

UNDERSTANDING STONE DECAY



WEATHERING RESEARCH GROUP
SCHOOL OF GEOGRAPHY,
ARCHAEOLOGY & PALAEOECOLOGY

QUEEN'S UNIVERSITY BELFAST

STONE SOILING

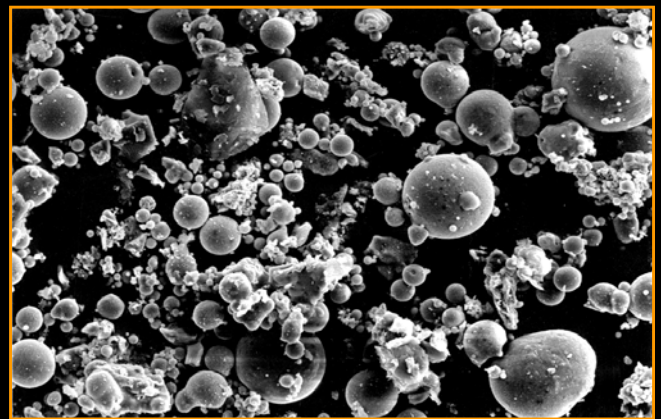
'Black crusts' represent the most extreme form of soiling on buildings. They can also mask ongoing decay mechanisms, such as salt weathering, which can continue beneath the crusts and eventually cause large amounts of material loss. Crusts build up in sheltered areas that are exposed to moisture in the form of fog, mist, or dew. This moisture is known as 'occult deposition', and contains pollutants in much higher concentrations than normal rainfall. This aids the production of gypsum, which crystallizes on the surface, binding any particles that have blown, or washed onto the stone. Diesel engines are one of the most damaging particle sources, but fossil fuel combustion also produces tiny particles (known as flyash) which can adhere to buildings. Street or airborne dust may also become trapped on the stone surface and ultimately bound in as part of the crust.



Buildings in Belfast City Centre. Façades which illustrate the contrast between soiled and cleaned buildings.

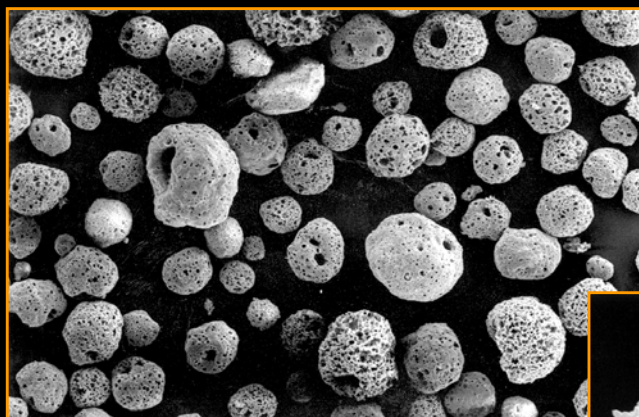


Gloucester Cathedral. Extensive black crust development on Paineswick Stone in an area protected from rain.

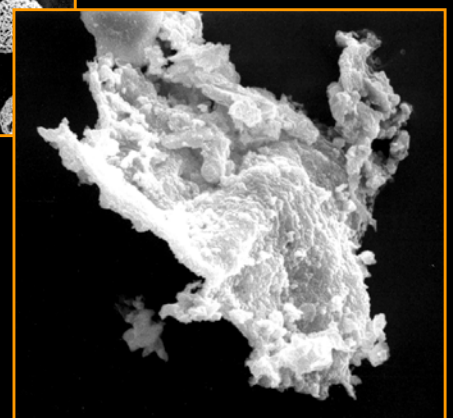


SEM Micrograph of flyash particles from coal combustion. These are composed primarily of silica and aluminium, with minor amounts of potassium, titanium, and iron. Picture width: c.70µm.

SEM Micrograph of flyash particles from oil combustion. These particles are rich in sulphur and are thought to facilitate the formation of gypsum through the combination of sulphuric acid and calcium carbonate in limestone. (Picture Width, c.560µm)



SEM Micrograph of a particulate produced by a car engine. These are rich in carbon and therefore very effective at soiling buildings. Their high specific surface area also enables them to trap moisture which is essential for the operation of decay processes. Picture width: c.70µm.



LIMESTONE DECAY

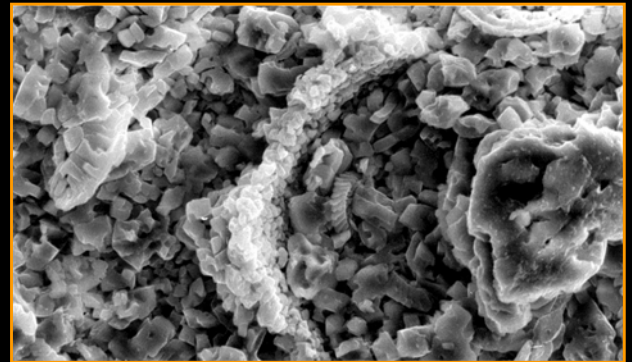


Castle Coole, Co. Fermanagh. Despite its rural location, parts of the building show evidence of significant solution and salt weathering of limestone. Castlecoole's proximity to Enniskillen means that it may be exposed to minor concentrations of urban pollutants, but probably receives most salt as wind-blown particulates from the Donegal coastline.

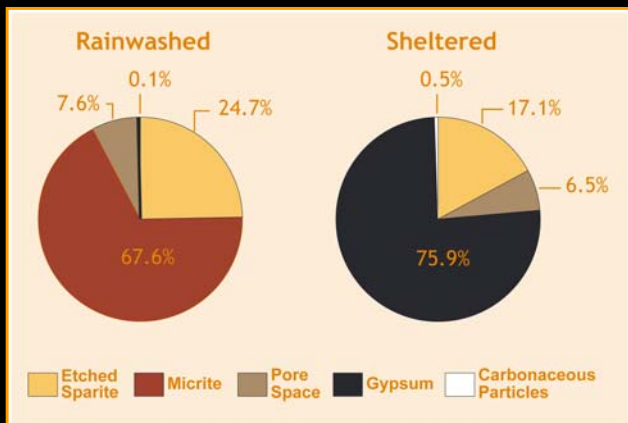
Limestone is a widely used building stone primarily because of its appearance and quality. However, it is particularly susceptible to deterioration principally through the effects of chemical dissolution. Even unpolluted rain contains carbon dioxide creating a weak carbonic acid which is able to dissolve calcite, the main mineral component of limestone. This natural acidity of rain is further increased by reactions with other atmospheric pollutants such as sulphur and nitrogen oxides, with a resultant increase in the rate of limestone dissolution.



Parts of the original balustrade at Castle Coole, removed during restoration, show obvious loss of architectural detail associated with the combined action of chemical dissolution and physical disruption by salt crystallisation.



SEM Micrograph showing the surface of a limestone sample exposed for 15 months in Venice. Chemical dissolution has resulted in the preferential removal of calcite leaving a fossil fragment ridge, rich in less soluble silica, standing proud of the surface (at centre). Picture width: c.60µm.



Urban air quality has greatly improved since the introduction of 'Clean Air' legislation in the 1950s. However, increased vehicular traffic and an associated rise in atmospheric sulphur and nitrogen oxides continues to pose a threat to our built heritage. The potential for stone surface change is shown by field trials in which small limestone tablets affixed to buildings in exposed and sheltered locations exhibited a range of surface alterations arising from the action of different weathering processes. (See pie charts)

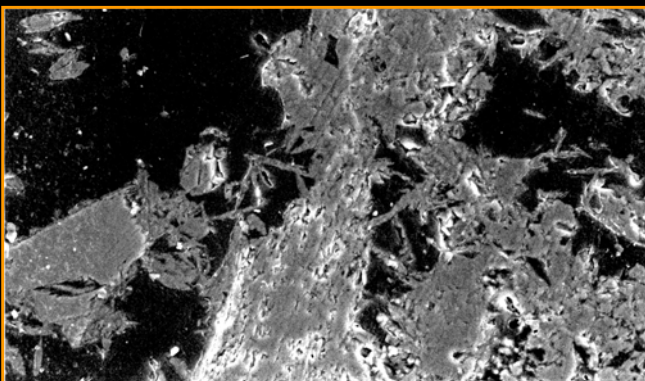
SALT WEATHERING



York Minster. This section of stonework shows differential weathering of original Tadcaster/Huddleston limestone and replacement Ketton stone, introduced as part of restoration work in the early 20th Century. Ironically, it is the replacement Ketton stone that is showing the most serious damage.

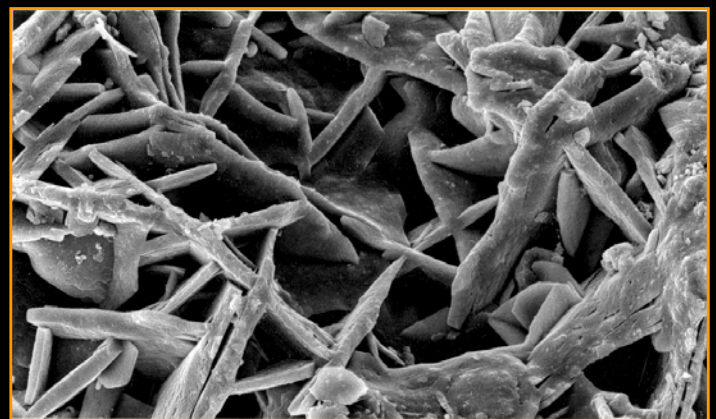


Salisbury Cathedral. A Chilmark stone capital which exhibits the catastrophic results of salt weathering – here in combination with Black Crust development. The surface has blistered and subsequently become detached, exposing disaggregated material to further weathering.



*SEM Micrograph of a black crust in section. The dark areas are pore spaces into which needle-shaped gypsum crystals have grown. It is this mechanism which disrupts the internal structure of stone, ultimately leading to scaling, flaking, and blistering on the surface.
Picture width: c. 110µm.*

Solution Weathering is continual but generally unthreatening to the structure of a building. Other weathering mechanisms may not be seen as often, but can be much more damaging to stone. One such mechanism is salt weathering. Salts occur naturally in the atmosphere e.g. at the coast, but in polluted environments their concentrations and variety are increased due to the chemical reactions between limestone and acid pollutants such as Sulphuric Acid. The salt most commonly produced by this reaction is *Gypsum* (Calcium Sulphate) and this is the salt most frequently associated with weathered limestone. The salt is soluble, passing into solution when the stone is wet. On drying, the salt precipitates out of solution into crystals either on the surface, or within the pores of the stone. Crystallisation within pore spaces can lead to dislodgement of individual grains (granular disintegration) or the development of scales and flakes of stone.



*SEM Micrograph of gypsum crystals on the surface of a black crust. They form a porous surface through which moisture can permeate, carrying with it potentially damaging salts in solution.
Picture width: c. 120µm.*