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~~beingthenortherntransformlimbofaproto-Caymanspreadingcenterthatwasactivein theearly Eocene(53Ma)andwasabandonedby49Ma(Reference499).This interpretationistheresultofthe southwardmigrationoftheleft-lateralstrikeslipfaultsthat makeuptheCaribbean-NorthAmerica plateboundary(e.g.,Reference639).Projectionsof theCretaceoustoEoceneophioliticsuture zone(roughlycoincidentwiththeDomingofault) areshownleft-laterallyoffsetbythestructure(e.g., Reference847).Noavailablegeologic mapsshowanynortheast-strikingfaultscuttingthe Mioceneandyoungerstratainthe vicinityofwherethisfaultshouldbelocated(e.g.,Reference846). Potentially,thisstructure isburiedbythestrataandwouldbepre-middleMioceneinage. Rosencrantz(Reference 529)mapsanortheast-strikingstructureacrosstheYucatanbasinandinterpretitasthe offshoreextensionofthesinistralLaTrochaFault.~~

~~*Camaguey Fault*~~

~~Mostgeologicmapsdonotshowaregionalnortheast-strikingfaultsuchastheCamaguey faultat thesurface,includingthe1:250,000scalegeologicmap(References846,500,and 847).However,ontectoniccompilationsitislocatedoutsideofthesiteregion(Figures 2.5.1-247and2.5.1-251)andisassignedaPaleogeneage(Reference848).The Camaguey fault,liketheLaTrochaorPinarfault,isinterpretedasaccommodating eastwardrotationand translationoftheCaribbeanPlatebeforethedevelopmentofthe Orientefaultsystem(Reference 445).Cotilla-Rodríguezetal.(Reference494)assessthe Camagueyfaultasactivebasedon possibleassociationofmicroseismicitywiththisfault.~~

~~*Cubitas Fault*~~

~~NeartheCamagueyfault,theCubitasfaultisanorthwest-strikingnormalfaultthatforms the southernboundaryofanareaofhighertopography(Figure2.5.1-288).Itisdescribed aspost-middleEoceneinageandsuggestedtobepartiallyresponsibleforupto200 metersupliftofhills, possiblyafterthedepositionofPlio-Pleistocenefluvialterraces (Reference500).Cotilla-Rodríguezetal.(Reference494)notethattheCubitasfaultis associatedwithlargescarpsand assignitaPliocene-Quaternaryage.~~

~~*Nipe Fault*~~

~~Thenortheast-strikingNipefault(namedCauto,Cauto-Nipe,Guacanayabo,orNipe-Guacanayabofaultinvariouspublications;referredtoasNipefaulthere)separatesthe mountainousSierraMaestraprovincefromtheCamagueyterrane(Figures2.5.1-251and 2.5.1-247).Thisstructureisnotmappedatthesurfaceonavailablegeologicmaps (References 846and848).Leroyetal.(Reference499)andRojas-Agramonteetal. (Reference445)interpretit asbeingthesoutherntransformlimbofthe earlyCayman spreadingcenter(Figure2.5.1-250).In theirmodel(andthatofReference445)thefault wasabandonedbytheearlyOligocene(20Ma)as theplateboundaryshiftedsouthtothe Orientefault,whereitistoday.Cotilla-Rodríguezetal. (Reference494)assesstheCauto- Nipefaultasactivebasedonpossibleassociationof microseismicitywiththisfault. However,theydonotdescribestratigraphic,geomorphic,orother evidenceforQuaternary activity.~~

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~~TheBaconaofaultisanorthwest-strikingfault,locatedinsoutheasternCuba(Figure2.5.1-288).Cotilla-Rodríguezetal.(Reference494)indicatethatitmayhavenormal,reverse, andleft-lateralstrike-slipkinematics.ThisfaultisnotshownontheCaseandHolcombe (Reference480)or the1:250,000scalegeologicmaps(Reference846).However,a dashed(postulated)structure onthe1:500,000scalegeologicmapisdepictedcutting Oligocene-Miocenestrata,butcovered byunfaultedPleistocenestrata(Reference848).It maydeformPleistoceneandQuaternary terracesandisassociatedwithpoorlylocated seismicity(Reference494).~~

Baconao fault

The Baconao fault is a northwest-striking fault located in southeastern Cuba (Figures 2.5.1-247 and 2.5.1-368 Sheet 3). At its nearest point, the Baconao fault is approximately ~~330 miles (530 km)~~ 530 kilometers (330 miles) from the Turkey Point Units 6 & 7 site. Garcia et al. (Reference 489~~, p. 2,571~~) provide only minimal discussion of this fault, but describe it as "better defined in its eastern part, where it has a clear expression mainly in relief and significant seismic activity at the intersection with the [Oriente fault zone]."

Cotilla-Rodríguez et al. (Reference 494) characterize the Baconao fault as active, based on geologic map relations, geomorphology, and its possible association with seismicity. Cotilla-Rodriguez et al. (Reference 494, ~~p. 515~~) describe the Baconao fault as "normal and reverse type with left strike-slip." Cotilla-Rodriguez et al. (Reference 494~~, p. 513~~) note that, along the easternmost portion of the fault near the modern plate boundary, there are "vast, continuous and abrupt escarpments and many distorted and broken fluvial terraces of the Quaternary and Pleistocene." These observations, coupled with the proximity to the modern plate boundary (i.e., Oriente fault; Figure 2.5.1-247), suggest that the eastern portion of the Baconao fault may be Quaternary active.

Cotilla-Rodriguez et al. (Reference 494) list five earthquakes that they suggest may have occurred on the Baconao fault, all of which occurred between 1984 and 1987. Each of these five earthquakes is assigned Medvedev-Sonheuer-Karnik (MSK) intensity IV (approximate Modified Mercalli Intensity (MMI) IV) (Reference 494). As shown on Figure 2.5.1-368 Sheet 3, however, there is little to no seismicity from the Phase 2 earthquake catalog along much of the length of the Baconao fault, especially along the northwestern two-thirds of its length northwest of the intersection of the Nipe fault. It should be noted that the Phase 2 catalog is a declustered catalog that includes earthquakes of M_w 3 and larger. Cotilla-Rodriguez et al. (Reference 494) indicate there are no earthquake focal mechanisms associated with this fault.

The Baconao fault is not shown on Case and Holcombe's (Reference 480) 1:2,500,000 scale map of the Caribbean. Perez-Othon and Yarmoliuk (Reference 848), however, show an unnamed, dashed fault on their 1:500,000 scale geologic map of Cuba. This unnamed fault is located in the vicinity of the Baconao fault and is depicted cutting Oligocene-Miocene strata, but covered by apparently unfaulted mid-Quaternary-age strata (Reference 848). According to mapping by Perez-Othon and Yarmoliuk (Reference 848), the Baconao fault appears to be offset in a right-lateral

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sense by two strands of the northeast-striking Nipe fault. As an inset to their geologic map, Perez-Othon and Yarmoliuk (Reference 848) provide an additional map that shows their estimates of fault ages in Cuba. A modified version of their inset map is provided as Figure 2.5.1-369. The inset map presented in Figure 2.5.1-369 was modified by enhancing the color-coding of the Perez-Othon and Yarmoliuk (Reference 848) age estimates and by adding fault name labels based on their relative locations. Most of the fault name labels added to the inset map are queried, however, indicating ~~T~~the uncertainty regarding which faults are, and which are not, shown on the inset map. If the unnamed fault depicted on Perez-Othon and Yarmoliuk's (Reference 848) inset map of fault ages in Cuba represents the Baconao fault, as is assumed on Figure 2.5.1-369, then they indicate a Neogene-Quaternary age for the southeastern one-third of the Baconao fault. The northwestern two-thirds of the Baconao fault as shown on Figure 2.5.1-368 Sheet 3 does not clearly appear on Perez-Othon and Yarmoliuk's (Reference 848) inset map (Figure 2.5.1-369).

The Nuevo Atlas Nacional de Cuba includes a 1:1,000,000 scale geologic map of Cuba (Reference 944, plate III.1.2-3) and a 1:2,000,000 scale neotectonic map of Cuba (Reference 944, plate III.2.4-8). No fault names appear on these two maps so it is not clear whether the Baconao fault is shown. The geologic map of Cuba from this atlas shows an approximately ~~30-mile-long (50-km-long)~~ 50-kilometer-long (30-mile-long), northwest-striking fault near Santiago de Cuba that may be the Baconao fault, but this fault is restricted to southernmost Cuba, southeast of the Nipe fault. This fault appears to cut middle Eocene strata. Likewise, the neotectonic map of Cuba from this atlas shows an approximately 75-kilometer-long (45-mile-long), ~~45-mile-long (75-km-long),~~ northwest-striking fault in the same area of southernmost Cuba that could be the Baconao fault. The Baconao fault is depicted and labeled on the 1:2,000,000 scale lineament map from this atlas (Reference 944, plate III.3.1-11). The Baconao fault is shown and labeled on Pushcharovskiy's (Reference 847) 1:500,000 scale tectonic map of Cuba.

Camaguey Fault

The Camaguey fault is a northeast-striking fault located in southeastern Cuba (Figures 2.5.1-247, 2.5.1-251, 2.5.1-368 Sheet 2, and 2.5.1-368 Sheet 3). At its nearest point, the Camaguey fault is approximately 530 kilometers (330 miles) ~~330 miles (530 km)~~ from the Turkey Point Units 6 & 7 site. Garcia et al. (Reference 489~~, p. 2,571~~) describe the Camaguey fault as a "regional transverse fault with lateral displacement that affects the whole crust and constitutes the boundary between two megablocks" and that "cuts young as well as old sequences." On their Figure 5, Garcia et al. (Reference 489) show the Camaguey fault as a normal fault with unspecified dip direction and sense of throw. Garcia et al. (Reference 489~~, p. 2,571~~) also note that "the gravimetric and magnetic fields show apparent inflections."

Cotilla-Rodríguez et al. (Reference 494) classify the Camaguey fault as active based on the possible association of seismicity with the fault. Cotilla-Rodriguez et al. (Reference 494~~, p. 514~~) describe the Camaguey fault as a sinistral strike-slip fault with an almost vertical plane associated with a low "level of seismic activity." They list ten earthquakes that they suggest may have occurred on the Camaguey fault. Three of these earthquakes are assigned MSK intensity III – IV (approximately MMI III – IV), with the remaining seven unspecified (Reference 494). As shown on Figures

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2.5.1-368 Sheets 2 and ~~2.5.1-368 Sheet~~ 3, however, there is little to no seismicity from the Phase 2 earthquake catalog located along the length of the Camaguey fault, with the possible exception of a single, minor-magnitude earthquake near the northeastern end of the fault. Alternatively, this minor earthquake may be associated with the northwestern end of the Baconao fault or some other unmapped structure (Figure 2.5.1-368 Sheet 3). Cotilla-Rodriguez et al. (Reference 494) indicate there are no earthquake focal mechanisms associated with this fault.

The Camaguey fault is not consistently shown on geologic and tectonic maps of Cuba. For example, it is not labeled on Pushcharovskiy et al.'s (Reference 846) 1:250,000 scale geologic map of Cuba, Pushcharovskiy's (Reference 847) 1:500,000 scale tectonic map of Cuba, the Nuevo Atlas Nacional de Cuba 1:1,000,000 scale geologic map (Reference 944, plate III.1.2-3), and van Hinsbergen et al.'s (Reference 500) mapping of the Camaguey area. The Camaguey fault is depicted and labeled on the 1:2,000,000 scale lineament map from the national atlas (Reference 944, plate III.3.1-11) and shown but not labeled on the 1:2,000,000 scale neotectonic map from the same atlas (Reference 944, plate III.2.4-8). Because they do not label faults by name, it is not clear whether the Camaguey fault is depicted on Perez-Othon and Yarmoliuk's (Reference 848) inset map of fault ages in Cuba, but they indicate a Paleogene age for an unnamed fault in the vicinity of the Camaguey fault (Figure 2.5.1-369).

Cochinos Fault

The Cochinos fault is a north- ~~(References 770 and 494)~~ (References 494 and 770)~~-~~to north-northwest-striking (Reference 493) fault in south-central Cuba. Figures 2.5.1-247, 2.5.1-368 Sheet 1, and 2.5.1-368 Sheet 2 show the location of the Cochinos fault after Hall et al. (Reference 770). As mapped by Hall et al. (Reference 770), the fault at its nearest point is approximately ~~205 miles (330 km)~~ 330 kilometers (205 miles) from the Turkey Point Units 6 & 7 site. Alternatively, mapping by Cotilla-Rodriguez et al. (Reference 494) suggests this fault may extend northward to within 175 miles (280 km) of the site, whereas mapping by Mann et al. (Reference 493) indicates a closest distance of approximately 210 miles (340 km). The Cochinos fault is the only onshore feature in intraplate Cuba identified as "neotectonic" by Mann et al. (Reference 493) (Figure 2.5.1-286). They map the Cochinos fault as two parallel, north-northwest-striking normal faults that form a graben (Figures 2.5.1-286, 2.5.1-368 Sheet 1, and 2.5.1-368 Sheet 2). The morphology of Bahia de Cochinos is consistent with this interpretation and suggests the possibility of fault control on the landscape.

Cotilla-Rodriguez et al. (Reference 494~~, pp. 514-515~~) describe the Cochinos fault as a "normal fault with a few inverse type sectors which demonstrates transcurrence to the left" and "normal and reverse type with left strike-slip." Recorded seismicity near the Cochinos fault is sparse. They list six earthquakes that they suggest may have occurred on the Cochinos fault. The largest of these is the December 16, 1982 Ms 5.0 earthquake. The Phase 2 earthquake catalog developed for the Turkey Point Units 6 & 7 ~~COL~~ site~~-~~does not include an earthquake on that date with similar magnitude and location. The Phase 2 earthquake catalog does, however, include an M_w 5.4 earthquake near the Cochinos fault that occurred on November 16, 1982 (Figures 2.5.1-368 Sheet 1 and 2.5.1-368 Sheet 2). Based on the similarity in location,

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magnitude, and year for the December 16 and November 16 earthquakes, it is assumed that these are the same earthquake and that the discrepancy in month is the result of a typographical error in Cotilla-Rodríguez et al.'s (Reference 494) manuscript. The remaining five earthquakes that Cotilla-Rodriguez et al. (Reference 494~~, p. 516~~) associate with the Cochinos fault "are all of low [and unspecified] intensity." In the Phase 2 earthquake catalog, the 1982 earthquake is located approximately 3 miles (5 km) northwest of the Cochinos fault trace (Figures 2.5.1-368 Sheet 1 and 2.5.1-368 Sheet 2). Cotilla-Rodriguez et al. (Reference 494) suggest that the 1982 earthquake may instead have occurred on the Habana-Cienfuegos fault. In addition to the 1982 earthquake, the Phase 2 earthquake catalog shows only four other earthquakes within 20 miles (32 km) of the Cochinos fault, the largest of which is assigned M_w 4.1 (Figures 2.5.1-368 Sheet 1 and 2.5.1-368 Sheet 2). Cotilla-Rodriguez et al. (Reference 494) indicate there are no earthquake focal mechanisms associated with this fault.

Cotilla-Rodríguez et al. (Reference 494) classify the Cochinos fault as active based on the possible association of seismicity with the fault. Cotilla-Rodríguez et al. (Reference 494~~, p. 514~~) provide no geologic evidence for activity on the Cochinos fault and describe the fault as "covered by young sediments." Indeed, the most detailed geologic maps inspected in the area (1:250,000 scale) show no fault cutting Miocene and younger strata (Reference 846). Because they do not label faults by name, it is not clear whether the Cochinos fault is depicted on Perez-Othon and Yarmoliuk's (Reference 848) inset map of fault ages in Cuba, but they indicate a Paleogene age for a northern extension of this fault (Figures 2.5.1-368 Sheet 1 and 2.5.1-368 Sheet 2). Pushcharovskiy's (Reference 847) 1:500,000 scale tectonic map of Cuba shows and labels the approximately 60-mile-long (100-km-long) Cochinos fault. The southern approximately 50 miles (80 km) of this fault are shown as a dashed line. Garcia et al. (Reference 489) provide no discussion of the Cochinos fault.

The Cochinos fault is depicted differently on various maps from the Nuevo Atlas Nacional de Cuba (Reference 944). The 1:1,000,000 scale geologic map of Cuba from this atlas (Reference 944, plate III.1.2-3) shows an approximately 87-mile-long (140-km-long) unnamed fault in the vicinity of the Cochinos fault that extends from Cuba's northern coast where it is mapped in Pliocene-age deposits southward into the Bahia de Cochinos. The southernmost 18 miles (30 km) of this fault are shown by a dashed line. The 1:2,000,000 scale neotectonic map of Cuba from this atlas (Reference 944, plate III.2.4-8) shows an approximately 140-kilometer long (87-mile-long) ~~87-mile-long (140-km-long)~~ unnamed fault in the vicinity of the Cochinos fault, the southernmost 50 kilometers (30 miles) ~~30 miles (50 km)~~ of which is offshore southern Cuba and shown by a dashed line. To the north, this fault on the neotectonic map is truncated by the Hicacos fault. The Cochinos fault is depicted and labeled on the 1:2,000,000 scale lineament map from this atlas (Reference 944, plate III.3.1-11). The 1:1,000,000 scale geomorphic map from the Nuevo Atlas Nacional de Cuba (Reference 944, plate IV.3.2-3) shows an approximately 60-kilometer-long (37-mile-long) ~~37-mile-long (60-km-long)~~ unnamed fault in the vicinity of the Cochinos fault. The map explanation indicates that this fault cuts a Quaternary-age marine abrasion platform that is at an elevation of either 2 – 3 m or 5 – 7 m above sea

level. They do not provide explanation for the lack of specificity in elevation of the platform nor do they provide a precise age for the Quaternary abrasion platform.

Cubitas Fault

The Cubitas fault is a northwest-striking, steeply south-dipping fault located in southeastern Cuba (Figures 2.5.1-247, 2.5.1-368 Sheet 2, and 2.5.1-368 Sheet 3). At its nearest point, the Cubitas fault is approximately 435 kilometers (270miles) ~~270 miles (435 km)~~ from the Turkey Point Units 6 & 7 site. Garcia et al. (Reference 489~~, p. 2,571~~) describe the Cubitas fault as a "deep fault that constitutes a portion of the Cuban marginal suture and is considered to be the main structure in central Cuba. It is cut by the Camaguey and the La Trocha transverse faults, where seismicity is documented." They associate the 1974 Ms 4.5 MSK VII Esmeralda earthquake (month and day unspecified) with the Cubitas fault.

Cotilla-Rodríguez et al. (Reference 494) characterize the Cubitas fault as active based on its possible association with seismicity. Cotilla-Rodriguez et al. (Reference 494, pp. 514-515) describe the Cubitas fault as "an almost vertical normal fault with some sectors of inverse type" and as "normal and reverse type." They describe large scarps associated with this fault, but do not provide additional descriptions of the scarps. They assign a Pliocene to Quaternary age for this fault. Cotilla-Rodriguez et al. (Reference 494) list ~~fifteen~~ 15 earthquakes that they suggest may have occurred on the Cubitas fault. Eight of these earthquakes are assigned MSK intensity III – V (approximately MMI III – V), with the remaining seven unspecified (Reference 494). The Phase 2 earthquake catalog includes several low-magnitude earthquakes that may be spatially associated with the northwestern half of the Cubitas fault (Figures 2.5.1-368 Sheet 2 and 2.5.1-368 Sheet 3). The central and southeastern portions of the fault appear largely devoid of seismicity. The Phase 2 earthquake catalog indicates M_w 4.0 and M_w 5.1 earthquakes occurred approximately 24 kilometers (15 miles) ~~15 miles (24 km)~~ south of the mapped trace near the northwestern end of the fault in 1974 and 1984, respectively, which may be associated with the Cubitas fault. Cotilla-Rodriguez et al (Reference 494) indicate there are no earthquake focal mechanisms associated with this fault.

Van Hinsbergen et al. (Reference 500) describe the Cubitas fault as a post-Middle Eocene, south-dipping normal fault that forms a steep slope along the southern margin of the Cubitas Hills. They describe approximately 200 meters (650 feet) ~~650 feet (200 m)~~ of uplift associated with the Cubitas Hills that post-dates deposition of Pliocene-Pleistocene (?) fluvial deposits north of the hills. If this interpretation is correct, then this uplift may have occurred in the hanging wall of the Cubitas fault, which may be Quaternary-active (Reference 500).

Pushcharovskiy et al. (Reference 846) do not label the Cubitas fault on their 1:250,000 scale geologic map. Pushcharovskiy (Reference 847) shows the Cubitas fault as an approximately 85 kilometers long (50-mile-long),~~50-mile-long (85-km-long),~~ south-dipping thrust fault on the 1:500,000 scale tectonic map. Because they do not label faults by name, it is not clear whether the Cubitas fault is depicted on Perez-Othon and Yarmoliuk's (Reference 848) inset map of fault ages in Cuba, but they indicate a Mesozoic age for an unnamed fault in the vicinity of the Cubitas fault (Figure 2.5.1-369).

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The Cubitas fault does not appear on the 1:1,000,000 scale geologic map of Cuba from the Nuevo Atlas Nacional de Cuba (Reference 944, plate III.1.2-3), but seemingly does appear as an unnamed fault on the 1:2,000,000 scale neotectonic map from this same atlas (Reference 944, plate III.2.4-8). The 1:2,000,000 scale lineament map from this atlas (Reference 944, plate III.3.1-11) labels an approximately 85-kilometer-long (50-mile-long) ~~50-mile-long (85-km-long)~~ feature as the Cubitas fault.

Domingo Fault

At its nearest point, the low-angle Domingo fault is located 282 kilometers (175 miles) ~~175 miles (282 kilometers)~~ south of the Turkey Point Units 6 & 7 site. This northwest-striking, south- dipping thrust fault carried the Cretaceous arc and serpentinites over the carbonate platform rocks and can be considered the former suture between North America and Caribbean plates (References 439 and 440) (Figure 2.5.1-247). The Domingo fault does not cut the uppermost Eocene and younger sedimentary units, and is late Eocene in age (References 440 and 439). A myriad of other thrusts are mapped in detail (though not shown Figure 2.5.1-247), which imbricate both the autochthonous and allochthonous units on the island (Reference 439). On 1:250,000 scale maps and interpreted cross sections, these faults also do not cut the uppermost Eocene and younger deposits, and so are not Quaternary in age (References 439, ~~440~~ 497, 497 ~~440~~, and 846) (Figure 2.5.1-248).

Guane Fault

The subsurface Guane fault is a northeast-striking fault in western Cuba (Figures 2.5.1-247 and 2.5.1-368 Sheet 1). At its nearest point, the Guane fault is approximately 370 kilometers (230 miles) ~~230 miles (370 km)~~ from the Turkey Point Units 6 & 7 site. Garcia et al. (Reference 489) provide no discussion of the Guane fault.

Cotilla-Rodríguez et al. (Reference 494) characterize the Guane fault as active based on its possible association with seismicity. Cotilla-Rodriguez et al. (Reference 494~~, p. 516~~) describe the Guane fault as a "large and complex structure totally covered by young sediments in the Palacios Basin" that is "predominantly vertical with left transcurrence." They list ~~nineteen~~ 19 earthquakes that they suggest may have occurred on the Guane fault, many of which are listed by year only without month, day, intensity, and magnitude information. The largest of these is the January 23, 1880 M_w 6.1 San Cristobal earthquake. In the Phase 2 earthquake catalog, seismicity in the vicinity of the Guane fault is sparse, but other light- to moderate-magnitude earthquakes within 20 miles (32 km) of the fault include the May 20, 1937 M_w 5.1, December 20, 1937 M_w 5.1, October 12, 1944 M_w 4.0, and September 11, 1957 M_w 4.0 earthquakes (Figure 2.5.1-368 Sheet 1). Cotilla-Rodriguez et al. (Reference 494) indicate there are no earthquake focal mechanisms associated with this fault.

Based on their review of aerial photographs and satellite imagery, Cotilla-Rodriguez and Cordoba-Barba (Reference 942~~, p. 186~~) note two rivers in the Palacios Basin (Bayate and San Cristobal rivers) that show, in plan view, what they call "fluvial inflections" that they interpret as the result of surface deformation associated with the Guane fault. Cotilla-Rodriguez and Cordoba-Barba (Reference 942~~, p. 186~~) indicate this allows for "the identification of an SW-NE alignment on the south plain of Pinar del Rio, corresponding to the Guane fault, whith *[sic]* was responsible for

the San Cristobal earthquake on the 28.01.1880." However, other rivers along strike to the northeast and southwest do not appear to show such inflections. Moreover, Cotilla-Rodriguez et al. (Reference 494~~, p. 516~~) indicate the Guane fault is "totally covered by young sediments in the Palacios Basin." Likewise, Cotilla-Rodriguez and Cordoba-Barba (Reference 943~~, p. 501~~) indicate the Guane fault "is located under ample thicknesses of sediments of the plain in southern Pinar del Rio." The Cotilla-Rodríguez et al. (Reference 494) and Cotilla-Rodriguez and Cordoba-Barba (Reference 943) studies do not specify a burial depth for the Guane fault, but seemingly are at odds with Cotilla-Rodriguez and Cordoba-Barba's (Reference 942) interpretation of surface manifestation of deformation.

Cotilla-Rodriguez and Cordoba-Barba (Reference 943) describe historical accounts of the January 23, 1880 earthquake, including first-hand observations of earthquake damage in San Cristobal, Candelaria, and elsewhere in the region. They note that the most severe and concentrated damage was located not in the mountainous regions of the Sierra del Rosario and Sierra de los Organos near the Pinar fault (discussed below), but rather within the Palacios Basin near the Guane fault. Cotilla-Rodriguez and Cordoba-Barba (Reference 943) cite this as evidence that the 1880 earthquake occurred on the Guane fault. Cotilla-Rodriguez and Cordoba-Barba (Reference 943~~, p. 514~~) conclude that the Pinar fault "is not the seismogenetic element of the January 23, 1880 earthquake" and that it is "subordinate to" the Guane fault. Alternatively, however, the pattern of 1880 damage could be explained by possible focusing of seismic waves within the basin, possible hanging-wall focusing effects, possible liquefaction, or possible differences in population density and building styles. In other words, the pattern of 1880 damage is not conclusive evidence that the earthquake occurred on the Guane fault, as opposed to on the Pinar fault or other structure.

The Guane fault is not depicted on Pushcharovskiy et al.'s (Reference 846) 1:250,000 scale geologic map of Cuba. Perez-Othon and Yarmoliuk (Reference 848) show an unnamed, dashed fault on their 1:500,000 scale geologic map of Cuba in the vicinity of the Guane fault that cuts Miocene strata, but is covered by unfaulted Pliocene-Pleistocene units. Because they do not label faults by name, it is not clear whether the Guane fault is depicted on Perez-Othon and Yarmoliuk's (Reference 848) inset map of fault ages in Cuba, but they indicate a Paleogene age for an unnamed fault in the vicinity of the Guane fault (Figure 2.5.1-369). The Guane fault does not seem to appear on any maps in the Nuevo Atlas Nacional de Cuba (Reference 944).

Habana-Cienfuegos Fault

The Habana-Cienfuegos fault is a northwest-striking, left-lateral strike-slip fault in western and central Cuba (Figures 2.5.1-247, 2.5.1-368 Sheet 1, and 2.5.1-368 Sheet 2). At its nearest point, the Habana-Cienfuegos fault is approximately 355 kilometers (220 miles) ~~220 miles (355 km)~~ from the Turkey Point Units 6 & 7 site. Cotilla-Rodriguez et al. (Reference 494) map the Habana-Cienfuegos fault as extending offshore in northern Cuba, where it terminates at or south of the

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Nortecubana fault, with which it forms a "morphostructural knot" (Reference 494~~, p. 516~~) (Figures 2.5.1-368 Sheet 1 and 2.5.1-368 Sheet 2). Offshore of southern Cuba, the Habana-Cienfuegos fault is shown as intersected and terminated by the Surcubana fault in a similar "morphostructuralknot" (Figures 2.5.1-368 Sheet 1 and 2.5.1-368 Sheet 2, and Figure 5 of Reference 494). Cotilla-Rodriguez et al. (Reference 494) indicate that the Habana-Cienfuegos fault is expressed in the topography in the northwest at Havana Bay and in the southeast at Cienfuegos Bay.

Garcia et al. (Reference 489) provide minimal discussion of the Habana-Cienfuegos fault. Garcia et al. (Reference 489~~, p. 2,571~~) indicate "although the earthquakes reported in Havana and some locations of its province cannot be attributed to the western portion of the Norte Cubana seismic region, the seismic activity of the Havana fault system is still under debate." Further to the southeast, Garcia et al. (Reference 489~~, p. 2,571~~) indicate that the Cienfuegos fault "coincides with a deep fault located under younger tectonic sequences, it does not have a well-defined character."

In the Phase 2 earthquake catalog, seismicity is sparse in the vicinity of the Habana-Cienfuegos fault (Figures 2.5.1-368 Sheet 1 and 2.5.1-368 Sheet 2). Cotilla-Rodriguez et al. (Reference 494) list nineteen earthquakes that they suggest may have occurred on the Habana-Cienfuegos fault, many of which are listed by year only without month, day, intensity, and magnitude information. The largest of these earthquakes is the December 16, 1982 Ms 5.0 earthquake. The Phase 2 earthquake catalog developed for the Turkey Point Units 6 & 7 COL does not include an earthquake on that date with similar magnitude and location. The Phase 2 earthquake catalog does, however, include an M_w 5.4 earthquake near the Cochinos fault that occurred on November 16, 1982 (Figures 2.5.1-368 Sheet 1 and 2.5.1-368 Sheet 2). Based on the similarity in location, magnitude, and year for the December 16 and November 16 earthquakes, it is assumed that these are the same earthquake and that the discrepancy in month is the result of a typographical error in Cotilla-Rodríguez et al.'s (Reference 494) manuscript. In the Phase 2 earthquake catalog, this earthquake is located approximately 11 kilometers (7 miles) ~~7 miles (11 km)~~ north of the Habana-Cienfuegos fault trace (Figure 2.5.1-368 Sheet 1). Cotilla-Rodriguez et al. (Reference 494) alternatively suggest that this earthquake may have occurred on the Cochinos fault instead. They also associate a Ms 2.5 earthquake and nine MSK intensity III – V earthquakes (approximately MMI III – V) with the Habana-Cienfuegos fault. Cotilla-Rodriquez et al. (Reference 494) suggest that the March 9, 1995, Ms 2.5 earthquake could have occurred on the Habana-Cienfuegos fault or on the nearby Guane fault. Cotilla- Rodriguez et al. (Reference 494) indicate there are no earthquake focal mechanisms associated with this fault.

The Habana-Cienfuegos fault is not shown on Pushcharovskiy et al.'s (Reference 846) 1:250,000 scale geologic map of Cuba and Pushcharovskiy's (Reference 847) 1:500,000 scale tectonic map of Cuba. Because they do not label faults by name, it is not clear whether the Habana-Cienfuegos fault is depicted on Perez-Othon and Yarmoliuk's (Reference 848) inset map of fault ages in Cuba, but they indicate a Paleogene age for an unnamed fault in the vicinity of the Habana-Cienfuegos fault (Figure 2.5.1-369).

The 1:1,000,000 scale geologic map of Cuba from the Nuevo Atlas Nacional de Cuba (Reference 944, plate III.1.2-3) shows an approximately 25-mile-long (40-km-long) unnamed fault near Havana in the vicinity of the northwestern-most portion of the Habana-Cienfuegos fault as shown on Figure 2.5.1-368 Sheet 1. Similarly, the 1:2,000,000 scale neotectonic map of Cuba from the Nuevo Atlas Nacional de Cuba (Reference 944, plate III.2.4-8) shows an approximately 37-mile-long (60-km-long) unnamed fault in the same vicinity, the southeastern 12 miles (20 km) of which is shown as a dashed line. Neither of these maps from the Nuevo Atlas Nacional de Cuba (Reference 944, plates III.2-3 and III.2.4-8) shows a fault extending from Havana southeastward to the southern coast of Cuba, as shown by Cotilla-Rodríguez et al. (Reference 494).

Hicacos fault

The Hicacos fault is an east-northeast-striking fault in north-central Cuba (Figures 2.5.1-247 and 2.5.1-368 Sheet 1). At its nearest point, the Hicacos fault is approximately 250 kilometers (155 miles) ~~155 miles (250 km)~~ south of the Turkey Point Units 6 & 7 site. Based on mapping by Cotilla-Rodriguez et al. (Reference 494), the Hicacos fault is the nearest fault in Cuba to the site identified as active by these authors. Some publications (Reference 769) refer to this fault as the Matanzas fault.

Garcia et al. (Reference 489~~, p. 2,571~~) provide minimal discussion of the Hicacos fault. They indicate it is "a deep fault above Paleocene-Quaternary formations, splitting the ophiolites sequence that makes the main Cuban watershed deviate abruptly, causing different types of fluvial networks." Garcia et al. (Reference 489~~, p. 2,571~~) state that the "earthquakes reported in Matanzas and more recently in the Varadero-Cardenas area are associated with this structure." They provide no additional information regarding these earthquakes.

Cotilla-Rodríguez et al. (Reference 494) characterize the Hicacos fault as active based on its possible association with seismicity. Cotilla-Rodriguez et al. (Reference 494~~, p. 516~~) describe the Hicacos fault as a "normal fault, transcurrent to the left" that is "expressed throughout the Peninsula de Hicacos and is internal in the island territory by the eastern edge of Matanzas Bay, delineating very well the Matanzas Block." Further to the west-southwest, Cotilla-Rodriguez et al. (Reference 494~~, p. 516~~) indicate that the Hicacos fault is "weakly represented" in the geomorphology.

Seismicity in the vicinity of the Hicacos fault is sparse (Figures 2.5.1-368 Sheet 1 and 2.5.1-368 Sheet 2). The nearest epicenters from the 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 11 kilometers (7 miles) ~~7 miles (11 kilometers)~~ southwest of, the mapped fault trace. Likewise, Cotilla-Rodriguez et al. (Reference 494) indicate sparse seismicity near the Hicacos fault, and note that no focal mechanisms are associated with earthquakes in the vicinity of this fault. According to Cotilla-Rodriguez et al. (Reference 494), historical

accounts suggest 10 earthquakes of less than or equal to MSK intensity V (approximately MMI V) occurred in the vicinity of the Hicacos fault (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.

Case and Holcombe's (Reference 480) 1:2,500,000 scale map of the Caribbean region shows segments of the Hicacos fault cutting upper Tertiary rocks. Perez-Othon and Yarmoliuk's (Reference 848) 1:500,000 scale geologic map of Cuba shows an unnamed fault in the vicinity of the Hicacos fault that extends from Matanzas for approximately 80 kilometers (50 miles) ~~50 miles (80 kilometers)~~ to the southwest. Because they do not label faults by name, it is not clear whether the Hicacos fault is depicted on Perez-Othon and Yarmoliuk's (Reference 848) inset map of fault ages in Cuba. They indicate, however, a Mesozoic age for an unnamed fault in the vicinity of the northeastern- most portion of the Hicacos fault (Figure 2.5.1-369). Pushcharovskiy et al.'s (Reference 846) 1:250,000 scale geologic map of Cuba shows an unnamed fault cutting lower Miocene rocks in the vicinity of the central Hicacos fault as shown on Figure 2.5.1-368 Sheet 1, but their mapping does not extend this fault as far northeast as the north coast of Cuba. The locally northeast-trending shoreline and a narrow peninsula near Matanzas are notably linear and on-trend with the fault, likely influencing where the fault is mapped in other representations. Pushcharovskiy's (Reference 847) 1:500,000 scale tectonic map of Cuba shows the northeastern extent of the Hicacos fault similar to the depiction shown in Figure 2.5.1-368 Sheet 1, and terminating to the southwest at Cuba's southern coast.

The Hicacos fault is depicted differently on different maps from the Nuevo Atlas Nacional de Cuba (Reference 944). The 1:1,000,000 scale geologic map from this atlas (Reference 944, plate III.1.2-3) shows an unnamed, northeast-striking, approximately 40-kilometer-long (25-mile-long) ~~25-mile-long (40-kilometer-long)~~ fault in the vicinity of the Hicacos fault. This unnamed fault is mapped within lower to middle Miocene-age deposits and does not appear to cut Holocene-age deposits near Matanzas at the northeastern end of the fault. The 1:1,000,000 scale geomorphic map from this atlas (Reference 944, plate IV.3.2-3) shows an unnamed fault offshore along the narrow peninsula that may be the Hicacos fault, but this offshore fault does not extend onshore to the southwest. The Hicacos fault is labeled on the lineament map from this atlas (Reference 944, plate III.3.1-11) as an approximately 175-kilometer-long (110-mile-long), ~~110-mile-long (175-km- long),~~ northeast-trending feature that extends from near Cuba's south coast, across Cuba, and along the narrow peninsula near Matanzas on Cuba's north coast. On the lineament map, the northeastern-most 35 kilometers (20 miles) ~~20 miles (35 km)~~ of this feature are shown as a dashed line. The 1:2,000,000 scale neotectonic map from this atlas (Reference 944, plate III.2.4-8) shows an unnamed, northeast-striking fault in the vicinity of the Hicacos fault that extends from Cuba's south coast, across Cuba, and along the narrow peninsula near Matanzas, and offshore where it is terminated by an unnamed fault that likely is the Nortecubana fault.

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Various researchers describe elevated marine terraces west of Matanzas Bay near the Hicacos fault along Cuba's north coast. Continuous and planar geomorphic surfaces like these can be used as Quaternary strain markers with which to assess the presence of tectonic deformation. Ducloz (Reference 915) and Shanzer et al. (Reference 923) provide observations of Pleistocene-age terraces in this region, including the Terraza de Seboruco terrace, which is currently a few meters above modern sea level. Both Ducloz (Reference 915) and Shanzer et al. (Reference 923) speculate that Pleistocene-age terraces in this region may have formed as the result of both tectonic uplift and global fluctuations in sea level.

More recent studies, however, conclude that tectonic uplift is not required to explain the present elevation of the Pleistocene-age Terraza de Seboruco terrace west of Matanzas Bay and near the Hicacos fault. Toscano et al.'s (Reference ~~946~~925) radiometric age dating of coral samples collected from the Terraza de Seboruco terrace indicates this surface formed at approximately 120 – 140 ka. Based on these ages, they associate the Terraza de Seboruco terrace with the global Substage 5e sea level high-stand at approximately 122 ka. Toscano et al. (Reference ~~946~~925) also observe that this terrace in the Matanzas area is just a few meters above mean sea level, similar to the elevation of other Substage 5e reef deposits throughout "stable" portions of the Caribbean, and therefore can be explained solely by changes in sea level. Toscano et al. (Reference 946) conclude that "no obvious tectonic uplift is indicated for this time frame along the northern margin of Cuba." Similarly, Pedoja et al. (Reference ~~945~~920) investigated late Quaternary coastlines worldwide and observe minor uplift relative to sea level of approximately 0.2 mm/yr, even along passive margins, outpacing eustatic sea level decreases by a factor of four. They suggest that, when accounting for eustatic changes in sea level, the Substage 5e terrace in the Matanzas area (i.e., the Terraza de Seboruco terrace) has been uplifted at an average rate that ranges from approximately 0.00 to 0.04 mm/yr over the last approximately 122 ka, consistent with uplift rates observed from other stable margins worldwide. If the effects of eustasy are ignored, Pedoja et al.'s (Reference ~~945~~920) data allow for an uplift rate at Matanzas of approximately 0.06 mm/yr over the last approximately 122 ka, following this "conservative" (Reference 920~~945, p. 5~~) approach.

Whereas recent studies indicate that tectonic uplift is not required to explain the present elevation of the Terraza de Seboruco terrace west of Matanzas Bay (References 920~~946~~ and 925~~945~~), these data do not preclude activity on the Hicacos fault. As described above, the location and extent of the Hicacos fault differs between various geologic maps and published figures, so it is unclear whether the Hicacos fault is overlain by the Terraza de Seboruco terrace. Furthermore, if the sense of slip on the Hicacos fault were primarily strike-slip as opposed to dip-slip, it could be difficult to observe surface manifestation of fault-related deformation on the Terraza de Seboruco terrace.

La Trocha Fault

The La Trocha fault is a northeast-striking fault in central Cuba (Figures 2.5.1-247 and 2.5.1-368 Sheet 2). At its nearest point, the La Trocha fault is approximately420 kilometers (260 miles) ~~260 miles (420 km)~~ from of the Turkey Point Units 6 & 7 site. Rosencrantz (Reference 529) maps a northeast-striking structure across the Yucatan basin south of Cuba (Figure2.5.1-286) and interprets it as the southwestern extension of the La Trocha fault.

Garcia et al. (Reference 489) provide minimal discussion of the La Trocha fault. Garcia et al. (Reference 489~~, p. 2,571~~) indicate it is a "deep fault more than 180 km (112 miles) long, with neotectonic transcurrent activity" and "its seismicity is documented bythe earthquakes in the Santi Spiritus region." They also indicate that the La Trocha fault is expressed in geophysical data, but they do not elaborate.

Cotilla-Rodríguez et al. (Reference 494) assign the La Trocha fault an age of Pliocene-Quaternary and also suggest a possible association with seismicity. Cotilla-Rodriguez et al. (Reference 494~~, p. 517~~) describe the La Trocha fault as "a fault zone transcurrent to the left with a large angle." They suggest a possible association between three earthquakes of less than or equal to MSK intensity V (approximately MMI V) and the La Trocha fault. The Phase 2 earthquake catalog shows very sparse seismicity associated with the La Trocha fault (Figure 2.5.1-368 Sheet 2). The largest earthquakes from the Phase 2 earthquake catalog near the La Trocha fault are the March 10, 1952 M_W 4.0 and January 1, 1953 M_W 4.3 events. Cotilla- Rodriguez et al. (Reference 494) indicate there are no earthquake focal mechanisms associated with this fault.

Leroy et al. (Reference 499) interpret the La Trocha fault as the northern transform limb of a proto-Cayman spreading center that was active in the early Eocene (53 Ma) and was abandoned by 49 Ma. This interpretation is the result of the southward migration of the left-lateral strike slip faults that make up the Caribbean-North America plate boundary (~~e.g., Mann et al. [~~Reference 639~~]~~).

The La Trocha fault is not shown on Pushcharovskiy et al.'s (Reference 846) 1:250,000 scale geologic map of Cuba. Review of Pushcharovskiy et al.'s (Reference 846) maps in the vicinity where Cotilla-Rodriguez et al. (Reference 494) map the La Trocha fault indicates no northeast-striking faults cutting Miocene and younger strata. Potentially, this structure is buried by the overlying strata and could be pre-middle Miocene in age. Pushcharovskiy's (Reference 847) tectonic map of Cuba, however, clearly depicts and labels the La Trocha fault with extent and location similar to the La Trocha fault shown in Figure 2.5.1-368 Sheet 2. Because they do not label faults by name, it is not clear whether the La Trocha fault is depicted on Perez-Othon and Yarmoliuk's (Reference 848) inset map of fault ages in Cuba, but they indicate a Neogene-Quaternary age for an unnamed fault in the vicinity of the La Trocha fault (Figure 2.5.1-369).

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The La Trocha fault is depicted differently on various maps from the Nuevo Atlas Nacional de Cuba (Reference 944). The 1:1,000,000 scale geologic map of Cuba from this atlas (Reference 944, plate III.1.2-3) does not include the La Trocha fault. The 1:2,000,000 scale neotectonic map of Cuba from this atlas (Reference 944, plate III.2.4-8) shows an unnamed fault in the vicinity of the La Trocha fault. This unnamed fault is mapped as terminating northward at the northern coast of Cuba. The 1:2,000,000 scale lineament map from this atlas (Reference 944, plate III.3.1-11) depicts and labels the La Trocha fault as an approximately 150-kilometer-long (90-mile-long)~~, 90-mile-long (150-km- long)~~, northeast-trending feature that extends from Cuba's southern to its northern coast.

Las Villas Fault

The Las Villas fault is a northwest-striking fault in central Cuba (Figures 2.5.1-247 and 2.5.1-368 Sheet 2). At its nearest point, the Las Villas fault is approximately 250 kilometers (155 miles) ~~155 miles (250 km)~~ south of the Turkey Point Units 6 & 7 site. Pardo (Reference 439~~, p. 316~~) maps the Las Villas fault as a south-dipping thrust with up to approximately 30 kilometers (18 miles) ~~18 miles (30 km)~~ of horizontal displacement. According to Pardo (Reference 439), the Las Villas fault displaces middle Eocene units, but exhibits greater displacement of older units, indicating that most of its movement was pre-middle Eocene.

Garcia et al. (Reference 489~~, p. 2,571~~) describe the Las Villas fault as a "deep fault that divides the younger coastal formations of the north from the older ones of the south, it appears as a negative anomaly in the gravimetric map and with positive and negative anomalies in the magnetic field. Medium-magnitude seismicity is associated with this fault."

Cotilla-Rodríguez et al. (Reference 494) characterize the Las Villas fault as active based on its possible association with seismicity and geomorphic expression. Cotilla-Rodríguez et al. (Reference 494~~, p. 517~~), however, provide only the following minimal description of the Las Villas fault:

> "This 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 (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."

Cotilla-Rodríguez et al. (Reference 494) do not 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. Likewise, Cotilla-Rodríguez et al. (Reference 494) do not provide additional discussion of the "young eroded scarps", nor do they provide reference to other publications that provide this

information. It is not clear from this limited description if these are fault scarps formed directly by recent slip on the Las Villas fault or if they are fault-line scarps formed by recent differential erosion along the fault trace. 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. (Reference 494), it is not possible to distinguish between these alternatives. There are no known paleoseismic trench studies or detailed geomorphic assessments of the Las Villas fault with which to assess recent earthquake activity on this fault. Where faults exhibit scarps in young deposits or surfaces, such as the Baconao fault in southernmost Cuba, Cotilla-Rodriguez et al. (Reference 494) provide clear description and do not include "eroded" in the description.

Figure 2.5.1-368 Sheet 2 indicates moderately sparse seismicity from the Phase 2 earthquake catalog that may be roughly aligned with the Las Villas fault, as mapped by Pardo (Reference 439). A total of 33 earthquakes from the Phase 2 earthquake catalog are located within approximately 10 kilometers (6 miles) ~~6 miles (10 km)~~ 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 5 kilometers (3 miles) ~~3 miles (5 km)~~ northeast of the fault (Figure 2.5.1-368 Sheet 2). Cotilla-Rodriguez et al. (Reference 494) indicate 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. (Reference 494) suggest that the largest recorded earthquake associated with the Las Villas fault is the Ms 5.6 event on August 15, 1939 (listed in the Phase 2 earthquake as M_w 5.84). Based on the fault mapping of Pardo (Reference 439) and the location of this earthquake from the Phase 2 earthquake catalog, however, this earthquake is located approximately 32 kilometers (20 miles) ~~20 miles (32 km)~~ northeast of this southwest-dipping fault (Figure 2.5.1-368 Sheet 2), suggesting a fault other than the Las Villas ruptured during this event.

Review of geologic mapping (References 480, 846~~848~~, and 848~~846~~) reveals that no units of Quaternary age are faulted, but the coarse scale of mapping (1:250,000 to 1:2,500,000) does not preclude recent activity. Because they do not label faults by name, it is not clear whether the Las Villas fault is depicted on Perez-Othon and Yarmoliuk's (Reference 848) inset map of fault ages in Cuba, but they indicate a Mesozoic age for an unnamed fault in the vicinity of the Las Villas fault (Figure 2.5.1-369).

The Las Villas fault is not shown on the 1:1,000,000 scale geologic map of Cuba from the Nuevo Atlas Nacional de Cuba (Reference 944, plate III.1.2-3). The 1:2,000,000 scale neotectonic map of Cuba from the same atlas (Reference 944, plate III.2.4-8) shows an unnamed fault in the vicinity of the Las Villas fault. Likewise, the 1:2,000,000 scale lineament map from this atlas (Reference 944, plate III.3.1-11) depicts and labels the Las Villas fault as an approximately 190-kilometer-long (120-mile-long) ~~120-mile-long (190-km- long),~~ , northwest-trending feature.

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Nipe Fault

The Nipe fault is a northeast-striking fault in southern Cuba (Figures 2.5.1-247 and 2.5.1-368 Sheet 3) that separates the mountainous Sierra Maestra province on the east from the Camaguey terrane on the west. At its nearest point, the Nipe fault is approximately 675 kilometers (420 miles) ~~420 miles (675 km)~~ from the Turkey Point Units 6 & 7 site. Other names for this fault include the Cauto, Cauto-Nipe, Guacanayabo, and Nipe- Guacanayabo fault.

Leroy et al. (Reference 499) and Rojas-Agramonte et al. (Reference 445) interpret the Nipe fault as the southern transform limb of the early Cayman spreading center. In their models, the Nipe fault was abandoned by the early Oligocene (approximately 20 Ma) as the plate boundary shifted south to its present location at the Oriente fault.

Cotilla-Rodríguez et al. (Reference 494) characterize the Nipe fault as active based on possible association of seismicity with the fault and gross geomorphic expression. Cotilla-Rodriguez et al. (Reference 494~~, p. 516~~) describe the Nipe fault as "a fault system with transcurrence to the left" whose "outline is labeled by several epicenters" including "some epicentral swarms" near its northeastern end. The Phase 2 earthquake catalog shows sparse seismicity associated with the Nipe fault (Figure 2.5.1-368 Sheet 3). The largest earthquakes in the vicinity of the fault include the August 3, 1926 M_w 5.3 and July 19, 1962 M_w 5.36 earthquakes (Figure 2.5.1-368 Sheet 3). Cotilla-Rodriguez et al. (Reference 494) indicate there are no earthquake focal mechanisms associated with this fault.

Unnamed faults in the vicinity of the Nipe fault are shown on Perez-Othon and Yarmoliuk's (Reference 848) 1:500,000 scale geologic map of Cuba. Because they do not label faults by name, it is not clear whether the Nipe fault is depicted on Perez-Othon and Yarmoliuk's (Reference 848) inset map of fault ages in Cuba, but they indicate a Paleogene age for an unnamed fault in the vicinity of the mapped position of the Nipe fault (Figure 2.5.1-369). Unnamed faults in the vicinity of the Nipe fault also are shown on Pushcharovskiy et al.'s (Reference 846) 1:250,000 scale geologic map of Cuba. Pushcharovskiy's (Reference 847) 1:500,000 scale tectonic map of Cuba depicts and labels the Nipe fault as the "Cauto-Nipe" fault.

The Nipe fault is not shown on the 1:1,000,000 scale geologic map of Cuba from the Nuevo Atlas Nacional de Cuba (Reference 944, plate III.1.2-3). The 1:2,000,000 scale neotectonic map of Cuba from the same atlas (Reference 944, plate III.2.4-8), however, shows two sub-parallel, unnamed faults in the vicinity of the Nipe fault. The 1:2,000,000 scale lineament map from this atlas (Reference 944, plate III.3.1-11) labels two faults as "Cauto I" and "Cauto II" in the vicinity of the Nipe fault. On this map, Cauto I strikes northeast and extends from Cuba's southern to its northern coast. Cauto II is more northerly striking and is truncated by Cauto I.

Nortecubana Fault

The Nortecubana fault system is the main structure within the Cuban fold-and-thrust belt offshore of, and near-shore to, northern Cuba (Figures 2.5.1-247, 2.5.1-368 Sheet 1, 2.5.1-368 Sheet 2, and 2.5.1-368 Sheet 3). The Nortecubana fault system dips south with a dip angle that varies along strike. At its nearest point, the Nortecubana fault system is approximately 240 kilometers (150 miles) 1~~50 miles (240 km)~~ from the Turkey Point Units 6 & 7 site.

The role of the Nortecubana thrust in the evolution of the Caribbean-North America plate boundary has been interpreted in different ways. The Nortecubana fault system may represent the ancestral subduction zone that was abandoned as the plate boundary shifted southward towards its current location south of Cuba. Alternatively, the Nortecubana thrust fault has been interpreted to represent the frontal decollement of an accretionary wedge associated with the collision of the Greater Antilles Arc and the North America plate south of Cuba (References 439~~786~~ and 786~~439~~). Regardless of its ancestral origins, the Nortecubana fault system underlies the preponderance of folding and deformation within and just north of Cuba, which is collectively referred to as the Cuban fold-and-thrust belt. Wells drilled directly offshore of northeastern Cuba have encountered faults and repeated stratigraphy indicating Eocene thrusting (Reference 439), and seismic reflection data have 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 (Figures 2.5.1-279, 2.5.1-280, 2.5.1-282, 2.5.1-287, and 2.5.1-288).

Cotilla-Rodríguez et al. (Reference 494) characterize the Nortecubana fault as active based on its possible association with seismicity. They note that the preponderance of this seismic activity is associated with eastern portions of the fault nearest the modern plate boundary. In the Phase 2 earthquake catalog developed for the Turkey Point Units 6 & 7 COL, seismicity along the west and central portions of the Nortecubana fault is sparse (Figures 2.5.1-368 Sheet 1 and 2.5.1-368 Sheet 2), relative to the easternmost portion of the fault (Figure 2.5.1-368 Sheet 3). The Phase 2 earthquake catalog includes a M_w 6.29 earthquake that occurred on February 28, 1914 off the north coast of southeastern Cuba (Figure 2.5.1-368 Sheet 3). Cotilla-Rodríguez et al. (Reference 494) suggest this earthquake occurred on the Nortecubana fault. Due to the absence of a permanent seismic monitoring network in Cuba, however, this epicenter is poorly located. The given location, at approximately 6 kilometers (4 miles) ~~4 miles (6 km)~~ north-northeast of the south-dipping Nortecubana fault (and approximately 640 kilometers [400 miles] ~~400 miles (640 km)~~ from the Turkey Point Units 6 & 7 site), suggests that this earthquake could have occurred on another fault. Due to uncertainties in the locations of the 1914 earthquake as well as the fault, this does 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. 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 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 or another fault.

The submarine Nortecubana fault typically does not appear on regional surface geologic maps. For example, the Nortecubana fault is not shown on Perez-Othon and Yarmoliuk's (Reference 848) 1:500,000 scale geologic map, Pushcharovskiy et al.'s (Reference 846) 1:250,000 scale geologic maps, and the 1:2,000,000 scale geologic map from the Nuevo Atlas Nacional de Cuba (Reference 944, plate III.1.2-3). This fault, however, is shown on regional tectonic compilations and other maps. For example, Pushcharovskiy et al.'s (Reference 847) 1:500,000 scale tectonic map of Cuba shows the Nortecubana fault as an unnamed, discontinuous, dashed line north of Cuba. The 1:2,000,000 scale neotectonic and lineament maps from the Nuevo Atlas Nacional de Cuba (Reference 944, plates III.2.4-8 and III.3.1-11) show but do not label the Nortecubana fault as solid and dashed lines, respectively. Because they do not label faults by name, it is not clear whether the Nortecubana fault is depicted on Perez-Othon and Yarmoliuk's (Reference 848) inset map of fault ages in Cuba, but they indicate a Mesozoic age for an unnamed fault in the vicinity of the Nortecubana fault (Figure 2.5.1-369).

Oriente Fault Zone

The most seismically active region of Cuba today is the Oriente fault zone, located offshore south of eastern Cuba (Figures 2.5.1-229, 2.5.1-247, 2.5.1-251, and 2.5.1-368 Sheet 3). This left-lateral fault system is part of the active North America-Caribbean Plate boundary and connects the Cayman Trough spreading center to the Septentrional fault (Figure 2.5.1-202). Geodetic data indicate that between 8 and 13 millimeters/year of slip are accommodated on this structure; hence it is classified as a capable tectonic source. For further discussion, see Subsections 2.5.1.1.2.3.1.2, 2.5.2.4.4.3.2.2, and 2.5.2.4.4.3.2.3.

Pinar Fault

The Pinar fault is a northeast-striking, steeply southeast-dipping fault in western Cuba (Figures 2.5.1-247, 2.5.1-251, 2.5.1-289, and 2.5.1-368 Sheet 1). As mapped by Tait (Reference 448) and shown on Figure 2.5.1-368 Sheet 1, the Pinar fault is located, at its nearest point, approximately 330 kilometers (205 miles) ~~205 miles (330 km)~~ from the Turkey Point Units 6 & 7 site. As mapped by Garcia et al. (Reference 489), the Pinar fault is approximately 320 kilometers (200 miles) ~~200 miles (320 km)~~ southwest of the site at its nearest point. As mapped by Cotilla-Rodríguez et al.(Reference 494), the Pinar fault is approximately 360 kilometers (225 miles) ~~225 miles (360 km)~~ southwest of the site at its nearest point. Rosencrantz (Reference 529) maps a series of offshore faults along the eastern Yucatan Platform and tentatively indicates they could be the offshore southwestern extension of the Pinar fault.

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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 associated with the Pinar fault. There are, however, conflicting opinions in the literature regarding whether the Pinar fault is active. Garcia et al. (Reference 489~~, p. 2,571~~) 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 23, 1880 M_w 6.13 earthquake (Figure 2.5.1-368 Sheet 1). Cotilla- Rodríguez et al. (Reference 494~~, p. 516~~) describe the Pinar fault as having "very nice relief expression" but conclude it is "inactive." Cotilla-Rodríguez et al. (Reference 494) provide no evidence in support of their assessment but suggest that the 1880 earthquake instead occurred on the subsurface Guane fault, which is subparallel to the Pinar fault and is located within the Los Palacios basin to the southeast (Figure 2.5.1-368 Sheet 1). Cotilla-Rodriguez and Cordoba-Barba (Reference 943) cite historical accounts of the severity and distribution of earthquake-related damage as evidence that the January 23, 1880 earthquake occurred on the Guane fault instead of the Pinar fault. Cotilla-Rodriguez and Cordoba-Barba (Reference 943~~, p. 514~~) conclude that the Pinar fault "is not the seismogenetic element of the January 23, 1880 earthquake" and that it is "subordinate to" the Guane fault. Gordon et al. (Reference 697) describe multiple phases of deformation in western Cuba in general and on the Pinar fault in particular. Gordon et al. (Reference 697~~, p. 10,078-10,079~~) are unable to constrain the upper bound of the age of most-recent deformation on the Pinar fault "because lower Miocene rocks were the youngest rocks from which observations were made."

The Phase 2 earthquake catalog indicates that a M_w 6.13 earthquake occurred on January 23, 1880 in western Cuba in the vicinity of the Pinar and Guane faults (Figure 2.5.1-368 Sheet 1). The epicenter of this poorly located, pre-instrumental earthquake is approximately 11 kilometers (7 miles) ~~7 miles (11 km)~~ south of the trace of the steeply southeast-dipping Pinar fault and approximately 8 kilometers (5 miles) ~~5 miles (8 km)~~ north of the Guane fault. As Garcia et al. (Reference 489) suggest, however, locational uncertainties for historical earthquakes in Cuba could be on the order of 15 to 20 kilometers (9 to 12 miles) or more. 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 fault in the region. No focal mechanism or depth determination for the 1880 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 Phase 2 earthquake catalog indicates generally sparse seismicity in the vicinity of the Pinar fault (Figure 2.5.1-368 Sheet 1). 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. The Phase 2 earthquake catalog indicates that additional minor- to moderate-magnitude (M_w 4 to 5.1) earthquakes occurred in western Cuba near the Pinar and Guane faults in 1896, 1937, 1944, and 1957 (Figure 2.5.1-368 Sheet 1).

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The Pinar fault is depicted on many regional scale maps of Cuba, including numerous maps in the Nuevo Atlas Nacional de Cuba (Reference 944) and Pushcharovskiy's (Reference 847) 1:500,000 scale tectonic map of Cuba. Available geologic mapping at scales between 1:250,000 and 1:1,000,000 is consistent with an active Pinar fault. These data do not, however, require that the Pinar fault is active. Generally, there is a lack of young deposits mapped along the Pinar fault with which to assess the age of its most-recent slip. Pushcharovskiy et al.'s (Reference 846) 1:250,000 scale geologic mapping shows an unnamed fault in the vicinity of the Pinar fault that, along most of its length, juxtaposes Jurassic-age limestones of the Arroyo Cangre and San Cayetano formations on the northwest against Paleogene- age deposits on the southeast. This map shows the southernmost kilometers (3 miles) ~~3 miles (5 km)~~ 5 of the fault as a dashed line that juxtaposes Jurassic limestone on the northwest against upper Pliocene to lower Pleistocene undifferentiated alluvial and marine deposits, which may constitute evidence for activity. Along strike immediately to the south near Playa de Galafre on Cuba's southern coast, however, the fault is covered by the same upper Pliocene to lower Pleistocene unit with no apparent deformation (Reference 846). Along the central portion of the fault near Pinar del Rio, Pushcharovskiy et al.'s (Reference 846) 1:250,000 scale geologic mapping shows an approximately 6-kilometer-long (4-mile-long) ~~4-mile-long (6-km-long)~~ section where weakly cemented upper Pliocene-lower Pleistocene undifferentiated alluvial and marine deposits on the southeast are fault-juxtaposed against middle Jurassic Arroyo Cangre formation on the northwest. This map relationship may indicate that the Plio-Pleistocene deposits are faulted. Alternatively, the Plio-Pleistocene deposits may have been deposited against pre-existing topography along the fault, and therefore possibly post-date the age of most-recent faulting. Based on the crude scale of mapping, it is unclear which of these alternative interpretations is correct.

Perez-Othon and Yarmoliuk (Reference 848) present geologic mapping of Cuba at a scale of 1:500,000. Their map does not include fault names, but shows a fault in the vicinity of the Pinar fault that generally juxtaposes Jurassic-age rocks on the northwest against Eocene to Miocene rocks on the southeast. Near Pinar del Rio, they map a small patch of Pliocene- to Pleistocene-age conglomerates that apparently are correlative with Pushcharovskiy et al.'s (Reference 846) upper Pliocene to lower Pleistocene undifferentiated alluvial and marine deposits in the same area and described above. According to Perez-Othon and Yarmoliuk's (Reference 848) mapping, and unlike Pushcharovskiy et al.'s (Reference 846) mapping, these Plio-Pleistocene deposits extend very close to, but are not in contact with, the fault. Instead, Perez-Othon and Yarmoliuk (Reference 848) show Jurassic-age limestone in fault contact with Eocene-age rocks in this area. Farther to the northeast near Los Palacios, Perez-Othon and Yarmoliuk (Reference 848) show an approximately 2- to 4-kilometer-long (1- to 2-mile-long) ~~1- to 2-mile-long (2- to 4-km-long)~~ stretch along the central section of the fault where Quaternary alluvial deposits are juxtaposed against Jurassic carbonate rocks. The resolution of Perez-Othon and Yarmoliuk's (1985) (Reference 848) mapping is insufficient to determine whether these Quaternary alluvial deposits are faulted or if they were deposited against pre-existing topography along the fault, and therefore possibly post-date the age of most-recent faulting. As an inset to their geologic map, Perez-Othon and Yarmoliuk (Reference 848) provide an additional map that shows their estimates of fault ages in Cuba. On their inset map of fault ages in Cuba, Perez-Othon and Yarmoliuk

(Reference 848) assign a Neogene- Quaternary age to a northeast-striking fault that is presumed to be the Pinar fault (the inset map does not include fault names). Despite this Neogene-Quaternary age on the inset map, their 1:500,000 scale geologic map shows unnamed northwest-striking faults, to which they assign a Paleogene age on their inset map, as offsetting the younger Pinar fault.

The Nuevo Atlas Nacional de Cuba includes a 1:1,000,000 scale geologic map of Cuba (Reference 944, plate III.1.2-3). No fault names appear on this map, but a fault in the vicinity of the Pinar fault is shown as juxtaposing Jurassic carbonate rocks on the northwest against Miocene and older rocks on the southeast. Due to the crude scale at which this map is presented, however, it is not possible to constrain with certainty the age of faulting. This atlas also includes a 1:2,000,000 scale neotectonic map of Cuba (Reference 944, plate III.2.4-8) that defines “zones of maximum neotectonic gradient” and classifies them as “moderate”, “intense”, or “very intense”. Only the modern plate boundary offshore southern Cuba is classified as “very intense” in this scheme. No fault names appear on this map, but a fault in the vicinity of the Pinar fault is shown within an “intense” zone.

Surcubana Fault

At its nearest distance, the Surcubana fault as mapped by Cotilla-Rodriguez et al. (Reference 494) is located approximately 370 kilometers (230 miles) ~~230 miles (370 km)~~ from the site (Figures 2.5.1-368 Sheet 1, 2.5.1-368 Sheet 2, and 2.5.1-368 Sheet 3). Cotilla-Rodriguez et al. (Reference 494) do not include the Surcubana fault in their list of twelve “seismoactive” faults in Cuba and this fault generally is not described by other studies of faulting in Cuba (e.g.,References 439~~489~~, 489~~786~~, and 786~~439~~).

In the Phase 2 earthquake catalog, seismicity is sparse along and near the Surcubana fault, with only a dozen or so earthquakes located within approximately 30 kilometers (20 miles) ~~20 miles (30 km)~~ of the more than 800-kilometer-long (500-mile-long) ~~500-mile-long (800-km-long)~~ trace (Figures 2.5.1- 368 Sheet 1, 2.5.1-368 Sheet 2, and 2.5.1-368 Sheet 3). Of these earthquakes, all are low to moderate magnitude and most are located at the southeastern end of the fault near the active plate boundary and may instead be associated with the Oriente fault. The closest earthquakes to the central and western sections of the Surcubana fault from the Phase 2 earthquake catalog are located at approximately 81° west longitude (Figures 2.5.1-368 Sheet 1 and 2.5.1-368 Sheet 2). The first of these is located approximately 8 kilometers (5 miles)~~5 miles (8 km)~~ north of the trace and occurred on March 27, 1964 with M_w 3.7. The second is located approximately 5 kilometers (3 miles) ~~3 miles (5 km)~~ south of the trace and occurred on October 22, 2005 with M_w 3.8. Because they do not label faults by name, it is not clear whether the Surcubana fault is depicted on Perez-Othon and Yarmoliuk’s (Reference 848) inset map of fault ages in Cuba, but they indicate a Mesozoic age for an unnamed fault in the vicinity of the Surcubana fault (Figure 2.5.1-369).

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Like the Nortecubana fault, the submarine Surcubana fault typically does not appear on regional surface geologic maps. For example, the Surcubana fault is not shown on Pushcharovskiy et al.'s (Reference 846) 1:250,000 scale geologic maps, and the 1:2,000,000 scale geologic map from the Nuevo Atlas Nacional de Cuba (Reference 944, plate III.1.2-3). This fault is shown on regional tectonic compilations and other maps. For example, Pushcharovskiy et al.'s (Reference 847) 1:500,000 scale tectonic map of Cuba shows the Surcubana fault as an unnamed, discontinuous, dashed line south of Cuba. The 1:2,000,000 scale neotectonic map from the Nuevo Atlas Nacional de Cuba (Reference 944, plate III.2.4-8) shows, but does not label, the Surcubana fault as a solid line. The lineament map from the same atlas (Reference 944, plate III.3.1-11) shows but does not label the Surcubana fault as discontinuous and dashed lines.

~~*Oriente Fault Zone*~~

~~ThemostseismicallyactiveregionofCubatodayistheOrientefaultzone,locatedoffshore southof easternCuba(Figures2.5.1-229,2.5.1-247,and2.5.1-251).Thisleft-lateralfault systemispartof theactiveNorthAmerica-CaribbeanPlateboundaryandconnectsthe CaymanTroughspreading centertotheSeptentrionalfault(Figure2.5.1-202).Geodetic dataindicatethatbetween8and13 millimeters/yearofslipareaccommodatedonthis structure;henceitisclassifiedasacapable tectonicsource.Forfurtherdiscussion,see Subsections2.5.1.1.2.3.1.2,2.5.2.4.4.3.2.2,and 2.5.2.4.4.3.2.3.~~

Other Cuban Structures

Numerous other tectonic structures exist on the island of Cuba. Some of these are limited in extent, unstudied, or unnamed. These include the Punta ~~Allegre~~**Alegre** fault, folds along the northern edge of Cuba, and many short, unnamed northeast- and northwest-striking faults. The Punta ~~Allegre~~**Alegre** fault was discovered by **logging** repeated strata in oil wells just offshore north-central Cuba (Figure**s 2.5.1-247 and** 2.5.1-290). This fault is not imaged with seismic data, but postulated from well data. It is depicted with a vertical dip, but its orientation and extent are unknown (Reference 501).

Eocene and older strata along the northern edge of Cuba are deformed in a series of anticlines and synclines typically associated with underlying thrust faults (Figures 2.5.1-252 and 2.5.1-282). Because these folds are covered by undeformed Miocene and younger strata, they are pre-Miocene in age, and probably formed during the Eocene collision of the Greater Antilles Arc with the Bahama Platform.

Many short (<10 kilometers [<6.2 miles] in length) northeast- and northwest-striking faults, with undetermined sense of slip, do cut strata as young as middle Miocene throughout the island of Cuba. Where younger units (such as Plio-Pleistocene) overlie these same structures, they are consistently unfaulted. This suggests that these short faults are pre-Quaternary in age. Many of these faults do not intersect units younger than Miocene. These structures may be correlated with post-early Miocene normal faults and cross-cutting strike-slip faults described in outcrops in western Cuba (Reference 697).

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

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structures (Table 2.5.1-204). ~~Nonetheless,availablegeologicmapping(at1:250,000and 1:500,000scales;References846,847,and848)providessomeinformationregardingthe timing ofactivityforsomeoftheregionalstructuresandlargelyindicatesthatthe Pleistoceneandyounger strataareundeformedthroughouttheisland.Thisisconsistent withgeodeticdatathatindicatethat lessthan3millimeters/yearofdeformationisoccurring withinCubarelativetoNorthAmerica (References502and503).~~ The available data indicate that the Oriente fault system, located offshore ~~just~~ **directly** 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.

The following new references will be included in a future revision of the FSAR:

942. Cotilla-Rodriguez, M.,~~O.~~ and D. Cordoba-Barba,~~D.,~~ *Study of the Cuban fractures*, Geotectonics, Vol. 44, No. 2, pp. 176–202, 2010.

943. Cotilla-Rodriguez, M.,~~O.~~ and D. Cordoba-Barba,~~D.,~~ *Study of the E~~e~~arthquake of the January 23, 1880, in San Cristobal, Cuba and the Guane F~~f~~ault,* Physics of the Solid Earth, Vol. 47, No. 6, pp. 496–518, 2011.

915. Ducloz, C., *Etude ~~g~~Geomorphologique de la region de Matanzas, Cuba avec une contribution a l'etude des depots quaternaires de la zone Habana-Matanzas*, Archives des Sciences, Societe de Physique et d'Histoire Naturelle de Geneve, Imprimerie Kundig, 402 pp., 1963.

944. Oliva Gutierrez, G., E. Sanchez Herrero,~~E.A.~~ (directors), *Nuevo Atlas Nacional de Cuba,* Instituto de Geografía de la Academia de Ciencias de Cuba, the Instituto Cubano de Geodesia y Cartografía, and the Instituto Geográfico Nacional de España, ~~220 pp.,~~ 1989.

~~945~~ ~~920~~. Pedoja, K., L. Husson, ~~L.,~~ V. Regard, ~~V.,~~ P. Cobbold, ~~P.R.,~~ E. Ostanciaux, ~~E.,~~ M. Johnson, M.E., S. Kershaw, ~~S.,~~ M. Saillard, ~~M.,~~ J. Martinod, ~~J.,~~ L. Furgerot, ~~L.,~~ P. Weill, ~~P.,~~ and B. Delcaullau, ~~B.,~~ *Relative sea-level fall since the last interglacial state: Are coasts uplifting worldwide?, Earth Science Reviews*, Vol. 108, p. 1–15, 2011.

923. Shanzer, ~~E.V.,~~ O. Petrov,~~O.M.,~~ and G. Franco,~~G.,~~ *Sobre las F~~f~~ormaciones C~~c~~osteras del Holoceno en Cuba, las T~~t~~errazas Pleistocenicas de la R~~r~~egion Habana-Matanzas y los S~~s~~edimentos V~~v~~inculados a E~~e~~llas,* Serie Geologica No. 21, Academia de Ciencias de Cuba, Instituto de Geologia y Paleontologia, pp. 1–26, 1975.

~~946~~ 925. Toscano, M~~.A.~~, E. Rodriguez, ~~E.,~~ and J. Lundberg, ~~J.,~~ Geologic investigation of the late Pleistocene Jaimanitas formation: science and society in Castro's Cuba*, Proceedings of the 9th Symposium on the Geology of the Bahamas and Other Carbonate Regions*, Bahamian Field Station, Ltd., San Salvador, Bahamas, pp. 125–142, 1999.

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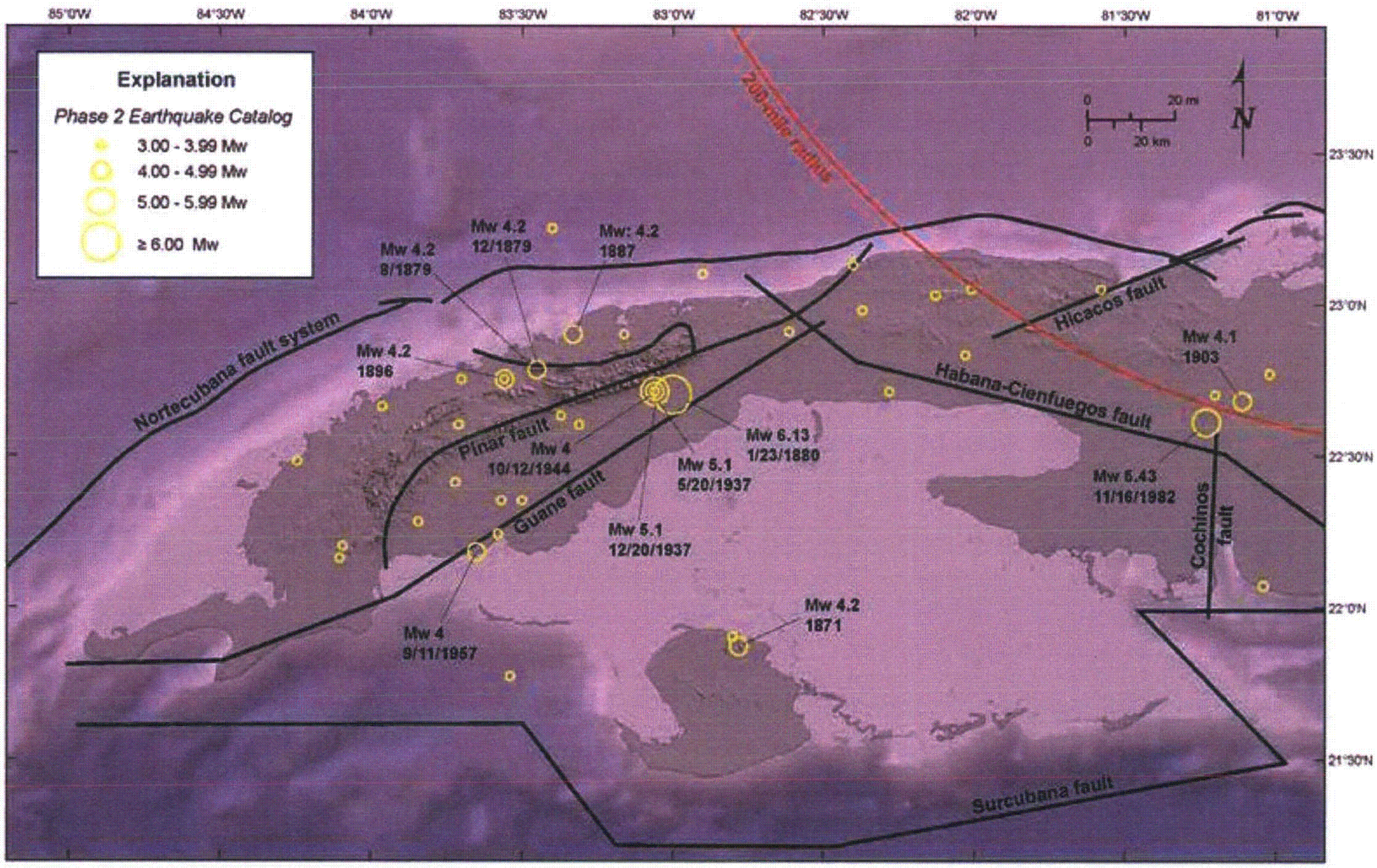
The following new figures will be added in a future revision of the COLA:

Figure 2.5.1-368. Fault Map of Cuba Showing Earthquakes from the Project Phase 2 Earthquake Catalog (Sheet 1 of 3)



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

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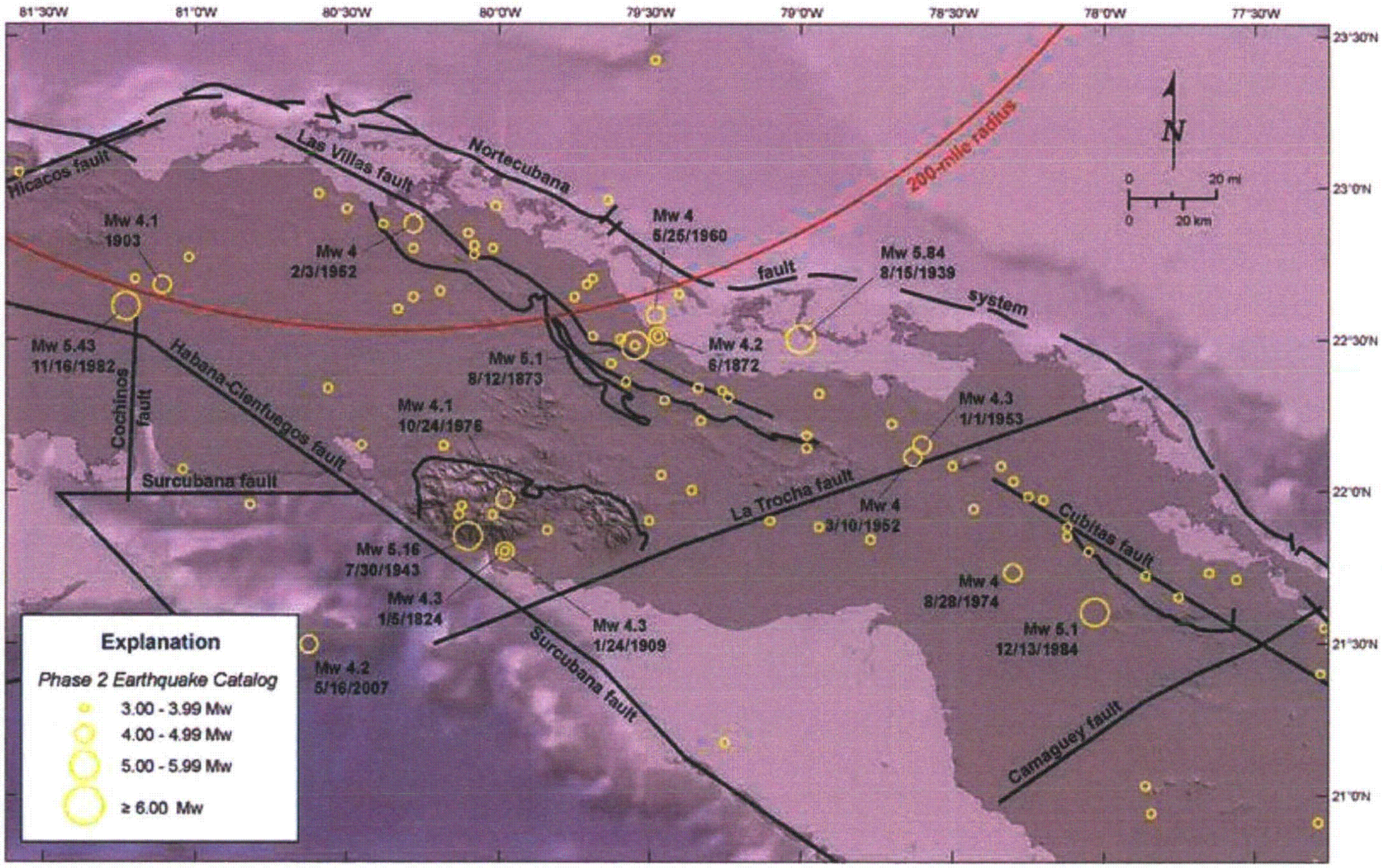
Figure 2.5.1-368. Fault Map of Cuba Showing Earthquakes from the Project Phase 2 Earthquake Catalog (Sheet 2 of 3)



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

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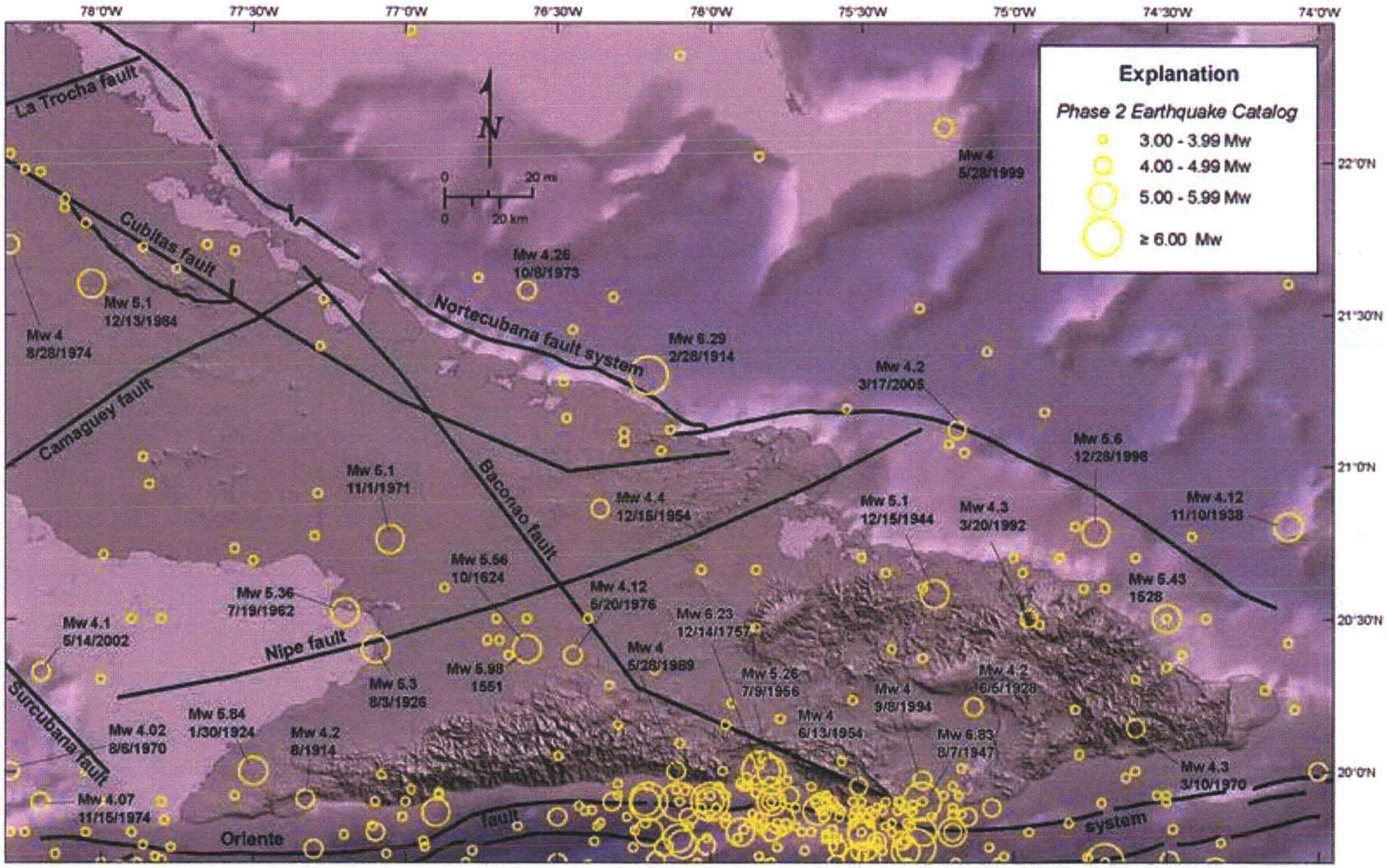
Figure 2.5.1-368. Fault Map of Cuba Showing Earthquakes from the Project Phase 2 Earthquake Catalog (Sheet 3 of 3)



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

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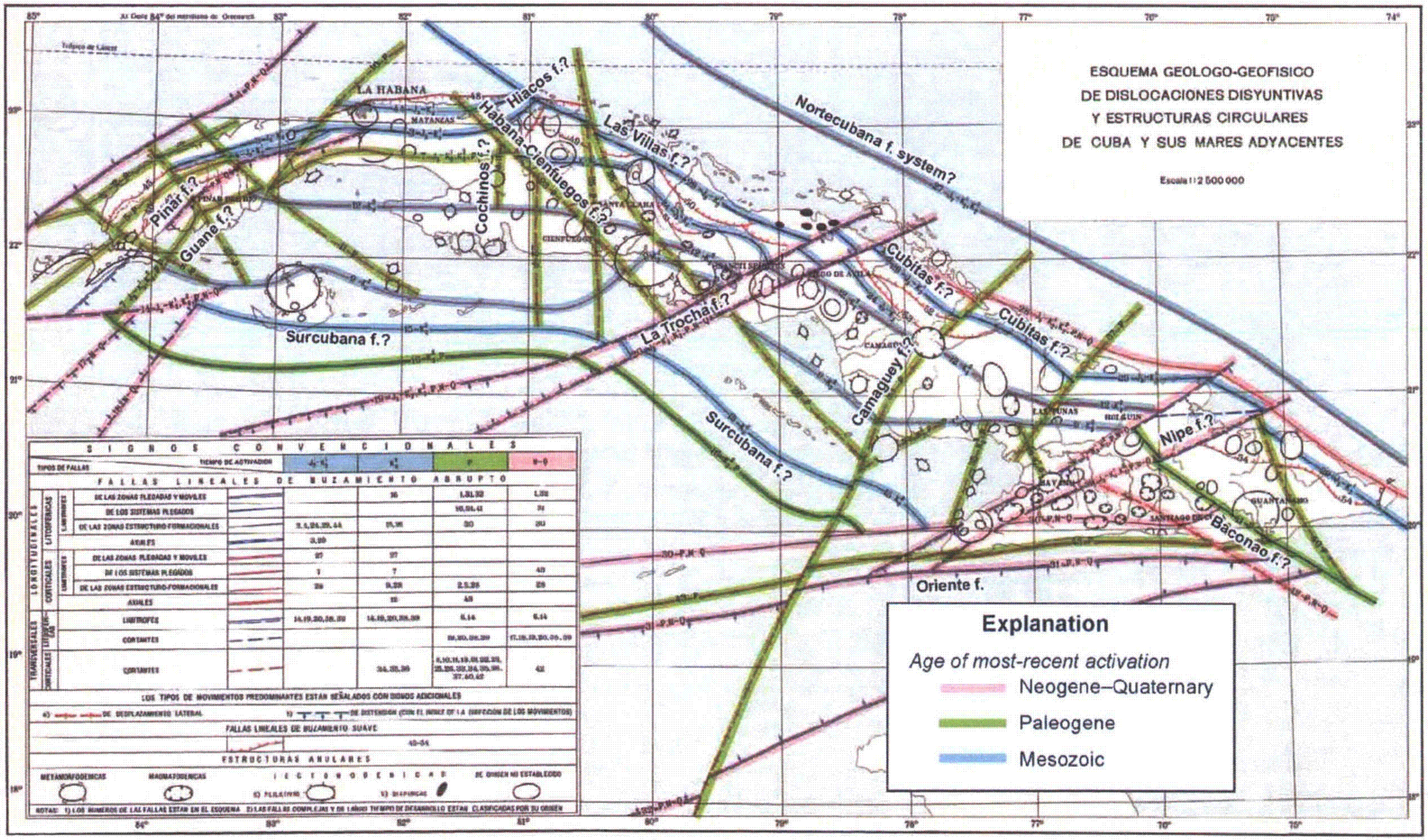
Figure 2.5.1-369. Map of Estimated Ages of Faults in Cuba



Note: Modified after Reference 848

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ASSOCIATED COLA REVISIONS:

The following text in FSAR Subsection 2.5.1.1.1.2.3, Stratigraphy of Cuba, will be revised in a future revision of the COLA.

After the last paragraph of this subsection:

flysch. The Eocene-Oligocene contact is at a depth of approximately 4500 feet (1370 meters). The Oligocene unit consists of up to 600 feet (183 meters) of deep-water chalk and limestone that grades laterally into an arenaceous and shaly limestone deposited in marine water of intermediate depth. This is overlain by 400 to 1000 feet (120 to 300 meters) of Miocene sediments consisting of deep-water marl, siltstone, and shaly limestone that grade into arenaceous and calcareous sediments with intercalated, fossiliferous sandy limestone deposited in a neritic environment (Reference 382). Late Tertiary deposits occur in the northern coastal area and dip gently toward the north. ~~**Miocenerocksaredividedinto marlandcarbonateunits.Mioceneandyoungerdepositsaredescribedashorizontal or onlyslightlytilted(Reference440).LateMiocenetoPliocenedepositsarepoorly developed andPleistocenerocksincludeshelfandcoastalcarbonatesthatinplaceshave been upliftedintoterraces(Reference383).**~~

Along Cuba's north coast ~~within~~ in the site region, the marine terraces that dip gently seaward (to the north) consist primarily of Miocene through Pleistocene age limestones (References ~~924~~ 923 and ~~923~~ 924) and extend laterally along the north coast (Reference 848) except where rivers have eroded gaps in the terraces (Reference 926). The terraces are wide, with gentle slopes, the karst processes are more pronounced (i.e., the formation of caves and caverns and sinkholes), and notches (a cut along the base of a sea cliff near the high water mark that forms by undercutting the sea cliff due to wave erosion and/or chemical solution) are pronounced (Reference 921). The Miocene rocks that the marine terrace deposits formed are divided into the Cojimar Formation marls and the Güines Formation carbonates (chalks, argillaceous bioclastic limestones, and reef limestones) that outcrop from Havana to Matanzas. The Cojimar Formation marls represent a middle Miocene deep open shelf that is overlain unconformably by the Güines Formation. The Güines Formation represents a carbonate platform that covered almost the entire Greater Antilles from the second half of the middle Miocene up to the late Miocene. Late Miocene-Pliocene deposits are only locally developed at the Morro Castle of Havana (the Morro limestones) and near Matanzas City at El Abra de Yumurí (El Abra Formation). The El Abra Formation is a fluvio-marine unit. Pleistocene carbonates of the Jaimanitas Formation (coral reef limestones and calcarenites) are exposed along the coastal plain of Havana and Matanzas (References 383 and 919) and along much of the north coast of Cuba (Reference 925).

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Terraces in Cuba near Matanzas are classified as erosional, depositional/cumulative and constructional (References 920 ~~923~~ and 923 ~~920~~). Erosional terraces on Cuba's northern coastline are located east of Boca de Juruco, province of Havana and in the vicinity of the Bay of Matanzas (Reference 923). Cumulative terraces are described as: (a) having a sandy beach with an inner edge of 1 to 1.5 meters (3.3 to 4.9 feet) ~~3.3 to 4.9 feet (1 to 1.5 meters)~~ above sea level, and (b) storm bank with heights of 2 to 3 meters (6.6 to 9.8 feet)~~6.6 to 9.8 feet (2 to 3 meters)~~ above sea level. Cumulative terraces occur on the northern coastline of Cuba, east of Havana. Constructional coral reef terraces are located on the north coast west of Havana to Mariel and the suburbs of Havana and Santa Fe Jaimanitas (References 920 ~~923~~ and 923 ~~920~~).

Four marine terraces near Havana occur at elevations 200, 100, 10-15 and 4-5 feet (61, 31, 3.1-4.6 and 1.2-1.5 meters) above mean sea level (References 383, ~~918~~ 917, ~~917~~ 918, and 926). Near Matanzas, six terraces have been observed at elevations 400, 300, 200, 140, 30, and 5-6 feet (122, 91, 61, 43, 9, and 1.5-1.8 meters) above sea level (References 917 ~~918~~, ~~917~~ 918, and 926). At Matanzas Bay, Ducloz (Reference ~~4~~ 915), Shanzar et al.~~,~~ (Reference ~~12~~ 923) and Penalver Hernandez et al., (Reference ~~10~~ 921) observed four terraces at the following approximate elevations 25–51 meters (82–167 feet) ~~82 – 167 feet (25 – 51 meters)~~ (Rayonera), 15–33 meters (49–108 feet ~~49 – 108 feet (15 – 33 meters)~~) (Yucayo), +/-16 meters (+/- 52 feet) ~~approximately 52 feet (approximately 16 meters)~~ ~~-~~(Puerto) and +/-8 meters (+/-26 feet) ~~13 – 33 feet (4 to 10 meters)~~ (Terraza de Seboruco) (Table 2.5.1-208). The Rayonera terrace is strongly karstic. The presence of sinkholes and caves indicate that the outer edge of the terrace has a height of 39 meters (128 feet) ~~128 feet (39 meters)~~ whereas the inner edge is ~~around~~ approximately 51 meters (167 feet) ~~167 feet (51 meters)~~ giving this surface a topographic slope of ~~around~~ approximately 3 to 4 degrees towards the coast. The rocks of this terrace are Pliocene-Pleistocene in age. As noted by its name, the Yucayo terrace is "narrow". It has an average height of 30 meters (98 feet) ~~98 feet (30 meters)~~ near the Bay of Matanzas. The terrace is cut off from the sea by a vertical cliff that is approximately ~~20 to 46 feet (6 to 14 meters)~~ (20 to 46 feet) 6 to 14 meters ~~in height~~ high. Sea caves are present and are indicative of coastal erosion. The Pliocene-Pleistocene rocks of this terrace are algal conchiferas, with hard, massive, and recrystallized limestone reefs. The Pliocene-Pleistocene Puerto terrace is similar to the Yucayo and Rayonera terraces. All three are characterized by the development of karst, sinkholes and a very sharp weathering surface known "diente de perros" (dog's teeth) (References 915 and 921). The Terraza de Seboruco~~-~~, the youngest of these terraces is located west of Matanzas Bay. It rises just a few meters (2 to 3 meters) (6.6 to 9.8 feet) above mean sea level with paleo-lagoonal facies extending inland ~~one~~ 1 or more kilometers. Near Havana and Matanzas, the elevation of the Terraza de Seboruco ranges from 2 to 3 meters (6.6 to 9.8 feet) above mean sea level to 4 to 5 meters (13 to 16 feet) above mean sea level, respectively. The terrace is described as porous or cavernous fossilized limestone from the Pleistocene Jaimanitas Formation with a weathering surface of "diente de perros" (References 915 and 925).

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The terraces and sea cliffs form a stair-step sequence, which suggests that reef deposition was followed by high sea level stands that cut the bench-like features in the sea cliffs (Reference 912). Several alternate processes can explain or partially explain the stair-step morphology and bench-like features that were described by Agassiz (Reference 912), Spencer (Reference 924), and Ducloz (Reference 915). The alternate hypotheses for what might have contributed to terrace formation as discussed in FSAR Subsections are eustatic changes in sea level (~~FSAR~~ Subsection 2.5.1.1.1.1.1.1), changes in ocean circulation pattern (~~FSAR~~ Subsection 2.5.1.1), rise and fall in sea level as a direct result of melting and formation of the continental glaciers (~~FSAR~~ Subsection 2.5.1.1.1.1.1.1), and tectonic activity (~~FSAR~~ Subsections 2.5.1 and 2.5.1.3.3).

U-Th dates were obtained on corals (two very large *Montastrea* sp. and one *Acropora* palmate) from the Terraza de Seboruco at the Cantera Playa Baracoa quarry and in the Santa Cruz del Norte canal. When corrected from the initial Uranium age dates, the ages of the samples correspond to the Marine Isotope Stage 5e sea level high stand at approximately 120–130 ka (Reference 925). Toscano et al. (Reference 925) observe that similar age terraces throughout "stable" portions of the Caribbean area are at similar elevations, which is evidence for the absence of active uplift near Matanzas in the past 120-130 ka. Therefore, based on the U-Th dates, the Terraza de Seboruco is correlative to the Cockburntown reef (Bahamas) (Reference 914), Barbados III (Barbados) (Reference 916), and Key Largo Limestone (Florida) (References 913 and 922).

The following text in FSAR Subsection 2.5.1.1.1.3.2.4, Cuba, will be revised in a future revision of the COLA.

After the last paragraph of Structures of Cuba in this subsection:

~~**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 geodetic data that indicate that less than 3 millimeters/year of deformation is occurring within Cuba relative to North America (References 502 and 503).**~~ 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.

~~**Additionally, elevated marine terraces were identified along the northern coast of Cuba as early as the late 19thth century (Reference 912). Recent studies of the marine terraces along the north coast of Cuba, especially for the stretch between Matanzas and Havana, are summarized below. Subsection 2.5.1.1.1.2.3 provides a description of the Quaternary deposits and surfaces in the Matanzas region, including the**~~

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~~Pleistocene-age Terraza de Seboruco surface west of Matanzas Bay. Ducloz (Reference 915) suggests that the elevated marine terraces along Cuba's north coast likely formed as the result of both fluctuations in sea level and epeirogenic uplift (Table 2.5.1-208). Ducloz (Reference 915) suggests that reactivation of a regional scale anticline may be partly responsible for formation of the terrace surfaces near Matanzas.~~

~~Similarly, Shanzer et al. (Reference 923) identify three Pleistocene-age marine terraces in the Matanzas-Havana region. Shanzer et al. (Reference 923) correlate segments of the Pleistocene-age Terraza de Seboruco between Matanzas and Havana and suggest that this terrace is approximately 1.5 to 3 meters (4.9 to 9.8 feet) lower at Havana than at Matanzas. Shanzer et al. (Reference 923) do not consider erosion of the terrace surface to explain the difference in elevation between Havana and Matanzas. Shanzer et al. (Reference 923) postulate that this difference in elevation may be the result of differential tectonic uplift, but they do not suggest what structure or structures may be responsible for this postulated tectonic uplift.~~

~~Toscano et al. (Reference 925) also observe that the Terraza de Seboruco in the Matanzas area is just a few meters above mean sea level, similar to the elevation of other Substage 5e reef deposits throughout "stable" portions of the Caribbean, and therefore can be explained solely by changes in sea level. Toscano et al. (Reference 925) conclude, "no obvious tectonic uplift is indicated for this time frame along the northern margin of Cuba."~~

~~Pedoja et al. (Reference 920) investigate late Quaternary coastlines worldwide and observe minor uplift relative to sea level of approximately 0.2 millimeter per year, even along passive margins, outpacing eustatic sea level decreases by a factor of four. Pedoja et al. (Reference 920) suggest that the decreasing number of subduction zones since the Late Cretaceous, coupled with relatively constant ridge length, has resulted in an increase in the average magnitude of compressive stress in the lithosphere. They argue that this average increase in compressive stress has produced low rates of uplift even along passive margins, as observed in their widespread measurements of uplifted continental margins. The measurements specific to Cuba suggest that the Substage 5e terrace in the Matanzas area (i.e., the Terraza de Seboruco) has been uplifted at an average rate that ranges from approximately 0.00 to 0.04 millimeter per year over the last approximately 122 ka (Reference 920).~~

Seismicity of Cuba

Maps of instrumental and pre-instrumental epicenters for Cuba show that seismicity can be separated into two zones: (a) the very active plate boundary region, including the east Oriente fault zone along Cuba's southern coast, and (b) the remainder of the island away from the active plate boundary region, which exhibits low to moderate levels of seismic activity (Figures 2.5.1-267, 2.5.2-220, and 2.5.2-221). **Regarding (b) above, along the north coast of Cuba between Havana and Matanzas, the ~~Turkey Point Units 6 & 7~~ Phase 2 earthquake catalog indicates sparse minor- to light-magnitude seismicity. It is possible that these earthquakes occurred on faults partially responsible for uplift of the marine terraces along Cuba's north coast in the site region. However, the association of the uplift of these terraces and earthquakes with individual faults in northern Cuba is uncertain. Based on the Phase 2 earthquake catalog, earthquakes do not appear to be aligned along faults in the Matanzas-Havana region. In addition,**

there are no known focal mechanisms available for these earthquakes that would help to constrain the causative fault or faults nor is there sufficient data to correlate uplift of marine terraces with these individual faults in northern Cuba.

It is possible that the elevations above modern sea level of marine terraces along Cuba's north coast in the site region are partially the result of tectonic uplift (References 915 and 923). The Terraza de Seboruco is the only terrace in northern Cuba for which radiometric age control is available. There is not sufficient data on this or other marine terraces in northern Cuba to assess the implications for active faulting. As discussed in Subsection 2.5.1.1.1.2.3, Toscano et al.'s (Reference 925) U-Th analysis of corals collected from the Terraza de Seboruco indicates that tectonic uplift is not required to explain the present elevation of this Substage 5e terrace. Instead, they conclude that the elevation of this terrace surface is consistent with other Substage 5e terraces in other tectonically stable regions of the Caribbean and that global fluctuations in sea level, not tectonic uplift, are responsible for the Terraza de Seboruco's present elevation above modern sea level. Likewise, Pedoja et al.'s (Reference 920) global study suggests that the elevation of the Terraza de Seboruco is consistent with the elevations of other Substage 5e terraces in tectonically stable regions worldwide.

Based on studies by Toscano et al. (Reference 925) and Pedoja et al. (Reference 920), active faulting is not required to explain the elevation of the Terraza de Seboruco along Cuba's north coast in the site region. However, observations of the Terraza de Seboruco cannot necessarily be used to preclude possible strike-slip faulting in the site region. As shown by the Phase 2 earthquake catalog, only sparse minor- to light-magnitude seismicity is observed along Cuba's northern coast between Havana and Matanzas. It is possible that at least some of these earthquakes occurred on the faults mapped in the region. However, in the absence of well-located hypocenters and focal mechanisms, these earthquakes cannot be definitively attributed to a particular fault or faults.

The east Oriente fault zone is an active plate boundary, with seismic activity concentrated on the Cabo Cruz Basin and the Santiago deformed belt. Focal mechanisms from the Cabo Cruz area show consistent east-northeast to west-southwest oriented normal faulting, indicative of an active pull-apart basin. In the Cabo Cruz Basin, all hypocenters are less then 30 kilometers (19 miles) deep. The Santiago deformed belt mechanisms show a combination of northwest-directed underthrusting and east-west left-lateral strike-slip, consistent with a bi-modal transpressive regime (Reference 504). In the Santiago deformed belt, thrust mechanisms occur between depths of 30 and 60 kilometers (19 and 37 miles), while the strike-slip mechanisms are shallower.

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The following text in FSAR Subsection 2.5.1.3, References, will be revised in a future revision of the COLA.

912. Agassiz, A., *A R~~r~~econnaissance of the Bahamas and E~~e~~levated R~~r~~eefs of Cuba*: Bulletin of the Museum of Comparative Zoology, ~~v~~Vol. 26, p. 203, 1894.

913. Broecker, W.~~S.~~, and D. Thurber, ~~D. L.,~~ *Uranium-S~~s~~eries D~~d~~ating of C~~c~~oral and O~~o~~olites from Bahaman and Florida Key L~~l~~imestones*: Science, V~~v~~ol. 149, pp. 58-60, 1965.

914. Chen, J. ~~H.,~~ H. Curran, ~~H. A.,~~ B. White, ~~B.,~~ G. Wasserburg, ~~G. J.,~~ *Precise C~~c~~hronology of the L~~l~~ast I~~i~~nterglacial P~~p~~eriod: 234U-230 The D~~d~~ata from F~~f~~ossil C~~c~~oral R~~r~~eefs in the Bahamas~~:~~*, Geological Society of America Bulletin, ~~v~~Vol.~~,~~ 103, pp. 82-97, 1991.

915. Ducloz, C., Etude G~~g~~eomorphologique de la R~~r~~egion de Matanzas, Cuba A~~a~~vec une C~~c~~ontribution a l'etude des depots quaternaires de la zone Habana- Matanzas, Archives des Sciences, Societe de Physique et d'Histoire Naturelle de Geneve, Imprimerie Kundig, 402 pp, 1963.

916. Gallup, C. ~~D.~~, R. Edwards, ~~R. L.,~~ and R. Johnson, R. G., *The T~~t~~iming of H~~h~~igh S~~s~~ea L~~l~~evels O~~o~~ver the P~~p~~ast 200,000 Y~~y~~ears*,~~:~~ Science, V~~v~~ol. 263, pp. 796-800, 1994.

917. Hayes, C.~~W.~~, T. Vaughan, ~~T.W.,~~ and A. Spencer, ~~A.C.,~~ *A Geological Reconnoissance [sic] of Cuba*, pp. 18-20, 1901.

918. Hill, R.~~T.~~, *Notes on the Geology of the Island of Cuba, Based Upon a Reconnoissance [sic] Made for Alexander Agassiz, Bulletin of the Museum of Comparative Zoology*, ~~v~~Vol. XVI, N~~n~~o. 15, pp. 264-274, 1895.

919. Iturralde-Vinent, M.~~A.~~, *Linked Earth Systems Field Guide Sedimentary Geology of Western Cuba*, The 1st SEPM Congress on Sedimentary Geology ~~[sp] of Cuba, pp. 18-20, 1901~~ August 13–16, St. Pete Beach, Florida, 1995..

920. Pedoja, K., L. Husson, ~~L.,~~ V. Regard, ~~V.,~~ P. Cobbold, ~~P.R.,~~ E. Ostanciaux, ~~E.,~~ M. Johnson, ~~M.E.,~~ S. Kershaw, ~~S.,~~ M. Saillard, ~~M.,~~ J. Martinod, ~~J.,~~ L. Furgerot, ~~L.,~~ P. Weill, ~~P.,~~ and B. Delcaullau, ~~B.,~~ *Relative S~~s~~ea-L~~l~~evel F~~f~~all S~~s~~ince the L~~l~~ast I~~i~~nterglacial S~~s~~tate: Are C~~c~~oasts U~~u~~plifting W~~w~~orldwide?*, Earth Science Reviews, ~~v~~Vol. 108, p. 1-15, 2011.

921. Penalver Hernandez, ~~L.,~~L., A. Castellanos Abella, ~~E.,~~ R. Perez Aragon, ~~R. O.,~~ and R. Rivada Suarez, ~~R.,~~ *Las Terrazas Marinas de Cuba y Su Correlacion Con Algunas Del Area Circumcaribe, Memorias Geomin, V Congreso de Geologia y Mineria,* Cuba, 24-28 De Marzo, La Habana, p~~p~~. 10, 2003.

922. Osmond, J. ~~K.,~~ J. Carpenter, ~~J.R.,~~ and H. Windom, ~~H.L.,~~ *230 Th/234 U A~~a~~ge of Pleistocene C~~c~~orals and O~~o~~olites of Florida*: Journal of Geophysical Research, ~~v~~Vol. 70, pp. 1843-1847, 1965.

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923. Shanzer, E.~~V.~~, O. Petrov, ~~O.M.,~~ and G. Franco, ~~G.,~~ Sobre las F~~f~~ormaciones C~~c~~osteras del Holoceno en Cuba, las T~~t~~errazas Pleistocenicas de la R~~r~~egion Habana-Matanzas y los S~~s~~edimentos V~~v~~inculados a E~~e~~llas, Serie Geologica N~~n~~o. 21, Acadamia de Ciencias de Cuba, Instituto de Geologia y Paleontologia, pp. 1-26, 1975.

924. Spencer, J.~~W.~~, *Geographical Evolution of Cuba*, Bulletin of the Geological Society of America, ~~v~~Vol. 7, pp. 67-94, 1895.

925. Toscano, M.A., E. Rodriguez, E., and J. Lundberg, ~~J.,~~ Geologic I~~i~~nvestigation of the L~~l~~ate Pleistocene Jaimanitas F~~f~~ormation: S~~s~~cience and S~~s~~ociety in Castro's Cuba, Proceedings of the 9th[th] Symposium on the Geology of the Bahamas and Other Carbonate Regions, Bahamian Field Station, Ltd., San Salvador, Bahamas. pp. 125-142, 1999.

926. Vaughan, T.~~W.~~, and A. Spencer, ~~A.,~~ *The Geography of Cuba*, Bulletin of the American Geographical Society, ~~v~~Vol. 34, ~~n~~No. 2, pp. 105-116, 1902.

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The following table in FSAR Subsection 2.5.1 will be added in a future revision of the COLA.

Table 2.5.1-208 Marine Terraces in the Matanzas Area of Northern Cuba

Marine Terrace (Reference 915)	Elevation of Marine Terrace (Reference 915)	Geologic Stratum (References 915 and 921)	Depositional Environment (Reference 915)	Possible Geologic Age (Reference 915)	Possible Geologic Age (Reference 921)
			Start of emergence	Start of the Upper Miocene	
			Erosion Cycle (No. 1)	Upper Miocene	
			Uplift and buckling (env. 60 m)	Pliocene (?)	
			Erosion Cycle (No. 2)		
			Uplift (env. 80 m)	Pliocene	
			Erosion Cycle (No. 3)		
			Uplift and folding (10 and 45 m)		
La Rayonera	25 and 51 m		Erosion Cycle (No. 4)		Pliocene-Pleistocene
			Uplift and folding (15 and 25 m)		
Yucayo	15 and 33 m		Erosion epicycle (No. 1)	Pliocene (?)	Pliocene-Pleistocene
			Drop in sea level: uplift, very light folding (10 m)	Pliocene (?)	
Puerto	16 m		Erosion epicycle (No. 2)	Start of the Illinoian Glaciation	
			Drop in sea level (11 and 13 m)		
submarine terrace	No. 1 (-1 m)		Erosion epicycle (No. 3)		
			Drop in sea level (1 m)		
submarine terrace	No. 2 (-2 and -6 m)		Erosion epicycle (No. 4)		
			Drop in sea level (env. 130 m)	Illinoian Glaciation Maximum	
Continental Shelf terrace			Erosion epicycle (No. 5)		
			Rise in eustatic sea level (+11 m)		
		Jaimanitas Formation (Terraza de Seboruco), Rosario Terrace (continental alluvial terrace)	Formation of fringing reefs on uplifted alluvium deposits	Sangamon Interglacial	Pleistocene
Limits of the Terraza de Seboruco	+/- 8 m		Drop in sea level (env. 12 m)	Start of the Wisconsinan Glaciation	
submarine terrace	No. 3 (-10 and -17 m)		Erosion epicycle (No. 6)		
			Drop in sea level (env. 10 m)		
submarine terrace	No. 4 (-20 and -55 m)		Erosion epicycle(No. 7)		
			Drop in sea level (env. 110 m)	Wisconsinan Glaciation Maximum	
Limit of the Restart of the Continental Plate			Erosion epicycle (No. 8)		
			Eustatic rise to present sea level	FlandrianTransgression	
		Recent alluvium	Induation of river valleys		

Source: References 915 and 921

Mark-ups to Revised Response
to NRC RAI No. 02.05.01-23 (eRAI 6024)

ASSOCIATED COLA REVISIONS:

The Cuban Fold-and-Thrust Belt section of FSAR Subsection 2.5.1.1.1.3.2.2 will be revised as shown in a future revision of the COLA:

North American passive margin strata are deformed in a series of north-vergent imbricate thrusts and anticlines along the northern edge of Cuba (Figures 2.5.1-248, 2.5.1-251, 2.5.1-252, 2.5.1-279, 2.5.1-280, and 2.5.1-281). These faults and folds are exposed onshore, particularly in western Cuba, but imaged with seismic data offshore, within about 20 miles (32 kilometers) of the Cuban coastline (References 221, 484, and 485) (Figure 2.5.1-248). ~~Syn-tectonic~~ Syntectonic 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~~ on 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~~ **syntectonic** strata **(References 220, 439 ~~485~~, and 485 ~~439~~) and** published structural interpretations indicating unfaulted Quaternary strata above these structures offshore **(References 484 and 485)**, ~~andunfaultedPleistoceneandyounger terracesalongthe northernedgeofCuba(Reference847)(Figure2.5.1-282),~~ these faults are concluded to be Tertiary in age and not capable tectonic structures. **This age determination is also in agreement with published summaries of the tectonic evolution of Cuba (References 217 and 440). Moreover, recent studies of the marine Substage 5e terrace that formed approximately 122 ka preserved on Cuba's north coast between Matanzas and Havana are consistent with the lack of ongoing or recent tectonic uplift (References 920 ~~912~~ and 925 ~~913~~).**

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

~~920~~ 925. Toscano, M. ~~A.,~~ E. Rodriguez, ~~E.,~~ J. Lundberg, ~~J.,~~ Geologic I~~i~~nvestigation of the L~~l~~ate Pleistocene Jaimanitas Formation: Science and S~~s~~ociety in Castro's Cuba, Proceedings of the 9th Symposium on the Geology of the Bahamas and O~~o~~ther Carbonate Regions, Bahamian Field Station, Ltd., San Salvador, Bahamas, ~~Curran, H.A., and Mylroie, J.E. (eds), San Salvador, Bahamian Field Station,~~ pp. 125-142, 1999.

~~925~~ 920 Pedoja, K., L. Husson, ~~L.,~~ V. Regard, ~~V.,~~ P. Cobbold, ~~P.R.,~~ E. Ostanciaux, ~~E.,~~ Johnson, M.E., S. Kershaw, ~~S.,~~ M. Saillard, ~~M.,~~ J. Martinod, ~~J.,~~ L. Furgerot, ~~L.,~~ P. Weill, ~~P.,~~ and B. Delcaullau, ~~B., 2011.~~ Relative sea-level fall since the last interglacial state: Are coasts uplifting worldwide?, Earth Science Reviews, Vol. 108, pp. 1–15, 2011.

Marked-up Revised Response
to NRC RAI No. 02.05.01-24 (eRAI 6024)

ASSOCIATED COLA REVISIONS:

The COLA will be revised to include information provided in this response pertaining to the Nortecubana fault. These COLA revisions are provided as part of the response to RAI 02.05.01-21.

FSAR Figure 2.5.1-279 will be replaced with the revised figure shown below in a future revision of the FSAR.

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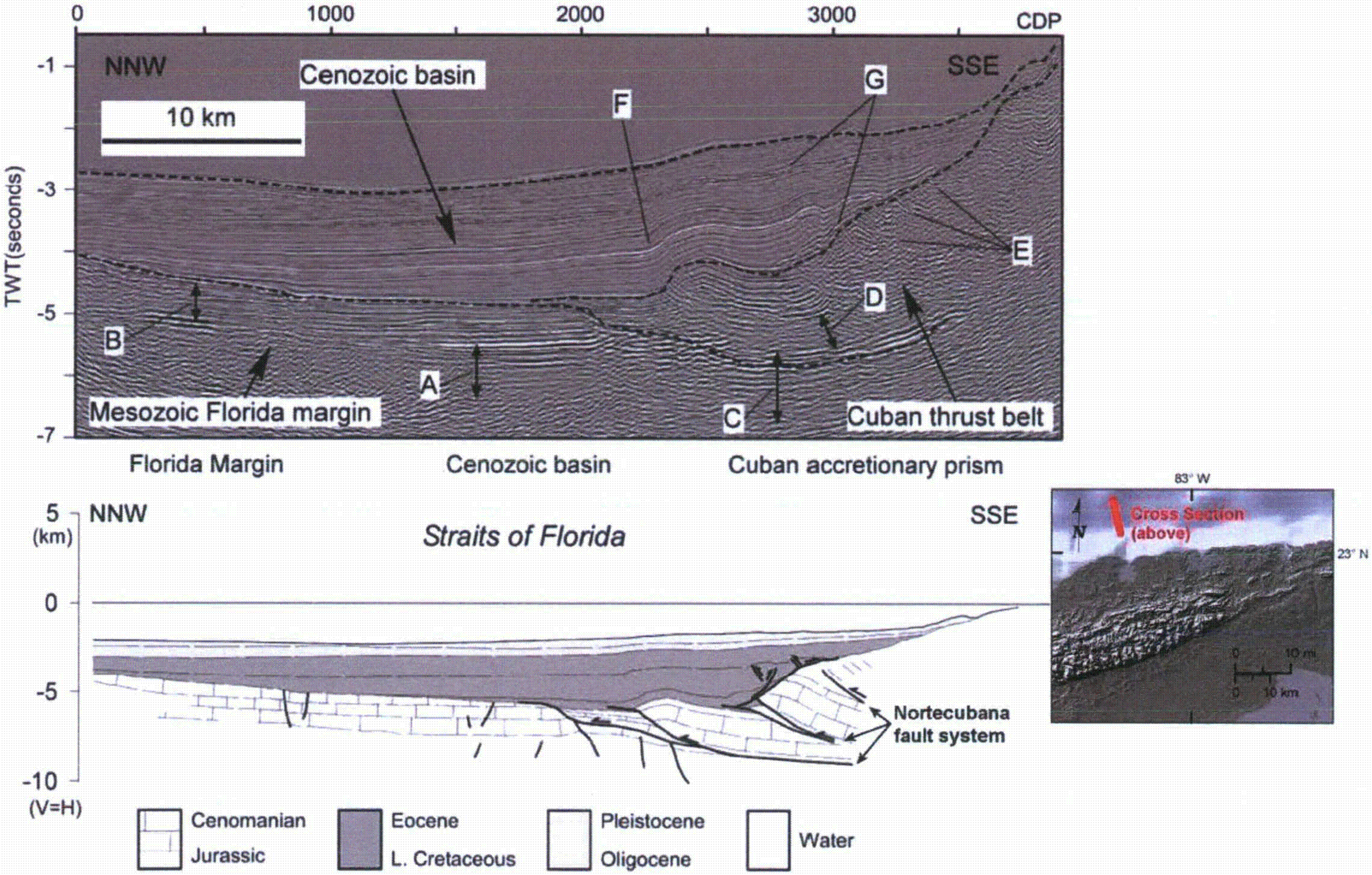
Figure 2.5.1-279 Offshore Cross Section across the Cuban Fold-and-Thrust Belt, Western Cuba



Marked-up Revised Response
to NRC RAI No. 02.05.01-29 (eRAI 6024)

ASSOCIATED COLA REVISIONS:

A discussion of marine terraces will be included in a future update to the FSAR, as detailed in the response to RAI 02.05.01-22.

The discussion of Cuban faults in FSAR Subsection 2.5.1.1.1.3.2.4 will be revised in a future update to the FSAR, as detailed in the response to RAI 02.05.01-21.

The footnote to FSAR Table 2.5.1-204 will be revised in a future update to the FSAR.

c) Mapa Geologico de la Republica de Cuba (Reference 848) ~~(Figure2.5.1-288)~~

The following note will be added to FSAR Figure 2.5.1-251 in a future update of the FSAR.

Note: The Matanzas fault shown here is the same structure as the Hicacos fault shown on Figure 2.5.1-247.

Marked-up Revised Response
to NRC RAI No. 02.05.01-30 (eRAI 6024)

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,availablegeologic mapping(at1:250,000and1:500,000scales;References846,847,and848) provides someinformationregardingthetimingofactivityforsomeoftheregional structuresandlargelyindicatesthatthePleistoceneandyoungerstrataare undeformedthroughouttheisland.Thisisconsistentwithgeodeticdatathat indicatethatlessthan3millimeters/yearofdeformationisoccurringwithin Cuba relativetoNorthAmerica(References502and503).~~ The available data indicate that the Oriente fault system, located offshore ~~just~~ **directly** 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.

Additionally, the COLA will be revised to include information provided in this response pertaining to the Pinar, Cubitas, and La Trocha faults. These COLA revisions are provided as part of the response to RAI 02.05.01-21.

Marked-up Revised Response
to NRC RAI No. 02.05.01-32 (eRAI 6024)

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**~~ **are** designated **by Cotilla-Rodriguez et al. (Reference 494)** as "active" ~~(Reference494)~~ **based on their ambiguous definition of the term.** ~~,butthatpublished~~ ~~**However, Cotilla-Rodriguez et al.'s**~~ **For many faults in intraplate Cuba, the Cotilla-Rodriguez et al. (Reference 494)** analysis does not provide sufficient information to conclude that a structure is **a** capable **tectonic source 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.