Assessment of Energy Release and Seismic Moment of the August 4, 1946 Hispaniola Earthquake

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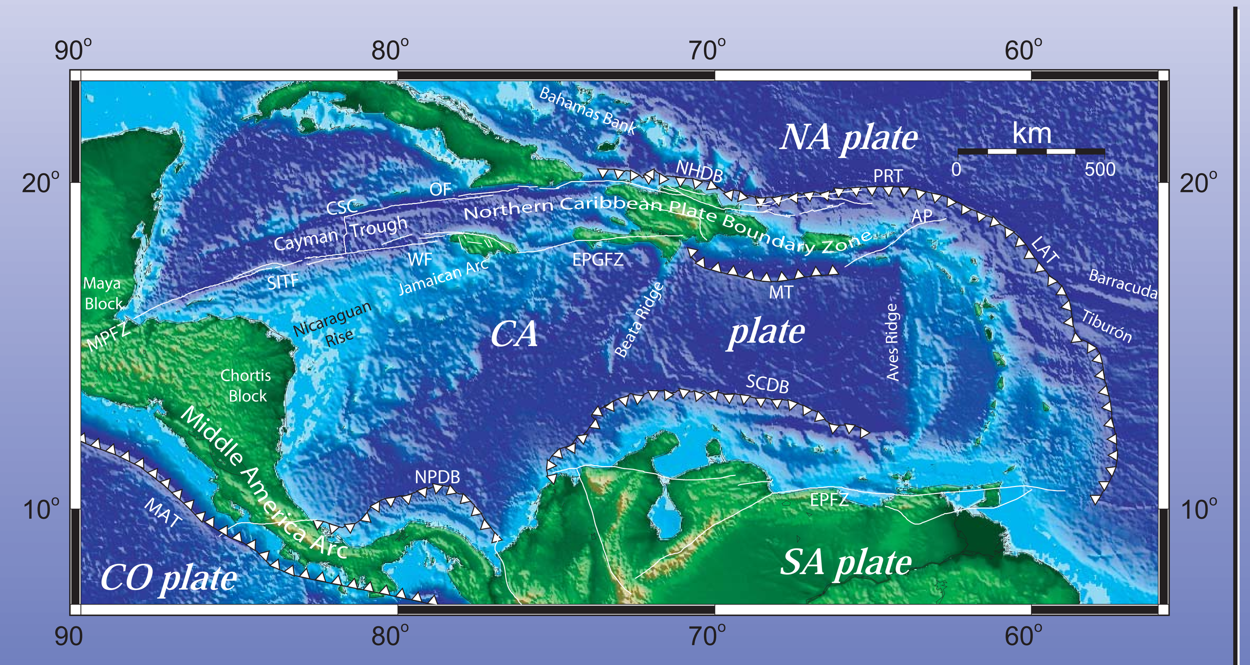
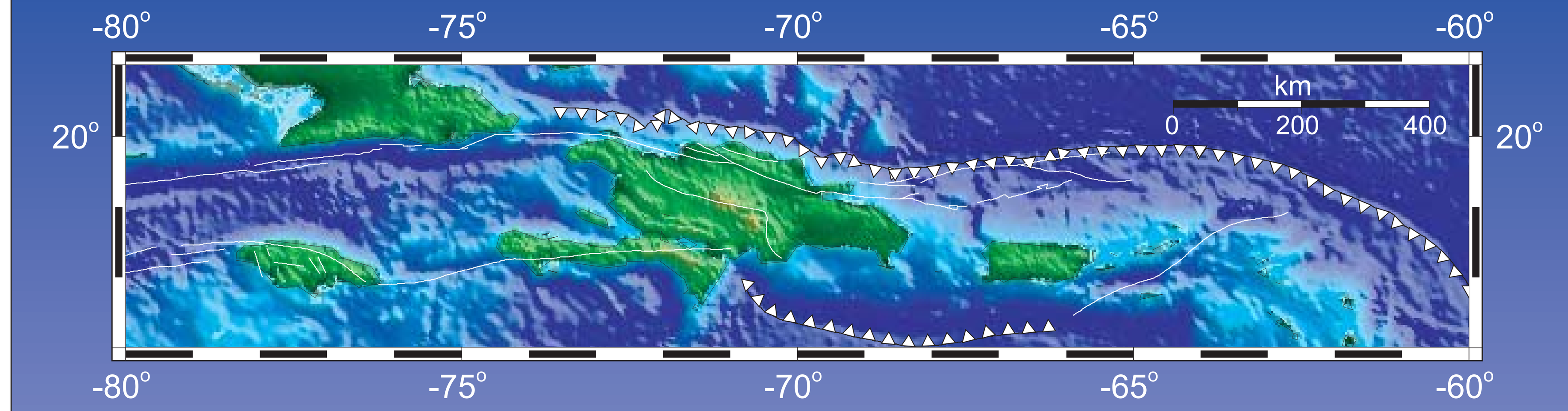
[07-132]

ABSTRACT

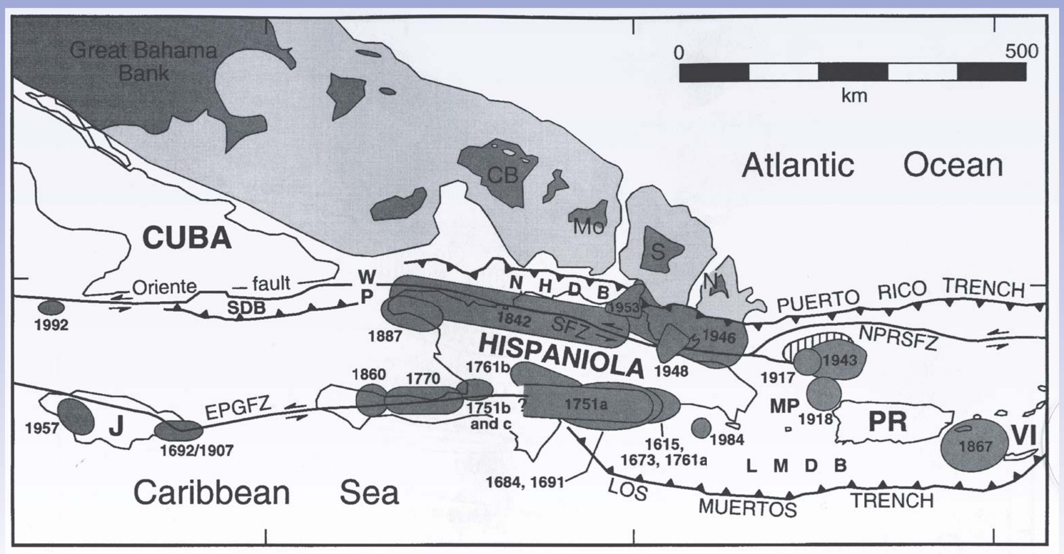
Although 60 years have passed since the occurrence of the August 4, 1946 earthquake in Hispaniola, overall knowledge and essential parameters of the event are still unknown or poorly constrained. Published magnitudes for the event have ranged from 7.8 to 8.1, estimated fault zone dimensions have had poor agreement between them, and waveform inversion studies have led to similar focal mechanisms with diverging interpretations as to the causative fault plane and an unknown seismic moment. More important is that the earthquake has never been successfully related to the occurrence of a catastrophic tsunami observed along the northeastern corner of the island, where casualties have been estimated to 1800. Hence, we have gone back to the seismic record to present results from digitized seismograms used to compute radiated energy and estimate the seismic moment. Using the method of *Newman and Okal (1998)* for estimating the Theta parameter, a useful slow earthquake discriminant, we have concluded the earthquake does not have an anomalous energy to seismic moment ratio, suggesting a non-tectonic source for the tsunami genesis. Collection of multi-beam bathymetry data along the northeastern coast of Hispaniola is essential to confirm or reject the suggestion of the tsunami being triggered by a submarine landslide.



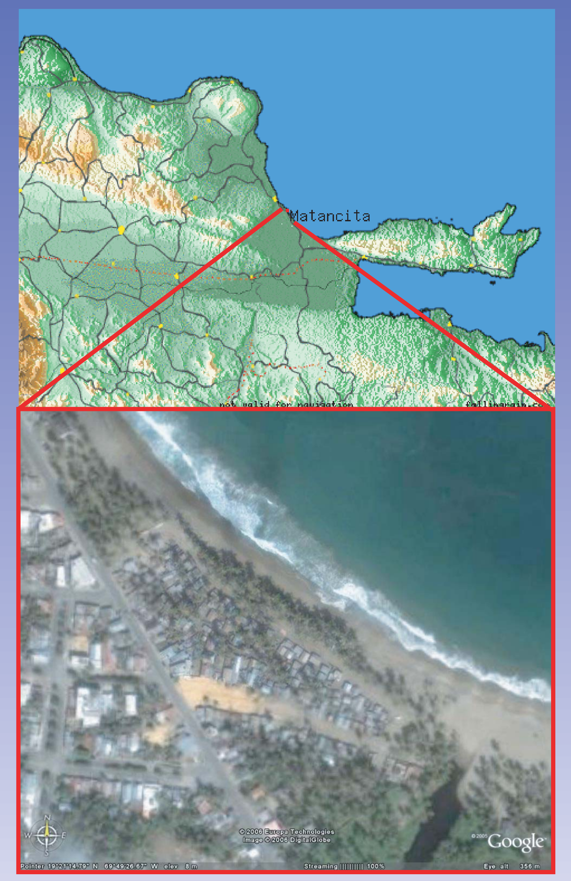
Although initial magnitude estimates for the Alaska-Aleutians event and the Hispaniola event were on the same range of Ms ~7 (*Gutenberg and Richter, 1954*) the latter did not resulted in the generation of an oceanwide tsunami, but rather a regional one. However, the casualties reported in the near field have been estimated to 1800, considerably more than those estimated for near and far-field combined for the Aleutians. More important is that the genesis of the tsunami, to this date, is uncertain. Was the tsunami generated by source dislocation, or was it a landslide on the northeastern corner of Hispaniola that was triggered by the earthquake? Literature regarding this particular event is limited, however, studies by *Gutenberg and Richter (1954)*, *Kelleher et. al. (1973)*, *Pacheco and Sykes (1992)*, *Russo and Villaseñor (1995)*, and *Dolan and Wald (1998)* estimated values of Ms varying from 7.8 to 8.1, an epicenter located south of the Samaná Peninsula at 20 km depth and dimensions of the rupture zones in the range of 200 x 100 km. Despite all these studies, the seismic moment of the event was never computed.



Descriptions of the effects of the tsunami are minimal. The only ones available are those of *Lynch and Bodle (1948)* and *Small (1948)*, who visited the island one month after the occurrence of the earthquake and made a visual inspection of the damages. Speculations based on the configuration of structures and the resulting location of the collapsed parts lead them to suggest an epicenter 40 miles offshore due northeast. According to the survey, the most affected area was the town of Matancitas where possibly more than 100 people drowned as a result of the tsunami. They do not give abundant details at this location, other than the town was abandoned as a result of 2.5 meter waves inundating for several kilometers inland due to the low beach relief. *Small (1948)* reported the tsunami reached the northern coastal areas of Matancitas to Cabreras and the cliffs of the northern Samaná peninsula with waves of 4 to 5 meters in height propagating from north to south.



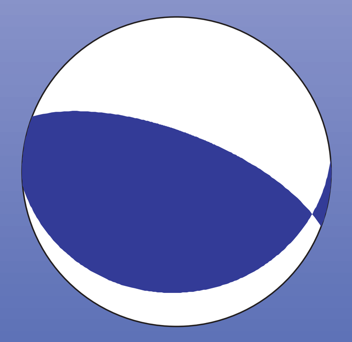
Location and fault area dimensions of major historical earthquakes in the Northern Caribbean Plate Boundary Zone (NCPBZ) taken from Figure 2 of *Dolan and Wald (1998)*. Eastern banks of the Great Bahamas Bank: Caicos (CB), Mouchoir (Mo), Silver (S) and Navidad (N). EPGFZ is the Enriquillo Plantain Garden Fault Zone, LMDB is the Los Muertos Deformed Belt, SDB is the Santiago Deformed Belt, NPRSFZ is the North Puerto Rico Slope Fault zone and MP is the Mona Passage.



Top: Map view of the location of the town of Matancitas in northeastern Domincan Republic. Bottom: Aerial photo of the area swept by the tsunami. Alegedly, around 1800 people lived in this coastal community when the tsunami struck. Despite the high casualties, people have retruned to build near the shore (Photocredit Google Earth).

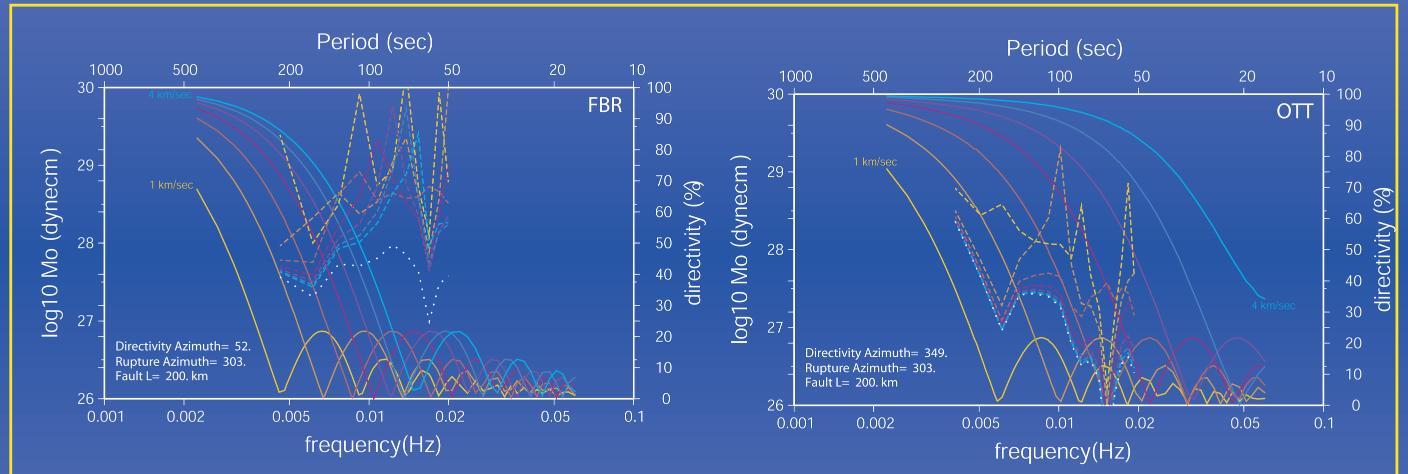
Russo and Villaseñor (1995)

Considered the most comprehensive study on the subject, *Russo and Villaseñor (1995)* re-localized the main shock and 63 aftershocks, estimated a rupture zone very much similar to that of *Kelleher et al. (1973)* and interpreted a spline fault dipping northeast as the causative fault. Their focal mechanism: 303, 62, 74 was obtained through two independent methods: seismogram wave arrival information and waveform modeling. Although they could not obtain decent waveform matching for the mainshock, they could use the fit of shapes of polarities of ***P*** and ***SH*** waveforms to constrain the depth at 20 km.

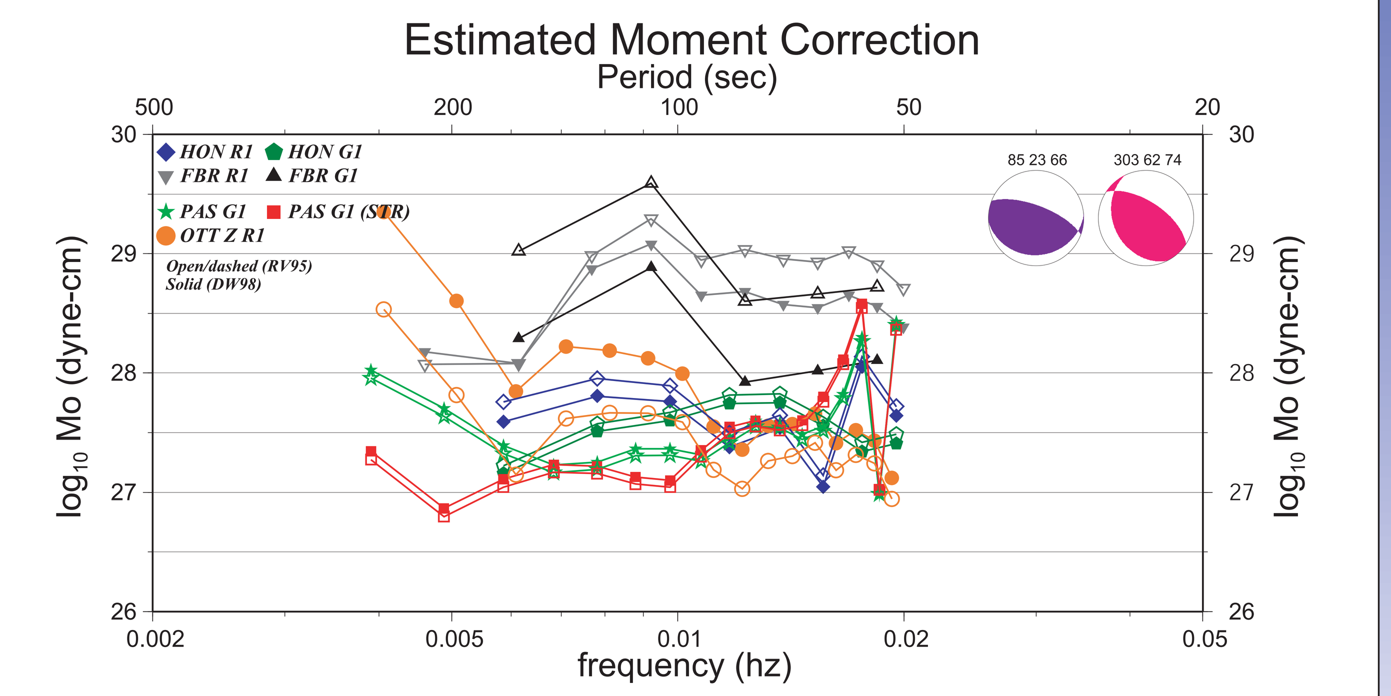


Dolan and Wald (1998)

Dolan and Wald (1998) did not find the interpretations of *Russo and Villaseñor (1995)* [RV95 for short] convincing and hence, developed their own focal mechanism (85,23,66) to postulate a different interpretation. Since the steeply northeast nodal plane can be well identified by wave arrivals they used body wave inversion to solve for the strike of the shallow southeast dipping plane, which they would use as their causative fault plane. Although their fault plane is in the vicinity of the auxiliary plane of RV95, they suggest the event reflects shallow southwest thrusting of North America beneath Caribbean instead of the event occurring on a steep splay fault, which would not be capable of accommodating a wide aftershock zone, rupture the surface and propagate downdip.

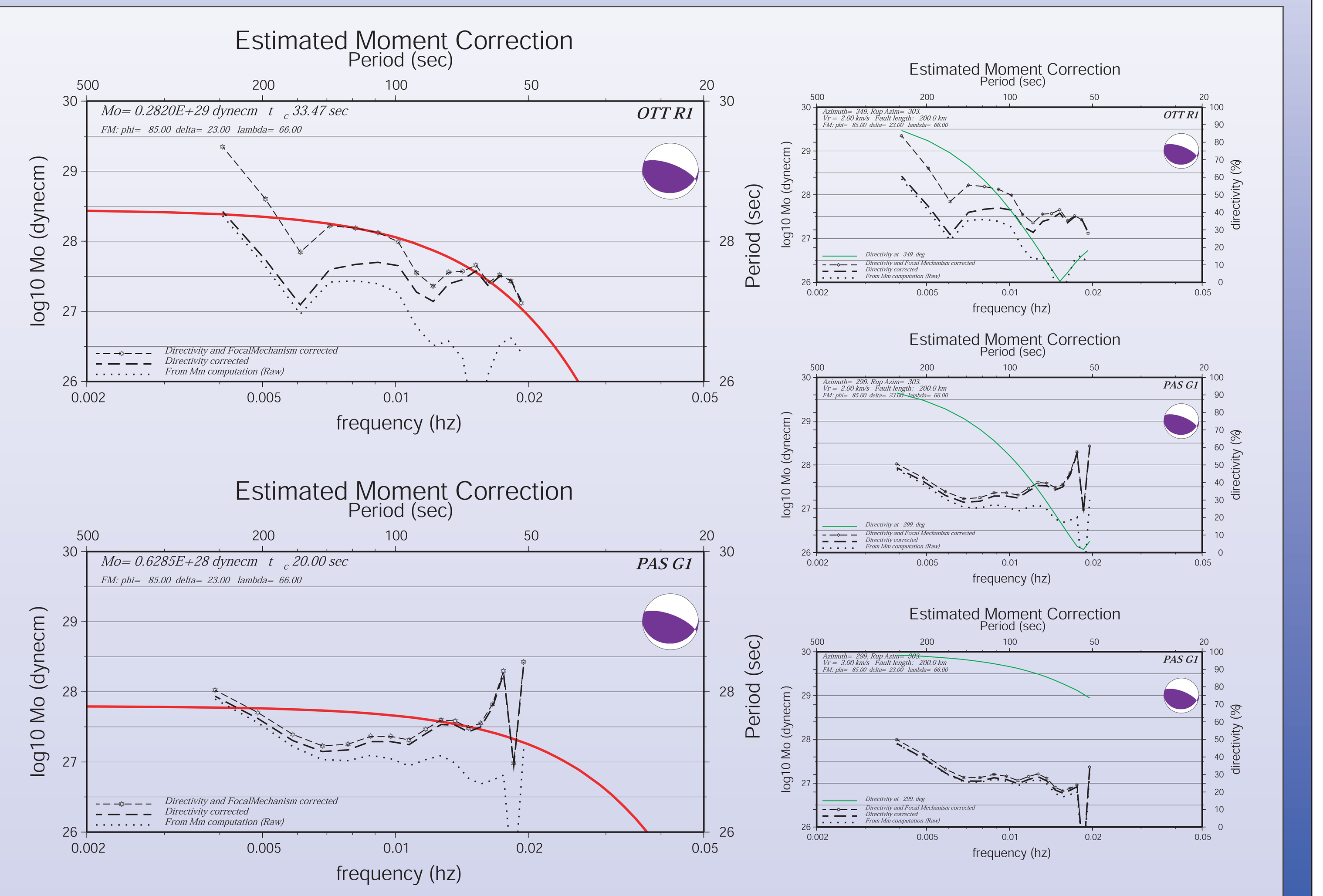


First step in correcting M_0 is to account for directivity effects. We used a rupture azimuth of 303°, which roughly corresponds to the regional trend of the Northern Hispaniola Deformed Belt. This simple calculation shows how a variation in rupture velocity (V_r) from 1-4 km/s (in 0.5 km/s increments) may impact the raw M_M measurements (dotted white line). FBR, more than 90° away from rupture azimuth is directivity defficient at longer periods for faster velocities, whereas OTT, with an azimuth closer to the rupture propagation direction, is not as affected. Notice how a V_r of 2 km/sec corrects for the spectral hole observed at both R_1 raw M_M values.

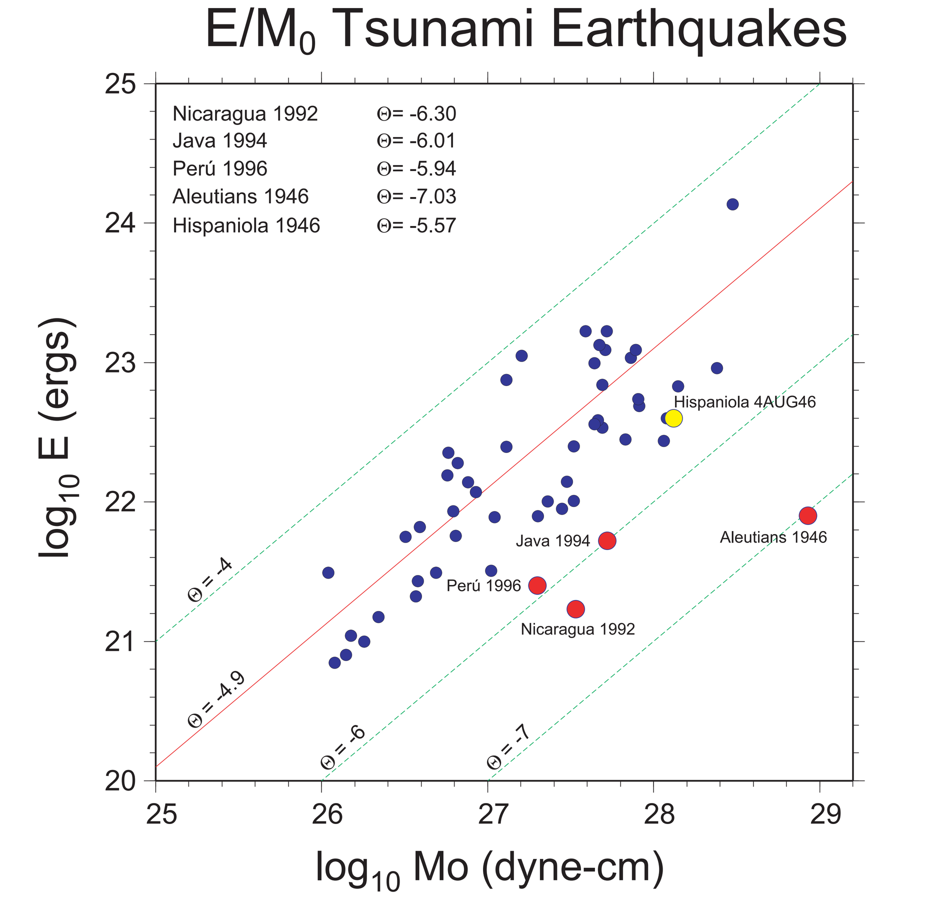


Second and final step in correcting M_0 is to account for focal mechanism by considering the detailed effect of the fault geometry. This figure compares how the two published focal mechanisms affect the directivity-corrected M_M. The fact that FBR is higher is due to both,the directivity effect and the focal mechanism of *Russo and Villaseñor* (1995) [shown in red], which favors a higher correction. When all the data shown here is used, we obtain a seismic moment of 1.7 x 10^{28} dyne-cm. However, if we exclude FBR from the computations an average M_0 of 1 x 10^{28} dyne-cm is obtained. Unfortunately, we do not have any other record at the moment from stations in Europe or in South America to corroborate FBR's estimates.

Although *Russo and Villaseñor (1995)* obtained seismic moments for some of the aftershocks, they could not estimate one for the main event. Furthermore, it was unknown whether this event caused the tsunami by featuring a slow rupture velocity, as it was the case of the Alaska-Aleutians April 1, 1946 event (*López and Okal, 2006*). Hence, we digitize available, good quality seismograms, and followed procedures of *Okal and Talandier (1989)* and *Newman and Okal (1998)* to estimate the seismic moment (M_0) via mantle magnitude (M_M) computations and radiated energy (E^E), respectively. To obtain the seismic moment we used first passage of Love and Rayleigh surface waves at Pasadena (PAS), Honolulu (HON), Ottawa (OTT), Tucson (TUO) and Barcelona (FBR). To estimate radiated energy we used *P* waves of stations PAS, TUO and OTT.



Examples of M_0 corrections for OTT R_1 and PAS G_1 using the focal mechanism of *Dolan and Wald* (1998). Figures at left show a best-fitting static Moment M_0 (solid red curve) obtained by using the algorithm of *Silver and Jordan* (1983) applied upon the directivity and focal mechanism corrected M_M curve (thin dashed line). Figures on the right column show the different corrections to the raw M_M analysis (dotted line): {1} Correction due to directivity effects (bold dashed line) by observing the variation in directivity with frequency at particular stations, and {2} Focal mechanism. The thin red line in the upper two graphs represent a rupture velocity (V_r) of 2 km/sec, whereas the bottom one, corresponds to a 3 km/sec. The fit of V_r of 2 km/sec at the spectral hole observed in PAS, OTT and TUO suggests the Hispaniola August 4, 1946 was not a slow earthquake.



Once the seismic moment and the estimated energy released are obtained, the ratio of these two values, better known as the Theta (Θ) parameter (*Newman and Okal, 1998*), is used to describe the slowness of a seismic source. Regular events (blue circles) have $-5.62 < \Theta < -4.5$, whereas slow events such as "tsunami earthquakes" (red circles) feature $\Theta < -6$. Using the values computed here, the Hispaniola August 4, 1946 event has a Θ of -5.57 (yellow circle), thus falling in the domain of "mainstream population". Therefore, the characteristics of this event, albeit close to the domain boundary, is that of a normal subduction event with no apparent slowness.

CONCLUSIONS

Previous works on the Hispaniola August 4, 1946 earthquake left unresolved the seismic moment of the earthquake and its relation to a devastating tsunami. Here, we have computed the seismic moment and estimated energy release by digitizing usable historical seismograms of the event. Unfortunately, the majority of stations used are in the propagation direction, due WNW. Hence, these preliminary results need to be supplemented with other stations in hopes of corroborating whether the estimates found at Barcelona are real. A rupture velocity of 2 km/sec has been obtained by fitting the directivity function with a prominent spectral hole observed at stations PAS, OTT and TUO. Static moment estimates were obtained by a best-fit curve to raw mantle magnitude computations that were corrected for directivity effects and focal geometry. Hence, the average seismic moment used is 1.5 x 10^{28} dyne-cm, whereas the computed estimated radiated energy averages 4 x 10^{22} ergs. With these values, we obtain a Θ of -5.57, which indicates the event is neither a "tsunami earthquakes" (slow event) nor a tsunamigenic event, and hence, we propose that it does not have a direct relation with the generation of the tsunami, but rather it may have triggered a submarine landslide that affected locally the Matancitas area. High resolution multichannel bathymetry of the area is necessary to corroborate these suggestions.

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