

THE GUANACASTE (COSTA RICA) EARTHQUAKE OF SEPTEMBER 5th, 2012 (Mw 7,6)

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Introduction

On Wednesday 5th of September 2012 a strong earthquake took place in the region of the peninsula of Nicoya, northern Costa Rica. This earthquake was felt in all the country and also in Nicaragua. Important damages were reported in the cities of Nicoya, Liberia, Cañas, Tilaran, Puntarenas, Grecia, Sarchi, and Naranjo. At the Central Valley where San José, Costa Rica's capital is located, the shake was strong and prolonged and caused the fall the objects of furniture and shelves, sheets of ceiling, some damages in masonry of buildings and the general alarm of the population that proceeded to evacuate the majority of the buildings as prevention. The maximum intensities, according to the reports of the populations close to the epicentral zone were VII (Mercalli scale).

Earthquake parameters:

Date: 5 of September 5th 2012

Local time: 8:42 am. 14:42 UTC

Epicenter: 10 km to the south of Samara, Guanacaste.

Coordinates: Lat. 9.688° N and Long. -85.627° W

Depth: 15.4 km

Magnitude: 7.6 Mw

Origin: Subduction of Coco's plate under Caribbean Plate.

During the following hours after the earthquake that was recorded at 08:42 am (local time), many aftershocks were registered. In the first 6 hours they were near 80, almost all of them with magnitudes under 5.5. The main ones recorded aftershocks up to the 23th of September 2012, had magnitudes Mw 5.4 and 5.2.

The introduction of the Cocos Plate under the Caribbean Plate originates a zone of seismicity that extends in depth, from the Mesoamerican trench toward the interior of the country (Fig. 1). This seismogenic zone generates the strongest earthquakes in Costa Rica, causing important

damages in the coastal regions close to the epicenter and toward the interior of the country. Besides, the stress generated by the activity between these two plates is translated in complex systems of tectonic faults in the continental region. The convergent margin of the Pacific of Costa Rica has been divided, based on its tectonic and seismic characteristic, in various segments. The NW region extends along the peninsula of Nicoya. This segment presents an orientation of compression NE and a dip angle of 45 degrees in average toward the NE. The earthquakes in this zone reach maximum depths in the order of the 100 km. Also other morphological characteristics are shown at the ocean floor caused by the subduction of seamounts, as lineal wrinkles, areas shaped as dome raised and sinkings of different dimensions. These morphological characteristics have been interpreted as the tracks of the dragging of the marine mounts in different states of subduction (von Huene et al., 1995).

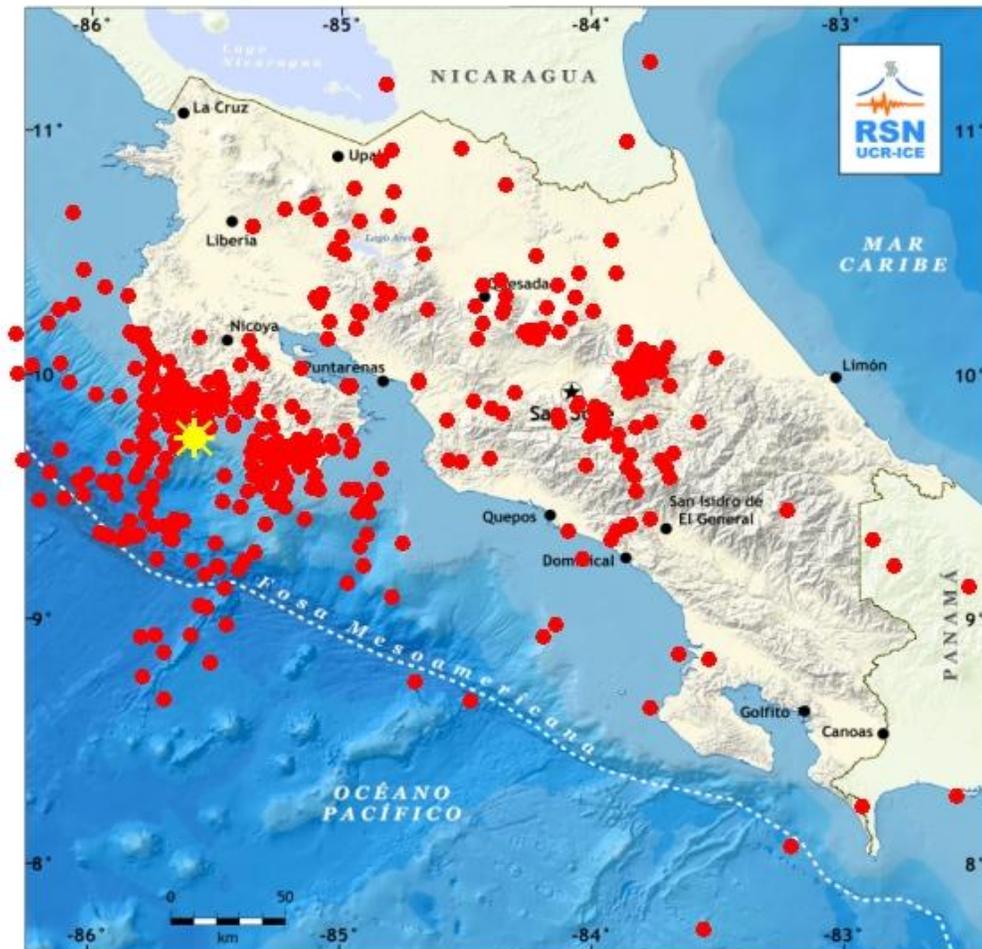


Fig. 1: September 5th earthquake and aftershocks recorded by RSN:UCR-ICE

Historic seismicity

The region of Guanacaste, northwest Costa Rica, has had at least 15 earthquakes that have caused damages since the 19th century. The most important have been related to the process of subduction of the Coco's plate under the Caribbean plate. There have been earthquakes in 1833, 1916, 1950, 1978 and 1990. The 1950 earthquake has been considered as the most destructive one. It generated large damages in the peninsula of Nicoya and other localities of the NW and central part of the country and the maximum intensities estimated were of VIII (Mercalli Mod.).

Damages and Mercalli intensities

The earthquake of September 5th, 2012 was felt practically in all the country including Nicaragua. Most of the damages reported were in the zone of the peninsula of Nicoya at the towns of Nicoya, Santa Cruz, Nandayure, Samara. At the northwestern Pacific coast a lifting in the line of coast was observed between 0.5 and 1.0 m at several beaches. Differential settlements in sandy zones saturated of water were also observed and some liquefaction. The slopes and mountains did not show sliding and there is little damage in dwellings and buildings. At the cities of Puntarenas, Mata de Limon and Jaco there were important damages as in the hospital of Puntarenas, and some buildings in Jaco. The population had problems in the supply of water and electricity by several hours mainly due to damages at an electric power station at Nandayure. At the cities of Grecia, Naranjo and Valverde Vega, important damages were observed in at least some 20 dwellings buildings. In the Central Valley, although the earthquake caused general alarm in the population, the damages were not so severe. They were mainly fall of objects, broken glasses, ceiling sheets fall in buildings, but there were no structural damages in buildings.

The Department of Public Education estimated that the preliminary costs of the damages surpass the 6.000 million dollars. 56 educational centers due should be demolish due to the serious damages that present in its infrastructure. That costs contemplates the expenses to reconstruct those 56 centers, the majority located in places as Nicoya (10 schools), Nandayure (9), Hojancha (4), Santa Cruz (9), Lepanto and Cobano, in the Pacific north, and in counties like Sarchí, Grecia and Naranjo, among others. The Costa Rican Institute of Aqueducts and sewer Systems reported 7 aqueducts affected chiefly in the provinces of Guanacaste and Puntarenas, but that the majority of them have been repaired. Eleven buildings affected were reported, among them the city halls of Puntarenas and Nicoya and nine educational centers, all in the province of Guanacaste. Besides, the National Emergency Commission (CNE) reported that 240 people are maintained in temporary shelters. They are located at Alajuela, Valverde Vega and Grecia) with 34 people and in Guanacaste with 206 people.

From the recount of the damages caused directly by the earthquake of September 5th, we can estimate that the maximum intensity for this earthquake was of VII (Mercalli scale) for the zone of the peninsula of Nicoya, Puntarenas and in Zarcero, Grecia and Naranjo. The effects observed in these coastal zones of Guanacaste do not surpass the degree of intensity VII. In Liberia, Cañas, Tilarán, Miramar, Ciudad Quesada and in the Central Valley of Costa Rica were the capital stands, it was estimated in V (Fig. 2).

The Costa Rican Government detailed that the different departments and official institutions valued in 44 million dollars the costs of the damages in public infrastructure and dwellings, distributed mainly in 20 counties of the country.

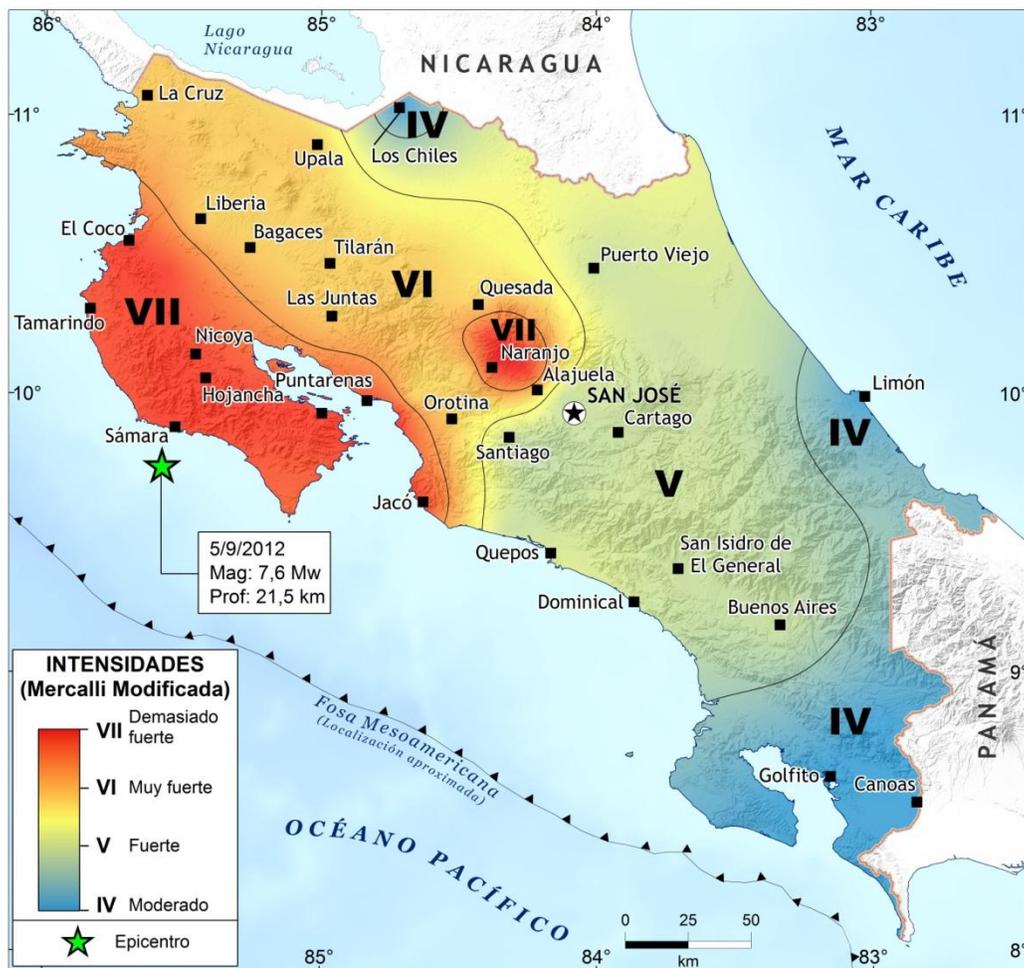


Fig. 2: Mercalli intensities of the Sept. 5th earthquake (RSN:UCR-ICE)

The National Electric Co. (ICE) reported that some components of the electricity broadcast system were seen affected. Only five electric lines and seven power stations in the country presented some problems, these represents only a 6% of the lines and a 12% of the stations. The electric lines that were out of service were: Miravalles-Arenal, Arenal-Lindora

and Santa Rita. The power stations that had some problems were: La Caja, San Miguel, El Coco, El Este, Tarbaca, Heredia, Ciudad Quesada and Colima. Of them the ones that suffered greater damages were that of Santa Rita and Arenal. The services were soon re-established almost in less than 24 hours. As for the telephone system telecom company (ICE) reported that after the earthquake a saturation of the system of fixed and cell phone systems was produced due to that the traffic of calls was quadrupled. 104 GSM radiobases and 202 3G were also out of operation by failure in the supply of electricity, but at the end of the day already almost all the systems were recovering. The main damages in Guanacaste as for the electric service was the fall of the service by some damages mainly in the station Santa Rita, and also by fall of polls for the electric lines, but the service was re-established several hours later. An inspection to the zone was performed and coastal lifting was observed. It was determined that the maximum intensity in the scale Mercalli Modified, in the coastal zone is of VII, thus same in the city of Nicoya. In some beaches with saturation of superficial water as Nosara and Ostional, differential settlement and liquefaction were observed.

Earthquake source parameters

The focal mechanisms of USGS, Global CMT Project and RSN indicate a pure inverse faulting dipping to the NE, coinciding perfectly with the subduction process in that seismic zone. The interpolate seismic zone of Nicoya stands an approximate area of some 5.400 km^2 . The current break by the earthquake of the 05 of September, 2012, seems to be limited by two lateral edges in NE direction, that served as limits or lateral ramps during the process of the displacement in the zone of failure. The zone of break has a longitude of approximately 55 km. The wide one in depth extends for some 40 km, to underneath of the Nicoya peninsula, resulting in an area of total break by the earthquake, of approximately 2.200 km^2 , what equals approximately to the 41% of the total seismic area. The sliding calculated along the failure surface is of 2.16 m. Coastal lifting was observed of approximately 45 cm at Puerto Carrillo (coordinates Lambert N 373,730 205.465) and of 75 cm at Pelada Beach (coordinates Lambert N 352.705 215.530).

Assuming a lineal behavior of the historic seismicity, the earthquake of Sept. 5th, 2012 Mw 7.6 perfectly copes with the normal occurrence of earthquakes of that size in the zone and not more large.

The magnitude of the earthquake was $M_w = 7.6$, the rupture area: $55 \text{ km} \times 40 \text{ km} = 2200 \text{ km}^2$. Seismic Moment: $M_o = 2.9 \times 10^{20} \text{ Nm}$ (USGS: double couple) Stiffness Module for Costa Rica = $6 \times 10^{11} \text{ dynes/cm}^2$. Maximum vertical sliding in the zone of failure $y = 2.16 \times \sin 35^\circ = 1.23 \text{ m}$. Total energy freed $1,58 \times 10^{23} \text{ Ergs}$. Power = $3.16 \times 10^{23} \text{ Tons of TNT}$ equivalent to 158 atomic bombs (Hiroshima type).

Seismicity generated by the earthquake of Sept. 5th in other regions of the country

After the earthquake of Sept. 5th several regions of the country presented some activity by earthquakes in local faults, the main zones activated were: Mountain range of Guanacaste and all around the Central Valley in Costa Rica where the main cities of the country stand (Fig. 3).

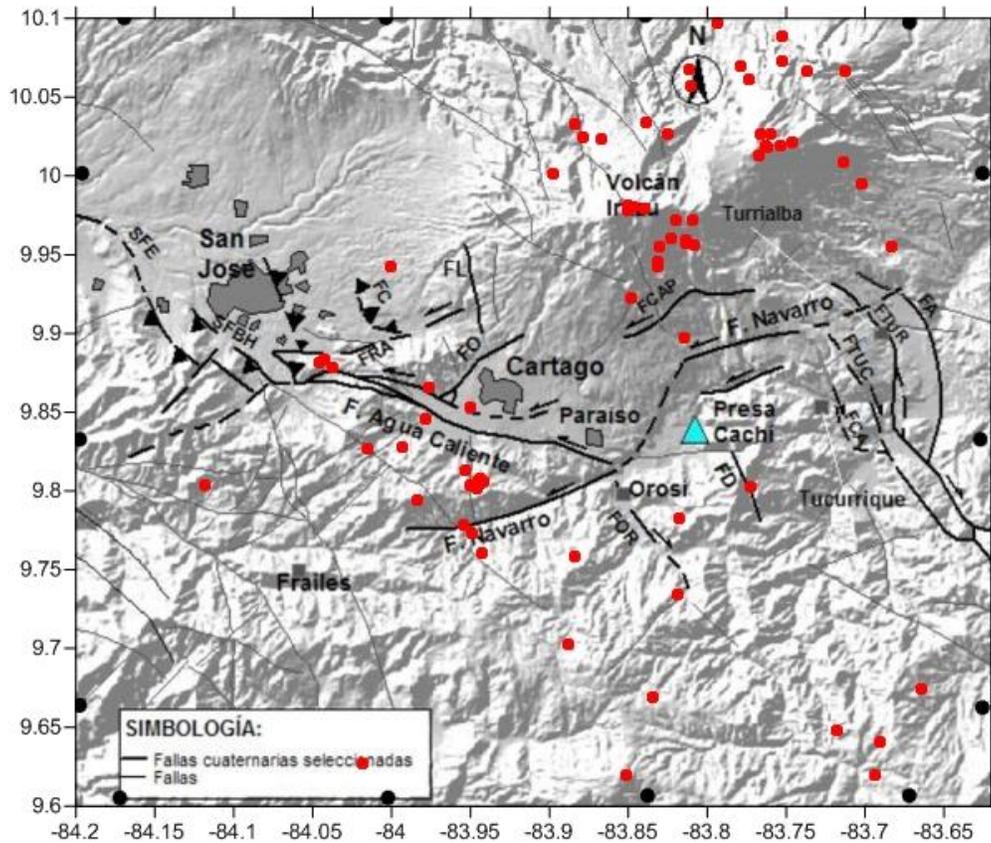


Fig. 3: Seismic activity followed by the September 5th earthquake at the Central Valley

Conclusions

The earthquake of September 5th, 2012 at 08:42 (local time) had a magnitude Mw 7.6, a depth of 15.4 km and was located 10 km south of Sámara beach, province of Guanacaste. The region of the north Pacific of Costa Rica has presented important historic earthquakes, associated to the process of subduction of the Coco's plate under the Caribbean plate where historic earthquakes has been recorded such as the 1950 earthquake (Ms 7.7) at Nicoya. The maximum intensity (Mercalli mod.) estimated for the earthquake of September 5th of 2012 was of VII in the region of the peninsula of Nicoya and Puntarenas that was where the greater damages in buildings, houses, highways were observed. In the zone NW and SW of the province of Alajuela, in populations as Grecia, Sarchi, Zarcero, by special conditions of soil and

directivity of the shock waves, important damages in dwellings they were presented, schools and highways, for which is estimated an intensity of VII. In the Central Valley intensity was estimated of V degrees, although there was alarm in the population and fall of objects in the dwellings and buildings, but not greater damages in the constructions were reported. The seismic source in the zone is a break of inverse type, dipping 24° to the NE. The zone of break covers an area of some 2.200 km².

Sliding along the failure surface is of 2.16 meters. The coastal lifting observed in the mesoseismic zone is between 50 - 70 cm. Power freed is equivalent to 158 atomic bombs (Hiroshima type).

With the present earthquake seems slip among plates, was approximately the 40% of the total area of the seismic zone and the remainder of the zone remains holds to the normal behavior of trembling or earthquakes in zones of subduction of central american margin. Or it would be able to be mobilized or to be slid earthquake-resistant, situation that is normal in a seismic zone as that of Nicoya, since it presents few harshness in the subduction slab, that perfectly can facilitate the sliding earthquake-resistant, like already well is known in that setting. An internal wave radiation toward the NE is given, affecting certain lands with problems of soil condition, between Miramar and Sarchi, combined with problems in the quality of the constructions.

The focal mechanisms of the USGS as well as the RSN's, for the earthquake of September 5th, 2012, gives a displacement of inverse type; they confirm the relation of this earthquake with the process of subduction of the Coco's plate under Caribbean plate.

There was no tsunami, the majority of the damages were moderate; liquefaction at the coastal areas in the alluvial terraces of some rivers and some bridges damaged; the buildings damages show defects of construction, this shows the importance to follow the Seismic Code of Costa Rica for any engineering work in our country.

References:

Von Huene, R., Bialas, J., Fluh, E., Cropp, B., Csernok, T., Fabel, E., Hoffmann, J., Emeis, K., Holler, P., Jeschke, G., Leandro, G., Pérez, I., Chavarría, S, Flores, H., Escobedo, Z., León, R., Barrios, L. 1995: Morphotectonics of the Pacific convergent margin of Costa Rica. En: Mann, P. (ed.) Geologic and tectonic development of the Caribbean plate boundary in southern Central America: Colorado-EEUU, Geological Soc. of Amer. Special paper 295, 249 pp.