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The internal structure and the cryologic importance of the rock glaciers of the Los Pelambres mine (Upper Choapa Valley, Semi-arid Andes of Chile)

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In semi-arid to arid contexts, rock glaciers, as other prominent permafrost features, can represent critical permanent resources of solid water. It is thus important to estimate their ice content, especially in mining areas where human activities may have an impact on permafrost features. In the upper Choapa Valley, semi-arid Andes of Chile (31.59°S, 70.50°W), several rock glaciers are encountered in the area of the open-cast copper mine Los Pelambres. We have investigated the internal structure of the rock glaciers of the Los Pelambres mine using boreholes, borehole temperature monitoring, and ground-penetrating radar (GPR). The boreholes were done using a classical diamond drill. Two boreholes were drilled in one rock glacier and average ice contents of 20 and 27%, respectively, were estimated, with noticeable vertical heterogeneity (ice content range from less than 10% to 100%). The monitoring of the temperature probe string installed in one borehole shows the presence of permafrost near its melting point. The GPR data allow for punctual determination of the radar wave velocity at or near the borehole locations, stratigraphy reconstruction, and 2D velocity modeling. The radar wave velocity determination at or near the borehole locations yielded a radar wave velocity range of 0.12-0.16 m/ns in the permafrost. The 2D velocity modeling was performed using hyperbola fitting-based velocity calculations and kriging interpolation. The reconstruction of the stratigraphy permits to highlight a dense stratigraphy in a depth range of $\sim$30 m. The interpretation of the overall GPR results depicts the rock glaciers as stratified features with pronounced longitudinal and lateral continuity of both stratigraphic units and radar wave velocities over 0.12 m/ns. The crossing of the different results permits to discuss the distribution of the ground ice in the rock glaciers and to give first estimations of the overall ice content and of the hydrologic significance of rock glaciers in this area.