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Using different seismic approaches to detect submarine permafrost and gas hydrates on the continental Beaufort shelf of the Canadian Arctic

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In the Canadian Arctic, permafrost and permafrost-associated gas hydrates formed extensively during the last 1 Ma. After the last glaciation, a marine transgression followed and former terrestrially exposed shelf areas became submerged. Subaerial mean annual temperatures of -20°C or even less changed to present submarine bottom water temperatures near -1°C. The relict submarine permafrost and gas hydrates present in the Beaufort Sea still react to this ongoing thermal change which results in their continued degradation. Thawing permafrost and destabilisation of permafrost-associated gas hydrates may release previously trapped greenhouse gases and can lead to even further gas hydrate dissociation. Moreover, thawing permafrost poses a geohazard in form of landslides and ground collapses. Yet, both the extent of the submarine permafrost and the permafrost-associated gas hydrates are still not well known. Here, we present three different approaches using marine 2D multichannel seismic data to improve the current knowledge of the distribution of offshore permafrost and gas hydrates occurrences in the southern Canadian Beaufort Sea. The acoustic properties of permafrost are determined by the content of ice and unfrozen pore fluids. Changing permafrost conditions affect the elasticity of the medium making seismic methods appropriate for permafrost detection. First, we identify direct and indirect seismic reflection indicators from permafrost and gas hydrates by the presence of cross-cutting, polarity-reversed, and upward-bend reflections as well as velocity pull-ups and shallow pronounced high-amplitude reflections. Second, using diving-wave tomography provides insights into the near-surface permafrost structure by imaging the velocity structure in greater detail than achievable by standard velocity analyses. And third, diffractions separated from the reflected wavefield yield insights into the sub-wavelength architecture of the permafrost realm on the southern Canadian Beaufort Shelf that may add information about weak phase-boundaries and small-scale heterogeneities. All methods are applied to seismic lines crossing the outer

continental margin, where a maximum thermal effect of the transgression is expected, and thus a maximum lateral variation in permafrost and permafrost-associated gas hydrate phase boundaries is expected to be present.