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Experimental frost/thaw studies on marbles

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Marble is now – since Ages – one of the most prominent natural materials. It still today is an expensive, very decorative stone that was used especially for important historical objects. Due to its easy workability and attractive appearance marble has gained great significance in cultural history as a building stone, as decorative material and, in particular, as material for statues. Marble was formed under high P/T conditions. This means that marble is – like most of the natural rocks – not stable under surface conditions. Due to its chemical composition as well as due to its physical properties marbles tend to weather rather easily and often show signs of physical, biological and chemical weathering. Due to the thermal anisotropy of the rock forming minerals calcite and dolomite especially physical weathering due to temperature changes plays an important role in weathering of marble. This is especially true for cold climates, like the alpine and mountainous climate, where besides general temperature changes also frost-thaw actions play an important role. A high number of frost days (diurnal temperature minimum below 0 °C) occur in many Alpine cities in central Europe. Bern, Klagenfurt or Innsbruck, for example, have more than 100 frost days per year, Salzburg, Linz, Bozen, or Graz nearly 100. Even Vienna (city center) has more than 50 frost days per year.

To simulate frost/thaw processes and their effect on marbles about 100 frost/thaw cycles have been conducted on three different alpine marbles in the laboratory. The effects on the rocks have been measured by weight difference, porosity measurements as well as thermal conductivity and ultrasonic velocity.

Even though most of the samples did not show any macroscopically visible damage due to frost-thaw experiments, we could show that frost-thaw events primarily lead to disintegration of grains at their grain boundaries, microcracking and fracturing within the rock structure. Mass loss due to disintegration of grains can be proved by mass loss. The increase of the a-value after frost-thaw experiments shows the increasing porosity (especially of the capillary active pores between 0.01 and 1 μm) of the generally very low-porous marbles and carbonates.

The measurement of ultrasonic velocities gives an additional insight into the rock structures and its damage due to frost-thaw-cycles. We measured p-waves and density and calculated the Young's modulus for the rocks. Already after the first measurement, after 20 frost-thaw-cycles, all three marbles show a clear decrease in the Young's modulus. For Wattenberg and Hagau marble from Tyrol was detected a decrease between 10 % and 20 % from the original value, for Laas marble from South Tyrol a decrease in the Young's modulus up to 40%.