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Stone decay at the Cologne cathedral – crust formation and the effect of air pollution

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Cologne cathedral faces severe stone decay. Different building stones show a large variation of weathering phenomena. The Drachenfels trachyte, which was the construction material for the medieval part of the cathedral, shows significant surface deterioration, back-weathering coexisting with flaking, crumbling or the massive formation of gypsum crusts. Deterioration in correlation with crust formation against the backdrop of interferences of different building stones and pollution impact is investigated. Negative interferences between different building stones, e.g. Schlaitdorfer sandstone and the Londorfer basalt lava or the Drachenfels trachyte and the Krensheimer muschelkalk were first mentioned by Wolff (1996).

Crust formation on the building stones from the Cologne cathedral as well as from the Xanten and Altenberg cathedrals are studied. These three buildings, showing varying degrees of deterioration, are located in different areas and exposed to varying industrial, urban, and rural pollution. The material investigated range from dark grey to black framboidal crusts. This 3 to 10 mm thick cauliflower-like form of gypsum crust incorporates particles from the pollution fluxes. It covers the stone surface and mainly occurs at sites protected from wind and direct rain. Secondly, thin laminar black crusts trace the stone surface and may cover complete sections of the building's structure not necessarily preferring protected sites. This kind of crust seems to have very strong bonds between the thin black crust and the stone surface. The latter are often accompanied by contour scaling of 5 to 15 mm thick scales. In areas of framboidal crusts significant disintegration to flaking and crumbling can be observed.

Major and trace element distribution analyses with Laser-ICP-MS on crust samples show an enrichment of sulfur, indicating the presence of gypsum, lead and other pollutants (arsenic, antimony, bismuth, tin etc.), which generally can be linked to traffic and industry. This indicates that even though the SO_2 emission decreased, the pollutants are still present in the crusts on the building stones. From systematic microscopic and chemical analyses (XRF, SEM, EDAX) on crust and weathered stone samples a correlation of pollution impact and structural disintegration can be drawn. It becomes evident that the total amount of pollution is less pronounced in the samples from rural sites compared to samples from an industrial setting, to which Cologne cathedral is exposed. The formation of gypsum occurs at lower amounts in Altenberg, which correlates well with the measured SO_2 content in the atmosphere.

The combination of different analytical techniques made it possible to clearly distinguish samples from the industrial or rural environment. The analyzed samples of the soiled zones of the built environment imply present but also past pollution fluxes, thus functioning as environmental proxies.