PMTurkeyCOLPEm Resource

From: Comar, Manny
Sent: Thursday, November 01, 2012 5:02 PM
To: TurkeyCOL Resource
Subject: FW: DRAFT RAI Responses FPL Turkey Point 6 & 7 for eRAI 6024 Basic Geologic and Seismic Information
Attachments: Draft Revised Response for NRC RAI Letter No. 041, RAI 02.05.01-32 (eRAI 6024).pdf; Draft Revised Response for NRC RAI Letter No. 041, RAI 02.05.01-11 (eRAI 6024).pdf; Draft Revised Response for NRC RAI Letter No. 041, RAI 02.05.01-13 (eRAI 6024).pdf

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From: Franzone, Steve [mailto:Steve.Franzone@fpl.com]
Sent: Friday, October 26, 2012 11:48 AM
To: Franzone, Steve; Comar, Manny
Cc: Burski, Raymond; Maher, William
Subject: DRAFT RAI Responses FPL Turkey Point 6 & 7 for eRAI 6024 Basic Geologic and Seismic Information

Manny,

To support a future public meeting, FPL is providing draft revised responses for eRAI 6024 (RAI questions 02.05.01-11, 02.05.01-13, and 2.5.1-32) in the attached files.

If you have any questions, please contact me.
Thanks

Steve Franzone
NNP Licensing Manager - COLA
"Never give in--never, never, never, never, in nothing great or small, large or petty, never give in except to convictions of honour and good sense. Never yield to force; never yield to the apparently overwhelming might of the enemy. " Sir Winston Churchill, Speech, 1941, Harrow School
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Draft Revised Response for NRC RAI Letter No. 041, RAI 02.05.01-32 (eRAI 6024).pdf	418193	
Draft Revised Response for NRC RAI Letter No. 041, RAI 02.05.01-11 (eRAI 6024).pdf	362338	
Draft Revised Response for NRC RAI Letter No. 041, RAI 02.05.01-13 (eRAI 6024).pdf	245573	

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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 Reference 2.5.1-494) and applied by them to 12 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. A capable tectonic source is described by at least one of the following characteristics:

- 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.
- A reasonable association with one or more moderate-to-large earthquakes or sustained earthquake activity that is usually accompanied by significant surface deformation.

- 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.

The term active fault is defined differently by different researchers and regulatory agencies. Cotilla-Rodriguez et al. (2007) (FSAR Reference 2.5.1-494) define a fault as active if it satisfies criteria spelled out by various other published sources, including the definition of an active fault from Hatter et al. (1993) and the definition of a Type I fault from NUREG-1451. Cotilla-Rodriguez et al. (2007) (FSAR Reference 2.5.1-494, 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)."*

To FPL's knowledge, however, the reference Hatter et al. (1993) does not exist. The full citation provided by Cotilla-Rodriguez et al. (2007) (FSAR Reference 2.5.1-494, 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 Reference 2.5.1-494) intended to cite Haller et al. (1993) (Reference 1):

> 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.

FPL believes this is a reasonable assumption, given the similarity in the names and initials of the authors in each citation, the similarity in the titles of each citation, and the identical number of pages listed for each reference. Despite the quotation above from Cotilla-Rodriguez et al. (2007) (FSAR Reference 2.5.1-494) in which they summarize "Hatter et al.'s (1993)" definition of an active fault, Haller et al. (1993) (Reference 1) do not provide this (or any) definition for an active fault in their report. Thus, the source of "Hatter et al.'s

(1993)” definition for an active fault remains unclear. Regardless of the origin of the definition of the term active fault provided by Cotilla-Rodriguez et al. (2007) (FSAR Reference 2.5.1-494), however, part (b) of this response provides discussion of whether or not any faults in northern Cuba satisfy the criteria presented.

Cotilla-Rodriguez et al. (2007) (FSAR Reference 2.5.1-494) also indicate that their definition of the term active fault is based on that provided by NUREG-1451. However, NUREG-1451 does not provide a definition for an active fault as Cotilla-Rodriguez et al. (2007) (FSAR Reference 2.5.1-494, p. 507) suggest. Instead, NUREG-1451 provides rationale for distinguishing between Type I, Type II, and Type III faults. NUREG-1451 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:

- Have instrumentally determined seismicity with records of sufficient precision that suggest a direct relationship with a candidate fault.
- 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.
- Have an orientation that makes them subject to displacement in the existing stress field.

Although NUREG-1451 does not equate a Type I fault with an active fault, Cotilla-Rodriguez et al. (2007) (FSAR Reference 2.5.1-494) seemingly treat these terms as synonymous. Part (b) of this response provides discussion of whether or not any faults in northern Cuba satisfy the NUREG-1451 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>

Cotilla-Rodriguez et al. (2007) (FSAR Reference 2.5.1-494) characterize 12 faults in Cuba as active. Garcia et al. (2003) (FSAR Reference 2.5.1-489) define 24 seismogenic source zones (SZs) that represent faults or groups of faults in Cuba. FPL recognizes that there is recent and ongoing seismicity in northern Cuba and that many of these earthquakes may have ruptured along or near one of Cotilla-Rodriguez et al.’s (2007) (Reference 2.5.1-494) active faults or within one of the Garcia et al.’s (2003) (FSAR Reference 2.5.1-489) SZs. However, there are no data to demonstrate that any fault in northern Cuba is a capable tectonic source according to the criteria established in RG 1.208. Seismicity in northern Cuba is ongoing, generally at low rates and low-to-moderate magnitudes, much like areas in the central and eastern United States. Also, like much of the central and eastern United States, these earthquakes are not definitively attributable to any mapped fault or faults. Across 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. This is especially true for lowermagnitude earthquakes in the region. It is possible that at least some of this earthquake activity in northern Cuba occurred on mapped faults, but it is also possible that many of these earthquakes occurred on faults that have yet to be mapped. The remainder of this response provides discussion of Cotilla-Rodriguez et al.'s (2007) (FSAR Reference 2.5.1-494) 12 active faults and Garcia et al.'s (2003) (FSAR Reference 2.5.1-489) 24 SZs and their relation to the seismicity of northern Cuba.

Cotilla-Rodriguez et al. (2007) (FSAR Reference 2.5.1-494, pp. 511-512) summarize the assessment of active faults in Cuba as follows:

> *"Figure 5 shows the twelve faults that demonstrate contemporary activity in Cuba, according to the criteria of Hatter et al. (1993). Specifically, these faults meet the above criteria a) and b), while only two of them (Bartlett-Cayman and Nortecubana) satisfy the third criterion, that of focal mechanism. Also, all of the faults meet well-known criteria of geomorphic type (Yeats et al., 1997). All are attributed to type I of the faults of NUREG-1451 (1992) and fulfill the conditions of Lay and Wallace (1995) and Reiter (1990) for active seismic structures. Hence, the Habana-Cienfuegos and Cauto-Nipe faults are hidden structures, since they agree with the description of the Working Group on California Earthquake Probabilities (1995)."*

According to Cotilla-Rodriguez et al. (2007) (FSAR Reference 2.5.1-494), 12 faults in Cuba meet their definition of active. These 12 faults include the Bacanao, Oriente, Cochinos, Camaguey, Caute-Nipe, Cubitas, Guane, Habana-Cienfuegos, Hicacos, La Trocha, Las Villas, and Nortecubana faults (Figure 1). Of these 12 faults, only seven are located in northern Cuba. These seven faults are the Cochinos, Guane, Habana-Cienfuegos, Hicacos, La Trocha, Las Villas, and Nortecubana faults.

Cotilla-Rodriguez et al. (2007) (FSAR Reference 2.5.1-494) state that each of these seven faults satisfies criteria (a) and (b) (attributed above to Hatter et al. 1993) and that two faults (Oriente and Nortecubana) satisfy criterion (c). 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 appear to satisfy criterion (a).

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 very few, if any, focal mechanisms are available for earthquakes in northern Cuba. Cotilla-Rodriguez et al. (2007) (FSAR Reference 2.5.1-494, 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." Similarly, Cotilla-Rodriguez and Cordoba-Barba (2011, pp. 502-503) (Reference 2) state, "The Cuban macroseismic catalogs possess a variable quality from one event to the next.

Even though some earthquakes have been studied enough to elaborate isoseismal maps, with the resulting increase in reliability in placing the epicenter, the majority have scarce data, preventing a single association with another seismogenic zone...What is known about the seismicity is very incomplete but it becomes more detailed as one moves from west to east." Regarding the locations of pre-instrumental earthquakes in Cuba, Garcia et al. (2003) (FSAR Reference 2.5.1-489, p. 2569) state, "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." Cotilla-Rodriguez et al.'s (2007) (FSAR Reference 2.5.1-494) Figure 6 depicts numerous focal mechanisms for fault zones along the modern plate boundary south of Cuba and throughout the Caribbean region, but none are depicted for northern Cuba. Therefore, no faults in northern Cuba appear to satisfy criterion (b).

Cotilla-Rodriguez et al. (2007) (FSAR Reference 2.5.1-494) state that two faults (Oriente and Nortecubana) satisfy 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 Reference 2.5.1-494) Table 2 indicates that focal mechanisms are available for some earthquakes on the Oriente fault (listed as the Bartlett-Cayman fault [BC] in their table) offshore of southern Cuba and the Nortecubana fault. Cotilla-Rodriguez et al. (2007) (FSAR Reference 2.5.1-494) indicate that the Nortecubana fault system is a long, segmented structure and that focal mechanisms are available only for its easternmost portion. Earthquake focal mechanisms are lacking for earthquakes in intraplate Cuba away from the modern plate boundary. Therefore, no faults in northern Cuba appear to satisfy criterion (c).

In addition, Cotilla-Rodriguez et al. (2007) (FSAR Reference 2.5.1-494) state that each of these 12 faults satisfies the NUREG-1451 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) (Gibbard et al. 2009) (Reference 3). There are faults in intraplate Cuba away from the modern plate boundary that potentially meet this criterion of a Type I fault. It is also likely that some faults in intraplate Cuba meet the NUREG-1451 criterion that faults are potentially subject to displacement if they are oriented such that they are subject to displacement in the existing stress field. The existing stress field in Cuba is not well constrained, but, given the range of orientations of faults in intraplate Cuba away from the modern plate boundary (Figure 1), it is likely that at least some are favorably oriented. 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.

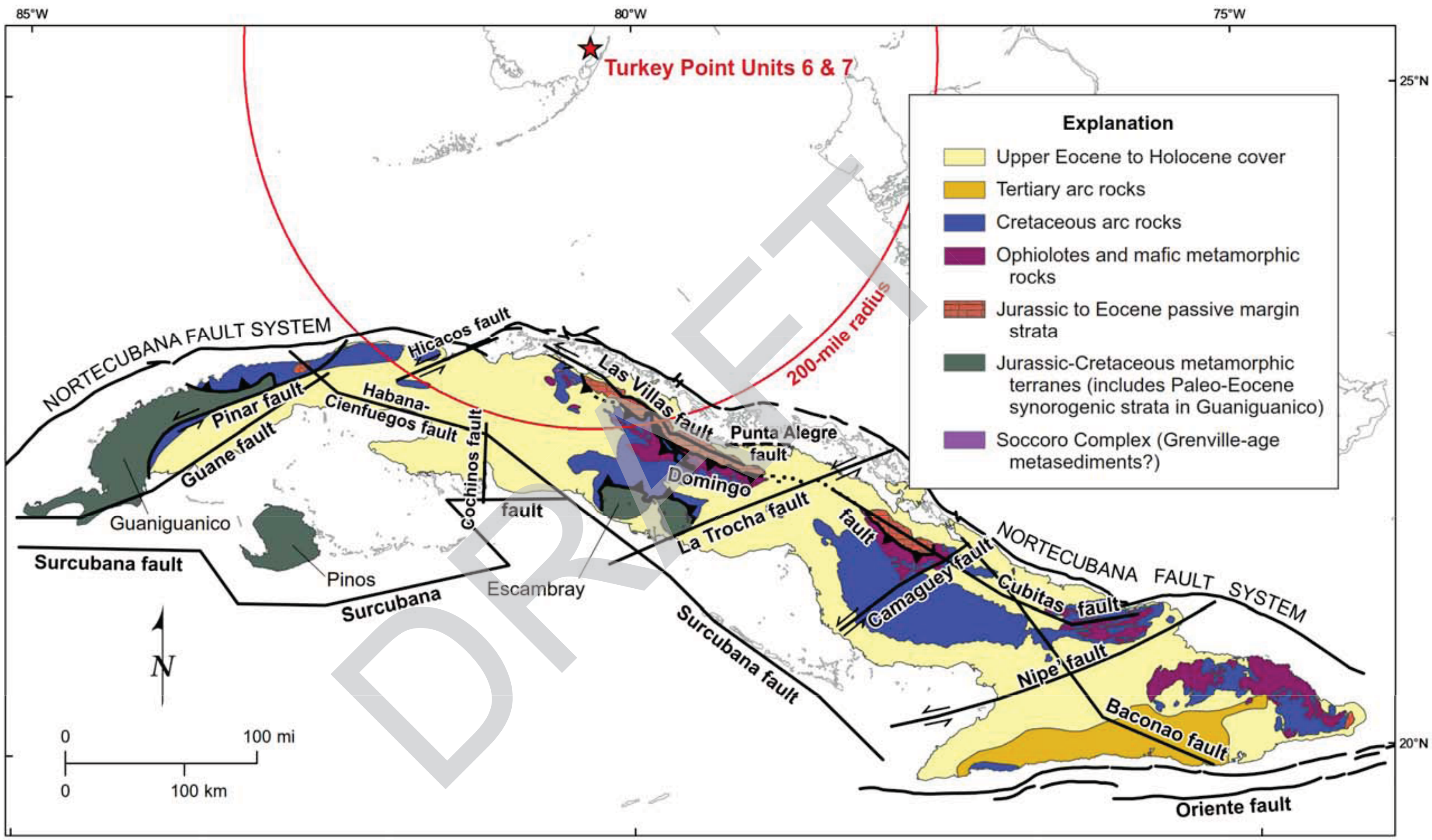
Garcia et al. (2003) (FSAR Reference 2.5.1-489) present seismic hazard maps for Cuba that are based on their seismic source model that includes seismogenic zone sources (SZs). They do not define fault sources in their model and they do not provide a systematic assessment of whether individual faults in Cuba are active. Instead, according to Garcia et al. (2003) (FSAR Reference 2.5.1-489), SZs are elongated areal seismic sources, each of which represents a potentially active fault zone or group of faults. According to Garcia et al.'s (2003) (FSAR Reference 2.5.1-489) seismic source model, each SZ must be large enough to envelop sufficient numbers of earthquakes to estimate separate rates of seismicity for each source from the earthquakes observed within that zone. The result is that their SZs in Cuba are tens of kilometers wide. Garcia et al. (2003) (FSAR Reference 2.5.1-489) allow for border uncertainty of 0 to 20 km (0 to 12 miles) for their SZs. As shown on Figure 6 of FSAR Reference 2.5.1-489), SZs collectively account for a significant percentage of the area of Cuba. As such, a significant percentage of past, and presumably future, seismicity is located within these zones.

In general, Garcia et al. (2003) (FSAR Reference 2.5.1-489) do not provide specific information indicating whether a particular fault in intraplate Cuba is active, because this is not the focus of their study. They do, however, provide very brief descriptions of the geologic and seismic settings of each of their SZs, which typically are named after a fault located within that zone. For example, the Pinar fault is located within their "Seismogenic Region Pinar" and the Hicacos fault is located within their "Seismic Region Hicacos". This naming convention implies that the individual faults that lend their names to the SZs are active, when in fact this may not necessarily be the case.

In a more recent study, Garcia et al. (2008) (FSAR Reference 2.5.1-490) present seismic hazard maps for Cuba that are based on a spatially smoothed seismicity approach. Garcia et al. (2008) (FSAR Reference 2.5.1-490) compare the results from the smoothed seismicity approach with those based on the Garcia et al. (2003) (FSAR Reference 2.5.1-489) SZ approach. From this comparison, Garcia et al. (2008) (FSAR Reference 2.5.1-490) conclude that, relative to the smoothed seismicity approach, the SZ approach tends to result in slightly higher PGA values in northwestern Cuba. Garcia et al. (2008) (FSAR Reference 2.5.1-490, p. 193) indicate that "an improvement of the seismicity data collection would be welcome for a better knowledge of the seismicity in northwestern Cuba." Moreover, Garcia et al. (2008) (FSAR Reference 2.5.1-490, p. 174) indicate that "although the definition of SZs is positive because it focuses on understanding the regional tectonics, this exercise could be misleading when not supported by data. Consequently, a mixture of the two approaches would probably be the best solution: a seismotectonic approach for the more seismic areas and only seismicity elsewhere." According to Garcia et al. (2008) (FSAR Reference 2.5.1-490, p. 182), "the northern intraplate region [of Cuba] is related to a moderate to low seismicity." This is consistent with observations made from the project Phase 2 earthquake catalog, which indicate a higher concentration of earthquakes and higher magnitudes in southernmost Cuba at and near the modern plate boundary. Therefore Garcia et al.'s (2003) (FSAR Reference 2.5.1-489) SZ modeling approach may not be applicable to the moderate to low seismicity areas of northern Cuba.

In light of the above, it is unclear whether the faults identified in Cotilla-Rodriguez et al. (2007) (FSAR Reference 2.5.1-494) as active fit the definition of the term and whether the ongoing seismicity in northern Cuba can be associated with those faults. Garcia et al.'s (2003) (FSAR Reference 2.5.1-489) 24 SZs occupy a large percentage of the area of Cuba and, therefore, it is not surprising that much of the broadly distributed seismicity in northern

Cuba occurs within these collective zones. Throughout northern 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. It is possible that at least some of this earthquake activity has occurred on mapped faults, but it is also possible that many of these small- to moderate-magnitude earthquakes have occurred on small faults within the crust that have yet to be mapped.



Note: Multiple sources were used to compile this map, including FSAR References 443, 448, 439. 770, 492 and 494.

Figure 1. Fault Map of Cuba

This response is PLANT SPECIFIC

References:

1. 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.

2. Cotilla-Rodriguez, M.O. and Cordoba-Barba, D., 2011. *Study of the earthquake of the January 23, 1880, in San Cristobal, Cuba and the Guane fault*, Physics of the Solid Earth, v. 47, no. 6, p. 496-518.

3. Gibbard, P.L., Head, M.J., and Walker, J.C., 2009. *Formal ratification of the Quaternary System/Period and the Pleistocene Series/Epoch with base at 2.58 Ma*, Journal of Quaternary Science, v. 25, no. 2, p. 96-102.

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 COLA revision:

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-Rodriguez et al.’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.

Additional COLA revisions will be made in a future COLA revision as presented in the response to RAI 02.05.01-21.

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 “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 its activity and regional tectonic setting. Updated FSAR discussions are presented in additional RAIs that are specific to each structure, as referenced below.

As discussed in FSAR Subsection 2.5.1.1.1.3.2.2, the Walkers Cay fault is located north of the Little Bahama Bank. Sheridan et al. (FSAR Reference 2.5.1-307) indicate that the Walkers Cay fault 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 interpretation of seismic reflection profiles and mapping of strands of the Walkers Cay fault up to or near the seafloor, documents Pliocene slip and suggests possible Quaternary activity on this fault.

The Santaren Anticline is located along the southern margin of the Bahama Platform and was active up until the Miocene (FSAR Subsection 2.5.1.1.1.3.2.2.). Although Masaferro et al. (FSAR Reference 2.5.1-479) calculated a non-zero fold uplift rate of 0.05 millimeters/year for a Quaternary bed that thinned over the crest of the anticline, since 20 Ma, the calculated fold uplift rates are so low that they are essentially indistinguishable from zero (See RAI 02.05.01-15 for a discussion). 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 References 2.5.1-501and 2.5.1-479).

As described in FSAR Subsection 2.5.1.1.1.3.2.2 and RAI Response 2.5.1-16, the Straits of Florida normal faults were primarily active in the Eocene and acted to thin the overthickened wedge of foreland material shed off the colliding Greater Antilles arc (FSAR References 2.5.1-221 and 2.5.1-482) (FSAR Figure 2.5.1-229). These structures were active in the Eocene and show very little evidence for younger deformation (Figure 2.5.1-209) though some may have been reactivated in response to far-field effects of collision in central and southern Cuba during the Miocene (FSAR Reference 2.5.1-484). In summary, these faults are clearly related to the collision of the Greater Antilles arc.

Some structures in northern Cuba exhibit the potential for post-Eocene deformation, and it is possible that some have been active in the Quaternary, although evidence for Quaternary activity on any Cuban fault within the site region is not definitive (see RAI 02.05.01-21). For example, small-scale maps indicate the Pinar fault crosscuts strata as young as lower-to-middle Miocene (FSAR Reference 2.5.1-846). Cotilla-Rodriguez et al. (FSAR Reference 2.5.1-494) suggest the Pinar fault is inactive, but others, including Garcia et al. (FSAR Reference 2.5.1-489), suggest instead that it is active. As suggested by Cotilla-Rodriguez et al. (FSAR Reference 2.5.1-494), other potentially active faults in Cuba within the site region include the Hicacos, Nortecubana, and Las Villas faults. A full discussion of the age uncertainty of the Hicacos, Nortecubana, Las Villas, and Pinar faults is provided in the response to RAI 02.05.01-21.

The statement in the FSAR that generally no tectonic deformation has occurred since the Eocene in the site region outside of the Greater Antilles arc collision will be revised in a future COLA revision to specifically mention the Eocene and younger structures discussed in this RAI. 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 may have been active in the Miocene or later and have uncertain relationships with the regional tectonic setting. 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 probably related to the collision of the Greater Antilles arc with the Bahamas platform. While the Straits of Florida normal faults are predominantly Eocene in age, structures along the coast of Cuba are treated as potentially Quaternary in age (RAI 02.05.01-21).

This response is PLANT SPECIFIC.

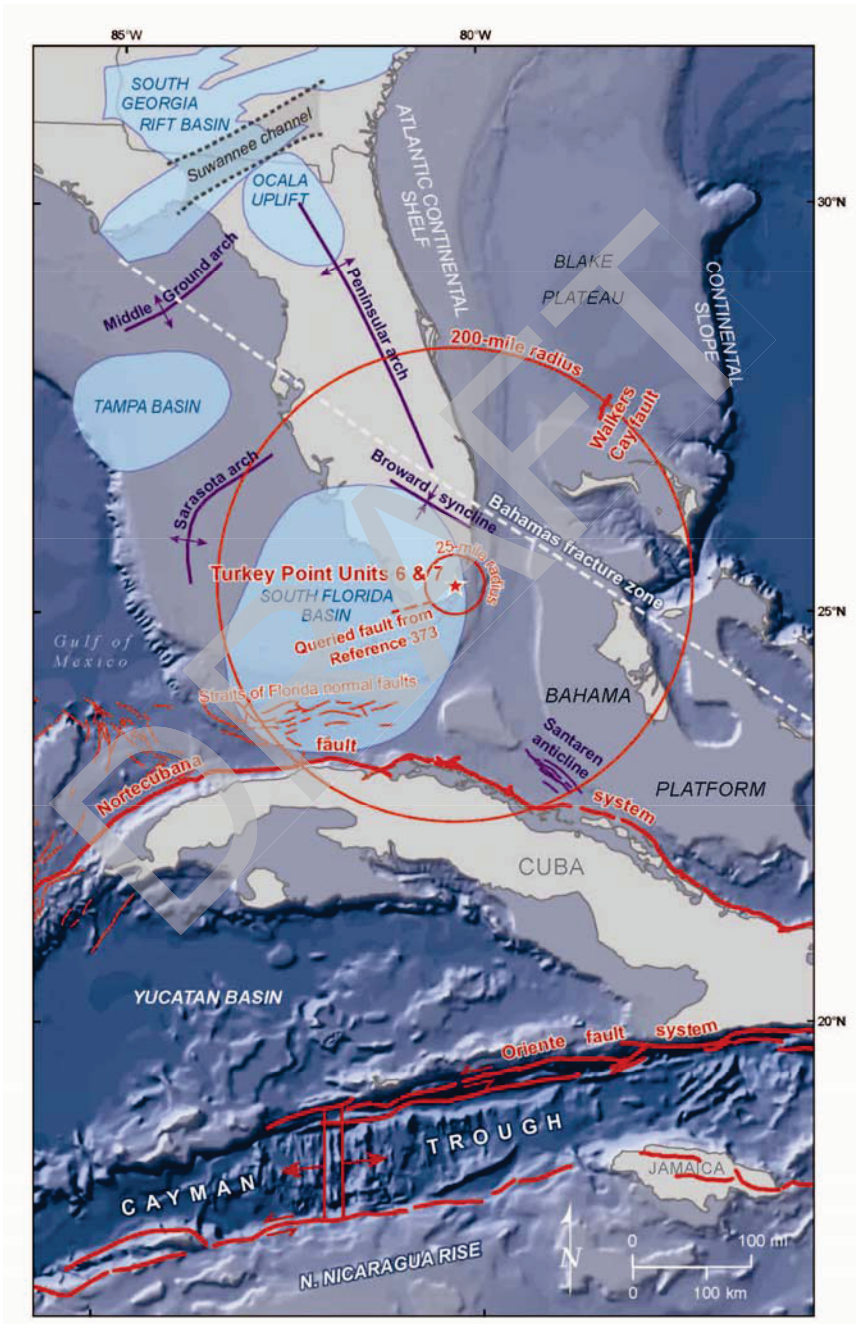
References:

None

ASSOCIATED COLA REVISIONS:

FSAR Figure 2.5.1-229 will be revised in a future COLA revision to include a label for the Straits of Florida normal faults as shown below:

Figure 2.5.1-229 Regional Tectonic Features



Sources: FSAR Section 2.5.1.3 References 2.5.1-822, 482, 823, 457, 212, and 421

The following paragraph of FSAR Subsection 2.5.1.1.1.3.2 will be revised in a future COLA revision as shown below:

2.5.1.1.1.3.2 Principal Tectonic and Structural Features

The site region is covered by a thick sequence of sedimentary rocks and deposits that obscure any Precambrian to Paleozoic tectonic features associated with the formation of Pangea (Figures 2.5.1-240, 2.5.1-242, and 2.5.1-201). In fact, this region has generally recorded only sedimentary processes since Mesozoic rifting, with the exception of the **possible** tectonic activity associated with ~~the collision of the Greater Antilles Arc with the Bahama Platform during Cretaceous to Eocene time~~**the Cuban fold and thrust belt, possibly active faults in northern Cuba, adjacent Straits of Florida normal faults, the Santaren anticline, and the Walker's Cay fault**. The Florida Platform has been a site of stable carbonate platform deposition continually since the Cretaceous. Variations in sediment thickness are interpreted as a series of arches, uplifts, basins, or embayments from geophysical or borehole data (Reference 413). Generally, these arches and basins are sedimentary responses to minor warping, regional tilting, sedimentary compaction, or sea level changes and are not considered associated with faulting or tectonic events (Reference 413). In some cases, the highs or lows seen in the stratigraphy may be mimicking Mesozoic paleotopography. The Bahama Platform is also largely undeformed, but does include sparse post-rift faulting or deformation, generally adjacent to the Cuban orogen. The EPRI (Reference 456) earthquake catalog and the updated earthquake catalog completed for the Units 6 & 7 site investigation (Subsection 2.5.2.1) indicate that north of Cuba and the northern Caribbean seismic source model (Subsection 2.5.2.4.4.3) earthquakes are sparsely and randomly distributed within the site region and that none of the earthquakes can be associated with a known geologic structure (Subsection 2.5.2.3).

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 Subsection 2.5.1.1.1.3.2.2 notes that normal faults cutting Cretaceous strata have been identified, but concludes the following: "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 interpreted in the Straits of Florida (FSAR Figures 2.5.1-243, -263, and -272), the western Bahama Bank (FSAR Figure 2.5.1-268), the Great Bahama Bank (FSAR Figures 2.5.1-269 and -271), and the southeast Bahama Plateau (FSAR Figure 2.5.1-270), all of which are discussed in FSAR Subsection 2.5.1.1.1.3.2.2.

Sheridan et al. (1988) (FSAR Subsection 2.5.1 Reference 307) interpret Lower Cretaceous strata (Albian-Aptian) as faulted, but Upper Cretaceous strata (Cenomanian to Conacian and Santorinian to lower Paleocene) strata are unfaulted (right panel of FSAR Figure 2.5.1-264), 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.

This response is PLANT SPECIFIC.

References:

None

ASSOCIATED COLA REVISIONS:

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

2.5.1.1.1.3.2.2 Bahama Platform Tectonic and Structural Features

Structures of the Bahama Platform

The Bahama Platform, like the Florida Platform, is best characterized by continuous, horizontal carbonate deposition, rarely interrupted by faulting or other deformation (Figure

2.5.1-245). Because the platform is largely submerged, all information about potential structures is gained from interpretations of seismic lines, and therefore is subject to limitations. The vast majority of seismic lines inspected and available to this study confirm the unfaulted nature of Cretaceous and younger strata across the Bahama Platform and southern Florida Platform (Figures ~~2.5.1-262,~~ 2.5.1-268, 2.5.1-263, 2.5.1-269, 2.5.1-270, 2.5.1-271, and 2.5.1-272). However, a few exceptions to this exist, such as the ~~normal fault~~ **deformation** associated with **the** Santaren Anticline **(Figure 2.5.1-278),** ~~and in~~ **normal faults in** the Straits of Florida (Figure 2.5.1-273**), the Walkers Cay fault (Figure 2.5.1-275) and the eastern Bahama Platform (right panel of Figure 2.5.1-264).** ~~These younger features are generally associated with, and in close proximity to, the Tertiary Cuban orogen.~~

Mesozoic Normal Faults of the Bahama Platform

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 and/or Upper** Cretaceous strata ~~(Figures 2.5.1-264 and 2.5.1-242~~**). In the eastern Bahama Platform, Sheridan et al. (Reference 307) interpret normal faults cutting Lower Cretaceous strata that are draped by unfaulted Upper Cretaceous (Santonian or Cenomanian) strata (right panel of Figure 2.5.1-264). On Figure 2.5.1-263 a north-south seismic line located east of the site indicates a normal faulted basement of Paleozoic to Jurassic strata draped by unfaulted Upper Jurassic to Lower Cretaceous strata. Similarly, the seismic line interpretation on Figure 2.5.1-243 indicates faulted basement covered by undeformed Upper Jurassic and younger strata. On Figures 2.5.1-268 and 2.5.1-269, flat unfaulted Lower Cretaceous and younger strata cover the Bahama platform.**

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