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THE IMPACT OF CLIMATIC CONDITIONS ON ARCHAEOLOGICAL SITES

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Abstract

The article presents the influence of climatic conditions on the object of archaeological and cultural heritage in general based on terms. The results of the influence of climatic conditions observed at the Toprakkala and Akchahankala monuments are presented. From this, the last ten-year report on climate monitoring work in the area where exactly two objects are located was studied.

Keywords; Archaeology, climate, object, thermoplasticism, corrosion, karst effect, salt crystallization, hydrometeorology, termite.

Introduction

Archaeological sites are among the most important written sources of human history. Although scholars often view them as documentation fields, this heritage should not be limited only to the domain of academic archaeology. Structures, objects, and cultural traces created centuries ago have not only architectural value today, but also possess profound sociological meaning. Whether formed by natural processes or human hands, everything found underground needs to communicate with people. This communication is established through careful interpretation, explanation, and presentation of archaeological heritage.

Visitors to archaeological monuments — that is, the non-specialist public — are actually the first to interpret this heritage. Therefore, the interpretation process should benefit not only the visitors, but also the monument itself. However, as archaeology is a complex field, this process must involve specialists from various disciplines, including conservation experts. Conservation is a crucial stage in systematically explaining, properly managing, and transmitting this heritage to future generations. Archaeological heritage is considered the main record of humanity's past activities. For this reason, its protection, preservation, and management is a shared responsibility not only of archaeologists, but also of other scientific specialists. Through proper management and legal protection, this heritage will be preserved not only for the present generation but also for future ones.

The protection of heritage is not limited only to archaeological excavations — it requires broader professional and scientific knowledge. For example, some elements of archaeological heritage have special value as architectural structures, and their preservation is based on the principles defined in the Venice Charter adopted in 1966. Furthermore, the direct involvement of local communities in protecting monuments related to their living traditions also plays an important role.

The main goal of managing archaeological heritage is to preserve monuments at their original location and in their authentic state. The following principles are of particular importance:

- Monuments should be preserved in situ and should not be relocated.
- The subsequent preservation of monuments uncovered during excavations must be guaranteed.

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- Local communities must actively participate in the heritage protection process.
- The scientific value and historical significance of objects should be taken into account during restoration.

Due to the limited availability of resources, restoration works are carried out selectively, based on scientific evaluation. In this process, not only the most famous or prominent monuments, but also those with high historical value that have so far remained neglected, must be taken into consideration.

Historical buildings, archaeological sites, and monuments, as well as their internal structures, collections, and intangible aspects, are all legacies from the past. They provide local communities with a sense of place, identity, and aesthetic well-being. These heritage objects have always interacted with their environment and will continue to do so; such processes are commonly referred to as weathering, usually caused by atmospheric conditions. Climate change—manifested through gradual changes in temperature, precipitation, atmospheric humidity, and wind intensity, as well as sea level rise and variations in the frequency of extreme events—is already affecting cultural heritage objects. Accordingly, the number of scientific studies evaluating the impact of climatic factors on cultural heritage and their effects is rapidly increasing.

Climate change is considered an additional risk that accelerates the rate of weathering or leads to the emergence of new forms of deterioration. This is because climate change intensifies the physical, chemical, and biological processes that result in material damage. Moreover, climate change increases the frequency and intensity of hazardous events such as droughts, floods, and landslides, and this has a wide range of negative effects on cultural heritage.

Similarly, cultural heritage is also threatened by factors such as sea level rise (SLR), intensification of storm surges, coastal erosion, changes in inland water flows, and desertification. Therefore, the number of studies dedicated to examining how these changes in the natural physical environment are affecting different types and materials of cultural heritage is increasing. Temperature, precipitation, atmospheric humidity, wind intensity, sea level rise, desertification, as well as the combined effects of climate change and air pollution – all these have been recognized by UNESCO as risks to cultural heritage, leading to the adoption of a special policy document in 2008.

In recent years, reports published by the International Council on Monuments and Sites (ICOMOS) have compiled the main climatic factors, their mechanisms of impact, and consequences based on consultations with experts.

Scientists have developed specific terms to describe the effects of climate change on cultural heritage. According to this:

Thermoclastism is caused by temperature changes (seasonal and daily fluctuations, direct sunlight), leading to the expansion and contraction of mineral grains on surfaces. This represents the impact of microclimatic change on cultural heritage through weathering mechanisms, and is summarized in various scientific studies based on climatic factors and their projected time horizons.

Changes in precipitation – Water is the most significant erosive factor for all structures, especially historical monuments. Due to climate change, an increase in precipitation can lead to soil saturation and excessive loading of gutters and pipes, increasing the risk of deeper moisture

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penetration into historic materials like brick walls. Water entering porous materials can occur through condensation or capillary action in the presence of ground moisture. This water infiltration accelerates the deterioration of materials through corrosion, biological activity, and subflorescence caused by salt crystallization.

Corrosion – Increased precipitation, especially in warm climates, intensifies the corrosion of metals and glassy materials, as well as the surface weathering of carbonate stones (such as limestone and marble) [3]. Corrosion is a chemical process, in which materials gradually deteriorate due to the action of water and often salts (mainly chlorides). For carbonate stones, this is particularly connected to acid rain and the high concentration of carbon dioxide (CO_2) in the atmosphere.

The natural (pure) pH of rainwater is about 5.6, which makes it slightly acidic and leads to the weathering of carbonate stones—a process known as the karst effect. As the level of atmospheric CO_2 increases due to human activity, the intensification of karst weathering of carbonate stones has been forecasted.

Atmospheric pollution – is often associated with the accumulation of pollutants on the stone surfaces of historical buildings, which also contributes to corrosion [3].

Biological deterioration – Changes in humidity influence the growth of microorganisms on stone and wooden heritage materials. Therefore, various studies have shown that increased relative humidity in warmer climates accelerates the biological deterioration of cultural heritage [3].

Prolonged moisture increases both relative humidity and the moisture content in materials, which, together with rising temperatures, creates favorable conditions for biological activity. This leads to the accumulation of biomass and the decay of historic wooden buildings through the action of fungi, algae, molds, lichens, and insects [3]; termite attacks can result in the collapse of wooden structures, and in warmer climates, their geographical spread may expand northward.

Salt crystallization cycles – Soluble salts dissolve and recrystallize depending on changes in temperature and humidity, giving rise to salt crystallization cycles. Certain salts change their structure during wetting and drying processes, for example, sodium sulfate (thenardite) and sodium sulfate decahydrate (mirabilite). The mirabilite phase can exert significant crystallization pressure within the stone's pores. Such repeated cycles cause stress and, in the long run, lead to deterioration. Increased precipitation and temperature variability raise the number of salt crystallization cycles in the presence of soluble salts within stone materials, resulting in greater damage.

The salt content in a building's material or structure can also increase due to the rise in precipitation, soil saturation, and capillary action. Even small changes in relative humidity can significantly affect the number of harmful salt crystallization cycles. When the relative humidity drops below the deliquescence point of certain soluble salts, they transition from the solution phase to the crystalline phase. The damage mechanism is that salts expand in volume as they crystallize, exerting mechanical pressure on the materials—this is known as subfluorescence. If salts crystallize on the surface, it can disrupt the legibility of artifacts—this effect is called efflorescence [3].

Drought and extreme heat. Drought and extreme heat increase the risk of fires. In Europe, it is predicted that cultural heritage sites, especially on the Iberian Peninsula, will become more vulnerable to fire hazards.

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Karst effect – These are natural geological formations and their effects caused by water interacting with limestone or other soluble rocks.

Impact of karst effect on archaeological sites:

Subsidence or loss of remains

Subsurface cavities, sinkholes, or dissolution voids created by karst processes can engulf archaeological remains, causing them to sink below the surface and eventually be lost.

Damage to objects

Karst-induced movement of soil and rocks can lead to the cracking, breaking, or complete destruction of archaeological layers and artifacts.

Preservation or protection of remains

Sometimes karst caves naturally protect archaeological finds, preserving them for long periods. For example, traces or remains of ancient humans have been discovered in karst caves.

Changes in soil and water conditions

In karst areas, rapid water flow and the presence of soluble rocks alter soil conditions, which can complicate archaeological excavations or present additional challenges.

If we consider the above-mentioned climate changes in the context of cultural heritage sites located in the Republic of Karakalpakstan, it is important to note that the climate of Karakalpakstan is sharply continental, with extremely cold winters and extremely hot summers. This has inevitably affected sun-dried bricks and ancient walls from antiquity. Extreme heat causes both macro (such as cracking, soot accumulation, color changes) and micro (changes in mineral structure and composition) degradation in stones, leading to their instability.

Long-term effects include the weakening of stones, increased risk of weathering due to salt crystallization, and thermal cycles. Drought leads to the drying of soils and unfired construction materials, causing structural issues in the foundations of historical buildings and archaeological sites.

For example, during the excavation of the Tuprakkala monument, the expedition's field diary [1] noted that the materials in the palace halls had been washed away due to heavy rainfall. Berenfeld predicted that climate change in Africa would lead to increased drought and desertification, resulting in the burial or damage of cultural sites by sand or floods. Pearson highlighted the increasing risk of soil erosion due to soil drying and higher wind speeds in arid regions like Australia, and noted the need for further research. At the monument site of Akchakhan Kala in Karakalpakstan, the impact of strong winds and large amounts of accumulated sand was also noted [5].

Wind and wind-driven rain (WDR) changes: Changes in wind speed and direction, as well as the intensification of winds in storms, can cause significant damage to cultural heritage structures and archaeological sites, affecting their structural integrity and even leading to collapse. Wind transports pollutants, salts, and sand, thus eroding cultural heritage materials—especially in arid regions, where the risk of aeolian sand erosion is high. Considering the example of the Akchakhan Kala site, murals found collapsed to the ground in excavation area X support this argument.

Wind and WDR damage both construction materials and archaeological stone artworks through erosion caused by wind-transported particles. WDR increases the risk of water penetration in

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porous materials, which affects salt migration and leads to discoloration of the walls of historic buildings.

At the Akchakhan Kala monument, cases of biological deterioration, such as termite attacks, can potentially lead to the collapse of wooden structures. During the 2025 excavation in section X, the presence of numerous termites was recorded [7]. The base and its decoration on the columns were preserved [8], and according to scientists, it is assumed that wood used for the column shafts was brought from elsewhere, since no hardwood or other durable tree species suitable for use in columns have been observed growing in this area [6]. The fact that the hardwood columns are no longer preserved, and that termites may have attacked other raw construction materials, is also suggested.

Reports from the Uzbekistan Hydrometeorological Service Center, Buston station, which monitors the climate conditions at these sites located in the southern part of Karakalpakstan, were studied. According to the center's report for the last 10 years at Buston station, the highest values for each ten-day period of every season were analyzed.

In January 2015, the average temperature was 4.8°C, the highest was 13.8°C, the lowest was -10.3°C, average humidity deficit was 7.0, and no precipitation was observed. In April, the average temperature was 17.0°C, humidity was 30.0, and only 10 minutes of precipitation was recorded. In July, the highest air temperature was 45.2°C, humidity deficit was 78.3, wind speed was 8 meters per second, and no precipitation was recorded. In November, the air temperature was 15.2°C, humidity deficit was 83, and wind speed was 10 meters per second.

In January 2020, during the third ten-day period, the highest temperature was 11.5°C, humidity deficit was 8.3, wind speed was 7 meters per second, and precipitation was observed 6 times. In April, during the third ten-day period, the highest temperature was 33.2°C, humidity deficit was 37.7, wind speed was 11 meters per second, and precipitation was recorded 4 times. In July, the air temperature was 39.5°C, humidity deficit was 56.6, wind speed was 20 meters per second, and precipitation was recorded twice. In November, air temperature was 21.0°C, humidity deficit was 18.4, wind speed was 11 meters per second, and precipitation was observed 5 times. In January 2025, the air temperature was -10.6°C, humidity deficit was 8.2, wind speed was 13 meters per second, and snowfall was observed 4 times. In April, during the third ten-day period, the air temperature was 38.8°C, humidity deficit was 56.7, wind speed was 15 meters per second, and precipitation was observed 7 times. In June, the air temperature was 42.0°C, humidity deficit was 68.3, wind speed was 12 meters per second, and no precipitation was recorded [9].

According to the report of the Uzbekistan Hydrometeorological Service Center, Buston station, the wind direction was observed as follows.

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On the wind direction observed at the Bostan meteorological station of the Hydrometeorological Center of the Republic of Karakalpakstan for 12 months of 2024 and 6 months of 2025

Information

№	Term	2024 year		2025 year	
		Direction	Gradus	Direction	Gradus
1	January	South	120	South	150
2	February	South	160	South	130
3	March	South	160	South	150
4	Aprel	South	170	South	140
5	May	South	180	South	170
6	June	Western	190	Western	210
7	July	Western	230		
8	Avgust	Western	190		
9	September	South	130		
10	October	South	170		
11	November	South	130		
12	December	South	120		

Tuproqqala Monument

Akchakhankala monument

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Termites found as a result of excavation of the Akchakhankala monument

References

1. S.P.Tolstov “Qadimgi Xorazm tsivilizatsiyasini izlab”, X.: 2018 y.
2. Prepared by the International Committee for the Management of Archaeological Heritage (ICAHM) an approved by the 9th General Assembly in Lausanne in 1990.
3. P.Brimblecombe and C.M.Grossi, I.Horris. “Climate change critical to cultural heritage”. London.; 2006. 387-393.
4. Hellin Phillips. “The capacity to adapt to climate change at heritage sites—The development of a conceptual framework” March 2015. 118-125
5. Каракалпакское отделение Академии наук Республики Узбекистан Каракалпакский научно исследовательский институт гуманитарных наук Сиднейский университетю Отчёт об археологических исследованиях 2022 года на городище Акшахан кала.6-7 с
6. 2025 yil 26 avgust dala ishlari kundaligidan, T.f.f.d. phd A.Toreniyazov ma’lumoti
7. 2025 yil 26 avgust dala ishlari kundaligidan, qazish natijalari.
8. 2025 yil 26 avgust dala ishlari kundaligidan, A.Bekbauliev ma’lumoti.
9. Qoraqalpog‘istonning janubiy qismida joylashgan bu obyektlarning iqlim sharoitini kuzatuvchi O‘zbekiston Respublikasi Gidrometeorologiya xizmati markazi, Boston stantsiyasi 2015-2025 yillar hisobotlari.