UNLOCKING the PAST!
THE SCIENCE OF ARCHAEOMETALLURGY
HOW THE TEAM AT CAIS KNOWS WHERE THIS MISSION BELL WAS MADE!
Welcome to the Center for Applied Isotope Studies (CAIS), and the amazing world of archaeometallurgy - where geoscientists and archaeologists use science to unlock the past! We’re going to be showing you how the chemicals inside ancient objects can tell us where an object was made - even something that’s been buried in the earth for hundreds of years.

Doing this kind of science takes a whole team of people. Here are the archaeologists and scientists at CAIS who make archaeometallurgy possible. They’re going to tell you what archaeometallurgy is used for, how it works and how they do it.

**DAVID**
Archaeologist and Curator of North American Archaeology at the American Museum of Natural History

**ANNA**
Archaeologist and Lab Director at the American Museum of Natural History

**ALICE**
Scientist at CAIS. Specialty: Materials Engineering

**DOUG**
Scientist at CAIS. Specialty: Geoscience
Anna and Dave are excavating a Spanish Mission on St. Catherines Island.

Dave, I’m finding a lot of fragments of metal in the trenches we’re excavating.

It’s bronze! That’s really interesting!

I think they’re pieces of mission bells.

Yes, I think you’re right.

The archaeologists on St. Catherines are looking for evidence that helps us understand the lives of the first European settlers in the New World.

Mission bells were usually made back in Spain or Mexico and brought with missionaries when they settled the New World.

Perhaps when the mission was destroyed, people wanted to keep fragments of the bells to recycle them into other objects.

Hmm, I wonder where the bells were actually made?
AT CAIS IN GEORGIA:

Hi Anna! Yes, we can definitely help you find an answer. You've sent us some of the bell fragments so we can get started!

Hmm. I can see under the microscope that some of the metal has not been cast very well.

Can you see those bubbles? They mean the bronze used to make the bell cooled too quickly in the mold.

HOW WERE THE MISSION BELLS MADE?

1. First, the shape of the bell is made out of wax surrounded by a mold made of clay.
2. Red-hot liquid bronze is poured into the space between the two parts of the mold. The wax melts and runs out.
3. The bronze goes into the space left behind by the melted wax, taking the same shape.
The bubbles mean the bells probably weren’t made in Spain. Spanish bell-casters were very good at making bells, and they wouldn’t have let the metal cool too quickly.

Can we find out where the metal came from? That might tell us where the bells were made.

Well, the metal contains copper, tin and lead... *

... so, yes: I think the lead isotopes could tell us.

Let’s take your samples to Doug.

* Scientists often use these abbreviations: copper: Cu  tin: Sn  lead: Pb

The bronze cools and goes solid.

The clay parts of the mold are taken away, and what is left is the bronze bell.

Finally, the bell is trimmed, polished and tuned so that it makes the correct sound.
WHY IS THERE LEAD IN THE BRONZE BELLS?

1. Lead is dug out of the ground in lead mines. There are other elements in the rocks and soil surrounding the lead.

2. Two of these elements—Thorium and Uranium—are radioactive. As they decay, neutrons and protons leave the nucleus of the elements, changing them to lead. This creates lead atoms with different numbers of protons and neutrons.

3. Different parts of the world have different amounts of naturally-occurring Thorium and Uranium in the soil and rocks.

4. ...and they create different amounts of each kind of lead isotope.

5. So how much of each isotope you have in a sample of lead can tell you were that lead came from.
Hi Doug! Here are the Mission Bell samples we are curious about.

The first step is to separate the lead from the copper and the tin in the sample using a CATION EXCHANGE COLUMN.

I use a special acid to release the lead from the column. I then collect it and take it to the multicolonctor for the next step.

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A small sample is removed from the bronze bell fragment.

The sample is poured into a column to trap the lead...

Everything else - ie: the Cu and Sn - flows through the column and drips out the bottom.

Because each element behaves differently, they move through the column at different speeds.

It takes a while for the sample to pass through the column, and we wait until the time is right to extract just the lead from the sample.
First the sample is introduced into the plasma and converted to positively charged ions.

Plasma is one of the four fundamental states of matter, the others being solid, liquid and gas.

Plasma is a mixture of negatively charged electrons and highly charged positive ions created when the sample is sprayed into a high temperature torch.

Next, the ions are focused into a very small beam of energy...

... and passed through the electrostatic analyzer or ESA.

The ESA uses an electric field to further focus the ions and allow only the ions of a given specific energy to pass through to the magnet.

The different isotopes of lead are separated out by the multicollector and counted separately in the collector array. This tells us how much of each isotope is present in the sample.

For each sample, we look at the amounts of four isotopes:

\[
\begin{align*}
204\text{Pb} \\
206\text{Pb} \\
207\text{Pb} \\
208\text{Pb}
\end{align*}
\]
The focused ion beam passes through the magnet, which causes the ions to travel in a curved path.

The magnetic field separates the particles by their mass and charge. Heavier ions travel along a wider curve than the lighter ions.

The ions are now separated into beams containing only ions of the same mass and charge - isotopes.

Each isotope is measured by the collector array: a series of detectors designed to count charged particles in a vacuum.

These detectors are called "Faraday cups," after the scientist Michael Faraday.

This process allows us to compare the amount of one isotope to another. This is called a ratio.

When we analyze lead, we're particularly interested in several ratios, such as:

\[
\frac{^{208}\text{Pb}}{^{206}\text{Pb}} \quad \text{and} \quad \frac{^{207}\text{Pb}}{^{206}\text{Pb}}
\]

\[
\frac{^{208}\text{Pb}}{^{206}\text{Pb}} \quad \text{and} \quad \frac{^{207}\text{Pb}}{^{206}\text{Pb}}
\]
These data show us how much of each lead isotope was in the sample from the bells.

This chart shows different sets of these two ratios... which help pinpoint the location on a geological map.

Each dot on the chart is a known source of lead...

...lead from mines in Mexico plots near the bottom and lead from Spain plots near the top. The red dots show the bells we analyzed.

So the bell with the bubbles matches one source in west Mexico perfectly and the other bells came from Spain.

That's more than a thousand miles from St. Catherines!
Knowing where metal for making objects like these mission bells comes from is really important. It tells us how distant historical places in North America are related.

This means one of our mission bells was made with lead that came from Mexico. This is definitely different than what we first thought!

That’s excellent news, Anna! It really changes our ideas about this mission site!
Separate the isotopes!

Game for two players: Take turns drawing straight lines from one to another, try and make a box around a group of lead isotope atoms of the same colour. Whoever separates out the most atoms, wins! One player challenge: Draw a single, continuous line from one to another, without crossing over your line, and see how many isotope atoms you can separate by colour!