RESELTAM

Development of web-bases education module for the craftsmen working in restoration sector to receive a vocational training according to european quality standardization

Palazzo Spinelli Firenze

e-Learning

Kamieniarstwo

Moduł 2
Zakresy zastosowania

Wstęp

Gdy kiedykolwiek naturalne kamienie ulegają degradacji i niszczeniu, potrzebne są kroki konserwacyjne i regeneracyjne. Zwykle wynika to wskutek wpływów atmosferycznych na jakikolwiek materiał na ziemi. Współczesna działalność przyczynia się do przyśpieszenia wzrostu stężenia zanieczyszczeń, a ich wpływ może znacznie stać się dotkliwy. Spadek jakości materiałów powoduje ich degradacje fizyczną stosowalności, a to nie pozostaje bez wpływu na dziedzictwo kulturowe: utrata odczytywalności oryginalnych dzieł – ich treści wyrazowych. Zatem,

Conservation and Restoration interventions are needed whenever degradation or deterioration is affecting natural stones. Such process is mostly due to the usual effects of atmospheric phenomena on any kind of materials on this planet. Due to human contemporary activity, and concentration of pollutants as its outcomes, these processes can be consistently increased and effects accelerated. Deterioration eventually causes the loss of the physical consistency of the material; when affecting cultural heritage this also implies loss of readability of the original work and its expressive contents. Therefore conservation interventions, together with maintenance, are aimed at slowing down such process if not, as in the case of restoration, giving back readability to that original work that partially lost it.
The fields where stone conservation and restoration is applied consist of the many and different occasions where deterioration appears: in the building sector this depends on the nature of the material, its role and position within the body of the edifice and its exposure to environmental conditions.
Deterioration processes affecting stones are usually due to:

- Physical causes;
- Chemical causes;
- Biological causes.

Most of these causes are activated by water which presence, within the stone, is due to direct exposure to atmospheric phenomena (rain, moisture, condensation etc.) or absorption by capillarity and therefore by its porosity.

It can be said that deterioration of stone is mostly due to:

- Physical variations of water (i.e. evaporation or freezing) and of the salts within it (crystallization);
- Chemical reactions caused by acid waters interacting with Calcium Carbonate, therefore affecting mostly carbonate rocks and carbonate-cemented sandstones, such as sulphatation, carbonation and argillification;
- Biological deterioration is a vast term comprising, in the case of stones, metabolic activity of one or more populations (animal or vegetal) living on stone's surface or sub-surface.

All of these deteriorations produce specific macroscopic alterations not difficult to discern and therefore to point out as the reasons for possible intervention.

1 Sedimentary stones

1.1 Main weathering processes

The kind of stones belonging to the group of sedimentary ones and representing the majority used in the building sector are:
- Sandstones, Limestones and Travertines.

The nature and distribution of pores in these stones greatly varies: from relatively low percentages for compact limestones, to medium-high ones and of little diameter for sandstones and medium percentages with big diameters for travertines. Having this figure in mind, capillarity will be highest for poorly compact species of the first two and usually lower for travertines, while all of them would be affected by natural permeability.

Physical deterioration due to water (freeze/thaw cycles) and salt crystallization pressures are then usual to all less compact sedimentary stones which also suffer of erosion or abrasion due to wind blown particles.

Chemical triggered deterioration of many sedimentary stones is quite often in urban polluted environments because of atmospheric water acidity. As belonging to the carbonate rocks group, both limestones and travertines are subject to sulphatation and carbonation which may occur also on carbonate-cemented sandstones.
Sandstones and in particular those containing silicon based minerals in the form of little grains or sands, are subject to slower processes, whenever in contact with acid waters, known as argillification. Because of the longer times needed to produce macroscopic effects, this deterioration is usually appreciable on stones exposed for a long time (more than 500 years) or in highly aggressive environments.

Biodeterioration of sedimentary stones is a general term identifying many forms of decay caused by fungi, vegetation or bacteria but even animals (because of their excrements). It is usually combined with humid microclimates and other conditions compatible with the growth of such populations (i.e. presence of certain chemical components or nutrients, light and temperature).
As of vegetation and omitting macroscopic plants which can infest most kinds of stone structures and finishing, musk and lichens are the most diffused. Both metabolism and roots growth of such vegetal (therefore chemical and physical actions) can attack the surface of all sedimentary stones mostly because of their pores' structure. Depth of such attack can get to some millimetres into the stone.
In the case of bacteria too, the deterioration can be physical and chemical with usual clear aesthetic consequences. Certain bacteria's metabolism produces acid composites (inorganic or organic) that can deteriorate carbonate whenever part of the stone constituents. Such is the case of the so called sulfoxidant (releasing sulphur acid that reacts with calcium carbonate as in the case of acid rains effect) and nitrificant bacteria (releasing nitric acid that solubilises calcium carbonate). Also algae and in particular the so called endolithic cynobacteria easily growing on carbonate stones, produce organic acids that can solubilise calcium carbonate.
The aggressive action of birds is both physical, caused by trampling and grazing, and chemical, caused by the dropping of acid excrement (guano) containing high amount of nitrate and phosphate compounds. Indirect damage is made by organic substances accumulated on stone surfaces, which can serve as nutritive substrata for heterotrophic micro flora (bacteria and fungi).

1.2 Macroscopic symptoms

Effects of water and salt crystallization are clearly visible as superficial disintegration with detachment and successive spalling of pieces of different dimension depending on the speed and amount of the phenomenon. In the case of salt crystallization, residual salt crystals can be observed as white incoherent layers on the surface of the stone. Can lead to the full disintegration of the piece of stone subject to such deterioration.

Fig. 1: clear signs of water crystallization effects on northern face of a sandstone column section, Florence (Italy).

Fig. 2: limestone blocks' surfaces deteriorated by salt crystallization cycles, Dubrovnik (Croatia).

Sulphatation leads to the typical formation of black crusts as the consequence of deposition and inclusion of fine black dust of unburned hydrocarbons (see polluted environment) or other atmospheric particulates, into the gypsum superficial layer produced by such phenomenon on carbonate stones.
Particularly visible on the undercut surfaces of building decoration, not subject to rain water streaming that washes out such atmospheric particulates deposition, it is strongly evident as carbonate stones are usually of light colour if not white. As thick crusts, they're to be expelled from the surface leaving a weak and sanding substratum ready for the process to repeat and cause other losses.


Fig. 3: signs of intense sulphatation outcomes on white limestone architectural details, Diocletian Palace, Split (Croatia).

Carbonation leads to the formation of typical incrustation of calcium carbonate that can cover with noteworthy thickness wide areas and decorative features hiding them. Such deterioration, although produced by the dissolution of part of a stone structure, is never disruptive as the stone underneath such incrustation is not degraded.

Fig. 4: outcomes of carbonation processes, namely incrustations, on limestone wall blocks, Dubrovnik (Croatia).

Argillification or the hydrolysis of feldspar in certain sandstones produces a typical weakening of the bonds between sand grains and the consequent “sugaring” or pulverization of the stone surface.

Fig. 5: effects of argillification on a long exposed XV cent. sandstone, Florence (Italy).

Biodeteriogens can be many and most of them clearly visible because of the extended areas of stone they usually spread over: lichens, algae, cynobacteria, fungi or musk together with primary plants and guano. Only some bacteria as the sulfoxidant type, especially when not showing in coloured population, are not easy to discern and produce effects that can be attributed to other causes as acid rains.


Fig. 6: surface of well tooled sandstone blocks covered and deteriorated by lichens' growth, Scotland (Great Britain).

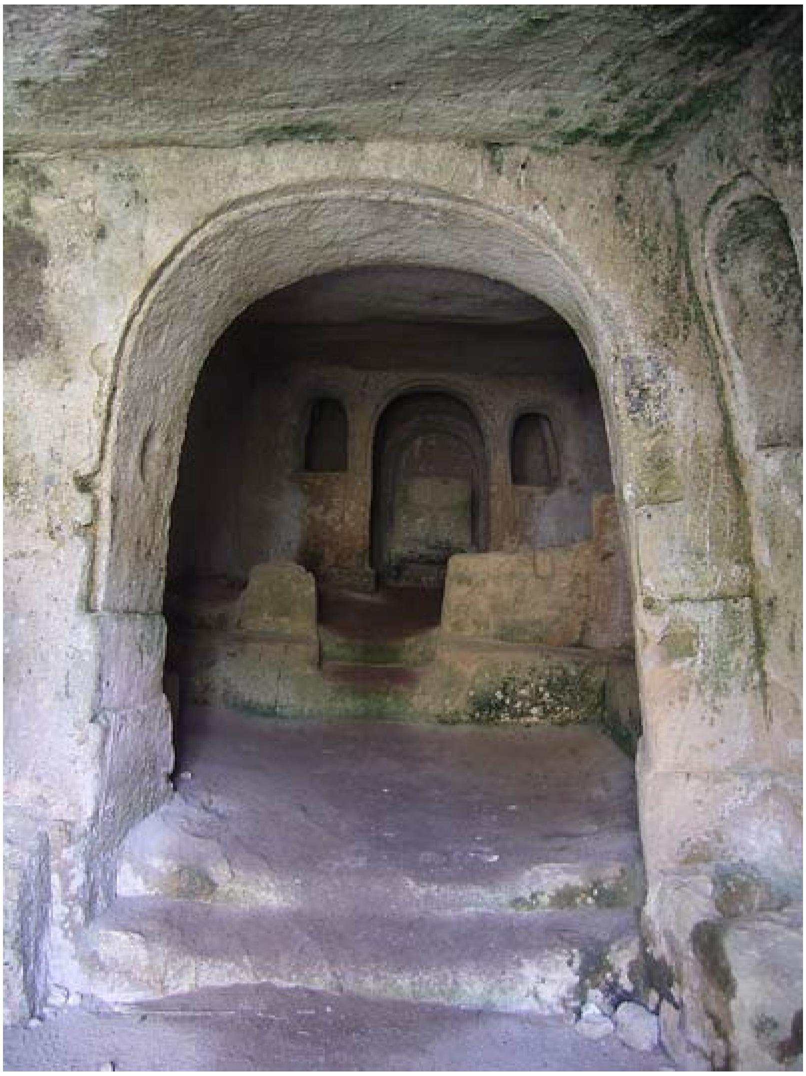
Fig. 7: the growing of cynobacteria on the surface of a rock cut monument, Matera (Italy).

2 Metamorphic stones

2.1 Main weathering processes

The kind of stones belonging to this group and representing the majority used in the building sector are:
- Marbles and Slates

The nature and distribution of pores in these stones varies but can be usually considered in the range of medium to low percentages thus showing good qualities and low weatherability especially when coming from deep quarries and therefore being more compact.

Physical deterioration due to water (freeze/thaw cycles) and salt crystallization pressures are typical for all less compact metamorphic stones, which is not a frequent case especially when good quality stones are employed or exposed surfaces are well polished. Depending on local factors, erosion or abrasion produced by direct exposition to particles blown by strong winds can be clearly damaging especially marbles.

As for the chemical deterioration, patterns vary consistently depending on the silicate or carbonate nature of the metamorphysed rock.

Belonging to the silicatic rocks group, slates are subject to no serious chemical deterioration. Yet sometimes the higher percentage of certain constituents produce physical or aesthetic deterioration.
On the other hand marbles, belonging to the carbonate rocks group, are subject to sulphatation (and in general weak under acid composites) which can reach severe grades of deterioration especially when little impurities are present and the most of the stone is pure calcium carbonate (in the form of calcite). As usual in fact the consequence of such chemical reaction is the formation of black crusts. It is to be noted that dolomitic marbles (composed of dolomite) are much more resistant to acid attack than calcitic marbles, showing usually little or no forms of sulphatation.

Biodeterioration of metamorphic stones is a general term identifying many forms of decay caused by fungi, vegetation or bacteria but even animals (because of their excrements). It is usually combined with humid microclimates and other conditions compatible with the growth of such populations (i.e. presence of certain chemical components or nutrients, light and temperature).
As of vegetation and omitting macroscopic plants which can infest most kinds of stone structures and finishing, musk and lichens are the most diffused. Both metabolism and roots growth of such vegetal (therefore chemical and physical actions) can attack the surface of all softer slates and marbles stones mostly because of their pores' structure. Depth of such attack can get to some millimetres into the stone.
The case of bacteria growth, producing both physical and chemical deterioration, can be mostly treated for the case of light marble for the usual clear aesthetic consequences. Certain bacteria's metabolism produces acid composites (inorganic or organic) that can deteriorate carbonate whenever part of the stone constituents. Such is the case of the so called sulfoxidant (releasing sulphur acid that reacts with calcium carbonate as in the case of acid rains effect) and nitrificant bacteria (releasing nitric acid that solubilises calcium carbonate). Also algae and in particular the so called endolithic cynobacteria easily growing on carbonate stones, produce organic acids that can solubilise calcium carbonate.
A recurrent biodeterioration producing clear visible and therefore undesirable effects on light marbles, especially in its architectural use, is the growth of lead resistant bacteria such as the Streptomyces specie which assume red colour. Lead is usually found in the form of lead nitrate which comes for the historical use of sealing the iron clips, connecting marble blocks or slates, with such malleable compound.
The aggressive action of birds is both physical, caused by trampling and grazing, and chemical, caused by the dropping of acid excrement (guano) containing high amount of nitrate and phosphate compounds. Indirect damage is made by organic substances accumulated on stone surfaces, which can serve as nutritive substrata for heterotrophic micro flora (bacteria and fungi).

2.2 Macroscopic symptoms

Although less frequent in good quality marbles and slates, effects of water and salt crystallization are clearly visible as superficial disintegration with detachment and successive spalling of pieces of different dimension depending on the speed and amount of the phenomenon.
In the case of salt crystallization, residual salt crystals can be observed as white incoherent layers on the surface of the stone (efflorescence). Consistent repetitive cycles can lead to the extended disintegration of the piece of stone subject to such process.
Marbles exposed to strong winds carrying abrasive particles can show heavy signs of erosion that are visible because of the loosing of an eventual polished finishing and the rough uneven surface.

Fig. 8: wind driven erosion of a white marble pillar’s surface, Florence Cathedral dome (Italy).

In the case of more porous slate the freeze/thaw cycles lead to the softening and delaminating of the stone.


Fig. 9: weathered slate softening and delaminating, Pennsylvania (USA).

Slates that are found with a higher percentage (around 3%) of compounds other than silicate, as calcium oxide and carbonate, produce efflorescence with consequent general superficial weakening. A mostly aesthetic degradation of slates, namely their discoloration, is caused by sunlight triggered oxidations of organogen carbonium which is the constituent giving the usual dark grey appearance of this stones.

Sulphatation, which affects calcitic marbles, leads to the typical formation of black crusts as the result of atmospheric particulates accretion. Because of the extended use of marble in monumental architectures and in particular for the execution of fine architectural details, the outcomes of such degradation can be strongly detrimental to the aesthetic and integrity of these artistic features and the cultural meaning they convey. Once mature black crusts (some millimetres in depth) are typically expelled; the underneath stone surface is left in a weak sugaring state prone to further fast degradation.

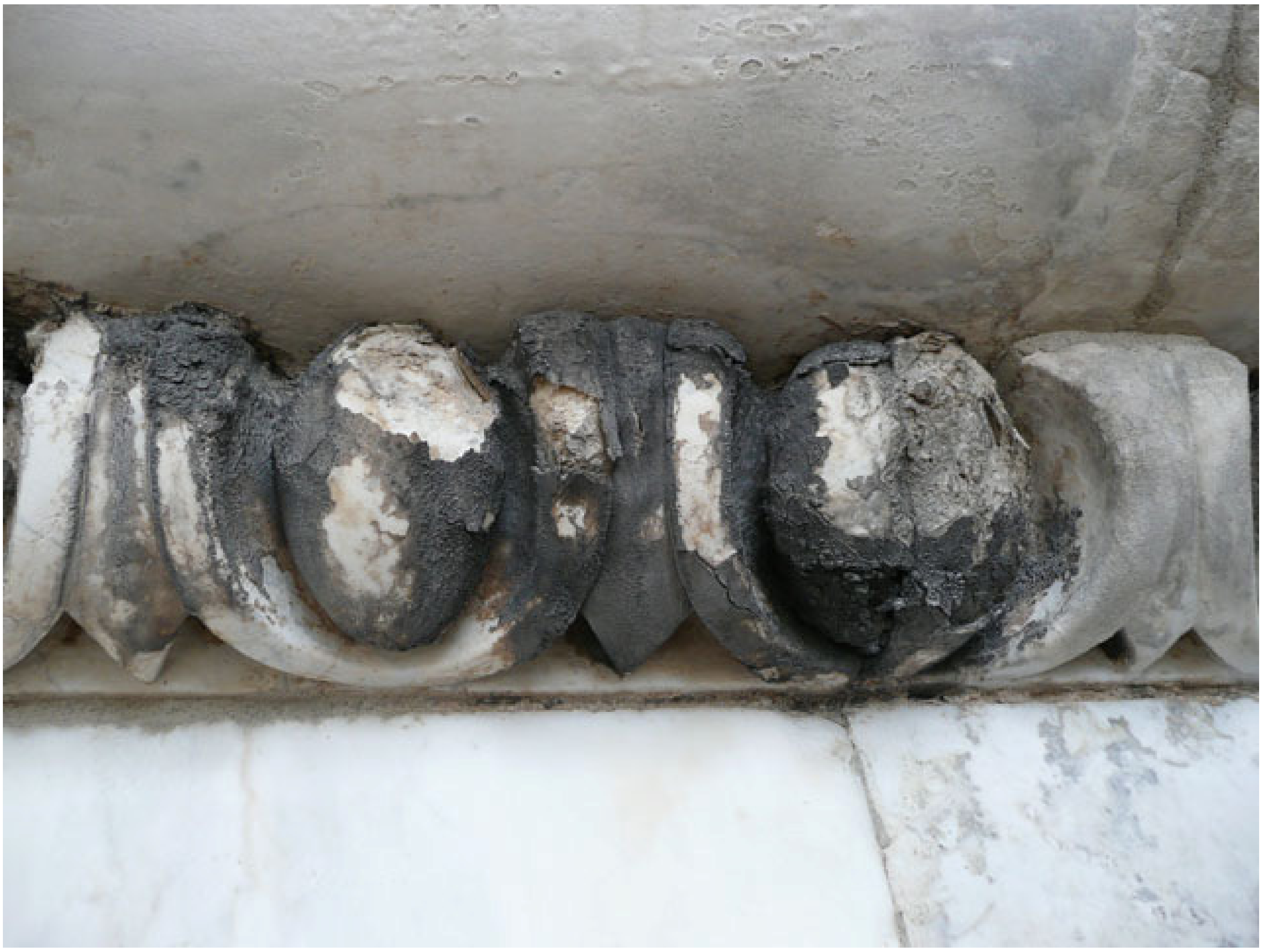

Fig. 10: “egg and darts” decoration affected by sulphatation and consequent black crusts formation, Florence Cathedral dome (Italy).

While non serious physical damages can be caused by biodeteriogens on slates because of their chemical and structural nature, different are aesthetic outcomes, also in the case of marbles, due to the dark or very light colours of such stones.
Similarly to the carbonate sedimentary rocks, calcitic marbles, being weak under acid conditions, can develop forms of superficial aesthetic and physical deteriorations whenever heavily affected by biodeteriogens such as lichens, sulphoxidant bacteria or endolithic cynobacteria and guano.
Lead resistant bacteria such as the Streptomyces specie, can diffuse in presence of lead nitrates close to marbles’ surface. Although not necessarily detrimental for the physical integrity of the stone, this spread generally weakens superficial layers which can more easily develop deterioration. Moreover such bacteria populations usually assume a marked reddish colour that is particularly visible on light calcitic marbles.

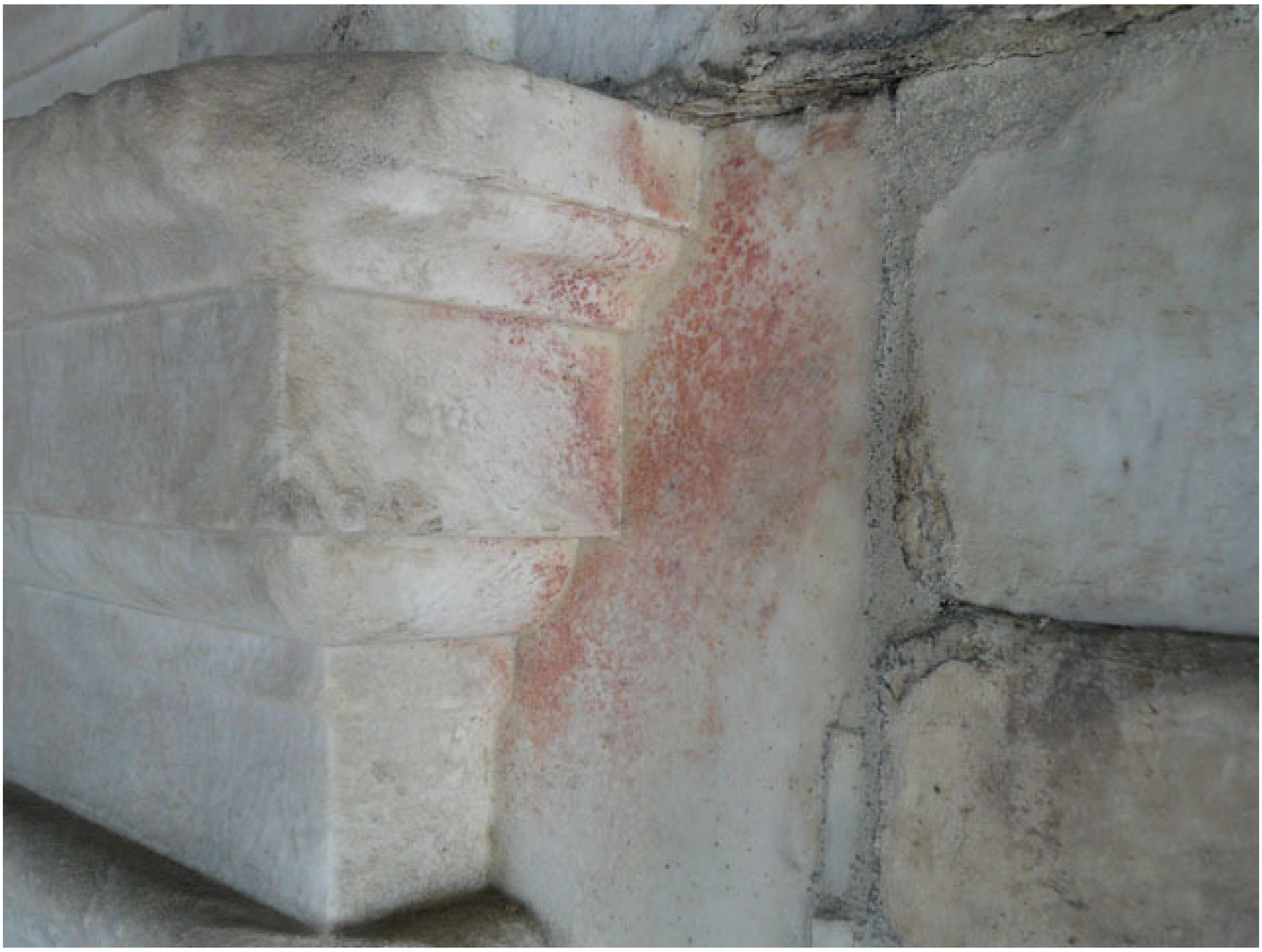

Fig. 11: red stains produced by lead resistant bacteria growing on marble's architectural detail surface, Florence Cathedral dome (Italy).

3 Igneous stone

3.1 Main weathering processes

The kind of stones belonging to this group and representing the majority used in the building sector are:
- Granites, Basalts and Tuffs.

The nature and distribution of pores in these stones greatly varies: from low and very low percentages for the compact and hard granites and basalts, to the high ones of the soft tuffs.

In terms of physical degradation this means that both granites and basalts can stand extreme environmental conditions suffering not the serious damages that other kind of stones could easily show including erosion. This behaviour is also further improved by the possible glass-like polishing of such stones.
Nonetheless water absorption is possible and in the presence of saline liquid their eventual crystallization can cause sub-florescence and superficial disintegration and flaking.
For their high porosity most of the tuffs are particularly subject to this form of deterioration.

Because of their silicatic nature, igneous stones are less subject to forms of chemical deterioration, as for example sulphatation, which typically affects carbonatic rocks. Even if this is true in the majority of cases, the possible leaching of salts and carbonates from new cementicious mortars or masonry carbonatic units can produce concentrated episodes of sulphatation too that can be quite disruptive. Also hydrolysis (or argillification) of silicates can deteriorate building igneous stones.

Biodeteriogens can attack also granites and basalts even if physical rather than aesthetical consequences are hardly severe. Different is the case of tuffs that for their high porosity can easily give enough superficial room for dust, clay and nutrients that together with water and light can provide the proper condition for vegetation, fungi, algae and bacteria to grow.

3.2 Macroscopic symptoms

The presence of salts brought by marine environment or neighbouring conditions is usually manifest in various forms of efflorescence and sub-efflorescence as to say with phenomena of decohesion, flaking and therefore of superficial losses.

Fig. 12: efflorescence and sugaring on a granite ashlar wall block, Aberden (Great Britain).

If such conditions can harm even hard igneous stones, the effect of the same causes can be quite disruptive on the softer tuffs.

Fig. 13: sub-efflorescence leading to extreme bulging and spalling of tuff ashlar wall blocks, southern Tuscany (Italy).

Also carbonate composites can introduce in the physical structure of the stone, alien elements that can give birth to phenomena such as solphatation and the usual appearance of black crusts in polluted environments.

Fig. 14: sulphatation and black crusts on a granite ashlar wall block, Aberden (Great Britain).

Considerations

Most forms of stone deterioration are due to environmental conditions and if polluted ones are taken aside, some of these deteriorations are more recurrent in certain geographical areas.
So that:

- water crystallization is usual in wet northern countries;
- salt crystallization pressure is recurrent on sea coasts;
- all sort of biodeteriogens are particularly active in hot damp climates.