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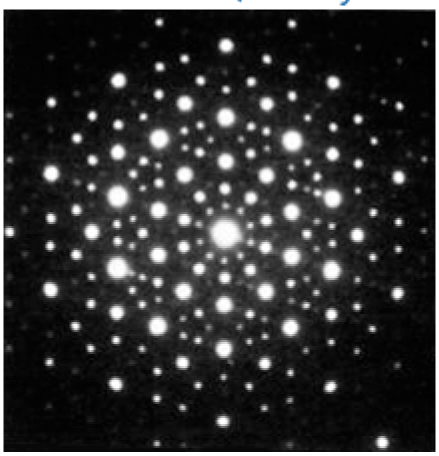
Why the Definition of Crystal Changed

The 2011 Nobel Prize for chemistry celebrated Daniel Shechtman's (Israel Institute of Technology, Haifa) 1982 laboratory discovery of quasicrystals. The non-repeating atomic pattern in fivefold symmetry that he found in his alloy of aluminum and manganese was considered impossible—forbidden by the known laws of crystal symmetry.

Electron Diffraction Pattern from an Icosahedral Quasicrystal



(Shechtman *et al.*, 1984, *Physical Review Letters*, v. 53(20), p. 1951-1954.)

Shechtman and colleagues published their findings in 1984; the symmetry of his sample was not only fivefold in two-dimensions but icosahedral in three-dimensions. [Read the Nobel Prize information about crystal symmetry in "**Crystals of Golden Proportions**".] The research results were not accepted at first and you can read about the years of commotion and criticism that revolved around the scientific battles and ultimate acceptance of quasicrystals in the Nobel Prize announcement, available at **www.nobelprize.org**. The discovery of quasicrystals revolutionized the science of crystal chemistry.

In 1993 the International Union of Crystallography changed the definition of crystal from "a substance in which the constituent atoms, molecules, or ions are packed in a regularly ordered, repeating three-dimensional pattern" to "any solid having an essentially discrete diffraction diagram."

Scientists have produced not only other kinds of quasicrystals in laboratories, but also discovered the first naturally occurring quasicrystal. Identified in 2009 in a rock collected from a stream bank in eastern Russia, this quasicrystal named icosahedrite has the composition $Al_{63}Cu_{24}Fe_{13}$, as reported in the May/June 2011 issue of **American Mineralogist**. An international team of scientists revisited the stream in 2011 to collect more samples and their preliminary conclusions were published in January, 2012. Luca Bindi (Museo di Storia Naturale of the Università degli Studi di Firenze, Italy) and coauthors found the rock has an unusual assmeblage of high- and low-temperature, **lithophile** and **chalcophile** elements, which is a puzzle they are still investigating. Intriguingly, the natural quasicrystal exists inside the mineral stishovite, a polymorph of silicon dioxide (also called shocked quartz) that only forms at high pressures and temperatures (≥10 **GPa** and (≥1,500 **K**). Moreover, oxygen isotopic measurements of the silicates associated with the icosahedrite in the rock match measurements in carbonaceous **chondrite meteorites**. Could this rock be a meteorite and could the icosahedrite have formed extraterrestrially or under the high temperatures and pressures upon impact on Earth? The researchers say their series of investigations suggest the rock is indeed a meteorite, the icosahedrite formed under astrophysical conditions, and quasicrystals can be as stable as crystals.

See:

· Bindi, L., Steinhardt, P. J, Yao, N., and Lu P. J. (2009) Natural Quasicrystals. *Science,* v. 324, p. 1306-1309. [**abstract**]

· Bindi, L., Eiler, J. M., Guan, Y., Hollister, L. S., MacPherson, G. J., Steinhardt, P. J., and Yao, N. (2012) Evidence for the Extraterrestrial Origin of a Natural Quasicrystal. *Proceedings of the National Academy of Sciences,* v. 109, p. 1396-1401. [***abstract***]

· Levine, D. and Steinhardt, P. J. (1984) Quasicrystals: A New Class of Ordered Structures. *Physical Review Letters,* v. 53(26), p. 2477-2480. [***abstract***]

· Shechtman, D., Blech, I., Gratias D., and Cahn, J. W. (1984) Metallic Phase with Long-Range Orientational Order and No Translational Symmetry. *Physical Review Letters,* v. 53(20), p. 1951-1954. [***abstract***]

NEW REFERENCES ADDED:

· MacPherson, G. J., Andronicos, C. L., Bindi, L., Distler, V. V., Eddy, M. P., Eiler, J. M., Guan, Y., Hollister, L. S., Kostin, A., Kryachko, V., Steinhardt, W. M., Yudovskaya, M., and Steinhardt, P. J. (2013) Khatyrka, A New CV3 Find from the Koryak Mountains, Eastern Russia. *Meteoritics & Planetary Science,* v. 48(8), p. 1499-1514. [***abstract***]

· Hollister, L. S., Bindi, L., Yao, N., Poirier, G. R., Andronicos, C. L., MacPherson, G. J., Lin, C., Distler, V. V., Eddy, M. P., Kostin, A., Kryachko, V., Steinhardt, W. M., Yudovskaya, M., Eiler, J. M., Guan, Y., Clarke, J. J., and Steinhardt, P. J. (2014) Impact-induced Shock and the Formation of Natural Quasicrystals in the Early Solar System, *Nature Communications,* v. 5:4040, doi: 10.1038/ncomms5040. [***abstract***]

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