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The application of refraction seismics in alpine permafrost studies

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Permafrost studies in alpine environments focus on landslides from permafrost-affected rockwalls, landslide deposits or periglacial sediment dynamics. Mechanical properties of soils or rocks are influenced by permafrost and changed strength properties affect these periglacial processes. To assess the effects of permafrost thaw and degradation, monitoring techniques for permafrost distribution and active-layer thaw are required. Seismic wave velocities are sensitive to freezing and, therefore, refraction seismics presents a valuable tool to investigate permafrost in alpine environments.

In this study, (1) laboratory and field applications of refraction seismics in alpine environments are reviewed and (2) data are used to quantify effects of rock properties (e.g. lithology, porosity, anisotropy, saturation) on p-wave velocities. In the next step, (3) influence of environmental factors are evaluated and conclusions drawn on permafrost differentiation within alpine periglacial landforms.

This study shows that p-wave velocity increase is susceptible to porosity which is pronounced in high-porosity rocks. In low-porosity rocks, p-wave velocity increase is controlled by anisotropy decrease due to ice pressure (Draebing and Krautblatter, 2012) which enables active-layer and permafrost differentiation at rockwall scale (Krautblatter and Draebing, 2014; Draebing et al., 2016). However, discontinuity distribution can result in high anisotropy effects on seismic velocities which can impede permafrost differentiation (Phillips et al., 2016). Due to production or deposition history, porosity can show large spatial differences in deposited landforms. Landforms with large boulders such as rock glaciers and moraines show highest p-wave velocity differences between active-layer and permafrost which facilitates differentiation (Draebing, 2016).

Saturation with water is essential for the successful application of refraction seismics for permafrost detection and can be controlled at laboratory scale. At landform scale, saturation shows temporal and spatial variation which is partially reflected in variation of seismic velocities of the active-layer (Draebing, 2016).

Environmental factors result in a high spatial variation of rock or soil properties that affect seismic velocities. However, in landforms such as rock glaciers and moraines active-layer and permafrost can be distinguished based on seismic velocities alone while p-wave velocity differences of these layers in talus slopes and debris-covered slopes decrease and, therefore, require additional geophysical techniques or boreholes for layer differentiation (Draebing, 2016).

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