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Nano-Cathedral

D1.4 – Report on decay phenomena

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CRACK AND DEFORMATION	
CRACK	**Definition :** **Individual fissure, clearly visible by the naked eye, resulting from separation of one part from another.** **Equivalent terms to be found in other glossaries :** *Fissure, fault, joint.* **Sub-type(s) :** - **Fracture :** Crack that crosses completely the stone piece - **Star crack :** Crack having the form of a star. Rusting iron or mechanical impact are possible causes of this type of damage. - **Hair crack :** Minor crack with width dimension < 0.1 mm - **Craquele :** Network of minor cracks also called crack network. The term *crazing* is not appropriate for stone, as this term should be used for describing the development of a crack *network* on glazed terracotta. - **Splitting :** Fracturing of a stone along planes of weakness such as microcracks or clay/silt layers, in case where the structural elements are orientated vertically. For instance, a column may split into several parts along bedding planes if the load above it is too high. **Not to be confused with :** - *Delamination*, which consists of detachment along bedding or schistosity planes, not necessarily orientated vertically. In delamination, mechanical overload is not noticeable. Delamination is transitional to splitting. **Other remarks :** *Cracking* may be due to weathering, flaws in the stone, static problems, rusting dowels, too hard repointing mortar. Vibrations caused by earth tremors, fire, frost may also induce cracking. *Cracks and fractures* occurring on rock carved surfaces are usually named after the geological terminology : joint if there is no displacement of one side with respect to the other, fault if there is a displacement.

DETACHMENT BLISTERING	
	definition :
	Separated, air-filled, raised hemispherical elevations on the face of stone resulting from the detachment of an outer stone layer. This detachment is not related to the stone structure.
	Equivalent terms to be found in other glossaries :
	-
	Other remarks :
	Blistering, in some circumstances, is caused by soluble salts action.

DETACHMENT DELAMINATION	
	Definition :
	Detachment process affecting laminated stones (most of sedimentary rocks, some metamorphic rocks...). It corresponds to a physical separation into one or several layers following the stone laminae. The thickness and the shape of the layers are variable. The layers may be oriented in any direction with regards to the stone surface.
	Equivalent terms to be found in other glossaries :
	Layering.
	Sub-type(s) :
	- *Exfoliation :* detachment of multiple thin stone layers (cm scale) that are sub-parallel to the stone surface. The layers may bend, twist in a similar way as book pages.
	Not to be confused with :
	- *Scaling :* kind of detachment totally independent of the stone structure.
	Other remarks :
	Efflorescences and *biological colonization* can be detected in-between the laminae.

DETACHMENT	
BURSTING	**Definition :**
	Local loss of the stone surface from the internal pressure usually manifesting in the form of an irregularly-sided crater
	Equivalent terms to be found in other glossaries :
	Break out
	Not to be confused with:
	Impact damage: loss of material due to a mechanical impact, which may have crater shape if the object hitting the stone surface is hard and small (a bullet f.i.)
	Other remarks :
	Bursting is sometimes preceded by star shaped face fracturing. This deterioration pattern is due to an increase of volume of the mineral inclusions (clays, iron minerals, etc) naturally contained in the stone and situated near the surface. The corrosion of metallic reinforcing elements may also induce bursting.

DETACHMENT	
DISINTEGRATION	**Definition :**
	Detachment of single grains or aggregates of grains.
	Relationship with the substrate :
	It affects only the surface of the stone or can occur in depth. Damage generally starts from the surface of the material. On crystalline marble, *granular disintegration* may reach several centimetres in depth, sometimes more.
	Equivalent terms to be found in other glossaries :
	Loss of cohesion, incoherence, decohesion, friability, disaggregation, *intergranular incoherence, pulverization.*
	Sub-type(s) :

	- **Crumbling**: Detachment of aggregates of grains from the substrate. These aggregates are generally limited in size (less than 2 cm). This size depends on the nature of the stone and its environment. - **Granular disintegration:** Occurs in granular sedimentary (e.g. sandstone) and granular crystalline (e.g. granite) stones. *Granular disintegration* produces debris referred to as rock meal and can often be seen accumulating at the foot of a wall actively deteriorating. If the stone surface forms a cavity (*coving*), the detached material may accumulate through gravity on the lower part of the cavity. The grain size of the stone determines the size of the resulting detached material. The following specific terms, all related to *granular disintegration*, refer either to the size, or to the aspect of corresponding grains : (1) **Powdering, Chalking**: terms sometimes employed for describing granular disintegration of finely grained stones. (2) **Sugaring**: employed mainly for white crystalline marble, (3) **Sanding**: used to describe granular disintegration of sandstones and granites.
	Other remarks : In the case of crystalline marbles, thermal stresses are known to be among the main causes of *granular disintegration*, thus leading occasionally to *deformation* patterns. Stones may display deterioration patterns intermediate between *granular disintegration* and *crumbling*, *scaling* or *delamination*. Partial or selective *granular disintegration* often leads to surface features such as *alveolization* or *rounding*. When occurring inside crystalline marble, *granular disintegration* may lead to *deformation* patterns.
FRAGMENTATION	**Definition :** **The complete or partial breaking up of a stone, into portions of variable dimentions that are irregular in form, thickness and volume**
	Relationship with the substrate : *The substrate remains apparently sound on both sides of the detachment plane. Fragmentation may occasionally affect the entire stone block, and may follow discontinuity planes*
	Sub-type(s) : - *splintering* - chipping

	Not to be confused with :

	Other remarks :
	Fragmentation may be found when stone blocks are subjected to an overload. Upper parts as well as lower parts of monolithic columns are particularly prone to chipping and splintering (large weight supported by a small area)

PEELING	**Definition**
	Shedding, coming off, or partial detachment of a superficial layer (thickness : submillimetric to millimetric) having the aspect of a film or coating which has been applied on the stone surface.
	Equivalent terms to be found in other glossaries :
	Peeling off.
	Not to be confused with :
	- *Blistering*, which is associated with a dome-like morphology. - *Scaling*, which is related to the detachment of stone layers (thickness: millimetric to centimetric).

SCALING	**Definition :**
	Detachment of stone as a scale or a stack of scales, not following any stone structure and detaching like fish scales or parallel to the stone surface. The thickness of a scale is generally of millimetric to centimetric scale, and is negligible compared to its surface dimension.
	Relationship with the substrate :
	The plane of detachment of the scales is located near the stone surface (a fraction of millimetres to several centimetres).
	Equivalent terms to be found in other glossaries :
	Desquamation, Scale, plaque or *plaquette* describe exclusively the features, and not the process.
	Sub-type(s) :

- **Flaking**: scaling in thin flat or curved scales of submillimetric to millimetric thickness, organized as fish scales.
- **Contour scaling**: scaling in which the interface with the sound part of the stone is parallel to the stone surface. In the case of flat surfaces, contour scaling may be called **spalling**. Case *hardening* is a synonym of *contour scaling*.

Other remarks :

- *Delamination* : corresponds to a detachment following the bedding or shistosity planes of a stone.

FEATURES INDUCED BY MATERIAL LOSS	
ALVEOLIZATION	**Definition :**
	Formation, on the stone surface, of cavities (alveolae) which may be interconnected and may have variable shapes and sizes (generally centimetric, sometimes metric).
	Equivalent terms to be found in other glossaries :
	Alveolar erosion, alveolar weathering, honeycomb.
	Other spelling :
	Alveolisation
	Sub-type(s) :
	- **Coving** : erosion feature consisting in a single alveole developing from the edge of the stone block.
	Not to be confused with :
	- *Microkarst*: refers to a network of millimetric to centrimetric interconnected depressions, clearly linked to a dissolution process. - *Pitting* : corresponds to the formation of point-like millimetric to submillimetric pits, generally not connected, on a stone surface.
	Other remarks :
	Alveolization is a kind of differential weathering possibly due to inhomogeneities in physical or chemical properties of the stone. *Alveolization* may occur with other degradation patterns such as *granular disintegration* and/or *scaling*. In those particular cases in which *alveolization* develops mainly in depth in a diverticular manner, it can be referred to as *vermicular alveolization*. In arid climates large size alveoles of meter size are frequently formed (e.g. Petra, Jordan).

FEATURES INDUCED BY MATERIAL LOSS	
EROSION	**Definition :**
	Loss of original surface, leading to smoothed shapes.
	Equivalent terms to be found in other glossaries :
	Loss of material is a very general expression that refers to any loss of original surface, which can be due to a variety of reasons such as *granular disintegration, scaling* etc. This term is too vague and should not be used.

	Sub-type(s) :
	- **Differential erosion**: to be preferred to *differential deterioration*: occurs when erosion does not proceed at the same rate from one area of the stone to the other. As a result, the stone deteriorates irregularly. This feature is found on heterogeneous stones containing harder and/or less porous zones. It may also occur as a result of selective lichen attack on calcitic stones. Differential erosion is generally found on sedimentary and volcanic stones. Differential erosion is synonymous with *relief formation*, i.e. the formation of irregularities on the stone surface. Differential erosion may result in *loss of components* or *loss of matrix of the stone* : (1) **Loss of components**: Partial or selective elimination of soft (clay lenticles, nodes of limonite, etc.) or compact stone components (pebbles, fossil fragments, geological concretions, lava fragments). (2) **Loss of matrix**: Partial or selective elimination of the stone matrix, resulting in protruding compact stone components. - **Rounding**: Preferential erosion of originally angular stone edges leading to a distinctly rounded profile. Rounding can especially be observed on stones which preferably deteriorate through granular disintegration, or when environmental conditions favour granular disintegration. - **Roughening**: Selective loss of small particles from an originally smooth stone surface. The substrate is still sound. Roughening can appear either progressively in case of long term deterioration process (for instance in case of granular disintegration), or instantaneously in case of inappropriate actions, such as aggressive cleaning.
	Other remarks :
	Erosion may have natural and/or anthropogenic causes. It can be due to chemical, physical or/and biological processes.

MECHANICAL DAMAGE	**Loss of stone material clearly due to a mechanical action**
	Equivalent terms to be found in other glossaries :
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	Sub-type(s) :
	- impact damage: mechanical damage due to the impact of a projectile (bullet, shrapnel) or of a hard tool. - Cut: loss of material due to the action of an edge tool. It can have the appearance of an excavated cavity, an incision, a missing edge, etc…Tool marks can be considered as special kinds of cuts but should not be considered as damage features.

	- Scratches: manually induced superficial and line like loss of material due to the action of some pointed object. It can be accidental or intentional. Usually it appears as more or less long groove. Tool marks can have the appearance of scratches, but should not be taken as damage features. - Abrasion: erosion due to wearing down or rubbing away by means of friction, or to the impact of particles - Keying: impact damage resulting from hitting a surface with a pointed tool, in order to get an irregular surface which will assist the adhesion of an added material, a mortar for instance.
	Other remarks :
	In most cases mechanical damage has an anthropogenic origin

MICROKARST	**Definition :**
	Network of small interconnected depression of millimetric to centimetric scale, sometimes looking like hydrographic network. Microkarst patterns are due to a partial and/or selective dissolution of calcareous stone surfaces exposed to water run-off
	Equivalent terms to be found in other glossaries :
	Karst, dissolution, cratering. This last term refers to bricks, not to stone
	Not to be confused with :
	- Alveolization, the depressions of which are similar in shape but bigger in size (centimetric scale) and are not systematically interconnected. Alveolization may be due to selective degradation by salts, whereas microkarst is exclusively linked to an obvious dissolution process. - Pitting: point like, usually not interconnected, millimetric or submillimetric cavities.
	Other remarks :
	There is no trace of any granular disintegration or scaling on the stone surface

MISSING PARTS	**Definition :**
	Empty space, obviously located in the place of some formerly existing stone part. Protruding and particularly exposed parts of sculptures

	(nose, fingers) are typical locations for material loss resulting in missing parts.
	Equivalent terms to be found in other glossaries :
	Lacuna.
	Subtype(s) :
	- **Gap** *: hollow place in the stone surface, hole.*

PITTING	**Definition :**
	Point-like millimetric or submillimetric shallow cavities. The pits generally have a cylindrical or conical shape and are not interconnected, although transitions patterns to interconnected pits can also be observed
	Equivalent terms to be found in other glossaries :

	Not to be confused with:
	Microkarst, which creates a network of small interconnected depressions
	Other remarks :
	Pitting is due to a partial or selective deterioration. Pitting can be biogenically or chemically induced, especially on carbonate stones. *Pitting may also result from a harsh or inadapted abrasive cleaning method*

DISCOLORATION AND DEPOSIT CRUST	**Definition :**
	Generally coherent accumulation of materials on the surface. A crust may include exogenic deposits in combination with materials derived

	from the stone. A crust is frequently dark coloured (black crust) but light colours can also be found. Crusts may have an homogeneous thickness, and thus replicate the stone surface, or have irregular thickness and disturb the reading of the stone surface details.
	Relationship with the substrate :
	A *crust* may be weakly or strongly bonded to the substrate. Often, *crusts* detached from the substrate include stone material.
	Sub-type(s) :
	- **Black crust** : Kind of crust developing generally on areas protected against direct rainfall or water runoff in urban environment. Black crusts usually adhere firmly to the substrate. They are composed mainly of particles from the atmosphere, trapped into a gypsum ($CaSO_4.2H_2O$) matrix. - **Salt crust** : Crust composed of soluble salts, which develop in the presence of high salt levels, and form from wetting and drying cycles.
	Not to be confused with :
	- *Encrustation*, which is also a coherent layer, but is always adherent to the substrate. The term *encrustation* is preferred to crust when the accumulation clearly results from water infiltration followed by precipitation. - *Algae* : Algae often have a dark colour during the dry season and may be confused with black crusts. Oppositely to black crusts, algae do not adhere to the substrate, and are usually located in outdoor situations, in areas exposed to direct rain impact, or on water pathways. These two characteristics differentiate algae from black crusts. - *Patina* : Black iron rich patinas, which develop usually as a thin layer enriched in iron/clay minerals on iron containing sandstones, and are located on all exposed parts of the building/sculpture, not only on parts sheltered from the rain impact.

DEPOSIT	**Definition :**
	Accumulation of exogenic material of variable thickness. Some examples of deposits : splashes of paint or mortar, sea salt aerosols, atmospheric particles such as soot or dust, remains of conservation materials such as cellulose poultices, blast materials, etc.
	Relationship with the substrate :
	A *deposit* generally lacks adhesion to the stone surface.
	Equivalent term to be found in other glossaries :

	Surface deposit.
	Not to be confused with :
	Bird and bat droppings are considered as *deposits*, whereas bird nests, spider webs are to be considered as *biological colonization*.
	Other remarks :
	A *deposit* can be described for colour, morphology, size and if possible nature and/or origin.

DISCOLOURATION	**Definition :**
	Change of the stone colour in one to three of the colour parameters : hue, value and chroma. (1) Hue corresponds to the most prominent characteristic of a colour (blue, red, yellow, orange etc.). (2) Value corresponds to the darkness (low hues) or lightness (high hues) of a colour. (3) Chroma corresponds to the purity of a colour. High chroma colours look rich and full. Low chroma colours look dull and greyish. Sometimes chroma is called saturation.
	Relationship with the substrate :
	It may affect the surface and/or be present in depth of the stone.
	Equivalent term to be found in other glossaries
	Chromatic alteration.
	Other spelling :
	Discoloration (US)
	Sub-type(s) :
	- **Colouration** (to be preferred to *colouring*) : change in hue, value and/or a gain in chroma - **Bleaching** (or *fading*) : gain in value due to chemical weathering of minerals (e.g. reduction of iron and manganese compounds) or extraction of colouring matter (leaching, washing out), or loss of polish, generally very superficial. Dark and bright colour marbles often show bleaching as a result of exposure to weather. - **Moist area** : corresponds to the darkening (lower hue) of a surface due to dampness. The denomination *moist area* is preferred to *moist spot, moist zone* or *visible damp area*.

	- **Staining** : kind of discolouration of limited extent and generally of unattractive appearance.
	Not to be confused with :
	- *Patina* : superficial modification of the material perceivable as a discolouration, in often having a favourable connotation. - *Soiling*: refers to a tangible deposit and has a negative connotation - *Deposit*: refers to the accumulation of material of variable thickness, possibly having a colour different from that of the stone.
	Other remarks
	Discolouration is frequently produced by salts, by the corrosion of metals (e.g. iron, lead, copper), by micro-organisms, or by exposure to fire. Some typical yellow, orange, brown and black *discolouration* patterns are due to the presence of carotenoids and melanin produced by fungi and cyanobacteria. Darkened areas due to moistening may have different shapes and extension according to their origin : pipe leakage, rising damp, hygroscopic behaviour due to the presence of salts, condensation.

ENCRUSTATION	**Definition :**
	Compact hard mineral outer layer adhering to the stone. Surface morphology and colour are usually different from those of the stone
	Relationship with the substrate :
	Encrustations generally adhere firmly to the stone surface. When an encrustation is removed, adhering stone materials may be taken away with it.
	Equivalent term to be found in other glossaries

	Other spelling :

	Sub-type(s) :
	- concretion: kind of encrustation having a specific shape: nodular, botroidal (grape-like) of framboïdal (raspberry like). Concretions may even have a conica shapes or form drapery-like vertcal sheets. Stalagmites and stalactites are kinds of

	concretions. In general, concretions do not outline, contour the surface of the stone, and are of limited extent.
	Not to be confused with :
	Crust: the term encrustation is used when the feature is clearly due to a precipitation process, following any kind of leaching. If there is no evidence of leaching and precipitation, the term crust will be employed -lichen: some lichens can look like encrustations. Lichens are not usually hard, when scratched, one can see blackish or green traces resulting from algae or cyanobacteria hosted by the lichen
	Other remarks
	Encrustations on monuments are frequently deposits of materials mobilized by water percolation and thus coming from the building itself: carbonates, sulphates, metallic oxides and silica are frequently found.

PATINA	**Definition :**
	Chromatic modification of the material, generally resulting from natural or artificial ageing and not involving in most cases visible surface deterioration
	Sub-type(s) :
	-iron rich patina: natural black to brown thin layer enriched iniron clay/minerals, which can be found on iron containing sandstones. This kind of patina is generally observed in outdoors environment, and develops quite uniformly on the stone surface. -Oxalate patina: orange to brown thin layer enriched in calcium oxalates. This kind of patina may be found in outdoors environment, often on marble and limestone substrates.
	Not to be confused with :
	-film, which is a thin visible homogeneous covering or coating layer generally of organic nature. -black crust, which is generally coherent accumulation of the materials on the surface. Black crusts are black to gray and have a perceivable tickness. -discolouration, which is a change of colour perceived as unattractive
	Other remarks

SOILING	Definition :
	Deposit of a very thin layer of exogenous particles (e.g. soot) giving a dirty appearance to the stone surface.
	Relationship with the substrate :
	With soiling, the substrate structure is not considered as affect ed. Soiling may have different degrees of adhesion to the substrate.
	Not to be confused with :
	- *Crust*, which has a visible thickness. - *Deposit*, which has a visible thickness, and not systematically a dirty appearance.
	Other remarks
	With increasing adhesion and cohesion, soiling can transform into a crust. Soiling may originate from atmospheric pollutants (industrial, domestic or car exhaust products) or from particles transported by running water or heating convection.

BIOLOGICAL COLONIZATION	
	Definition :
	Colonization of the stone by plants and microorganisms such as bacteria, cyanobacteria, algae, fungi and lichen (symbioses of the latter three). Biological colonization also includes influences by other organisms such as animals nesting on and in stone.
	Relationship with the substrate :
	Direct growth on and in stone or stone cavities ; also indirect influences by nearby trees and other organisms.
	Equivalent term to be found in other glossaries
	Biological growth, biological overgrowth, living exogenous material.
	Other spelling :
	Biological colonisation.
	Not to be confused with :
	- *Deposit* : consists of an accumulation of exogenic material, such as dust, droppings, on the stone surface. For instance, a bird's nest, a spider web are part of biological colonization, but bird or bat droppings are deposits.
	Other remarks
	Biological colonization may be used when a mixture of different types of organisms are present on a stone, and are not distinguishable from each other. *Biofilm* : Mono- to multi-layered microbial colony attached to surfaces with varying thickness of up to 2mm. Often a biofilm consists of very few cells of different microorganisms embedded in large amounts of extracellular slime. These cohesive often sticky layers may shrink and expand according to the supply of water. Biofilms often create multi-coloured biopatina by production of colouring agents. Higher plants grow sometimes to a considerable size at unexpected locations.

ALGA	
	Definition :
	Algae are microscopic vegetal organisms without stem or leaves which can be seen outdoors and indoors, as powdery or viscous deposits (thickness: tenth of mm to several mm). Algae form green, red, brown, or black veil like zones and can be found mainly in situations where the substrate remains moistened for long periods of time. Depending on the environmental conditions and substrate

	type, algae may form solid layers or smooth films. On monuments, algae are constituted of unicellular to pluricellular clusters, and they never form macroorganisms.
	Relationship with the substrate :
	Algae generally constitute superficial films. They may be found also deeper into the substrate (under scales, in cracks).
	Other spelling :
	Plural form: *algae*.
	Not to be confused with :
	Algae may be confused with *epilithic lichen*, with fungae and sometimes with soot or mineral deposits soiling the stone surface. If algae are present, wetting and brushing the surface will turn it to green due to the presence of chlorophyll.
	Other remarks
	Several groups of algae may grow on and in stone depending on climate and stone type. Green algae (sometimes red, e.g. trentepohlia) diatoms (usually yellow to brown), and in rare cases red algae may occur. Cyanobacteria (formerly called blue-green algae) are very frequent stone dwellers and can cause black, bluish or even violet stains. In some cases the stone serves as a source of nutrients. However usually the stone surface is only a solid host for growth.

MOSS	**Definition :**
	Vegetal organism forming small, soft and green cush ions of centimetric size. Mosses look generally like dense micro-leaves (sub- to millimetric size) tightly packed together. Mosses often grow on stone surface open cavities, cracks, and in any place permanently or frequently wet (masonry joints), and usually shady.
	Relationship with the substrate :
	Mosses develop brown rhizomes and may create a micro-soil zone between the stone surface and the green part.
	Not to be confused with :
	- *Lichen*, which are composed of a thallus and do not have the typical organisation of micro-leaves tightly packed together.

	- *Algae* : Algae are green during the humid season, but look different from mosses (viscous consistency, absence of microleaves).
	Other remarks
	Mosses often change morphology and colour under lack or excess of water. During dry periods of the year, the cushions shrink, become harder and brittle, and their colour turns to brown.

LICHEN	**Definition :**
	Vegetal organism forming rounded millimetric to centimetric crusty or bushy patches, often having a leathery appearance, growing generally on outside parts of a building. Lichen are most commonly grey, yellow, orange, green or black and show no differentiation into stem, root and leaf
	Relationship with the substrate :
	A lichen is composed of a thallus, eventually bearing fruiting bodies, generally developed on the stone surface, and rhizines that may penetrate deep into the stone (tens to several millimetres).
	Sub-types(s):
	Lichen usually are divided into crustose, folious and epilithis types. When their thallus is mainly inside the stone, they are called endolithic lichen.
	Not to be confused with :
	Moss, alga, mould
	Other remarks
	All lichen represent symbiotic growth of a fungus and green alga or a cyanobacterium. Lichen Is a common feature on outdoor stone and is generally best developed under clean air conditions, but growth may be facilitated by certain pollutants such as nitrogen oxides mainly from vehicle pollution or agriculture. Former lichen growth may be detected by typical pitting structures or lobate or mosaic patterns and even depressions

PLANT	**Definition :**
	Vegetal living being, having, when complete, root, stem and leaves, though consisting sometimes only of a single leafy expansion
	Relationship with the substrate :
	Equivalent terms to be found in other glossaries:

	Higher plant, vegetation
	Other remarks
	If buildings are not maintained, plants will eventually colonise places where water is accessible, extending roots into joints and fractures. As the roots grow they can widen these joints and cracks and break the stone. They may also contribute to keeo areas damp. This in turn, exacerbates other processes such as salt deterioration

ST. STEPHEN'S CATHEDRAL - VIENNA

Introduction

Founded in 1137, Vienna's Cathedral is a late romanesque gothic Church, dedicated in 1147 to Saint Stephen. Although the first structure was completed in 1160, major reconstruction and expansion lasted until 1511, and repair and restoration projects continue to the present day.

From 1230 to 1245, the initial structure was extended westward; the present-day west wall and romanesque towers date from this period. In 1258 a great fire burned down much of the original building. A larger replacement structure, also romanesque in style, and reusing the two towers, was constructed over the ruins of the old church and consecrated in 1263. In 1304 a gothic three-nave choir was constructed east of the church, wide enough to meet the tips of the old transepts. In 1359, a westward Gothic extension of the Albertine choir in the vicinity of the present south tower was built. This expansion would eventually entirely encapsulate the old church. The southern tower was completed in 1433, while the vaulting of the nave was carried out from 1446 to 1474. The foundation of a northern tower was laid in 1450, its construction was abandoned when major works on the cathedral ceased in 1511.

During the World War II, the fire severely damaged the roof of the cathedral causing it to collapse. The rebuilding began immediately after, with a limited reopening in 1948 and a full reopening in 1952.

Lithotype and decay phenomena

The lithotypes used at St. Stephens Cathedral in Vienna are:

- **St. Margarethen calcareous fossil arenite**
- **Au calcareous fossil arenite**
- **Siliceous sandstone from lower Austria**
- **Mannersdorf limestone.**
- **Bihac Limestone**

Those rocks are of a biogenetic calcareous nature and due to their local lithological variations they are differing in fineness of fossil shells and various amounts of terrigenous silicate components. A variation of

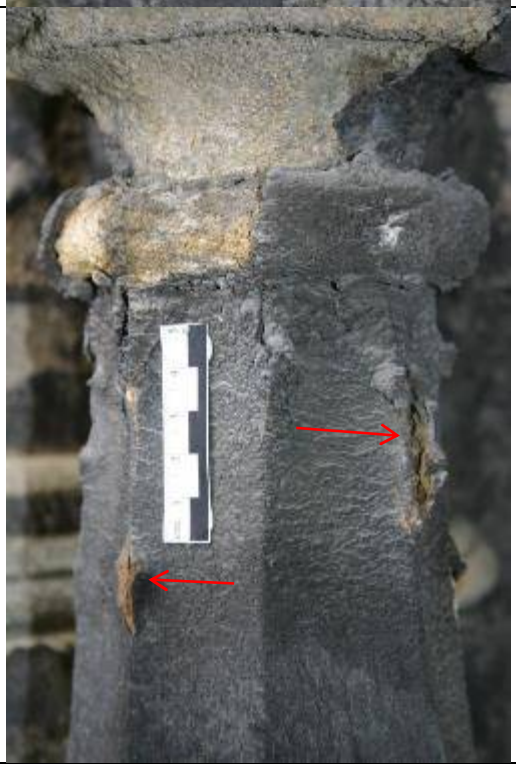
fine and highly porous to coarse and relatively compact lithotypes can be found relating to their different degrees of recrystallization and cementation.

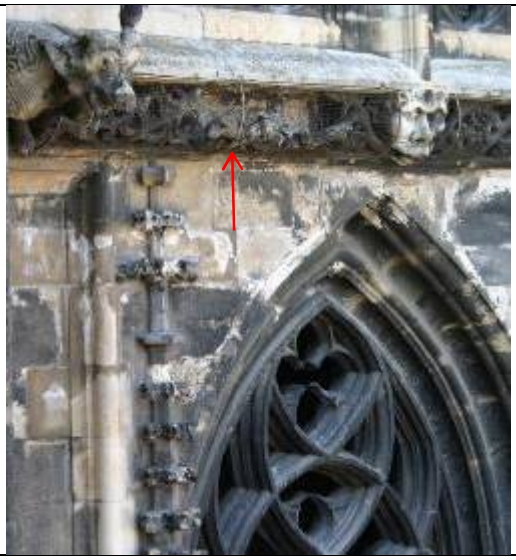
According to the importance for the St. Stephens Cathedral and due to their typical decay phenomena two different types of stones were chosen for the main research activities within the project Nano-Cathedral: AU and St. Margarethen Calcareous fossil arenite.

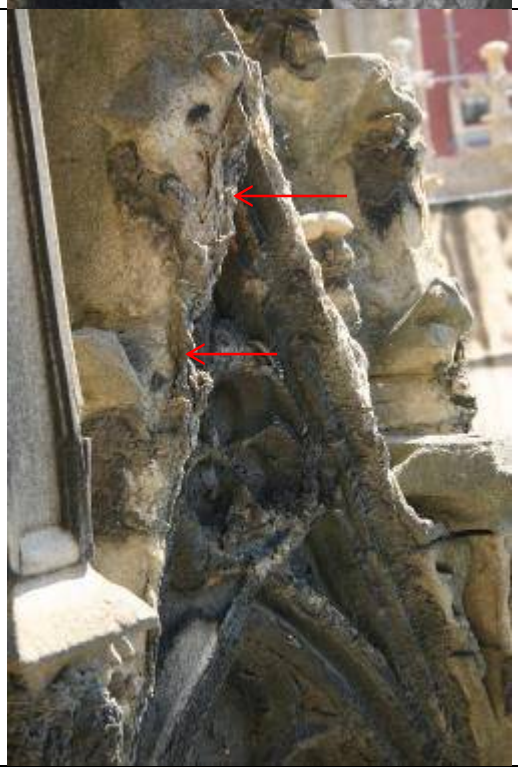
Both of them are generally prone to the action of water and acidic air pollutants. In general stone surfaces, which are protected from the impact of rain or running-off water, are covered by black crusts composed of gypsum. Those lithotypes are affected by dissolution and erosion and thus appear clean in more exposed areas. Chemical weathering of the calcite minerals leads to significant losses of grain cement and hence cohesion in the interior fabric of the stones, while dense crusts form in areas of precipitation in protected areas. Beside these specific main decay phenomena, typical deterioration patterns can be found and will be described in detail below.

Concerning its environmental conditions, Vienna, belongs to a central European area and is mainly characterized by a continental weather.

HAIR CRACK		*Vertical **hair cracks** due to shear stresses between crusts and the porous substrate.* *Lithotype: calcareous arenite from St. Margarethen*
SPLITTING		***Splitting** of a limestone corner ashlar.* *Lithotype: calcareous arenite from St. Margarethen*

BLISTERING		***Blistering*** *on surface caused by different gradient of compactness within the stone.* *Lithotype: calcareous arenite from St. Margarethen*
BLISTERING		***Blistering*** *on surface caused by expansion of the weathered, compact surface layer.* *Lithotype: calcareous arenite from St. Margarethen*

BURSTING		***Bursting*** *of limestone elements due to an extensive exposure and caused by bending planes and a too high load of the lost material.* *Lithotype: calcareous arenite from St. Margarethen*
BURSTING		***Bursting*** *of ornamental elements most probably caused by long-term exposure to extensive weathering.* *Lithotype:* *Au calcareous arenite*

DELAMINATION			***Delamination*** *of limestone due to chemical weathering and biological colonisation.* *Lithotype: calcareous arenite from St. Margarethen*
EXFOLIATION			***Exfoliation*** *of thin stone layers sub-parallel to the stone surface.* *Lithotype: calcareous arenite from St. Margarethen*

SANDING		***Sanding*** *beneath a black crust.* *Lithotype: calcareous arenite from St. Margarethen*
POWDERING		***Powdering*** *appearing as whiter areas with an irregular surface.* *Lithotype: Au limestone*

PEELING		***Peeling*** *of a surface layer on a limestone element.* *Lithotype: calcareous arenite from St. Margarethen*

SCALING		***Contour scaling*** *of a surface layer on a limestone element developed as thin detachment on the ornamental element.* *Lithotype: calcareous arenite from St. Margarethen,*

ALVEOLIZATION		***Alveolization*** *of a porous St. Margarethen limestone* *Lithotype: calcareous arenite from St. Margarethen*

EROSION		***Erosion*** *of carved details and smoothed shapes.* *Lithotype: calcareous arenite from St. Margarethen*

MISSING PART		***Missing part*** *of a buttress.* *Lithotype: calcareous arenite from St. Margarethen*

BLACK CRUST		***Black crust*** *tracing the surface of carved element.* *Lithotype: calcareous arenite from St. Margarethen*

DEPOSIT		***Deposit*** *of pigeon excreta.* *Lithotype:* *Au limestone*

STAINING		***Staining*** *due to former impregnation with linseed oil.* *Lithotype:* *Au limestone*

EFFLORESCENCE		*Epsomite* ***efflorescence****.* *Lithotypes: Au and Mannersdorf limestones*

SOILING		***Soiling*** *on a surface protected from direct rainfall.* *Lithotype: calcareous arenite from St. Margarethen*

ALGA		***Green algae*** *developing in a corner**.* *Lithotype: calcareous arenite from St. Margarethen*
ALGA		***Green algae*** *and* ***saccharomyces albicans*** *developing in a corner where it stays humid for a longer period of time.* *Lithotype: calcareous arenite from St. Margarethen*

MOSS		***Moss*** *in the crack on an ashlar* *Lithotype: calcareous arenite from St. Margarethen*

S. PETER AND MARY CATHEDRAL – COLOGNE

Introduction

The Construction of Cologne Cathedral started in 1248 and was interrupted in 1473, leaving it unfinished. The work started again in the 19th century and was completed, according to the original plan, in 1880.

When the construction began in 1248, the site had already been occupied by several previous roman structures. The eastern arm was consecrated in 1322. In the mid 14th century the works on the west front started, this work was interrupted in 1473, leaving the southern tower complete up to the belfry level. Some work proceeded intermittently on the structure of the nave between the west front and the eastern arm, but during the 16th century this ceased.

In the 19th century it was decided to complete the cathedral; work resumed in 1842 to the original design of the surviving medieval plans and drawings, thus using more modern construction techniques, including iron roof girders. The nave was completed and the towers were added. The cathedral was finally completed in 1880.

Lithotypes and decay phenomena

The Cathedral was built using different lithotypes:

- **Tercé limestone**
- **Schlaitdorf sandstone**
- **Obernkirchen sandstone**

A Tercé Limestone was used to build some sockles and baldachins holding the portal figures. The architectonical elements built using this material are, at a different level, covered by a layer of soiling and deposit, and not seriously affected by pigeons dejections, the surface is affected by detachment phenomena such as sanding, and deposition as black crusts, microkarsts and a biological growth of green algae. Under the surfaces affected by black crusts, several detachment phenomena damage the stone surfaces such as bursting, delamination and disintegration. In some more exposed parts, some chiselled elements are missing

and the remaining surface is affected by the above indicated disintegrations phenomena. Some impact damages were noticed. The parts corresponding to less protected areas are affected by exfoliation.

Schlaitdorf sandstone, also used in this building, shows the above indicated decay phenomena, among which emerges the disintegration of the stone with a consequent crumbling granular disintegration, sanding, delamination and scale formation, black crusts, red iron crusts, deep alveolization, sub-efflorescence and efflorescence, and in some parts a differential erosion affects the sandstone blocks. A lighter exfoliation and hair cracks were documented.

A third lithotype was taken into account, the Obernkirchen Sandstone, actually not on the building, but consisting in either a model or an artifact that has been sorted out, now stored on an outside terrace. The main decay phenomena consist in biological contamination (green algae) and soiling, salt contamination, scaling, flaking, granular disintegration, powdering and black crusts.

ST. PETER AND MARY CATHEDRAL - COLOGNE -

DECAY PHENOMENA ILLUSTRATED GLOSSARY

SPLITTING		*Vertical **splitting*** *Lithotype: Obernkirchen sandstone*
CRACKS		***Cracks** net due to a mechanical damage* *Lithotype: Obernkirchen sandstone*

HAIR CRACK		*Vertical* ***hair cracks*** *Lithotype: Schlaitdorf sandstone*

BURSTING		***Bursting*** *of a chiselled element on the Baldachin of a portal figure* *Lithotype: Tercé limestone*

DELAMINATION		***Delamination*** *in subparallel stone layers* *Lithotype: Obernkirchen sandstone*

EXFOLIATION		***Exfoliation*** *under the black crust layer* *Lithotype: Obernkirchen sandstone*

EXFOLIATION		***Contour scaling*** *developed as thin detachment on the ornamental element.* *Lithotype: Obernkirchen sandstone*

GRANULAR DISINTEGRATION		***Crumbling*** *appearing as a whiter area with an irregular surface.* *Lithotype: Schlaitdorf sandstone*

POWDERING		***Powdering*** *appearing as whiter area with an irregular surface.* *Lithotype: Obernkirchen sandstone*

SANDING		***Sanding*** *of an ornamental element* *Lithotype: Tercé limestone*

SANDING		***Sanding*** *of an ornamental element.* *Lithotype: Tercé limestone*

PEELING		***Peeling*** *of a surface.* *Lithotype: Obernkirchen sandstone*

PEELING		***Peeling*** *of a surface layer* *Lithotype: Obernkirchen sandstone (detail)*

SCALING		***Scaling*** *of a chiseled element* *Lithotype: Obernkirchen sandstone*

SCALING		***Scaling*** *due to Fe-III oxyde* *Lithotype: Schlaitdorf sandstone*

FLAKING		***Flaking*** *of the surface in a scale shape* *Lithotype: Obernkirchen sandstone*

ALVEOLIZATION		***Deep Alveolization*** *Lithotype: Schlaitdorf sandstone*

EROSION		***Erosion*** *of carved details and smoothed shapes.* *Lithotype: Tercé limestone*

DIFFERENTIAL EROSION		***Loss of Matrix*** *Lithotype: Schlaitdorf sandstone*

IMPACT DAMAGE		***Loss of material*** *due to an impact damage* *Lithotype: Obernkirchen sandstone*

IMPACT DAMAGE		***Impact damage*** *due to an action of a pointed tool* *Lithotype: Schlaitdorf sandstone*

MISSING PART		***Missing part*** *in a sculpted element* *Lithotype: Obernkirchen sandstone*

MISSING PART		***Loss d**ue to a mechanical damage* *Lithotype: Obernkirchen sandstone*

PITTING		***Pitting** visible in the whitish area* *Lithotype: Schlaitdorf sandstone*

BLACK CRUST		***Black crust*** *tracing the surface of carved element.* *Lithotype: Obernkirchen sandstone (detail)*

BLACK CRUST		***Black crust*** *located in an area protected from rainwater fall* *Lithotype: Schlaitdorf sandstone*

BLACK CRUST		***Black crust*** *over a chieseled element* *Lithotype: Obernkirchen sandstone*

SALT CRUST		***Salt contamination*** *Lithotype: Schlaitdorf sandstone*

DEPOSIT		***Deposit** laid over a sculpted area* *Lithotype: Obernkirchen sandstone (detail)*

DEPOSIT		***Pigeon dropping*** *Lithotype: Tercé limestone*

STAINING		*Lithotype: Schlaitdorf sandstone*

SOILING		***Soiling*** *in an area away from rain water seeping* *Lithotype: Obernkirchen sandstone*

SOILING		***Soiling*** *deposit in area protected from rain water* *Lithotype: Obernkirchen sandstone*

EFFLORESCENCE		***Efflorescence*** *as a whitish layer on the stone surface* *Lithotype: Schlaitdorf sandstone*

EFFLORESCENCE		***Efflorescence*** *and subefflorence* *Lithotype: Schlaitdorf sandstone*

ALGA		***Green algae*** *Lithotype: Obernkirchen sandstone*

ALGA		***Green algae*** *Growing under and over the peeled layer* *Lithotype: Obernkirchen sandstone*

ALGA		***Green algae*** *developing on a chiseled element* *Lithotype: Tercé limestone*

SINT-BAAFS CATHEDRAL - GHENT

Introduction

St. Baafs Cathedral dates back to Ghent's oldest parish church, consecrated in 942, and was subsequently expanded in the romanesque style in the 11th century. Some traces of this phase of expansion are still evident in the present day crypt. From the 14th century onwards, several parts of the church were demolished and replaced in the gothic style. A new choir, radiating chapels, expansions of the transepts, a Chapterhouse, nave aisles and a single tower western section were all added during this period. The building was considered completed in 1569"

Lithotypes and decay phenomena

The Cathedral was built with different lithotypes:

- **Balegem Limestone: Arenaceous limestone belonging to the Lede formation,** (Belgium),
- **Gobertange Limestone** was used in original gothic construction of the Cathedral,
- **French limestones from Euville, Savonnières and Massangis** were used as replacement materials.

The limestones are generally affected by granular disintegration, sulphatation, bursting, erosion and scaling. The Balegem Limestone is affected by scaling, cracks, black crusts and sulphatation.

The stone, as below indicated, is prone to several degradation factors: cracks, mainly corresponding to areas that underwent a mechanical stress Some cracks affect the different kinds of stone, such as the Balegem limestone, never in a very serious way.

Exfoliation phenomena affect both Balegem and Gobertange stone; peeling phenomena are visible on chiseled architectonical elements. Several sections, regardless of the material used, are affected by black crusts. It was frequently observed that the surface under the black crusts shows disintegration phenomena, as crumbling and sanding, affecting several elements of the building.

Erosion affects all lithotypes at a different scale, some stone blocks, built in Balegem limestone, appear to be carved, in some other cases the architectonical shape has become smoother because of the prolonged erosion.

A biological attack of different kinds is remarkable: algae, muss and plants grow on the surfaces, corresponding to humid areas, such as the ones close to the ground and to defective rain water drainage and also on the ones protected by direct sun light. In some cases the plants grow on vertical surfaces in the joints between the stone blocks. Further damages to the surfaces are due to holes made on the surface, while holes due to the erosion are visible on sculpted elements emerging from the wall. Some deposit and soiling cover the parts that are more exposed.

Ghent is located in a northern European area which is characterized by a coastal climate.

CRACK		*Vertical **cracks** due to stress between the stone pillar and the metal frame.* *Lithotype Balegem limestone*

HAIR CRACK		*Vertical **hair cracks** developing on the stone ashlar* *Lithotype: Balegem limestone*

EXFOLIATION		***Exfoliation** of thin stone layers* *Lithotype: Bagelem limestone*

EXFOLIATION		***Exfoliation*** *of thin stone layers* *Lithotype: Gobertange limestone*

POWDERING		***Powdering*** *beneath a black crust, appearing as a whiter area* *Lithotype: Balegem limestone*

POWDERING		***Powdering*** *beneath a black crust, appearing as a whiter zone under the black crust* *Lithotype: Balegem limestone*

CRUMBLING		***Crumbling*** *beneath a black crust.* *Lithotype: Balegem limestone*

PEELING		***Peeling*** *of a surface layer on a limestone element* *Lithotype: Balegem limestone*

SCALING		***Contour scaling*** *of a decorative element* *Lithotype: Balegem limestone*

CONTOUR SCALING		***Contour scaling*** *of the stone blocks* *Lithotype: Balegem limestone*

EROSION		***Coving*** *of the stone block's surface* *Lithotype: Balegem limestone*

DIFFERENTIAL EROSION		***Differential Erosion*** *of the stone decoration* *Lithotype: Gobertange limestone*

EROSION		***Erosion*** *of the stone blocks and rounding of the edges* *Lithotype: Gobertange limestone*

ROUNDING		***Erosion*** *of the angular element* *Lithotype:* *Balegem limestone*

MISSING PART		*Loss of material due to the mechanical pressure of the metal frame* *Lithotype: Balegem limestone*

BLACK CRUST		***Black crust*** *tracing the surface of carved element.* *Lithotype: Balegem limestone*

BLACK CRUST		***Black crust*** *Lithotype: Gobertange limestone*

BLACK CRUST		***Black crust*** *Lithotype: Gobertange limestone*

DEPOSIT		***Deposit*** *on an exposed stone work* *Lithotype: Gobertange limestone*

STAINING		***Staining*** *due to an oxidised iron element* *Lithotype: Balegem limestone*

MOIST AREA		***Moist area*** *with subsequent algal growth due to a defective water drainage* *Lithotype: Gobertange limestone*

MOIST AREA		***Moist area***

ENCRUSTATION		*Cementitious pointing over the stone blocks surface* *Lithotype: Gobertange limestone*

SOILING		***Soiling*** *on window upper frame*

ALGAE		***Green algae*** *developing in a corner in humid area. Close to the ground**.***
ALGAE		*Algae growing in a wet area corresponding to a leaking water drainage* *Lithotype: Gobertange limestone*

PLANTS		***Plants*** *growing in the joints between the stone blocks*

MOSS		***Moss*** *growing in a wet and shady corner*

SANTA MARIA CATHEDRAL – PISA

Introduction

Founded in 1064 and consecrated in 1118, the construction of the Cathedral knew two phases, respectively related to the architects Buscheto, who wrote the original structure with body basilica with five aisles, with three naves and transept dome on the cruise and Rainaldo, who extended the building and the facade. The construction was finally completed only in the last quarter of the twelfth century, when, in the central portal, were placed the bronze doors by Bonanno, lost in the devastating fire of 1595, following which they were made several substitutions destroyed works and started a extensive decorative program.

Lithotypes and decay phenomena

The Cathedral of Pisa was built using different lithotypes such as:

- **Mount Pisano marble**
- **black limestone**
- **apuan marble**
- **proconnesian marble**
- **calcarenite granitoid rocks**
- **serpentinite.**

The surfaces are affected by the climatic conditions and by the air pollutants to which the degradation phenomena are connected. Some kind of cracks are visible on the surface (hair cracks, star shaped cracks and craquele). Some delamination phenomena can be observed on the stone surface and disintegration affects the stone in forms of crumbling, sugaring and granular disintegration.

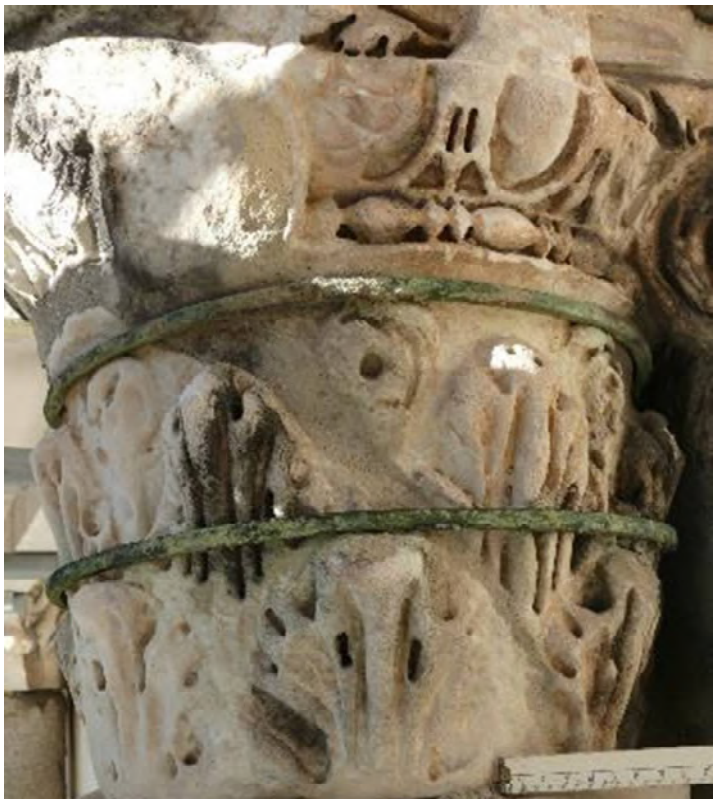
Some erosion phenomena affect the material while impact damages and gaps are responsible for the loss of material. Limited areas affected by pitting were observed too. Black crusts are to be observed in several areas as much as staining due to iron and bronze oxidation. Some incrustations and patinas were observed and the soiling deposit cover the areas protected by wind and rain fall.

The biological colonization is presently affecting the monument in several forms i.e. algae, lichens, moss and plants growing in the joints between the stone slabs.

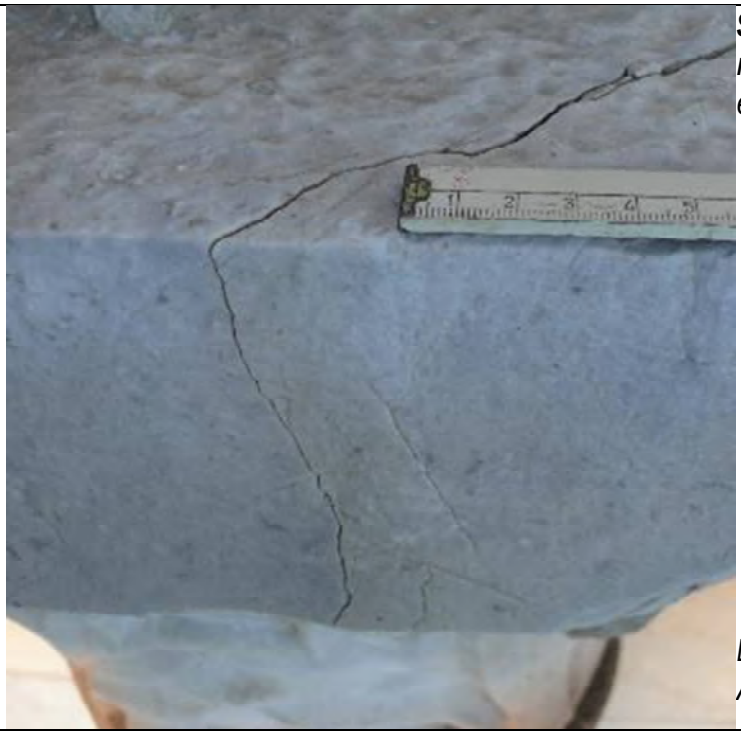
Pisa belongs to a Coastal southern European climate.

SANTA MARIA CATHEDRAL – PISA

DECAY PHENOMENA ILLUSTRATED GLOSSARY

FRACTURE		***Fracture*** *of a capitel* *Lithotype: Apuan marble*

STAR CRACK		***Star crack*** *due to an impact damage* *Lithotype: Apuan marble*
CRACK		***Crack*** *affecting an ashlar* *Lithotype: Mount Pisano marble*

SPLITTING		***Splitting*** *of a marble element* *Lithotype: Apuan marble*

BURSTING		***Bursting*** *due to an internal pressure* *Lithotype: Apuan marble*

DELAMINATION		***Delamination*** *visible as a physical separation into layers following the stone laminae* *Lithotype: Proconnesian marble*

DELAMINATION		***DELAMINATION*** *following the stone laminae* *Lithotype: Mount pisano marble*

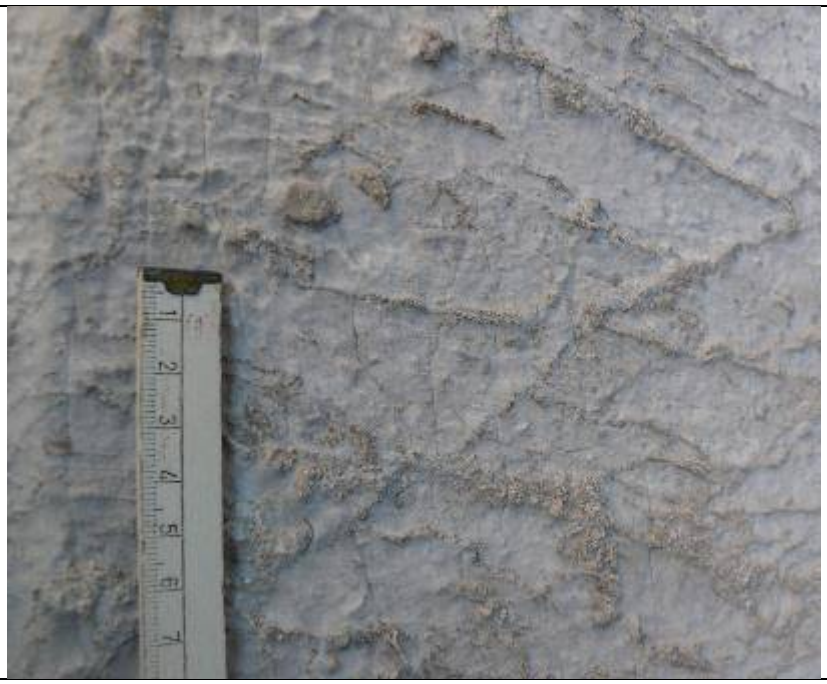
EXFOLIATION		***Exfoliation*** *of a chiseled capitel element* *Lithotype: Apuan marble*

SUGARING		*Sugaring with loss of crystals* *Lithotype: Proconnesian marble*
GRANULAR DISINTEGRATION		***Disintegration** in grains* *Lithotype: Apuan marble*

CHIPPING		***Fragmentation*** *of the column under the capitel* *Lithotype: Apuan marble/granite*

FLAKING		***Flaking*** *appearing as very thin scaling* *Lithotype: Mount Pisano marble*

DIFFERENTIAL EROSION		***Differential erosion*** *consisting in the loss of the stone matrix* *Lithotype: Mount Pisano marble*

DIFFERENTIAL EROSION		*Loss of matrix* *Lithotype: Mount Pisano marble*

EROSION		*Rounding of the angular element* *Lithotype: Mount Pisano/Apuan marble*

EROSION		*Rounding of the stone work of the capital* *Lithotype: Apuan marble*

IMPACT DAMAGE		***Impact damage*** *on a marble column* *Lithotype: Apuan marble*

IMPACT DAMAGE		***Impact damage*** *causing a star crack* *Lithotype: Apuan marble*

MECHANICAL DAMAGE		*On a marble element over the capital* *Lithotype: Apuan marble*

MICROKARST		***Microkarst** affecting the base of the capital* *Lithotype: Apuan marble*

MISSING PART		*Loss of the upper decoration of the capital* *Lithotype: Apuan marble*

GAP		***Gap** due to an impact damage* *Lithotype: Apuan marble*

PITTING		***Pitting*** *affecting the lower part of a capital* *Lithotype: Apuan marble*

BLACK CRUST		***Black crust*** *developing on an area protected against direct rainfall* *Lithotype: Apuan marble*

BLACK CRUST		***Black crust*** *developing on an area protected against direct rainfall* *Lithotype: Apuan marble*

DEPOSIT		***Deposit*** *of pigeon excreta* *Lithotype: Mount Pisano marble*

DEPOSIT		***pigeon excreta*** *on a surface already covered by soiling* *Lithotype: Apuan marble/ plaster*

DEPOSIT		***Deposit** located in an area protected from rain fall* *Lithotype: Apuan marble*

STAINING		***Staining*** *due to a bronze element* *Lithotype: Apuan marble*

STAINING		***Staining*** *due to iron oxidation* *Lithotype: Apuan marble*

STAINING		***Staining*** *due to the oxidation of an iron nail* *Lithoptype: Apuan marble*

ENCRUSTATION		***Encrustation*** *over a marble surface* *Lithotype: Apuan marble*

FILM		*Film over a marble surface* *Lithotype: Apuan marble*

PATINA		***Patina*** *over a chiseled element* *Lithotype: Apuan marble*

PATINA		***Patina*** *over a sculpted element* *Lithotype: Apuan marble*

SOILING		***Soiling*** *on a surface protected from direct rainfall.* *Lithotype: Apuan marble*

SOILING		***Soiling*** *on a surface protected from direct rainfall.* *Lithotype: Apuan marble/ plaster*

ALGA		***Green algae*** *Lithotype: Apuan marble*

MOSS		***Moss** growing on the mortar layer between two marble ashlars* *Lithotype: Apuan marble*

LICHEN		***Lichen*** *growing on a marble surface* *Lithotype: Apuan marble*

PLANT		***Plant*** ***g****rowing in the joint between two marble slabs* *Lithotype: Apuan marble*

SANTA MARIA CATHEDRAL - VITORIA GASTEIZ

Introduction

The Cathedral of Santa María was built on the cemetery of the primitive village of Gasteiz; the romanic church of Santa María collapsed burned down by the fire of 1202. Alfonso VIII of Castile (who had conquered the city just 2 years earlier), ordered the city be rebuilt and the cathedral was raised at the site of a former one, in order to serve two different purposes: regular religious services and weapon storage. These have been the functions of the Cathedral of Santa Maria, both church and temple-like fortress that served as entry to the city. The cathedral, built in the thirteenth century, was erected within the city walls in the second half of the century and during the next century the church was endowed its Gothic appearance. The project changed along with the centuries, so that each modification was made without taking into account the previous structures. This was the case in the 15th century (when the church became collegiate), and finally in the 1960s, when it was decided to reverse the previous works of strengthening of the external walls and widen the windows, made purely for aesthetic reasons, which had severely damaged the stability of the building.

Lithotypes and decay phenomena

The lithotypes used in this cathedral are:

- **Ajarte lumachelles limestone**
- **sandstone from the Elguea mountain.**
- **Calcarenite from Olarizu**

The majority of white rocks used to build in the cathedral come from Ajarte lumachelle, A limestone mainly consisting in shells, They are used as ashlar stones and columns, on the web spandrels of the lateral naves as well as in almost all of the sculptures. The most important alterations are the fractures affecting the ashlar stones, due to differential forces.

On the lower sections, in contact with the substratum, there is usually some loss of material as a result of chipping and weathering. Occasionally salts crystals. This is all due to the high percentage of porosity which

encourages capillarity and the filtration of fluids. In areas exposed to friction, we can see anthropic wear, a result of the rock's low resistance.

Nevertheless, we do not observe any intrinsic alteration, only alterations due to the action of external agents.

With regards to the climate of the area, it can be said to be a transitional area between an oceanic and Mediterranean climate, with predominant Atlantic characteristics as there is not a true dry summer.

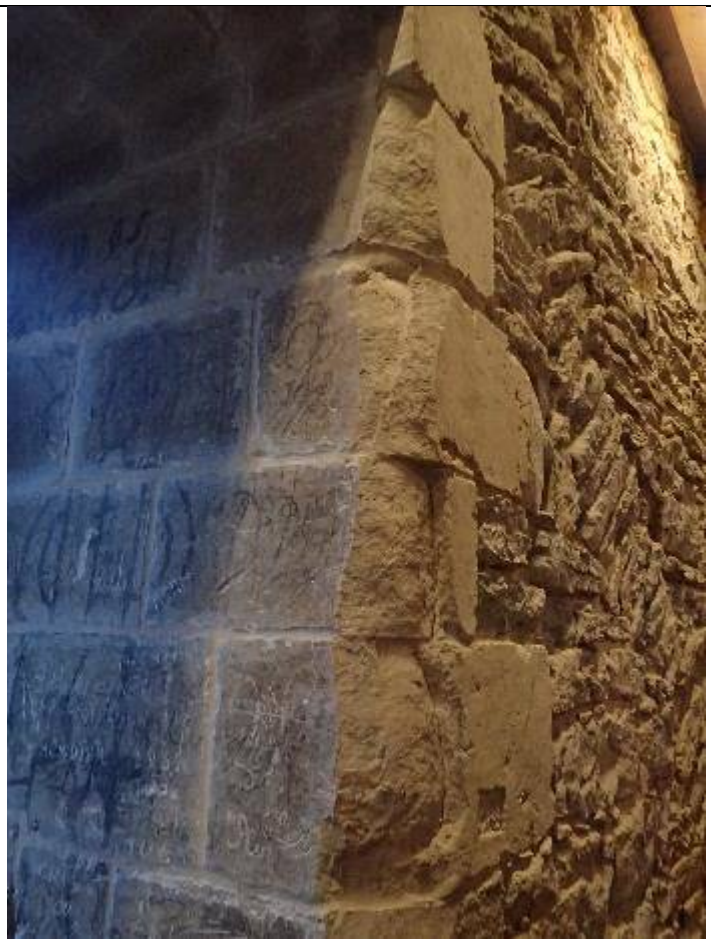
SANTA MARIA CATHEDRAL VITORIA - GASTEIZ

DECAY PHENOMENA ILLUSTRATED GLOSSARY

CRACK		***Crack*** *affecting in a vertical line the wall ashlars* *Lithotype: limestone/ sandstone*

CRACK		***Cracks*** *on the steps of the inner staircase* *Lithotype: Lumachella limestone*

BLISTERING		***Blistering*** *of the surface layer of the stone* *Lithotype: Sandstone*

BURSTING		***Bursting*** *of the angular elements* *Lithotype: limestone*

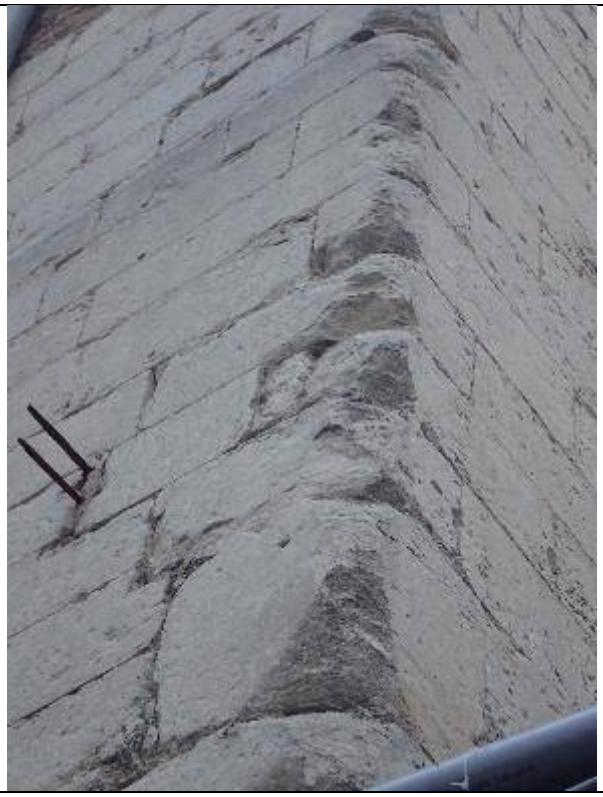
BURSTING		***Bursting*** *of the corner blocks* *Lithotype: sandstone*

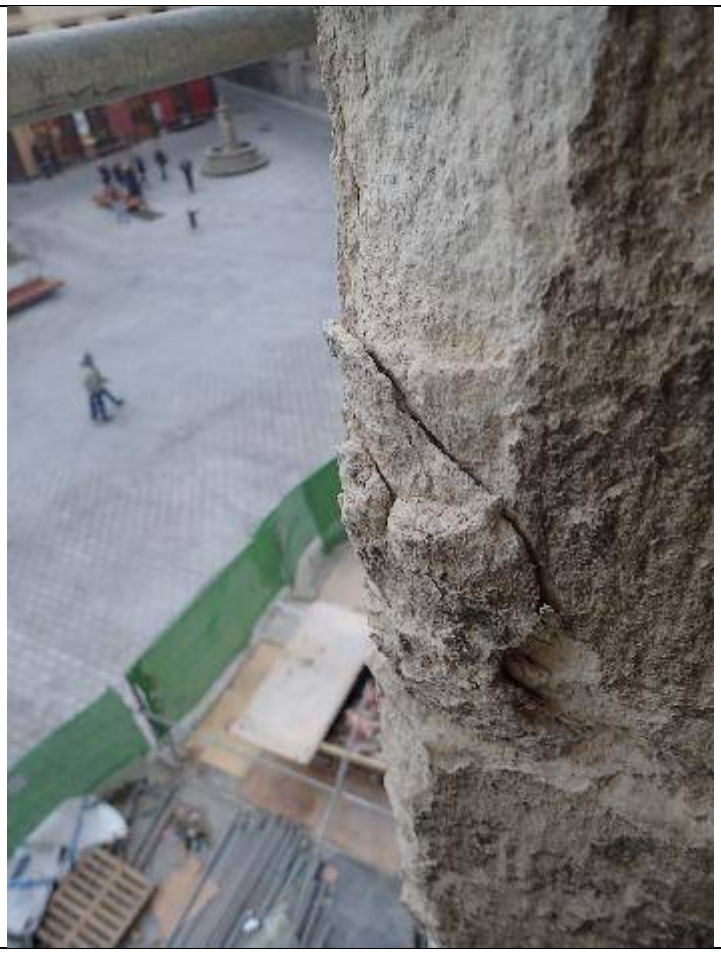
DELAMINATION		***Delamination*** *of the surface of the lower stone blocks* *Lithotype: sandstone*

DELAMINATION		***Delamination*** *of the surface of the stone blocks* *Lithotype: sandstone*
DELAMINATION		***Delamination*** *in parallel sublayers* *Lithotype: limestone*

SANDING		***Sanding*** *affecting the stone blocks surface* *Lithotype: Sandstone*
POWDERING		***Powdering*** *affecting the entire stone blocks surface* *Lithotype: limestone*

CRUMBLING		***Disitntegration*** *affecting the whole stone block* *Lithotypes: limestone/ sandstone*

SPLINTERING		***Splintering*** *affecting the corner stone blocks* *Lithotype: sandstone*

SPLINTERING		***Splintering*** *affecting the corner's stone blocks* *Lithotype: Sandstone*
CHIPPING		***Chipping*** *affecting the upper part of the stone block* *Lithotype: limestone*

PEELING		***Peeling*** *affecting the surface of the sculpted ashlar* *Lithotype: sandstone*

PEELING		***Peeling*** *Affecting the surface of the stone blocks* *Lithotype: limestone*

PEELING		***Peeling*** *affecting the surface of the pillars* *Lithotype: sandstone*

SCALING		***Scaling*** *in parallel layers the stone block* *Lithotype: limestone*

CONTOUR SCALING		***Scaling*** *affecting the edges of the stone blocks* *Lithotype: limestone/ sandstone*

ALVEOLIZATION		***Deep alveolization*** *of the limestone blocks* *Lithotype: limestone*

ALVEOLIZATION		***Deep alveolization*** *Lithotype: limestone*

ALVEOLIZATION		***Alveolization*** *affecting the entire surface of a stone block* *lithotype sandstone*

ALVEOLIZATION		***Alveolization*** *located on the steps of the limestone staircase* *Lithotype: limestone*

DIFFERENTIAL EROSION		***Differential erosion*** *affecting the stone components* *Lithotype: sandstone*

DIFFERENTIAL EROSION		***Differential erosion*** *affecting the stone component* *Lithotype: sandstone*

ROUNDING		***Rounding*** *of the lower part of the wall* *Lithotype: sandstone/ limestone*

ROUNDING		***Major rounding*** *visible on the corner of the wall* *Lithotype: limestone*

ROUNDING		***Rounding*** *Affecting the corners, more exposed to weathering and damaging factors* *Lithotype: limestone*

IMPACT DAMAGE		***Impact damage*** *Leading to the loss of material* *Lithotype: limestone*

CUT		***Cuts made with a tool*** *located on the corner of the blocks* *Lithotype: limestone*
SCRATCH		***Line like loss of material*** *due to the action of some pointed object* *Lithotype: sandstone*

ABRASION		***Abrasion*** *Due to the wearing down by means of friction* *Lithotype: limestone*
KEYING		***Keying*** *On stone blocks to assist the adhesion of an added material* *Lithotype: limestone*
MICROKARST		***Microkarst*** *Affecting the pillar and the steps* *Lithotype: limestone*

MICROKARST		***Net of microkarst*** *Affecting the wall of the staircase area* *Lithotype: limestone*

MISSING PART		***Missing part*** *on the upper part of the decorated pattern* *Lithotype: limestone*

MISSING PART		***Loss*** *Affecting a stone section of a pillar* *Lithotype: limestone/ sandstone*
PERFORATION		***Perforation*** *of the outer wall* *Lithotype limestone/ sandstone*

PITTING		***Pitting*** *affecting the stone blocks* *Lithotype: sandstone*

BLACK CRUST		**Black crust** *Located in an area protected from rain fall* *Lithotype: limestone*

BLACK CRUST		**Black crust** *Completely covering the stone surface* *Lithotype: limestone*

SALT CRUST		***Salt efflorescence*** *appearing as a whitish layer over the stone surface* *Lithotype: limestone*

SALT CRUST		**Salt efflorescence** *Lithotype: limestone*

DEPOSIT		***Deposit** located in an area away from rain fall* *Lithotype: limestone*

BLEACHING		***Bleaching*** *Due to frequent rainwater seeping* *Lithotype: sandstone*

MOIST AREA		***Moist area*** *Located in a section probably away from sun exposure* *Lithotype: limestone/ sandstone*

STAINING		***Staining*** *due to iron oxidized element* *Lithotype: limestone*

EFFLORESCENCE		**Efflorence** Visible on the stone surface as a whitish layer *Lithotype: limestone*

EFFLORESCENCE		**Salt Efflorescene** On the slope of the architectonical element *Lithotype: limestone/ sandstone*

CONCRETION		**Thick concretion** on an angular ashlar *Lithotype: limestone/ sandstone*

CONCRETION		**Concretion located on** a limestone block *Lithotype: limestone*

ENCRUSTATION		**Encrustation** on a decorative element *Lithotype: limestone/ sandstone*

FILM		**Film** over the limestone element *Lithotype: limestone*

GLOSSY ASPECT		**Glossy aspect** Due to the continuous use of the steps *Lithotype: Limestone*

GRAFFITI		**Ink** on a stone surface *Lithotype: sandstone*
IRON-RICH PATINA		**Iron rich patina** visible on the stone surface *Lithotype: limestone*
OXALATE PATINA		**Oxalate patina** covering the entire blocks *Lithotype: limestone*

SOILING		**Soiling** located where no rain water removes the deposit *Lithotype: limestone*

ALGA		**Algal growth** located in a humid shaded area *Lithotype: sandstone*
LICHENS		**Lichens** growing on the stone surface *lithotype sandstone*

MOSS		**Moss** Growing together with lichens on a stone block *Lithotype: sandstone*

MOULD		**Mould** Located on the steps of a shady area *Lithotype: limestone*

PLANT		**Plant** growing on a soil deposit between the stone joints *Lithotype: sandstone*

OPERA HOUSE - OSLO

Introduction

The Oslo Opera house is the home of The Norwegian National Opera and Ballet in Norway. The building construction started in 2003 and was completed in 2007. The building is situated in the Bjørvika neighborhood of central Oslo, at the head of the Oslofjord. The opera is designed by the Norwegian architecture firm Snøhetta, and has received several prestigious awards. One of which is the European Union Prize for Contemporary Architecture or Mies van der Rohe Award in 2009.

Much of the building is covered in white granite, and "*La Facciata"* that is the part considered in this survey is built with a white Italian Carrara marble.The marble roof is designed by the artists Kristian Blystad, Kalle Grude and Jorunn Sannes. The metal cladding of the Opera's fly tower was created in collaboration with Løvaas and Wagle.

Interior surfaces are covered in oak to bring warmth to spaces in contrast to the coolness of the white exterior. The lobby is surrounded by large scale windows that allows a panoramic view of its exterior surroundings and glimpses of rehearsals and workshop activities for the public at street level from outside the building. The roof is supported by thin angled columns also designed not to interfere with views. The main auditorium is a horseshoe shape room reminiscent of classical theaters of the past. It is illuminated by an oval chandelier containing 5,800 handmade crystals.

Lithotype and decay phenomena

the building was built using:

- **white granite**
- **white carrara marble**

The Carrara marble is the one taken into account in this survey. According to the macroscopic observations and the photographic images, the main decay phenomena is the presence of the yellow stains on the marble elements. The presence of stains is wide in outdoor of the Opera House building and covers almost the entire area. Some visible *cracks* are attributed to the weather conditions. Different kinds of *yellow* **s***tains* are shown probably associated with external parameters, such as deposition of soiling with pollutants.

Yellow large stains affect a big part of the surfaces that are often cleaned by mechanical brushing machines using high water pressure and are also expanded in the vertical sides of the marble.

The marble show differences in the finishing of the surfaces of the slopes of the ground. Nevertheless, in this level the yellow stains appear with the same intensity as those of the previous levels. The parapet of the building seemed to be cleaned without any discoloration on the surfaces. This is probably due to the presence of an anti-graffiti product, which was applied on these surfaces, thus providing water repellency. Some other spare stains are covering the surfaces, in limited spots, due to local staining and not to a wide phenomenon. Oslo belongs to a scandinavian climate area and is characterized by a coastal environmental condition.

It is to note that the documentation provided consists in a condition assessment carried out, probably for other purposes, in cooperation with the Technical University of Crete and the Politecnico di Milano, not meant to be written as a part of this research. The documentation provided is mainly centered on the marble staining, not highlighting any other decay phenomena. We cannot therefore assess that there are no further decay phenomena other than the ones below indicated, mostly showing a staining and few cracks. The following considerations should therefore be considered a partial and to be confirmed assessment.

CRACK		**crack** on a marble slab *Lithotype: Carrara marble*
CRACK		**Cracks** on a Marble slab *Lithotype: Carrara marble*

EROSION		**Erosion**. *Lithotype: Carrara Marble*

STAINING		**Staining** on a Marble Slab *Lithotype: Carrara marble*

STAINING		**Staining** *Lithotype: Carrara marble*