Linking Aqueous Sedimentary Processes to Earthquake Recurrence Models

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A primary paleoseismologic observational constraint on earthquake recurrence comes from turbidites, which are characteristic stratified coarse-to-fine-grained deposits left behind by seismically triggered, sub-aqueous, sediment gravity flows (that sometimes become turbidity currents). Linkage to causative earthquake shaking relies on demonstrating synchronous initiation of sediment gravity flows across a rupture zone. Synchroneity may be inferred from overlapping deposit ages and/or correlation of sedimentological and stratigraphic turbidite characteristics. However, transport and depositional features commonly vary greatly spatially, rendering correlation uncertain and subjective. Depositional ages have uncertainties on the order of decades or more. We re-evaluate previously correlated turbidite facies in core photographs and X-Ray computed tomography images from the Cascadia subduction zone and present a new more objective and repeatable approach to correlate turbidites. We use a dynamic time warping (DTW) optimization algorithm to correlate pairs of Cascadia sediment core magnetic susceptibility logs, providing quantitative measures of correlation. To assess correlation significance, we compare these correlation metrics to those derived from distributions of randomly generated turbidite sequences and find that only a small number of core pairs can be more confidently correlated than randomly stacked turbidites. On the basis of a subset of the photographs, CT images, and their depositional provinces, our careful (albeit) qualitative examination of the turbidite stratigraphic characteristics corroborates the DTW results.

Going forward, a variety of paths may lead to greater confidence in earthquake recurrence models based on turbidite paleoseismology. Increasing the spatial sampling of core stratigraphy while using cores from more densely spaced sites (separated by km or less) should improve correlation of turbidite characteristics and increase confidence in tests of synchronous turbidite initiation and deposition. In Cascadia and elsewhere, thick turbiditic homogeneous mud layers sometimes overlie the more commonly correlated stratified turbidite deposits. These mud caps have been inferred to be indicative of sediment mobilization by low-frequency, long-wavelength shaking radiated by very large earthquakes, and/or by sediment ponding in enclosed basins. Their use as correlative turbidite characteristics for paleoseismology has been underexplored and they may provide new constraints on earthquake spectra and sizes. Our approach developed for

Cascadia of combining quantitative DTW analyses with corroboration by careful qualitative evaluations may provide more definitive results by expanding the DTW analysis to include X-ray and photographic imagery. Even more informative results may come from applying this approach in lacustrine settings, where age uncertainties are fewer, and denser sediment, bathymetric, and subsurface samplings are more feasible than in marine ones. Finally, instrumental measurements and simulations of seismic shaking on the seafloor (e.g., as from the Japanese S-Net or DONET cabled arrays) or lake-bottoms, coupled with water column measurements of sediment flows (or lack of), will provide more direct constraints on the relations between shaking and flows than do deposits formed hundreds to thousands of years ago. Even in the absence of sediment flow observations, modern seafloor or lake-bottom data may be used to distinguish site and source effects, which is key when making paleoseismic inferences.