ANCIENT CONCRETE? REALLY?

July 29, 2011 Jennifer Murgatroyd Day of Archaeology, Day of Archaeology 2011, Italy, Roman, Science alteration products, Ancient construction, Archaeometry, Building materials, Calcium, Cement, chemical composition, chemical data, chemical reactions, Concrete, Construction,Freemasonry, Italy, Masonry, Microscopy, Mortar, Ostia, Pozzolan, preserved city-sized site, pretty straight forward, Roman, Roman concrete, Rome, Scanning electron microscope, X-ray

Yes, really. I first fell in love with old buildings in Pompeii, where I spent summers working as an excavator from 2002-2008. Every day it struck me that I was in a place that still looked and *felt* like a real city. To my mind, this was down to the fact that the buildings are still standing. After more than 2000 years. Someone did something very, very right when making those buildings and I want to know more.

For my D.Phil research, I have landed in an opportunity to study structures in Ostia, Italy, which is also a preserved city-sized site. The structures I'm investigating are all brick and mortar masonry, with concrete filling up the center wall core. This is what Vitruvius called *opus caementicium*. To be honest, I'm most interested in the people who made it: the builders who developed this wonderful, magical material that is still performing successfully more than 2000 years after it was first installed. Where did they get their materials? Why were certain materials preferred over others? How were the materials processed and mixed together? How did builders' choices affect the concrete and its performance? Were the same mix types used for both public and private structures? Why is this stuff still standing? These are the questions driving my research, and I am looking to answer them by investigating the material itself.

To give a quick overview, the mortar and concrete I am analyzing was made of lime, volcanic sand aggregate, and water. Sounds rather simple, however, the combination of materials they were using produced complex chemical reactions, known to modern concrete scientists as pozzolanic reactions, which resulted in a sophisticated, high quality material. My sample collection was collected from a series of structures in Ostia from the 2^{nd} century CE, by which time – at least in Rome – concrete was well-developed and had been employed in large-scale Imperial building projects. My task now is to analyze the Ostian structures to determine how well-developed their concrete industry had become by that time. The benefit of a site like Ostia is that the ancient city is left largely in tact without modern development. This means that unlike in Rome, where centuries of modern development has destroyed all but the most protected monumental structures, it will be possible to evaluate the buildings within their original cultural context.

The analytical techniques employed for my research are borrowed from geology and concrete science, which makes this a truly interdisciplinary project. My samples are essentially synthetic composites of natural materials that can be investigated with traditional petrography. I'm using light microscopy of thin sections to identify and quantify the aggregate, to describe the cementitious matrix, and to identify any obvious degradation features or alteration products. Today I'm working on point counting one of the samples, which is pretty straight forward. I move across the sample in 1 mm steps, and at each location I record what I see in the cross hairs of the eyepiece. Besides the obvious benefit of quantifying each of the different components, I'm also getting to the know the sample really well. As I go, I'm recording information about the state of degradation or alteration, the shape and fillings of any cracks or holes, particle size and shape, and any other details that may give me a clue about what the builders were doing when they made the concrete.

I am also using scanning electron microscopy (SEM) to collect high-resolution, high-magnification backscatter images of the samples. At this scale I can get a better look at the binder-aggregate interface to see how well-bonded these components are. It is also possible to see any microscopic cements that have formed in pores, cracks, and the vesicles of aggregate clasts that would otherwise not be visible. The SEM also detects the atomic weights of everything in the sample, which show up as differences in the greyscale colour of the image. It also can calculate the chemical composition of the different components, so using a combination of chemical data and backscatter images, I can determine what types of cements have formed (strengthening) and how much leaching has occurred across the matrix (degradation). The ratio of calcium to silica is key in both cases.

X-ray diffraction is also on the menu, assuming I can find the funding to pay for it. This technique is incredibly useful for identifying the mineral assemblage in rocks and materials. In this case, I will use it to confirm the original petrographic identification of minerals in the aggregate and to find any other alteration minerals that could not be seen in thin section. The presence of certain minerals like gypsum or ettringite usually indicate alteration of the mortar itself, but minerals such as stratlingite and calcium-aluminum-silicate-hydrates suggest the mortar was rather well-formed in the first place.

So today, I'll be giving an account of what it's like for me in the lab. I realize that being stuck in the lab sounds like a death sentence to some people, but for me, it's where the magic happens.