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Seismic strengthening of diatom-rich sediments: A comparison of slope sediments from Chilean lakes and the Japan Trench margin

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Earthquakes are a main trigger of subaqueous landslides and surficial sediment remobilization at ocean margins and lake basins. If the earthquake loading is insufficient to lead to sediment failure, the subsequent dewatering and inherent compaction may enhance the shear strength of sedimentary slopes, a process termed „seismic strengthening“, which is believed to be especially relevant for the upper 10s of meters. This mechanism has been suggested to explain the observed paucity of submarine landslides on active margins when compared to the short recurrence of strong earthquakes in such settings. However, only few field studies were dedicated on this topic and little is known about which settings are especially prone to seismic strengthening.

Here, we present geotechnical data from diatom-rich sedimentary slopes in Chilean lakes and at the Japan Trench margin. We use the overburden-normalized undrained shear strength as an indicator of consolidation state. In Chile, this data is derived from in-situ dynamic cone penetrometer measurements, whereas the Japan data is obtained by lab vane shear tests on sediment cores. Both settings show extremely elevated shear strength of about ~5-10 times higher than expected for normally-consolidated sediment in the upper meters of a sequence. Significant overconsolidation is confirmed by one-dimensional compression tests, providing overconsolidation ratios of ~2-8 (Chilean lakes) and 4-9 (Japan Trench). For each setting, the shear strength profiles of sites with different sedimentation rates show very similar trends when they are normalized over the sediment age instead of over overburden stress. As older sediments experienced more earthquakes, this apparent age-dependency may form a new argument supporting the hypothesis of seismic strengthening. Following previous lab experiments on mixtures of diatoms and clayey-silt, we postulate that a high susceptibility to seismic strengthening in both settings is caused by the abundance of diatom frustules which are typically characterized by a high particle interlocking and surface roughness. On the Japan Trench margin, biogenic opal forms ~15% in dry weight, and given the hollow structure of diatom frustules, we infer that diatoms take up a considerable space in the in-situ sediment texture. We conclude that seismically active margins with diatom-rich sediments have a reduced susceptibility to submarine landslide hazards.