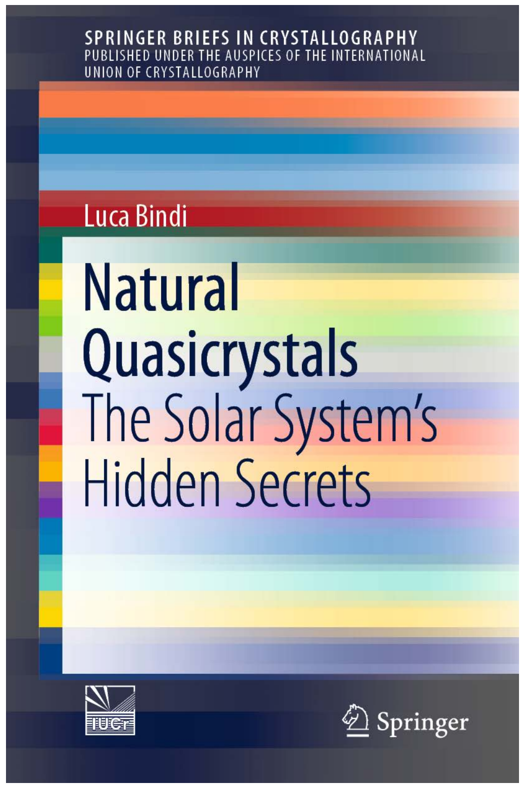
Book Review

Book Review: Natural Quasicrystals: The Solar System's Hidden Secrets. (2020) By Luca Bindi. SpringerBriefs in Crystallography. eBook ISBN 978-3-030-45677-1, $44.99. Softcover ISBN 978-3-030-45676-4, $59.99. 89 p. 61 illus., 21 illus. in color.



Quasicrystals, the third state of solids following crystals and glasses, have a unique crystallographic characteristic; their structures have five-, seven-, eight-, and higher-fold rotational symmetries that are strictly forbidden in crystals. An Al-Mn alloy with a five-fold symmetry axis was first made by Daniel Shechtman and his colleagues in 1984, followed by a theoretical explanation to its structure by Dov Levine and Paul J. Steinhardt in the same year. The discovery opened a new window to solid-state physics and chemistry, and their extensive contributions brought the 2011 Nobel prize in chemistry to Shechtman. On the contrary, natural examples had not been found despite prolonged efforts by mineralogists. A quarter-century after the first quasicrystal synthesis, natural analogues were finally discovered. How are they formed in rocks? What is the importance of natural quasicrystals in the fields of Earth and planetary sciences? Luca Bindi, who first discovered natural quasicrystals, icosahedrite and decagonite, answers these questions in his book: *Natural Quasicrystals*.

This book consists of 9 chapters, each with separate reference lists. Following the general introduction in Chapter 1, Chapter 2 briefly describes the concept of quasicrystals and how the existence of quasicrystals was established after several years of disputes. The journey into the Solar System's hidden secrets started from a peculiar sample labeled as "khatyrkite", few millimeters in size, found in the collections of the Natural History Museum of the University of Florence (Italy). Chapter 3 highlights exciting stories including the discovery of the first natural Al-Cu-Fe quasicrystal icosahedrite by powder XRD, TEM, and EMPA, difficult but enthusiastic hunting for the original rocks in the Russian mountains of the Kamchatka peninsula, and finding the second natural quasicrystal with an Al-Ni-Fe composition, decagonite. Intriguingly, oxygen isotopic analyses found crucial evidence for the extraterrestrial origin of khatyrkite's host rock as a carbonaceous chondrite, and that rock was named as the Khatyrka meteorite. In Chapter 4, the readers can understand what an "approximant to a quasicrystal" is and take a tour of these structures with colored illustrations. The structures seem very complicated, but the beauty of their geometries is purely fascinating.

For the quasicrystal formation, high-pressure and high-temperature conditions are needed as suggested by an icosahedrite inclusion in a stishovite grain in the Khatyrka meteorite. Chapter 5 explains the stability and compressional behavior of icosahedrite using a laser-heated diamond anvil cell; the novel mineral is stable at least up to 50 GPa of pressure and temperatures lower than 1500 K. Another approach to the formation process of the quasicrystals are dynamic high-pressure experiments. Chapter 6 explains that the author and his colleagues have intensively performed shock recovery experiments up to around 20 GPa using target materials consisting of alloys and alloys-silicates composite to mimic the meteorites. Being tiny and of small amounts, icosahedrite and decagonite were successfully synthesized and characterized by microanalysis techniques such as TEM, EMPA, and SEM-EDS-EBSD. Based on the results of high-pressure experiments, the author explains in Chapter 7 a

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possible formation process of natural quasicrystals as a shock-induced melting and (quasi)crystallization mechanism by impact events on the parental asteroids in the Solar System. From the consideration of theoretical physics, Chapter 8 lays down the possible range of chemical compositions that can stabilize quasicrystal structures in the alloy systems based on the cluster-line approach. In the final Chapter 9, the author predicts more quasicrystals will be discovered in extraterrestrial materials deduced from the discovery of Al-bearing alloys in naturally shocked materials, and finally inspires us to do further studies on natural quasicrystals for a better understanding of the Universe.

The book is currently the only available textbook on natural quasicrystals. Overall, it includes both basics and advanced discussions covering descriptive, experimental, and theoretical mineralogy, nevertheless is concise and written in plain sentences. It contains many intriguing photographs of quasicrystals including amazing high-resolution TEM images and electron diffraction patterns (a five-fold symmetric pattern!) that mineralogists had never seen. Therefore, it should be the best guide for mineralogists to the world of quasicrystals, although specific literatures on solid-state physics are needed for deeper understanding. This book is strongly recommended to both experienced mineralogists and petrologists, as well as beginners, and in particular, for the high-pressure mineral physics and meteoritics researchers.

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