Found: Primordial Water

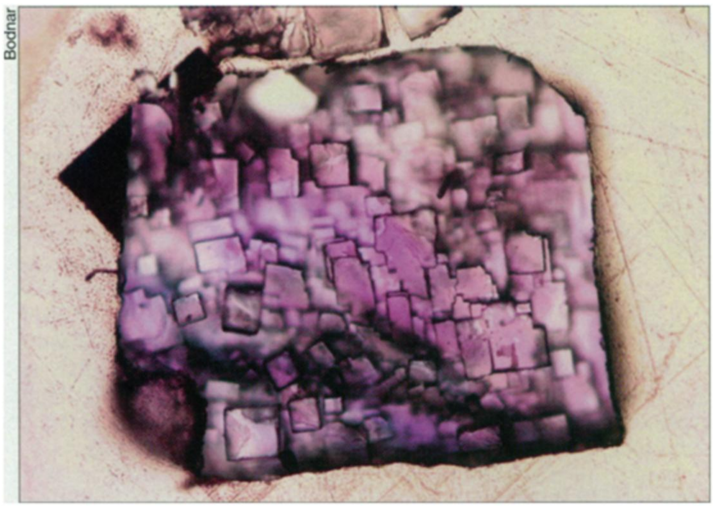
A meteorite's salty tale

By RON COWEN

In the desert town of Monahans, Texas, a rainstorm is a major event. But, a visitor that brought in just a trace of water last year has made a much bigger splash.

On a Sunday evening 19 months ago, 11-year-old Alvaro Lyles, his younger brother, and five friends were playing basketball in the Lyles' backyard when they heard what sounded like three sonic booms. At first, the youngsters thought another boy on the sidelines, throwing rocks, had made the noise. Then, in a vacant lot some 30 yards away, they spotted an object they'd never seen before. The black rock was the size and shape of a squashed grapefruit. A few minutes later, when one of the boys placed the 2.2-pound chunk in the hands of Eric's father, Orlando Lyles, it was still warm.

Orlando Lyles recognized the rock for what it was: a meteorite that had just fallen to Earth. No one guessed, however, the precious cargo that the rock was carrying.



Purple salt crystals in a sample of the Monahans 1998 meteorite. Crystals are about 3 millimeters long.

Last August, a fragment of the meteorite, dubbed Monahans 1998, returned to the spotlight, this time garnering headlines worldwide. Researchers reported that the rock contains water from the birth of the solar system.

Locked inside purple-tinged salt crystals that date from the solar system's formation 4.5 billion years ago, the water is presumed to be of the same vintage as the sodium chloride vessicles. The amount of fluid is minuscule, but it's the first time that scientists have detected water—an essential ingredient for life—of primordial origin.

Michael E. Zolensky and Everett K. Gibson Jr. of NASA's Johnson Space Center in Houston, along with Robert J. Bodnar of the Virginia Polytechnic Institute and State University in Blacksburg and their colleagues, describe their findings in the Aug. 27 SCIENCE.

"This [water] is the first real sample of the solar nebula gas, the gas from which all the planets formed," comments cosmochemist Robert N. Clayton of the University of Chicago.

Monahans 1998 belongs to a class of meteorites known as ordinary chondrites, which astronomers have believed are fragments of asteroids that contain little or no water.

One explanation for the water in this meteorite is that its parent asteroid acquired it after the rock formed. A water-rich, icy projectile, such as a comet, could have plowed into the newborn asteroid and spilled some of its water. Alternatively, if the water was incorporated into the asteroid as it coalesced, planetary scientists may have to revise their thinking about the lineage of ordinary chondrites, says Clayton.

The findings have a far more intriguing implication. To carry a concentrated salt solution today, Monahans 1998 must have once been in contact with several times more water than now remains, the researchers note. Clayton agrees with the team's assessment. "There had to have been quite a lot of water passing through [the rock], even though only a tiny fraction of it has been trapped in the crystals," he says.

"I think it changes our whole perception of how the early solar system formed, what the conditions might have been like, and what the possibility of life was like this early," says Bodnar. "One of the big questions we're asking is, Is the Earth unique in terms of having life? If water was as common in the solar system [as implied] by these findings, then that would suggest that there were many environments in the solar system where the conditions were right for the development of life."

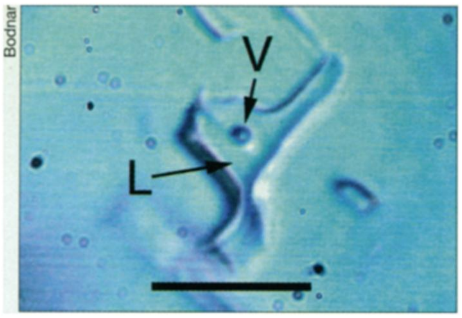
Water in chondrites could explain water on Earth, says Alan P. Boss of the Carnegie Institution of Washington (D.C.). The origin of terrestrial water has perplexed scientists for decades.

Astronomers have proposed that comets, the frozen, water-bearing émigrés from the outer solar system, could have delivered much of Earth's water during the first few hundred million years of the planet's existence. During this epoch, known as the late heavy bombardment, comets pelted Earth and the other inner planets at a far higher rate than they do today.

However, the ratio of deuterium to hydrogen in cometary water is much higher than in water on our planet. Researchers don't yet know the deuterium ratio of the water in Monahans 1998. If it is lower than that in comets, the finding could indicate that meteorites or their parent asteroids are just as important as comets in ferrying water to Earth. A mix of water from comets and asteroids could be the recipe required to create today's oceans.

Although scientists have searched for primordial water in space rocks for decades, they hadn't come up with a drop. Bodnar and his colleagues note that if the water typically resides within salt crystals, the fragile evidence could easily have washed away or evaporated. The researchers succeeded in finding water this time, they assert, because a member of their team retrieved the rock in record time.

As luck would have it, Monahans isn't very far from the Houston space center. As soon as news of the meteorite fall got out, Gibson hopped on a plane to west Texas and met with the Monahans City Council. A Texas native who grew up just 70 miles from the town, Gibson gave the council his personal guarantee that if he could borrow the rock, he'd return it within 60 days.



Bodnar

Ancient water: Image shows liquid (L) inside a salt crystal in the Monahans 1998 meteorite. A gas bubble, or vapor (V), resides inside the fluid. Bar indicates a scale of 15 micrometers.

With the town's blessing, he packed up the meteorite in a plastic bag and within 46 hours of its landing had transported it to the NASA center. Researchers have never before studied a space rock so soon after its arrival on Earth, Gibson says. He later returned the meteorite, minus a tiny sample, to the city.

In November 1998, after researchers at the space center had been studying the sample for several months, Bodnar happened to attend a conference there. Visiting his former classmate Zolensky, Bodnar peered at a salt crystal from the meteorite under the microscope. Along with fluid locked inside the crystal, he and Zolensky saw a moving bubble of gas. Among the materials that could be present in the meteorite, only water and carbon dioxide can exist as both a fluid and a vapor at room temperature.

Bodnar suspected that the material was water because liquid carbon dioxide could only become trapped under extremely high pressure. It was doubtful that fragile salt crystals could have survived under that condition.

At Virginia Tech, he confirmed his hunch. Chilling the salt sample, a mere millimeter in length, Bodnar found that the fluid it contained froze at –21.2°C, the temperature expected for salt water. After bringing the sample back to room temperature, he illuminated it with the green light of an argon laser. The light emitted by the fluid showed the characteristic fingerprint of water.

Bodnar was excited but also cautious. Without doubt, Monahans 1998 contained water, but could the fluid have entered the rock after it landed?

He and his colleagues were only too aware of scientists' jumping to the wrong conclusion. In the early 1980s, researchers reported that they had found primordial water in a meteorite that they had cut open with a diamond saw. Moisture from the lubricant they had used in the cutting process, however, had penetrated microscopic fractures within the rock. Gibson was a member of the chagrined team that had to retract its finding.

In this case, Gibson and his colleagues had an essential clue that the water in Monahans 1998 hadn't come from Earth. The fluid resided within salt crystals that have a purplish hue. Newly formed salt is colorless, but it darkens when cosmic rays and radiation bombard it. Too little time had elapsed for the discoloration to have taken place on our planet, so the salt—and presumably its watery cargo—had to have been incorporated into the rock well before it landed.

"The fact that the salt was purple was evidence that [the water] was in it when the rock was in space," says Bodnar.

Finally, radioactive dating revealed that the salt crystals were 4.6 billion years old. "Our conclusion that the water is that old is based on our interpretation that the salt is that old," Bodnar notes. "Some of the water clearly penetrated when the salt crystals formed."

The researchers are now pursuing two lines of study. They hope to analyze the ratio of deuterium to hydrogen in the water. Because their sample is so small, they will have to crush the entire salt grain to squeeze out every last water drop. The team will practice this technique with equally small samples of salt water made in the laboratory, before preparing to ship the meteorite-derived fluid to a colleague in England. That colleague will measure the isotopes using a mass spectrometer.

"We can't afford not to do it right the first time," says Bodnar.

In addition, Zolensky is scouring science museums and meteorite catalogues for rocks that landed in dry locales and were retrieved soon after they fell. Such rocks, he reasons, are more likely to still contain traces of any water they might have carried when they struck Earth. A telltale clue of ancient water, if Monahans 1998 is any example, is the purplish hue of salt crystals, he adds.

The team may already have found another specimen. A meteorite called Zag, named for the arid Moroccan town in which it fell last year, contains purple salt crystals. It also contains water, and in his laboratory Bodnar is about to determine how old it is.

"We now think that [water] is much more common in ordinary chondrite meteorites than people have recognized," says Bodnar. The salt crystals may be so tiny in most rocks, he notes, that scientists have overlooked them.

"We're pushing the limits of technology here in terms of the amount of sample we have to work with. If you looked at the container with the Zag [salt crystal] in it, you'd think the bottle was empty."

As with the water in Monahans 1998, Bodnar and his colleagues are anxious to measure the ratio of deuterium to hydrogen isotopes within the Zag sample. Even if the ratio in the two meteorites is a closer match to terrestrial water than to water in comets, the finding won't entirely explain where Earth's water came from, cautions theorist Tobias C. Owen of the University of Hawaii in Honolulu.

Meteorites, he notes, contain 10 times as much xenon, relative to other noble gasses, than occurs in Earth's atmosphere. In addition, the relative abundance of xenon isotopes found in meteorites doesn't jibe with the pattern found on Earth. If meteorites did deliver most of the water to our planet, they also would have provided xenon, and our atmosphere would have to have a very different composition, Owen maintains.

Back in the town of Monahans, the chunk of rock in which Zolensky and his colleagues found the water is no longer there. Last year, after Gibson returned the rock, the boys and their families sold it to a private collector for $23,000. So far, according to the researchers, the collector has not wanted to part with any of his heavenly treasure.

Mark Sterkel, Odessa American

Monahans policeman Reggie Bailey holds a chunk of the meteorite.

The town, however, has another piece of the same meteorite, a fragment that happens not to contain water. Found by a deputy sheriff the day after the boys' discovery, this chunk had gouged a crater in a city street. The town proudly placed the fragment in a showcase in the lobby of city hall.

Travelers in western Texas are now taking the business route off Interstate 20, dropping by just to pay homage to the meteorite that promises to change the way we view our planet's past. □