University of Glasgow

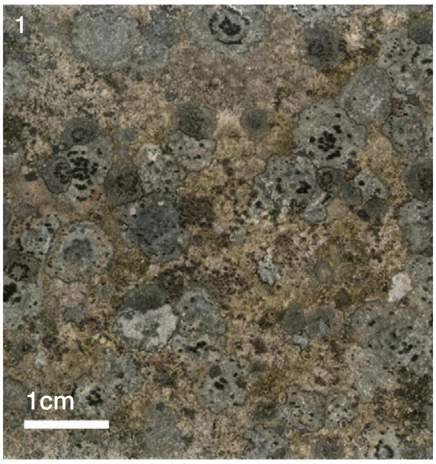
ISAAC
Imaging Spectroscopy And Analysis Centre

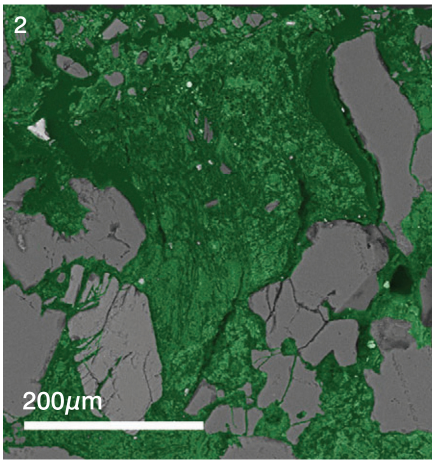
Measuring the Impact of Climate Change on Historic Buildings

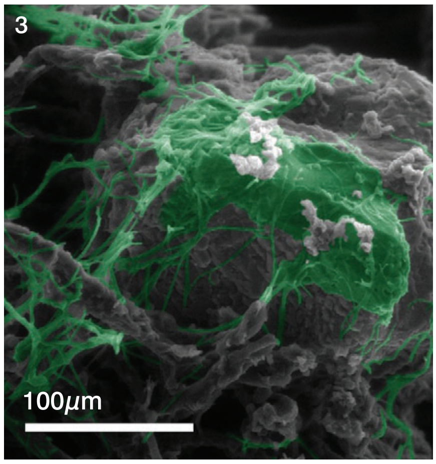
Elgin Cathedral

Climate Change – A Major Concern for Historic Buildings

In Scotland's wet climate, rainfall can have a critical impact on the rate of sandstone decay in historic buildings. With climate change, predicted increases in winter rainfall may, in addition to stone saturation, accelerate the decay process by affecting the growth and loss of biological and pollutant crusts on building stonework. This leads to sandstone discolouration, spalling (i.e., flaking), and exposure of the underlying face, with further weakening to the structural integrity. Knowledge of the potential effects of climate change is vital to Historic Scotland, which is responsible for safeguarding the nation's built heritage. Understanding how sandstone decay may be impacted by higher rainfall will be a key factor in developing strategies to limit damage to historic buildings and inform Historic Scotland's maintenance plan for properties in its care.







Biological and Biomineralic Crusts Pose a Difficult Customer Challenge

Biological and biomineralic crusts are difficult to characterise by conventional laboratory techniques, and so their composition and structure are poorly understood. Some will aggressively attack sandstone through the action of organic acids or by grain plucking; others can actually protect the underlying stone by binding the top surface and reducing weathering effects. Abrasive cleaning or the application of biocides can be used to remove biological materials, but this may not always be the best means for minimising long-term decay.

Because of its expertise in this field, the University of Glasgow's School of Geographical and Earth Sciences (GES) is being funded to assess the impact of different stone compositions and mineralogies on the development of biological crusts on sandstone and to determine whether increased rainfall due to climate change is likely to accelerate sandstone decay. Analytical support is being provided for the project by the Imaging Spectroscopy and Analysis Centre (ISAAC) in GES.

GES's objectives in the project are to evaluate whether sandstone composition (particularly cement mineralogy) is a controlling factor in developing biomineralic crusts, establish whether higher rainfalls are more likely to promote biomineralic crust development or to accelerate its removal, assess whether sandstone decay increases in step with biological activity, and investigate how the rate of sandstone decay responds to the removal of biomineralic crusts (such as by destabilising the underlying rock).

Stone Characterisation with Raman and Electron Microscopy

By using Raman spectroscopy with scanning electron microscopy (SEM), both of which are non-destructive techniques available in ISAAC, the mineralogy of sandstones and their cements can be characterised. Over time, biological activity may be measured and compared for a range of samples under varied environmental conditions. Raman is a suitable tool for determining the chemistry of stone samples. It can also be used to identify whether the biological growth is superficial or the underlying rock substrate is affected by acids and chelating agents, both sources of chemical weathering, produced by the growth of surface organisms.

ISAAC has two SEM's that are ideally configured for characterising the mineralogy of stone samples and the effects of biological growth and/or wetting on mineral cements. Both have field-emission guns that can operate in low vacuum to produce very high-resolution images. One SEM can operate in 'environmental' mode, which is essential for studying microbes. These analyses will reveal whether decay is caused by cement dissolution or bio-mechanical processes affecting pore spaces within the sandstone.

The biomineralic crusts examined to date are dominated by the biomarker carotene, a compound used to protect cells from damage during photosynthesis. Carbonaceous compounds have also been found in black crusts that come from atmospheric particulates of an inorganic origin. Grains embedded in lichen structures have also been observed. Raman spectroscopy has allowed these to be identified as plucked grains rather than secondary precipitates, such as calcium oxalate.

GES and ISAAC Expertise Informs Historic Building Preservation and Restoration

GES's expertise and knowledge, combined with ISAAC's state-of-the-art facilities, enable the University of Glasgow to offer comprehensive characterisation and analysis of sandstone mineralogy and the impact on biological activity from higher rainfalls, guiding Historic Scotland's decision-making in several key areas. Variations in sandstone mineralogy, including cements, may show that stone from one quarry (or quarry zone) may be less susceptible to biological attack than other stones. Similarly, certain sandstones with particular mineralogy, porosity, and permeability may be proven to be preferable for use in restoration work. Whether climate change increases biological activity and associated stone decay rates, or whether crusts are 'washed off' and underlying stones are destabilised, will be predictable. Finally, an assessment can be made as to whether 'self-cleaning' of biological crusts, due to higher rainfalls, is likely to reduce the need for biocides and/or replacement of soiled and decaying stonework.

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Images

1. *Sandstone block covered in lichen (flora dominated by Rhizocarpon spp)*
2. *False colour backscattered electron (BSE) SEM image of lichen hyphae breaking up a building stone surface*
3. *False colour SEM image of lichen hyphae surrounding quartz grain plucked from underlying sandstone*