Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.30594

Not so frozen... Fluid flow in permafrost, time constraints by Ra isotopes

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The archipelago of Svalbard, at 76-80^{o}N, is located at the heart of the continuous permafrost zone, implying that all exposed areas (glacier-free) are covered by 100-400m thick permafrost. Valley permafrost is often saline due to Early Holocene seawater ingression, followed by regression and permafrost aggradation. We studied the chemistry and Ra isotopes of ground ice from saline permafrost at Adventdalen, central Svalbard. Cores recovered from two adjacent drillholes, 10 km from the sea, demonstrated significantly different compositions. While one core, with up to seawater salinity, showed similar-to-seawater composition, ground ice in two less saline cores exhibited evidence for water-rock interaction. The cores also showed substantial differences in their radium isotopes. Ratios of long to short-lived isotopes (e.g. $^{226}Ra/^{223}Ra$) in ground ice of the less saline cores were much higher than in the more saline one (<20 and >>20, respectively). Notably, Ra isotope ratios in the latter were similar to (i.e. in secular equilibrium with) the ratios of their radioactive parents (e.g. $^{230}Th/^{227}Ac$) on sediment surfaces (CEC fraction), while in the less saline cores, ratios approached parent ratios in bulk sediments.

Another drillhole, 5 km from the sea, intruded a cryopeg (permafrost with overcooled brines), with hypersaline ground ice up to 4m from surface. At a depth of 11m, we encountered briny water (50,000mg Cl l^{-1}) flowing into the borehole. Composition of both brine and the ground ice was very similar to seawater, indicative of freezing-associated solute rejection with no crystallization or water-rock interaction involved. Importantly, $^{226}Ra/^{223}Ra$ ratios in brines and ground ice were very low, mostly <<10.

We suggest that the high $^{226}Ra/^{223}Ra$ ground ice of the less saline cores represent the original Early Holocene sediment fluids, which had interacted with sediments, diluted and froze (top-down) upon exposure to the atmosphere. On the other hand, the low $^{226}Ra/^{223}Ra$ ground ice of the more saline cores is evidently much younger (no diffusion of the long-lived ^{226}Ra from inside the grains), probably produced by Late Holocene (<2,000 years to recent) brine infiltration from the underlying basement. This highlights the liability of saline pernafrost to fluid migration and its vulnerability to climate change.