

## Notes on three earthquakes in Santiago de Cuba (14.10.1800, 18.09.1826, 07.07.1842)

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### Abstract

Damage and parameters of the earthquakes of October 14, 1800, September 18, 1826, and July 7, 1842, in Santiago de Cuba, in southeastern Cuba, have been studied. A quantitative re-evaluation of the size of the events is not feasible due to a lack of data. Hence, we have reinterpreted existing data to establish likely intensities and determine the epicentral region of occurrence. Available data do not permit accurate depth determinations. Intensities estimated from contemporary documentary sources give maximum values of 8, 8–9 and 8 (MSK scale), respectively. These seismic shocks were located in the Southeastern Seismotectonic Province of Cuba, Plate Boundary Zone Caribbean—North American. The earthquakes are associated with the Oriente fault system.

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*Keywords:* Cuba; earthquake damage; historical seismicity; intensity; Santiago de Cuba

### Introduction

Southeastern Cuba is a region of moderate seismic activity, where earthquakes with magnitudes above 5 are infrequent (Cotilla, 1993). Therefore, the study of such events is quite important, although at an overall level they may seem rather trivial.

The most comprehensive compilation of historic seismicity in Cuba was done by Poey (1855a,b, 1857). Later, several studies offered more information, but still incomplete (Cotilla, 2003). An extensive search for documents relative to three earthquakes (October 14, 1800, September 18, 1826 and July 7, 1842) was made in libraries and archives. These seismic events had approximately the same epicentral area and strongly affected the city of Santiago de Cuba. The final result of the search was a collection of contemporary documents of different types and quality.

The main aim of this study is to establish the extent of damage and the importance of these three earthquakes using the original sources. Thus, this study is focused on the three above mentioned earthquakes which occurred near the city of Santiago de Cuba.

### Tectonic and seismicity of the area

Cuba is an archipelago (110,922 km<sup>2</sup>) located in the Caribbean (Fig. 1, *a*). It is the largest island in the Greater West Indies arch. Cuba's linear extension is 1,256.20 km with a coastal perimeter of 5,745.92 km (3,208.81 km and 2,537.11 km on the northern coast and the southern coast, respectively) (González et al., 2003). From a neotectonic point of view Cuba is a megablock (or microplate) located in the southern part of the North American plate (Fig. 1, *a*) (Cotilla, 1993; Lewis and Draper, 1990). The active plate boundary is situated along the southeast coast where the main seismic activity follows the Bartlett–Cayman fault zone (Calais and Mercier de Lèpinay, 1991; Cotilla, 1998; Mann and Burke, 1984). In this segment, faulting is mostly left-lateral strike-slip (Cotilla, 1993). The general pattern of seismicity of the Caribbean region is shown in Fig. 1, *b*. Large earthquakes occur along the plate boundary near Hispaniola, Jamaica and Puerto Rico (Álvarez et al., 1985; Pacheco and Sykes, 1992), but no event since the eighteenth century has reached a magnitude of 7.0 (Cotilla, 1998; Cotilla and Udías, 1999). Low magnitude seismicity (*M*<sub>s</sub>) occurs throughout the western region of the island and particularly around Santiago de Cuba (Oriente fault) (Cotilla, 1993). The Cotilla et al. (1991) results suggest that Cuba is a seismotectonic province, composed of

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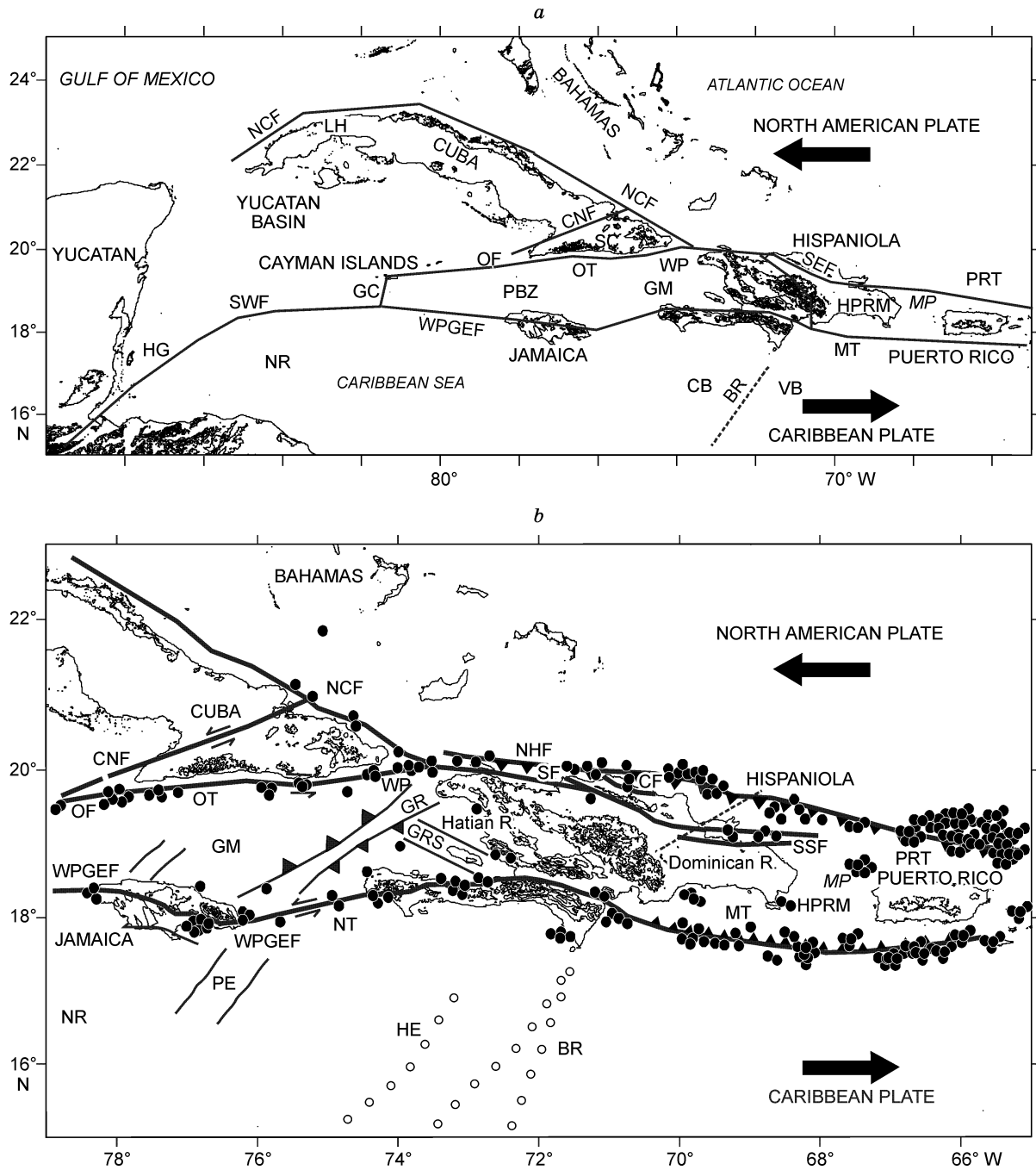


Fig. 1. Simplified tectonic map of the Caribbean. (a) Heavy black arrows, sense of plate movements; black lines, main fault systems: CNF, Cauto-Nipe; NCF, Nortecubana; HG, Honduras–Guatemala; OF, Oriente; SEF, Septentrional; SWF, Swan; WPGEF, Walton-Platain Graden-Enriquillo. Other structures: CB, Colombia basin; MP, Mona Passage; MT, Muertos trough; NR, Nicaragua Rise; OT, Oriente trough; PBZ, Plate Boundary Zone; PRT, Puerto Rico trench; VB, Venezuela Basin; WP, Winward Passage; localities: LH, La Habana; SC, Santiago de Cuba. (b) Heavy black arrows, sense of plate movements; black points, epicenters; black lines, main fault systems: CF, Cam; CNF, Cauto-Nipe; HG, Honduras-Guatemala; NCF, Nortecubana; NHF, North Hispaniola; OF, Oriente; SF, Saman; SEF, Septentrional; SWF, Swan; WPGEF, Walton-Platain Graden-Enriquillo; the drawing of the points outlines the structure BR, Beata Ridge; HE, Hess Escarpment; passages: MP, Mona; WP, Windward; islands: Cuba, Hispaniola, Jamaica, Puerto Rico; microplates: GM, Gonave; HPRM, Hispaniola-Puerto Rico; troughs: MT, Muertos; NT, Navassa; OT, Oriente; PRT, Puerto Rico. Other structures: CB, Colombia Basin; GR, Gonave Ridge; GRS, Gonave Rise; NR, Nicaragua Rise; PE, Pedro Escarpment; VB, Venezuela Basin.

four units (Western, Central–Eastern, Eastern, and Southeastern) (Fig. 2, a).

It is known that the most of the stress accumulated by the Caribbean–North American plate’s motion is released seismically along the northern Cuban margin during relatively few

but strong earthquakes (Álvarez et al., 1985). In this region, the epicenters of our study are located in the Southeastern Seismotectonic Province. The distribution of historical shocks with maximum MSK intensities equal to or greater than 8 degrees show a regular arrangement along the southeastern

Cuban coast, and specifically between Cabo Cruz and Baconao (Oriente fault) (Fig. 1, b).

### The earthquake of October 14, 1800

Herrera (1847), Valiente (1853), Poey (1855a,b, 1857), Salteráin y Legarra (1884), Bacardí (1925), Samohano (1969), and Álvarez et al. (1999) have reported data on this earthquake. However, only Poey (1855a) catalogues the earthquake in his study. His entry is as follows: *On October 14 and 15, great tremor at Santiago de Cuba. The author states also the occurrence of other earthquake in the same zone, and says: Le 2 novembre, tremblement à Santiago de Cuba, accompagné d'un ouragan du S-E, avec une abondante pluie qui dura six heures.* Poey (1857) writes: (1) *October 14–15—Santiago de Cuba*; (2) *November 2—Santiago de Cuba*. Cotilla and Udías (1999) classify the earthquake of 14.10.1800 from the Poey catalogue (1855a,b, 1857) as Good Quality.

In Bacardí (1925) is found: (*October 14, 1800*) *Strong earthquake that fills the population with panic; this earthquake is named the Santa Teresa earthquake.* Álvarez et al. (1999) enter the following data: 1800.10.14, 19.90°N, 75.80°W,  $h = 20$  km,  $M_s = 4.2$ ; 1800.10.15, 20.02°N, 75.84°W; 1800.11.02, 19.90°N, 75.80°W,  $h = 20$  km,  $M_s = 4.1$ ; 1800.12.02, 19.90°N, 75.80°W.

A recapitulation of the document located by the authors in the General Archive of the Indies (AI), Spain, entered as CUBA 98C. It is a letter directed to Don Salvador del Muro y Salazar (Marquis of Someruelos) and General Governor of the Island of Cuba (1799–1812) for the Governor of Santiago of Cuba (16th October 1800).

*...For these lands have suffered on the 14 past a strong earthquake...we were in our beds, and the Sun there was not outside...the ground of the city several times has been moved, we have counted some ten and so many times...some buildings have collapsed...the cathedral has serious damage...some churches are destroyed...all our dependencies of the port are destroyed...there are inhabitants moving toward the outsides of the city...the earthquake surprised us...*

This document relates: (1) the occurrence of an earthquake in Santiago of Cuba; (2) the date (14.10.1800); (3) that it happened before dawn (05:00–06:00 h); (4) that it had several aftershocks; (5) that it caused severe damage to buildings; (6) that it caused shifts in the population toward other localities (panic); (7) that there were no data on perceptibility at other sites; (8) that there were no tsunamis; (9) that there were no foreshocks. On the basis of these data it can be considered that: (1) the earthquake had its epicentre in the marine part of the Southeastern Cuba, specifically to the south of the bay of Santiago of Cuba (Oriente fault) (Fig. 2); (2) the maximum seismic intensity was of 8 degrees (MSK scale) in the zone of the port, where the level of the phreatic mantle is superficial and soils are loose sediments (Heredia et al., 1982).

### The earthquake of September 18, 1826

This is one of the most severe earthquakes that has ever affected Cuba (Cotilla, 1993). However, it is not possible to establish: (1) the exact hour of occurrence; (2) the coordinates of the epicentre; (3) the area of perceptibility. A group of authors has collected data on the earthquake: Alcedo (1826), Annual Register (1826), Moniteur et Constitutionnel (1826), Allgemeine Zeitung (1826), Gazette de France (1826), Brewster (1827), Cotte (1827), Férussac (1827, 1828a,b, 1829), Atlantis par Rivinus (1827), Cuadro Estadístico de la Siempre Fiel Isla de Cuba (1829), Mallet (1854), Archivo Histórico Nacional (1828), Hoff (1830), Perrey (1843, 1845, 1846, 1856), Valiente (1853), Pichardo (1854), Poey (1855a,b, 1857), de la Sagra (1869, 1872), Monteulieu (1968), Samohano (1969), Chuy and Pino (1982), Chuy (1999), and Álvarez et al. (1999).

Alcedo (1826) records the following information: *18 Septembre, entre 3 et 4 h. du matin; San-Iago (Cuba); tríos secousses très-fortes; chacune a duré environ une minute, et a été précédée d'un bruit semblable à celui que feraient des chariots pesamment chargés roulant sur une route pavée; à ce roulement a succédé une terrible explosion. Une grande partie de la ville a été détruite.* That same author indicates that: *...Septembre 18, la meine heure qu'à Cuba; Jamaïque; deuz fortes secousses.*

Brewster (1827) wrote: *Le secousse fur ressentie à Kingston, à la Jamaïque, le même jour et à la même heure.*

Perrey (1843) stated that: *September 18, 1826. At 3–4 in the morning three strong shakes. One part of the village was destroyed. Much noise.* Later, Perrey (1845) wrote that: *18th September 1826 entre 3 et 4 heures du matin, à Saint-Iago (île de Cuba), trois secousses très-forte; chacune a duré environ une minute, et a été précédée d'un bruit semblable à celui que feraient des chariots pesamment chargés, roulant sur une route pavée; à ce roulement succédé une terrible explosion. Une grande partie de la ville a été détruite. On les ressentis à la Jamaïque, à Kingston.* (It is evident that Perrey based his study on Alcedo (1826), but adds the perceptibility in Jamaica.)

Pichardo (1854) wrote: *...those of 1826 [September 18] and 1842 [July 7] are also important with some prior events, and all this alone in the city of Santiago de Cuba; since though the quakes occur from the Eastern part to the meridian of Bayamo, Holguín and Manzanillo [to the west of Santiago de Cuba], they are neither so strong nor so repeated...*

Poey (1855a) said: *Le 18 septembre, entre 3 et 4 heures du matin, à Santiago de Cuba, trois secousses très – fortes, chaceme a duré environ une minute, et a été précédée d'un bruit semblable à celui que feraient des chariots pesamment chargés, roulant sur une route pavée; à ce roulement a succédé une terrible explosion. Une grande partie de la ville a été détruite. On les a ressenties à la Jamaïque, à Kingston [by Perrey, 1845].* In Poey (1855b) he states that: *Le 18 septembre, à Santiago de Cuba. Les secousses furent aussi ressenties à Kingston (la Jamaïque), quoique plus légères. La chaleur éatit intolérable. A l'endroit de mon catalogue où j'ai*

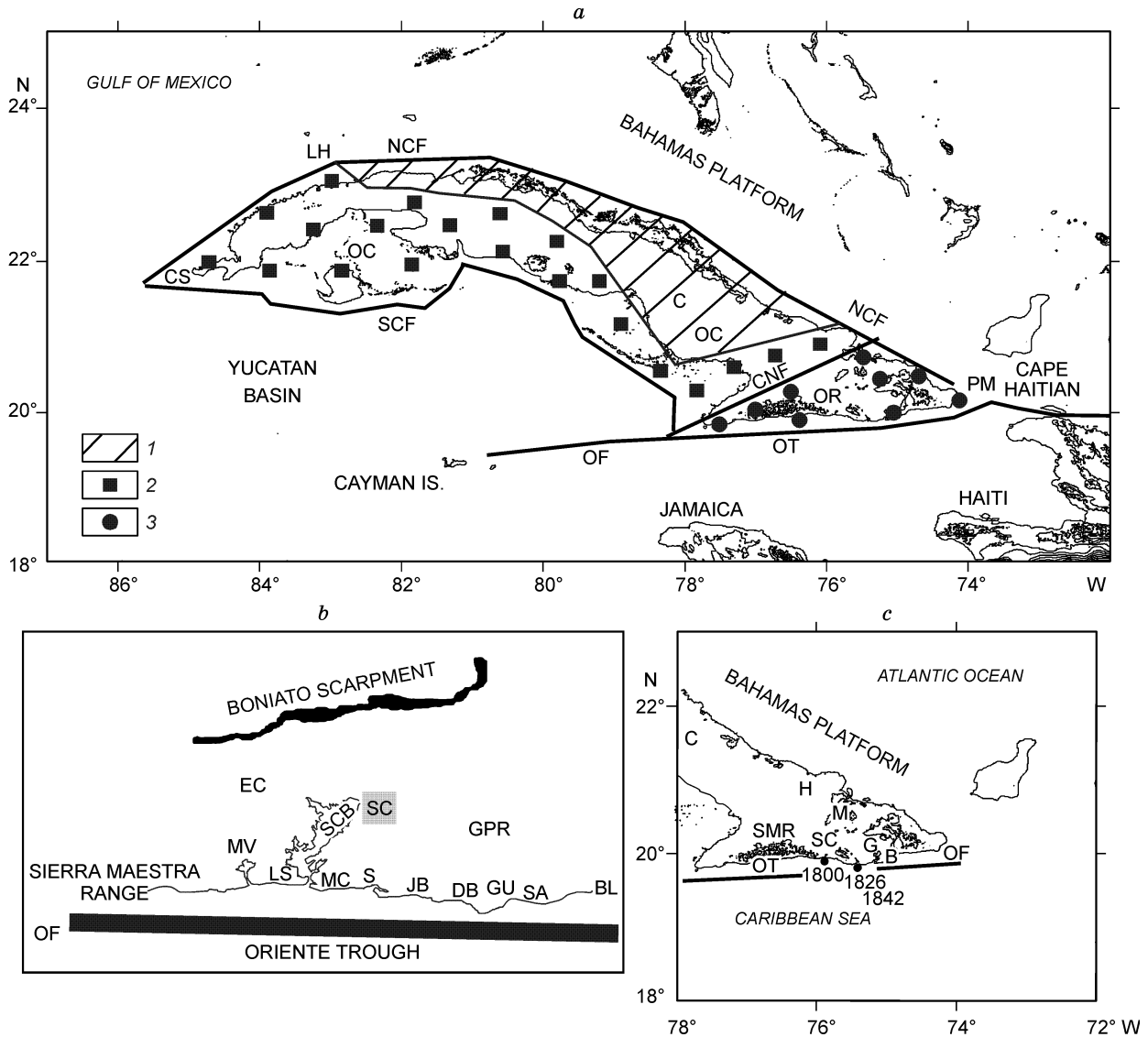


Fig. 2. Cuban megablock according to Cotilla et al. (1991). (a) Heavy black line, faults: CNF, Cauto-Nipe; NCF, Nortecubana; OF, Oriente; SCF, Surocubana; Neotectonic Unit: OC, Western; OR, Eastern; crust type: 1, postorogenic complex; 2, orogenic complex; 3, volcanic arc complex; localities: C, Camagüey; CS, Cabo de San Antonio; LH, La Habana; PM, Punta de Maisí. (b) Santiago de Cuba area. Heavy black line, Oriente Fault (OF); localities: BL, Baconao lagoon; DB, Dos Bocas; EC, El Cobre; GU, Güira; JB, Jibacoa; LS, La Socapa; MC, Morro Castle; MV, Mar Verde; S, Sardinero; SA, Salado; SC, Santiago de Cuba City; SCB, Santiago de Cuba Bay. Other structures: GPR, Gran Piedra Range. (c) Eastern Cuba. Localities: B, Baitiquirí; C, Camagüey; G, Guantánamo; H, Holguín; M, Mayarí; SC, Santiago de Cuba City; SMR, Sierra Maestra Range. Other structures: OF, Oriente Fault; OT, Oriente trough.

mentionné trois secousses très-fortes, ajoutez: « dont la seconde, surtout, fut la plus forte ». Finally, Poey (1857) reports that: *September 18, 3h 4m a.m.–Santiago de Cuba, Jamaica (Kingston).*

It can be asserted that Poey reproduces everything reported by Alcedo (1826) and by Perrey (1843, 1845). Cotilla and Udías (1999) classify to this earthquake from the Poey catalogue as Good Quality and argue that the main shock caused major damage in the southeastern coastal areas and the city of Santiago de Cuba and was perceptible in the entire Oriente region and that it was reported at Camagüey, Jamaica and Haïti. Many of the persons who felt the 1826 event commented on the loud noises that accompanied the shocks.

Bacardí (1925) wrote: *Around four in the morning an earthquake of some 50 seconds of duration. There were*

*damages in nearly all the buildings, mainly in the neighbourhoods of the La Cantera and the La Marina. Thus damage includes the following: 1) Damages in the Cathedral of Santiago de Cuba (part of the central tower fallen) and collapse of the outside walls to the south; 2) Destruction of 10 houses in the rise of the port to the Cathedral; 3) Collapse of the sheds and facilities of the port; 4) total destruction of the gunner summons of Baconao, with one person injured; 5) Ten continuous shakes of the ground in the afternoon and the night; 6) In the city 3 fatalities and 20 injured; 7) The warehouses of the north of the city lost; (8) The population frightened by the quakes is routed to the Plazas [open places] and pray in processions; 9) The San Pedro de la Roca Castle [El Morro] in Santiago de Cuba was destroyed. (This was built of blocks of calcareous stone in 1638 for the Italian*

engineer Juan Bautista Antonelli. The old castle was destroyed also by the earthquake of 11.06.1766 in the same summons (Cotilla, 2003)).

Chuy and Pino (1982) conclude that the earthquake in question happened around 04:00 h. Chuy (1999) says it was  $M_s = 6.0$  and assigns a maximum intensity of 7 degrees (MSK scale) in Santiago de Cuba. Álvarez et al. (1999) present the following data: 1826.09.18, 09:29, 19.90°N, 76.00°W,  $h = 30$  km,  $M_s = 5.8$ ,  $I = 7$  degrees (MSK scale).

In the Spanish Archivo Histórico Nacional (1828), File 6370 (8–31 March 1828) was located. In the file, it is said that the Governor of the Island of Cuba Don Francisco Dionisio Vives, informed the King of Spain (Fernando VII (1813–1833)) on the material damages caused by the last earthquake of Santiago de Cuba (1826). There is no information on victims sustained or that there were several persistent shakes from at least four days before (foreshocks) and that the population left in processions by the Villa (panic). He adds that the mines of the El Cobre felt shakes and had slight losses. The governor solicited additional monetary funds for the restoration of Santiago de Cuba.

We have found in the AI a total of seven written documents under the signature CUBA 2057 that refer to data on the earthquake. A recapitulation of the contents appears below, as well as some commentaries by the authors:

[Document 1.–] Correspondence of Don Melchor Aymerich, dated October 3, 1826, with the seal of the Army Office of the Island of Cuba directed to the General Captain Don Francisco Dionisio Vives

*...Late in the evening of the day September 17 was perceived in this Villa [Santiago de Cuba] a severe shake of the ground...many neighbours who stayed would be awoken [foreshocks]...In the morning a tremendous earthquake launched us and beat brutally [main shock]...the city is in ruins and in a calamitous state...we have found three fatalities, some twenty injured peasants, and also there are 10 negroes...the tower of the Cathedral collapsed...the foreign walls of the Palace of the Illustrious Governor is collapsed...heavy panic in the population...we listened to chime it of bells [oscillations of the ground]...the port is sunk [warehouses and customhouse]...the defence of the city, the El Morro Castle is very affected [strong earthquake]...in the mines of the El Cobre there are houses splits and cracks in walls that lost the lead [inclined]...in Bayamo, Baitiquirí, Guantánamo, Mayarí, La Socapa and coffee fields of the Sierra del Este [actually the Gran Piedra Range] there are severe damages...the chiefs of the garrisons testified to me that felt strong hesitations of the firm...*

[Document 2.–] Correspondence of the Governor of Santiago de Cuba with the Governor of the Island of Cuba, Don Jerónimo Valdés y Sierra (November 2, 1826)

*...they are many letters that advise us of shakes repeated in all the Eastern District [perceptibility]...the troops are maintained alert...in the city the earthquakes are different in number and force [aftershocks]...the warehouses and customhouse of the port have collapsed...we ask you to provide soon*

*consolations to the sad neighbouring of the village in the misfortunes that suffer...*

[Document 3.–] Correspondence dated as of September 22, 1826, of the Governor Lieutenant of Puerto Principe, Don Francisco Yllas to the Governor of Santiago of Cuba

*...The villa of Puerto Principe [today Camagüey] has been shocked by a noisy blow of ground...the House of Government crunched and the neighbours showed nervous...this morning of 18th of September were recalled reports of the scenes of the year 1766...we supposes that it is again the wanted villa of Santiago the one which suffers a new fatigue from the ground...*

The located correspondence includes that of various messages were sent to the Governor of Santiago de Cuba, as summarized below:

[Document 4.–] Of the Militias Captain Don Juan Méndez, Chief of the Quarter of the Sardinero, September 26, 1826

*...I have realized an exhaustive inspection of the coastal towns of this locality and always toward the east, to the coordinates of the Lagoon [Baconao lagoon]...the totally of houses are capsized and lied destroyed in the ground...the roads are difficult and with many and large heavy stone...the open cracks in the land are of up to 10 feet...*

[Document 5.–] Of the Commanding Don Domingo Morales, Chief of the troop of Control of the Mar Verde and La Socapa zone, September 29, 1842

*...all the officers, sergeants, ends and dragons are disposed for the defence of the Villa if it would be necessary...we work with energy in repairing the damage to the military buildings...*

[Document 6.–] Of the Squad Captain Don Agustín Gómez, Commanding of the Plaza de El Morro Castle, September 29, 1826

*...the troop works with zeal on the remains of the El Morro Castle as defence of the city...this Castle and the La Socapa are in very bad situation...*

[Document 7.–] Of the Lieutenant Don José M<sup>a</sup> Domínguez, Headquarters Chief, of the September 30, 1826

*...the military hospital, the quarters and military posts of Boniato [Boniato scarpment], Baitiquirí, La Piedra [Gran Piedra Range], Sardinero and Carpintero, and the dependencies of the La Alameda are very damaged and several threaten ruin...*

It can be seen in these documents that: (1) the date of a strong earthquake in Santiago de Cuba (September 18, 1826); (2) that there were seismic shakes of at least one strong foreshock; (3) the occurrence time of the main event (09:29 h); (4) the occurrence of several aftershocks, some of them strong; (5) the perceptibility of the earthquake in the eastern region of Cuba and to Camagüey (westward); (6) the perceptibility in Jamaica; (7) that the epicentre was in the surroundings of Baconao (Oriente fault) (Fig. 2); (8) the destruction of the El Morro Castle; (9) the damages in many civilian and religious buildings of the city of Santiago de Cuba; (10) three fatalities and a score of injured; (11) that there was no tsunami. On this basis, it can be stated that the main event had a maximum seismic intensity of 8–9 degrees (MSK scale).

## The earthquake of July 7, 1842

The following documents contain information on this earthquake: Férussac (1828a,b, 1829), Kimbell (1842), Perrey (1843, 1845, 1846, 1856), Cuadro Estadístico de la Siempre Fiel Isla de Cuba (1846), Tegg (1853), de la Torre (1854), Poey (1855b, 1857), de la Pezuela (1866), de la Sagra (1869, 1872), Bacardí (1925), Cruz (1958), Monteulieu (1968), Samohano (1969), Chuy (1999), and Álvarez et al. (1999). Information is also found in these newspapers: Faro Industrial (1842), Diario de La Habana (1853) and La Discusión (1842). The data provided by some of those authors are indicated below:

Poey (1855b) wrote: *Le 7 juillet [1842], á Santiago de Cuba, tremblement qui renversa plusieurs maisons et se fit sentir sur une étendue de 1500 milles.* In Poey (1857) appear: *7 juillet [1842].—Santiago de Cuba.*

Bacardí (1925) stated: *Strong earth tremor on the afternoon of July 7, 1842, with successive tremors almost daily, even on day 15, causing damage to the buildings, most of all the Palace; repeating the phenomenon will put out of plumb the building itself.*

Elsewhere, one can consult Poey's catalog which said a pre-monitor occurred before the 1842 event. For the location of this event, Álvarez et al. (1999) determine: 19.50°N, 71.50°W,  $h = 33$  km,  $M_s = 7.7$ . But Poey (1855a) also indicated that some days before (May 7, 1842, 17:25 h local time) a very strong northern earthquake occurred on Haiti, and the Spaniards noticed the shaking in Cuba. Other works that record this event are: Diario de La Habana (1842), Faro Industrial de La Habana (1842), Cuadro Estadístico de la Siempre Fiel Isla de Cuba (1846), Henderson (1853), Tegg (1853), and Scherer (1912).

Márquez (1976) said with respect to the May 7, 1842, earthquake that the main shock was around 80–90 s. There were a great number of aftershocks. The number of victims according to Poey (1855a) reached 4000. But Scherer (1912) maintained that the victims were 6000. This was an event with its epicentre in northern Haiti (Cabo Haitiano) (Iniguez et al., 1975; Taber, 1922a,b; Tomblin and Robson, 1977). Bacardí (1925): *May 7, 1842, the land during a month experiences, around 5 of the afternoon, a loud moderate earthquake; they feel moderate earthquakes from time to time. In Baracoa, at the mountains the El Yunque and Marcos Reyes, two large rocks came off, over 20 rods in length, and another one so much in width, the land cracked, advertising the phenomenon four day before, for little crabs' plague that invaded the population to his last corners, fleeing away from sulfurous emanations that were filling its caves and disappearing when suspending the aforementioned motions. There were also strong shakings at St. Domingo's and Haiti's Island; it was at Cabo Haitiano disastrous, and the former dealer of this city Mariano Merantier died.* Acosta (1984) said that there was a tsunami. In Álvarez et al. (1999) this location appears: 22:15:00, 19.80°N, 72.20°W,  $h = 60$  km,  $M = 8.2$ . But the Cuban literature holds that there was another earthquake on that date in the eastern zone. For that earthquake, Álvarez

et al. (1999) give the following data: 19.90°N, 75.80°W,  $h = 20$  km,  $M = 4.10$ . This shows, once again, how the information contained in the Cuban catalogs has varied on numerous occasions without explanation. For example, Chuy and Rodríguez (1980) initially presented this event to seismic hazard studies, with  $I = 8$  degrees (MSK scale), in Baracoa. Chuy (1982) ratified the data. In Chuy and Pino (1982) the same data appear. Chuy et al. (1984) reiterated its existence, intensity and damage. However, in the catalog of Álvarez et al. (1993) the earthquake does not appear. Chuy (1999) contributed the following information: 1842.07.07, 19.90°N, 76.00°W,  $h = 30$  km,  $M_s = 6.0$ ,  $I = 7$  degrees (MSK scale) in Santiago de Cuba.

The data of the AI are in seven documents that are grouped under the signature CUBA 2340: Correspondence of some personalities to the Governors of the Island of Cuba.

[Document 1.–] Directed to the General Governor of the Island of Cuba (Don Javier Ulloa) for the Governor of Santiago de Cuba (July 9, 1842)

*...I have the duty of expressing the plea of a town wounded by nature...the past month May [May 7, 1842] we felt the land to shake and we feared the worst thing then, passed we believed days to be out of danger, but now the land here shook with more force and fury [July 7, 1842] all that has seemed to expose me, and begging Your Lordship deign happening to with his providences this need, especially with the relative to money...*

[Document 2.–] Directed to the General Governor of the Island of Cuba (Don Leopoldo O'Donell y Jonis) for the Governor of Santiago de Cuba (September 20, 1842)

*...know you sir that this faithful servant is not manly of false way of walking in life, you are not for my needs that you have them, but for the one belonging to my city that I supplicate helps to Your Gracethe El Cobre quarters need any recompositionI need laborers at all of the citythe control points in Sardinero and Baitiquirí have fallen nowthe troop's barracks fellI have few resources and operated for the help, the conservation and the subsistence of the troop and of the neighborhood...*

[Document 3.–] Directed to the Queen Isabel II (1833–1868) by the Governor of Cuba (September 24, 1842)

*...My Fair Lady Señora, our dear Villa of Santiago de Cuba has been again hit by a terrible earthquake the last July 7our neighbors supplicate cost-reducing helps and the administrative arks do not possess capability...*

[Document 4.–] Directed to the Governor of Santiago de Cuba by the Brigadier Don Juan Benavente de Casas, Artillery Chief of the El Morro Castle (July 15, 1842)

*...a second strong shock from the West...the walls outside of the zone of the East Wind of the El Morro have suffered and showed a large cracks of 5–6 pies...Mar Verde towns have suffered to much...there break down everything...[the epicentre is to the west of the Santiago de Cuba bay].*

[Document 5.–] Directed to the Governor of Santiago de Cuba by the Brigade Don Juan Medina, Army leader of the rural sector of the Eastern zone (August 19, 1842)

...the troop is worry...the damages are so much in all the army points and quarter of an extense zone Dos Bocas, Baitiquiri, Güira, Salado, Laguna [Baconao Lagoon]...there are a lot of rocks at the roads...

[Document 6.–] Directed to the Governor of Santiago de Cuba by Don José de Armas Representative of the Merchants of the south zone (September 10, 1842)

...I request and priest to Government of Santiago de Cuba Village helps economic to compensate damages...

[Document 7.–] Directed to the Governor of Santiago de Cuba by the Military Engineer Pedro Díaz Díaz (September 16, 1842)

...it is necessary to repair and to reinforce this eastern walls of this Castle [El Morro] of urgent form, the rest of the structure has resisted the walls have deep and catercornered cracks, that gives away that impulse came of the East-South-east the trenches are all right, but the bases of the pieces the artillery are displaced toward the Port...

From these documents it can be concluded that: (1) a strong earthquake happened on July 7, 1842 in the vicinity of Santiago de Cuba; (2) there was a foreshock; (3) there were several aftershocks; (4) damages occurred in the buildings of the city; (5) the most affected zone was the city of Santiago de Cuba and its eastern coastal segment; (6) the outside walls of the El Morro Castle were damaged; (7) the epicentre was about the Baconao Lagoon (Fig. 2); (8) there was no tsunami. On this basis, the maximum seismic intensity is estimated at 8 degrees (MSK scale).

## Final remarks

The occurrence area of the earthquakes of October 14, 1800, September 18, 1826 and July 7, 1842 is associated with the marine part of the Southeastern Cuba stern in the surroundings of the city of Santiago de Cuba. Concretely, the epicentre of the October 14, 1800, earthquake is about the bay of Santiago de Cuba; while the epicentres of the earthquakes of September 18, 1826, and July 7, 1842, are to the east of the bay of Santiago de Cuba. All these seismic shocks are located in the Southeastern Seismotectonic Province of Cuba, Plate Boundary Zone Caribbean–North American (Fig. 1, a). The earthquakes are associated with the Oriente fault system. In this region, other strong earthquakes have occurred (June 11, 1766 (M = 6.8), August 20, 1852 (M = 6.6), February 3, 1932 (M = 6.75), and August 7, 1947 (M = 6.75)) (Cotilla, 2003).

For these three earthquakes, no isoseismal maps were available but there were intensity observations at the time. The maximum intensity values (MSK scale) estimated are: 14.10.1800 (I = 8), 18.09.1826 (I = 8–9) and 07.07.1842 (I = 8). These earthquakes have intensities greater than those presented in Table 1. The coordinates proposed in this work (14.10.1800, 19.9°N, 75.9°W, and 18.09.1826 and 07.07.1842, 19.75°N, 75.35°W) are also different from what is stated in Table 1.

From the maximum intensities before indicated (8 and 8–9 degrees (MSK) at SC) and using the Sponheuer (1960)

Table 1 Earthquake data according to Chuy (1999)

Date	Time	Lat. N	Lon. W	Magnitude	h, km	Intensity (MSK)	Locality
1800.10.01		19.90	75.80	Ms = 4.2	20		S. Cuba
1826.09.18	09:29	19.90	76.00	Ms = 5.8	30	7	S. Cuba
1842.07.07	17:25	19.90	76.00	Ms = 6.0	30	7	S. Cuba

Table 2 Data of the population censuses

Year	Data
1792	On the island 205,000 Spaniard
1817	Santiago de Cuba= 26,740 people (9302 white; 10,032 black free; 7404 black slaves)
1827	In the island 704,487 people (311,000 white; 106,000 black free; 286,000 black slaves)
1842	In the island 1,037,624 people (448,291 white; 152,838 black free; 436,495 black slaves)
1846	In the island 896,294 people

Table 3 Economic data of La Habana and Santiago de Cuba

Commerce of the ports	Imports (\$ Cuban pesos)	Exports (\$ Cuban pesos)	Total value (\$ Cuban pesos)
La Habana	13,374.343	9,609.858	22,984.201
Santiago de Cuba	1,278.697	1,412.358	2,690.955

relation ( $M_s = 0.66I_o + 1.7 \log h - 1.4$ ), assuming depths of 30 km and 35 km (Cotilla, 1993), we obtain magnitudes of 6.4 and 6.9. Another expression that relates magnitude and intensity is  $M_s = 1 + (2/3)I_o$ . This relation gives the magnitude values of 6.4 and 6.7. Then, our idea is that the earthquake magnitudes are: October 14, 1800 (6.4), September 18, 1826 (6.4) and July 7, 1842 (6.8).

Finally, Table 2 shows data on the population censuses around the occurrence dates of the studied earthquakes (Capitanía General, 1842; Boletín de la Sociedad Mexicana de Geografía y Estadística, 1863). Indirectly, this demonstrates that the growth of the population in Cuba was normal during that period. However, in terms of comparative development, the economic life of the city of Santiago de Cuba declined very much in comparison with La Habana from the beginning of the nineteenth century (Carta Geográfico-Topográfica de la Isla de Cuba, 1832) (Table 3). This is seen in the decreased quality of the civil buildings, and the great quantity of housing in the areas with the worst geological-engineering conditions. These were areas that are very favourable to the amplification of the seismic waves, and consequently there are serious damages with the earthquakes.

## Conclusions

Historical sources were used to evaluate the extent of the damage of three Cuban earthquakes. The information provides

knowledge on the effects of the earthquakes on persons, buildings and the terrain near the epicenters. The data shows the October 14, 1800 ( $I = 8$  degrees, MSK scale), September 18, 1826 ( $I = 8-9$  degrees, MSK scale), and July 7, 1842 ( $I = 8$  degrees, MSK scale), earthquakes are representative of the seismicity in southeastern Cuba. They are associated with the Oriente fault (14.10.1800, 19.9°N, 75.9°W; 18.09.1826, 19.75°N, 75.35°W; and 07.07.1842, 19.75°N, 75.35°W). The occurrence of tsunami associated with these earthquakes is not supported by the information found in the contemporary documents.

We conclude that studies of historical earthquakes are of great importance in the evaluation of seismic hazard, especially in regions where large seismic shocks are infrequent.

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