

Characterization of restoration lime mortars and decay by-products in the Meditation area of Machu Picchu archaeological site

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Abstract

Machu Picchu citadel is the main archaeological Inca sanctuary widely known around the world, and a World Heritage Site of high cultural and natural value. For its construction a whitish granitic rock, extracted from the “Vilcapampa or Vilcabamba” batholith formation was used. During time, some of the granitic rocks from the natural stonewalls of the Meditation area of the Archaeological Park were restored. For the restoration works done in the 50s' a specific lime mortar called *Clarobesa* was used. After the inclusion of this joining mortar, many efflorescences are nowadays visible in the mortar itself and on the surface of the edges of the annexed rocks. To evaluate the possible impact of these salts crystallizations in the conservation state of these natural stonewalls, a multi-analytical methodology was designed and applied. With a combination of non-invasive and destructive techniques such as X-ray Diffraction, Raman microscopy, Scanning Electron Microscope coupled to an Energy Dispersive X-ray Spectrometer and ion chromatography, the mineralogical composition and the nature/concentration of the soluble salts present in the *Clarobesa* mortar was determined.

The experimental results suggest that *Clarobesa* mortar is a hydraulic lime mortar. The study of salts crystallizations by Raman microscopy allowed identifying the presence of calcium sulfates with different hydration waters and also nitrates. In some samples, the concentration of sulfates was high, reaching values up to 10% w/w. Although the concentration of nitrates is not extremely high, a clear contribution of ammonium nitrates coming from the decomposition of the nearby vegetation was assessed. Since the *Clarobesa* mortar can be considered an important input of ions that can migrate to the joined granitic rocks, in the future, it will be recommendable to monitor possible changes in the conservation state of the joined rocks.

Keywords:

Machu Picchu, Clarobesa lime mortar, Salts crystallizations, X-ray diffraction; Raman microscopy; Ion chromatography