How microorganisms and pollution destroy stone surfaces

Bringing Back the Past

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Neither beautiful Italian marbles nor colorful Polish sandstones, not even hard Scandinavian granites are impervious to the "tooth of time." No matter kind of stone we carve statues of our beloved poets and leaders from, they can all expect to meet the same depressing end – unless we get to know the culprits and learn to put up a fight

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Stone, a symbol of hardness and permanence, has been put to use by man since time immemorial, and it retains its primary role in construction and decoration to this very day. Yet the permanence of stones is only symbolic – they, too, do not last forever. Their endurance depends on their mineral composition and on the kind of climate they are subjected to. Weathering processes, whose intensity is closely tied to atmospheric conditions, lead to their inevitable destruction. These processes remain of little significance to humans as long as they destroy rocks in their natural environment. But once such phenomena begin to degrade stone-wrought cultural and artistic monuments that are highly valuable to us, or in fact priceless, they take on more importance.

If we study the factors that determine the way stone weathers and the pace of such weathering, we find that such destruction moves particularly quickly in industrialized or urbanized environments. This fact clearly indicates that the causes for such a state of affairs should be sought within our impact on the natural environment. A particularly important role in this regard is played by air pollution, the factor most responsible for putting various substances onto stone surfaces. In the poorly ventilated space of urban agglomerations, these substances can reach unnaturally high concentrations.

Bursting from the inside out

Aside from the gasses that are essential for the life of all organisms on our planet, air also contains certain gasses that facilitate the weathering of rocks and all sorts of stonework. Nitrous oxides and sulfur dioxide are particularly good at doing so – together with water vapor they form the very aggressive compounds: nitric and sulfuric acids. By penetrating the pores and crevices of a stone, these acids can dissolve certain minerals. Then various salts crystallize out of the resulting solutions, changing the stone's chemical composition and consequently its technical parameters and outward appearance. Certain salts exert considerable pressure through such crystallization, thus bursting the stone from the inside out, just like repeatedly frozen water.

For example, one type of stone that is particularly sensitive to this kind of destruction is sandstone, whose binding material often contains a certain amount of calcite (calcium carbonate) or dolomite (calcium magnesium carbonate). Contact with acid rain, containing diluted sulfuric acid, causes such minerals to become washed away and replaced with the much less soluble gypsum (calcium

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Sandstone sculptures forced to withstand the joint attack of big-city atmosphere and microorganisms

sulfate). This process manifests itself in the appearance of white deposits and coatings on the stone surface, yet it most importantly affects the stone's internal structure as well, reducing its durability.

Living monuments

While we commonly think of stones and rocks as being some of the most lifeless and inanimate objects, paradoxically they are in fact full of life. Resident bacteria, fungi, algae, and lichens all play a part in weathering. The metabolisms of these microorganisms generate oxalic acid, which reacts with calcite and leads to the formation of calcium oxalate. Such reactions might even occur 2-3 cm beneath the stone surface.

Under appropriately humid conditions, fungi can live not only on a stone's surface but also within its pores, and the organic acids they produce can destroy such generally susceptible rocks as limestone, dolomite, and sandstone, as well as such resilient ones as granite and basalt. The destructive influence of fungi can also lead to changes in the degree of oxidization of certain ions, causing changes in coloration or more menacing phenomena such as flaking, particularly striking in the case of sculptures and architectural elements made of sandstone.

In humid climates, a major role in physical destruction and the appearance of secondary stone discolorations can be played by algae colonies, which keep the underlying stone surfaces moist. In cooler climates, in turn, the characteristic reddish-brown crust that appears on objects made of limestone and marble is the work of lichens.

Bacteria are another group of microorganisms that operate actively on rocks. This is particularly true for autotrophic bacteria, which obtain the energy they need to live by catalyzing certain chemical reactions in their environment. Such organisms include sulfobacteria, able to quickly deteriorate stonework in the presence of sulfuric acid, and nitrobacteria, which oxidize the non-organic nitrogen compounds that are plentiful in the highly polluted urban atmosphere.

Certain strains of heterotrophic bacteria are also able to survive in stone, even with the very small amounts of organic compounds available. They can make do with the dirt left behind by the masonry process itself. Such bacteria usually give rise to pink, orange, or red spots or brownish "water stains," especially on sculptures and architectural elements made of marble.

Keeping the stone solid

How hospitable stone surfaces are for all sorts of microorganisms depends on the stone's porosity, absorbability, and mineral composition. Fighting against such organisms is made even more difficult by the fact that the internal breakdown of a stone can already be at an advanced stage before any sort of alarming changes occur on the surface. Moreover, some microorganisms can even withstand very extreme conditions, such as if the stone is subjected to drying for extended periods.

In order to protect stonework from the harmful impact of chemically active rain, a process called "hydrophobization" is used, involving agents that prevent moisture from being absorbed by stone. These agents usually also act as biocides, working to kill the microorganisms living in a stone. The applied solutions are chosen so as to easily impregnate the material, to combine well with its mineral components, and also not to change the structure of the stone, retaining its natural porosity and outward appearance. Coupled with increasingly more effective methods for cleaning old monuments and building façades, such protective measures guarantee that future generations will always be able to see our monuments the way their creators saw them - without time taking its toll. ■

Further reading:

Lorenc M. W. (2003). What Destroys Stone Monuments? [in Polish] *Spotkania z Zabytkami*, 8: 37-39.

Lorenc M. W. (2003). Stone Object Deterioration and Prevention Methods [in Polish] *Biuletyn Informacyjny Konserwatorów Dzieł Sztuki*, 14 (3-4): 44-48.