Notes of a Protein Crystallographer: Crystallographer's tour of La Alhambra

There was a unique event after the 26th IUCr Congress that made the exhausting meeting days well worthwhile. The Commission of Crystallography, Art and Cultural Heritage (CrysAC) organized a tour of the Palace of the Alhambra in the southern city of Granada. This promised to be no ordinary visit to this shrine of Islamic Art. From the flier for the workshop: *The palace complex of the Alhambra in Granada (Andalusia) is the most comprehensive collection of Hispano-Islamic ornamental art at its peak development and offers examples spanning a wide range from plane groups of symmetry to quasilattices. The 2 1/2-day excursion from Madrid will present and analyze ornamental patterns based on simple plane groups and dichroic plane groups, give an analysis of an Islamic approach to polychromatic patterns, the use of layer groups and 1-D groups, the conscious combinations of different symmetry principles in one pattern and, finally, two-dimensional decagonal and octagonal quasicrystalline patterns. An afternoon session with presentations and discussion will precede the in situ study of the ornaments the following day.*

The organizers and tour guides of this event were two specialists in Hispano-Islamic ornamental art: Purificación Fenoll Hach-Alí (Dept.Mineralogy and Petrology, Universidad de Granada, Inst. Andaluz of Earth Sci.) and Emil Makovicky (Dept. of Mineralogy, Geological Inst., U Copenhagen). Together they have published more than twenty papers on the mathematical analysis of some of the most beautiful and intriguing decorative patterns in the treasure trove of symmetrical patterns at the Alhambra.[1,2] Emil Makovicky has also investigated very extensively the quasiperiodic decagonal[1] and dodecagonal tiling patterns in Islamic architecture.[3] Incidentally, Fenoll Hach-Alí was the person who first introduced me to Bragg's Law in a graduate course in crystallography in Salamanca, Spain. I had not seen him since the early 1970s. My motivation to participate in this excursion was irresistible both personally and professionally.

Emil Makovicky and the 14 participants were transported in a comfortable minibus from Madrid to Granada. During the five hour journey we passed the spectacular quartzite rock formations of the pass of '*Despeñaperros*' which marks the boundary of the southern limit of the castilian plateau and is the gateway to Andalusia. The Sierra Morena mountain range extends for 500 km, and this narrow pass is at the eastern end of the range. This part of Spain has been the theater for many historical battles, among them Navas de Tolosa (1212) against the Arab invaders, and Bailén (1808) against the Napoleonic troops that occupied Spain. When the mountains gave way to the open plateau we saw the extensive and beautiful olive groves so characteristic of the landscape of this part of Spain.

View of the Alhambra from the window of one of the rooms at the Carmen de la Victoria.

Although small, our minibus was too big to crawl along the narrow streets of the historical section of Granada and we had to abandon our bus in the center of town and catch a smaller one in order to get to the Carmen de la Victoria, where we were staying. The 'Carmen' was an amazing place, right across from the palace of the Alhambra in the part of Granada called 'El Albaicín'. The view from the windows was breathtaking. Our secluded and superb accommodations were courtesy of U Granada and Fenoll Hach-Alí.

But we had also come to Granada to work. Emil gave an excellent introduction to plane group symmetry, layer group symmetry, color groups and polychromatic patterns as well as quasiperiodic patterns. All of this was condensed in a concise and beautifully illustrated booklet edited by him, entitled *Crystallographer's Alhambra*, a remarkable and unique compendium of crystallographic and symmetrical patterns in the Alhambra. I will treasure my copy. Dinner at the Carmen was a collegial and friendly event where we had the opportunity to learn more about the interests of the other participants in the tour: there were young artists, established university professors, mineralogists and materials scientists. Several of the participants had used diffraction and spectroscopy to authenticate works of art or archeological artifacts.

The climax of our excursion was the visit to the Alhambra palace with our distinguished experts in the decorative patterns of Islamic Art and other experienced guides. We walked along the different gates, halls, rooms, and courtyards of the palace as Emil and the other guides described the historical aspects of the palace. Hundreds of photographs were taken by workshop participants. I will describe the different parts of the Alhambra and the main architectural and decorative landmarks in an attempt to entice you to visit whenever you have the chance.

The Alhambra or Alcazaba (an Arab word) refers to a set of buildings consisting of an old fortress and the palaces that extend away from it. Several palaces were built in Roman times, but the renaissance style incomplete palace across from the Alcazaba was started ~1562 by Charles V. In 1492 the Alhambra fell to the Spanish Catholic monarchs Isabella of Castile and Ferdinand of Aragon, leaving the recently unified Spanish kingdom in a position to send the Columbus expedition to the West.

We entered through the ~1348 Gate of Justice and continued on into the Court of the Mexuar itself. Around the Court of Myrtles (Patio de los Arrayanes) we visited the Palace of Comares, Sala de la Barca and the Hall of Ambassadors (Salon de Comares). We stopped

often to hear about a special ornamental or decorative element of which the corresponding symmetry was explained in detailed by our guides. The mathematical features described by Emil were augmented by historical anecdotes or insights by the other guides. One of the gems of the Alhambra is the Court of Lions with the Hall of Mocarabes and Hall of the Two Sisters around it. Unfortunately, the beautiful fountain of the lions was under extensive restoration and was not open for visitors, but we did visit some of the surrounding galleries (see below). Along the way we saw the Gardens of Generalife and the Torre of the Infantas (Tower of the Infantas).

One striking example of the magnificent decorative designs that delight the visitor to the Alhambra. This is a unique p3 pattern color-modulated by a four-colored wavelength across the horizontal (light blue-amber-black-green-light blue; first row and rows below). The image corresponds to one of the decorations in the Patio de los Arrayanes (Court of the Myrtles). Photo courtesy of P. Fenoll Hach-Alí.

The group of participants mesmerized by Emil Makovicky's explanation of the symmetrical patterns in one of the galleries around the Courtyard of the Lions. Photo courtesy of P. Fenoll Hach-Alí).

Previous studies of the crystallographic patterns of the Alhambra[1,2] have described how all 17 plane space groups are represented in the decorations of the different palaces, gates or residences of the Alhambra; one of the major achievements of the artisans. However, the workshop at the Carmen de la Victoria and the detailed tour by Emil Makovicky made clear that the complexity of symmetrical patterns goes far beyond that simple observation. A rigorous description of the ornamental patterns in the Alhambra has to include also: i) layer patterns and layer groups of symmetry; ii) dichroic and polychromatic symmetry groups (see above); iii) geometric theory of octagonal and decagonal quasilattices and quasiperiodic patterns; and iv) even twinning patterns. A separate study would be required to describe and annotate properly within the context of crystallographic symmetry the structure of ceilings, domes (for instance in the Salón de Comares) and muqarnas (large stalactite vaults) as well as the plaster/stucco ornaments. The following quote is from Emil Makovicky's booklet, page 49: *Islamic art was created to admire and analyze or, alternatively, to analyze and admire. […]. On the one hand the workshops of the Alhambra and Nasrid Granada created some of the most beautiful examples of mosaic and ornamental art of the World of Islam, constructed in agreement with classical plane, dichroic and layer groups. On the other hand, some of their creations also represent pinnacles of applied geometry, several centuries ahead of the modern geometric and physical concepts of quasiperiodicity as we know them today.*

All in all, the excursion was an unforgettable visit and an exhilarating experience. This note of appreciation is intended to recognize the efforts of the organizers and to offer sincere thanks for their friendliness and camaraderie during the visit. I do hope that this brief note entices other crystallographers to visit the Alhambra in the company of the reading materials prepared by our hosts P. Fenoll Hach-Alí and Emil Makovicky. If possible, try to stay at the Carmen de la Victoria. As it was written on a majolica tile by the famous Spanish writer M. Vazquez Montalbán: *it just seems as if these were created one for the contemplation of the other.*

Cele Abad-Zapetero

1. P. Fenoll Hach-Alí, and A. López Galindo: *Simetría en la Alhambra, Ciencia, Belleza e Intuición, (Symmetry in the Alhambra, Science, Beauty and Intuition),* 2003, Universidad de Granada, Consejo Superior de Investigaciones Científicas.

2. E. Makovicky: *Crystallographer's Alhambra. Beauty of symmetry – symmetry of beauty,* 2011, Special booklet published by University of Copenhagen and University of Granada, Dept of Mineralogy and Petrology for the participants in the visit. ISBN:978-84-931819-8-7.

3. E. Makovicky & N. Makovicky: *The first find of dodecagonal quasiperiodic tiling in historical Islamic architecture*, 2011, *J. Appl. Cryst.* **44**, 569-573.