

acknowledges the likely scenario that “we blow out our carbon budget”, but then remove enough CO<sub>2</sub> from the atmosphere to bring the temperature back down to, or even below, 1.5 °C above pre-industrial levels.

However, this strategy is risky, says Nebojsa Nakicenovic, energy economist and former chief executive of the International Institute for Applied Systems Analysis in Vienna.

Overshooting emissions targets and then removing the carbon from the atmosphere

“means we are postponing the problem to the second half of this century”, and CO<sub>2</sub> removal technologies have a long way to go before they are scalable, he says.

It is clear, based on evidence such as the results of the new modelling, that achieving the deep fossil-fuel emissions reductions needed to keep warming below 1.5 °C will be a “Herculean task” and we must start immediately, Nakicenovic says. “It’s not enough to have promises for 2050.”

looks more robust.

If further studies confirm that Rochette is basalt, that would be scientifically exciting because, once it has been returned to Earth, researchers could use the decay of radioactive elements in the rock to date its formation precisely. This has never previously been possible for a Martian rock because no samples have ever been brought back from the planet.

NASA’s previous Mars rover, Curiosity, which landed in a different crater in 2012, came across rocks that were, unexpectedly, too hard for it to drill – the opposite of Perseverance’s initial problem. And a 2008 Mars lander, Phoenix, had trouble collecting grains of dirt until mission managers worked out that the dirt needed to be kept out of direct sunlight so that ice between the grains didn’t melt, refreeze and cement them together. “Mars is a real planet, with surprises,” says Raymond Arvidson, a planetary scientist at Washington University in St. Louis, Missouri, who has worked on a number of Mars rover missions, although not Perseverance.

# SUCCESS! MARS ROVER FINALLY COLLECTS ITS FIRST ROCK CORE

## NASA’s Perseverance rover lives up to its name, drilling into Martian rock after a misstep in August.

By Alexandra Witze

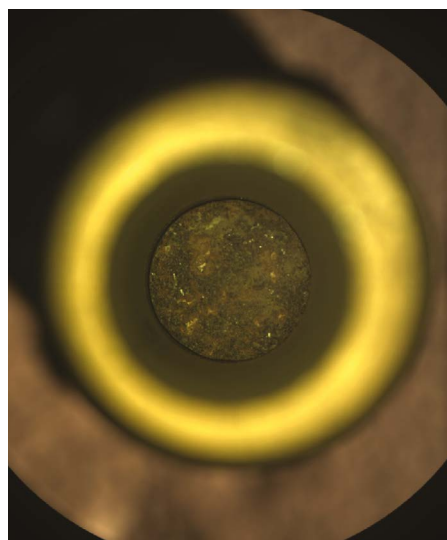
**A**fter a failed attempt last month, NASA’s Perseverance rover has successfully drilled, extracted and stored a sample of Martian rock – the first ever Mars sample destined to be flown back to Earth for study.

“This is a momentous achievement,” said NASA administrator Bill Nelson in a statement.

When the rover first attempted the manoeuvre, on 6 August, the rock it was trying to sample crumbled into powder before making it into a sample tube. The second attempt, on 1 September at a different location several hundred metres away, went smoothly: the drill bit pulled a slim cylinder out of a 70-centimetre-long rock named Rochette. Engineers then paused the process so that they could photograph the core in its sample tube, to ensure it was intact, before sealing the specimen inside days later.

The core from Rochette now rests in Perseverance’s belly, hermetically sealed and ready to wait many years until future spacecraft can retrieve it and any other cores the rover manages to collect. The goal is to gather about 35 cores representing the geological history of Jezero Crater, Perseverance’s landing site – which was home to a river delta billions of years ago and might contain evidence of ancient Martian life.

How Rochette fits into that history isn’t yet clear. Early investigations by the rover suggest that it is a rock type known as basalt, and might have been part of an ancient lava flow that makes up the ridge where Perseverance is parked, says Kenneth Farley, a geologist at the California Institute of Technology in Pasadena



Perseverance’s first intact rock core, visible inside its sample tube, on 6 September.

and the mission’s project scientist. Rochette shows reddish patches and staining, as well as small cavities filled with salts, all of which suggest it interacted with water over a period of time – perhaps at the bottom of the ancient lake that once filled Jezero.

Rochette turned out to be a much better rock to drill into than the one the rover first attempted to sample – a rock named Roubion that lay elsewhere on the crater floor. Roubion also showed signs of interacting with water long ago, but in its case the water seems to have physically weakened the rock, because it turned to dust when Perseverance hammered in its drill bit. The rover might try drilling into another rock similar to Roubion later in its mission, says Farley, if it can find one that

### Crunch time

Now the pressure is on for Perseverance to start collecting cores more efficiently. It landed in Jezero in February, so it has taken more than six months to collect its first sample. It is supposed to gather its first suite of cores from the crater within one Mars year of landing (a little less than two Earth years). And because the rover landed slightly over 2 kilometres from its main sampling target, Jezero’s ancient river delta, it probably won’t even reach that formation until early next year.

But Arvidson says he’s not concerned about the pace of the mission so far. The first three months were used, among other things, to test and fly a miniature helicopter, which has made a dozen flights so far and is helping mission scientists to pick interesting directions for the rover to travel. The rover itself has driven 2.17 kilometres, south and then west from its landing site, surveying the terrain and doing experiments that don’t involve drilling, such as using ground-penetrating radar to probe beneath the planet’s surface.

Following its successful sample collection, Perseverance will drive a few hundred metres north-west, into a region known as South Séitah, full of sand dunes, ridges and other rocks and boulders. Mission planners will soon have a brief break, from 2 October to 14 October, when it will not be possible to communicate with the rover because Mars will move behind the Sun relative to Earth.

NASA and the European Space Agency are planning a complex set of future robotic missions that would travel to Jezero, pick up the samples collected by Perseverance and fly them back to Earth for scientists to study. It will be at least 2031 by the time the samples arrive on Earth.