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Creeping deformation mechanisms for mixed hydrate-sediment submarine landslides

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Globally widespread gas hydrates are proposed to stabilize the seafloor by increasing sediment peak shear strength; while seafloor failure localises at the base of the gas hydrate stability field (BGHS). The primary mechanism by which gas hydrates are proposed to induce slope failure is by temperature or pressure controlled dissociation of hydrate to free gas resulting in a significant pore pressure increase at the BGHS. Direct evidence for this process is lacking however, and the interaction between gas hydrate and seafloor stability remains poorly understood. We present evidence that, contrary to conventional views, gas hydrate can itself destabilize the seafloor. Morphological (Kongsberg-Simrad EM300 and EM302 multibeam) and high-resolution multichannel seismic refection data from a 100 km2 submarine landslide complex in ∼450 m water depth, 20 km off the east coast of New Zealand indicate flow-like deformation within gas hydrate-bearing sediments. This “creeping” deformation occurs immediately downslope of where the BGHS reaches the seafloor, as indicated by a hydrate-indicating bottom simulating reflector (BSR) cutting through the landslide debris, suggesting involvement of gas hydrates.

We propose two mechanisms to explain how the shallow gas hydrate system could control these landslides. 1) The Hydrate Valve: Overpressure and/or temperature fluctuations below low-permeability gas hydrate-bearing sediments causes hydrofracturing where the BGHS approaches the landslide base, both weakening sediments and creating a valve for transferring excess pore pressure into the upper landslide body. 2) Hydrate-sediment Glacier: Gas hydrate-bearing sediment exhibits time-dependent plastic deformation enabling glacial-style deformation. This second hypothesis is supported by recent laboratory observations of time-dependent behaviour of gas-hydrate-bearing sands. Given the ubiquitous occurrence of gas hydrates on continental slopes, our results may require a re-evaluation of slope stability following future climate-forced variation in bottom water temperatures.