The 2016 Capellades Earthquake and its seismic sequence: expression of strike-slip faulting in the volcanic arc of Costa Rica

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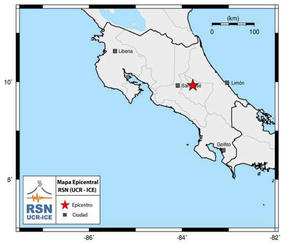
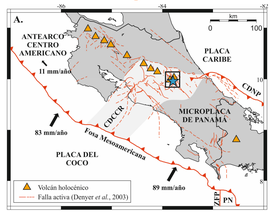
1. Introduction

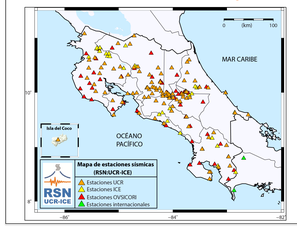


- On 30 November 2016 at 18:25 (1st December at 00:25, UTC time) a Mw 5.5 earthquake occurred at 2.7 km depth near the town of Capellades de Alvarado, Costa Rica.
- It was the main shock of an earthquake sequence including foreshocks and aftershocks, located between the active volcanoes Irazú and Turrialba.
- Using mainly the seismic records from the National Seismological Network (RSN), we present in this study a seismological analysis of the earthquake sequence and the location and characteristics of the fault that originated this seismicity. Additionally, we describe the geotectonic context of the fault and the Capellades earthquake effects.
- Costa Rica is located in a region where four main tectonic plates interact: Cocos, Caribbean, and Nazca Plates, and Panama Microplate. The Capellades Earthquake occurs within the Central Costa Rica Deformed Belt.
- Costa Rica has ~150 active faults and 68 damaging earthquakes since 1821 (on average one every 3 years).
- Also: 14 magnitude ≥ 7.0 since 1821 (on average one every 13 years).
- RSN network operates ~200 seismic stations.

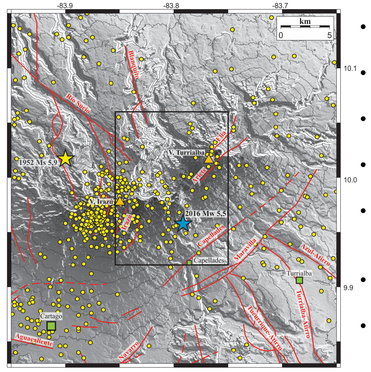
Tectonic Setting

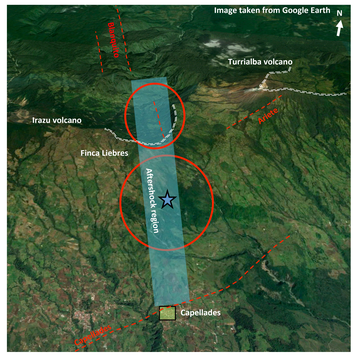


RSN Seismic Network Map



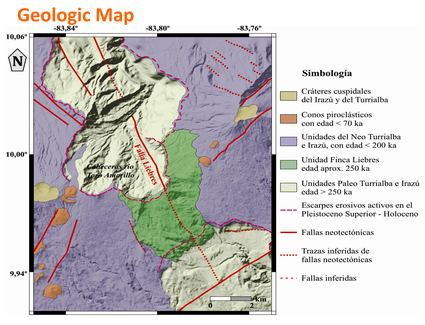
2. Previous Seismicity, Geology, and Geomorphology





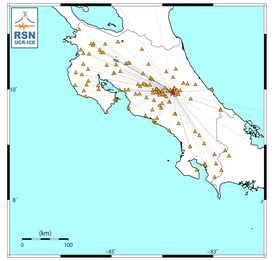
- The main fault systems near the Capellades epicenter are : Atirro, Río Sucio, Aguacaliente, and Navarro (Montero et al., 2013; 2016).
- Seismicity 1973-Nov 2016: There were more earthquakes in the Irazu volcano and few near the Capellades epicenter.
- The last damaging earthquake in this region was the Patillos earthquake in 1952 (Ms 5.9).
- The Capellades earthquake is the first Mw > 5.0 in the Turrialba volcano recorded in the RSN seismic catalogue.
- The main geomorphological features in the area include a volcanic collapse mark in the Turrialba volcano, fault escarps, and linear valleys related to the Blanquito and Ariete faults.
- There are no prominent geomorphological features in the epicentral area.
- The closest known fault near the mainshock was the Capellades fault, located to the south and a geomorphological lineament was previously recognized to the north of the mainshock.

Geologic Map

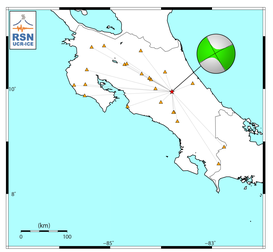


3. Earthquake Locations

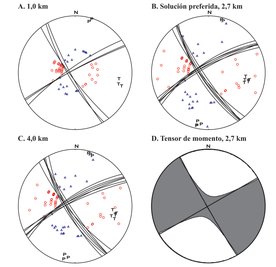
Stations for Mainshock Location



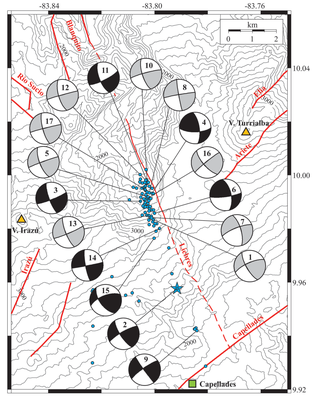
Stations for Moment Tensor



Focmec Mainshock Solutions



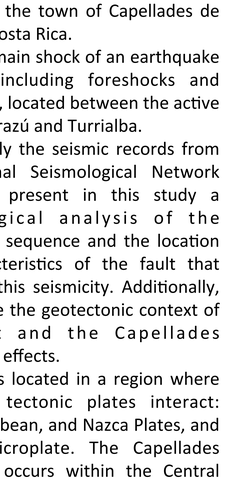
All Focmec Solutions

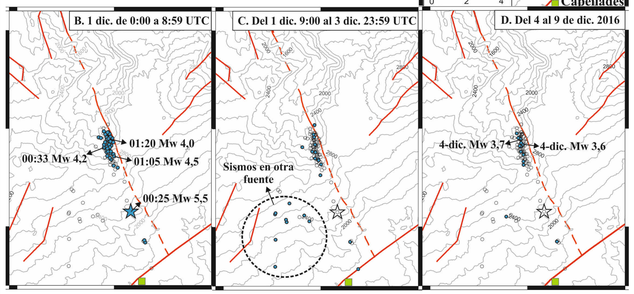


- Mainshock was located using RSN stations and also OVSICORI, INETER, UPA, and OSOP stations obtained via IRIS.
- Detection and location of events was performed using SeisComp, Earthworm, Seisan, HypoDD.
- There was a visual inspection of the readings and uncertainty weighting scheme was applied.
- Focal mechanisms were calculated using FOCMEC and the Moment Tensor using scmtv SeisComp program.
- Mainshock Focmec calculated with 68 polarities.
- Focal depth explored from 0.5 to 5 km. The chosen solution at 2.7 km has the minimum RMS.
- Focmec calculated for 16 aftershocks with 22-40 polarities.
- Focmecs were classified based on quality: A (black) with < 5 solutions and B (gray) with 13-58 solutions.
- Nodal vertical planes: NW-Right Lateral and NE-Left Lateral.
- All events have similar solutions including the foreshock (April 24 2016, number 1), the mainshock (number 2), aftershocks to the NW, and SE of the mainshock.

4. Earthquake Sequence

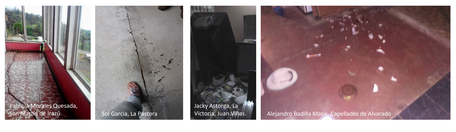
- 120 events were relocated using > 8 stations. These earthquakes have Mw 2.5-4.5. There were only 3 earthquakes with Mw > 4.
- Foreshocks occurred during April and November 2016.
- Aftershocks occurred to the NW and SE of the mainshock.
- There were some events in a different source to the west of the fault.



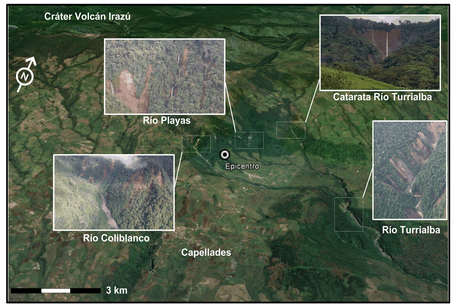


5. Effects

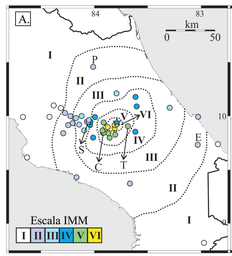
Earthquake Damage



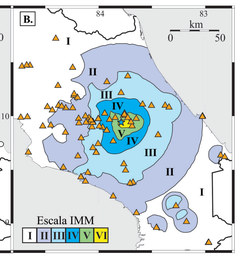
Main Landslides



Intensity Map

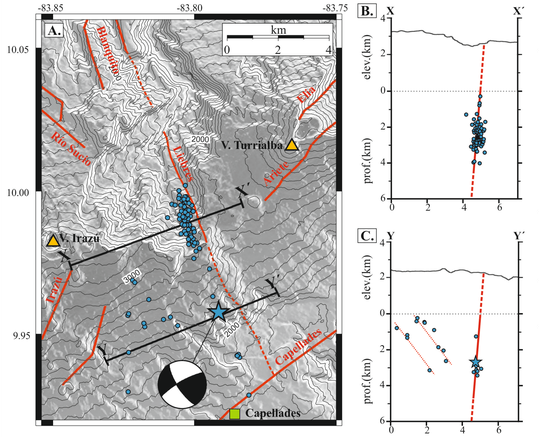


Shake Map



- Intensities were calculated based on Facebook comments and instrumental records.
- The mainshock was felt in most of the country, with a maximum intensity of VI+.
- Forty landslides occurred in a region of 7 x 5 km. These landslides triggered mud flows on several rivers.
- Five people were injured and 25 were evacuated due to the landslides.
- Intensity VI was observed in an area of 10 km² around the epicenter.

6. Conclusions



- The earthquake sequence shows a clear 8-km long alignment striking north-northwest between Irazú and Turrialba volcanoes.
- The joint interpretation of the earthquake relocation, the main-shock moment tensor solution, and the focal mechanisms of 17 events allows for determining the source in a nearly vertical right-lateral strike-slip fault, in agreement with regional active fault systems.
- This structure had not been previously recognized and has been named Liebres Fault in this study.
- The mainshock was felt in most of the country, with a maximum intensity of VI+.
- This earthquake has been the largest in the eastern part of the Central Volcanic Range since the 1952 Patillos earthquake (Ms 5.9) and the first Mw > 5.0 earthquake recorded by the RSN in the Turrialba volcano edifice.
- Despite the proximity to this active volcano, which has been erupting periodically since 2010, there were no immediate eruptive effects.

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