Finding Seismic Faults Beneath Nicaragua

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1. Hazard Mitigation

Figure 1. Photo of a person in their destroyed home in Nagarote after the 2014 earthquake. (AP photo/ Esteban Felix)

- On April 10, 2014, an earthquake beneath Lake Managua struck lakeside cities, causing a heart attack, injuring 266 people, and damaging 1500 buildings.
- Most of this damage occurred in Nagarote, but shaking was felt in Managua and several other towns around Lake Managua
- The 1972 Managua earthquake, which occurred on a nearby fault, killed up to 11,000 people, injured 20,000, and left 300,000 homeless.
- Knowing the locations and orientations of the faults on which these earthquakes occur has the potential to save lives and reduce damage.

2. Plate Motion

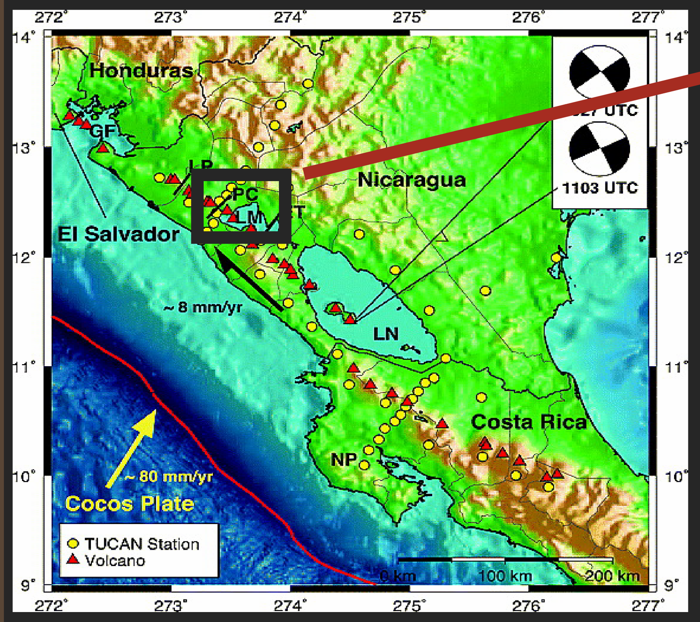


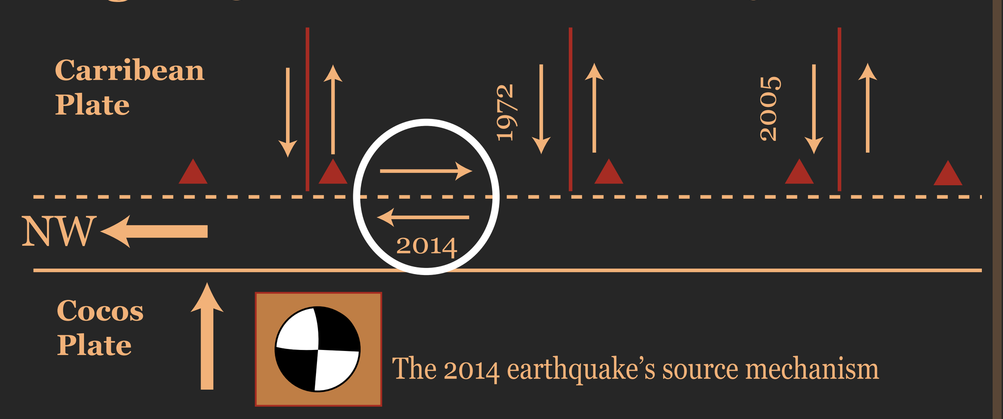
Figure 2. From French et. al. 2010: Map of the Cocos Plate subducting beneath the Caribbean Plate. showing direction of fore-arc sliver transport (black arrow).
Red line = trench, triangles = volcanoes.
The sliver of lithosphere between the volcanic arc and the trench moves along the plate boundary at a rate of 8mm per year.

- To understand how lateral fore-arc sliver transport is accommodated in the upper crust, we need to know the locations and orientations of the faults.
- Fluids from the subducting plate cause mantle melting and an arc of volcanoes which weakens the crust. Faults are theorized to occur in brittler crust between volcanoes.
- I examined the 2014 earthquake and its foreshocks and aftershocks to determine how it fits into the bookshelf faulting model.
- The source mechanism of this earthquake is consistent with either a fault striking parallel or perpendicular to the plate boundary.

2, Continued. Bookshelf Faulting

- Bookshelf faulting is one theory to explain how the fore-arc sliver moves.
- In bookshelf faulting, small faults run perpendicular to the plate boundary, creating blocks that rotate and accommodate fore-arc sliver motion.
- According to the source mechanism, The 2014 fault could be perpendicular to the boundary and consistent with bookshelf faulting, or parallel to it, suggesting that faulting is more complex.

Figure 3. From Suarez et al., 2015, rotated



3. The Fault Beneath Lake Managua

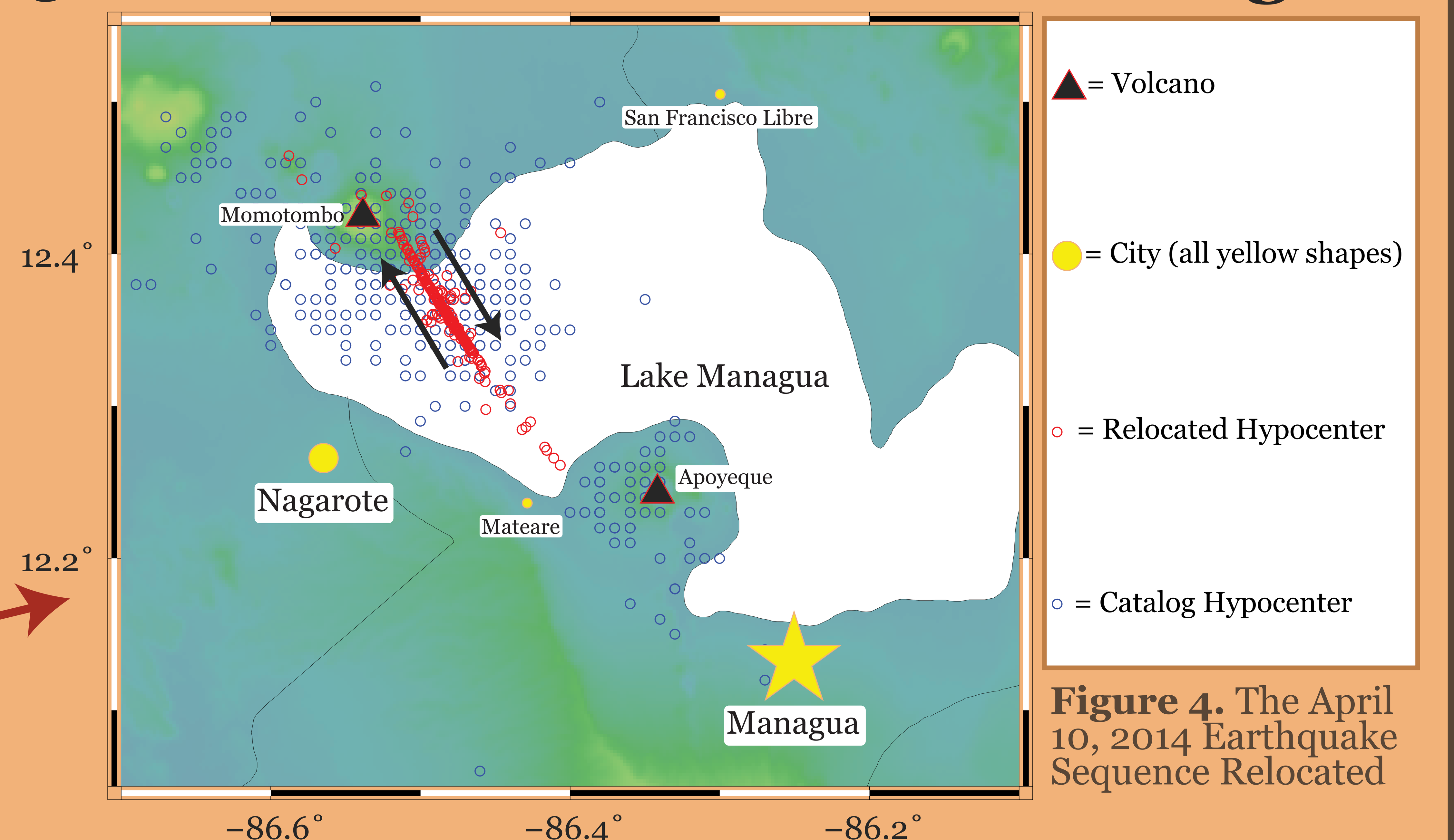


Figure 4. The April 10, 2014 Earthquake Sequence Relocated

- Relocated earthquakes clearly delineate a fault that trends **parallel** to the plate boundary.
- A group of aftershocks was catalog located under the Apoyeque volcano, but did not converge to a specific fault after relocation.

4. Conclusions

- Mateare and Nagarote are the biggest population centers in direct danger of heavy shaking from earthquakes on this fault. Because Managua is more distant, its hazard from this fault is lower.
- The fault the 2014 earthquake occured on strikes NW-SE, parallel to the boundary.
- The orientation of the fault coupled with the earthquake source mechanism indicates that faulting in the Lake Managua region is more complex than simple bookshelf faulting.

5. Relocation Method

- I applied the Double-Difference relocation method (Waldhauser and Ellsworth, 2000), which cancels out the effects of Earth structure and uses P-wave travel time differences to solve for accurate locations.
- I gathered waveforms of P-waves of 1,300 foreshocks and aftershocks from INETER (the Nicaraguan hazards monitoring agency) recorded at 21 different stations.
- I used moving noise and signal windows to more accurately pick the phase onset time.

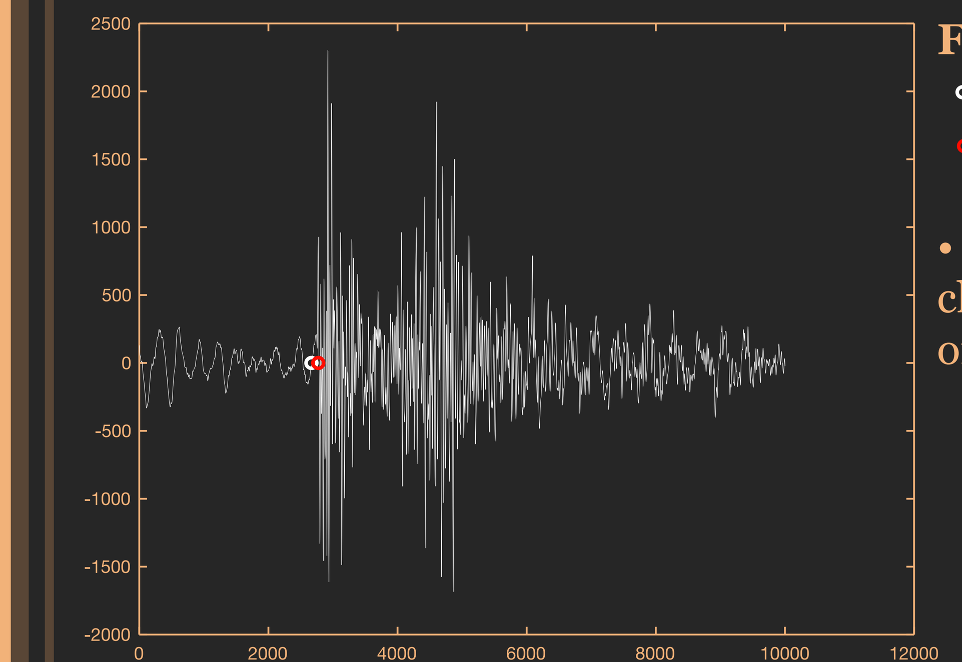
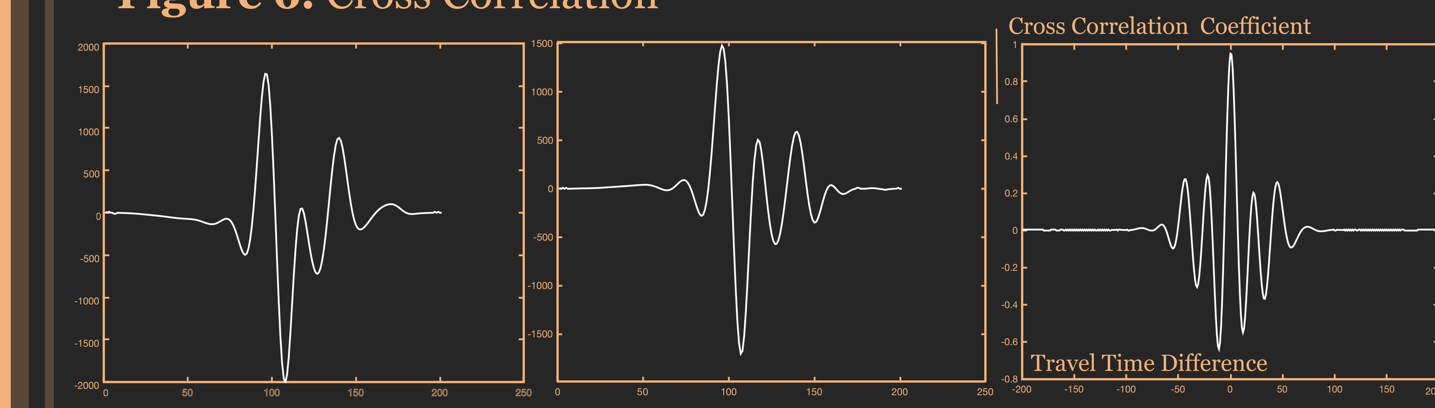


Figure 5. Phase Picking
∘ = Taup time
∘ = windowed time.

- The windowed time is closer to the actual phase onset.

- I cross correlated waveforms to measure travel time differences between pairs of earthquakes recorded at one station.

Figure 6. Cross Correlation



- Using only well-correlated waveforms, such as the above recorded at the BOAB station, increases the accuracy of the solution.
- I then applied HypoDD, a program that utilizes the Double-Difference relocation method (Waldhauser and Ellsworth, 2000), to find more accurate locations for the 2014 earthquake sequence.

6. Acknowledgments

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7. References

1. French, S. W., Warren, L. M., Fischer, K. M., Abers, G. A., Strauch, W., Protti, J. M., and Gonzalez, V. (2010)
2. Suárez G. et al. (2015)
3. Waldhauser and Ellsworth (2000)