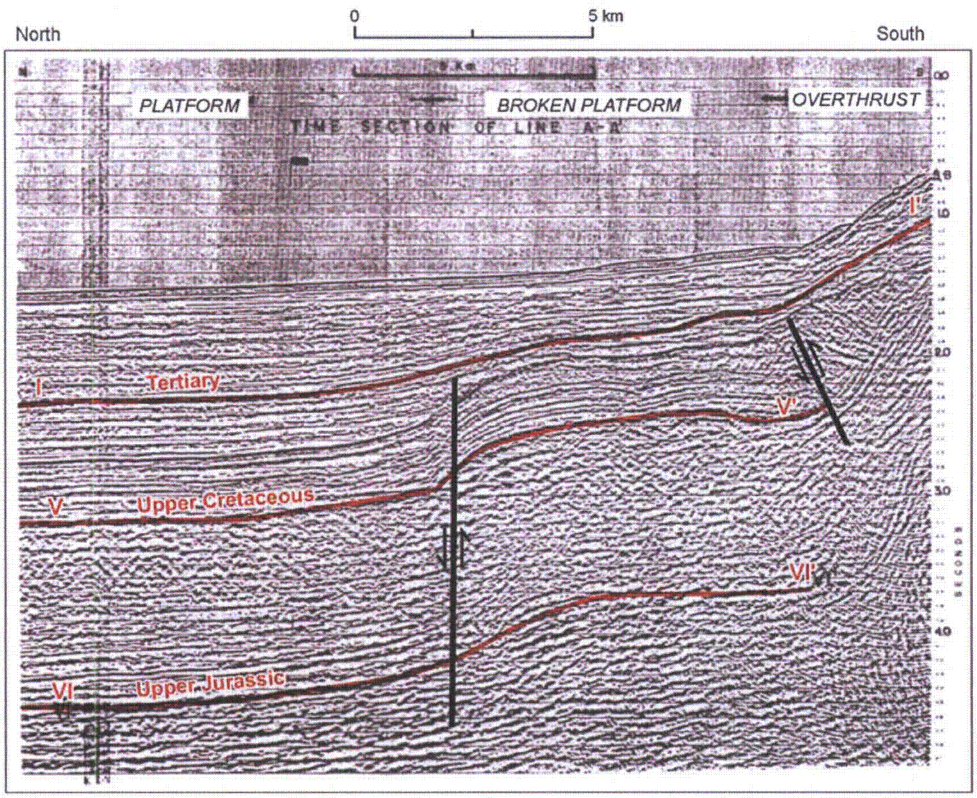

Note: Red star denotes Turkey Point Units 6 & 7.
Modified from: Reference 785

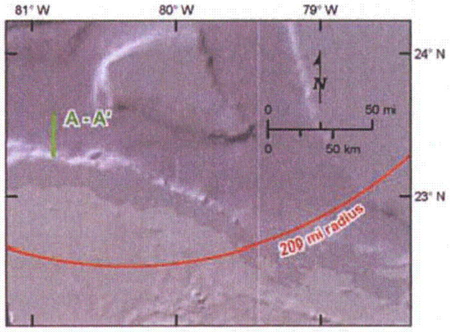
**Figure 2.5.1-278 Seismic Line and Interpretation across the Santaren Anticline**




Source: Reference 479

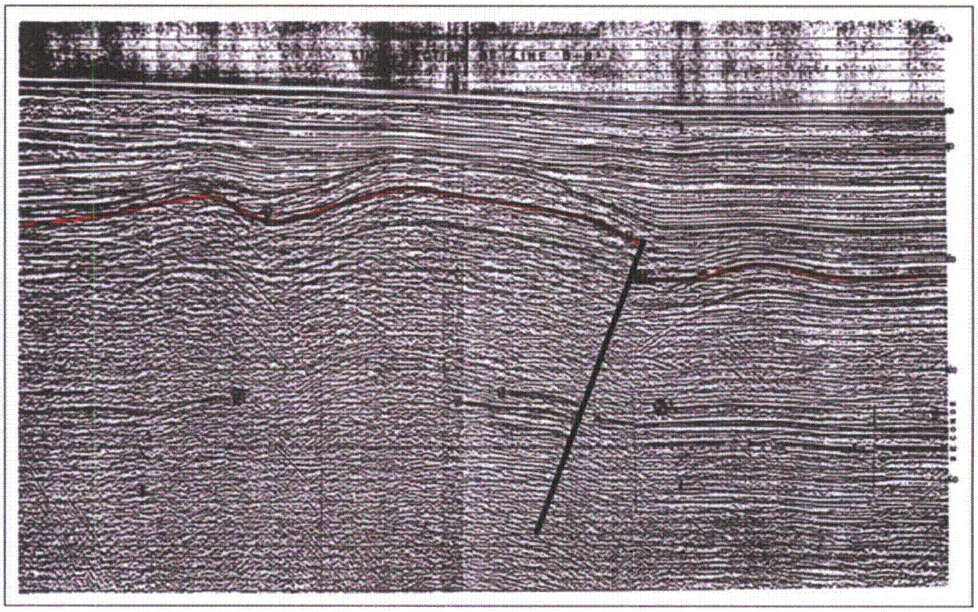
**Figure 2.5.1-280 Offshore Interpreted Seismic Line, Cuban Thrust Belt**

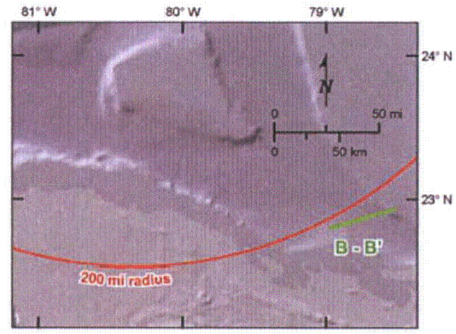



Modified from: Reference 497

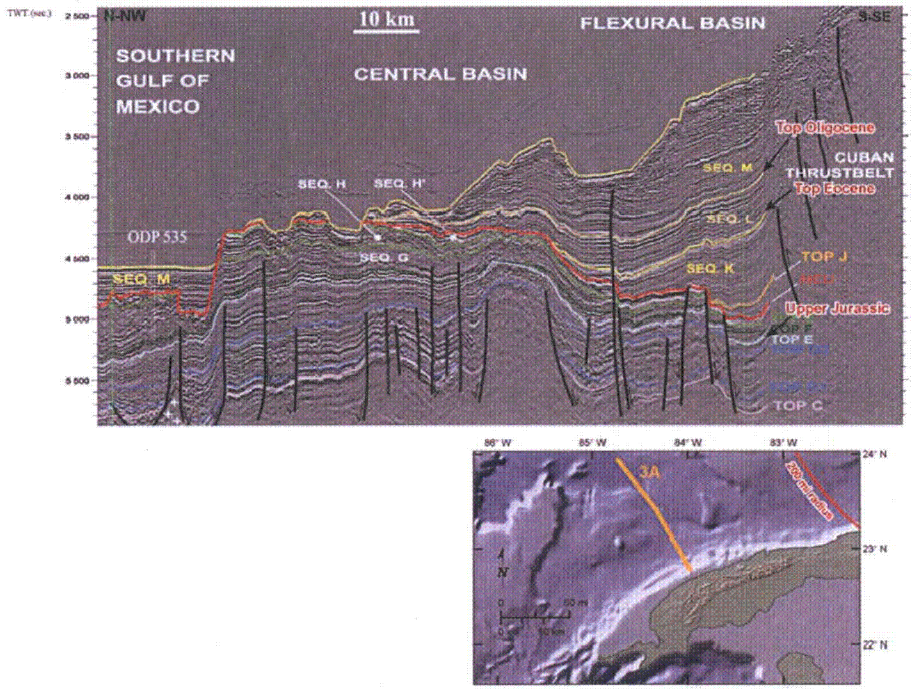
**Figure 2.5.1-281 Offshore Interpreted Seismic Line, Cuban Thrust Belt**






Modified from: Reference 497

**Figure 2.5.1-287 Interpreted Seismic Line across Cuban Thrust Belt, Line 3A**




Modified from: Reference 484

## ASSOCIATED ENCLOSURES:

None

**NRC RAI Letter No. PTN-RAI-LTR-041**

**SRP Section: 02.05.01 - Basic Geologic and Seismic Information**

QUESTIONS from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

**NRC RAI Number: 02.05.01-19 (eRAI 6024)**

FSAR 2.5.1.1.1.3.2.2, "Structures of the Bahamas Platform" passage, states that because the Bahamas platform is largely submerged, all information about potential structures is gained from interpretations of seismic lines, and consequently is subject to limitations. The FSAR adds that the majority of the inspected and available seismic lines confirm the unfaulted nature of Cretaceous and younger strata across the Bahamas Platform and southern Florida Platform. The staff considers, however, that more assessment is needed to understand the tectonic structures in the Bahamas platform.

In order for the staff to determine the adequacy of the regional geologic characterization and in support of 10 CFR 100.23, please asses the following questions:

a. Describe the limitations that apply to the detection of active tectonic structures deduced from seismic reflection data within the Bahamas Platform.

b. Discuss the uncertainties in resolution and age control of the seismic interpretations, especially in cases where seismic data is used to infer the unfaulted nature of Cretaceous and younger strata.

**FPL RESPONSE:**

<u>a) Describe the limitations that apply to the detection of active tectonic structures deduced from seismic reflection data within the Bahamas Platform</u>

Detection of active tectonic structures from seismic reflection data is contingent upon resolution of structures produced by tectonic deformation in the seismic reflection data and determination of the ages of the youngest lithologies that the resolved deformation effects. Limitations in resolving structure in seismic reflection data are related to the vertical resolution available from the specific data set (details discussed below) and resulting constraints in resolving offset of seismic events or structurally induced warping of events. Also, in order to determine if the imaged deformation results from "active" tectonism, it is necessary that the youngest events that can be clearly resolved with significant signal to noise ratio be of geologically recent origin.

Several generations of seismic reflection data are available for the Bahamas Platform and the vertical resolution available for each would depend on the usable frequency content available from the specific acquisition and processing (for instance Anselmetti et al., 2000 (FSAR 2.5.1 Reference 228) quote a resolution of 5 m). Also, the Bahamas Platform is the site of recent active deposition and is capped in many places by Quaternary pelagic sediments (Austin et al., 1988) (FSAR 2.5.1 Reference 785), so resolution of relatively recent deformation should be recognizable.

b) Discuss the uncertainties in resolution and age control of the seismic interpretations, especially in cases where seismic data is used to infer the unfaulted nature of Cretaceous and younger strata.

Vertical resolution uncertainties in seismic reflection data are discussed in detail in Sheriff and Geldart (1994; p.172-177) but generally, for high signal to noise ratio data, the resolution limit is considered to be $1/4^{th}$ the dominant wavelength of the reflection data. Uncertainty in age control on the seismic events, and consequently the age of permissible deformation, is dependent on correlating seismic reflection events to datable elements in the imaged stratigraphy. How well this can be accomplished depends on the amount and types of well control for the seismic data set such as fossil age control, velocity logs and check shot surveys. The Deep Sea Drilling Program, Ocean Drilling Program and industry wells have been used for this purpose (see Sheridan et al., (1981) (FSAR 2.5.1 Reference 424) for an example.) Although these sources do not explicitly state the resolution of their seismic data, Harwood and Towers (1988) (FSAR 2.5.1 Reference 476) used these data and state that they were able to resolve seismic sedimentologic features to better than 10 m.

This response is PLANT SPECIFIC.

**References:**

*Sheriff, E. E., Geldart, L. P. (1994) Exploration Seismology. Cambridge University Press, 592p*

**ASSOCIATED COLA REVISIONS:**

None

**ASSOCIATED ENCLOSURES:**

None

**NRC RAI Letter No. PTN-RAI-LTR-041**

**SRP Section: 02.05.01 - Basic Geologic and Seismic Information**

QUESTIONS from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

**NRC RAI Number: 02.05.01-20 (eRAI 6024)**

FSAR Section 2.5.1.1.4, states with respect to the "Contemporary Stress Regime within the Site Region", that "the boundary between the mid-plate and Gulf Coast stress provinces terminates in the northern Florida Peninsula, but there is a lack of stress data from areas near the Florida Peninsula and most of Cuba. Because the southern Florida Peninsula doesn't exhibit the geologic features (such as salt-rooted normal faults) associated with the Gulf Coast stress province, the site region is generally interpreted to be part of the mid-plate stress province (Reference 705) (Figure 2.5.1-330)."

In order for the staff to determine the configuration of the state of stress within the site region and in support of 10 CFR 100.23, please address the following:

a) Address the focal mechanism for the Sept 10, 2006 Gulf of Mexico earthquake with respect to the Gulf Coast stress province and show stress orientation indicated by this focal mechanism on Figure 2.5.1-330.

b) Indicate on Figure 2.5.1-330 the boundary between the Gulf coast and mid plate stress provinces as it is currently interpreted within the TPNPP site region.

c) Explain if analyses were performed to characterize the stress direction and magnitude in northern Cuba in light of the abundant seismicity along the northern parts of Cuba. Indicate on Figure 330 how the boundaries of the Gulf Coast and the mid plate stress provinces resolve in the vicinity of northern Cuba.

**FPL RESPONSE:**

<u>a) Address the focal mechanism for the Sept 10, 2006 Gulf of Mexico earthquake with respect to the Gulf Coast stress province and show stress orientation indicated by this focal mechanism on Figure 2.5.1-330.</u>

As discussed in the FSAR (Subsection 2.5.1.1.4), the Gulf Coast stress province is characterized by northeast-southwest to north-northeast to south-southwest horizontal tension, driven by sediment loading and subsidence of the gulf. The resulting "typical" faults in this regime are down-to-the-gulf growth faults in Cenozoic cover sediments that glide over a weak salt layer, the Louann formation (e.g., Wu et al., 1990). This is distinct from the mid-plate stress province that most of the CEUS falls into, characterized by northeast-southwest compression driven by forces originating at the mid-Atlantic Ridge.

The focal mechanism for the September 10, 2006 Gulf of Mexico earthquake, shown in Attachment A, is representative of thrust faulting along a steep northwest-striking fault plane, with $\sigma 1$ oriented at 214° with a plunge of 19° (FSAR 2.5.1 Reference 703). This is consistent with the mid-plate stress province of the CEUS, rather than the Gulf Coast stress province, and mostly likely means that the Sept 10, 2006 earthquake was produced by basement faulting beneath the Louann salt formation (Angell and Hitchcock, 2007). This would be consistent with the depth of the earthquake, which at 22-31 kilometers (FSAR

Reference 2.5.2-290) is well beneath the 5-14 kilometers of sedimentary cover in the gulf and associated stresses. Stresses acting on basement faults in the Gulf of Mexico would instead align with those experienced by the rest of the CEUS.

As described in FSAR Subsections 2.5.2.4.3.1 and 2.5.2.4.3.2, the original EPRI-SOG source zones within the site region were updated to account for the September 10, 2006 Emb 5.90 Gulf of Mexico earthquake. Figure 2.5.1-330 has now been revised to also include the stress orientation from this event.

b) Indicate on Figure 2.5.1-330 the boundary between the Gulf coast and mid plate stress provinces as it is currently interpreted within the TPNPP site region.

Figure 2.5.1-330 depicts the boundary between the Gulf Coast and mid-plate stress provinces as interpreted by Zoback and Zoback, 1991 (FSAR 2.5.1 Reference 705). We have not extended their stress boundary into the Florida Peninsula for two reasons. First, there is little stress data near the Florida Peninsula and Cuba that can be used to demarcate stress boundaries in this area. Second, the Florida Peninsula lacks the geologic features characteristic of the Gulf Coast stress province. Both of these points are discussed in Subsection 2.5.1.1.4 of the FSAR.

The Gulf Coast stress province describes the area where growth faulting in response to sedimentary loading and subsidence is observed, primarily in the northern gulf. The geomorphic expression of such faulting is clearly evident in the bathymetry depicted in Figure 2.5.1-330. The continental shelf and slope of the northwestern gulf appears highly broken, whereas the shelf of western Florida, the seafloor of the Florida Straits, and the shelf extending north from the Yucatan all appear to be relatively flat and continuous.

Given the lack of stress data and the absence of specific geologic features, the Gulf Coast stress province is not interpreted to lie within the TPNPP site region; as such, we would not draw a boundary between the Gulf Coast and mid-plate stress provinces there.

c) Explain if analyses were performed to characterize the stress direction and magnitude in northern Cuba in light of the abundant seismicity along the northern parts of Cuba. Indicate on Figure 330 how the boundaries of the Gulf Coast and the mid plate stress provinces resolve in the vicinity of northern Cuba.

Analyses were not performed to characterize the stress direction and magnitude in northern Cuba. The stress inversions required for such an analysis rely on a critical mass of focal mechanisms, rather than a catalog of seismicity. Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494) state that focal mechanisms for Cuba are only available along the Oriente fault and at the eastern end of the Nortecubana fault. The magnitudes and locations of the earthquakes in northern Cuba are primarily based on intensity data instead of instrumentation; as such, few focal mechanisms are available for an analysis of the stresses in northern Cuba.

As explained in part (b) above, based on the absence of these salt-rooted normal faults, we do not interpret the Gulf Coast stress province to extend into the Florida Peninsula, nor do we interpret it to extend further south towards Cuba. We would expect that if the stress field in Cuba is different from that of the remainder of the TPNPP site region, (including most of the Florida Platform and portions of the Bahama Platform), the boundary between the two regions would be subparallel to and just offshore of the coast of Cuba. However, stress data are inadequate in the site region to reliably determine whether stress differences exist, and where those boundaries may be.

This response is PLANT SPECIFIC.

**References:**

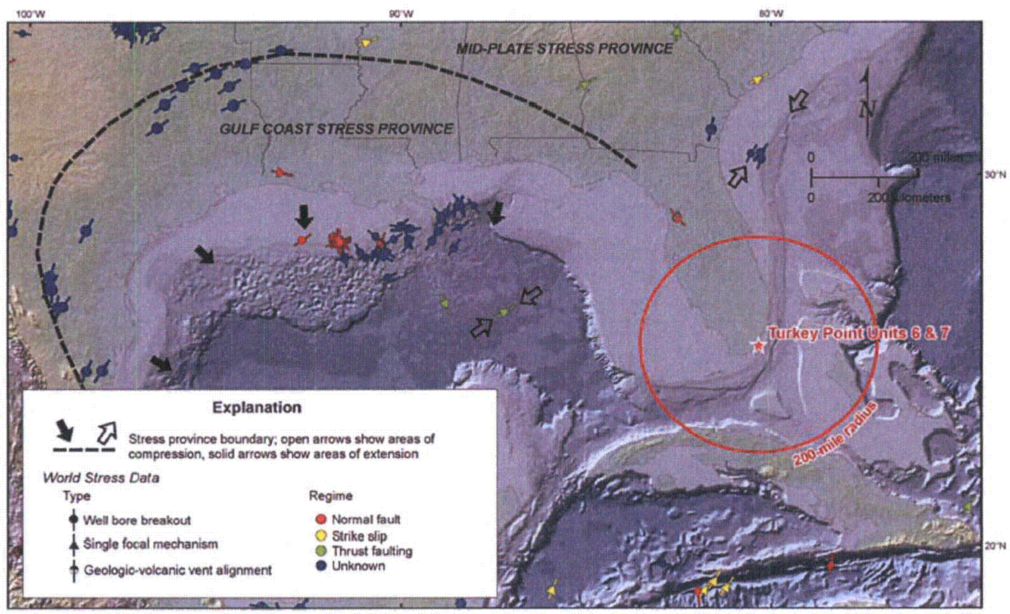
Angell, M. and Hitchcock, C., *A geohazard perspective of recent seismic activity in the northern Gulf of Mexico, Offshore Technology Conference*, Houston, Texas, p. 8, 2007.

Wu, S., Bally, A.W., and Cramez, C., 1990, Allochthonous salt, structure and stratigraphy of the north-eastern Gulf of Mexico. Part II: Structure, Marine and Petroleum Geology, v. 7, pp. 334-370.

**ASSOCIATED COLA REVISIONS:**

FSAR Figure 2.5.1-330 will be replaced with the revised figure shown below in a future revision of the FSAR:

**Figure 2.5.1-330 North America Stress Provinces**




Base Source: Reference 822
Source of world stress data: Reference 731

## ASSOCIATED ENCLOSURES:

None

**NRC RAI Letter No. PTN-RAI-LTR-041**

**SRP Section: 02.05.01 - Basic Geologic and Seismic Information**

QUESTIONS from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

**NRC RAI Number: 02.05.01-21 (eRAI 6024)**

FSAR Section 2.5.2.4.4.3.2, states that an area source model is used for Cuba because of the lack of knowledge on fault behavior and slip rates for Cuban faults with which to support assessment of fault-specific sources. In order to evaluate the possibility of capable tectonic sources within the site region and in accordance with 10 CFR 100.23 please provide a detailed geologic discussion of tectonic features and their potential impact on the PSHA.

**FPL RESPONSE:**

FSAR Subsection 2.5.1.1.1.3.2.4 describes faults and other tectonic features mapped in Cuba. This discussion is supplemented by FPL's responses to RAIs 02.05.01-25 through 02.05.01-28, which will provide related information on specific faults and tectonic features in Cuba. FPL's response to RAI 02.05.01-31 will provide information regarding the suitability of geologic mapping in Cuba for neotectonic assessments and seismic source characterization. FPL's response to RAI 02.05.01-32 will provide related information on identifying capable tectonic features in northern Cuba.

The inclusion of individual faults as sources for use in a Probabilistic Seismic Hazard Analysis (PSHA) requires some knowledge of each proposed fault source's geometry, maximum magnitude (Mmax), and earthquake recurrence. The decision to model intraplate Cuba as an area source, as opposed to multiple fault sources or a combination of fault and area sources, is based on the lack of sufficient information for individual faults in Cuba with which to characterize fault source parameters. Available geologic mapping and literature provide ambiguous, and sometimes conflicting, information on fault activity, geometry, potential segmentation, and, in some cases, even the existence of a fault.

Similar to the central and eastern United States (CEUS), several faults are mapped within intraplate Cuba. However, evidence documenting late Quaternary movement for these faults is lacking. Tectonic features in Cuba formed under different tectonic regimes and stress conditions than the present intraplate environment. A thorough review of literature and geologic maps failed to reveal paleoseismic data or detailed map relations documenting late Quaternary activity of faults within Cuba. Therefore, significant asssumptions are required to categorize geologic structures as capable tectonic sources or seismogenic sources for use in PSHA.

Based on extensive literature reviews and discussions with subject matter experts, no fault in intraplate Cuba has unambiguous data constraining the occurrence of large earthquakes. In addition, there are no paleoseismic trench studies or detailed tectonic geomorphic assessments of faults in northern Cuba. There are no historical observations of surface rupturing earthquakes in intraplate Cuba. Historical and instrumentally recorded earthquakes in Cuba are poorly located and the limited number of focal mechanisms for earthquakes in intraplate Cuba precludes the association of earthquakes with mapped faults. Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494, p. 327) state, "the detailed association between destructive earthquakes and active tectonic features is extremely complex and not known in depth...there is not a close correlation of seismic events with individual faults in Cuba." Furthermore, they (FSAR 2.5.1 Reference 494, p. 331) state, "most [historical, pre-instrumental earthquakes] have scarce data and do not permit a clear association to a seismic zone. There is no uniform knowledge about the historical seismicity of Cuba."

No fault in intraplate Cuba is characterized with a published late Quaternary slip rate estimate. As described in FSAR Subsection 2.5.1.1.1.3.2.4, total deformation for intraplate Cuba is crudely estimated based on limited GPS geodetic data, which suggest a deformation rate across Cuba relative to North America of <3 millimeters/year, and likely much less. However, data are insufficient to determine how much of this deformation is accommodated seismically and which faults or tectonic features in Cuba accommodate this low amount of deformation.

Because of the lack of information with which to constrain fault source parameters such as geometry, Mmax, and earthquake recurrence, intraplate Cuba is modeled as an area source in the Turkey Point Units 6 & 7 PSHA. Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494, p. 509) state "many aspects of Cuba fault geometry, kinematics, and slip rates...are unclear." The decision to model intraplate Cuba as an area source is consistent with recent peer-reviewed seismic hazard studies of Cuba. Garcia et al. (2003) (FSAR 2.5.1 Reference 489) initially developed a PSHA for Cuba that incorporated individual fault sources and source zones. However, a more recent study (Garcia et al. 2008; FSAR 2.5.1 Reference 490) performed by many of the same researchers utilizes a spatially smoothed seismicity approach in place of fault sources. According to Garcia et al. (2008) (FSAR 2.5.1 Reference 490, p. 173), the rationale for this change in approach is "to avoid drawing seismic sources in a region where the seismogenic structures are not well known." Moreover, they state (FSAR 2.5.1 Reference 490, p. 174) that "since the northern part of the Cuban region lies in an intraplate region and is characterized by a moderate seismicity [sic], the association of earthquakes to faults is problematic and, consequently, the definition of [seismic sources] is based, in some cases, on subjective decisions."

In many ways, Cuba is analogous to the CEUS, where relatively low rates of seismicity occur in crust deformed largely in old collisional events. Earthquakes in intraplate Cuba do not appear to correlate with faults, many of which lack definitive geologic constraints on the timing of last movement. Collectively, the significant uncertainties in all of the key seismic source parameters would lead to a very speculative seismic source characterization for intraplate Cuba faults. If fault sources were to be incorporated, significant uncertainties and a lack of constraining data for key seismic source parameters would lead to a very speculative seismic source characterization for intraplate Cuba. The decision to model intraplate Cuba as single area source zone, as opposed to multiple fault sources, was based on recognition of insufficient information, and in some cases conflicting information, available from geologic maps and other studies with which to constrain fault parameters. FPL's response to RAI 02.05.02-4 will provide related information regarding the rationale for the exclusive use of an areal source rather than multiple areal sources or a combination of fault sources and areal sources.

This response is PLANT SPECIFIC.

**References:**

None

**ASSOCIATED COLA REVISIONS:**

None

**ASSOCIATED ENCLOSURES:**

None

**NRC RAI Letter No. PTN-RAI-LTR-041**

**SRP Section: 02.05.01 - Basic Geologic and Seismic Information**

QUESTIONS from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

**NRC RAI Number: 02.05.01-23 (eRAI 6024)**

FSAR Section 2.5.1.1.1.3.2, under the Cuban Fold-and-Thrust Belt passage states: "On the basis of well-dated Eocene syn-tectonic strata, published structural interpretations indicating unfaulted Quaternary strata above these structures offshore, and unfaulted Pleistocene and younger terraces along the northern edge of Cuba (Reference 847) (FSAR Figure 2.5.1-282), these faults are concluded to be Tertiary in age and not capable tectonic structures." However, FSAR Figure 2.5.1-279 (S-SE end of seismic profile) shows mapped basement faults of the Cuban Fold and Thrust belt with overlying and laterally continuous reflectors that appear to be deformed and folded up to and including the seafloor. Additionally, the unfaulted, but uplifted, Pleistocene and younger marine terraces along the northern edge of Cuba may actually demonstrate a capable tectonic structure. Lastly, FSAR Figure 2.5.1-282 shows Tertiary, post-tectonic deposits (Unit 6) as faulted. The uppermost Tertiary deposits appear to lap-onto, rather than drape, an underlying fold on the same FSAR Figure 2.5.1-282. Both relations are consistent with deformation that continues to present day.

In order for the staff to assess the tectonic and structural features within the site region and in accordance with 10 CFR 100.23 please address the following:

a) Discuss the tectonic implications of the seismic reflection features above the mapped faults for Plio-Pleistocene activity in the Cuban Fold and thrust belt.
b) Clarify how the unfaulted and uplifted Pleistocene marine terraces demonstrate a lack of capable tectonic feature.
c) Discuss the suitability of using the schematic diagram (FSAR Figure 2.5.1-282) to conclude that faults of the Cuban Fold-and-Thrust Belt are Tertiary in age and not capable tectonic structures.

**FPL RESPONSE:**

a) <u>Discuss the tectonic implications of the seismic reflection features above the mapped faults for Plio-Pleistocene activity in the Cuban Fold and thrust belt</u>.

FSAR Figure 2.5.1-279 is modified slightly after Saura et al.'s (2008) (FSAR 2.5.1 Reference 485) Figure 8, which shows: (a) an annotated seismic reflection profile from the Straits of Florida offshore north of Cuba; and (b) a geologic cross section interpreted from this seismic reflection profile. According to Saura et al. (2008) (FSAR 2.5.1 Reference 485), the dashed lines shown in their panel (a) (and reproduced in the upper panel of FSAR Figure 2.5.1-279) represent "approximate boundaries between the main domains". In this upper panel, reflectors within the "Cuban thrust belt" domain appear as faulted and deformed. This deformation continues upward into their "Cenozoic basin" domain.

Saura et al.'s (2008) (FSAR 2.5.1 Reference 485) panel (b) (reproduced in the lower panel of FSAR Figure 2.5.1-279) shows their interpreted geologic cross section and provides more detailed age information for the sediments. This lower panel shows that deformation and faulting associated with the "Cuban thrust belt" extends upward into Late Cretaceous to Eocene reflectors (dark gray), but does not appear to deform overlying Oligocene to Pleistocene reflectors (light gray). This is consistent with Saura et al.'s (2008) (FSAR 2.5.1 Reference 485, p. 13) statement that "[the Cuban thrust belt] was a long-lived structure, which could be active at least up to late Eocene times. However, the main growth stage corresponds to the lowermost part of the sequence, which from borehole data is known to be pre-Middle Eocene."

This is consistent with FSAR Subsection 2.5.1.1.1.3.2.2 (Bahama Platform Tectonic and Structural Features), which states:

"Syn-tectonic strata of foreland and piggyback basins are well dated onshore and indicate that the thrust faulting is Eocene in age (References 220, 485 and 439). Based upon a series of north-northeast-trending seismic lines extending north from the Cuban shoreline in the Straits of Florida, Moretti et al. (Reference 484) conclude that the foreland fold and thrust belt developed in the Eocene and indicate that post-tectonic Tertiary and Quaternary sediments are undeformed by the thrusts. Moretti et al. (Reference 484) do note occasional Miocene reactivations of either the early Tertiary thrusts or Jurassic normal faults. On the basis of well-dated Eocene syn-tectonic strata, published structural interpretations indicating unfaulted Quaternary strata above these structures offshore, and unfaulted Pleistocene and younger terraces along the northern edge of Cuba (Reference 847) (Figure 2.5.1-282), these faults are concluded to be Tertiary in age and not capable tectonic structures."

b) Clarify how the unfaulted and uplifted Pleistocene marine terraces demonstrate a lack of capable tectonic feature.

Elevated marine terraces along Cuba's northern coast likely formed as the result of high sea level stands and regional tectonic uplift. As shown on 1:500,000-scale geologic maps (FSAR 2.5.1 Reference 847), these terraces seemingly are cut into deposits as young as Pleistocene in age, and therefore suggest regional uplift as young as Pleistocene. However, the association of the uplift of these terraces with individual faults in northern Cuba is problematic. Available mapping provides ambiguous, and sometimes conflicting, information on the locations, fault styles, and ages of faults in northern Cuba. For this reason, it is not apparent which fault or faults are responsible for the uplift of these terraces. For example, the relationship between marine terraces and the Hicacos fault is unclear because available publications provide ambiguous, and in some cases conflicting, information on the location, sense-of-slip, and age for the Hicacos fault. FPL's response to RAI 02.05.01-22 will provide related information on the ages and formation of these terraces, and the response to RAI 02.05.01-29 (FPL letter No. L-2011-504) provides related information regarding the possible association of uplifted marine terraces and the Hicacos fault. FPL's response to RAI 02.05.01-31 will provide related information regarding geologic and fault mapping in Cuba and its usefulness in neotectonic evaluations and seismic source characterization.

c) Discuss the suitability of using the schematic diagram (FSAR Figure 2.5.1-282) to conclude that faults of the Cuban Fold-and-Thrust Belt are Tertiary in age and not capable tectonic structures.

FSAR Figure 2.5.1-282 is a schematic diagram modified after Moretti et al.'s (2003) (FSAR 2.5.1 Reference 484) Figure 4. This figure serves as a simplified illustration of the tectonic evolution of the northwest offshore area of Cuba, as presented in more detail in the text of Moretti et al. (2003) (FSAR 2.5.1 Reference 484). Specifically, this figure shows the end of the Cuban orogen in the early Eocene, with slight compressive reactivation on some faults restricted to the early Tertiary. Moretti et al. (2003) (FSAR 2.5.1 Reference 484, p. 678) describe this figure as illustration that "the [Cuba fold-and-thrust belt] thrusting ceased in the Eocene, whereas infilling of the basin continued to the Quaternary because of sediment influx resulting from the mountain belt erosion. Few minor reactivations occurred during the Tertiary." The FSAR relies on Moretti et al.'s (2003) (FSAR 2.5.1 Reference 484) more detailed text descriptions and not their schematic Figure 4 to conclude the Cuban fold-and-thrust belt structures are not capable tectonic sources.

This response is PLANT SPECIFIC.

**References:**

None

**ASSOCIATED COLA REVISIONS:**

None

**ASSOCIATED ENCLOSURES:**

None

**NRC RAI Letter No. PTN-RAI-LTR-041**

**SRP Section: 02.05.01 - Basic Geologic and Seismic Information**

QUESTIONS from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

**NRC RAI Number: 02.05.01-24 (eRAI 6024)**

FSAR Section 2.5.1.1.1.3.2.4, discusses Structures of Cuba; however, the staff needs more information regarding the various fault systems within the Cuba areal source.

In order for the staff to assess the tectonic and structural features within the site region and in accordance with 10 CFR 100.23, please address the following:

a) Identify the Nortecubana fault or faults on seismic reflection sections and provide a map showing the surface trace or projection of the Nortecubana fault or faults with respect to topography and bathymetry.
b) Clarify the relationship between the Nortecubana fault system and the Cuban Fold and Thrust Belt.
c) The FSAR states "Cotilla-Rodríguez et al. (Reference 494) indicate that the Nortecubana Fault Trench is expressed in the bathymetry north of Cuba, but this does not constitute direct evidence for activity." Please clarify what processes give rise to a bathymetric expression of an inactive fault in a sedimentary basin.
d) Discuss the February 1914 (Mw 6.2) earthquake offshore northeastern Cuba near the Nortecubana fault in light of the FSAR Section 2.5.1.1.1.3.2.4 that states that "there is no direct evidence that these earthquakes occurred on the Pinar and Nortecubana Faults". Please clarify what direct evidence is required to establish a connection between the earthquake and the faults.
e) Discuss the location of the Nortecubana fault as depicted in the reflection profiles (i.e., dip, depth).

**FPL RESPONSE:**

a) Identify the Nortecubana fault or faults on seismic reflection sections and provide a map showing the surface trace or projection of the Nortecubana fault or faults with respect to topography and bathymetry.

Figure 1 in the response to RAI 02.05.01-25 will show the surface projection of the Nortecubana fault on a bathymetric map. Additionally, FSAR Figures 2.5.1-202 and 2.5.1-229 both plot the projection of the Nortecubana fault on bathymetric maps.

The surface projection of the Nortecubana fault system is located roughly at the continental slope off northern Cuba. Here, the Nortecubana fault system splays updip into a broad zone of thrust faults collectively referred to as the "Cuban thrust belt" or "Cuban fold-and-thrust belt", as shown on seismic reflection sections in FSAR Figures 2.5.1-279, -280, -287 and -288. In addition, the Nortecubana fault system is schematically represented in FSAR Figure 2.5.1-282.

b) Clarify the relationship between the Nortecubana fault system and the Cuban Fold and Thrust Belt.

The Nortecubana fault is the main structure within the Cuban fold-and-thrust belt offshore and near-shore northern Cuba. The Nortecubana thrust fault represents the ancestral subduction zone associated with the collision of the Greater Antilles Arc and the Bahama Platform. It underlies the preponderance of folding and deformation in the hanging wall, which is collectively referred to as the Cuban fold-and-thrust belt.

c) The FSAR states "Cotilla-Rodríguez et al. (Reference 494) indicate that the Nortecubana Fault Trench is expressed in the bathymetry north of Cuba, but this does not constitute direct evidence for activity." Please clarify what processes give rise to a bathymetric expression of an inactive fault in a sedimentary basin.

The surface projection of the Nortecubana fault system is roughly coincident with the continental slope off northern Cuba. In describing the Nortecubana fault, Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494, p. 517) state:

"This is a normal system of inverse, vertical, and en echelon faults that occur sideways to each other, in the form of arch along the entire continental slope of northern Cuba (Levchenko and Riabujin, 1971; Buznevy, 1968). The depth and the gradient of the slope vary considerably from east to west. The deepest and most abrupt parts are, in this order, the eastern (Punta de Maisi-Camaguey) and the western (Cabo de San Antonio-Hicacos), and the most representative with respect to transverse spectrum is the central part (east of the Peninsula de Hicacos until Camaguey). The situation is a contemporary differential geodynamic reaction to the different geological contents of the region (Cotilla et al., 1996)."

They do not state that the Nortecubana fault is expressed in the bathymetry as a well-defined fault scarp as FSAR Subsection 2.5.1.1.1.3.2.4 implies. In their Table 2, Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494, p. 515) indicate that the Nortecubana fault is expressed in the "sea" as opposed to the "land", but this does not imply the existence of a fault scarp expressed in the bathymetry. To be consistent with the text of Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494), the FSAR will be revised to remove the statement about the Nortecubana fault's supposed "expression in the bathymetry north of Cuba".

d) Discuss the February 1914 (Mw 6.2) earthquake offshore northeastern Cuba near the Nortecubana fault in light of the FSAR Section 2.5.1.1.1.3.2.4 that states that "there is no direct evidence that these earthquakes occurred on the Pinar and Nortecubana Faults". Please clarify what direct evidence is required to establish a connection between the earthquake and the faults.

According to the Phase 2 earthquake catalog developed for the Turkey Point Units 6 & 7 project, a $M_w$ 6.2 earthquake occurred on February 28, 1914 off the northeastern coast of Cuba (FSAR Figure 2.5.2-214). The direct evidence required to establish a connection between the earthquake and the Nortecubana fault is unavailable. Due to the absence of a permanent seismic monitoring network in Cuba, this epicenter is poorly located at approximately 6 kilometers north-northeast of the south-dipping Nortecubana fault, as mapped by French and Schenk (2008) (FSAR 2.5.1 Reference 492), approximately 400 miles from the site. Uncertainties in the locations of the 1914 earthquake as well as the fault do not preclude the 1914 earthquake from having occurred on the Nortecubana fault. No focal mechanism or depth determination for this earthquake is available with which to help identify the causative fault. Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494) suggest this earthquake may have occurred on the Nortecubana fault, but state that the positional accuracy of epicentral locations is limited by the lack of a permanent seismic network in Cuba. It is unlikely that an earthquake of this magnitude would have ruptured to surface of the ocean floor but, even if it had, bathymetric data are insufficient to assess for the presence of a submarine fault scarp and no detailed submarine paleoseismic studies are available for the region. Thus, it is not possible to definitively state whether the 1914 earthquake occurred on the Nortecubana fault or another fault.

e) Discuss the location of the Nortecubana fault as depicted in the reflection profiles (i.e., dip, depth).

The Nortecubana fault dips south with a dip angle that varies along strike. For example, Saura et al. (2008) (FSAR 2.5.1 Reference 485) present a cross-section from offshore northern Cuba near Bahia Honda. They convert their seismic profile from two-way travel time to kilometers, and produce a 1:1 interpreted cross-section of the Cuban thrust belt (FSAR Figure 2.5.1-279). In this cross-section, the Nortecubana fault basal thrust is imaged at depths of 5 to ~9 km, with an apparent average dip of approximately 9.5° to the south. As interpreted in this figure, the Nortecubana fault appears to flatten southward.

This response is PLANT SPECIFIC.

**References:**

None

**ASSOCIATED COLA REVISIONS:**

The text in FSAR Subsection 2.5.1.1.1.3.2.4, sixth paragraph, will be revised as follows in a future update of the FSAR:

*Nortecubana Fault System*

The Nortecubana fault system is the arcuate thrust system that marks the northern extent of south-dipping thrusts associated with the collision of the Greater Antilles Arc and the Bahama Platform. The fault system is located north of the Domingo fault and entirely offshore, and therefore detailed geologic mapping along this fault zone is not available. However, wells drilled directly offshore of northeastern Cuba have encountered thrusts and repeated stratigraphy indicating Eocene thrusting (Reference 439), and seismic reflection data has imaged northward thrusting of basin deposits (Reference 307). Seismic lines typically indicate that the offshore north-vergent thrusts are draped by unfaulted late Tertiary to Quaternary sediments (References 497 and 484) (Figure 2.5.1-279, 2.5.1-287, 2.5.1-288, 2.5.1-282, and 2.5.1-280). At its nearest point, the Nortecubana fault is approximately 150 miles (241 kilometers) from the Units 6 & 7 site. Garcia et al. (Reference 489) describe offshore seismic reflection profiles showing up to 984 feet (300 meters) of vertical displacement associated with the Nortecubana fault, but do not provide constraints on the timing of the most-recent fault slip. ~~Cotilla-Rodríguez et al. (Reference 494) indicate that the Nortecubana Fault Trench is expressed in the bathymetry north of Cuba, but this~~

~~does not constitute direct evidence for activity.~~ Ongoing seismicity is concentrated near its intersection with the Oriente fault in easternmost Cuba near the plate boundary and substantially decreases westward into the site region (References 489 and 494). Within the site region, there is no direct evidence that earthquakes occur on the Nortecubana fault.

**ASSOCIATED ENCLOSURES:**

None

**NRC RAI Letter No. PTN-RAI-LTR-041**

**SRP Section: 02.05.01 - Basic Geologic and Seismic Information**

QUESTIONS from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

**NRC RAI Number: 02.05.01-25 (eRAI 6024)**

FSAR Section 2.5.1.1.1.3.2.4 discusses the Hicacos, Surcubana, Habana-Cienfuegos, La Trocha and the Sierra Maestra faults; however the staff notes that more information is needed to assess the potential activity of these faults.

In order for the staff to assess the tectonic and structural features within the site region and in accordance with 10 CFR 100.23, please address the following:

a) Provide a map of the Hicacos fault and seismicity, including earthquake location errors, and discuss the relationship of the Hicacos fault to nearby seismicity.

b) Provide a map and discussion of the activity of the Surcubana fault zone.

c) Provide a map of the surface trace of the Habana-Cienfuegos fault (including the undersea extension proposed in Cotilla-Rodriguez et al. Reference 494), including seismicity with location uncertainties. In addition, Discuss other nearby active faults that might have been the source of the "associated earthquake epicenters" referred to by Cotilla-Rodriguez.

d) Provide a map of the La Trocha fault trace and nearby seismicity, including location uncertainties and discuss potential sources of the observed seismicity.

e) Provide map and discussion of the faults associated with the Sierra Maestra. Consider for example Taber (1931)[1] which describes a scarp associated with the Sierra Maestra as "so fresh that its age must be measured in hundreds of years rather than tens of thousands." In addition discuss the relationship of these faults to nearby seismicity.

[1] Taber, S., 1931, The structure of the Sierra Maestra near Santiago De Cuba: The Journal of Geology. v. 39, n. 6, 532–557

**FPL RESPONSE:**

a) <u>Provide a map of the Hicacos fault and seismicity, including earthquake location errors, and discuss the relationship of the Hicacos fault to nearby seismicity</u>.

Figure 1 shows epicenters from the project Phase 2 earthquake catalog and faults in Cuba. These earthquakes include both instrumentally located earthquakes and pre-instrumental earthquakes whose locations are based on historical felt intensity reports. The accuracy of the instrument-derived earthquake locations is limited by the lack of permanent seismic recording stations in Cuba, especially for lower-magnitude earthquakes. In fact, many of the earthquake magnitudes and locations from the instrumental era are intensity-based as well, and therefore, the uncertainties in locations of Cuban earthquakes are both high and variable. The accuracy of intensity-based locations is a function of the number and reliability of felt reports, the population density and distribution, and other factors. Even for earthquakes with well-constrained intensity centers, there remains ambiguity in the location of the epicenter because of possible seismic wave directivity effects and other seismologic phenomena, including localized amplification of seismic waves from site effects such as basin structure.

Earthquake location errors are not shown on Figure 1 because the data with which to estimate these errors for each earthquake are not available. According to Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494, p.518), the "epicenter determination [for earthquakes] in the western, central, and central-eastern [portions of Cuba] have limitations because of scarce or no permanent seismic stations." The accuracy of the pre-instrumental earthquakes in Cuba is limited by the fact that felt intensity reports are restricted to onshore areas and are concentrated in near-coastal areas where population density historically is greater than the interior of the island. Both of these factors potentially bias the locations of pre-instrumental earthquakes to coastal and near-shore Cuba. Regarding the locations of pre-instrumental earthquakes in Cuba, Garcia et al. (2003) (FSAR 2.5.1 Reference 489, p. 2,569) state that, "Taking into account the complexity of the Cuban tectonic environment, the poor knowledge about the kinematic evolution of the principal fault systems, and the uncertainty in the hypocentral location of historical events (uncertainty of 15-20 kilometers or more in the historical coordinates is reasonable), it is impossible to associate earthquakes with individual faults." This is consistent with descriptions in FSAR Subsection 2.5.2.1.3, which states "most earthquakes in the Cuba catalog (FSAR 2.5.2 Reference 205), whose magnitudes have been obtained from macroseismic data, do not have well constrained locations and depend on inherently subjective information."

Figure 1 indicates only sparse seismicity near the Hicacos fault. The nearest epicenters from the project Phase 2 earthquake catalog to the Hicacos fault are four co-located $M_w$ 3.1 to 3.7 earthquakes that occurred near the central portion of the fault in 1812, 1852, 1854, and 1970. Another earthquake occurred in 1777 with $M_w$ 3.7, located on strike with, but approximately 7 miles southwest of, the mapped fault trace. Likewise, Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494) indicate sparse seismicity near the Hicacos fault. Historical accounts suggest five earthquakes of less than or equal to Medvedev-Sponheuer-Karnik (MSK) intensity 5 (approximately MMI V) occurred in the vicinity of the Hicacos fault (FSAR 2.5.1 Reference 494). However, the association of these earthquakes with the Hicacos fault or another mapped or unmapped fault is problematic due to the uncertainties associated with the locations of both faults and earthquakes in Cuba and the paucity of available focal plane solutions.

b) <u>Provide a map and discussion of the activity of the Surcubana fault zone</u>.

At its nearest distance, the Surcubana fault as mapped by Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494) is located approximately 230 miles from the site (Figure 1). Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494) do not include the Surcubana fault in their list of twelve "active" faults in Cuba. FPL's response to RAI 02.05.01-32 will provide related information regarding the ambiguity associated with Cotilla-Rodriguez et al.'s (2007) (FSAR 2.5.1 Reference 494) use of the term active.

Seismicity is sparse near the Surcubana fault along its entire length, with only a dozen or so earthquakes located within approximately 20 miles of the mapped trace (Figure 1). Of these dozen earthquakes, all are low to moderate magnitude and most are located at the southeastern end of the fault near the active plate boundary and likely are instead associated with the Oriente fault. The closest earthquakes to the central and western sections of the Surcubana fault from the project Phase 2 earthquake catalog are located at approximately 81° west longitude (Figure 1). The first of these is located approximately 5 miles north of the trace and occurred on March 27, 1964 with $M_w$ 3.7. The second is located approximately 3 miles south of the trace and occurred on October 22, 2005 with $M_w$ 3.8. However, as described in part a) above, the association of these earthquakes with the Surcubana fault or another mapped or unmapped fault is problematic due to the uncertainties associated with the locations of both faults and earthquakes in Cuba and the paucity of available focal plane solutions.

c) Provide a map of the surface trace of the Habana-Cienfuegos fault (including the undersea extension proposed in Cotilla-Rodriguez et al. Reference 494), including seismicity with location uncertainties. In addition, Discuss other nearby active faults that might have been the source of the "associated earthquake epicenters" referred to by Cotilla-Rodriguez.

Figure 1 indicates only sparse seismicity from the project Phase 2 earthquake catalog near the Habana-Cienfuegos fault. As described in part a) above, earthquake location errors are not shown on Figure 1 because the data with which to estimate these errors for each earthquake are not available.

Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494, p. 516) identify "associated earthquake epicenters" that they suggest may have occurred on the Habana-Cienfuegos fault, based presumably on proximity. The basis for this association is not specified. The largest "associated earthquake epicenter" identified by Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494) is the December 16, 1982 $M_s$ 5.0 earthquake (listed in the project Phase 2 earthquake catalog as the November 16, 1982 $M_w$ 5.4 earthquake). According to the project Phase 2 earthquake catalog, this earthquake is located approximately 7 miles north of the Habana-Cienfuegos fault trace. Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494) also suggest that this earthquake may have occurred on the Cochinos fault instead. They also associate a $M_s$ 2.5 earthquake and nine MSK intensity 3 to 5 earthquakes (approximately MMI III to V) with the Habana-Cienfuegos fault. However, as described in part a) above, the association of these earthquakes with the Habana-Cienfuegos fault or another mapped or unmapped fault is problematic due to the uncertainties associated with the locations of both faults and earthquakes in Cuba and the paucity of available focal plane solutions.

Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494) map the Habana-Cienfuegos fault as extending offshore in northern Cuba (Figure 1 and Figure 2 of FSAR 2.5.1 Reference 494), where it forms a "morphostructural knot" (FSAR 2.5.1 Reference 494, p. 516) with the Nortecubana fault. Offshore of southern Cuba, the Habana-Cienfuegos fault is shown as intersected and terminated by the Surcubana fault (Figure 1 and Figure 5 of FSAR 2.5.1 Reference 494).

d) Provide a map of the La Trocha fault trace and nearby seismicity, including location uncertainties and discuss potential sources of the observed seismicity.

The La Trocha fault is mapped as a northeast-striking fault in central Cuba by Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494) (Figure 1). The La Trocha fault is not shown on Pushcharovskiy et al.'s (1988) 1:250,000-scale geologic map of Cuba (FSAR 2.5.1 Reference 846). Review of Pushcharovskiy et al.'s (1988) (FSAR 2.5.1 Reference

846) maps in the vicinity where Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494) map the La Trocha fault indicates no northeast-striking faults cutting Miocene and younger strata. Potentially, this structure is buried by the strata and could be pre-middle Miocene in age.

Figure 1 indicates only sparse seismicity from the project Phase 2 earthquake catalog near the La Trocha fault. Only four earthquakes from the Phase 2 catalog are located within 6 miles of the fault trace, the largest of which is the January 1, 1953 $M_w$ 4.3 earthquake. As described in part a) above, earthquake location errors are not shown on Figure 1 because the data with which to estimate these errors for each earthquake are not available. Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494) suggest a possible association between three earthquakes of less than or equal to MSK intensity 5 (approximately MMI V) and the La Trocha fault. However, as described in part a) above, the association of these earthquakes with the La Trocha fault or another mapped or unmapped fault is problematic due to the uncertainties associated with the locations of both faults and earthquakes in Cuba.

e) <u>Provide map and discussion of the faults associated with the Sierra Maestra. Consider for example Taber (1931) which describes a scarp associated with the Sierra Maestra as "so fresh that its age must be measured in hundreds of years rather than tens of thousands." In addition discuss the relationship of these faults to nearby seismicity</u>.

The Sierra Maestra is an east-west trending mountain range in southernmost Cuba, located approximately 450 miles from the site and adjacent to the offshore Oriente fault. Figure 2 shows a simplified depiction of faults in the Sierra Maestra, based on mapping by Rojas-Agramonte et al. (2005). The Oriente fault and near-shore portion of the Sierra Maestra are an area of abundant ongoing seismicity (Figure 1 and revised FSAR Figure 2.5.2-217 (see the response to RAI 02.05.02-7, FPL letter No. L-2011-511) and neotectonic faulting (Rojas-Agramonte et al. 2005). Taber's (1931, p. 532) observation from the near-shore Sierra Maestra at Puerto Pelado ridge near Santiago de Cuba of a "scarp so fresh its age must be measured in hundreds of years" is consistent with this active tectonic setting.

For the purposes of characterizing ground-motion hazard at the site, the entire plate boundary rate is modeled on the offshore Oriente fault source and is not represented as a more complex series of diffuse faults along the plate boundary. A thin strip of the near-shore portion of the Sierra Maestra is excluded from the Cuba areal seismic source zone (revised FSAR Figure 2.5.2-217). The seismic moment release from this thin near-shore portion of the Sierra Maestra is assumed to be related to deformation associated with the Oriente fault system and therefore is included in the seismic source model as part of the Orient fault-East seismic source. The remainder of the Sierra Maestra is included in the seismic source characterization as part of the Cuba areal source, and the seismicity observed from this portion of the Sierra Maestra is included in the assessment of seismicity recurrence rate for the entire areal source.

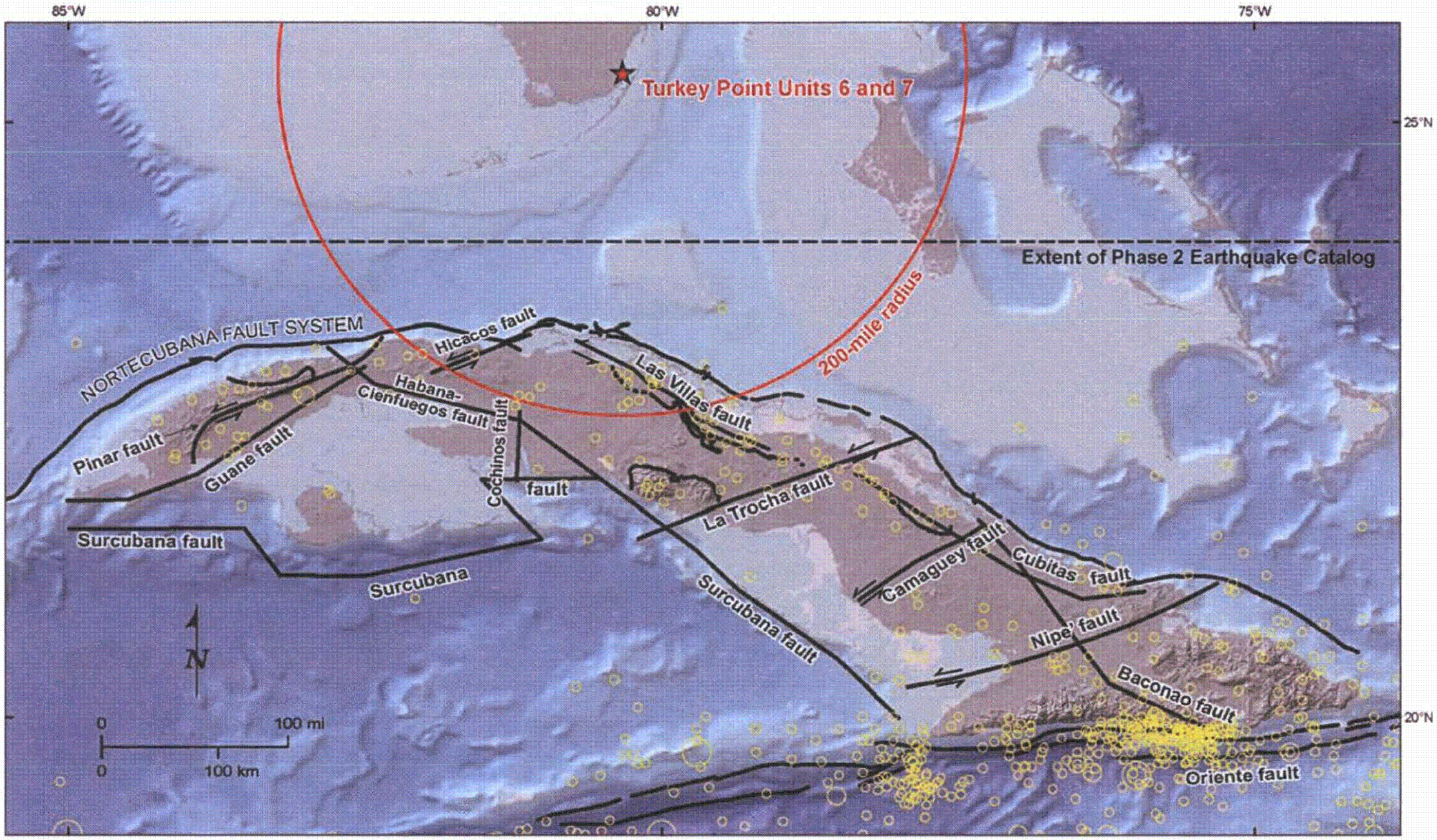



Figure 1 – Phase 2 Earthquake Catalog Seismicity and Fault Map of Cuba

Sources of fault mapping: FSAR 2.5.1 References 439, 440, 443, 492, 494, and 770

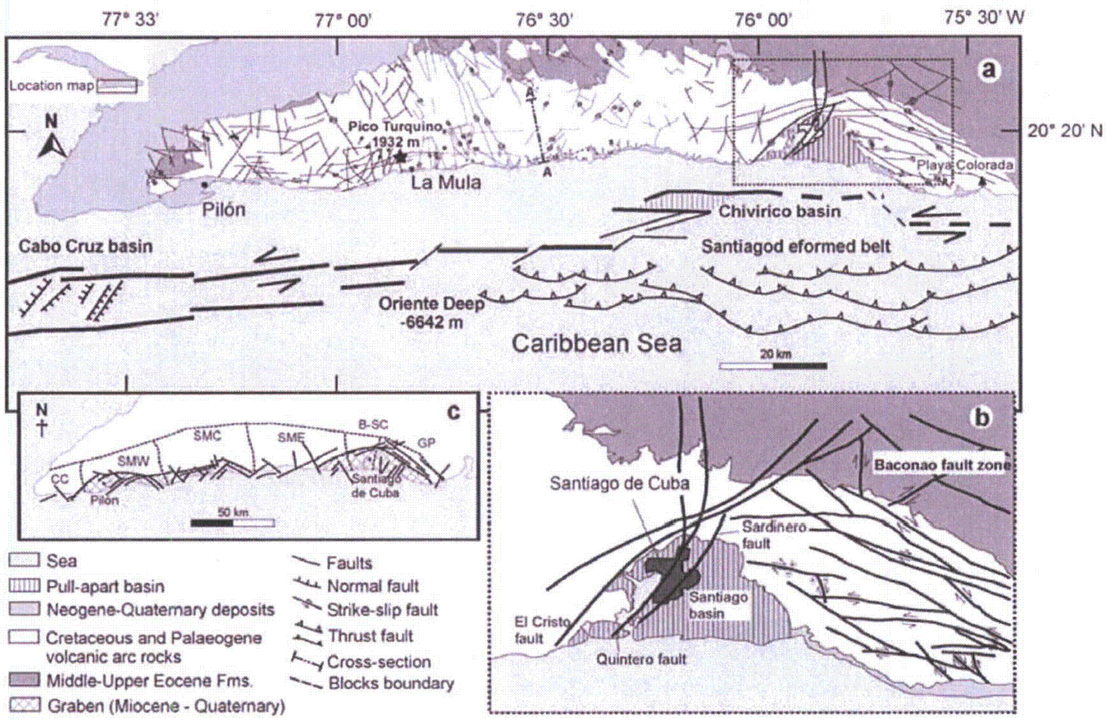



Figure 2 – Geologic Maps of Sierra Maestra Region of Cuba (Rojas-Agramonte et al. 2005)

This response is PLANT SPECIFIC.

**References:**

Rojas-Agramonte, Y., Neubauer, F., Handler, R., Garcia-Delgado, D.E., Friedl, G., Delgado-Damas, R., Variations of paleostress patterns along the Oriente transform wrench corridor, Cuba: significance for Neogene-Quaternary tectonics of the Caribbean realm, Tectonophysics, v. 396, pp. 161-180, 2005.

Taber, S.T., The structure of the Sierra Maestra near Santiago de Cuba, Journal of Geology, v. 39, no. 6, pp. 532-557, 1931.

## ASSOCIATED COLA REVISIONS:

None

## ASSOCIATED ENCLOSURES:

None

**NRC RAI Letter No. PTN-RAI-LTR-041**

**SRP Section: 02.05.01 - Basic Geologic and Seismic Information**

QUESTIONS from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

**NRC RAI Number: 02.05.01-26 (eRAI 6024)**

FSAR Section 2.5.1.1.1.3.2.4 states, in the "Cochinos Fault" passage, that Cotilla Rodriguez et al. (2007) provided no geologic evidence for activity in this fault and described it as covered by young sediments. The FSAR also indicates that the Cochinos fault appears to be geographically associated with sparse instrumental seismicity, but that these earthquakes are poorly located and no focal mechanisms are available.

In order for the staff to assess the tectonic and structural features within the site region and in accordance with 10 CFR 100.23, please address the following:

a) Provide a map of the Cochinos fault with respect to topography and bathymetry, and discuss if the association of the Cochinos fault with bathymetric relief provides geologic evidence for activity.

b) Map seismicity with respect to the Cochinos fault trace, showing location uncertainties, and discuss the relationship of the fault to seismicity.

**FPL RESPONSE:**

a) Provide a map of the Cochinos fault with respect to topography and bathymetry, and discuss if the association of the Cochinos fault with bathymetric relief provides geologic evidence for activity.

FSAR Figure 2.5.1-286 shows the location of the Cochinos fault as mapped by Mann et al. (1990) (FSAR 2.5.1 Reference 493), including bathymetric and topographic information. The Cochinos fault is the only onshore feature in intraplate Cuba identified as "neotectonic" by Mann et al. (1990) (FSAR 2.5.1 Reference 493). Mann et al. (1990) (FSAR 2.5.1 Reference 493) map the Cochinos fault as two parallel, north-striking normal faults that form a graben. The morphology of Bahia de Cochinos is consistent with this interpretation and suggests the possibility of fault control on the landscape.

Figure 1 from the response to RAI 02.05.01-25 will show the location of the Cochinos fault as mapped by Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494), including bathymetric and topographic information. Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494, pp. 514-516) describe the Cochinos fault as a "normal fault with a few inverse type sectors which demonstrates transcurrence to the left. It is covered by young sediments in a homonymous asymmetrical basin of NNW-SSE strike." Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494) identify the Cochinos fault as one of twelve "active" faults of Cuba. FPL's response to RAI 02.05.01-32 will provide related information regarding the ambiguity associated with Cotilla-Rodriguez et al.'s (2007) (FSAR 2.5.1 Reference 494) use of the term active.

Review of geologic mapping (Perez-Othon and Yarmoliuk 1985, Pushcharovskiy et al. 1988) (FSAR 2.5.1 References 848 and 846) reveals that the Cochinos fault does not cut units of Quaternary age, but the coarse scale of mapping does not preclude recent activity.

There are no paleoseismic studies of the Cochinos fault with which to assess recent earthquake activity on this fault.

b) Map seismicity with respect to the Cochinos fault trace, showing location uncertainties, and discuss the relationship of the fault to seismicity.

Figure 1 from the response to RAI 02.05.01-25 indicates only sparse seismicity, if any, from the project Phase 2 earthquake catalog near the Cochinos fault. As will be described in FPL's response to RAI 02.05.01-25, earthquake location errors are not shown on Figure 1 from the response to RAI 02.05.01-25 because the data with which to estimate these errors for each earthquake are not available.

The largest "associated earthquake epicenter" identified by Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494) is the December 16, 1982 $M_s$ 5.0 earthquake (listed in the project Phase 2 earthquake catalog as the November 16, 1982 $M_w$ 5.4 earthquake). According to the project Phase 2 earthquake catalog, this earthquake is located approximately 3 miles northwest of the Cochinos fault trace. Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494) also suggest that this earthquake may have occurred on the Habana-Cienfuegos fault instead. As will be described in FPL's response to RAI 02.05.01-25, the association of these earthquakes with the Cochinos fault or another mapped or unmapped fault is problematic due to the uncertainties associated with the locations of both faults and earthquakes in Cuba and the paucity of available focal plane solutions.

This response is PLANT SPECIFIC.

**References:**

Angell, M. and Hitchcock, C., *A geohazard perspective of recent seismic activity in the northern Gulf of Mexico, Offshore Technology Conference*, Houston, Texas, p. 8, 2007.

Wu, S., Bally, A.W., and Cramez, C., 1990, Allochthonous salt, structure and stratigraphy of the north-eastern Gulf of Mexico. Part II: Structure, Marine and Petroleum Geology, v. 7, pp. 334-370.

**ASSOCIATED COLA REVISIONS:**

None

**ASSOCIATED ENCLOSURES:**

None

**NRC RAI Letter No. PTN-RAI-LTR-041**

**SRP Section: 02.05.01 - Basic Geologic and Seismic Information**

QUESTIONS from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

**NRC RAI Number: 02.05.01-27(eRAI 6024)**

FSAR Section 2.5.1.1.1.3.2.4, "Las Villas Fault" passage, states that according to Cotilla-Rodríguez et al. (2007), the Las Villas fault has 'young eroded scarps', but it is not clear if these features represent erosional fault scarps or if they were formed directly by recent slip on the Las Villas fault. The FSAR also described, quoting Cotilla Rodriguez et al. (2007), "a single instrumental event (1939) in the vicinity of the Las Villas fault for which no focal mechanism is available, and historical accounts of four events of intensity MMI V and less, are all poorly located". The staff notes however, that Cotilla-Rodriguez et al. (1997) states in the same paragraph as the above quoted statement, that the Las Villas fault "is of Pliocene-Quaternary age. The associated seismic events are: 15.08.1939 ($Ms = 5.6$); 01.01.1953 ($I = 5$ MSK); $I = 4$ MSK (03.02.1952 and 25.05.1960), 22.01.1983($I = 3$ MSK); and noticeable without specification 04.01.1988".

In order for the staff to assess the tectonic and structural features within the site region and in accordance with 10 CFR 100.23, please address the following:

a) Provide more detail from the Cotilla-Rodríguez et al. (2007) paper regarding the young eroded scarps of the Las Villas fault and specifically address Cotilla's conclusion that the fault is Pliocene-Quaternary in age.

b) In the context of the chronology of geomorphic surfaces on Cuba, clarify the distinction between erosional processes that may have recently created "young" fault-line scarps along the Las Villas fault and Quaternary tectonic fault scarps.

c) Discuss bathymetric evidence for the offshore location and recency of faulting along the Las Villas fault.

d) Address the alignment of epicenters shown on Figure 2.5.1-267 along the Las Villas fault with respect to its tectonic activity. Please plot the uncertainties in event locations and include this information in the discussion.

**FPL RESPONSE:**

a) <u>Provide more detail from the Cotilla-Rodríguez et al. (2007) paper regarding the young eroded scarps of the Las Villas fault and specifically address Cotilla's conclusion that the fault is Pliocene-Quaternary in age</u>.

Cotilla-Rodríguez et al. (2007) (FSAR 2.5.1 Reference 494, p. 517) provide only the following minimal description of the Las Villas fault:

> "[The Las Villas] fault maintains the prevailing strike of the island on the southern part of the Alturas del Norte de Las Villas, from the surroundings of the Sierra Bibanasi to the Sierra de Jatibonico. It is a normal type fault with a large angle, with inverse type sectors. It is intercepted to the east by the La Trocha fault. Its outline has young eroded scarps. It is of Pliocene-Quaternary age. The associated seismic events are: 15.08.1939 ($M_s = 5.6$); 01.01.1953 ($I = 5$ MSK); $I = 4$ MSK; (03.02.1952

> and 25.05.1960), 22.01.1983 ($I$ = 3 MSK); and noticeable without specification 04.01.1988."

Cotilla-Rodríguez et al. (2007) (FSAR 2.5.1 Reference 494) do not provide additional discussion of the "young eroded scarps", nor do they provide reference to other publications that provide this information. Likewise, Cotilla-Rodríguez et al. (2007) (FSAR 2.5.1 Reference 494) fail to describe their basis for concluding that the Las Villas fault is Pliocene–Quaternary in age and they do not provide reference to other publications that provide this information.

b) <u>In the context of the chronology of geomorphic surfaces on Cuba, clarify the distinction between erosional processes that may have recently created "young" fault-line scarps along the Las Villas fault and Quaternary tectonic fault scarps</u>.

According to Cotilla-Rodríguez et al. (2007) (FSAR 2.5.1 Reference 494, p. 517), the Las Villas fault has "young eroded scarps", but it is not clear from this limited description if these are fault scarps formed directly by recent slip on the Las Villas fault. Alternatively, these "young eroded scarps" could be fault-line scarps formed by differential erosion of adjacent but different rock types juxtaposed along the fault. It is also possible that these "young eroded scarps" formed by preferential erosion of sheared rocks within the fault zone. Based on the scant information provided in Cotilla-Rodríguez et al. (2007) (FSAR 2.5.1 Reference 494), it is not possible to distinguish between these alternatives. There are no paleoseismic trench studies or detailed geomorphic assessments of the "young eroded scarps" of the Las Villas fault with which to assess recent earthquake activity on this fault.

c) <u>Discuss bathymetric evidence for the offshore location and recency of faulting along the Las Villas fault</u>.

The Las Villas fault as mapped by Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494) and shown on their Figure 5 is entirely onshore and therefore is not expressed in the bathymetry. The Las Villas fault as mapped by Pardo (2009) (FSAR 2.5.1 Reference 439) (Figure 1 from the response to RAI 02.05.01-25, FSAR Figure 2.5.1-247) strikes offshore and continues to the northwest roughly parallel to the coast for approximately 40 miles. Pardo (2009) (FSAR 2.5.1 Reference 439) does not describe bathymetric expression of this fault.

d) <u>Address the alignment of epicenters shown on Figure 2.5.1-267 along the Las Villas fault with respect to its tectonic activity. Please plot the uncertainties in event locations and include this information in the discussion</u>.

Figure 1 from the response to RAI 02.05.01-25 indicates moderately sparse seismicity from the project Phase 2 earthquake catalog that may be roughly aligned with the Las Villas fault, as mapped by Pardo (2009) (FSAR 2.5.1 Reference 439). As will be described in FPL's response to RAI 02.05.01-25, earthquake location errors are not shown on Figure 1 from the response to RAI 02.05.01-25 because the data with which to estimate these errors for each earthquake are not available. A total of 33 earthquakes from the Phase 2 catalog are located within approximately 6 miles of the Las Villas fault along its length. Of these, 29 are located northeast of the trace of this southwest-dipping fault, with the remaining four located southwest of the fault trace. The largest earthquake near the Las Villas fault is the August 12, 1873 $M_w$ 5.1 earthquake, located approximately 3 miles northeast of the fault. Focal mechanisms for these earthquakes are unavailable, so it is not possible to assess whether these possibly roughly aligned epicenters occurred on the Las Villas fault or on another fault or faults.

Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494) suggest that the largest recorded earthquake associated with the Las Villas fault is the $M_s$ 5.6 event on August 15, 1939 (listed in the project Phase 2 earthquake as $M_w$ 5.8). Based on the fault mapping of Pardo (2009) (FSAR 2.5.1 Reference 439), however, this earthquake is located approximately 20 miles northeast of this southwest-dipping fault, suggesting a fault other than the Las Villas ruptured during this event. Historical accounts suggest four other earthquakes of less than or equal to MSK intensity 5 (approximately MMI V) occurred in the vicinity of the Las Villas fault (Cotilla-Rodriguez et al. 2007) (FSAR 2.5.1 Reference 494). As will be described in FPL's response to RAI 02.05.01-25, the association of these earthquakes with the Las Villas fault or another mapped or unmapped fault is problematic due to the uncertainties associated with the locations of both faults and earthquakes in Cuba and the paucity of available focal plane solutions

This response is PLANT SPECIFIC.

**References:**

None

**ASSOCIATED COLA REVISIONS:**

None

**ASSOCIATED ENCLOSURES:**

None

**NRC RAI Letter No. PTN-RAI-LTR-041**

**SRP Section: 02.05.01 - Basic Geologic and Seismic Information**

QUESTIONS from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

**NRC RAI Number: 02.05.01-28 (eRAI 6024)**

FSAR Section 2.5.1.1.1.3.2.4, "Seismicity of Cuba", states that two of the largest earthquakes in the central and western region of Cuba occurred in January 1880 (MMI VIII and magnitude 6.0 to 6.6) near the Pinar fault in western Cuba, and February 1914 (Mw 6.2) offshore northeastern Cuba near the Nortecubana fault. However, the FSAR also states that there is no direct evidence that these earthquakes occurred on the Pinar and the Nortecubana faults.

In order for the staff to assess the tectonic and structural features within the site region and in accordance with 10 CFR 100.23, please address the following questions:

a) Provide a thorough discussion of the Pinar fault zone including plotting seismicity, and location uncertainties, with respect to the Pinar fault.

b) Discuss the possible sources of the January 22, 1880 M 6.0 - 6.6 San Cristobal earthquake and clarify what evidence is required to establish a connection between the 1880 earthquake and the Pinar fault. If the 1880 earthquake did not occur on the Pinar fault, please provide a detailed discussion of other faults or tectonic features that might have been responsible for the 1880 event.

c) If the Pinar fault is not active, please discuss geological processes that might lead to preservation of the continuous, linear fault trace through map units of variable ages and lithologies.

**FPL RESPONSE:**

a) <u>Provide a thorough discussion of the Pinar fault zone including plotting seismicity, and location uncertainties, with respect to the Pinar fault</u>.

Figure 1 from the response to RAI 02.05.01-25 will show the location of the Pinar fault as mapped by Tait et al. (2009) (FSAR 2.5.1 Reference 448) and earthquake locations from the Turkey Point Units 6 & 7 project Phase 2 earthquake catalog. As will be described in FPL's response to RAI 02.05.01-25, earthquake location errors are not shown on Figure 1 from the response to RAI 02.05.01-25 because the data with which to estimate these errors for each earthquake are not available. There does not appear to be an alignment of epicenters along the Pinar fault, but rather sparse earthquakes appear distributed throughout western Cuba both north and south of the fault in the Sierra del Rosario Mountains and the Palacios Basin.

b) <u>Discuss the possible sources of the January 22, 1880 M 6.0 - 6.6 San Cristobal earthquake and clarify what evidence is required to establish a connection between the 1880 earthquake and the Pinar fault. If the 1880 earthquake did not occur on the Pinar fault, please provide a detailed discussion of other faults or tectonic features that might have been responsible for the 1880 event</u>.

The Turkey Point Units 6 & 7 project Phase 2 earthquake catalog indicates that a $M_w$ 6.1 earthquake occurred on January 23, 1880 in western Cuba in the vicinity of the Pinar fault. The epicenter of this poorly located, pre-instrumental earthquake is approximately 7 miles southeast of the trace of the steeply southeast-dipping Pinar fault, as mapped by Tait et al. (2009) (FSAR 2.5.1 Reference 448). However, Garcia et al. (2003) (FSAR 2.5.1 Reference 489, p. 2,569) suggest that locational uncertainties for historical earthquakes in Cuba could be on the order of 15 to 20 kilometers or more.

As described in FSAR Subsection 2.5.1.1.1.3.2.4, Garcia et al. (2003) (FSAR 2.5.1 Reference 489) suggest that the Pinar fault may have produced the 1880 earthquake. On the other hand, Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494, p. 516) indicate the Pinar fault is "inactive", but do not provide evidence in support of this statement. They suggest instead that the 1880 earthquake occurred on the subsurface Guane fault, which is subparallel to the Pinar fault and is located within the Las Palacios basin to the southeast of the Pinar fault (Figure 1 from the response to RAI 02.05.01-25). The location of the 1880 earthquake from the project Phase 2 catalog is approximately 4 miles northwest of the surface projection of the Guane fault, as mapped by Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494).

Based on available information, it is not possible to definitively state whether the 1880 earthquake occurred on the Guane fault, the Pinar fault, or another mapped or unmapped fault in the region. No focal mechanism or depth determination for this earthquake is available with which to help identify the causative fault. Moreover, no paleoseismic trench studies or detailed tectonic geomorphic assessments are available for the Pinar fault, Guane fault, or other faults in the region.

The text of FSAR Subsection 2.5.1.1.1.3.2.4 will be revised to indicate that the 1880 $M_w$ 6.1 San Cristobal, Cuba earthquake occurred on January 23, not on January 22.

c) <u>If the Pinar fault is not active, please discuss geological processes that might lead to preservation of the continuous, linear fault trace through map units of variable ages and lithologies</u>.

The Sierra del Rosario in western Cuba displays a prominent and fairly linear southeast-facing mountain front, suggesting the possibility of recent or ongoing uplift. However, there are conflicting opinions in the literature regarding whether the Pinar fault is active. Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494) indicate that the Pinar fault is inactive. FPL's response to RAI 02.05.01-32 will provide related information on their use of the term "active". Garcia et al. (2003) (FSAR 2.5.1 Reference 489) suggest that the Pinar fault may have produced the 1880 earthquake. Gordon et al. (1997) (FSAR 2.5.1 Reference 697, pp. 10,078-10,079) are unable to constrain the upper bound of the age of most-recent deformation "because lower Miocene rocks were the youngest rocks from which observations were made."

Available geologic mapping of the Pinar fault provides conflicting information regarding the age of most-recent slip on this structure. In their 1:500,000-scale geologic map of Cuba, Perez-Othon and Yarmoliuk (1985) (FSAR 2.5.1 Reference 848) assign a Neogene-Quaternary age to the Pinar fault. Despite this, they show unnamed northwest-striking faults that they assign to the Paleogene and which they map as offsetting the younger Pinar fault. Moreover, there is a lack of young deposits mapped along the Pinar fault with which to assess the age of its most-recent slip (Perez-Othon and Yarmoliuk 1985, Pushcharovskiy 1989, Pushcharovskiy et al. 1988) (FSAR 2.5.1 References 848, 847 and 846).

Recurrent normal faulting along the southeastern margin of the Sierra del Rosario could have formed the observed relatively linear mountain front. Gordon et al. (1997) (FSAR 2.5.1 Reference 697) describe multiple phases of deformation in western Cuba in general and on the Pinar in particular. Their deformation phase IV on the Pinar fault is characterized by early Miocene normal faulting. It is possible that the present-day morphology of the Sierra del Rosario front reflects this Miocene deformation phase. Alternatively, the linear mountain front could be the result of erosion along southeast-facing dip-slopes, as suggested by Google Earth imagery. This may be similar to the "flat-iron" escarpment along the east margin of the U.S. Rocky Mountains, which is not controlled by active faulting.

This response is PLANT SPECIFIC.

**References:**

None

**ASSOCIATED COLA REVISIONS:**

The text in FSAR Subsection 2.5.1.1.1.3.2.4, tenth paragraph, will be revised as follows in a future update of the FSAR:

*Pinar Fault*

The Pinar fault is a left-lateral, northeast-striking Tertiary strike-slip structure (Reference 220). As mapped by Garcia et al. (Reference 489), the Pinar fault is approximately 197 miles (317 kilometers) southwest of the Units 6 & 7 site at its nearest point (Figure 2.5.1-247). Cotilla-Rodríguez et al. (Reference 494), however, map the Pinar fault as approximately 225 miles (362 kilometers) southwest of the site at its nearest point. Mapping indicates that the fault generally cuts lower to middle Miocene and older strata, but shows a 6.5 kilometers segment of the structure forming the boundary of (and potentially cutting) an upper Pliocene to lower Pleistocene unit (Reference 846). However, along strike, the fault is covered by the same upper Pliocene to lower Pleistocene unit (Reference 846). Crosscutting sets of striae on the fault indicate that the initial strike-slip movement was overprinted by dip-slip kinematics (Reference 485). Cotilla-Rodríguez et al. (Reference 494) describe the Pinar fault as having "...very nice relief expression" but conclude it is "inactive" (p. 516). Cotilla-Rodríguez et al. (Reference 494) provide no evidence in support of this assessment. Garcia et al. (Reference 489) note the Pinar fault is grossly expressed as a prominent escarpment and suggest the Pinar fault "was reactivated in the Neogene-Quaternary" (p. 2571) and may have produced the ~~January 22~~**January 23**, 1880 M 6.0 earthquake. Detailed examination of outcrops along the structure indicates that it developed first as a thrust in the Paleocene, but this was overprinted by the dominant phase of deformation, sinistral strike-slip faulting in the early Eocene (References 697 and 220) (Figure 2.5.1-289). Rosencrantz (Reference 529) mapped a series of offshore faults along the eastern Yucatan Platform and tentatively indicates they could be the offshore extension of the Pinar fault and responsible for Paleocene rifting.

**ASSOCIATED ENCLOSURES:**

None

**NRC RAI Letter No. PTN-RAI-LTR-041**

**SRP Section: 02.05.01 - Basic Geologic and Seismic Information**

QUESTIONS from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

**NRC RAI Number: 02.05.01-30 (eRAI 6024)**

FSAR Section 2.5.1.1.1.3.2.4, the "Seismicity of Cuba" passage, states that "In summary, many faults have been mapped on the island of Cuba...only a few detailed studies of the most recent timing of faulting are available and conflicting age assessments exist for many of the regional structures (Table 2.5.1-204). Nonetheless, available geologic mapping (at 1:250,000 and 1:500,000 scales; References 846, 847, and 848) provides some information regarding the timing of activity for some of the regional structures and largely indicates that the Pleistocene and younger strata are undeformed throughout the island." The staff notes that this statement appears to contradict other statements in FSAR Sections 2.5.1.1.1.3.2.4 and FSAR 2.5.1.1.2.1.3 that suggest recent tectonic deformation such as:

- "Garcia et al. (Reference 489) note the Pinar fault is grossly expressed as a prominent escarpment and suggest the Pinar fault 'was reactivated in the Neogene-Quaternary' and may have produced the January 22, 1880 M 6.0 earthquake."
- "...the Cubitas fault is a northwest-striking normal fault that forms the southern boundary of an area of higher topography (Figure 2.5.1- 288). It is ...suggested to be partially responsible for up to 200 meters uplift of hills, possibly after the deposition of Plio- Pleistocene fluvial terraces (Reference 500). Cotilla-Rodríguez et al. (Reference 494) note that the Cubitas fault is associated with large scarps and assign it a Pliocene-Quaternary age."
- "The La Trocha fault strikes east-northeast in Cuba, within the Greater Antilles deformed belt province, and continues southwest as the Trans Basin fault across the Yucatan Basin (Figure 2.5.1-286)....the onshore La Trocha fault (in the Greater Antilles deformed belt geologic province) is considered Pliocene- Quaternary seismoactive by Cotilla-Rodríguez et al. (Reference 494), who correlate five macroseismic events with the fault. Additionally, only two Phase 2 earthquake catalog earthquakes of $M_w \geq 7$ are located within the Yucatan Basin, one of which ($M_w$ 7.7) is located well within the province margins and nearly coincident with the Trans Basin fault mapped by Rosencrantz (Reference 529)."

In order for the staff to assess the tectonic and structural features within the site region and in accordance with 10 CFR 100.23, please clarify the statement: "...the timing of activity for some of the regional structures and largely indicates that the Pleistocene and younger strata are undeformed throughout the island" within the context of the mentioned FSAR statements.

**FPL RESPONSE:**

The seemingly contradictory statements in the FSAR regarding potentially active faults in Cuba reflect the ambiguous and sometimes contradictory information available in the published literature and geologic mapping of the island. FPL's responses to RAIs 02.05.01-

25 and 02.05.01-28 will provide related information regarding the La Trocha and Pinar faults, respectively. FPL's response to RAI 02.05.01-31 will provide related information regarding the suitability of available geologic mapping of Cuba for use in neotectonic evaluations and seismic source characterization.

This response is PLANT SPECIFIC.

**References:**

None

**ASSOCIATED COLA REVISIONS:**

The text in FSAR Subsection 2.5.1.1.1.3.2.4, 22nd paragraph under the subheading 'Other Cuban Structures', will be revised as follows in a future update of the FSAR:

In summary, many faults have been mapped on the island of Cuba. Aside from the Oriente fault, most of these faults were active during the Cretaceous to Eocene, associated with subduction of the Bahama Platform beneath the Greater Antilles Arc of Cuba and the subsequent southward migration of the plate boundary to its present position south of Cuba (Figure 2.5.1-250). However, only a few detailed studies of the most recent timing of faulting are available, and conflicting age assessments exist for many of the regional structures (Table 2.5.1-204). ~~Nonetheless, available geologic mapping (at 1:250,000 and 1:500,000 scales; References 846, 847, and 848) provides some information regarding the timing of activity for some of the regional structures and largely indicates that the Pleistocene and younger strata are undeformed throughout the island. This is consistent with g~~ Geodetic data ~~that~~ indicate that less than 3 millimeters/year of deformation is occurring within Cuba relative to North America (References 502 and 503)**, but it remains unclear which structures accommodate this deformation**. The available data indicate that the Oriente fault system, located offshore just south of Cuba, should be characterized as a capable tectonic source. Aside from the Oriente fault, no clear evidence for Pleistocene or younger faulting is available for any of the other regional tectonic structures on Cuba, and none of these faults are adequately characterized with late Quaternary slip rate or recurrence of large earthquakes. The scales of available geologic mapping (1:250,000 and 1:500,000; References 846, 847, and 848) do not provide sufficient detail to adequately assess whether or not individual faults in Cuba can be classified as capable tectonic structures.

**ASSOCIATED ENCLOSURES:**

None

**NRC RAI Letter No. PTN-RAI-LTR-041**

**SRP Section: 02.05.01 - Basic Geologic and Seismic Information**

QUESTIONS from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

**NRC RAI Number: 02.05.01-31 (eRAI 6024)**

FSAR Section 2.5.1.1.1.3.2.4, the "Seismicity of Cuba" passage, states that available geologic mapping (at 1:250000 and1:500000 scales) "largely indicates that the Pleistocene and younger strata are undeformed throughout the island." The staff notes that the same paragraph in the FSAR states that, "The scales of available geologic mapping do not provide sufficient detail to adequately assess whether or not individual faults in Cuba can be classified as capable tectonic structures." These two statements are seemingly contradictory.

In order for the staff to assess the tectonic and structural features within the site region and in accordance with 10 CFR 100.23, please address the following:

a) Clarify if available geologic mapping in Cuba is suitable for neotectonic fault evaluation.

b) If available geologic mapping is insufficient for the assessment of active faulting as stated above, clarify the first statement that mapping "largely indicates that the Pleistocene and younger strata are undeformed throughout the island."

c) If available geologic mapping is insufficient for the assessment of active faulting, as stated above, further discuss your fault-activity-conclusions based on small scale mapping.

**FPL RESPONSE:**

a) Clarify if available geologic mapping in Cuba is suitable for neotectonic fault evaluation.

Available geologic and tectonic maps for Cuba are small in scale (1:250,000 and 1:500,000) (FSAR 2.5.1 References 848, 847 and 846). As such, they are not well suited for use in neotectonic evaluations. However, these are the best-available maps that cover the whole of Cuba. Larger-scale maps are available in the published literature for selected areas of Cuba, but these are limited in extent, variable in quality, and most were not developed for use in neotectonic evaluations, but rather for stratigraphic or other geologic studies.

b) If available geologic mapping is insufficient for the assessment of active faulting as stated above, clarify the first statement that mapping "largely indicates that the Pleistocene and younger strata are undeformed throughout the island".

As will be described in FPL's response to RAI 02.05.01-30, the text in FSAR Subsection 2.5.1.1.1.3.2.4 will be revised in a future update of the FSAR to remove this statement.

c) If available geologic mapping is insufficient for the assessment of active faulting, as stated above, further discuss your fault-activity-conclusions based on small scale mapping.

Conclusions regarding fault activity in intraplate Cuba are based on the best available data, including assessment of small scale (1:250,000 and 1:500,000) geologic and tectonic maps of Cuba (FSAR 2.5.1 References 848, 847, and 846), the possible association of mapped faults with seismicity in the project Phase 2 earthquake catalog, and published literature (e.g., Cotilla-Rodriguez et al. (2007); FSAR 2.5.1 Reference 494). It is possible that some of the faults mapped in intraplate Cuba could be active or capable tectonic sources. However, there are no definitive data to support this. Therefore, based on limitations for evaluating neotectonic activity in intraplate Cuba, the seismic source characterization developed for the Turkey Point Units 6 & 7 project utilizes an areal source zone for Cuba instead of discrete fault sources.

This response is PLANT SPECIFIC.

**References:**

None

**ASSOCIATED COLA REVISIONS:**

None

**ASSOCIATED ENCLOSURES:**

None

**NRC RAI Letter No. PTN-RAI-LTR-041**

**SRP Section: 02.05.01 - Basic Geologic and Seismic Information**

QUESTIONS from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

**NRC RAI Number: 02.05.01-32 (eRAI 6024)**

FSAR Section 2.5.1.1.1.3.2.4 states: "In an effort to explain seismicity that continues on intraplate Cuba, 12 faults on the island of Cuba have been designated as 'active' (Reference 494), but that published analysis does not provide sufficient information to conclude that a structure is capable". The staff notes that this statement does not corroborate conclusions made by published experts in the area (e.g. Cotilla-Rodríguez et al. 2007, Garcia et al. 2003) regarding active faults in Cuba.

In order for the staff to assess the tectonic and structural features within the site region and in accordance with 10 CFR 100.23, please address the following:

a) Clarify the distinction between active and capable fault.

b) If the 12 faults are not capable tectonic sources, please discuss what is the structure or source of the seismicity of northern Cuba in light of Cotilla-Rodríguez et al. 2007 and Garcia et al. 2003 alternative conclusions.

**FPL RESPONSE:**

The terms "capable tectonic source" and "active fault" appear in FSAR Subsection 2.5.1.1.1.3.2.4. These terms have similar, but not identical, definitions. The term capable tectonic source is defined in RG 1.208 and is used throughout the FSAR. The term active fault in this context is defined by Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494) and applied by them to twelve faults in Cuba.

Part a) of this response defines these two terms and clarifies the distinction between them. Part b) of this response provides discussion of whether or not faults in northern Cuba satisfy one or both of these definitions and describes the lack of knowledge regarding the sources of seismicity in northern Cuba.

<u>a) Clarify the distinction between an active and a capable fault.</u>

The FSAR adopts the definition of a capable tectonic source as presented in RG 1.208. According to RG 1.208, a capable tectonic source is a tectonic structure that can generate both vibratory ground motion and tectonic surface deformation such as faulting or folding at or near the earth's surface in the present seismotectonic regime. It is described by at least one of the following characteristics:

(1) Presence of surface or near-surface deformation of landforms or geologic deposits of a recurring nature within the last approximately 500,000 years or at least once in the last approximately 50,000 years.
(2) A reasonable association with one or more moderate to large earthquakes or sustained earthquake activity that are usually accompanied by significant surface deformation.
(3) A structural association with a capable tectonic source that has characteristics of either item above, such that movement on one could be reasonably expected to be accompanied by movement on the other.

Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494) classify twelve faults in Cuba as active based on their ambiguous definition of the term. They do not adopt one accepted definition for active, but instead consider a fault to be active if it satisfies criteria spelled out by various sources, including the definition of a Type I fault from NUREG-1451 (1992) and the definition of an active fault from "Hatter et al. (1993)". To our knowledge, however, the latter reference does not exist. The full citation provided by Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494, pp. 520-521) for "Hatter et al. (1993)" is:

> "Hatter, K.M., Michael, N., Richard, L.D., 1993. Guidelines for US database and map for the maps of major active faults, Western Hemisphere, International Lithosphere Program (ILP), Project II-2. US Department of Interior, US Geological Survey, 45`p."

For this response, FPL assumes that Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494) intended to cite:

> Haller, K.M., Machette, M.N., and Dart, R.L., 1993, Maps of major active faults, Western Hemisphere, International Lithosphere Program (ILP), Project II-2; guidelines for U.S. database and map, U.S. Geological Survey Open-File Report 93-338, 45p.

Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494, pp. 507-508), summarize "Hatter et al.'s (1993)" definition of an active fault as follows:

> "On the basis of Hatter et al. (1993) a fault, fault zone or fault system are considered seismically active if one or several of the following criteria are satisfied: a) direct observation of faulting in connection with at least one earthquake; b) occurrence of well-located earthquake or microearthquake activity close to a known fault. In addition, a well-constrained fault-plane solution with one nodal plane showing the same orientation and sense of displacement as the fault is required; c) close correspondence of orientation of nodal planes and senses of displacement of well-constrained fault-plane solutions to the type and orientation of young faults or fault zones observed in the epicentral region; d) mapping of hypocenters by high-precision location of individual events of local clusters of earthquakes displaying almost identical signal forms, controlled by well-constrained fault-plane solution (s)."

Haller et al. (1993) do not, however, provide this (or any) definition for an active fault in their report. Regardless of the source of the definition in the quotation above, Part b) of this response provides discussion of whether or not any faults in northern Cuba satisfy "Hatter et al.'s (1993)" criteria for an active fault.

Likewise, NUREG-1451 (1992) does not provide a definition for an active fault as Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494) suggest. Instead, NUREG-1451 (1992) provides rationale for distinguishing between Type I, Type II, and Type III faults. NUREG-1451 (1992) defines a Type I fault as a fault that: (1) is subject to displacement; and (2) may affect the design and/or performance of structures important to safety. To be considered a Type I fault, a fault must show evidence for Quaternary displacement. In cases where the Quaternary record is incomplete or unclear, faults are considered subject to displacement if they satisfy one or more of the following criteria:

(a) Have instrumentally determined seismicity with records of sufficient precision that suggest a direct relationship with a candidate fault.

(b) Have a structural relationship (i.e., displacement on one fault could cause displacement on another) to a fault that meets one or more of the other criteria.

(c) Oriented such that they are subject to displacement in the existing stress field.

Although NUREG-1451 (1992) does not equate a Type I fault with an active fault, Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494) seemingly treat these terms as synonymous. Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494, p. 511) state that the twelve faults in Cuba they identify as active "all are attributed to type I of the faults of NUREG-1451 (1992)". Part b) of this response provides discussion of whether or not any faults in northern Cuba satisfy the NUREG-1451 (1992) criteria for a Type I fault.

<u>b) If the 12 faults are not capable tectonic sources, please discuss what is the structure or source of the seismicity of northern Cuba in light of Cotilla-Rodríguez et al. 2007 and Garcia et al. 2003 alternative conclusions.</u>

According to Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494), twelve faults in Cuba meet their ambiguous definition of active. These twelve faults include the Bacanao, Oriente, Cochinos, Camaguey, Caute-Nipe, Cubitas, Guane, Habana-Cienfuegos, Hicacos, La Trocha, Las Villas, and Nortecubana faults. Of these twelve faults, only seven are located in northern Cuba. These seven faults, shown on Figure 1 from the response to RAI 02.05.01-25, include the Cochinos, Guane, Habana-Cienfuegos, Hicacos, La Trocha, Las Villas, and Nortecubana faults.

Specifically, Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494) state that each of these seven faults satisfies "Hatter et al.'s (1993)" criteria a) and b) and that two faults (Oriente and Nortecubana) satisfy "Hatter et al.'s (1993)" criterion c). "Hatter et al.'s (1993) criterion a) requires direct observation of faulting in connection with at least one earthquake. However, there are no direct historical observations of surface rupture on any faults in northern Cuba. Additionally, there are no paleoseismic trench studies that constrain the time of most-recent earthquake slip on faults in northern Cuba. Therefore, no faults in northern Cuba satisfy "Hatter et al.'s (1993)" criterion a).

"Hatter et al.'s (1993)" criterion b) requires the occurrence of well-located earthquake activity close to a known fault and a well-constrained fault-plane solution with one nodal plane showing the same orientation and sense of displacement as the fault. Depending upon the definition of "close" in this context, it can be argued that some epicenters in northern Cuba are close to mapped faults. However, none of these epicenters are well located and no focal mechanisms are available for earthquakes in northern Cuba. Therefore, no faults in northern Cuba satisfy "Hatter et al.'s (1993)" criterion b). FPL's responses to RAIs 02.05.01-24 through -28 will provide related information regarding the association of seismicity with faults mapped in northern Cuba.

Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494) state that two faults (Oriente and Nortecubana) satisfy "Hatter et al.'s (1993)" criterion c), which requires close correspondence of orientation of nodal planes and senses of displacement of well-constrained fault-plane solutions to the type and orientation of young faults or fault zones observed in the epicentral region. Cotilla-Rodriguez et al.'s (2007) (FSAR 2.5.1 Reference

494) Table 2 indicates that focal mechanisms are available for some earthquakes on the Oriente fault offshore southern Cuba and for the easternmost portion of the Nortecubana fault only. Earthquake focal mechanisms are lacking for earthquakes in northern Cuba. Therefore, no faults in northern Cuba satisfy "Hatter et al.'s (1993)" criterion c).

In addition, Cotilla-Rodriguez et al. (2007) (FSAR 2.5.1 Reference 494) state that each of these twelve faults satisfies NUREG-1451's (1992) criteria for a Type I fault. To be considered a Type I fault, a fault must show evidence for displacement during the Quaternary Period, which in 2007 was defined as extending back to approximately 1.8 million years before present (and since revised to 2.6 million years before present). There are faults in Cuba that meet this criterion of a Type I fault. However, it is possible for a fault to be Type I and yet not satisfy the RG 1.208 criterion for a capable tectonic source of evidence for tectonic deformation of a recurring nature within the last approximately 500,000 years or at least once in the last approximately 50,000 years. FPL's response to RAI 02.05.01-31 will provide related information on the suitability of geologic mapping in Cuba for neotectonic assessments and seismic source characterization.

In their probabilistic seismic hazard assessment (PSHA) for Cuba, Garcia et al. (2003) (FSAR 2.5.1 Reference 489) characterized "fault-like" seismic sources. However, subsequent publications by a working group comprised of many of the same authors (e.g., Garcia et al. 2008; FSAR 2.5.1 Reference 489) favors moving away from defining multiple fault-like sources in intraplate Cuba, and instead proposes the use of a smoothed seismicity approach. Garcia et al. (2008) (FSAR 2.5.1 Reference 489, p. 173) state that their rationale for adopting a smoothed seismicity approach for Cuba is "to avoid drawing seismic sources in a region where the seismogenic structures are not well known". Moreover, they state that "since the northern part of the Cuban region lies in an intraplate region and is characterized by a moderate seismicity [sic], the association of earthquakes to faults is problematic and, consequently, the definition of [seismic sources] is based, in some cases, on subjective decisions" (FSAR 2.5.1 Reference 489, p. 174). FSAR Subsection 2.5.2.4.4.3 (especially 2.5.2.4.4.3.2.1) and FPL's response to RAI 02.05.01-31 will provide related information regarding the suitability of geologic and fault mapping in Cuba for use in seismic source characterization.

Seismicity in intraplate northern Cuba is ongoing, generally at low rates and low to moderate magnitudes, much like areas in the central and eastern U.S. Also, like much of the central and eastern U.S., these earthquakes are not definitively attributable to any mapped fault or faults. Across intraplate Cuba the association of earthquakes with individual faults is highly problematic due to the uncertainties associated with the locations of both earthquakes and mapped faults and the paucity of available focal plane solutions. FPL's responses to RAIs 02.05.01-24 through 02.05.01-28 will provide related information on the association of seismicity with individual faults in northern Cuba.

This response is PLANT SPECIFIC.

**References:**

Haller, K.M., Machette, M.N., and Dart, R.L., Maps of Major Active Faults, Western Hemisphere, International Lithosphere Program (ILP), Project II-2; guidelines for U.S. database and map, U.S. Geological Survey Open-File Report 93-338, 45p, 1993.

NUREG-1451, Staff Technical Position on Investigations to Identify Fault Displacements and Seismic Hazards at a Geologic Repository, McCornell, K.I., Blackford, M.E., Ibrahim, A-K., U.S. Nuclear Regulatory Commission, 66p, 1992.

## ASSOCIATED COLA REVISIONS:

The text in FSAR Subsection 2.5.1.1.1.3.2.4, fourth paragraph, will be revised as follows in a future update of the FSAR:

Summaries of the tectonic events of the Eocene to Recent only mention the development of the Oriente-Swan fault system (Reference 440). Iturralde-Vinent (Reference 440) also indicates that late Eocene to Recent deposits are slightly deformed by normal faults and minor strike-slip faults, mentioning the Pinar, La Trocha, Camaguey, and Nipe faults by name but providing no further detailed information regarding the age of displaced units. A neotectonic map compiled for Cuba identifies only the Cochinos fault and structures in south easternmost Cuba as active, and these active structures are not depicted extending within the site region (Reference 493) (Figure 2.5.1-247). In an effort to explain seismicity that continues on intraplate Cuba, 12 faults on the island of Cuba have been designated **by Cotilla-Rodriguez et al. (Reference 494)** as "active" ~~(Reference 494)~~ **based on their ambiguous definition of the term.** ~~, but that published~~ **However, Cotilla-Ridriguez's (Reference 494)** analysis does not provide sufficient information to conclude that a structure is capable **according to RG 1.208**. Table 2.5.1-204 provides a summary of these and other regional fault zones of Cuba. Available geologic and tectonic maps are 1:250,000 (Reference 846) and 1:500,000 scale (References 848 and 847), respectively, and therefore do not have sufficient detail to properly characterize fault activity based on map relations alone. Available information for the six regional Cuban faults that extend to within the site region, and several that lie beyond it, is summarized below.

**ASSOCIATED ENCLOSURES:**

None