

# CHARACTERISTIC EARTHQUAKE, SEISMIC GAP AND INFRASTRUCTURE VULNERABILITY IN THE PENINSULA DE NICOYA – COSTA RICA

By

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## ABSTRACT

The Peninsula de Nicoya in Costa Rica has been affected for big earthquakes on the years: 1853, 1900 and 1950, characterizing this region as a continuous potential seismic area each almost 50 years. On this segment, from the manifestation of the last big earthquake (1950) a passive seismicity compare to the next north site (Nicaragua) and the next south site (central and south part of Pacific coast of Costa Rica) has been happened. A big magnitude earthquake could occur on this region in a near future and it could affect a large part of the infrastructure of this region.

## 1. INTRODUCTION

The Peninsula de Nicoya is located in Costa Rica, Central America. This Peninsula forms a part of Puntarenas Province and a part also of Guanacaste Province. (Figure 1)

Several big cities are localized on this area where since two decades ago many tourism projects have been developed, especially along the coastal line of this Peninsula; This region represent an important part of the Costa Rica's economic structure.

In January 2009, Central area of Costa Rica was affect for an earthquake Mw. 6.2 and 4 km depth.



Figure 1. Location of the Peninsula de Nicoya.

This event produced a severe impact in Costa

Rica due to the fact that many houses, churches, schools, an hydroelectric generator plant and the public road infrastructure was severe damaged, affecting the social, academic, power and commercial activity of the region. (Figures 2 and 3).



Figure 2. Damage on roads after earthquake 2009.



Figure 3. Damage on Cinchona Church after earthquake 2009.

Peninsula de Nicoya covers approximately  $2400 \text{ km}^2$  of the northern Costa Rican fore arc and lies parallel to the Middle American Trench and the northern Costa Rican volcanic arc. [1]

Oral histories describing a M 7.7 Nicoya subduction earthquake in October 1950, interviews (48 residents) show a coseismic uplift of at least 1 m on the coast line and killed

and injured dozens of people, several damaged buildings and roads, and produce landslides and liquefaction. [1]

Additionally, on this segment, others big earthquakes haven occurred before (1853 and 1900) [2] characterizing this region as a continuous potential seismic area each almost 50 years. But currently this interval is overpassed for more than one decade, increasing the risk of a big earthquake on this region.

### **CHARACTERISTIC EARTHQUAKE MODEL AND SEISMIC GAP**

In many places around the vicinity of the world's tectonic plates, during long time, have been a spatial variability in coseismic slip. Characteristic earthquake model is related when a significant earthquake occurs in a particular region within a recurrent interval of time; assuming constant stress rate and constant material properties in the fault plane, the stress is accumulating to a given level during a period of time until the failure strength is exceeded.

This model has been used to identify asperities of upcoming significant earthquakes from gaps in seismic activity patterns. Nankai trough along the Philippine Plate and Eurasia Plate in from of Japan is an example of this kind of characteristic earthquake and seismic gap process [3].

### **CHARACTERISTIC EARTHQUAKE AND SEISMIC GAP IN THE PENINSULA DE NICOYA**

Costa Rican territory is localized along the

Southern Middle America Trench where the Cocos plate is subducting northeastward beneath the Caribbean plate and the Panama micro-plate. The Caribbean-Panama boundary traverses the central part of Costa Rica and intersects the Pacific coast near to the southeast of the Peninsula de Nicoya [4]. This central boundary limited the northern Costa Rican fore arc where the Peninsula de Nicoya is localized. (Figure 4)

along the Peninsula de Nicoya (in the Middle America Trench), nearly in an orthogonal direction and exceeds 90 mm/year [5].

Earthquakes occurred 1916 (M. 7.3) and 1992 (M. 7.6) in front Nicaraguan coast line and 1939 (M.7.1) and 1990 (M. 7.0) in front the central pacific coast line in Costa Rica, have been permitted to limited the northern Costa Rica fore arc and then the Peninsula de Nicoya seismic gap [1]. (Figure 5)

The subduction causes forarc deformation

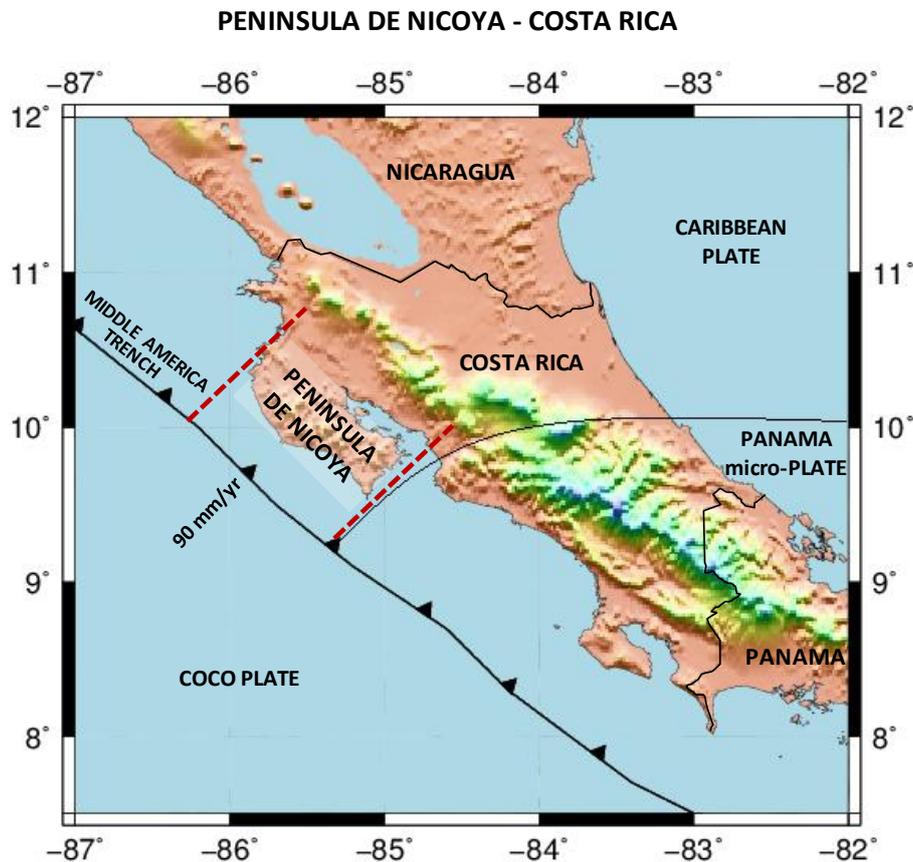


Figure 4. Tectonic boundaries around the Peninsula de Nicoya.

On 1978, an earthquake Mw. 6.8 occurred in the central part of the Peninsula de Nicoya (Samara), this event broke an area less than 15% of total area of the Peninsula de Nicoya

segment [6].

The possible rupture area is estimated about 8000 +/- 1500 km<sup>2</sup> and could generate an earthquake too close to Mw. 8.00 [7].

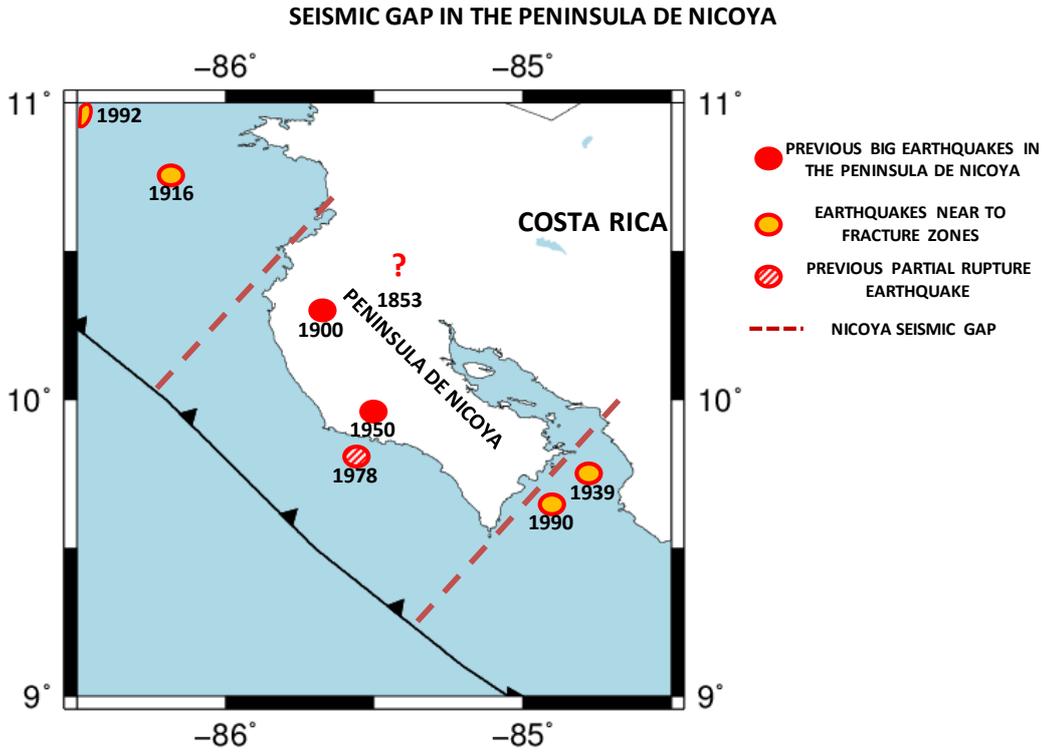


Figure 5. Seismic gap area, previous earthquakes occurred around the Peninsula de Nicoya.

Figure 6, shows a seismicity map of Costa Rica, prepared and plotted using the software SEIS-PC (K. Nakamura and Y. Ishikawa), this map shows events occurred between January 1940 and December 2010 with magnitude bigger than 5.0 and depth shorter than 250 km.

Through this map, it is possible to appreciate the passive seismicity along the Peninsula de Nicoya compare to the next north site (Nicaragua) and the next south site (central and south part of Pacific cost of Costa Rica).

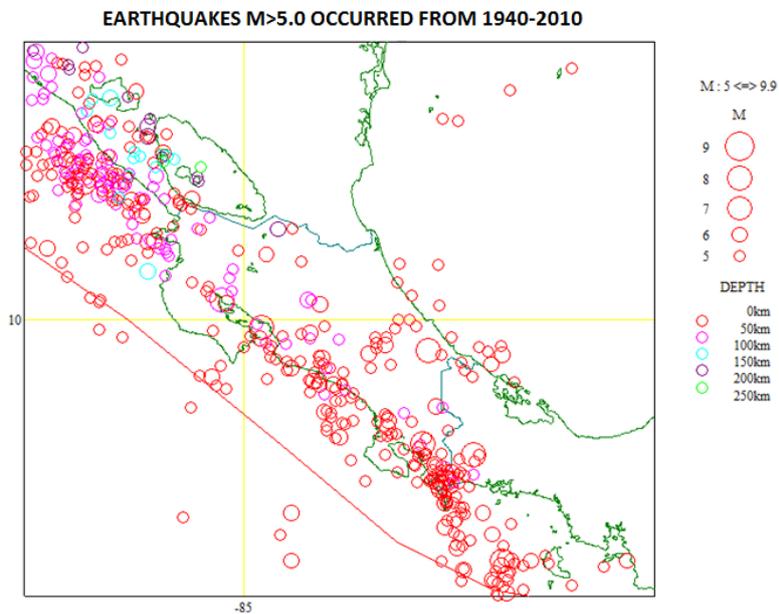


Figure 6. Earthquakes M > 5.0 occurred from 1940-2010 (Elaborated with SEIS-PC).

This passive seismic activity on this region is the most important evidence related to the seismic gap in the Peninsula de Nicoya; positioning the epicenters of previous events is a manner to limit and appreciate the possible

rupture area for the next big earthquake on this region.

Figure 7, shows the possible rupture area for the next big earthquake in the Peninsula de Nicoya.

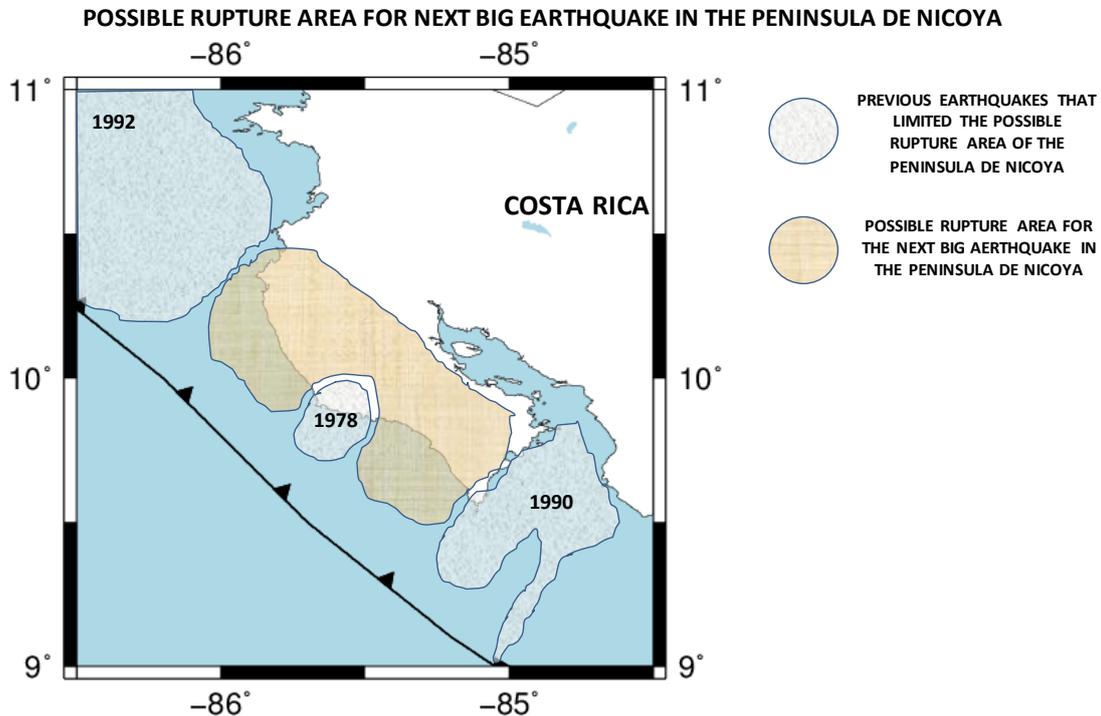


Figure 7. Possible rupture area for next big earthquake in the Peninsula de Nicoya (Adapted from ref.6)

**POSSIBLE INFRASTRUCTURE AFFECTATION BY A BIG EARTHQUAKE ON THE PENINSULA DE NICOYA**

An event Mw. 8.00 in this area could affect a large part of the infrastructure, principally in Guanacaste and the northwestern part of Puntarenas (houses, schools, industries, hotels, roads and others). Currently infrastructure dedicated for the emergency attention as hospitals, clinics, fire stations, Red Cross Committees and bridges should be prepared for this event.

Figure 8, shows a scenery where it is possible to experiment high seismic intensities due high ground accelerations that could destroy many infrastructure on that filled area

Table 1, represents a list of essential infrastructure for the emergency attention, this table shows their quantity according to their location inside the scenery showed in the figure 8.

**Table 1. List of Health Public Attention Institutions**

Institution	Quantity
Main Publics Hospitals	2
Public Health Centers	17
EBAIS (Limited attention centers)	72
Fire Stations	8
Red Cross Committees	15

special attention to this capacity before the occurrence of this event, in order to prevent serious consequences like others previous earthquakes in Costa Rica and other countries around the world [8].

The structural capacity of this infrastructure could be a weak link in the emergency attention, for this reason it is necessary to pay

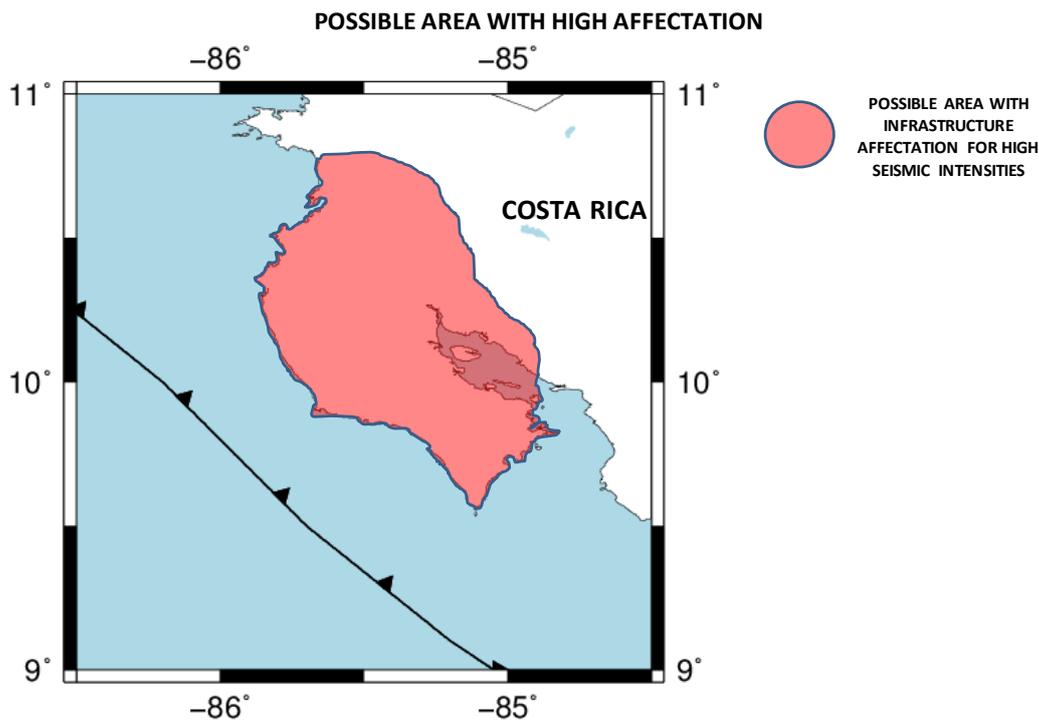


Figure 8. Possible area with high affection by the next big earthquake in the Peninsula de Nicoya.

## CONCLUSIONS

Peninsula de Nicoya in Costa Rica have been affected according to registered documentation by big magnitude earthquakes (bigger than M. 7.0) on the years 1853, 1900 and 1950, characterizing this region as a continuous potential seismic area each almost 50 years. Currently this interval is overpassed for more

than one decade, increasing every day the risk of a big earthquake on this region.

Earthquake Mw. 6.8, occurred on 1978 (Samara) broke just a minor part of the total area of the Peninsula de Nicoya segment, remaining still a large amount of stored energy of this tectonic contact between Cocos plate and Caribbean plate.

The quantities and position of previous events demonstrate the seismic gap on this Peninsula and permit to limit the possible rupture area for the next big earthquake on this region.

In order to reduce the effects of the next big earthquake on this region and also be ready for

the emergency attention, the structural evaluation and seismic retrofitting on the essential infrastructure as hospitals, clinics, fire stations, bridges and others vital infrastructure is strongly recommended and this must be one of the priority of the national and local authorities.

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