

Subglacial oxidation of organic carbon supported by diffusive oxygen transport: a case study from Allan Hills, East Antarctica

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Despite Antarctica's vast size, its subglacial environment and any biogeochemical interactions within remain poorly known. This knowledge gap stems partly from the continent's remote location and the challenges of contamination-free subglacial sampling. Ice cores, which are commonly used to provide information of the past climate, can potentially record the signatures of biogeochemical subglacial processes. Here, we utilize two shallow ice cores obtained through dry drilling (i.e. without the use of any drilling fluids) from the Allan Hills blue ice area, East Antarctica. These cores contain ice up to 4 million years old and have been used to constrain past atmospheric CO₂. Although the majority of the ice is considered to record pristine atmospheric composition, the bottom ~8-meter section of the ice is characterized with elevated CO₂ levels accompanied by negative carbon isotope ratios ($\delta^{13}\text{C}$) explicable in terms of *in situ* conversion of organic carbon into CO₂. We also found progressive depletion of oxygen with depth in the deepest 1 meter of ice, with up to ~50% of the oxygen lost in deepest measured sample. While the oxidation of organic carbon must consume O₂, the imbalance between CO₂ gain and O₂ loss suggests that the reaction did not occur entirely *in situ*. We hypothesize the existence of biogeochemical reactions at the ice-bedrock interface and propose a diffusion-reaction model to describe the process. The model is capable of successfully reproducing the depth profile of O₂ in the ice, but to account for the limited increase in CO₂, there must be either an inorganic sink for O₂ (such as pyrite) or for CO₂ (such as silicate). The exact mechanisms remain to be elucidated through future subglacial drilling in this region. We note that such diffusion-controlled subglacial processes may not be limited to present-day Antarctica but could also have occurred during Earth's geological history and on other celestial bodies. Furthermore, the impact of such subglacial processes is only limited to the bottom 2 meters of the trapped gases, so the ice above can still be used as paleoclimate archives.