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The record of frost weathering of quartz grains in micromorphology and grain-size composition – an experimental study

Frost weathering is a process of mechanical disintegration of rocks, which occurs as a result of cyclic transitions of temperature through 0˚C, causing freezing and thawing of water in the pores and fissures of the rock. Its effects can be observed on a macro scale, as cracked and weathered rock blocks, and on a micro scale, as cracked mineral grains and a wide range of microtextures formed on their surface. However, the micro-scale frost weathering process itself is still poorly understood, and the factors determining its course are difficult to determine. Experimental research, in which individual factors that influence the course of the weathering process are strictly controlled, may be crucial in this regard.

The doctoral dissertation documents the course of a long-term (1000 freeze-thaw cycles) laboratory experiment simulating micro-scale frost weathering of quartz grains. The aim of the research was to identify its short- and long-term effects recorded in the grain-size composition of sediments and the micromorphology of quartz grains. The assumed research goals were achieved by: 1) preparation of a laboratory experiment, collection of samples in the field, and selection of quartz grains; 2) conducting a laboratory experiment, including sampling after 50, 100, 300, 700, and 1000 freeze-thaw cycles; 3) laboratory analyses of quartz grains subjected to experimental frost weathering, including the analysis of grain size and micromorphology of grain surface; 4) statistical analysis of the results; and 5) interpretation of the results.

Three types of sand-sized quartz grains were subjected to the experimental simulation of frost weathering. They included two types of mechanically crushed vein quartz (Q_W, Q_K) and one type of quartz originating from the aeolian environment (Q_A). The experimental simulation of frost weathering was conducted under controlled laboratory conditions using a freeze-thaw device programmed for automated and defined temperature changes ranging from -5˚C up to +10˚C. The experiment was carried out on samples arranged as a combination of three types of quartz (Q_W, Q_K, Q_A), different water availability (dry samples; moistened samples, where the grains were on filter paper soaked with water; and wet samples, where the grains were immersed in water) and different degrees of water mineralization (distilled, low mineralized, and highly mineralized water). The reference sample (consisting of grains that were not subjected to experimental frost weathering) was prepared for all the studied types of quartz (Q_W, Q_K, Q_A).

After a certain number of freeze-thaw cycles (50, 100, 300, 700, 1000), grain-size analysis and microstructural analysis of the grain surface in a scanning electron microscope were conducted for each sample.

The results of the research were presented in three scientific publications. They document the course of a long-term experimental simulation of frost weathering of sand-sized quartz grains. The research proved that the frost-induced disintegration of quartz grains refers to a wide range of fractions, including the coarse sand fraction. The effects of frost weathering in grain micromorphology are visible after a certain number of freeze-thaw cycles and occur in a specific sequence (large-sized conchoidal fracture → small-sized conchoidal fracture → breakage blocks). The course of frost weathering of quartz grains is controlled mainly by internal factors, i.e. the structure of quartz grains and the characteristics resulted from transport in other environments. External factors, i.e. water availability and water mineralization, are of minor importance. The obtained results provide an insight into the course of frost weathering of vein-quartz and aeolian-originated quartz grains, which is an important step towards more accurate microtextural interpretations. The proposed research methodology may be a starting point for future experimental studies of micro-scale frost weathering of quartz grains.