otherwise hold oil. The finding "makes life more complicated," says Kitty Milliken, a geologist at the University of Texas, Austin, who studies mudstones, "but it gives us the tools to be clear and figure it out."

The main evidence for the local origin of quartz silt comes from an analogy with authigenic quartz sand that Schieber observed several years ago. The quartz had precipitated inside sand-sized, hollow algal cysts—tough, protective bodies that algae commonly form when they reproduce. These cysts had been partially compressed by overlying sediment, leaving them with characteristic dents and projections. The same shapes turned up in quartz silt when Schieber and Dave Krinsley of the University of Texas and the University of Oregon examined slices of late Devonian (370-million-year-old) laminated mudstone, called black shales, from the eastern United States. The grains have concentric rings that look as if they were precipitated sequentially. Bordering the quartz grains are amber-colored rims that resemble the walls of algal cysts. Taken together, these characteristics distinguish authigenic from continental quartz, Schieber says.

To double-check the diagnosis of authigenesis, Schieber and Lee Riciputi of Oak Ridge National Laboratory in Oak Ridge, Tennessee, focused an ion microprobe at quartz silt in the shale samples. Quartz silt they had pegged as authigenic from its appearance had oxygen isotope values typical of other kinds of quartz precipitated at low temperatures—and three times higher than that of quartz silt that was not homegrown. They knew that this "imported" quartz had come from metamorphic rocks in distant mountains, because it has a mottled texture typical of metamorphic quartz.

What's most surprising, experts say, is the amount of authigenic quartz in these shales. In some samples, Schieber found that all the silt had grown in place. By volume, the authigenic silt may make up 40% of the shale. The presence of so much homegrown silt may have skewed geological interpretations of mudstone, Schieber says. Mistaking authigenic quartz silt for windborne silt, for example, might lead one to postulate desertlike conditions on land, when in fact the climate may not have been particularly dry. Authigenic quartz could also make it hard to estimate distance from the ancient shore, especially in broad expanses of mudstone that accumulated slowly, such as the late Devonian shales of North America.

How important these findings are depends in part on whether other times and places typically produced shales similarly rich in homegrown quartz. Lee Kump, a geochemist at Pennsylvania State University, University Park, points out that algal cysts tend to be most abundant during particular periods, such as times of stressful environmental conditions, so fewer of these hosts may be deposited in mudstone during happy times. Schieber believes that quartz grains might form in other fossil pores or the spaces between particles. In any case, he's already shown that the truth behind even the most ordinary rocks can be clear as mud.

–ERIK STOKSTAD

MOLECULAR STRUCTURE

Physicists Glimpse How Quasicrystals Boogie

If you have ever tapped a fine wineglass with a fork, you know crystals sing. Now, scientists have proved that quasicrystals, the slightly unpredictable cousins of crystals, can also dance. A new series of rapid-fire photographs has finally captured the expected do-si-do of atoms in the changing latticework of a quasicrystal. Although scientists had observed defects in quasicrystalline structures left behind by the flip-flops, called phasons, this is the first time anyone has spotted a real phason in action.

Unlike humans, molecules shiver less when they get cold. And as the molecules chill out, they are more amenable to bonding with their neighbors. The usual result is a crystal—a periodic pattern of identical clusters of atoms, in which every distance is an exact multiple of the size of the fundamental atomic cluster. It is an elegant picture, and for more than 150 years scientists believed that crystallization was the inevitable result of dropping temperatures.

They were wrong. In 1985, Danny Schectman of the Technion–Israel Institute of Technology in Haifa, Israel, discovered an aluminum alloy that cools to form a stable quasi-periodic structure that never exactly repeats. He called the structure a quasicrystal. In contrast to crystals, a quasicrystal has two length scales, says physicist Michael Widom of Carnegie Mellon University in Pittsburgh, Pennsylvania. Some quasicrystals, for example, mix two distinct three-dimensional structures, one hexagonal, the other pentagonal.

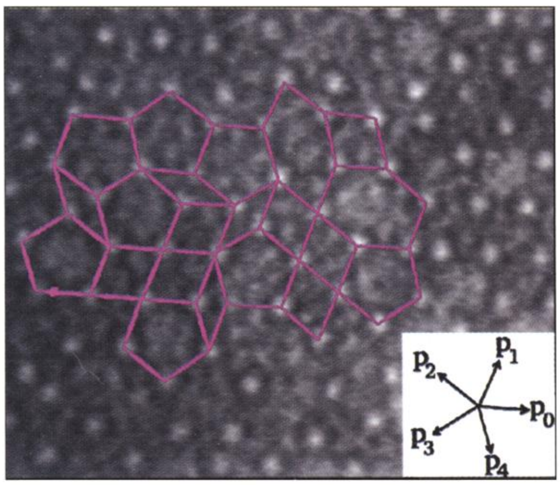
Quasicrystals know how to jump and jive. If you pluck one of the wires of a regular crystal, a vibration called a phonon hums through the entire crystal. The single crystalline length scale implies that the phonon is the only possible distortion of the crystal. Extending the connection between length scales and distortions to quasicrystals, theorists predicted that quasicrystals support an extra kind of oscillation called a phason. Phasons rearrange the quasicrystal structures by making individual atoms jump as much as a few angstroms. But no one had ever seen the wiggles caused by a passing phason.

Now, physicist Keiichi Edagawa and his collaborators at the University of Tokyo have for the first time used a high-resolution electron-tunneling microscope to capture the metamorphosis of a quasicrystal on film. They first heated an aluminum-copper-cobalt mixture to 1173 degrees Celsius, then cooled it to room temperature to form a quasicrystal of interlocking hexagonal and pentagonal rhombi. A series of photographs revealed a column of atoms jumping approximately 1 nanometer, the team reports in the 21 August *Physical Review Letters*. The jump changes a hexagonal rhombus to a pentagonal one and makes an adjacent pentagonal rhombus become hexagonal. Within minutes, the column jumps back and flips the rhombi back to the original configuration.

"This is a breakthrough, because we can now see the dynamical effects of phasons," says physicist Paul Steinhardt of Princeton University. But it leaves an important question unanswered: Why do quasicrystals form? Most scientists believe that quasicrystals are the lowest available energy state, so cooling molecules must eventually settle into that state, just as a marble must roll to the bottom of a bowl. Widom, on the other hand, supports the so-called "entropy model" that says quasicrystals continuously flip through a nearly infinite number of equally likely and constantly changing configurations. The new imaging technique may help scientists decide between the two.

–MARK SINCELL

Mark Sincell is a science writer in Houston.



Rhombus rumpus. Phasons tear through a quasicrystal, shifting the irregular latticework shown in this electron micrograph.

CREDIT: PHYSICAL REVIEW LETTERS