Q&A: Curiosity's spectacular Yellowknife Bay side-trip

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Curiosity: The Next Mars Rover. Image courtesy of NASA/JPL-Caltech

When the Curiosity rover landed in Gale Crater on Mars in August 2012, its primary destination was Mount Sharp, a three-mile-high mound a few miles south of the rover's landing site. But before making for the mountain, mission planners and scientists decided to take a slight detour to the North. Orbital instruments had spied an interesting-looking region of rock outcrop between the mountain and the crater rim. Because the rover had landed about a quarter-mile from this spot, it seemed worth popping up to take a look before proceeding to Mount Sharp, where the Curiosity is headed now.

That little side trip paid off in a big way. Using its full suite of instruments, Curiosity was able to show the area, known as Yellowknife Bay, was likely host to an environment that could have sustained life in the distant past. NASA announced the striking news to the public last

March. Six scientific papers describing Curiosity's findings in detail were published online today in the journal *Science*.

Ralph Milliken, assistant professor of geological sciences at Brown, is a participating scientist on the mission and a co-author on three of the papers. He spoke with Brown science news officer Kevin Stacey about the findings.

What was it about Yellowknife Bay that prompted the detour?

It's one of the lowest spots topographically on the crater floor. Just upslope from it were what looked like ancient streambeds and fluvial channels—evidence for flowing water in the ancient past. So the idea was perhaps flowing water might have ponded in this low-lying area, and that's what we wanted to investigate. We also had some satellite observations that suggested that the rocks there were interesting. We didn't know exactly what to expect about the minerals or chemistry of the rocks. It's a dusty area, and that prevents us from identifying minerals from orbit. But we knew there was a high probability that there was bedrock exposed. So based on the potential payoff of testing the scientific hypotheses that we had formed, and the fact that we happened to land so close to it, we made the decision to drive in the opposite direction from Mount Sharp.

What did Curiosity find when it arrived?

I think what we found at Yellowknife Bay well surpassed our wildest imaginations for this early in the mission. We found evidence that there were mudstones, which are the kinds of rocks you might find in lakebeds on earth. So it appears as though there may have been an ancient lake. Presumably that water could have been sourced from the channels that are upslope in the crater wall. There's evidence of sandstones in this area as well that look like they were formed by flowing water, which we can tell from our detailed imagery the rover provides. So there's a lot of evidence that water flowed over the surface and interacted with the sediments at the surface. It's all very consistent with the presence of ancient streams and what was likely a lake.

Ultimately, Curiosity was able to find evidence of an ancient habitable environment at Yellowknife Bay. What did the rover find that led to that conclusion?

When we think of habitability, we need to be clear that the goal of the mission is not to find evidence of life on Mars. Although we have the ability to detect organic matter, if it happens to be present, this is not a life-detection mission. What we can assess is whether the rocks we examine had the raw ingredients for life to have been supported at some point in time. That's what we found at Yellowknife Bay. For an environment to be habitable, there are a couple of things we need. One is water, and there's plenty of evidence that there was once water at Yellowknife Bay. We found clay minerals in the rocks, which require water to have formed. We also found other minerals that require water—things like gypsum—in fractures in the rocks and indicate water flowed through them. When we look at the minerals as a group and the chemistry of those minerals, the water that was associated with them seems to have been relatively benign—not overly acidic and likely habitable for many types of microbes. We've also detected certain elements that we know to be the building blocks of life. These are things like carbon, hydrogen, oxygen, phosphorous, and sulfur.

One of the other things we would need for habitability is some source of energy that microbes could use for metabolism. That could be a lot of different things. It could be from sunlight or from the chemistry in the rocks themselves. You can kind of think of it like a car battery that has positive and negative terminals. Certain elements can have various states of charge. Iron and sulfur are good examples. They can be oxidized or reduced, and microbes can utilize those gradients for metabolism. We found iron and sulfur in various states of oxidation in the rocks at Yellowknife Bay. That's a potential source of energy that microbes could use.

These are some of the basic building blocks you need for life as we know it to form and survive, and we've detected evidence of all of these in one way or another in the rocks at Yellowknife Bay. This evidence of an ancient habitable environment is what makes this location so interesting.

How long ago was this area potentially habitable?

We have pretty big differences in the age estimates of the rocks we analyzed, but no matter how you slice it, we're talking billions of years ago. Whether it's 2 billion or 4 billion, that debate will likely continue. But a lot of the evidence suggests it's probably somewhere between 2 and 3.8 billion years ago. Previous to these discoveries, many scientists would probably have assumed that only the most ancient rocks on Mars likely preserved evidence of habitable conditions. A lot of people think that starting around 3.5 billion years ago Mars was already drying out and becoming the cold, arid environment it is today. It's been argued that you need to go to the most ancient rock record on Mars—4 billion years ago or more—to find these habitable environments on the surface in what may have been a warmer and wetter Mars. However, if the rocks we examined in Yellowknife Bay really are at the "younger" end, say 2 billion years old, then what we've found extends the window of possible habitable surface conditions on Mars by quite a bit.

What's next for Curiosity?

It just so happens that we've already made a huge step forward and achieved one of the primary mission goals by finding evidence of a habitable environment. But we're on our way to Mount Sharp now, and I have hopes that what we find there will be even more spectacular. We know from orbital data that the rocks at the bottom of the mountain have water-bearing minerals, but as you go higher they start to disappear. So the idea of going to Mount Sharp is that maybe these three miles of rock are capturing what we think was a global change on Mars. By going layer by layer we might be able to piece together what happened—why Mars dried out. We can also relate that information back to what we found at Yellowknife Bay and try to determine whether the environment we saw at Yellowknife Bay is unique or is representative of a longer period of Martian history. I'm excited to see what we might turn up.

Provided by Brown University

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