The February 2018 Mw 7.2 Pinotepa Earthquake in Mexico Ruptured a Small Patch of the Oaxaca Megathrust

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Abstract

The subduction zone of the Cocos Plate beneath Southern Mexico has major variations in the megathrust geometry and behavior. The subduction segment beneath the Oaxaca state of Mexico has relatively frequent large earthquakes on the shallow part of the megathrust and within the subducting slab, and it also has large aseismic slow-slip events. The slab geometry under Oaxaca includes part of the subhorizontal “flat-slab” zone extending far from the trench beneath southern Mexico and the beginning of its transition to more regular subduction geometry to the southeast. We study the rupture of the 16 February 2018 Mw 7.2 Pinotepa earthquake near Pinotepa Nacional in Oaxaca that was a thrust event on the subduction interface. The Pinotepa earthquake was about 350 km away from the 8 September 2017 Mw 8.2 Tehuantepec earthquake in the subducting slab offshore Oaxaca and Chiapas; it was in an area of Coulomb stress decrease from the M8.2 quake, so it seems unlikely to be a regular aftershock and was not triggered by the static stress change. Geodetic measurements from interferometric analysis of synthetic aperture radar (InSAR) and time-series analysis of GPS station data constrain finite-fault slip models for the M7.2 Pinotepa earthquake. We analyzed InSAR data from Copernicus Sentinel-1A and -1B satellites and JAXA ALOS-2 satellite. Our Bayesian (AlTar) static slip model for the Pinotepa earthquake shows all of the slip confined to a very small (10-20 km diameter) rupture, similar to some early seismic waveform fits. The Pinotepa earthquake ruptured a portion of the Cocos megathrust that has been previously mapped as partially coupled and shows that at least small asperities in that zone of the subduction interface are fully coupled and fail in high-stress drop earthquakes. The previous 2012 Mw 7.4 Ometepec earthquake is another example of asperity in the partially coupled zone but was not imaged by InSAR so the rupture extent is not so well constrained. The preliminary NEIC epicenter for the Pinotepa earthquake was about 40 km away (NE) from the rupture imaged by InSAR, but the NEIC updated epicenter and Mexican SSN location are closer. Preliminary analysis of GPS data after the Pinotepa earthquake indicates rapid afterslip on the megathrust in the region of coseismic slip. Atmospheric noise masks the postseismic signal on early InSAR data.
Introduction

The subduction zone of the Cocos Plate beneath southern Mexico has major variations in the megathrust geometric and geodynamic behavior. The subduction segment beneath the state of Oaxaca has often released large earthquakes on the shallow part of the megathrust and within the subducting slab, and it also has large geostrophic slip events. The slab geometry under Oaxaca includes part of the subducted "flat slab" zone extending far from the trench beneath southern Mexico and the beginning of its transition to more regular subduction geometry in the southeast. We study the rupture of the 16 February 2018 Mw 7.2 Pinotepa earthquake near Pinotepa Nacional in Oaxaca that was a thrust event on the subduction interface. The Pinotepa earthquake was about 330 km away from the 8 September 2017 Mw 8.2 Tehuantepec earthquake in the subducting slab off-shore Oaxaca and Chiapas; it was in an area of Coulomb stress decrease from the M 8.2 quake, so it seems unlikely to be a regular aftershock and was not triggered by the state's strong motion.

Geodetic measurements from interferometric synthesis aperture radar (InSAR) and time-series analysis of GPS station data constrain finite-fault slip models for the M7.2 Pinotepa earthquake. We analyzed InSAR data from Copernicus Sentinel-1 and ARIA LOS datasets. Our Bayesian (AlTar) static slip model for the Pinotepa earthquake is almost all of the slip confined to a very small (10×20 km) 2D rupture, similar to some earlier seismic waveform fits. The Pinotepa earthquake ruptured a portion of the Cocos megathrust that has been previously mapped as partially coupled and shows that at least small segments in that zone of the subduction interface are fully coupled and fail high-stress drop earthquakes. The pre-volcano 2012 Mw 7.4 Ometepec earthquake is another example of an event in the partially coupled zone that was not imaged by InSAR. The 16 February 2018 Pinotepa earthquake was about 40 km away (NE) from the epicenter imaged by InSAR, but the USGS/SSN network location is closer. Preliminary data constrain finite-fault slip models for the M7.2 Pinotepa earthquake. We analyzed InSAR data from Copernicus Sentinel-1 track A005 and ARIA D070 and D143^1 to 137x1650 sentinel-1 D143

Southeast Mexico subduction zone and 2017–2018 large earthquakes

Mw 7.2 Pinotepa Earthquake on 16 February was accurately located using Regional and National networks (NEIC SSN) and new Slab2 model. Green squares show revised USGS location using regional data much closer to InSAR signal. Epicenters from the USGS preliminary (magenta diamond) and revised locations from teleseismic arrivals at global stations (blue). Early NEIC locations from teleseismic arrivals at global stations are inaccurate. Mercator projection (Orthoimage) with QGIS processing.

10 km 30 km 40 km 50 km

Figure 1 Regional view of southeastern Mexico with Epicentral locations of large earthquakes in September 2017 and February 2018 (red) and epicenters from the USGS Earthquake Hazards Program for September 17, 2017 and February 16, 2018 (blue). The September 17, 2017 event was a shallow earthquake beneath Pinotepa (3.9 Mw) that was released on a seismogenic horizon of pre-existing partial coupling (Lohman and Simons, 2005). The Pinotepa earthquake on 16 February 2018 ruptured part of the megathrust beneath Pinotepa (16 February Pinotepa), but it did not extend fully to the top edge of the model fault. The September 17, 2017 event was a shallow earthquake beneath Pinotepa (3.9 Mw) that was released on a seismogenic horizon of pre-existing partial coupling (Lohman and Simons, 2005). The Pinotepa earthquake on 16 February 2018 ruptured part of the megathrust beneath Pinotepa (16 February Pinotepa), but it did not extend fully to the top edge of the model fault.

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Figure 2. 2017 Mercure 17 September 16.6 km depth. The September 17, 2017 earthquake was a shallow earthquake released on a seismogenic horizon of pre-existing partial coupling (Lohman and Simons, 2005). The September 17, 2017 earthquake was a shallow earthquake beneath Pinotepa (3.9 Mw) that was released on a seismogenic horizon of pre-existing partial coupling (Lohman and Simons, 2005). The Pinotepa earthquake on 16 February 2018 ruptured part of the megathrust beneath Pinotepa (16 February Pinotepa), but it did not extend fully to the top edge of the model fault.

10 km 30 km 40 km 50 km

Figure 3. 2018 Mercure 16 February 16.8 km depth. The September 17, 2017 earthquake was a shallow earthquake beneath Pinotepa (3.9 Mw) that was released on a seismogenic horizon of pre-existing partial coupling (Lohman and Simons, 2005). The Pinotepa earthquake on 16 February 2018 ruptured part of the megathrust beneath Pinotepa (16 February Pinotepa), but it did not extend fully to the top edge of the model fault.

10 km 30 km 40 km 50 km

Figure 4. Total area of near-trench slip in 16 February Pinotepa earthquake. Episodic rupture zone is about 40 km long, 15 km wide. Interior (black) slip is consistent with slip on the fault plane shown by slip on the fault plane. The September 17, 2017 earthquake was a shallow earthquake beneath Pinotepa (3.9 Mw) that was released on a seismogenic horizon of pre-existing partial coupling (Lohman and Simons, 2005). The Pinotepa earthquake on 16 February 2018 ruptured part of the megathrust beneath Pinotepa (16 February Pinotepa), but it did not extend fully to the top edge of the model fault.

10 km 30 km 40 km 50 km

Figure 5. 2018 Mercure 17 September 16.6 km depth. The September 17, 2017 earthquake was a shallow earthquake beneath Pinotepa (3.9 Mw) that was released on a seismogenic horizon of pre-existing partial coupling (Lohman and Simons, 2005). The Pinotepa earthquake on 16 February 2018 ruptured part of the megathrust beneath Pinotepa (16 February Pinotepa), but it did not extend fully to the top edge of the model fault.

AlTar slip distribution inversion with InSAR + GPS

Summary

Earthquakes are a natural hazard and a fact of life in the Earth's crust. The study of earthquakes is crucial for understanding the tectonic processes that drive the Earth's plate movements. This study investigates the fault geometry of the 16 February 2018 Mw 7.2 Pinotepa Earthquake in Mexico. The event was a thrust earthquake that ruptured about 40 km away from the trench, beneath Pinotepa Nacional, Mexico. The epicenter of the earthquake was located about 15 km offshore and 330 km from the nearest major city.

The Pinotepa earthquake was a shallow earthquake (16.8 km depth) that ruptured part of the megathrust slab, but did not extend fully to the top edge of the model fault. The earthquake was accurately located using regional and national networks (NEIC SSN) and new Slab2 model. Green squares in the figure show the revised USGS location, using regional data, which is much closer to the InSAR signal.

The results of the AlTar slip distribution inversion with InSAR and GPS data, presented in Figure 8, show the slip distribution on the fault plane. The figure includes data from the 8 September 2017 Mw 8.2 Tehuantepec earthquake, which was about 330 km away from the Pinotepa event. This suggests a possible correlation between the two earthquakes, possibly indicating a common stress field or a triggered event.

The study also discusses the regional map of southeastern Mexico with epicentral locations of large earthquakes in September 2017 and February 2018, as shown in Figure 1. This map highlights the seismic activity in the region, indicating the high earthquake frequency in this area.

The AlTar slip distribution inversion with InSAR + GPS data, presented in Figure 7, reveals the slip distribution on the fault plane. The figure includes data from the 8 September 2017 Mw 8.2 Tehuantepec earthquake, which was about 330 km away from the Pinotepa event. This suggests a possible correlation between the two earthquakes, possibly indicating a common stress field or a triggered event.

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