FPL

L-2015-175
10 CFR 52.3

June 17, 2015

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
Voluntary Revised Response to NRC Request for Additional Information Letter No. 041 (eRAI 6024) SRP Section: 02.05.01 - Basic Geologic and Seismic Information

References:

1. FPL Letter L-2014-281 to NRC, dated October 3, 2014, Voluntary Revised Response to NRC Request for Additional Information Letter No. 041 (eRAI 6024) SRP Section: 02.05.01 - Basic Geologic and Seismic Information

2. FPL Letter L-2015-169 to NRC, dated June 8, 2015, Response to NRC Request for Additional Information Letter No. 081 (eRAI 7804) SRP Section 02.05.01 – Basic Geologic and Seismic Information

In Reference 1, FPL submitted a revised response to Request for Additional Information (RAI) 02.05.01-15. During the preparation of the response to RAI 02.05.01-35 provided in Reference 2, FPL determined that the response to RAI 02.05.01-15 would need to be revised to be consistent with the response to RAI 02.05.01-35 with respect to the Phase 2 earthquake catalog. Additionally, during the preparation of this revised response to RAI 02.05.01-15, FPL identified that the graphical depiction of the Santaren anticline shown in Figure 3 and FSAR Figure 2.5.1-350 provided as part of that response, was inconsistent with the graphical presentation shown in the source document in Masaferro et al. (1999). This revised response also addresses this inconsistency. The attachment identifies changes that will be made in a future revision of the Turkey Point Units 6 and 7 Combined License Application (if applicable).

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

D097
NRO

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

Executed on June 17, 2015.

Sincerely,

William Maher
Senior Licensing Director – New Nuclear Projects

WDM/RFB

Attachment: FPL Revised Response to NRC RAI No. 02.05.01-15 (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**

Question from Geosciences and Geotechnical Engineering Branch

**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:**

**INTRODUCTION**

This submittal is a revised response to RAI 02.05.01-15, which was previously submitted to the NRC as Attachment 15 to FPL letter L-2014-281, "Voluntary Revised Response to NRC Request for Additional Information Letter No. 041 (eRAI 6024) SRP Section: 02.05.01 - Basic Geologic and Seismic Information," dated October 3, 2014. This revision includes changes to the RAI response text for consistency with the response to RAI 02.05.01-35 related to the Phase 2 earthquake catalog. In addition, it has been identified that the graphical depiction of the Santaren anticline shown in Figure 3 and FSAR Figure 2.5.1-350 provided as part of the response to RAI 02.05.01-15 (Attachment 15, Page 9 of 11 and Page 11 of 11, respectively) are inconsistent with the graphical presentation shown in the source document in Masaferro et al. (1999) (FSAR Reference 2.5.1-426). To address this issue, this submittal also contains a revision to Figure 3. A revision to associated FSAR Figure 2.5.1-350 will be provided in the response to RAI 02.05.01-34.

**REVISIONS TO RAI 02.05.01-15**

**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).**

Part (a) of this response summarizes data and interpretations presented in the literature pertaining to the Santaren anticline. Specifically, part (a) of this response addresses evidence in the literature for: (1) ongoing deformation; (2) calculations of present day rates of shortening; and (3) the possible existence of a thrust fault that cores the Santaren anticline. For the purposes of this response, the terms "ongoing" and "present day" are understood to refer to any activity in the Quaternary period.

Ball et al. (1985)

Based on seismic reflection, gravity, and magnetic data collected from the southwest edge of the Bahama Platform, Ball et al. (1985) (FSAR Reference 2.5.1-501) interpret subsurface geology and structures associated with the northern edge of the Bahama-Cuba collision zone. Ball et al. (1985) (FSAR Reference 2.5.1-501) identify the Santaren anticline as an approximately 10-km-wide, 70-km-long, northwest-trending structure (FSAR Figure 2.5.1-343). Ball et al. (1985) (FSAR Reference 2.5.1-501) resolve regional thinning of upper Cretaceous beds from north to south across the Santaren anticline, with the largest magnitude of thinning (up to a factor of four) occurring off the anticline's southern flank within uppermost Cretaceous and lower Cenozoic carbonate beds (p. 1285) (Figure 1). Ball et al. (1985) (FSAR Reference 2.5.1-501, pp. 1,285-1,287) 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." Ball et al. (1985) (FSAR Reference 2.5.1-501, p. 1,292) reiterate "the [Santaren anticline] appears to have been formed in the Late Cretaceous and early Cenozoic."

Ball et al. (1985) (FSAR Reference 2.5.1-501, pp. 1,290-1,292) also provide a structural interpretation of the Santaren anticline in their Figure 9b (Figure 1), noting "Deep terminations occur, below 4 km depth, in inferred basinal sediments beneath the anticline, 3 km north of the zone of dip and thickness variation. Some major dislocation related to faults may have caused the aberrant dips and local thickness variations. However, the regional thinning was caused by southward onlap of basinal carbonates on shallow-water carbonate material. Subsequent compressional tectonism produced the anticline." Based on the previously quoted age determinations, the location of the anticline, the interpreted asymmetry of the anticline, and the interpretation of a fault below 4 km depth, Ball et al. (1985) (FSAR Reference 2.5.1-501, p. 1,294) state "We speculate that this structure is a hanging-wall anticline marking the northern limit of thrusting in the Cuban arc."

These data and interpretations are not used by Ball et al. (1985) (FSAR Reference 2.5.1-501) to provide evidence of ongoing deformation or to calculate present day rates of shortening across the Santaren anticline. Ball et al. (1985) (FSAR Reference 2.5.1-501, p. 1287) specifically note that "late Cenozoic expression" (which presumably refers to the interpretation of thinned Paleogene strata, the youngest strata that are discussed) may not be related to tectonic processes, but may instead be the result of differential compaction.

Ball et al. (1985) (FSAR Reference 2.5.1-501) do not calculate shortening rates for the Santaren anticline. Furthermore, it should be noted that the location of the steeply dipping fault dashed in Ball et al.'s (1985) (FSAR Reference 2.5.1-501) Figure 9b (Figure 1) is kinematically incompatible with the location of the Santaren anticline. As drawn, at least half of the interpreted hanging-wall anticline is actually on the footwall of the dashed fault.

Masaferro et al. (1999)

Masaferro's Ph.D. dissertation (1997) (FSAR Reference 2.5.1-477) is the source for seismic reflection data that are analyzed in subsequent peer-reviewed publications, including Masaferro et al. (1999) (FSAR Reference 2.5.1-426) and Masaferro et al. (2002) (FSAR Reference 2.5.1-479). Masaferro et al. (1999) (FSAR Reference 2.5.1-426) combine these seismic reflection data with well logs acquired during the Ocean Drilling Project (ODP) to provide a more detailed stratigraphic and structural analysis of the Santaren anticline, relative to the analysis conducted by Ball et al. (1985) (FSAR Reference 2.5.1-501). Using the geometries and inferred ages of growth strata associated with the Santaren anticline, Masaferro et al. (1999) (FSAR Reference 2.5.1-426, p. 630) reinterpret the Santaren anticline "as a detachment fold involving limb rotation and perhaps tangential-longitudinal strain", expressly stating that the fold geometry imaged in their seismic reflection data "argues against a fault-bend and/or fault propagation fold" (p. 623-624) as suggested by Ball et al. (1985) (FSAR Reference 2.5.1-501). Masaferro et al. (1999) (FSAR Reference 2.5.1-426, p. 630) conclude the Santaren anticline experienced fold growth "from the Mid-Eocene to Pliocene and perhaps to the present day", although they note that "the youngest beds might be post-tectonic." Masaferro et al. (1999) (FSAR Reference 2.5.1-426) calculate vertical fold growth rates of between 0.006 mm/yr and 0.014 mm/yr for the last 19 million years before present (Ma), and a fold shortening rate of 0.001 mm/yr over the same time period.

The data and interpretations of Masaferro et al. (1999) (FSAR Reference 2.5.1-426) do not conclusively provide evidence for ongoing tectonic deformation (as suggested by the queried reference to present day folding in the title of the reference) and they do not calculate present-day rates of shortening. As noted above, Masaferro et al. (1999) (FSAR Reference 2.5.1-426) allow for the youngest beds to be post-tectonic, although "youngest" is not defined. The present-day rate of shortening is not directly stated by Masaferro et al. (1999) (FSAR Reference 2.5.1-426), however, this rate can be calculated using data from their youngest two horizons in their Table 5. Masaferro et al. (1999) (FSAR Reference 2.5.1-426) calculate a change in cumulative shortening of 1 m between deposition of horizon M (cumulative shortening of 785 m) and horizon N (cumulative shortening of 786 m), over an interval of the past 3.6 Ma (their Table 5). This corresponds to a mid-Pliocene shortening rate of 0.0003 mm/yr. However, the calculation of cumulative shortening is dependent on a number of assumptions and uncertainties. Masaferro et al. (1999) (FSAR Reference 2.5.1-426) note that these errors are not quantifiable, but suggest each cumulative shortening value has an associated error of ±10%. Thus, the calculation of a present-day shortening rate relies on the ability to detect a difference of 1 m between two values that may each vary by ±78 m. Viewed another way, calculation of a shortening rate relies on the ability of Masaferro et al. (1999) (FSAR Reference 2.5.1-426) to resolve a difference in horizon bed length of 1 m in horizons that are approximately 11 km long, or a 0.009% change in horizon length. This is likely beyond the resolution of the data.

Masaferro et al.'s (1999) (FSAR Reference 2.5.1-426) interpretation of the Santaren anticline as a detachment fold (in the context of Epard and Groshong, 1995; Homza and Wallace, 1995; Poblet and McClay, 1996) (References 2, 3, and 4) directly contradicts the idea that the anticline might be cored by a steeply dipping thrust fault, as proposed by Ball et al. (1985) (FSAR Reference 2.5.1-501), because a detachment fold is interpreted as resulting from movement along a horizontal detachment surface.

Masaferro et al., 2002

Masaferro et al. (2002) (FSAR Reference 2.5.1-479) build on the analysis presented in Masaferro et al. (1999) (FSAR Reference 2.5.1-426) by identifying a number of additional subhorizons between the horizons originally identified in the 1999 manuscript. This allows Masaferro et al. (2002) (FSAR Reference 2.5.1-479) to model the temporal variability in sedimentation and fold-growth rates since Late Oligocene time; shortening amounts and rates are not discussed. Masaferro et al. (2002) (FSAR Reference 2.5.1-479) 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 Reference 2.5.1-479, p. 21). This is in contrast to the conclusion of Masaferro et al. (1999) (FSAR Reference 2.5.1-426), which proposes that the Santaren anticline experienced approximately constant, slow growth. Masaferro et al. (2002) (FSAR Reference 2.5.1-479) further suggest 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) (Figure 2). Since that time, the average fold uplift rate is approximately 0.03 mm/yr. Masaferro et al. (2002) (FSAR Reference 2.5.1-479, p. 21) 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" 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 a Late Miocene age. Since deposition of beds K2 and K3, Santaren anticline fold uplift rates have been at or near zero (FSAR Reference 2.5.1-479, Table 4c) (Figure 2). The youngest interval for which a non-zero uplift rate was calculated was the interval between deposition of early Quaternary beds M2 and M3, which has a 0.05 millimeters per year (0.002 inches per year) fold uplift rate (FSAR Reference 2.5.1-479) (Figure 2).

The data and interpretations of Masaferro et al. (2002) (FSAR Reference 2.5.1-479) do suggest possible tectonic deformation in the Quaternary period. As stated above, Masaferro et al. (2002) (FSAR Reference 2.5.1-479) interpret the Santaren anticline to have experienced episodic tectonic growth and sedimentation since at least Oligocene time, with the most recent episode of tectonic uplift interpreted to have occurred in the early Quaternary (between deposition of beds M2 and M3, with a fold uplift rate of 0.05 mm/yr).

The calculation of present day rates of shortening is less straightforward. First of all, the tectonic activity that is interpreted to have occurred between deposition of early Quaternary beds M2 and M3 is followed by no tectonic activity between deposition of beds M3 and N (FSAR Reference 2.5.1-479, Figure 4c) (Figure 2). The absolute age of subhorizon M3 is not explicitly provided in FSAR Reference 2.5.1-479, however, ages are plotted in their Figure 3a. Using the scale provided, it is clear that the interval from deposition of bed M3 to deposition of bed N spans the period from approximately 1 Ma to present. It is reasonable to question the degree to which an early Quaternary rate would accurately characterize a structure that has exhibited no activity for the past 1 million years.

In addition, the episodic tectonic growth, indicated by some beds thinning across the anticline while others do not, could also be caused by variations in local sedimentation rate, variations in sea level, and erosion by bottom currents. Masaferro et al. (2002) (FSAR Reference 2.5.1-479) indicate that erosion by bottom currents and variations in sea level can be ruled out because strata in one location nearby do not exhibit such variations, however, other examples of Miocene and Pliocene erosional unconformities exist just to the north at Site 1007 (Eberli et al. 2002) (Reference 1).

Furthermore, the assumptions and uncertainties associated with fold uplift rates (which are based on differences in cumulative fold-crestal relief) are identical to those described above for shortening rates. Masaferro et al. (2002) (FSAR Reference 2.5.1-479) do not provide cumulative fold-crestal relief data for subhorizons M2 and M3, however, these values should logically fall between the values for horizons M and N, which are 1302 m and 1326 m, respectively (Masaferro et al. 1999, Table 4). This means that calculation of the M2-M3 fold uplift rate relies on the ability to discern less than 24 m of cumulative fold-crestal relief between two values that each can vary by approximately +/- 130 m (Masaferro et al. 1999, Table 4). It is likely that the calculation of the early Quaternary 0.05 mm/yr fold uplift rate exceeds the resolution of the data.

Masaferro et al. (2002) (FSAR Reference 2.5.1-479) recognize previous interpretations of the Santaren anticline as a fault-related fold (i.e., Ball et al. 1985 (FSAR Reference 2.5.1-501)) or a detachment fold (Masaferro et al. 1999 (FSAR Reference 2.5.1-426)). Masaferro et al. (2002) (FSAR Reference 2.5.1-479) do not provide any additional discussion or interpretation of fold-growth models for the Santaren anticline.

**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 Santaren anticline and three unnamed fold axes directly to its southwest from Masaferro et al. (1999) (FSAR Reference 2.5.1-426) are shown on Figure 3, along with earthquake epicenters from the Phase 2 earthquake catalog. Earthquake activity is very sparse in the vicinity of the Santaren anticline, and there does not appear to be a spatial association between seismicity and the Santaren anticline or with the unnamed fold axes directly to the southwest (Figure 3).

As discussed above, different structural frameworks have been suggested to explain the Santaren anticline. Ball et al. (1985) (FSAR Reference 2.5.1-501) suggest the Santaren anticline may be cored by a steeply dipping thrust fault, whereas Masaferro et al. (1999) (FSAR Reference 2.5.1-426) interpret the Santaren anticline as a detachment fold. Masaferro et al. (2002) (FSAR Reference 2.5.1-479) note these different interpretations but provide no further discussion of any 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 (<0.1 mm/yr), it is not clear that this shortening is accommodated by a seismogenic structure capable of producing vibratory ground motion or tectonic surface deformation.

Regardless of these structural interpretations, the issue of whether or not the Santaren anticline is a capable tectonic structure is addressed by data presented by Masaferro et al. (2002) (FSAR Reference 2.5.1-479). The calculated fold uplift rates for the Santaren anticline, as depicted in Figure 4c of FSAR Reference 2.5.1-479 (Figure 2), show no uplift since deposition of beds M2-M3. As detailed in part (a) of this response, this period of tectonic quiescence spans the period from approximately 1 Ma to present. The fact that FSAR Reference 2.5.1-479 depicts no uplift in the most recent 1 million years would therefore support the conclusion that the Santaren anticline does not represent a capable tectonic structure. The sparse seismicity near this structure further supports this argument (Figure 3).

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

The Santaren anticline and the Nortecubana fault system are discussed in FSAR Subsections 2.5.1.1.1.3.2.2 and 2.5.1.1.1.3.2.4 as being spatially and temporally associated with the northern reaches of the Cuban orogeny, and, as such, it is likely they were genetically associated with similar convergent plate boundary driving forces. Additionally, the Santaren anticline appears to be on trend with the eastern portion of the Nortecubana fault (Figure 3). 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 Phase 2 earthquake catalog provides 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 northwestward into the site region (FSAR Subsection 2.5.1.1.1.3.2.4). Seismicity in the vicinity of the Santaren anticline is discussed in part (b) of this response and appears very sparse. There does not appear to be a spatial association between seismicity and the Santaren anticline or with the unnamed fold axes directly to its southwest (Figure 3). Likewise, seismicity is lacking in the approximately 30-km-wide gap between the Santaren Anticline and the Nortecubana fault system (Figure 3). Given the lack of data suggesting a structural link between these features, there is no reason to conclude that the Santaren anticline and the Nortecubana fault system are linked.

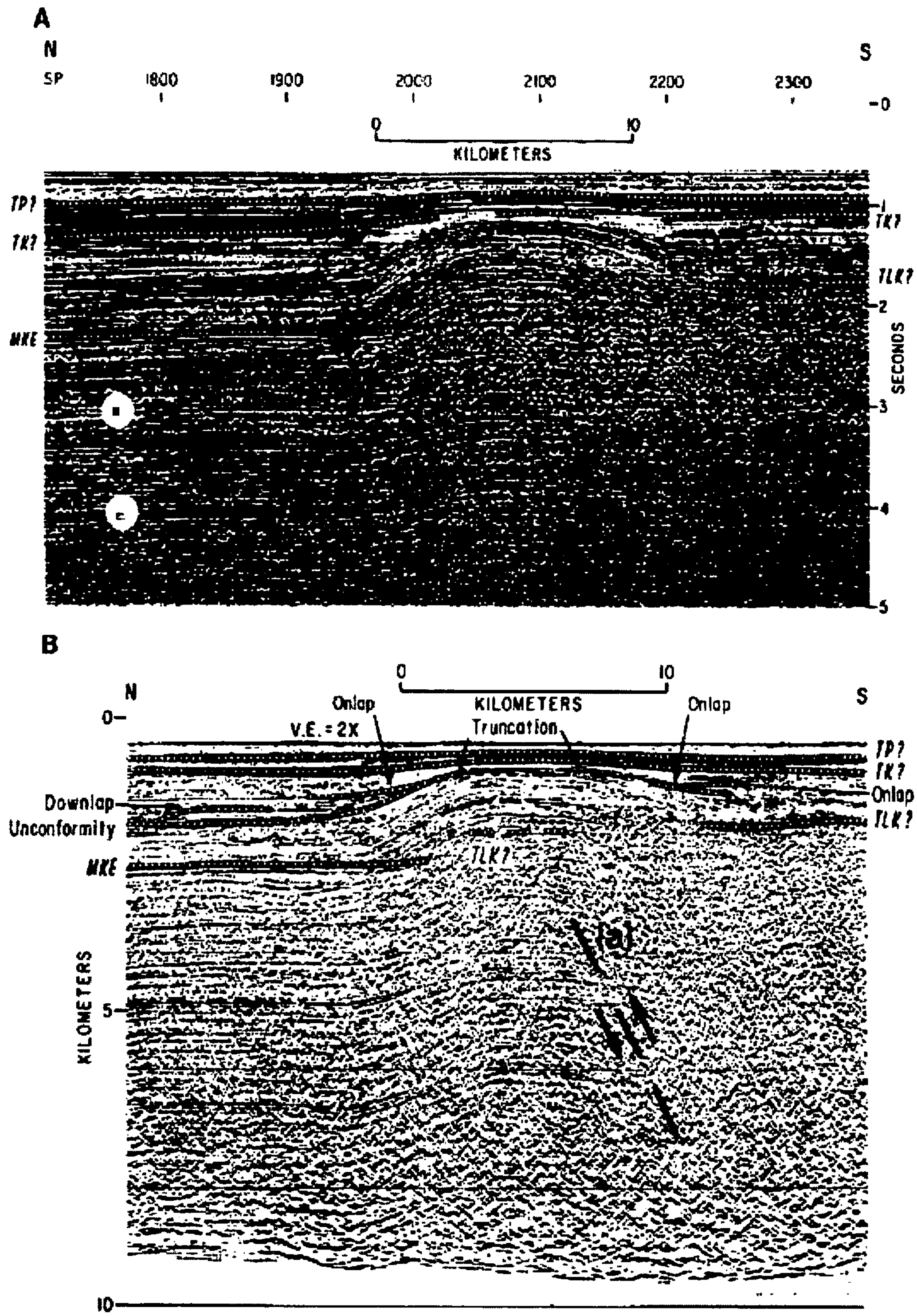


**Figure 1. (A) Time section of Santaren Anticline from Ball et al. (1985) (FSAR Reference 2.5.1-501, Figure 9). (B) Migrated depth section of profile from (A) with 2x vertical exaggeration. Ball et al. (1985) (FSAR Reference 2.5.1-501) propose a fault as dashed.**

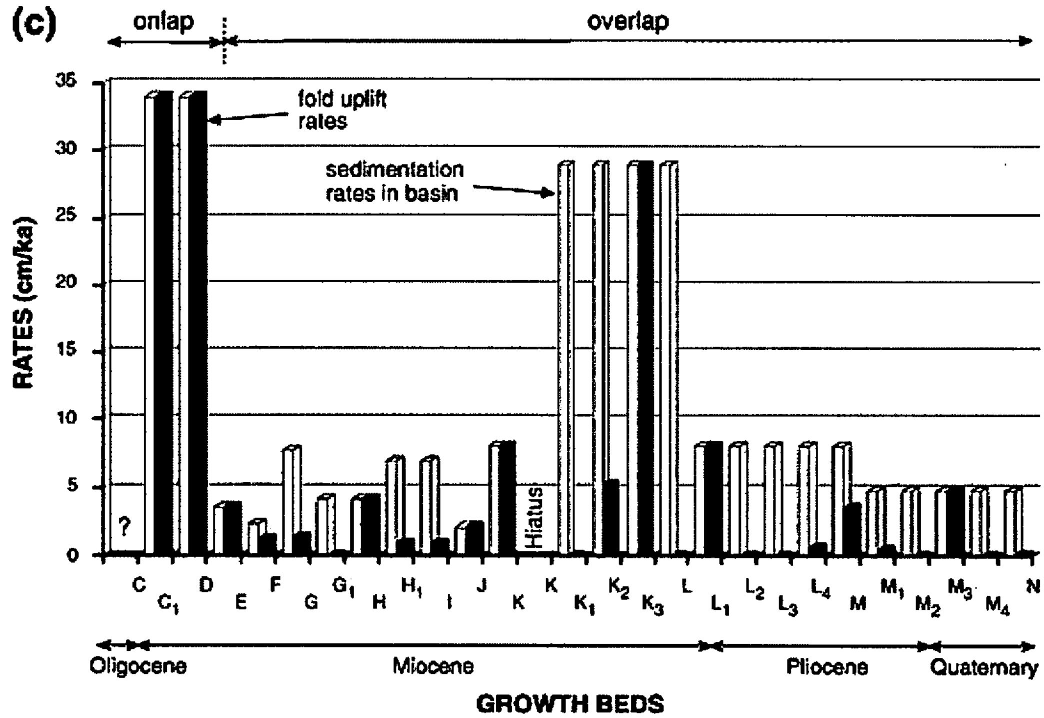


**Figure 2. Calculated sedimentation and fold uplift rates for the Santaren anticline, from Masaferro et al. (2002) (FSAR Reference 2.5.1-479, Figure 4c).**

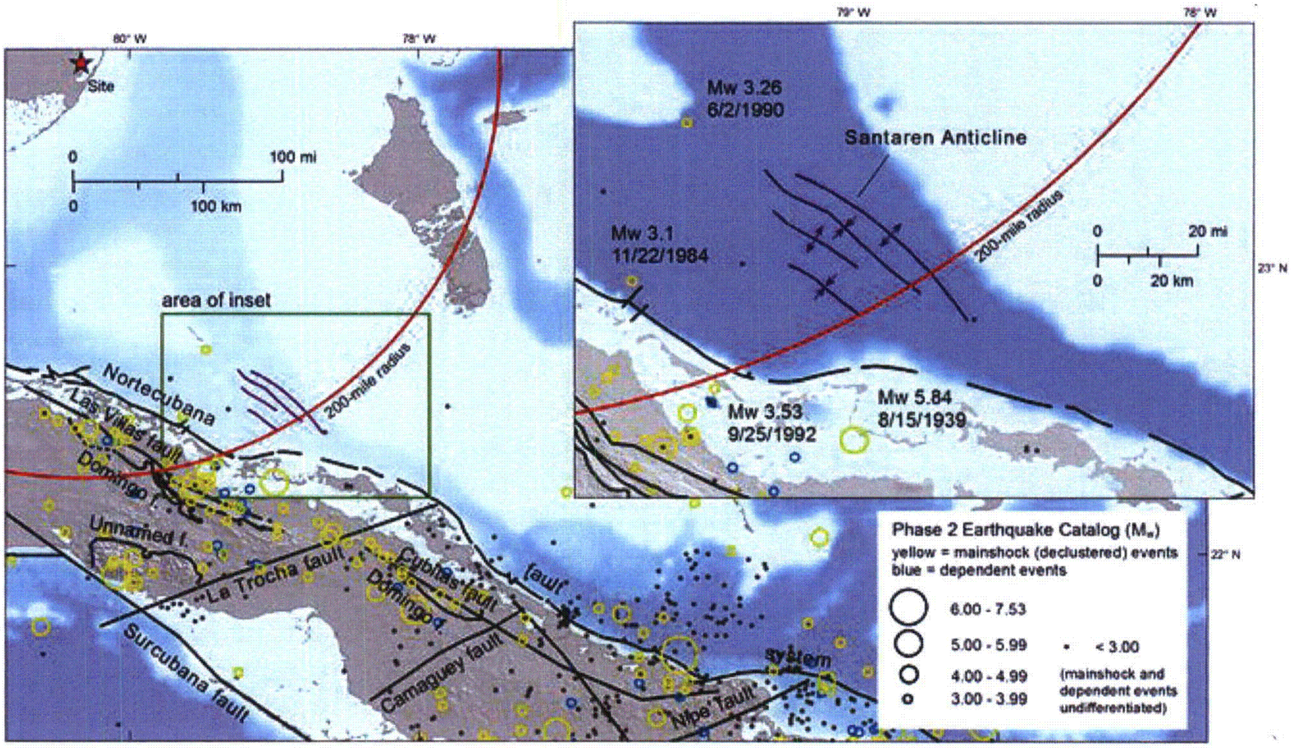


**Figure 3. Seismicity in the Vicinity of the Santaren Anticline.**

**Source: FSAR Section 2.5.1.3 References 2.5.1-477, 492, 443, 770, 494, 448, and 439.**

This response is PLANT SPECIFIC.

**References:**

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

2. Epard, J.-L., and Groshong, R.H., 1995, Kinematic model of detachment folding including limb rotation, fixed hinges and layer-parallel strain, Tectonophysics, v. 247, pp. 85-103.

3. Homza, T.X., and Wallace, W.K., 1995, Geometric and kinematic models for detachment folds with fixed and variable detachment depths, Journal of Structural Geology, v. 17, no. 4, pp. 575-588.

4. Poblet, J., and McClay, K., 1996, Geometry and kinematics of single-layer detachment folds, American Association of Petroleum Geologists Bulletin, v. 80, no. 7, pp. 1085-1109.

## ASSOCIATED COLA REVISIONS:

The Associated COLA Revisions previously submitted to the NRC in Attachment 15 to FPL Letter L-2014-281, Pages 10 to 11, were incorporated in Revision 5 of the COLA. A new revision to FSAR Figure 2.5.1-350 (Figure 3 in this response) will be provided in the response to RAI 02.05.01-34 for incorporation into a future COLA revision.

## ASSOCIATED ENCLOSURES:

None