However, this problem was thought to have been solved for the first time in 1976, when mathematician Roger Penrose created *aperiodic* quasi-crystalline tilings with five-fold symmetry. Such patterns are aperiodic in that though they possess symmetry they never repeat themselves exactly and therefore are not perfectly crystalline either.

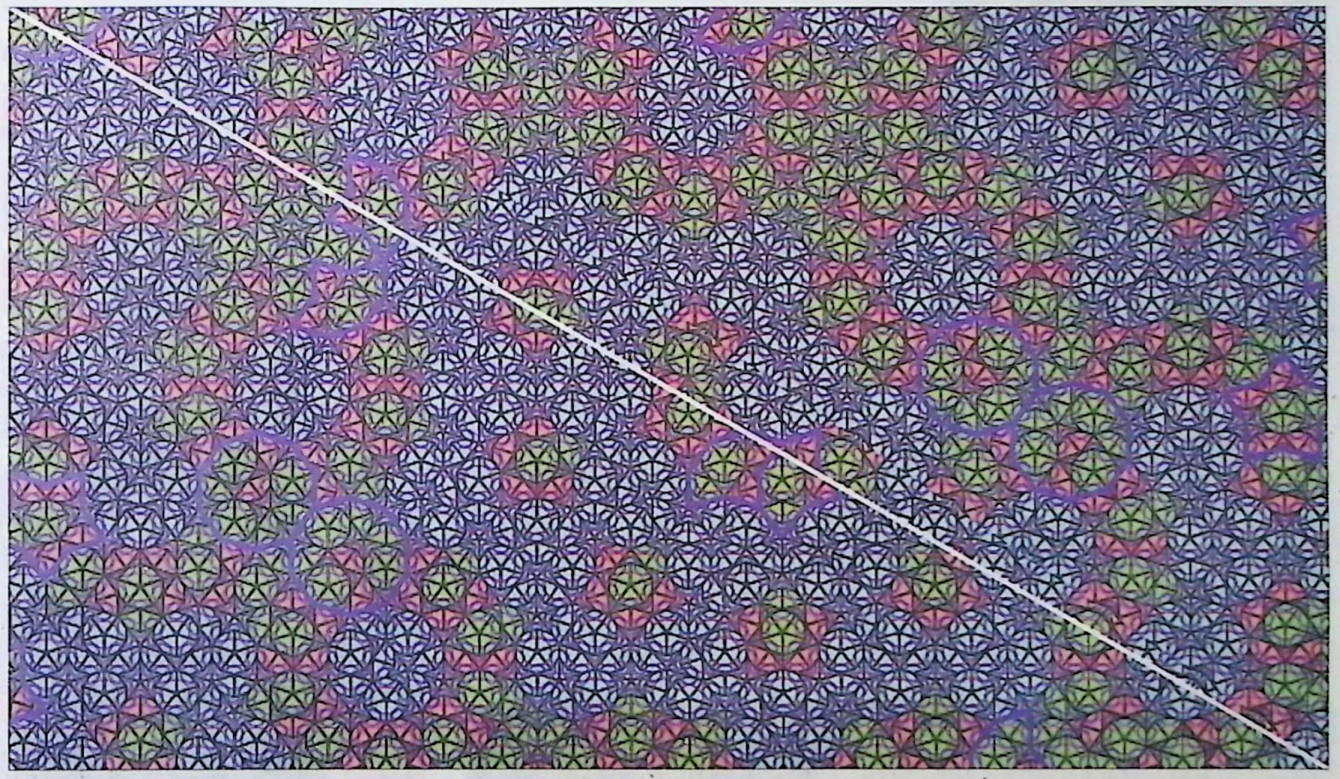
To generate the patterns in question requires complicated mathematical knowledge and the higher mathematics underlying such geometry has only come to be understood in the past thirty years by mathematicians.

Gunbad-i-Kabud (Blue Tomb) at Maragha in western Iran. Other early examples such as the Mama Hatun Mausoleum in Tercan, Turkey (about 1200 C.E.), another Seljuk era building, also appear to show pentagonal geometry.

But, as Lu and Steinhardt note, while a great conceptual breakthrough occurred in the creation of tessellations in 12th century Islam, which included the pentagonal motif, it was not until the 15th century that "the tessellation approach was [used] to construct nearly perfect quasi-crystalline Penrose patterns, five centuries before their discovery in the West." One such example of the latter exists on the Darb-i-Imam shrine (1453 C.E.) in Isfahan, Iran, which the two mathematicians have mapped directly onto Penrose tilings.

standing of these elements."

The question then arises: how did medieval architects generate these patterns? There do exist intriguing documents such as the Topkapi scroll, from 15th century Timurid Turkmenistan, in which ink diagrams drafted by architects, and used by artisans, provide outlines of various pentagonal tile shapes that can be used to create aperiodic five-fold symmetries. It is likely that mathematicians of the Islamic world, who famously gave us the concept of zero in mathematics and invented algebra, advised in the geometry of such designs. But exactly how the complex patterns were first conceptualised and then realised is still unknown.



However, scientists and mathematicians first began to note the likeness of certain Islamic designs to Penrose tilings in the 1990s.

In 1992, Dr. Emil Makovicky, a crystallographer at the Geological Institute of Copenhagen University, reported that "discovery of a 800-year-old tiling from Seljuk Iran represents a matter of considerable interest [due to its similarity to] aperiodic tiling with pentagonal geometry, discovered by Penrose."

The tiling Makovicky was referring to can be found on the 12th century

But how much of the higher maths did the medieval designers understand? "Although the Darb-i-Imam pattern illustrates that Islamic designers had all the elements needed to construct perfect quasi-crystalline patterns," say Lu and Steinhardt, "we nonetheless find indications that the designers had an incomplete under-

Moreover, the identity of the designers -- the medieval mathematicians, architects and artisans who were able to create some of the most complex geometry known to modern man -- remains a mystery. Whoever they were, as Lu and Steinhardt conclude, "[Their] geometrical sophistication led the medieval world."

. **Rashida Ahmad** *is Contributing Editor, Forum.*