Using Bayesian seismic refraction and electrical resistivity to study critical zone science and near-surface geophysics

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The critical zone (CZ) is the region of the Earth's surface that extends from the bottom of the weathered bedrock to the tree canopy and is important because of its ability to store water and support ecosystems. A growing number of studies use active source shallow seismic refraction and electrical resistivity to explore CZ structure, including depth to saprotile-bedrock transition and porosity distribution across landscapes. However, measurement uncertainty and model resolution at depth are generally not evaluated, which makes the identification and interpretation of CZ features inconclusive. To reliably resolve seismic velocity with depth, we implement a Transdimensional Hierarchical Bayesian (THB) framework with reversible-jump Markov Chain Monte Carlo to generate samples from the posterior distribution of velocity structures. We explore the velocity structure in a sedimentary ridge-valley system in Rancho Venada (RV), northern California and a granodioritic plateau in Utuado, central Puerto Rico. At RV, the posterior distribution of velocity models shows an increasing thickness of low velocity material from channels to ridgetops along a transect parallel to bedding strike, implying a deeper weathering zone below ridgetops and hillslopes than below channels. In Utuado, the weathering front is generally deep on the plateau and shallow on the steep hillslopes. We find that topographic relief on the plateau is about the same as the critical zone, suggesting that depth to saprolite-bedrock transition sets the maximum depth where material can be transported laterally. Electrical resistivity surveys in Utuado indicate overall an increase in saturation towards channels. Field studies presented in this work demonstrate the ability to reliably use Bayesian inversion to image and interpret CZ structure as well as other near-surface geophysics studies.

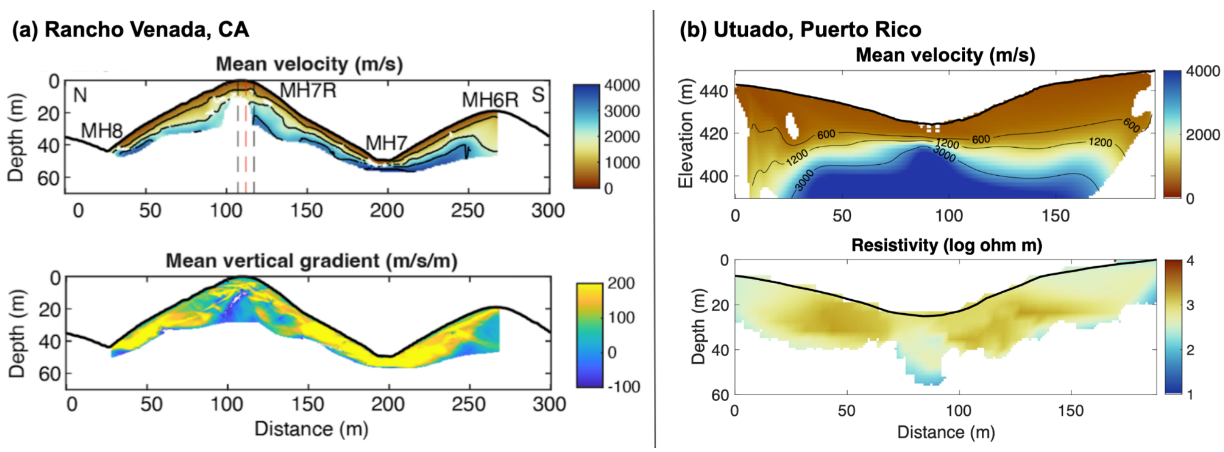

Figure 1. Study sites in **(a)** Rancho Venada, northern California and **(b)** Utuado plateau, Puerto Rico. **(a)** Mean velocity indicates velocity increases to 3000 m/s more than 20 m below the ridgetops (MH6R & MH7R), but < 5 m below the channels (MH7 & MH8). Vertical gradient shows a transition zone with rapid velocity increase that is sub-parallel to the ground surface. **(b)** Mean velocity shows a thick low velocity (< 600 m/s) zone below the channel elevation, and rapidly increased to 3000 m/s about 30 m below the ground surface. The electrical resistivity result shows a decrease of resistivity at shallower depth from hillslopes towards the channel. For both sites, regions with low model resolution are masked out.