Cliff Mine Archaeology Project

YOU DIG?: MTU ARCHAEOLOGISTS EXCAVATING PRESERVED LAUNDERS IN THE 1850–1860 STAMP MILL AND WASH HOUSE OF MICHIGAN'S FAMOUS CLIFF MINE

Archaeological Engineering

How an archaeologist and a chemical engineer are working together to conserve historical artefacts

TIMOTHY SCARLETT AND GERARD CANEBA
SPEAK TO HELEN TUNNICLIFFE

WE ALL know that chemical engineering is the "boundaryless profession". Our industry improves processes in the oil and gas, pharmaceutical, food and drink, energy, consumer goods, petrochemical, inorganic chemical and plastics industries, and so enhances the lives of billions of people all over the world.

Chemical engineering has always been a discipline that looks forward to the future, and now, it is helping a discipline that very much looks back to the past – archaeology. Gerard Caneba, a chemical engineering professor at Michigan Technological University (MTU) in the US, is helping MTU colleague Timothy Scarlett, an associate professor of archaeology, preserve some of the most fragile metal archaeological artefacts for posterity, using high-tech supercritical fluid technology.

Archaeology and chemical engineering are perhaps not the most obvious disciplines to put together but Scarlett, whose main interest is industrial archaeology, explains that the union was partly aided by MTU's ethos of fostering experience-based learning and cross-departmental collaboration.

Industrial archaeologists frequently uncover corroded metal artefacts, for example from metallurgical processes or mining hand tools, and preserving them is difficult. Back in 2010, Scarlett read a report about the use of supercritical chemistry to preserve wood fragments, and wondered whether it could be applicable to metal objects.

"I got onto our research connections website at Michigan Tech to find someone who might have some experience in supercritical chemistry, and I emailed Gerry Caneba, as he'd just published a book related to the subject," says Scarlett. And that's how it started.

As well as the interest in supercritical chemistry, Caneba is a polymers expert. His research focuses on a variety of technologies including free-radical retrograde-precipitation polymerisation (FRRPP), carbon nanotube and polymer composites, and mathematical and computer modelling. He has published books on energetic systems in microreactors that can be related to those of celestial bodies. Boundaryless indeed. Alongside this, he has retained an interest in history, so Scarlett's request was immediately interesting.

"History always teaches us that there are lessons to be learned, and preservation of historical and archaeological artefacts is a very effective way of not only making history alive but also of maintaining historical credibility," he says. "This always comes to mind whenever I think about the pre-Spanish era in the Philippines, where I was born and raised. I have seen negative effects to the psyche of an ethnic group that has little tangible historical roots. Thus, even though I am a technical person, I have always been a scholar of history, and historical preservation has always been dear to me."

THE SUPERCRITICAL PROCESS

Many excavated metal objects, especially iron-based objects, are heavily corroded, and treating and conserving them is a long process.

"A large cannon recovered from a shipwreck, for example, is a big challenge. It can take years to extract the salts and stabilise the surface. Generally, conservators work with electrolytic cleaning where they use direct current to bubble off the corrosion and plate the cannon with a new metal and then dry it. That process can literally take years," says Scarlett.

Some preservation techniques can simply involve coating the object with a varnish such as polyurethane, but this can fundamentally change the colour, texture and appearance of an object, which is undesirable. The supercritical process can tackle all of these problems. It does little to change the aesthetics of an item. Scarlett explains the archaeological conservation is governed by the 'do-no-harm' principle, or 'least-possible-harm'.

Caneba adds: "You want some variability. One of the things about archaeological artefacts is that you don't want to cover them completely. You don't know what's in them and then later on, you might want to get access again to the areas that you've covered. You need control over how you encase things, and I think we have the proper chemistry and physics for it."

Theoretically at least, the impregnation process is reversible, so if a more advanced conservation technology or examination technology comes along in the future, this can be carried out. The process is also much faster than conventional techniques.

Looking at the example of the shipwreck cannon, Scarlett says: "If we can scale up the supercritical process, it's an order of magnitude difference. What would have taken eight years could take eight days."

THE PROCESS

A supercritical fluid is at such a temperature and pressure that it is a liquid but with the properties of a gas. This means that the fluid can easily penetrate into the tiny spaces or pores in an object. Unwanted substances that could damage the object, like water, salt or even toxic chemical contamination, which is common at industrial sites, dissolve into the supercritical fluid. A second process introduces the conservation polymer, which protects the artefact from the environment and further corrosion.

Caneba and Scarlett use supercritical carbon dioxide as the basis of the process, as it is well understood and relatively benign. As a co-solvent, they use acetone, while the conservation polymer they selected is acryloid.

West Point Foundry Archaeological Project

PIGGING OUT: A CAST IRON PIG FROM THE THE WEST POINT FOUNDRY IN COLD SPRING, NEW YORK. (TOP) AS RECOVERED FROM FOUNDRY BROOK; (MIDDLE) ON ARRIVAL IN THE LAB, WEEKS LATER; (BOTTOM) AFTER ELECTROLYTIC CLEANING AND TREATMENT

"Acryloid is a polymer that is really well established in conservation. Everyone knows it and it's used everywhere from major institutions to mom-and-pop museums where they just have volunteers. It's environmentally benign and it's soluble in acetone, which is nail polish remover and most people are comfortable with that," says Scarlett. "That allowed us to concentrate our argument on the supercritical process. We didn't want to get trapped in a debate about polymer selection."

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A researcher places the object to be conserved into a thick steel pressure chamber which is then sealed. Caneba says that the first stage of the process is a pressure sweep purge, where the system is pressurised with carbon dioxide from around 500 psi, somewhat less than the supercritical pressure, and then depressurised to atmospheric pressure. This is done three times to remove all air and ensure that the only other substance in the chamber is the supercritical carbon dioxide. Then, he will apply the supercritical conditions. This is a pressure of at least 700 psi and a temperature of 32°C. These conditions are applied to the object overnight. After that, the pressure is released, flashing off carbon dioxide gas. Depressurisation takes about a minute.
"When you flash off this carbon dioxide, it will produce dry ice on the outside of the material, which captures the contaminants. It's really nice because you can just remove the dry ice physically," says Caneba.

The clean, contaminant-free artefact then undergoes the same procedure a second time, this time with the acetone and acryloid mixture. The acetone and acryloid dissolve into the supercritical carbon dioxide, forming one supercritical fluid, which again enters the pores in the artefact, condensing layer by layer. When the system is depressurised again (slowly this time, Caneba warns, to prevent the liquid coating the lab as well!) the polymer stays in the pores, while the carbon dioxide and acetone evaporate. Once dried, the artefact is perfectly sealed and protected.

THE NEXT STEP

Scarlett and Caneba would like to experiment with different polymers and solvents to optimise the process. Caneba knows of several he thinks may be more hardwearing, and even suggests experimenting with molecules that polymerise in the object, which would be smaller and thus be able to penetrate more deeply. As previously suggested, scaling up the process is likely to be the first improvement. At present, the pressure chamber is just slightly larger than a can of fizzy drink, limiting the technology to very small bits of metals such as small pieces of wrought iron or screws.

"With our resources here, it's feasible to treat longer pieces," says Caneba. When we get to broader ones then we need to start thinking about other means of containment, autoclaves for example. Or we have to be even more creative. I have some ideas about doing it underground – we could use sealed mine shafts for really big pieces!"

Various other institutions, such as the Warren Lasch conservation centre at Clemson University, are also looking into supercritical and subcritical technologies and Scarlett hopes for much more collaborative efforts in future to push the technologies on still further, including to conserve non-metal artefacts.

CHEMICAL ENGINEERING KEEPS ON GROWING, KEEPS ON EVOLVING, AND IT'S EXCITING FOR US HERE TO BE ABLE TO PUT OUR EXPERIENCE INTO IT, AND FOR OUR STUDENTS

Of course, one of the big things will be heritage institutions and funding agencies interested in the technology. They hope to be able to attract funding to employ a post-doctoral researcher, whether a chemical engineer with an interest in conservation or a conservator with a chemical engineering background, to help take the research further. Bringing together a team of interdisciplinary students would really help. Eventually, a company could be spun-off to commercialise the technology and license it, a model MTU is keen on.

"Once you have a setup for doing this kind of work, you can train people to use it. This kind of material is generally benign and safe. You work with high pressures so it takes some training, but it's not a big deal. Almost 30 years ago, I got a C in college chemistry. If I can do it, any museum staff could learn how to do it," says Scarlett.

LOOKING TO THE FUTURE

Scarlett has big dreams for the technology. Ultimately, he would like to develop a mobile system for use in the field as soon as something has been found. For metal artefacts, timing can be critical. One of the biggest projects he worked on was an excavation of the site of the former West Point Foundry in New York, a critically important industrial site in the early 19th century that was painted by some of the great American landscape artists, and which made some early steam locomotives and manufactured a rifle cannon called the Parrott gun, a vital piece of ordinance in the American Civil War. Whilst digging on the site, he and his colleagues found a piece of cast iron in a stream, stamped with the letters WPF, for the foundry, and a date stamp from 1830s.

"At the time, it had a relatively stable corrosion patina. We treated and stabilised it as best we could and shipped it back to the lab, but by the time we opened it up, it had decayed, and we had to treat it electrolytically. In its conserved state, the object was less satisfying than when we took it from the environment. If we'd been able to treat it straight away it could have sat for years," he says.

Scarlett envisages a mobile truck with the supercritical process equipment in the back, which could drive around archaeological sites, carrying out the conservation process as soon as an artefact had been excavated.

The same truck could also visit museums and research institutions. Many governments around the world, including in the US and Europe, are committed to conserving archaeological artefacts. Scarlett believes that the number of artefacts must run into tens of millions, and the cost of conserving them all would be "almost unimaginable".

"If we can operationalise this system, we could quadruple the shelf-life of metal objects before they would have to be sent to a conservator again. The cost savings would more than pay for the creation of a couple of teams to travel around and do these treatments for museums and institutions. The potential here is really profound, it isn't just quirky little experiments," he says.

Caneba points out that you cannot necessarily put a value on heritage conservation in any case. He too, is enthusiastic about the prospects of the technology, and the new research frontiers it opens up.

"This is a non-traditional field for chemical engineering, I don't think it's even a field yet! It's totally new and very exciting and I think we have to look more into it. Chemical engineering keeps on growing, keeps on evolving, and it's exciting for us here to be able to put our experience into it, and for our students," he says. ■

Full report – http://bit.ly/1qCI6og