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Imaging of thick permafrost and gas hydrate using seismic methods: a case study from Richards Island, Mackenzie Delta, Canada.

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2D and 3D seismic reflection data acquired by industry on Richards Island, in Canada's Northwestern Territories are used to map heterogeneities in permafrost and to determine the extent of gas hydrate occurrences beneath it. On Richards Island, the permafrost can reach a thickness of 700 m and in part reflects a complex Quaternary history of surface temperatures and geologic processes. In particular, lakes and rivers which cover between 20 and 50% of the landscape played an important role in conditioning ground temperatures. Many of the lakes are deeper than the thickness of winter ice and have taliks that penetrate permafrost. Positive mean annual temperatures beneath the lakes (and indeed river channels or the ocean), if imposed for a significant amount of time, can thaw the permafrost, creating a thermal talik (above 0°C). More common perhaps, warmer permafrost beneath lakes affects the proportion of liquid water versus ice within the sediment matrix. Both conditions can modify the physical properties of sediments, affecting the propagation of seismic waves. Here, we show some effects of deep taliks on seismic reflection data set. Beneath lakes, the seismic data show weaker amplitudes, locally compromising images of the geology within and below the permafrost. Amplitude effects on the seismic data arise from velocity and attenuation variations associated with frozen and un-frozen parts of the permafrost. Travel-time tomography algorithms were used to produce sections and a volume of the permafrost velocity structure. The velocity sections and volume clearly reveal a heterogeneous velocity distribution, primarily related to thermal variations within the permafrost and effects from taliks are observed down to 250 m below the surface. Gas hydrate accumulations located beneath the permafrost are also imaged on the seismic data in areas not dominated with effects from lakes.