Source characteristics and the mechanism of intermediate-depth earthquakes

Germán A. Prieto
Universidad de Los Andes, Colombia

Abstract

The physical mechanism of intermediate-depth earthquakes is still under debate. In contrast to conditions in the crust and shallow lithosphere, at temperatures and pressures corresponding to depths >50 km one would expect rocks to yield by creep or flow and not by brittle failure, so there has to be a physical mechanism that allows for brittle or brittle-like failure for intermediate-depth earthquakes. Two such mechanisms have been proposed: dehydration embrittlement and thermal shear runaway.

Earthquake nests represent a region with high earthquake concentration that is isolated from nearby activity. Here I present general observations on the famous intermediate-depth earthquake Bucaramanga nest. Large amounts of high-quality and high-resolution seismological observations (tectonic setting, precise earthquake locations, focal mechanisms, stress drops, etc.) may provide key constraints on the mechanism responsible. Given the nature and characteristics of this nest, it can be thought as natural laboratory for understanding the physics of intermediate-depth earthquakes.

Earthquake Nests and Tectonics Setting

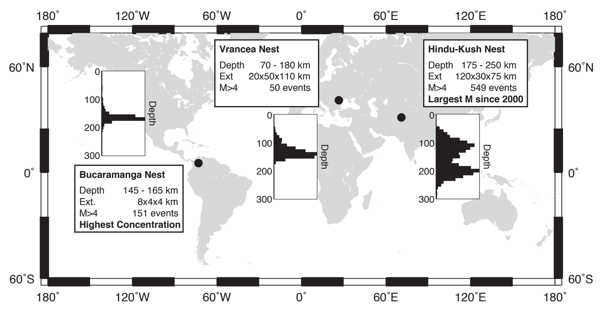

Figure 1 (Left). Global map with locations of well-known earthquake nests and general characteristics.

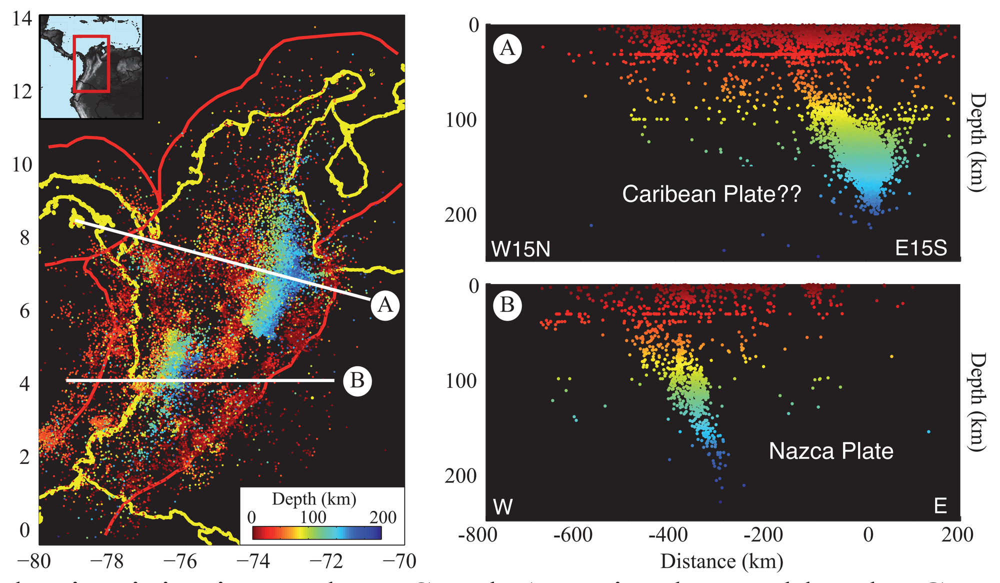

Figure 1 (Right). Map view of regional seismicity in northern South America located by the Colombian Seismic Network (RSNC). Cross sections A and B show two major (independent?) subduction-like features interpreted as being associated with the Caribbean plate (A) and the Nazca Plate plate (B).

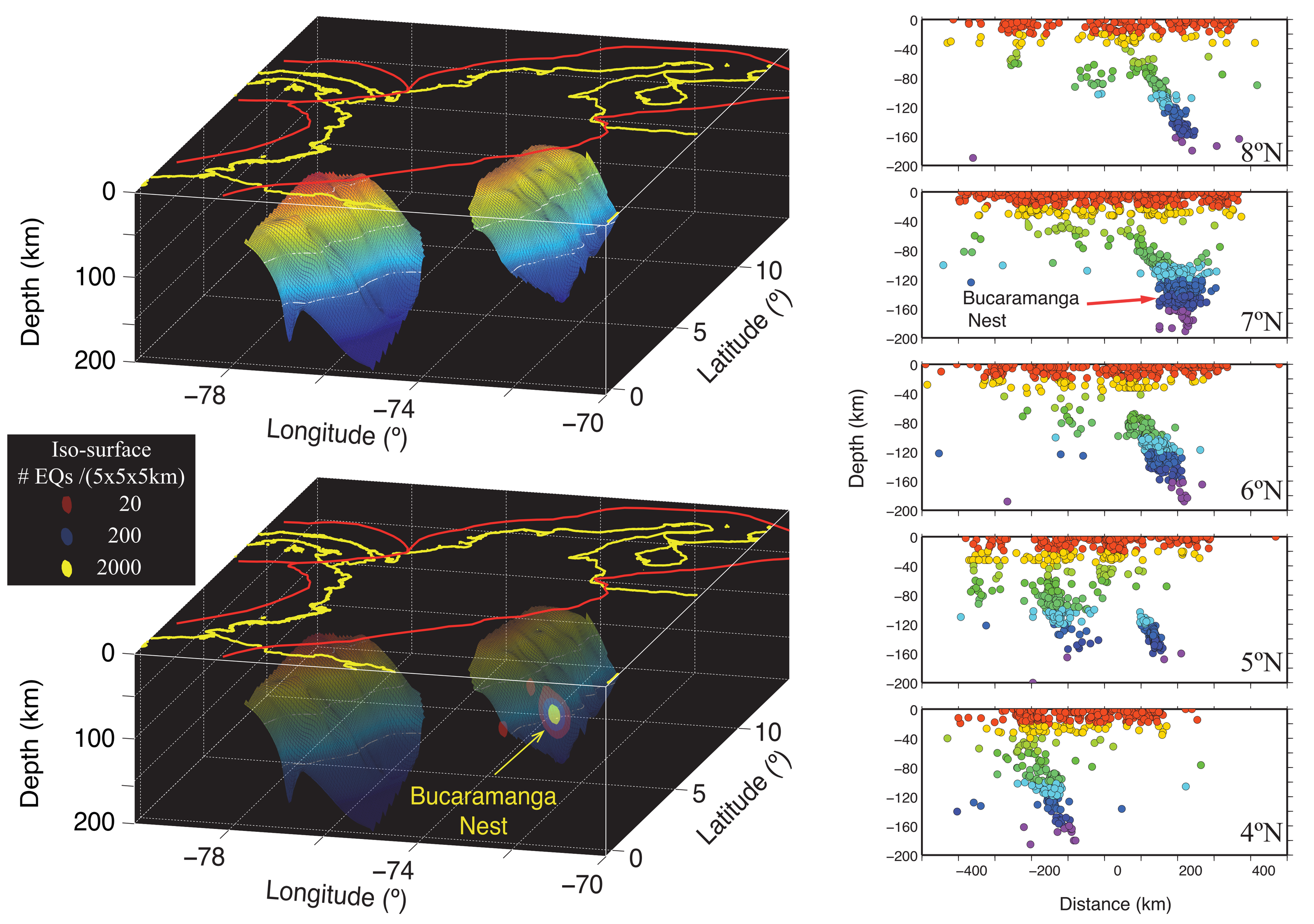

Figure 2. Earthquake density and cross-sections. 3D maps (left) of top of the Benioff zone estimated from the earthquake locations in Figure 1. Bottom panel shows earthquake density over a period of 12 years. The Bucarmanga nest is clearly visible inside the volume with over 2.000 earthquakes in a 5 km radius. Cross sections (right) of seismicity showing the location of the Bucaramanga nest.

Earthquake locations using hypoDD

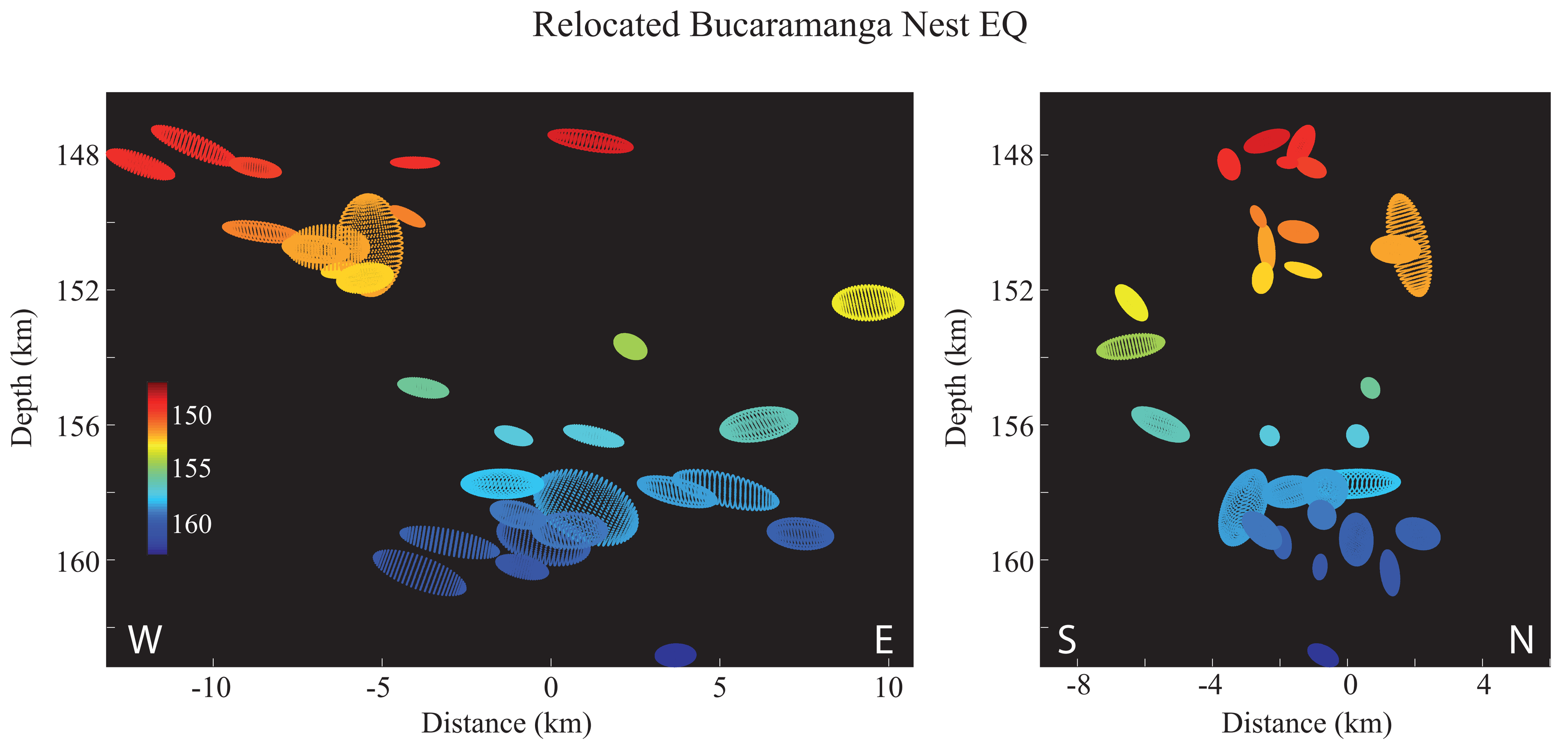

Figure 3. Relocated earthquakes using double-difference algorithms. E-W and N-S cross sections across the Bucaramanga nest for earthquakes M>4.0 and small location uncertainty. Ellipses represent 95% confidence region. The locations suggest that the Bucaramanga nest is not a cloud of seismic activity but that at least the larger earthquakes preferentially locate along sub-horizontal planes of concentrated seismicity, maybe related to pre-existing structures.

Earthquake focal mechanisms and repeating earthquakes

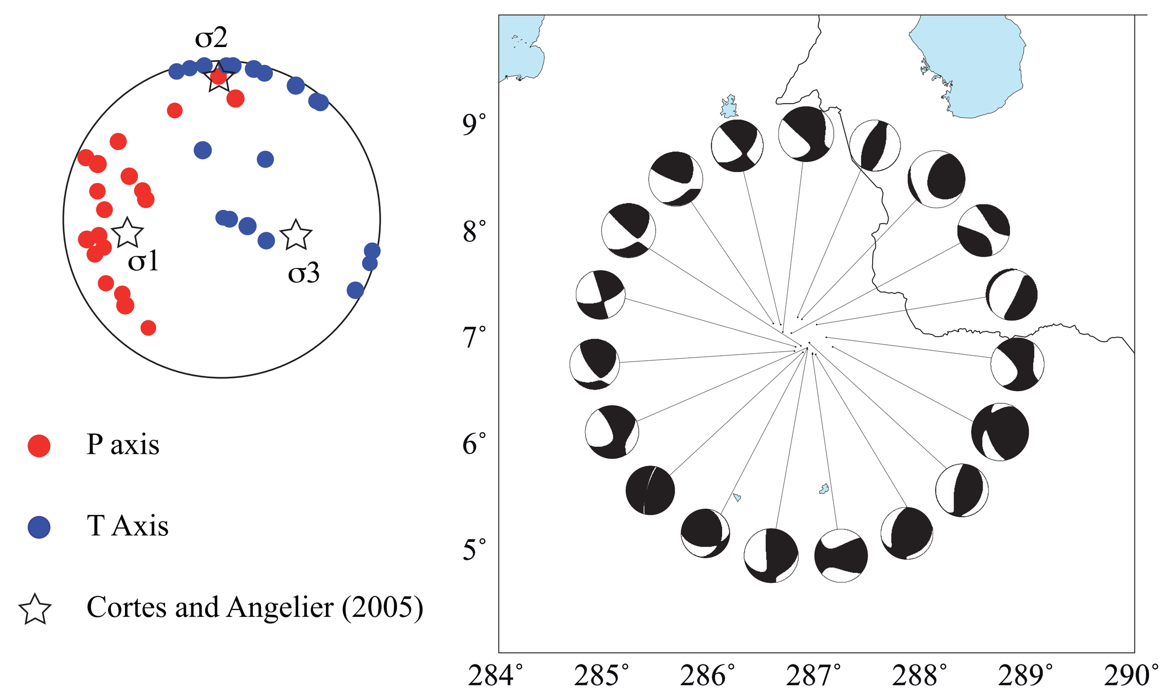

Figure 4 CMT focal mechanisms Left panel shows the P and T axis of these focal mechanisms and the estimated principal directions of stress as estimated from Cortes and Angelier (2005) with down dip extension. Note the widely variable focal mechanisms present in the 19 earthquakes shown in the map, with reverse, normal and strike-slip faulting on a very tight volume

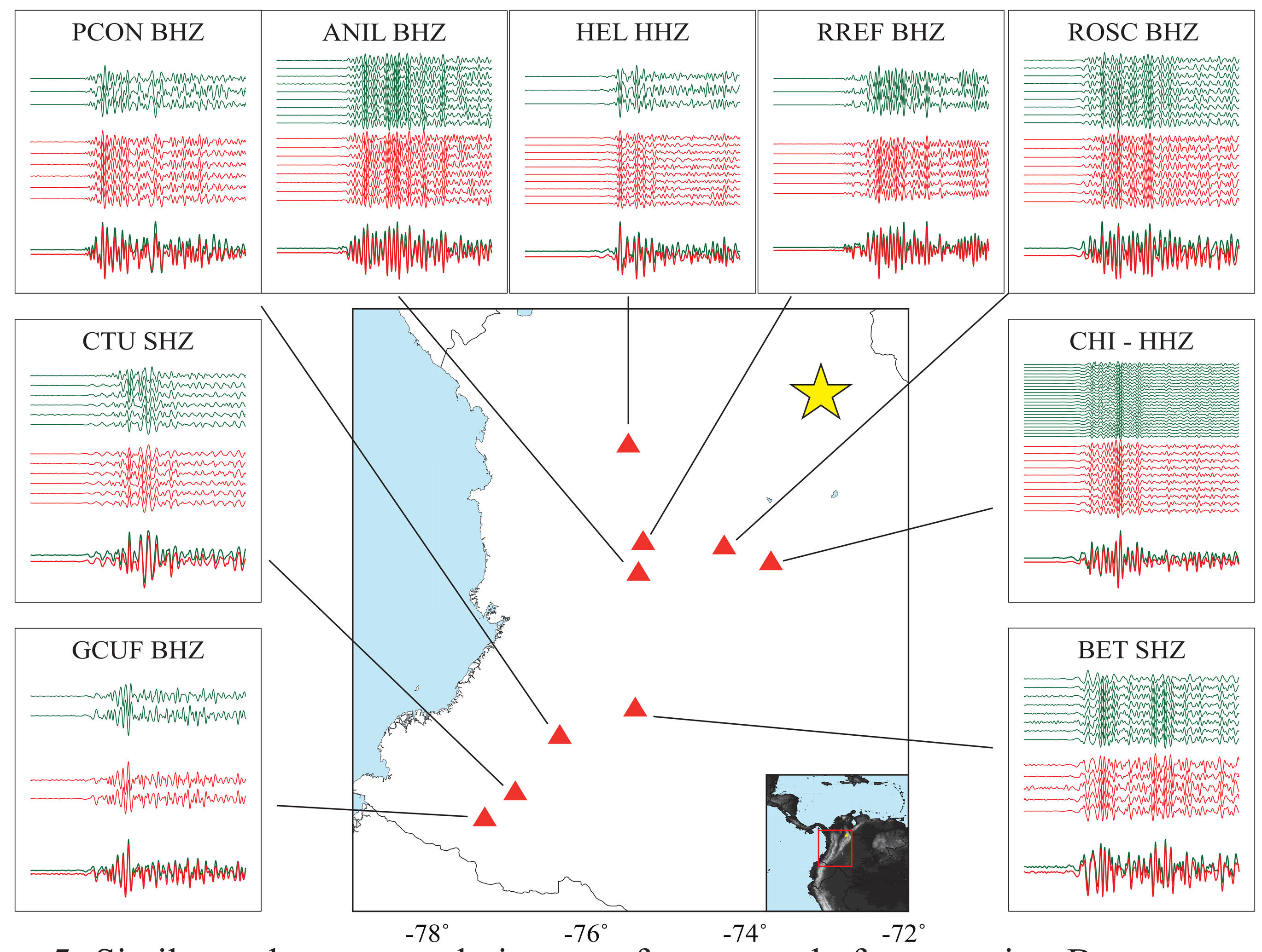

Figure 5. Similar and reverse polarity waveform records for repeating Bucaramanga nest earthquakes (yellow star). Records at multiple stations of similar waveforms (CC>0.9 in at least 5 stations) with respect to a "master" event (ID 63214). For each panel green waveforms represent waveforms with reverse polarity, while red waveforms have equal polarity. Bottom signals (thick waveforms) represent the stack of the reverse and normal polarity waveforms (note that green stack has been flipped for comparison purposes).

Stress drops and radiation efficiency

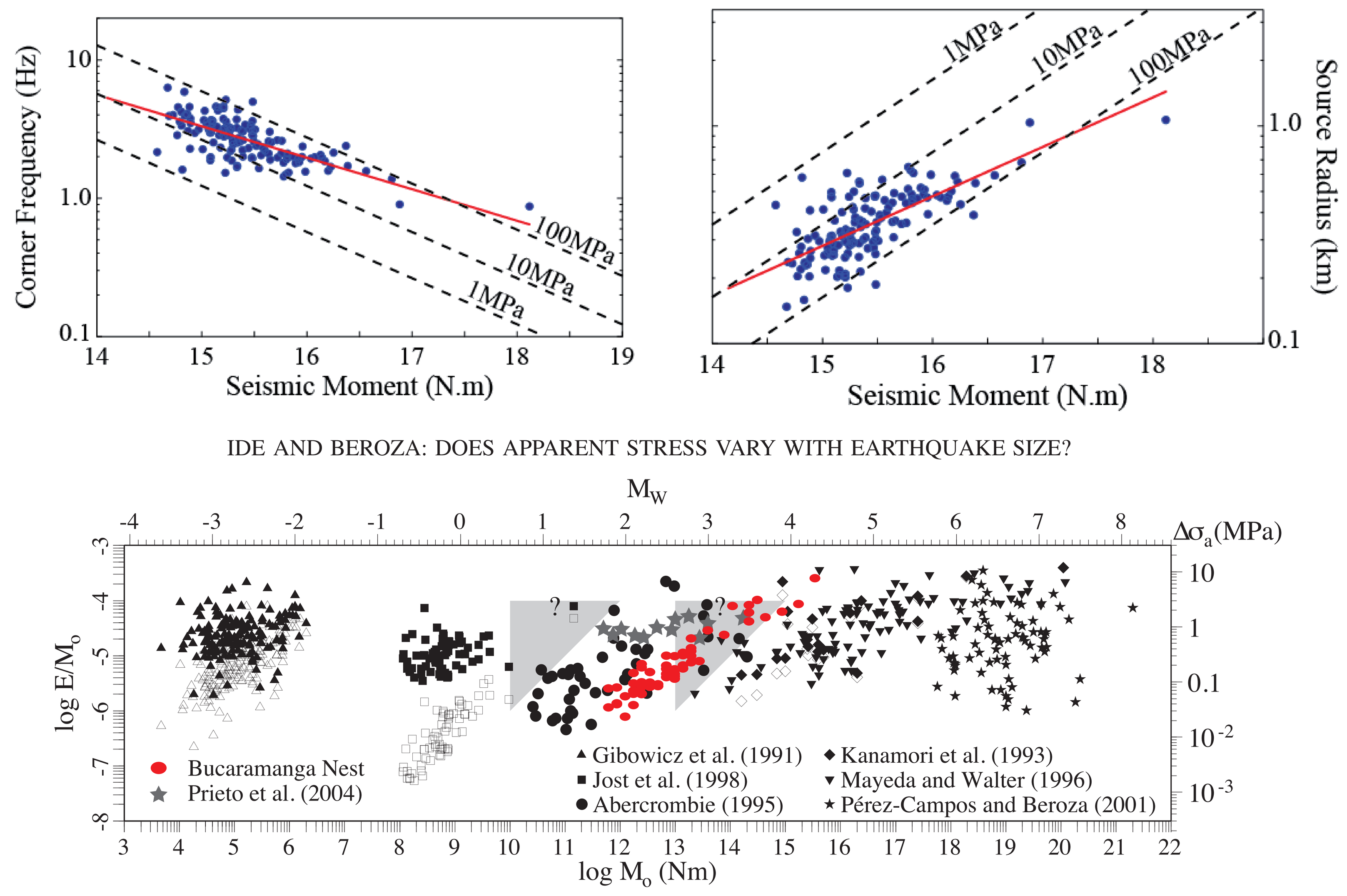

Figure 6. Spectral estimatesof earthquake source parameters from broadband seismic records of nest earthquakes. Corner frequency is directly estimated from the source spectrum after accounting for path effects. Source radius based on Madariaga, assuming a 0.9b rupture speeds show small rupture sizes and thus have very large stress drops (average of 30MPa). Estimated scaled radiated energy is similar to shallow earthquakes suggesting a very low seismic efficiency for these earthquakes.

Conclusions

Bucaramanga Nest related to subducting Caribbean Plate
Bucaramanga Nest shows linear trend in relocated earthquakes
Larger number of repeating & "anti-repeating" earthquakes observed
High stress drops, with small seismic efficiencies.

Observed results may help better constraint the physical mechanism of intermediate-depth earthquakes.