

Rapid early- to mid-Holocene thinning of Pine Island Glacier detected using cosmogenic exposure dating

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The West Antarctic Ice Sheet is thought to be inherently unstable and has the potential to contribute up to 3.3 metres to sea level rise. Recent years have seen dramatic rates of thinning of major ice streams flowing into the Amundsen Sea, and in particular Pine Island Glacier. Onshore measurements of these changes are restricted to decadal timescales and in particular the satellite era, which makes it difficult to judge their significance and whether such changes are unprecedented. One way to place these events in a longer-term context is to study the geological record of past ice sheet change. This approach also provides data that are critical for building reliable ice sheet models that will predict the magnitude and timing of sea level change.

Recent advances in exposure dating afford new approaches for dating Holocene ice sheet thinning: we present the first study combining precise ¹⁰Be and in-situ ¹⁴C surface exposure ages from Antarctica. We used glacially-transported erratic cobbles as a vertical 'dipstick' for tracing past fluctuations in thickness of the West Antarctic Ice Sheet, focusing on the lower elevations of three nunataks in the Hudson Mountains (immediately north of Pine Island Glacier and close to its present-day grounding line). Exposure ages from the lowermost 100 m of two nunataks (Mt Moses and Maish Nunatak) suggest that rapid thinning was sustained there over a few hundred years in the early- to mid-Holocene, and brought the ice sheet surface close to its present elevation by ~6 ka. We also report exposure ages from within 40 m of the modern ice surface at Meyers Nunatak.

Formation of the Si-rich layer on olivine surfaces during carbonation under *in-situ* conditions

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Olivine dissolution releases divalent cations (Mg²⁺, Fe²⁺) into solution and in the presence of dissolved CO₂ will result in the precipitation of carbonate minerals. This process, known as mineral carbonation, has the potential to safely store CO₂ in the subsurface over geologic time. Although the reaction is thermodynamically favored and occurs naturally, the kinetics are typically slow at temperatures < 100°C and thus limit industrial applications of the process. Previous results from this group and others have shown that the dissolution rate of olivine drops over two orders of magnitude as the reaction solution approaches saturation with respect to amorphous silica (a by-product of metal silicate carbonation). This study aims to understand why and how the rate drop occurs, using a series of batch reactions in a three-phase system (water, solid, and supercritical CO₂) at conditions relevant to in-situ carbonation (60°C, 100 bar P_{CO2}). Analysis of the mineral reaction products indicates the formation of a Si-rich, Mg-depleted layer on the olivine surface as soon as 2 days after reaction is started and before the bulk solution reaches silica saturation. Ion probe analysis of olivine grain surfaces produced by reaction with a ²⁹Si-spiked, CO₂-containing aqueous solution suggests that a Si-rich layer up to 1.5 μm deep forms on the grain surfaces, and that after 2 weeks of reaction this layer is primarily due to preferential removal of cations (leaching) rather than re-precipitation of silica. At t<20 days and pH<5, the Si-rich layer appears to control the rate of olivine dissolution. After 20 days, the layer no longer controls the dissolution rate, the rate increases, and carbonation occurs. Although Mg-carbonate precipitation requires significant oversaturation with respect to magnesite, the overall rate-limiting step for olivine carbonation as measured in our experiments involves the formation and subsequent break-down of the Si-rich layer. Current work is aimed at preventing the formation of the leached layer.