

ERWAN ROUSSEL (\*) & MARIE-FRANÇOISE ANDRÉ (\*\*)

## QUANTITATIVE ASSESSMENT OF PRE- AND POST-RESTORATION WEATHERING RATES OF LIMESTONE MAYAN TEMPLES (UXMAL, YUCATAN)

**ABSTRACT:** ROUSSEL E. & ANDRÉ M.-F., *Quantitative assessment of pre- and post-restoration weathering rates of limestone Mayan temples (Uxmal, Yucatán)*. (IT ISSN 0391-9838, 2013).

The House of Turtles is one of the Mayan buildings of the Uxmal site in Yucatan. It has been erected during the Terminal Classic Period (AD 890-915), abandoned around AD 1050, and restored between 1969 and 1972. This monument was selected to quantitatively assess the impact of contemporary restoration practices on limestone weathering. Based on archival research and multi-scale photogrammetric surveys, weathering rates were calculated for two periods, covering respectively almost 1000 years (1050-2012) and 50 years (1972-2012). Whatever the spatial scale, whatever the construction choice, post-restoration weathering rates are systematically faster long-term rates: at the scale of the whole façade, stone recession has operated 38 times faster since restoration than on non-restored historical parts of the building (7.6 mm instead of 0.2 mm per century). This general trend is ascribed to the removal of the stucco coating that has protected limestone and delayed deterioration from the Mayan building times until the contemporary clearing and restoration operations. Another factor responsible for accelerated limestone decay is the replacement of wooden lintels by cement lintels, as indicated by the spatial distribution of deterioration hotspots on the façade and by the computed weathering rates obtained for six fine-scale win-

dows taking into account the construction/restoration choices. This quantitative assessment leads to emphasise the need for softer, less intrusive restoration practices and conservation strategies, that should restrict the use of incompatible materials like cement and reinforced concrete, and consider stucco as a protective skin worth being maintained.

**KEY WORDS:** Rock weathering, Decay assessment, Limestone, Cultural heritage, Conservation strategies, Maya architecture, Yucatán.

### CONTEXT AND OBJECTIVES

The singular and irreplaceable value of temples and other ancient buildings is nowadays fully acknowledged, and many monuments have been inscribed by UNESCO on the list of World Heritage Sites (WHS). Appropriate conservation and management strategies are being defined and implemented in order both to preserve this fragile cultural heritage and to open the sites to the public. In this context, the community of geomorphologists has been involved in recent years in the assessment of weathering damages (Pope & *alii*, 2002; Turkington & Paradise, 2005). Many researchers report an overall aggravation of damage since the 19-20th centuries, and pollution has first been blamed as the main driver of accelerated stone decay, due to enhanced salt weathering related to sulfur dioxide emissions (see review in Brimblecombe, 2003, and Watt & *alii*, 2009). In the 2000s, the deleterious effects of four other types of human interventions on the buildings and their environment have been demonstrated. They include: (i) the climatic stress induced by forest clear-cutting around the monuments (André & *alii*, 2012); (ii) the direct impact of touristic frequentation (Paradise, 2005; Honeyborne, 2011); (iii) the use of abrasive or corrosive techniques of stone cleaning (Young & *alii*, 2003); and (iv) the incorporation of incompatible materials such as cement mortar during restoration operations (Quist, 2009; Phalip & *alii*, 2012).

(\*) Maison des Sciences de l'Homme, CNRS/Université Blaise Pascal, Clermont-Ferrand, France. E-mail: erwan.rousseau@univ-bpclermont.fr

(\*\*) GEOLAB - Laboratoire de Géographie Physique et environnementale, CNRS/Université Blaise Pascal, Clermont-Ferrand, France. E-mail: M-Francoise.ANDRE@univ-bpclermont.fr

The authors thank the Institut Universitaire de France in Paris and the Maison des Sciences de l'Homme in Clermont-Ferrand for financial and human support. They owe special thanks to D. Michelet (ArchAm) who provided most useful scientific information regarding the Puuc region and with whom the Chunhubub and Xcalumkin sites were visited. They are also grateful to O. Ortega-Morales (Universidad Autónoma de Campeche) and P.-E. Genet (GEOLAB) for stimulating exchanges in the field. They also express their sincere thanks to C. Rhyne (Reed College) who compiled the online «Annotated Bibliography» dedicated to Mayan archaeological sites. The authors would like to thank the two anonymous reviewers for their efficiency and their valuable comments and suggestions. Last but not least, they warmly thank Professor Monique Fort whose work on Alpine environments has guided and significantly inspired our research in colder regions than the Yucatán.