Isaac ASIMOV (Rusia, 1920-1992): "El aspecto más triste de la vida es que la ciencia reúne el conocimiento más rápidamente que la sociedad la sabiduría."

2- Comments on the Nortecubana Fault

2- Comments on the Nortecubana Fault
{Comentarios Sobre la Falla Nortecubana}

Abstract- Nortecubana Fault is a complex marine geological structure, arched and segmented into four parts, between Cabo de San Antonio and Punta de Maisí. Its linear extension is ~1,200 km and has two directions SW-NE and NW-SE. The figure is concave to the south and responds to a zone of structural deformation in the vicinity of La Habana-Peninsula de Hicacos. It is the northern limit of the Cuban mega block at the southern edge of the North American Plate and has at least 380 earthquakes and 2 local tsunamis (years: 1931 and 1939). The M_{max} registered in the sea is 6,2 (I_{max}=7 MSK) in 1914 for Gibara. The active depth of its four seismic segments is 10-75 km. The central segment (Punta de Hicacos-Ciego de Ávila) is the longest. The Ciego de Ávila-Bahía de Nipe segment, near Gibara, has the highest seismic level. There are three induced series of earthquakes in 1981 and 2014-2017 earthquakes occurred on the Nortecubana Fault and one in 2000-2017 associated with Hicacos Fault. Nortecubana Fault has no continuity link with the Septentrional Hispaniola Fault (M_{max}=8,2/ more than 10 local tsunamis).

Keywords: Active fault, earthquake, seismicity, tsunami

Introduction

Cuba, from the physic-geographical point of view, is an archipelago that together with other islands (Jamaica, Hispaniola (Haiti and Dominican Republic) and Puerto Rico) form the Greater Antilles Arc (**Figure 1**). This group has suffered and continues to suffer the effects of two natural phenomena, hurricanes and earthquakes. Our focus is on the second of these. The first earthquake in Cuba was reported in 1528 in Baracoa city, founded village (and capital of Cuba) by the Spaniards since their arrival in 1492. The city is in the northeastern part, near Punta de Maisí.

A characteristic of Cuba is the location of important urban and tourist centers along its coasts and particularly in the northern part. In addition to the population and its material goods, it is necessary to consider, in the studies of seismic hazard, the port infrastructures located there. The zone of greatest seismic activity in Cuba is in the southeastern zone, Cabo Cruz-Santiago de Cuba (**Figure 1**). But, the work target is the Nortecubana Fault, responsible of the Baracoa´s earthquake.

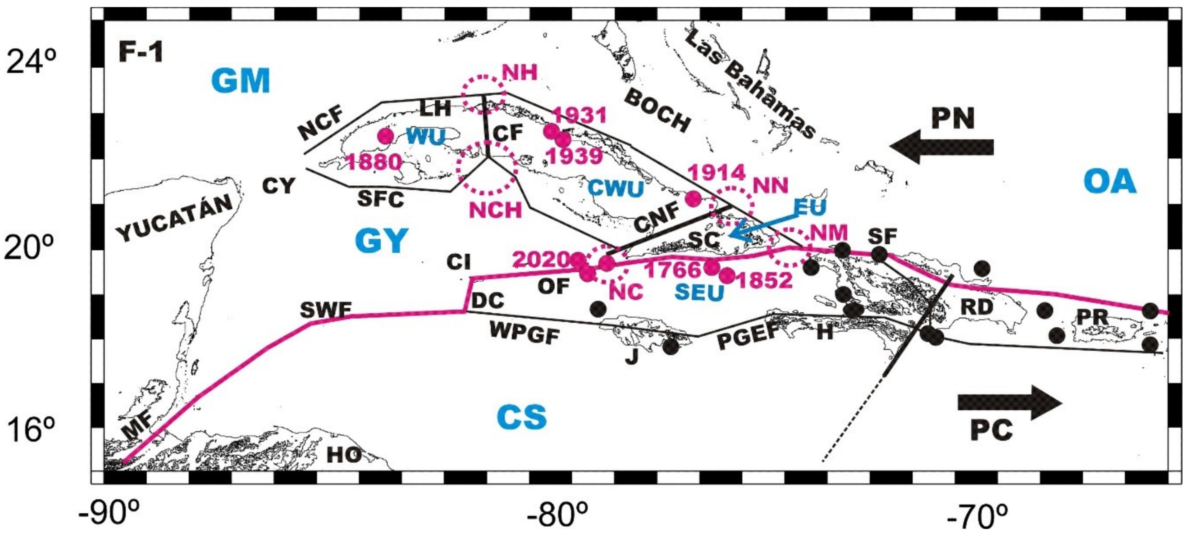

Figure 1. Neotectonic Units and Seismicity (Cotilla *et al*. [30]). Appears: 1) epicentre (circle in black and red colors (year); 2) thick black arrow (direction of movement of the plates: PC=Caribbean, PN=North American); 3) locality and region (LH=La Habana, SC=Santiago de Cuba DC=Oceanic Crust Dispersion Center, BOCH=Old Channel of The Bahamas, CY=Yucatan Channel); 4) bodies of water (blue acronym: GM=Gulf of Mexico, GY=Gulf of Yucatan, CS=Caribbean Sea, OA=Atlantic Ocean); 5) knot (discontinuous circle and acronym in red: NC=Cabo Cruz, NCH=Cochinos, NH=Hicacos, NM=Maisí, NN=Nipe); 6) country (H=Haití, HO=Honduras, CI=Cayman Islands, J=Jamaica, PR=Puerto Rico, RD=Dominican Republic); 7) Neotectonic Unit (CWU=Central Western, WU=Western, EU=Eastern, SEU=South Eastern); 8) fault zone 8.1) continuous black line: CF=Cochinos, NCF=Nortecubana, SCF=Surcubana; 8.2) continuous red line (Plate Boundary): MF=Motagua, OF=Oriente, PGEF=Plantain Garden-Enriquillo, SF=Septentrional, SWF=Swan-Walton, WPGF=Walton-Plantain Garden.

2.1 Notes About Fault`s Activity

Fault and earthquakes are very well known by specialists. Nevertheless, their relation in the majority of time result quite complicate. Along the history several academic results are published and used around the World [6, 11, 43, 44, 55, 59, 72, 83, 84, 87, 92].

Fault refers to a brittle deformation zone formed by rock strata that have or have not been through the soil consolidation process. A fault can be classified into two main types: active and inactive. We put our attention to the first one. An active fault is a 3-D structure that has relation with at least an earthquake and is likely to become the source of another one sometime in the future. It is commonly considered to be active if it has been movement observed or evidence of seismic activity during the last 10.000 years. Such structure is considered to be a geologic hazard and related to earthquakes as a cause. Some effects of movement can included landslides and rock falls, liquefaction, strong ground motion, surface faulting, tectonic deformation, tsunamis and seiches.

The largest active faults are associated with the plate boundaries. There are several geologic and geomorphologic methods in order to determine a fault and its activity. More recently, using space photos and images it is possible to recognize the boundaries and figure of the faults. Other results from Guelfand *et al*. [42] and Assinovskaya *et al*. [5] allowed to define the activity in regions with strong earthquakes potential. But, another type of region and seismicity is determined inside the plates. It is denominated as intraplate

[49, 75, 81, 85, 89]. In summary an active fault is a neotectonic structure that: 1) it has been offset during the present seismotectonic regime; 2) it has the probability or potential for future renewal or recurrence of offset; 3) it has evidence of recent activity, as may be shown by physiographic evidence; 4) it may have associated earthquake activity. We are going follow these elements in our research as the Rule 1 of Cotilla [16].

2.2 The Nortecubana Fault

The Nortecubana Fault (Figure 1) has been studied over time by different specialists [14, 30, 32, 33, 52, 62-64, 78, 79]. It is described in the northern marine part of Cuba, between Cabo de San Antonio and Punta de Maisí. Its figure corresponds to the layout and configuration of the coastline. It has a length of ~1.200 km. The structural inflection of the Island, including this fault, is in the vicinity of La Habana-Matanzas. The Nortecubana Fault is a seismic active structure, and has several perceptible earthquakes and two local tsunamis.

Cotilla [16] considers that the Nortecubana Fault, as the southern structure of the North American plate, has four segments (Figure 2): FNC1 (Cabo de San Antonio-La Habana), FNC2 (La Habana-Ciego de Ávila), FNC3 (Ciego de Ávila-Nipe) and FNC4 (Nipe-Punta de Maisí). In the segments: 1) FNC3 occurred the Gibara earthquake of 1914 M_{max}=6,2/ I_{max}=7 MSK; 2) FNC2 two local tsunamis hit in 1931 and 1939 the localities of Playa Panchita and Caibarién; 3) FNC1 and FNC2 were noticeable two earthquakes series. They were produced by geophysical exploration work for gas and oil, years 1981 and 2014-2017.

On the other side, it has been determined that the Nortecubana Fault is not linked to the Septentrional Fault (Fig. 2) (M_{max}=8,0/ >10 local tsunamis/ ~500 deaths) [19, 22, 23, 25, 29, 69]. The latter one is part of the Caribbean and North American Plate Boundary (Figure 1).

2.3 Neotectonic and Seismicity

The following references are used for the preparation of the heading: Álvarez *et al*. [1, 2]; Cobiella [12, 13]; Cotilla [14-18]; Cotilla and Córdoba [19-24]; Cotilla and Udías [25]; Cotilla *et al*. [26, 27, 29, 30-34]; Dixon *et al*. [36]; Erickson *et al*. [38]; Hernández *et al*. [45]; Iturralde [47]; Levchenko and Riabujin [52]; Linares *et al*. [53]; Mann and Burke [56]; Mann *et al*. [57, 58]; MINBAS [62, 63]; MINCM, [64]; Moretti *et al*. [65]; Mossakovsky *et al*. [66]; NPE [69]; Núñez-Escribano [70]; Núñez *et al*. [71]; Prentice *et al*. [73]; Quintas *et al*. [74]; Rubio *et al*. [76]; Shein *et al*. [78-80]; WSM [90].

The relative motion between the Caribbean and North American Plates controls the tectonic regime of the area at a regional scale. It was argued that the eastward motion of the Caribbean Plate relative to the North American Plate occurs at a rate of 12-40 mm/yr. It was estimated 18±3 mm/year for Southeastern Cuba. The eastward motion of the Caribbean Plate produces a left-lateral strike slip deformation along the Bartlett-Cayman Fault Zone and left-lateral strike slip along the Walton-Plantain Garden-Enriquillo Fault Zone. There are four important local structures that affect the tectonic regime in the area: 1) the Mid-Cayman Rise Spreading Center (Cayman Islands); 2) the Cabo Cruz Basin; 3) the Santiago de Cuba Deformed Belt; 4) the Maisí Area. All they account for more than 85% of the seismicity along this part, related with Oriente Fault and included in the Plate Boundary Zone. The general pattern of the seismicity in the Caribbean region is in figure 3. Large earthquakes occur along the Plate Boundary near Hispaniola, Jamaica and Puerto Rico Islands.

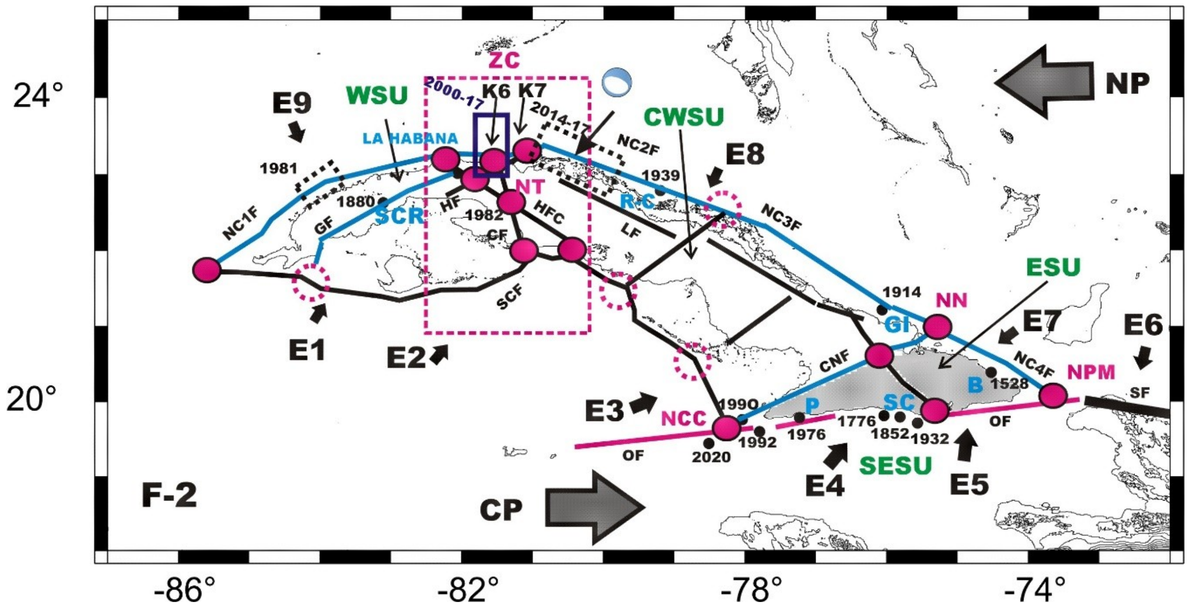

Figure 2. Simplified Seismotectonic map of Cuba. Appears: 1) areas of induced seismicity in: 1.1) 1981 and 2014-2017 (black discontinuous rectangle); 1.2) 2000-2017 (black continuos rectangle); 2) epicentre (circle and year in black); 3) fault: 3.1) black line: CF=Cochinos, HF=Hicacos, HCF=Habana-Cienfuegos, LF=Las Villas, SF=Septentrional, SCF=Surcubana; 3.2) 2nd Category faults (blue line): FCN=Cauto-Nipe, FG=Guane. FNC=Nortecubana (with blue letter, segments: FNC-1): 3.3) 1st Category faults (red line): OF=Oriente); 4) locality (blue letter; B=Baracoa, GI=Gibara, P=Pilón, R-C=Remedios-Caibarién, SC=Santiago de Cuba, SCR=San Cristóbal); 5) knot (circle and red letter: NCC=Cabo Cruz, NN=Nipe, NPM=Punta de Maisí, NT=Torriente-Jagüey Grande, K6=Matanzas Bay, K7=Varadero Bay); 6) plate (CP=Caribbean, NP=North American); 7) direction of movement of the plates (thick gray arrow); 8) tensor $\sigma_{hmáx}$ (thick black arrow and letter-number E1-9); tensor $\sigma_{hmáx}$ (thick black arrow and letter-number E1-9); 9) Seismic momentum tensor (USGS) 2014.09.1 (M_W=5,0) in Corralillo; 10) Seismotectonic Unit (green letter: WSU=Western, CWSU=Central Western, ESU=Eastern, SESU=South Eastern); 11) ZC=Area of significant structural change (dashed rectangle and dashed circle, in red).

Cuba is a mega block in the southern part of the North American Plate. The active Plate Boundary runs along the southeastern coast. It was identified two types of seismicity: 1) inter plate; 2) intraplate. The first type is due to the direct interaction of the Caribbean and North American Plates. It is located in the Oriente Fault where occur the greatest number of earthquakes and those of greatest magnitude (Ms>7,0). The intraplate earthquakes take place in the rest of the Cuban territory and the adjacent marine area out of the Plate Boundary Zone. They are significantly less strong and less frequent than the previous mentioned type. Low magnitude seismicity (Ms<4,0) occurs throughout the Western region of the island.

From them we can distinguish a significant and regular decrease of the seismicity from the contact zone of the Caribbean-North American Plates, in the southeastern part, towards the interior of the Cuban territory in the western part. This corresponds directly to the neotectonic situation and the influence of the plate systems that support the existence of four independent Seismotectonic Units: Western, Central-Western, Eastern and Southeastern (**Figure 2,** Table 1).

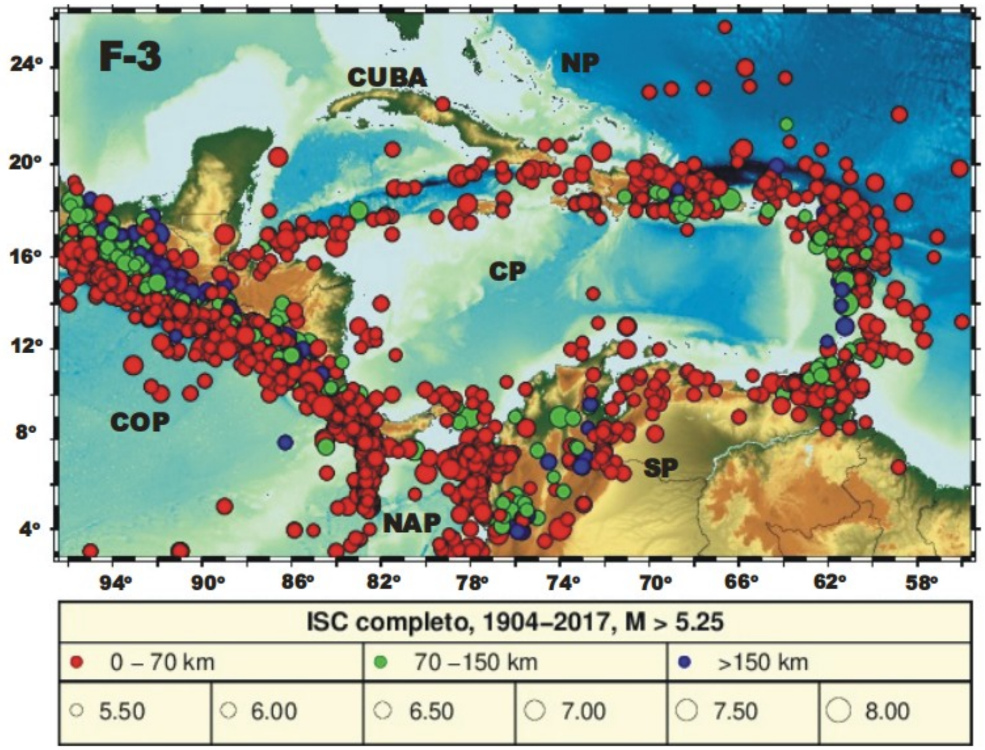

Figure 3. Seismicity in the Caribbean. Plate (CP=Caribbean, COP=Cocos, NP=North American, NAP=Nazca, SP=South American).

Dutton [37], Wilson and O'Halloran [88], McClain and Meyer [60], Liu and Zoback [54], Campbell [8], Sykes [81], Scholz *et al*. [77], Johnston and Kanter [49], Talwani and Rajendran [82], Gubbins [41], Leonov [50], Wysession *et al*. [91], Johnston [48], Amorèse *et al*. [3], Weiran *et al*. [86] and Middleton *et al*. [61] among others, created a basis for the studies of intraplate seismicity. In the same line of reasoning, Leroy and Mauffret [51], based on seismic surveys, determined that the Caribbean Plate has active deformation zones. Also, Cuba has an articulated set of intraplate blocks and regions that include: **1)** Corralillo and its surroundings that are in a morphological structure with a tendency to descend that includes a series of low and flat plains, related to keys and mangroves, and where there is no superficial river network. In this environment there are three active fault zones, Cochinos, Hicacos and Nortecubana (**Tables 2-3**); **2)** a large deformation or structural change area and which has seven joint knots, in the morphotectonic plane; 3) gas and oil bags. In this environment, several perceptible seismic events have occurred that were recorded by international stations in 2014-2017 (Figure 4, Table 4).

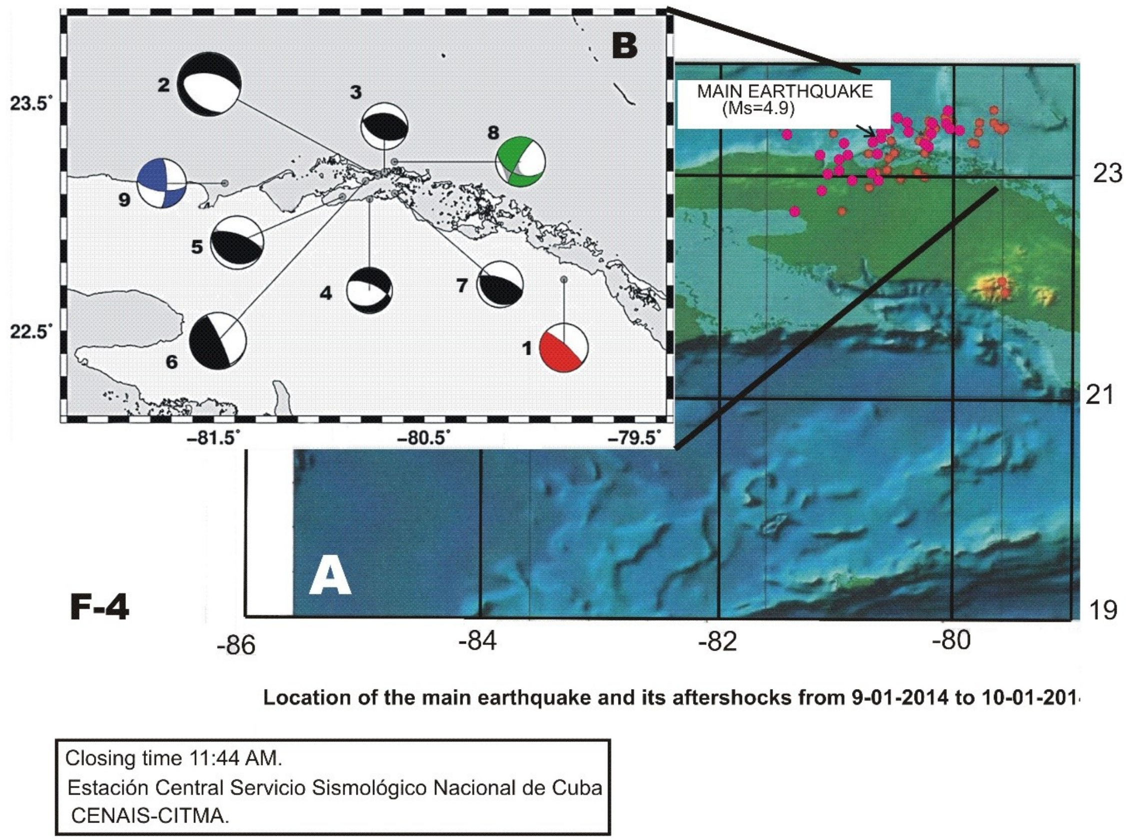

Figure 4. Seismicity and tensors in the Corralillo environment. 4A. Modified from the Special Information Bulletin No. 2/ 2014 [9]; 4B. Moment tensors and fault plans (modified from Braunmiller *et al*. [7]. Appears: 1) eight moment tensors with overlapping fault plane solutions associated with the North Cuban fault, near Corralillo (2-9); 2) each has the date and time (1=2012.11.20/ 00:19 (red color)/ in black color: 2=2014.01.09/ 20:57, 3=2014.01.10/ 02:25, 4=2014.01.10/ 11:23, 5=2014.02.05/ 03:09, 6=2014.03.09/ 11:26, 7=2014.03.30/ 21:50/ 8=2015.08.16/ 11:47 (green color)/ 9=2017.07.30/ 03:41 (blue color)); 3) the solution to the 2014.01.9 earthquake is of Arango-Arias *et al*. [4] and the other 8 solutions are from Braunmiller *et al*. [7].

The figures 5A-D show very well the existence of the Nortecubana Fault. They are in correspondence with expressed before about an active fault (historic and registered seismic events). When the requirement on number of stations used in hypocenters location grows (from A to D), weak seismicity tends to disappear, but middle magnitude events maintain. Another data about the activity of this fault are the events induced by gas and oil geophysical works. Cotilla *et al*. [30] studied two different group of these events: 1) year 1981 in FNC1 (northern of Pinar del Río); 2) period 2014-2017 in FNC3 (in the vicinity of Corralillo) (Figure 6). These events were perceptible.

Table 1. **Data from the three strongest earthquakes in Western and Central-Western Units.**

Date/ Region/ Fault	M/ I (MSK)	Coordinates (N W)	Aftershocks	Isosists/ Epicentre in	Tipe/ Shape index	Area (10^3 km^2)	Rupture (km)
1880.01.23/ Western/ G	6,2/ 8	22,70 83,00	65	Yes/ Ground	Full/ 0,68	40	35
1914.02.28/ Central-Eastern/ NC	6,2/ 7	21,30 76,20	9	Yes/ Sea	Half/ 0,75	25	15
1939.08.15/ Central/ NC	5,6/ 7	22,50 79,25	24	Yes/ Sea	Half/ 0,71	19	20

Notes: 1) G=Guane Fault, NC=Nortecubana Fault; 2) the highest values in all tables are indicated in red color.

Table 2. **Some historical earthquakes in the Nortecubana Fault.**

Segment			
Western/ Total	**Central/ Total**	**Eastern/ Total**	**Total**
1810, 1812, 1835, 1843, 1849, 1852/ 6	1824, 1837, 1852 (3)/ 5	1528/ 1	12

Table 3. **Summary of earthquakes associated with the Nortecubana Fault.**

	Segment/ rank of M/ rank of h (km)				
Earthquakes	**Western**	**Central**	**Eastern**	**Total**	**Years**
Historics	21/ 2,5-4,2/ 10-20	13/ 3,1-4,5/ 10-15	1/ 5,0/ 10	35	408
Recorded	25/ 2,5-4,4/ 10-20	166/ 0,1-6,2/ 2-74	111/ 0,2-5,6/ 2-74	302	123
Total	**46**	**179**	**112**	**337**	**530**

Table 4. **Data from three international sources for three earthquakes of Corralillo in 2014.**

Source	Month.Day	Time	M	h (km)	Coordinates (N W)	Source	Month.Day	Time	M	h (km)	Coordinates (N W)
USGS	02.05	3:19:32	4,3	12	23,168 80,821	USGS	09.01	20:57:43	5,0	10	23,182 80,728
GEOFON		:38	4,4	12	23,21 80,70	GEOFON		:44	5,0	10	23,23 80,76
EMSC		:31	4,4	14	23,25 80,69	EMSC	-	-	-	-	-
USGS	03.09	11:26:18	4,7	9	23,183 80,751	**Source**	**Month.Day**	**Plane**	**N1**	**Plane**	**N2**
GEOFON		:18	4,7	10	23,27 80,69	USGS*	09.01	113 25	-88	291 65	-91*
EMSC		:18	4,8	10	23,17 80,77	GEOFON		107 38	-93	281 52	-93

Note: * See figures 2 and 4.

Table 5. **Data of two actives Cuban faults.**

Fault	Seismotectonic Unit	Type of seismicity	Category/ Segments	L/ W/ D	M_{max}	Earthquakes/ Total	Isoseismal	Knots
CH	Western	Intraplate	III/ 2	200/ 30/ 20	5,0	1903, 1927, 1928, 1964, 1974, 1982, 2015/ 6	YES	3
H	Western	Intraplate	III/ 3	230/ 20/ 20	3,0	1812, 1843, 1852, 1852 (2), 1880, 1914, (2), 1974, 1978/ 10	NO	2

Note: Fault (CH=Cochinos, H=Hicacos); L=Longitude (km), W=Wide (km), D=Depth (km).

It is quite important to understand that recording of weak seismicity depend of the existing local seismic stations. Then, the Central-Western part of Cuba are less documented, as can be seen when the increasing the number of stations recording an earthquake grows. Nevertheless, at Varadero-Santa Marta localities, Matanzas province, there were registered and reported some earthquakes (7.10.2000/ M=2,7 and 2,8/ I_{max}=V) [10]. After that and according with the USGS it was registered the most strong earthquake in the same area on 30.07.2017 (M=4,4/ I=V/ h=10 km/ 3:41:29/ 23,148 N -81,446 W). All they were perceptible. Cotilla [14] argued the existence of an articulation knot with the Hicacos, Cochinos (**Table 5**) and Nortecubana Faults (**Figure** 2). Later on the first author showed the knot Matanzas Bay (figure 6 of Cotilla [16]) and the differentiation of the seismic activity with two knots K6 (Matanzas Bay) and K7 (Varadero) (figure 3a of Cotilla [18]).

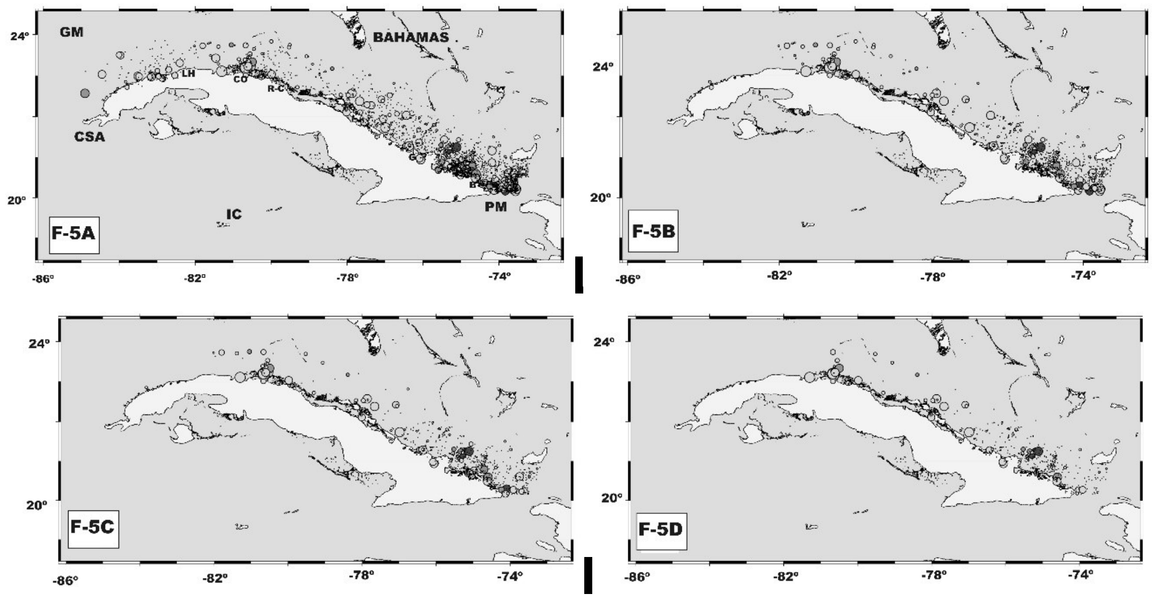

Figure 5. Maps of registered seismicity (until 2018, CENAIS [9]). Appears: B=Baracoa, CO=Corralillo, G=Gibara, GM=Gulf of Mexico, IC=Cayman Islands, LH=La Habana, PM=Punta de Maisí, R-C=Remedios-Caibarién. There are 4 possibilities of determination: 5A) 1 or more stations; 5B) 2 or more stattions; 5C) 3 or more stations; 5D) 4 or more stations.

Cotilla *et al*. [30] maintain that the events of 1981 and 2014-217, mentioned above, correspond to the induced seismicity in the adjacent faults by the oil exploitation. They argued that the continuous extraction of gas and oil deforms the subterranean chambers and consequently varies the stress field in the region. Although we have no real volume data about oil and gas exploitation in Varadero-Santa Marta area, we consider that the conditions are propitious to induced seismicity also, and those mentioned earthquakes could be induced ones. In addition, we sustain that: 1) the largest magnitude of future induced earthquakes in Cuba by oil and gas extraction should be always lesser than 5,0. The overall oil and equivalent gas production in Cuba is about 4.10^6 tons at a year, distributed in a lot of small reservoirs; then, no big stress modifications may be present; 2) it would be essential to install a seismic station in that area to record weak events with greater certainty.

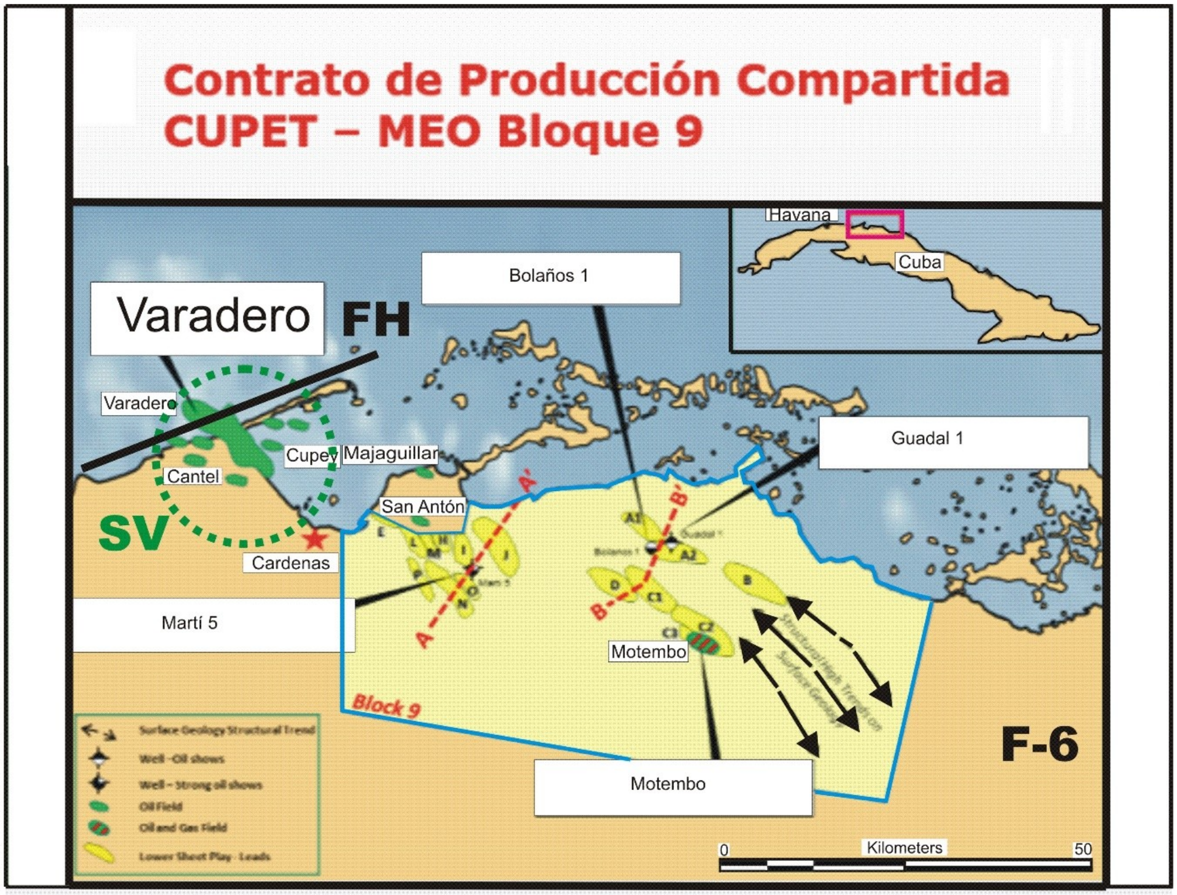

Figure 6. Modified image of *"Petróleo en Cuba: ¿dónde está el oro negro?"* (In: *CubaDebate* (16.09.2016/ María del Carmen Ramón)). They appear, immediately, to the west of Cárdenas: 1) Block 9. Landscape rectangle and adjacent to the N coast; 2) four areas of work (Bolaños 1, Guadal 1, Martí 5, Motembo). All in the municipalities of Corralillo, Quemado de Güines and Sagua La Grande; 3) in green are the oil bags of Varadero and San Anton, outside that block; 4) MEO=is an Australian company that signed a contract with CUPET to be exploited the Block 9; 5) FH=Hicacos Fault (line and acronym); 6) seismic group in Varadero (discontinue circle in green color).

Table 6. Data on active study faults.

	Fault		
Characteristic	**Nortecubana**	**Oriente**	**Septentrional**
Active fault features (Rule 1)	3	3	**4**
Country associated	Cuba	Cuba	Hispaniola (Haití and Dominican Republic)
Dead/ injured	No/ 2	80/ 700	**~5.000/ 10.000**
Earthquakes (M≥7,0)	No	1	**12**
Economic losses (10^6 U.S.D.)	~0,2	~60	**~200**
Focus depth (km)	10-75	10-70	**0-200**
I_{max} (MSK)	7	9	**10**
Induced seismicity	Yes	No	No
Local tsunami	2	No	**10**
Located at	North	South	North
Longitude (km)	**~1.200**	~750	~750
M_{max}	6,2	7,7	**8,2**
Paleo seismological research	No	No	Yes
Period of recurrence of strong	**>150**	90	70

earthquakes (year) [T]			
Regional Category	IV	II	**I**
Segments	**4**	3	2
Seismicity type	Intraplate	Inter plates	Inter plates
Seismic dislocation	No	No	Some
Thickness of the seismic layer (km)	~12	~30	**~90**

Cotilla *et al*. [30] maintain that the events of 1981 and 2014-217, mentioned above, correspond to the induced seismicity in the adjacent faults by the oil exploitation. They argued that the continuous extraction of gas and oil deforms the subterranean chambers and consequently varies the stress field in the region. Although we have no real volume data about oil and gas exploitation in Varadero-Santa Marta area, we consider that the conditions are propitious to induced seismicity also, and those mentioned earthquakes could be induced ones. In addition, we sustain that: **1)** the largest magnitude of future induced earthquakes in Cuba by oil and gas extraction should be always lesser than 5,0. The overall oil and equivalent gas production in Cuba is about 4.10^6 tons at a year, distributed in a lot of small reservoirs; then, no big stress modifications may be present; **2)** it would be essential to install a seismic station in that area to record weak events with greater certainty.

2.4 Discussion

The neotectonic framework of the Caribbean was well adjusted with Mann and Burke [56]. It shows the main differences between the structures of Cuba and Hispaniola. The contribution of Mann *et al*. [57] and Dixon *et al*. [36] regarding the dynamics of the plates improved it. But, the relationship between some few structures in the region remained uncertain. Prentice *et al*. [73] and Mann *et al*. [58] made the first paleo seismological researches in Hispaniola and confirm the activity of the main faults. Cotilla [15] and Cotilla and Córdoba [20, 24] improved the tsunami catalogue and point out that North of Hispaniola is the most active in the region.

The investigations of NPE [67], Cobiella [12, 13], Cotilla *et al*. [26, 27], Quintas *et al*. [74] and Rubio *et al*. [76] demonstrated that Oriente Fault and Northern Hispaniola Fault do not have, in the contemporary stage, a relationship of continuity. Subsequently, the results of Cotilla *et al*. [29], Cotilla and Córdoba [19], Núñez-Escribano [70] and Núñez *et al*. [71] confirmed it. In these last ones, it was argued that: **1)** Cuba is in the North American plate [32]; **2)** the Nortecubana Fault is an active structure of plate interior [14]; **3)** the Nortecubana and Oriente Faults form an articulation knot to justify a seismogenic model of the Eastern Seismotectonic Unit of Cuba [34].

Cotilla and Cordoba [22] indicated other geological and geomorphological differences between Guantanamo (Cuba) and northern Haiti regions. Cotilla and Córdoba [23] used morphostructural data, reports of historical and registered earthquakes, isoseismals and focal mechanism solutions of this area to assured that there are no relation between these faults. Cotilla *et al.* [32] and Cotilla [18] exposed that the transmission of efforts from the limit of Caribbean-North American Plates to Cuba was the cause of crust deformations and seismic activity. They explain that there is: **1)** a morphostructral contrast (Yucatan Basin and Gulf of Mexico) between the Western Seismotectonic Unit and the Nortecubana and Surcubana Faults (**Figures 1-2**); **2)** an important area of structural change (La Habana-Península de Hicacos) that deforms these faults and morphostructures and has 9 knots (Fig. 2); **3)** a significant increase in seismicity along the Nortecubana Fault from west to east.

Later on, Cotilla *et al*. [30] showed that in some areas of weak tectonics, induced earthquakes can occur. The differences among the three mentioned faults of our interest are explained from several elements: **1)** Cuba is an active mega block located to the north of the plate boundary. North of Cuba is the Nortecubana Fault where there are important differences in the effort transmission (distance and type of crust); **2)** in the eastern part of Cuba the effort transmission is direct from the Oriente Fault to the Eastern Seismotectonic Unit and the closest Nortecubana Fault that has a different type of crust to the north; **3)** northeast of Punta de Maisí, the Septentrional Fault has a more efficient transmission by interacting between two areas of modified oceanic crust.

Table 6 has a summary of the most significant data for the Nortecubana, Oriente and Septentrional Faults. From this information, it is clear that the most active fault; **1)** of the region is the Septentrional; **2)** of Cuba is Oriente.

Conclusions

The authors argue that the main elements about the Nortecubana Fault have been well discussed and confirmed. Among them are the following: **1)** the presence in northern Cuba of interior seismicity type of the North American Plate; **2)** the existence of the Nortecubana Fault with ~1.200 km in length; **3)** the condition of the Nortecubana Fault as the active northern limit of the Cuban mega block at the southern edge of the North American Plate; **4)** the segmentation of the Nortecubana Fault in four parts as a heterogeneous seismic system; being the Central Eastern segment, FNC3, the one with the highest level and where the strongest event has occurred (M_{max}=6,2/ I_{max}=7 MSK/ T>150 years); **5)** the occurrence, in segments FNC2 and FNC3, of more than 380 earthquakes; **6)** the FNC2 segment has associated two local tsunamis (1931 and 1939).

The main conclusions are: **1)** the depth of the four seismic zones of the Nortecubana Fault is between 10-35 km; **2)** the seismic activity of: **2.1)** 2014-2017 in the FNC3 segment, was caused by geophysical research works and gas and oil extraction, as it happened in 1981 at FNC1 segment, together with the changes of tensions in the crust as a result of more than 90 years of exploitation of the gas-naphtha Motembo field; **2.2)** 2000 in Varadero-Santa Marta (FNC2 segment) may be caused also by gas and oil extraction; **3)** induced seismicity, due to the characteristics of reservoirs, should be always less than Mw=5; **4)** Septentrional Fault is the most active in the region; **5)** Oriente Fault is the most active in Cuba; **6)** Oriente and Nortecubana Faults have no relation of continuity with the Septentrional Fault.

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