Scientists study ways to preserve world heritage sites damaged in armed conflicts

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Ancient heritage sites caught in the crossfire of war are, in many ways, little different from civilian populations trapped in the midst of armed conflict: Even when they continue to stand, they are crumbling inside.

A new study set out to re-create the impact of small arms fire on stone columns and structures that have endured thousands of years of sun, wind and rain. When struck by small arms fire, it found, these ancient artifacts show little sign of outward damage.

But the impact of a .22-caliber bullet creates a network of tiny capillaries that spreads beneath the stony surface of, say, a column or its capital. As water or environmental toxins seep into those newly opened vessels, the result is likely to be the rapid degradation of irreplaceable antiquities.

The new study was published this week in the journal *Royal Society Open Science*.

Compared with the firearms wielded by armies, militias and insurrectionists across the world's hot spots, the .22-caliber rifle used by the researchers is practically a spitball to a structure that has baked in the sun and been pelted by rain, wind and snow for millenniums.

But the researchers had to start somewhere, they wrote. Despite reports that world heritage sites have been caught up in conflicts in Iraq, Afghanistan, Syria, Libya and Yemen, the effect that flying bullets have on the integrity of structures built thousands of years ago has scarcely been studied.

And when they used an AK-47 to study the impact of weapons fire on blocks of quarried stone, the researchers found they had little left to investigate.

To gauge the impact of small-arms fire on the kinds of structures found in archaeological sites across the Middle East and Europe, the researchers got freshly quarried stone from the Huesca region of northeast Spain.

This sandstone - largely composed of quartz, gypsum, calcite and muscovite - is pretty typical of the kind of stone used in many of the Western world's heritage sites. Eons of exposure to the elements causes chemical changes in the stone that makes up many ancient structures, giving them a hardened outer shell. To mimic that effect, the researchers applied to half of the test stones a preservative, called Wacker OH 100, that is sometimes used by archaeological conservators to harden the surface of delicate or newly exposed stone structures.

At a rifle range in Oxfordshire, England, the researchers took up positions 20 meters from their stony subjects and fired four .22-caliber lead bullets at each. They then carried the stones back to a lab and either sat them in a puddle of water or plunged them into a special cabinet that mimics the extreme temperatures and conditions of the arid and semiarid Middle East.

The effects, seen under microscopes, in X-ray images and in tomographic scanners, "were far greater than appreciated from a visual inspection," the authors wrote. Stone treated with the Wacker OH 100 preservative - and probably ancient building material that has naturally developed a tough outer crust - appears to transmit the energy of a bullet to the area behind the impact.

Not only is the surface wound subject to the indignities of environmental exposure all over again, but fracture networks have formed beneath, the authors wrote. As moisture follows these paths, the result could be an acceleration of the stone's deterioration, both at the surface and beneath.

Until recently, preservationists, archaeologists and classical scholars thought the principal threats to

the world's cultural treasures were age, exposure to the elements and, occasionally, a surfeit of human enthusiasm for them. Now, these treasures are not only becoming collateral damage in armed conflicts with powerful weapons. At the hands of such groups as the Islamic State, architectural antiquities have themselves become the target of attack.

"These tests are based on relatively small .22-caliber bullet impacts with minimal surface material loss, yet the effects were far greater than appreciated from a visual inspection," the authors of the new study wrote. "The results from this study, therefore, beg the question; if such small impacts can alter the stone to this extent, what are the long-term consequences of larger impacts such as AK-47s?"