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Camp Century ice core basal sediments record the absence of the Greenland Ice Sheet within the last million years

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The Greenland Ice Sheet (GrIS) is melting in response to a rapidly warming climate. It is imperative to understand GrIS sensitivity to past climate, especially during periods when the ice sheet was smaller than present or possibly absent. The Camp Century ice core from NW Greenland, collected in 1966 and the first ice core to be drilled to the bed of the GrIS, revolutionized our understanding of global paleoclimate since 125 ka. However, basal sediment from the ice core was not fully explored and then sat in storage for decades – until it was re-discovered two years ago. We are now investigating these unique samples from the sub-glacial environment using modern analyses.

Here, we present initial results from two samples, the upper and lower portions of >4 m of basal sediment. We applied an array of geochemical analyses to characterize paleoenvironment (lipid biomarkers, $\delta^{13}C$, $\delta^{15}N$), to infer past climatic conditions ($\delta^{18}O$, δD) from frozen pore water, and to determine the exposure and burial history of the sediments below the ice sheet (optically stimulated luminescence [OSL], cosmogenic ^{10}Be, ^{26}Al, and ^{21}Ne).

The sub-glacial sediment consists of poorly sorted, reddish-brown, quartz-rich diamict, with paleo-permafrost features in some layers. This material contains woody macrofossils, fungal sclerotia (*Cenococcum geophilum*), and mosses (*Tomenthypnum nitens, Polytrichum juniperinum*)

that yield a ^{14}C age >55 ka. Woody tissue from the upper and lower samples yield stable $\delta^{13}C$ ratios of -26.7±0.1‰ and -29.6±0.1‰ and $\delta^{15}N$ ratios of 2.4±0.8‰ and -2.3±0.8‰. Leaf wax (n-alkanoic acid) distributions are similar to modern Arctic shrubs. Frozen pore water yielded $\delta^{18}O$ ratios of -23.06±0.08‰ and -21.49±0.08‰, enriched relative to all overlying ice (<-27‰). Deuterium-excess values are 4.3±0.8 ‰ and 13.4±0.4 ‰, respectively. These stable isotope measurements of pore water suggest snowfall precipitation at temperatures similar to today if the site were ice-free. OSL measurements from the lower sediment suggest a minimum depositional age >600 ka. In situ ^{10}Be concentrations in quartz decrease with depth from 7.7±0.1 x10^4 atoms/g (500-850 μm) and 6.6±0.2 x10^4 (250-500 μm) in the upper sediment to 1.6±0.1 x10^4 atoms/g (500-850 μm) and 1.8±0.1 x10^4 (250-500 μm) in the lower sediment. The $^{26}Al/^{10}Be$ ratio also decreases with depth. In the upper sediment, $^{26}Al/^{10}Be$ ratios range between 4.2 and 4.9 indicating > 900 ka of burial. In the lower sediment, $^{26}Al/^{10}Be$ ratios range from 1.4 to 2.0 indicating >2 Ma of burial. Measured $^{21}Ne/^{10}Be$ ratios in quartz exceed 1000, which could indicate long-term burial and/or the presence of nucleogenic ^{21}Ne.

These results demonstrate that Camp Century basal sediment was exposed under ice-free conditions that supported vegetation similar to today. Cosmogenic data indicate the deeper sediment has been buried for most of the Pleistocene and the OSL date rules out surface exposure of the deeper material at MIS 11. Cosmogenic analysis indicates that the upper sample experienced less burial or more recent re-exposure. These data are consistent with a growing body of evidence indicating a dynamic Pleistocene GrIS, even under a pre-industrial climate system in which atmospheric CO_2 concentrations did not exceed ~300 ppm.