What a tiny micrometeorite from the Pilbara can tell us about the ancient sky

May 13 2016, by Andrew Tomkins, Monash University

Those tiny streaks sometimes land, and they can tell us a lot about the sky.
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Not long ago, my colleagues and I found some micrometeorites in the Pilbara region in Western Australia. What's truly remarkable about them is that these tiny meteorites can tell us a great deal about the chemistry of Earth's atmosphere 2.7 billion years ago.

And this week our findings were the subject of a paper in the journal

Nature.

This is pretty exciting for us, because getting published in *Nature* is seen as a bit of a holy grail for scientists of all disciplines. But perhaps more interesting is the behind-the-scenes story that led to our publication.

Roaming the Pilbara

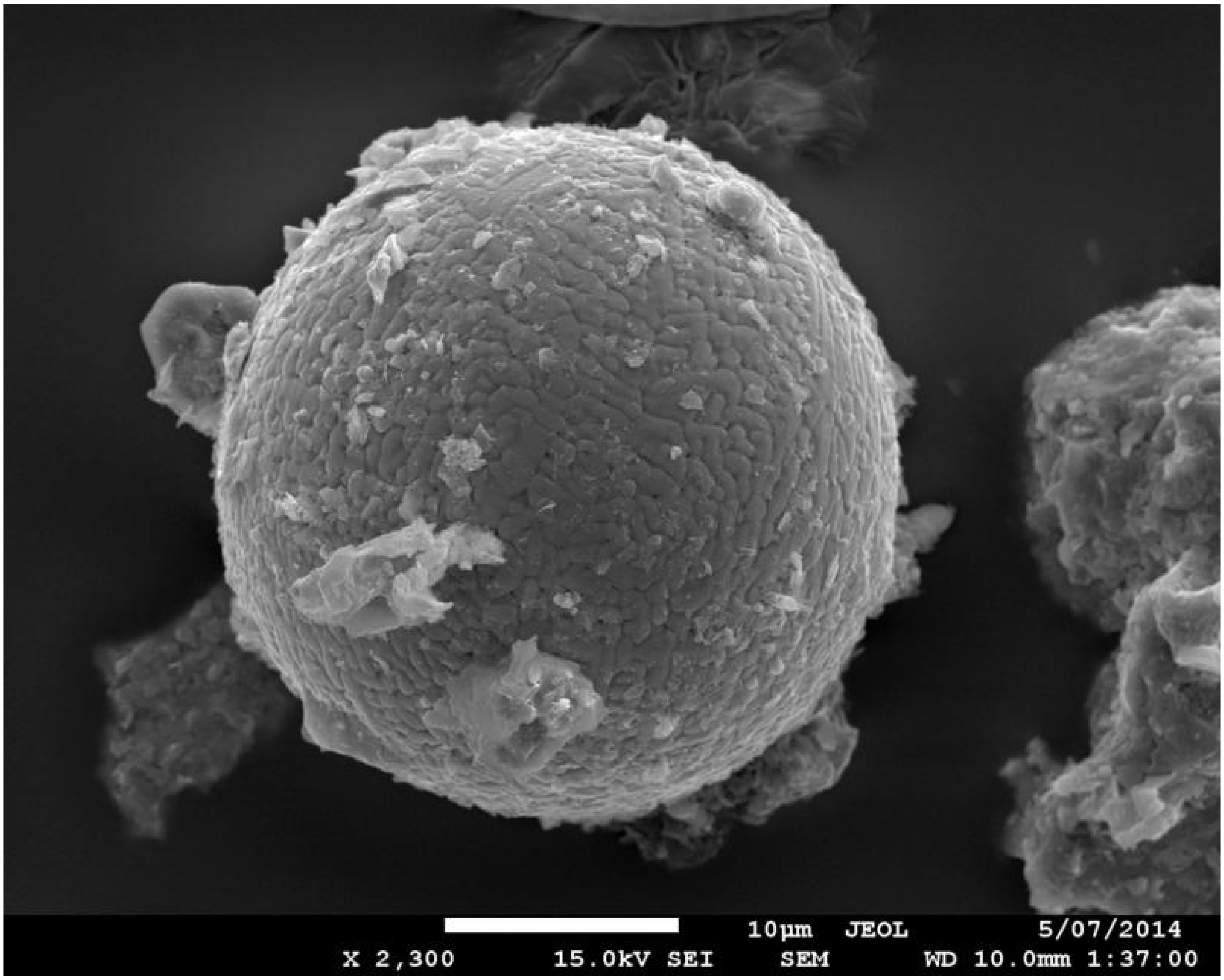
The story starts with me doing my once-a-month scan through of the top journals in my field. I came across an article by Tetsuji Onoue and colleagues in the journal *Geology*.

They'd recovered 240 million-year-old fossil micrometeorites from a sedimentary rock called chert.

I thought:

Wow, that's cool! Wouldn't it be interesting to try to find the world's oldest micrometeorites and use them to estimate the flux of space dust to Earth billions of years ago!

A year or so later, Lara Bowlt came into my office at the end of the third year of her geoscience degree looking for an honours research project. Lara was torn between doing a minerals industry-focused project, which she thought might help her get a job, and following her interest in meteorites and planetary science. Luckily, she chose the latter.



One of the micrometeorites recovered from the Pilbara.

To find the oldest micrometeorites ever, we had to use a bit of basic geoscience logic. Micrometeorites are constantly falling to Earth. They are the remnants of meteors (shooting stars) that you can see on any night of the week.

Some of those meteors end up as tiny particles – micrometeorites – that land anywhere on the Earth's surface. They can be collected from the roof of your house for example, and scientists can easily recover them from the ocean floor by dragging a magnet along the bottom, as many are magnetic.

Because they are constantly falling to Earth, sediments that accumulates very slowly will have a greater abundance of micrometeorites. The oldest sedimentary rocks in Australia are located in the Pilbara region in Western Australia, so we decided to go there for samples. We also decided to target limestone sedimentary rock because this can be easily dissolved in mild acid, leaving behind the micrometeorites.

Lara and I flew over to Port Hedland. From there, we spent several days driving around in a 4WD, camping in tents and sampling 2.7 billion-year-old limestone. We collected large solid blocks with very thin and straight laminations, indicating very slow sediment accumulation in a quiet setting.

Back in Melbourne, Lara cut the weathered rind off the outside of the limestone blocks, before crushing the unweathered interior into small fragments.

With the help of Sasha Wilson, the crushed limestone was then bathed in vats of mild acid for a few weeks, kept constantly covered to avoid contamination from modern micrometeorites. Lara then used a magnetic separator and hand picking under a microscope to separate what she thought might be micrometeorites from the residue.

After using an electron microscope to see the fine details on the surface of the extracted particles, I got a very excited message from Lara:

Oh my goodness, I think we found some!!!!!!!!!!!

Atmospheric revelations

We contacted micrometeorite specialist Matt Genge at Imperial College in London, who confirmed that we had indeed found a number of micrometeorites.

These were mostly I-type micrometeorites, which formed when sand-sized particles of iron metal floating around in space entered Earth's atmosphere moving at very high speeds (more than 43,000 km/h), causing them to melt and form spheres.

One of the curious things that we noted about the I-type micrometeorites is that they were composed primarily of the iron oxide minerals, with metal preserved in a few examples. The mineralogy crew – Sasha and Helen Brand – used fancy gizmos such as the Australian Synchrotron to confirm mineral proportions.

This was a surprising result, because it is widely believed that the Earth's atmosphere 2.7 billion years ago contained very little oxygen.

I realised that this meant that the micrometeorites had reacted with a narrow band of the upper atmosphere during the brief period when they were superheated, and oxidised upon atmospheric entry. This would have occurred at about 90 to 75 km altitude.

So this was the first sample of Earth's ancient atmosphere from 2.7 billion years ago!

Matt generated a mathematical model of how much oxygen would need to be present in the ancient atmosphere to cause the observed mineral changes in the micrometeorites.

This model suggested that oxygen concentration in the upper atmosphere would need to be close to modern-day concentrations to explain the observations. Jeremy Wykes and I backed this up by evaluating the effects of CO_2 and CO on oxidation.

This was initially a surprise, because it is widely accepted that Earth's lower atmosphere contained less than 0.001% O_2 before about 2.3 billion years ago.

But interestingly, our results somewhat confirmed the predictions of atmospheric chemists. These scientists had generated a series of models of the chemical structure of the ancient atmosphere, based on the composition of gases emitted from volcanoes and the knowledge that ultraviolet light from the sun breaks gas molecules like CO_2 into smaller molecules like CO and O_2.

They had predicted elevated oxygen in the upper atmosphere at this time, caused by UV-induced decomposition of CO_2. Although our results suggested a little higher O_2 and less CO than they had predicted.

So a bit of purely curiosity-driven science had identified a new way to study the chemistry of the ancient Earth's upper atmosphere. And there is still much more to do from here!

As an epilogue to this story, it turns out that curiosity did not kill the cat; Lara got a great job as an exploration geologist, which is exactly what she wanted.

This article was originally published on The Conversation. *Read the* original article.

Source: The Conversation

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