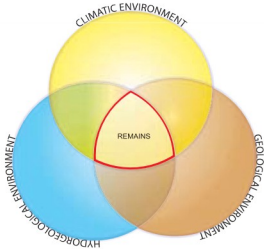


The conservation of an archaeological site, in urban or rural...



PREVENTIVE AND CURATIVE CONSERVATION : INTRODUCTION

Faced with this kind of problems for nearly 15 years, the methodology we are proposing has been initiated in 1998, following extensive building work on the Place Saint Lambert in Liège (Belgium) in the prospect of its rescue and then the later promotion of the remains within the Archeoforum (an underground exhibition space built below the place that opened to the public in 2003).



Explanatory diagram for the impact of the natural environment on the remains.

1. Ba Dinh site, Thang Long Imperial Citadel, Hanoi, Vietnam.

2. Remains of the former infirmary of the abbey Saint-Jacques, Liège, Belgium.

Photo : Ken Dethier © SPW

3. Archeological underground exhibition space of the "Archeoforum", Liège, Belgium.

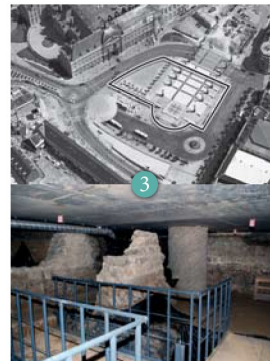
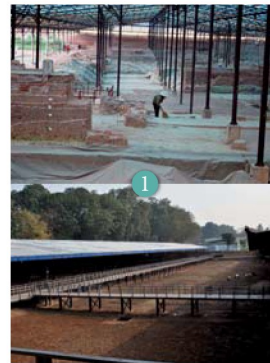
4. Neolithic flint mines of Petit-Spiennes, Spiennes, Belgium.

Photo : J.-L. Dubois © SRPH

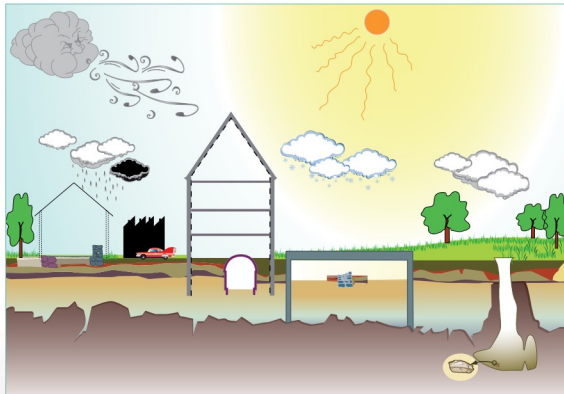
Following this first experience, we had through the approach of the other cultural heritage preserved in specific and varied environmental context, the opportunity to develop necessary know-how and the Public Service of Wallonia (SPW) provides today assistance in different sites to contribute to the equipment, data collection and analyses as well as training of the end users.

The remains of the infirmary of the Benedictine abbey Saint Jacques in Liège (Belgium) date largely from the 14th century. Set in an urban environment, the reshaped but still standing building preserves a most of the original medieval structures as well as a succession of later additions, of which particularly remarkable murals from the 16th century.

Implanted in a rural area and listed as a UNESCO World Heritage Site since 2000, the Neolithic flint mines of Spiennes date as far back as 4300/4000 BC. Some of these subterranean galleries dug in chalk by Neolithic peoples and accessible through shafts 8 to 10 meters deep for a diameter of a little more than 1 meter will soon be opened to the public.



Study made by the Department of Archaeology in the Province of Liège (SPW, DGO4, Direction of Liège I)
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Explanatory diagram for the general context of four presented sites

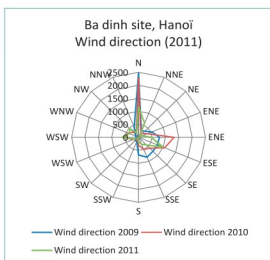
The conservation of an archaeological site, in urban or rural, whose remains are either buried, exposed and/or still standing preserved is extremely complex, given the multitude of parameters to be taken into account, their means of operation and the interplay that governs them.

Within the framework of a collaboration with the Vietnam Academy of Social Sciences (VASS), the excavated remains located in the heart of the "Forbidden City" in the ancient Imperial Citadel of Ba Dinh (Vietnam), classified since 2010 as a UNESCO World Heritage Site, benefit from an important conservation program which aims at promoting them in a new group of museums included in the project of the General Assembly.

This can be quite challenging in urban contexts...



THE CONSERVATION OF ARCHAEOLOGICAL REMAINS : FUNDAMENTALS AND ACTION PLAN



Annual distribution of wind direction from 2009 to 2011 at the site of Ba Dinh, Hanoi, Vietnam.

1. Disintegration of terracotta as a result of an accumulation of salt deposits, Ba Dinh site, Hanoi, Vietnam.
2. Disintegration of coating and tufa as a result of an accumulation of on-surface salts, former infirmary of the abbey Saint Jacques, Liège, Belgium.
3. Salt crystallizations on stone materials, Archeoforum, Liège, Belgium.
4. Biological developments on the chalky walls of the Neolithic flint mines, Spiennes, Belgium.

Our conservation programs are based on a series of preliminary studies, permanent monitoring, yearly appraisals of existing conditions and maintenance of a log of field actions. All of these investigations and observations lead to an annual plan of preventive and curative actions (PIC: Program of interventions to be undertaken in the framework of conservation).

Fundamentals :

Preliminary studies

These studies generally involve climatology, hydrogeology, geology, stability, biology, chemistry, mycological growth, stone materials, etc. They consist of all disciplines that can improve our knowledge of the site, our understanding of its natural environment and its mode of operation. These fundamental data will be exploited to address the issue of conservation in order to target the origin and operation of disrupting factors. The objective is to anticipate risks and avoid damage by proposing an appropriate program of surveillance (via monitoring), a program of maintenance and preventive interventions. Actually, it is already too late when it becomes necessary to repair damages by curative procedures.

Monitoring

Permanent monitoring (measurement of the external climate, humidity and salt concentrations in the sediments, level and temperature of aquifers, etc.), continuously readjusted and improved, is installed; its role is to oversee and understand changes in the state of the remains. The data collected are analyzed, correlated and interpreted in an annual report.

Appraisal

Surveillance of the site inevitably involves annual collection of a precise photographic record, with detailed comments, that is materialized in the form of files inserted into a database.

Log of field actions

A log of field action is created to systematically record all procedures, observations, reports, etc., occurring at the site.

Whether for reasons of identity, historical value or scientific value of archaeological relics, it is not rare, here and there on the globe, to need to take on the responsibility for their conservation, sometimes in the context of their presentation to the public. This can be quite challenging in urban contexts because remains often represent the earliest settlement of the city that houses them now; they are dense, complex, numerous and surrounded by many constraints limiting their preservation.



Action plan:

The general action plan is based on all of the information collected and described above. It focuses on seven categories of actions: indirect procedures related to the environment of the remains, direct procedures (on the remains themselves), recurrent maintenance measures, verification reports and analyses, surveillance, complementary research and work and specific recommendations. It is continually being improved and updated.



Reading of the recording instruments in the Neolithic flint mines, Spiennes, Belgium.



Installation of an access tube for the PR2/6 probe by Delta-T Devices, Archeoforum, Liège, Belgium.

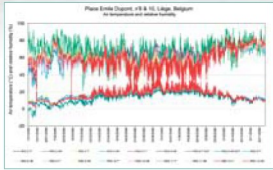


Training of the Vietnamese team in topographic surveying in June 2010.

The control of the climatic conditions which govern cultural heritage sites is essential...



PREVENTIVE CONSERVATION : MONITORING THE CLIMATIC OPERATION OF A SITE



Histogram of the annual internal thermo-hygrometric parameters recorded inside the former infirmary of the abbey Saint Jacques, Liège, Belgium.

Explanatory diagram of the impact of external parameters on the functioning of the archaeological underground exhibition space of the Archeoforum, Liège, Belgium.



Meteorological station installed near the Ba Dinh site in Hanoi by the Japanese government within the framework of a collaborative effort between Vietnam and Japan.

Autonomous Data-logger of air temperature and relative humidity. Graphics : H. Draux © SPW



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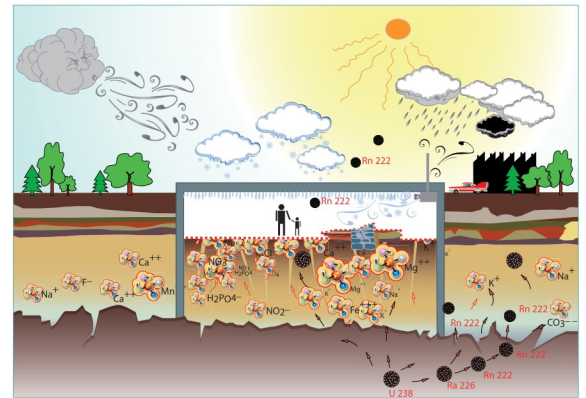
Planimetric reconstruction of the annual hygrometric averages, Archeoforum, Liège, Belgium.

The inadequacy and the fluctuations of the climatic parameters have damaging consequences on the stability and thus on the conservation of the hygroscopic materials which undergo in particular movements of contraction and expansion, phases of dehydration and humidification, heating and cooling, phenomena of condensation, of weathering which engender mechanical changes but also external and internal processes of irreversible physicochemical damages. For these reasons, it is important to limit the impact of the outside climate subjected to hourly, daily and seasonal variations on the microclimate imposed on the remains by proposing an ad hoc climatic stability to guarantee their conservation.

Either direct or indirect, the impact of the outside climate is both detrimental and often heterogeneous according to the specificity of the site and the considered areas. Indeed, differences appear in connection with the general configuration of the sites (crypt, cave, flint mines, building, outdoor site, roofed site...), their orientation, geographical position, altitude, but also according to particular museographic developments such as windows, light shafts... and also easy access to the entrances, confined spaces... as well as the public use and accessibility of cultural heritages.

The control of the climatic conditions which govern cultural heritage sites is essential and indispensable to secure their durability. The adequate criteria depend on the nature of the materials to be protected. Their definition is complex and thresholds difficult to specify when we are confronted with heterogeneous materials, possibly mixed inside the archaeological structures. This phenomenon requires therefore the implementation of consensus according to this plurality but also to the specificity and the environmental and natural context of the site.

Generally speaking, for archaeological sites with prevailing masonry, rock materials, sedimentary and anthropogenic layers such as may be found at the "Archeoforum" of Liège, the Neolithic flint mines of Spiennes and the Ba Dinh site in Hanoi in particular, the ideal solution is to maintain a low and stable temperature throughout the year, a low temperature allows more easily to keep high hygrometric values which limit the creation of an evaporation front of the aquifer table through the remains,



drying phenomena as well as mechanisms of salt precipitation on the ground surface.

Besides, important daily variations in hygrometric levels and temperatures accelerate and amplify the processes of degradation. Generally, we conclude that the acceptable daily values relative to the fluctuations are +/- 5 % for the hygrometric level and 1° C for the temperature. The respect of all the defined rates is systematically verified through monitoring (weather station and autonomous digital data-loggers), by recording outside and internal temperatures and relative humidity. All these data are analyzed and correlated to identify the general climatic dynamics.

Beyond the specificity and stability of the thermo-hygrometric parameters, another factor highly prejudicial must be considered: ventilation; which, in particular conditions, encourages phenomena of evaporation and erosion detrimental to most materials. It seems nevertheless that a minimum renewal is often necessary to limit concentrations of gaseous pollutants whose origins are either human (CO₂, water vapor), atmospheric (gases, fine particles), industrial and/or natural such as radioactive gases like radon.



The water which is nevertheless indispensable to ensure the cohesion...

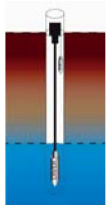


PREVENTIVE CONSERVATION : MONITORING THE HYDROGEOLOGICAL OPERATION OF A SITE



Manual measurement of water level in a groundwater monitoring pipe, Archeoforum, Liège, Belgium.

Manual measurement of water level in a well on the Ba Dinh Site, Hanoi, Vietnam.



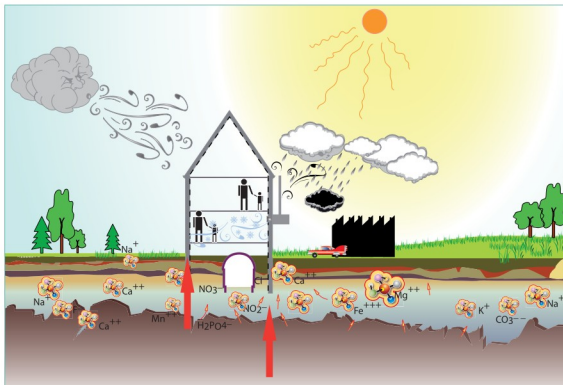
Probe for automatic measurement and registration of groundwater levels and temperatures.
Graphics : H. Draux © SPW

Explanatory diagram of the hydrogeological context of an archaeological site.

The stability of the aquifer contributes to guaranteeing soil moisture stability and thus the preservation of the sedimentary and archaeological layers (including the artifacts within them) which would otherwise be continually subjected to phenomena of crystallization and dissolution of the salts contained in the materials (salt weathering and water weathering) due to fluctuations in pressure surfaces but also characteristic phenomena of retreat and expansion of the hygroscopic materials.

Daily reports of the different aquifers can be realized either by manual measurements with sounding apparatus with acoustic or light signal or by automatic probes located in boreholes, groundwater monitoring pipes, etc. These data-loggers also allow obtaining information about the water temperature and quality, with a particular focus on its conductivity, salinity, dissolved oxygen, pH and turbidity.

Through capillary action, water from the water table penetrates the sedimentary substrate, into the profoundly buried masonry structures and into the archaeological remains, sometimes to reach in specific conditions the ground surface. This circulation is permanent and not without risk from both chemical and physical aspects. The water which is nevertheless indispensable to ensure the cohesion of the archaeological and sedimentary deposits is a vector of deteriorations when it evaporates on the surface of the structures.



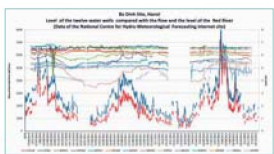
Collecting data and reprogramming of the automatic temperature and groundwater level probe in Camp-à-Cayaux, Spiennes, Belgium.



To try to understand its origin and mode of operations, all of the data collected at the site should be correlated also with, on the one hand, data obtained from piezometers located immediately outside the site and, on the other hand, with daily data about the water levels of the rivers and/or lakes situated nearby and their discharge, as well as the local pluviometry.

This close supervision also allows to highlight quickly the existence of disturbances of the hydrological system of a site consecutive to human use such as the modification of the levels through the presence of wells which engender cones of depression, accentuation of the daily and seasonal fluctuations, groundwater discharge... and to take the necessary measures to limit the impact of these interventions. It is sustained inevitably by information and awareness campaigns towards the authorities in charge of this specific problem and of its repercussions on the conservation of the archaeological reserves.

In addition to these records, physicochemical analyses of the water in the water table must be done annually to evaluate its quality and show possible changes in its composition. The chemical components may migrate to the surface and cause, through evaporation and crystallizations phenomena, significant damage to the remains.



Water levels in the twelve wells of Ba Dinh site in Hanoi compared to the discharge and level of the Red River. (Data from NCHMF)

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All of these relics form a fragile interface...



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PREVENTIVE CONSERVATION : MONITORING THE SEDIMENTARY SUBSTRATE AND THE STABILITY OF ARCHAEOLOGICAL REMAINS



First measure of the water content in the sediments with the PR2/4 probe by Delta-T Devices, Ba Dinh site, Hanoi, Vietnam.

To ensure the preservation of the deposits, it is imperative to avoid going below the limits of "retreat" of the sediments at the risk of seeing significant and irreversible damage appear, such as drying, hardening, cracking, desiccation polygons, salt crystal formation, etc. Attention will also prevent the creation of an evaporation front of the aquifer table through the remains by limiting ventilation and maintaining high and stable humidity. Should the opposite occur an accumulation of soluble salts contained in the layers and in the aquifer is going to happen at the interface sediment/atmosphere. The alternation of mechanisms of precipitation and redissolved salts weakens the internal structure and causes physicochemical and mechanical changes within the materials, leading to their damage and ultimate destruction.

These phenomena find within particular contexts grounds favorable to their development according to various factors, whit, in particular, a high temperature, a low hygrometric level, a low atmospheric pressure, a significant ventilation as well as the presence of underground water.



Salt deposits, Ba Dinh site, Hanoi, Vietnam.

A network of measurements is also established to oversee developments in the state of conservation, not only of the archaeological layers exposed, but also those still buried, which are termed the "archaeological reserve" or still natural sedimentary layers surrounding them. All of these relics form a fragile interface between the atmosphere and the underlying hydrogeological context.

Several types of automatic probes allow the recording of water content of soil and substrates to verify that they keep sufficiently moist and above the limits of retreat either by the TDR method (Time Domain Reflectometry) or by the FDR method (Frequency Domain Reflectometry). These data-loggers can also supply information about the temperature



Desiccation polygons, Archeoforum, Liège, Belgium.



Crack measure apparatus set up on a half-timbered partition, the exfoliation of wall fillers and mortars further to an accumulation of salts, former monastic infirmary of the abbey Saint Jacques, Liège, Belgium.

and the conductivity which are discriminating parameters within the framework of the preservation of archaeological deposits.

Complementarily to these measurements, analyses of the percentages of soluble salts in the sediments should be done annually to evaluate the presence and/or changes in the mechanisms of salt precipitation on the ground surface.



Salt Deposits on the chalky walls and the implementation of telltale plaster to supervise the stability of the structures, Spiennes, Belgium.

To this end and to check the stability, crack measure apparatuses or telltale plaster have also been positioned on all the hygroscopic materials such as archaeological and sedimentary layers, on the woodwork in the case of building as well as masonry structures to specify the degree, the variability and the origin of the movements as well as the phenomena of contraction and expansion of the structures.

Study made by the Department of Archaeology in the Province of Liège (SPW, DGO4, Direction of Liège I)

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