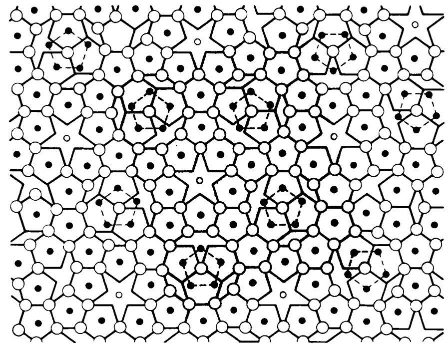
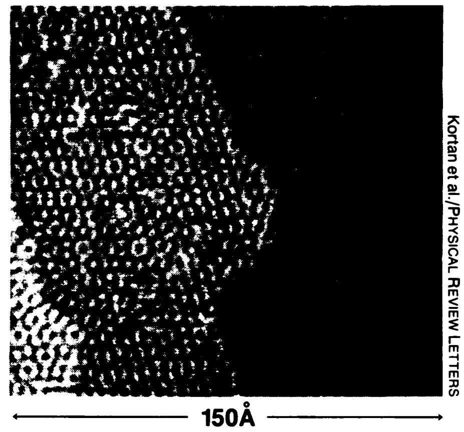
Tilings for picture-perfect quasicrystals





Kortan et al./PHYSICAL REVIEW LETTERS

At right, a network of points and ring-like structures, corresponding to atomic positions, covers a 150-angstrom-square region of a quasicrystalline alloy. The surface shows four prominent steps, revealing parts of the material's four top layers. This picture suggests a tiling model (left) in which aluminum atoms (open circles) tend to settle into pentagonal rings with copper or cobalt atoms (filled circles) at their centers. Shaded box corresponds to a surface region about 20 angstroms wide.

Since the 1984 discovery of the first alloy with atoms arranged in a pattern having a symmetry forbidden by the usual rules of crystallography, scientists have debated whether such alloys belong to a special category of materials known as quasicrystals or instead consist simply of tiny, conventional crystals joined in unusual ways. New images showing atoms on the surface of an aluminum-cobalt-copper alloy provide the best evidence yet that at least some materials actually do solidify into quasicrystals.

"For the first time, we've been able to resolve individual atoms on the surface of a quasicrystal," says A. Refik Kortan of AT&T Bell Laboratories in Murray Hill, N.J. The resulting pictures clearly show that atoms can arrange themselves into patterns having a fivefold or a tenfold symmetry. The findings, reported in the Jan. 8 PHYSICAL REVIEW LETTERS, establish the feasibility of growing near-perfect quasicrystals (SN: 3/11/89, p.149) and demonstrate that simple tiling models can explain the structure of such materials down to the atomic level.

In the theoretical model of a quasicrystal, units consisting of groups of atoms fit together like tiles or blocks to create an orderly, space-filling arrangement. But the fitted units are not equally spaced, or periodic, as in a conventional crystal. Instead, the sequence of spacings follows a more complicated mathematical formula. A Penrose tiling (SN: 7/16/88, p.42), in which two types of diamond-shaped tiles combine to create just such a quasiperiodic pattern, provides one possible mathematical model for a quasicrystalline solid.

The alloy studied by Kortan and his coworkers crystallizes into small, 10-sided columns. Earlier studies had shown that these crystals seem to consist of neatly stacked, two-dimensional quasicrystalline layers. By preparing the crystals carefully, the researchers obtained samples with only a small number of defects, suitable for studying with a scanning tunneling microscope.

The tunneling microscope images of a cut, polished and cleaned surface show a network of points and ring-like structures, which correspond to the positions of atoms. When viewed at an angle, these structures appear to line up in five directions spaced 72° apart, attesting to the material's fivefold symmetry. Moreover, the fact that these lines continue across the steps that mark the edges of different layers in the material indicates that the positions of atoms are strongly correlated from one layer to the next.

The pictures effectively rule out the possibility that this alloy consists of a jumble of tiny, "multi-twinned" conventional crystals. "Since the full decagonal symmetry is realized on scales as small as 60 angstroms, and no periodic structures are seen, we can conclude that multi-twinning does not adequately describe the features in the [microscope] images," the researchers report.

"It's the first time anyone has confirmed at the atomic level the existence of a quasicrystalline material that appears to be perfect," says Paul J. Steinhardt of the University of Pennsylvania in Philadelphia. "The atoms map out a beautiful Penrose tiling."

Kortan and his colleagues propose a tiling model for this alloy in which each layer consists of a framework of pentagonal rings made up largely of aluminum atoms, with either cobalt or copper atoms at the center of each ring. Each successive layer has roughly the same pentagonal pattern but rotated by 36°.

"That's more or less what the data suggest, but it's obviously not our final model," Kortan says. "The basic interatomic distance we measure in this pentagonal network is in good agreement with the aluminum-aluminum distance one would find in similar transition-metal compounds." *— I. Peterson*

Minoan culture survived volcanic eruption

The Minoan civilization of ancient Crete literally rose from the ashes, according to new evidence. Advanced Minoan culture and its grand palaces disappeared around 1450 B.C. — a collapse attributed by many researchers to a devastating volcanic eruption on the nearby island of Thera (now known as Santorini). But recent excavations on Crete indicate the Minoans rebuilt their dwellings on top of large quantities of volcanic ash soon after the Santorini blast.

"We have conclusive evidence for the survival of Minoan civilization after the [Santorini] eruption," says Jeffrey S. Soles of the University of North Carolina at Greensboro, who conducted the excavations with Greek colleagues. He described the findings Dec. 29 at the annual meeting of the Archaeological Institute of America in Boston.

Researchers had already begun to question the argument that the Santorini explosion triggered the Minoan collapse. Other investigators recently reported that seeds in Santorini's volcanic ash date to about 1600 B.C., 150 years prior to previous estimates of the eruption and the decline of the Minoans.

Soles and his colleagues are working at the site of Mochlos on the north coast of Crete, an island near mainland Greece. Their project represents the first systematic excavation at Mochlos since 1908.

Last summer, the researchers took a closer look at a domestic structure largely uncovered in 1908. Numerous examples of Minoan pottery dot the floor of the three-room house. Beneath the floor lies a layer of soft, grainy volcanic ash covering a 23-square-foot area, ranging in thickness from 2 to 8 inches.

"It appears the house was built on top of the ash immediately after the ash fell, thus sealing and preserving [the underlying ash]," Soles maintains.

The 1908 investigators dug around the ash but did not comment on it at the time and probably considered it unimportant, he adds.

The Minoan civilization rose to prominence between about 2000 B.C. and 1450 B.C. It developed a sophisticated economy and traded extensively with nearby peoples. With the elimination of the Santorini eruption as the major culprit in the collapse of the Minoan culture, an alternative theory now gains support: The Minoans may have been conquered by members of the Mycenaean civilization that emerged on mainland Greece around 1600 B.C. *— B. Bower*