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Perspective

Anthropogenic global warming threatens world cultural heritage

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Numerous cultural sites of the United Nations Educational, Scientific and Cultural Organization (UNESCO) world cultural Heritage are located in low-lying coastal regions. Because of anthropogenic global warming and induced sea level rise, many of these sites will be partially or totally flooded in the coming centuries/millennia. This is shown in a recent study by Marzeion and Levermann (2014 *Environ. Res. Lett.* **9** 034001). Projecting future sea level rise and associated regional variability, these authors investigate which sites will be at risk. Because UNESCO cultural sites represent the common heritage of human beings and reflect the Earth and humanity history, they need to be protected for future generations.

Keywords: global warming, sea level rise, world cultural heritage

In 1972, the United Nations Educational, Scientific and Cultural Organization (UNESCO) adopted a convention in order to identify and protect sites of exceptional importance to the common heritage of humankind. This initiative went back to the late 1950s when Egypt decided to build the Assouan dam along the Nile River. Such a project would have had for consequence to flood the Abu Simbel and Philae temples of the ancient Egyptian civilization, a dramatic loss for humanity. Under the auspices of UNESCO, about 50 countries joined together to take apart, move and put back piece by piece the temples in more secure location. The 1972 UNESCO convention established a number of criteria to protect against damage and destruction sites having archeological, historical, architectural, environmental or physical interest. Such sites are considered as the common heritage of human beings and reflect the Earth and humanity history. Today, about 980 properties are inscribed on the world heritage list—760 of which are cultural. The worldwide distribution of cultural sites is far from being random. This is not surprising as most of them are located at places where ancient civilizations started to develop in the beginning of the Holocene. An important concentration of UNESCO sites is observed in the Middle East and all around the Mediterranean Sea. It is indeed in the Middle East that the first permanent settlements of human societies developed during the Bronze and Iron ages, in the 4th millennium BC. Besides, the Mediterranean region was the cradle of Egyptian, Phoenician, Greek and Roman civilizations that left us with so many archeological masterpieces. Between the 3rd and 2nd millennium BC, highly developed civilizations also developed in Asia, in particular in the Indus Valley and in China where many cultural sites are located.

Considerable interest exists nowadays for these archeological and historical treasures. These are unique witnesses of humankind cultural history. In recent years, some of these sites have become in danger or were damaged by modern societies, e.g., the Timbuktu cultural site in Mali or the Buddha statues of the



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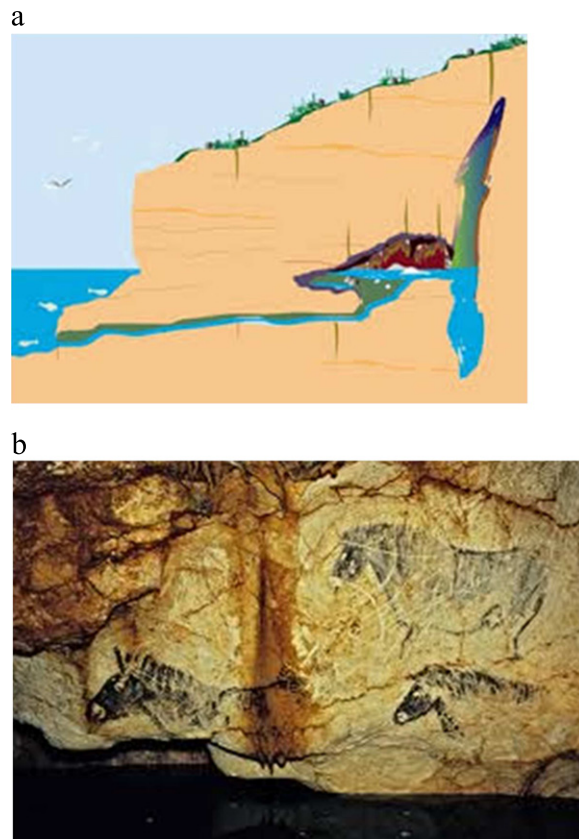


Figure 1. (a) Schematic view of the Cosquer cave (Marseille, France) under present-day sea level. (b) Prehistoric horse paintings (dated 18 500 years BP) in the partially submerged main chamber of the Cosquer Cave. Courtesy of V Feruglio and J Clottes

Bamiyan Valley in Afghanistan. But other threats hang over sites located in low-lying coastal areas because of future sea level rise in response to anthropogenic global warming.

In a recent study, Marzeion and Levermann (2014) investigated how many cultural world heritage sites will be affected by sea level rise over the next 2000 years. Building on a previous study by Levermann *et al* (2013), they computed the sea level elevation expected as a function of global mean temperature increase above pre-industrial values in the coming two millennia. An important aspect of their work is to account for the regional variability that superimposes the global mean rise. In a warming climate, sea level rise is not expected to be uniform. In effect, different factors, e.g., nonuniform ocean warming, changes in salinity of sea waters, and deformations of ocean basins due to the viscous/elastic response of the solid Earth to past and future land ice melt, as well as changes in mutual gravitational attraction between ice/water loads, produce regional sea level variations that in most instances, significantly amplify the global mean rise. Regional sea level variations are currently observed by altimeter satellites. Climate models project that by 2100, a large proportion (75%) of the world coastlines will suffer local sea level rise significantly higher than the global mean (IPCC, 2013). Regional sea level variability will be also the norm on much longer time scales, with strong negative impacts on population, infrastructures and goods.

The study by Marzeion and Levermann is the first to address the impact of future regional sea level rise on world cultural heritage sites. It shows that for a temperature elevation between 2 K and 3 K above pre-industrial, a substantial number of cultural sites will be damaged or even totally flooded within the next

few centuries/millennia, especially in China and India. But south-east Asia, Japan, the United States of America and Egypt will also be impacted.

Another interesting aspect of Marzeion and Levermann's study was to determine future sea level rise impact on coastal boundaries of the world's countries and on population. They assumed that the present distribution of the world population represents an indicator of locations where future cultural centers may develop in the coming centuries. They show that for a temperature increase of 3 K, coastal land loss (hence potential future cultural world heritage) will affect between 5% and 9% of the global population, China, India and south-east Asia being the most affected regions. Thus, this study not only identifies which existing cultural heritage sites will be negatively affected by continuing global warming and associated sea level rise, but also the potential sites, not yet existing but having a high probability to develop in the future.

Because of natural sea level rise since the end the last glacial maximum (20 000 years ago), some prehistoric paintings of the Cosquer cave (dated –27 000 years to –19 000 years) have been definitely lost. The cave discovered in 1991, is located at the French Mediterranean coast and is now partially flooded (its entrance is 37 m below sea level; see figure 1, Clottes and Courtin 1994). To avoid similar dramatic situations, cultural sites built during the last 6 millennia of human history need to be protected for the next generations. Marzeion and Levermann's inventory of the most vulnerable world heritage sites under anthropogenic sea level rise is a precious piece of information and a first step towards safeguard and protection. Moreover, identification of future permanently flooded coastal zones should allow adapted strategies for developing in the future, new cultural properties in nonrisky locations.

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