Constraints on Post-Glacial Seismic Activity of Southern New York from Precarious Balanced Glacial Boulders

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Precariously Balanced Rocks (PBRs) in Harriman State Park have survived an unknown number of seismic events since their deposition during the deglaciation at the end of the Pleistocene. The maximum magnitude of prehistoric earthquakes in the Ramapo fault region are unknown, though analysis of PBRs provides constraint on the resulting horizontal ground accelerations that the PBR experienced. We photographed assumed PBRs on the hillside at the Black Rock Mountain (BRM) site and West Mountain (WM) site in Harriman SP, and used photogrammetry to develop 3D models of them. We calculated the position of their center of mass and determined the minimum horizontal acceleration needed to tip over the boulder using quasi-static analysis. These boulders have not experienced horizontal ground accelerations greater than 0.4-0.5g, consistent with the definition of a semi-PBR. Additionally, we calculated the horizontal ground acceleration needed to overcome static friction for two Precariously Perched Rocks (PPRs) high on hillsides at the BRM site, using measurements of the slope of the rock pavements on which they stand. The PPRs at the BRM site did not experience accelerations of more than 0.3g since coming to rest near the peak of their respective slopes. Previously published seismic attenuation curves indicate that all these boulders would have survived a nearby earthquake of magnitude 6, but would have slid in a magnitude 7 (e.g. rupture of a 40 km segment of the Ramapo fault) and therefore rule out the latter. This establishes an upper limit of less than one magnitude 7.0 earthquake on the Ramapo fault per 17-20 thousand years. Future work may be able to establish an upper limit of the rate of earthquakes of magnitude 6, for many other apparent PBRs and PPRs were inventoried but not studied in detail.