



# **XXV European Crystallographic Meeting**

## **Satellite Conference**

### **Symmetry and Crystallography in Turkish Art and Culture**

Istanbul, Turkey, 14-16 August 2009

*Organized by*

The IUCr Commission on Mathematical and Theoretical Crystallography (MaThCryst)

The IUCr Commission on Crystallography in Art and Cultural Heritage (CrysAC)

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*Program and Abstracts*

## Program

### 14 August

8:45 Welcome

9:00-10:30 *Emil Makovicky*: Islamic patterns of Seljuk and post-Seljuk era in Iran and Turkey

10:30-11:00 Coffee break

11:00-12:30 *Imameddin Amiraslan*: Micro Art of Crystallizing; Background less Geometric Calligraphy

12:30-14:00 Lunch

14:00-15:30 *Hacali Necefoğlu*: Turkish Crystallographic Patterns: From Ancient To Present

15:30-16:00 Coffee break

16:00-18:00 *Şahika Ünal*: Symbolic Meanings and Characteristics of Anatolian Kilim Motifs

### 15 August

9:00-10:30 *Izumi Nakai*: X-ray diffraction and fluorescence analysis of archaeological anatolian artifacts by portable equipments

10:30-11:00 Coffee break

11:00-12:30 *Manfred Schreiner*: The monetary history of the Ottoman Empire - The silver content of the Akce coins during the reigns of Murad III, Mehmed III, and Ahmed I

12:30-14:00 Lunch

14:00-15:30 *Workshop, part 1*: a. Lets Knot Together! (How to make a Turkish Knot for an Anatolian Carpet); b. Puzzle Out Together! (Jigsaw Puzzle, An Anatolian Kilim).

15:30-16:00 Coffee break

16:00-18:00 *Workshop, part 2*: Kaleidoscope from Crystallographic Patterns

**16 August:** Visit to the The Blue Mosque = Sultanahmet Camii, Turkish & Islamic Arts Museum and The Sokollu Mehmet Pahsa Camii.





## **Invited lectures**

## Islamic patterns of Seljuk and post-Seljuk era in Iran and Turkey

Emil Makovicky, *University of Copenhagen* [Emilm@geo.ku.dk](mailto:Emilm@geo.ku.dk)

The history of Seljuk Islamic art started when, between 1037 and 1055, Turcoman Seljuks conquered Central Asia, Iran and occupied Bagdad. During this conquest, they captured Esfahan and made it their capital in 1051. In 1071 they defeated Byzantines and founded the Sultanate of Rum (centred on Konya, central Turkey). They were defeated by Mongols in 1243 (although already in 1219 in Iran) and Turkish sultans continued to rule under a Mongol protectorate. Still, it was a time of *the artistic apogee* in Turkey (1250-1300). In Iran, *artistic renaissance* starts under Il Khanid rulers of Mongol origin (from 1295).

The first Ottoman sultan in Turkey (Bursa) took power in 1298. The Ottoman conquest of Turkey ends by a capture of Constantinople (Istanbul) in 1453.

Seljuk architecture of Iran, created in the times of a limited development of glazed bricks, excels in ornaments created from unmodified bricks, based on the play of light and shadow under the sharp rays of the southern sun. Two different ornament styles present are (a) patterns obtained by various stackings of bricks, without or with recessed interspaces, and (b) patterns created from brick ribs in various orientations and, in part, from shaped bricks. Rare blue, turquoise and black-glazed bricks can be incorporated in the pattern (pale to strong blue glaze appears since 1058 but more frequently after 1113-1127) but the Seljuk architecture essentially is the art of a pre-glaze age. Objects adorned include mosques, minarets and the typical Seljuk burial towers (gunbad, türbe). Seljuk architecture in Turkey was much more stone-oriented, because of the climatic and geological conditions. As a consequence, many geometric ornaments were carved out of stone.

The first locality we shall study are the Kharraqan burial towers W of Qazvin, N Iran. The two Seljuk tomb towers still standing at this locality were built by the same architect (Muhammad ibn Makki-al-Zanjani) for unnamed Turkoman chieftains in 1067 and 1086, respectively. The eastern tower has 61 2D- and 1D- patterns; the western tower has 36 patterns. These patterns are realized either as large wall panels, or they cover triple niches, coat buttresses and pilasters, occur as top friezes, or adorn tympana. In this connection, selected problems of classification of patterns will be discussed: a use of plane and layer groups of symmetry, occupation of distinct Wyckoff positions, and derivation of various structural series.

A typical adorned minaret of Seljuk era is found at Damghan, N Iran, built about 1058 as a part of Masjed-e-Jameh (Great Mosque) that largely disappeared. Its revetment consists of a brick-work in relief (ribs on recessed background) in the upper portions and a flat brickwork with partly unfilled joints in the lower portions. This also is the appropriate moment to discuss the Seljuk choice of plane groups of symmetry for complex large-scale patterns as opposed to that observed for simple

patterns.

Caravanserai Rubat-i-Sharaf, constructed about 1120 and restored about 1154 is one of the finest caravanserais of the Silk Road. It is situated E of Mashad, in north-eastern Iran (Khurasan), nowadays in a desolate landscape. Splendid relief brickwork, use of flat brickwork and carved stucco distinguished this caravanserai.

Stucco patterns, moulded or carved in fresh plaster, were integral part of Iranian (and Mesopotamian) Islamic art. We shall analyze interesting ornamental patterns from Na'in (about 960), Nishapur (9-10<sup>th</sup> century) and Rey (11-12<sup>th</sup> cent.). Besides interesting local symmetries, most intriguing is a variety of 2D patterns, based on a hexagonal grid, that are inscribed in certain elements of point-group designs.

The top achievement of Seljuk ornamental art is a construction of the first known decagonal quasiperiodic pattern. The Blue Tomb (Gunbad-i-Qabud), with walls covered by this pattern, was built in A.D. 1196-97 in the town of Maragha in western Iran. It is an eight-sided tomb tower built for an unknown Seljuk personality. This ornament, together with the following examples, marks the eastern Islamic tradition of quasiperiodic patterns constructed by *tile composition*. A very similar pattern has been used in the *iwan* of the mosque Darb-i-Imam in Esfahan (A.D.1453). A brief analysis and comparison of these tilings will be given. Tiles used in these patterns were also used in a number of nice periodic patterns up to the Safavid period.

Closest to the Seljuk brick-based style are later, Qajar – Safavid glazed creations which we call a 'bitmap style' in allusion to their similarity to a bitmap of a coloured object, created by a composition of individual pixels.

The 'richly ornamented demise' of old geometric mosaics came with the invention of multicoloured glazes, a style known as *haft rengi* (seven-coloured tiles) with the decoration painted upon a tiled surface. In the majority of cases, tiles used were square *kashi* tiles, cut from larger panels on which the ornament had been painted. The glaze-painted tiles were fired and mounted. This technique was perfected especially under the Safavid dynasty, from which Shah Abbas I (1587-1629) is the most distinguished builder. Large-scale designs with higher symmetries were preferred and symmetry requirements were less stringent. Prominent elements and scrolls characterize these designs. Still, a few excellent examples of geometric mosaics were produced as well.

An inescapable observation: development of technology always comes at the expense of certain skills and even ideas...

## Micro Art of Crystallizing

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In general, when we are talking about crystals, their reflection of light from their surfaces with various shades and their geometrical shapes are emphasized. In addition, their purity and shape perfection are recognized as a criterion of beauty. However, detailing of crystallization process with more attention created such a belief in me that *micro-art* of this process is richer than what we thought; *micro-art* obtained in this way can become a new and perfect style of creative work. Following major reasons underlie this variation and innovation:

- The crystallization process is mostly going on in the solutions. It is well known that both solutions and crystals are usually transparent. That is why crystal photography must be performed by the way of recording the light passing through an object. Photos made by recording of the passing light contain data not only about the surface but also about the volume.

- Since attractive forces between the atoms, ions and molecules during the crystallization process are much stronger than gravitational forces, crystallization is pretty much similar to the process going on in the state of weightlessness. This allows for formation of more free 3D shapes.
- By the way of turning Polarization lens it is possible to obtain unrestricted number of colour tinges.
- Modern digital cameras (higher than 10Mpx) allow making of quality and large boards of detailed and even micro size objects.
- Obtaining of initial photo data in a form of digital files that can be used in computers render high capabilities to optimize them by Photoshop and other appropriate programs.
- 3D view capacity of photo pairs is extremely aesthetic. Feeling such an aesthetic effect from other art styles is not easy.

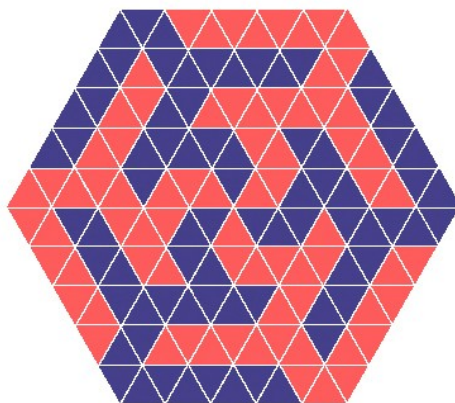
Dozens of artworks created by micro-photography will be presented in this report. In these artworks you can see a variety of forms. For instance, one group of pictures is a world of plants – trees, flowers surrounding us; another group is of landscape type. Some of them can be classified as an abstract colour art, others as a statuary art. One of the most loved art groups is 3D cross-eye view pairs. Practical aspects of crystal growing and taking photo of micro-crystal medium will also be discussed.

**Keywords: micro-photography, 3D view, crystal photography**

## Two Dimensional Repetitive Backgroundless Geometric Calligraphy

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The history of two-dimensional repetitive tightly packed ornamental design is very old and dates back thousands of years. There are many examples in which ancient (BC) and medieval implements and architecture were gilded by ornamental designs. One group of **two-dimensional repeating ornaments** is composed by tightly packed geometrical figures, such as triangles, quadrangles, etc. A second type of them is the famous tessellations of M.C. Escher, which also appears in the works of his pursuer. Unlike the first group ornaments, in these artistic endeavors the geometrical figures are, however, substituted with stylized forms of living objects. Among historical ornaments we can explicitly distinguish another type, for convenience we will call as **maze-like repeating** ornaments. There are dozens of such samples with unknown semantic, dated BC. Most of these ornaments were created in the middle Ages by using Arabic characters (writing). It is well known that the Arabic writing very amenable for creating wonderful calligraphy in free manner as well as for maze-like geometric calligraphy. These kind of maze-like geometric ornaments contain background, which is proportional to the letters. It is often difficult to distinguish the inscription from the background for the people who are not familiar with Arabic writing. Therefore, the aesthetic effects of these ornaments rely on the inscription and background being of equal proportion to each other. However, among such ornaments there are a few examples, where the background is absent completely. All of these ornaments are composed of the Arabic word “Ali”. The reason for this is that the Arabic word “Ali” is very simple and written without dots and **confined** areas, which are characteristic of most of the Arabic letters. Fig.1 shows a **wonderful** example of these kind ornaments taken from the palace of the “Şirvanşahlar Sarayı” (Baku, Azerbaijan, XIV – XV century), in which a regular hexagon is filled up with six inscriptions of “Ali” (three light and three dark).



It should be noted that these ornaments, which are composed by Arabic inscriptions, are presented in the literature as samples of “Islamic Art”. However, our investigation has shown [1, 2] that the history of this style of ornaments is older than Islam and originates from territories of Altay, Siberia, Central Asia and the Caucasus many thousands years ago. This art-style is not grounded on

Islam but has rather been appropriated from older cultural sources by finding convenient and majestic expression through Arabic holy words.

In this presentation the historical, evolutionary and aesthetical aspects of these ornaments will be discussed. The new geometric calligraphic ornaments composed by author will be shown as well [3].

[1] Kh. S. Mamedov. *Crystallographic Patterns*, Comp. & Maths. with Appls. Vol 12B, Nos. 3/4, pp. 511-529, 1986

[2] Kh. S. Mamedov, I.R.Amiraslanov, H.N.Najafov, A.A.Mursaliyev. *Nakhishlarin Yaddashi* (Memory of ornaments, in Turkish ), 1996, Istanbul, Turkey

[3] Imameddin Amiraslan. *Azerbaijani tessellations*, 2007, Ankara, Turkey.

**Keywords: Crystallography, Escher-like ornaments, tessellations**

## Turkish Crystallographic Patterns: From Ancient To Present

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As far as I know, the term, Crystallographic Patterns (CPs), was first introduced by my PhD supervisor, the famous Azerbaijan Crystallographer Prof. Khudu Mamedov (1928-1988) [1,2] (Fig. 1). He has named these patterns as CPs due to their resemblance to the structure of crystals [3].

Among the first CPs that drew Kh. S. Mamedov's attention was the motive on the Barda Tomb (Fig. 2). This Tomb was build by Ahmed Ayyupoglu in 1322 AD. The words Allah were tiled on the cylindrical Tomb with colourful bricks. Professor of Crystallography Kh.S. Mamedov not only paid attention to the arrangement of those words on the surface of cylinder as in the arrangement of organic molecules in crystal, but also saw that there was much resemblance without exception.

The other pattern, drawing my supervisor's attention, was also another pattern on the Barda Tomb. This pattern was similar to structure  $\text{SiO}_2$ , at the same time, and  $\text{AX}_2$ , in general, are the structure diagram of many crystals. Since the Middle Ages, this pattern has been often encountered in Anatolia. For example, the Green Tomb is one of them (Fig. 3).

Prof. Mamedov who met such similarities in various old monuments called such motives as backgroundless patterns in the book [4] he published with his assistants, but afterwards he called them as Crystallographic Patterns [3]. In the book he tried to answer the question: "What is the reason for the similarity between crystal structures and crystallographic patterns?" Of course, pattern creators could not have knowledge about matter formation at the time of pattern composition. According to Prof. Mamedov the reason may be the similar formation styles. And also he supposes that creation of crystallographic patterns depends on geographical surroundings as well as nomadic life [3].



**Figure 1.** Prof. Khudu Mamedov (1927-1988)



**Figure 2.** Barda Tomb, Azerbaijan



**Figure 3.** Green Tomb, Bursa, Turkey

In this lecture, crystallographic aspects of ancient, medieval and modern Turkish ornaments are dealt with. Crystallographic patterns (CPs) are considerably different from other patterns. The following are characteristic of CPs: the edge of ornament elements draws the edge of the figure; maximal compactness of the ornament elements; the lack of background or transformation of background to ornament elements; minimization of the variety of ornament elements; symmetry is not used for form creation. In the process of the construction of CPs, symmetry appears as a result of combination, not as a means of its formation that is characteristic of other ornaments. Their symmetries are analogous to symmetries of natural objects. The atoms and molecules dispose themselves in crystals just as elements arrange themselves in CPs. CPs are constructed according to the same principles of crystal formation, i.e. the principle of tight packing. In other words, CPs are formed according to complementary principles. The figures used as ornament elements are placed on the plane such that there exists no space among them or the spaces are equidistant from each other. In other words, pattern elements should be placed at a maximum compactness as molecules dispose themselves inside crystals. As is seen the way crystals are formed is the same with those of CPs. Such is the case that if there is a resemblance between pattern elements and molecules or atom groups the illustration of the formation of a pattern and a crystal will be the same. Of course, it is not possible to form CPs from every kind of shape. It is necessary for the selected shape or shapes of a pattern to be complementary to one another, as stated previously [5].

The similarity (isomorphism) of crystals and ornaments enables us to describe the ornaments with structural analysis terms, and the similarity between ornaments and crystal structures can be also used in chemistry education. This will bring an aesthetical aspect to education. An invisible part of nature can be studied as ornament creation. Each newly created CP is the structural scheme of a number of possible compounds. The familiarity with such ornaments and the ability to create them are important for solving compound structures. Similarity of patterns with some crystal structures enables us to reach the following conclusions: mankind may make use of the principles from which nature was created, and he may achieve a resemblance to the creation of nature in ideal; mankind may create nothing whose prototype does not exist in nature.

- [1] Hargittai I (2007) *Structural Chemistry* **18**: 535-536
- [2] Mackay AL (1991) "Form and Pattern in Azerbaijani civilisation" In *East-West: A Dialogue of Cultures in a Changing World*, Baku, 5-11 October 1991
- [3] Mamedov KhS (1986) *Comp. & Maths. with Appl.* **12B**:511-529
- [4] Mamedov KhS, Amiraslanov IR, Nadzhafov GN, Mursaliev AA (1981) *Nakhyshlaryn Yaddashy (Memory of Ornaments)*. Azernashr: Baku, in Azerbaijani.
- [5] Amiraslan I (2006) *Azerbaijani Tessellations*. Ankara: Publisher Hacali Necefoglu, p.10.

## **Symbolic meanings and characteristics of Anatolian kilim motifs**

Şahika Ünal, *Ankara, Turkey*

Kilim is the best-known type of flat weave, and an indispensable component of social life in Turkey. In recent years, being eloquent and stimulating works of art, Anatolian kilims are highly esteemed by the world public opinion and have assumed the place they deserve. Compared to the kilims of other countries where similar weavings are produced, Anatolian kilims display some differences in terms of general characteristics and are preferred by art enthusiasts all around the world.

The colours, motifs and compositions introduced by various cultures flowing from different directions to Anatolia which already had produced outstanding examples in the art of weaving lead to an incredible increase in the variety of these kilims. The Turkish tribes moving into Anatolia have introduced new dimensions to the art of kilim weaving. Research indicates that Turks had an established weaving tradition before they came to Anatolia, pile-knotted carpets, kilims and other types of weaves being an important part of their life. Though produced for daily use, they are loaded with profound aesthetic values. Researchers believe that the colours and motifs used on kilims display a type of symbolism which serves to differentiate various social groups from others.

Some experts suggest that these motifs were transported to Anatolia, through the migration process of Turcoman groups, mixing as they do with the cultures in the regions they passed through, and intermingled with the already existing rich varieties of textiles in Anatolia to produce new variations. Migrations, marriages, friendship and kinship relations in different regions have led to flow of motifs from one region to another, causing an interaction, and the different colours, patterns and compositions brought in by these waves have occasionally increased diversity, while the motifs specific to a tribe or group were faithfully preserved.

Kilims, which are generally woven by rural women in Anatolia, were produced in royal workshops during the Seljuk and Ottoman periods. Various sources state that, although there were specimens influenced by tribal kilims. The designs of these kilims were drawn by court designers to suit the various tastes of the period in terms of motifs and compositions and the weavers used these models in weaving. Such drawings are not used in the production of tribal kilims. Even today, Anatolian women weave kilims from memory/ by heart without using any kind of drawing. It is known that the motifs are transferred from one generation to the other in a process where weavers learn from their mothers or grandmothers.

Although the kilims which the Anatolian rural population, procuring the necessary material with their own means, produced for their own use are functional, they have an extraordinary decorative characteristic. The decorative characteristic is derived by the colour of natural dyes extracted from local plants, as well as the motifs and compositions which lead the viewers into a mysterious search for meaning every time they look at it. The fact that the variety of colour and richness of design displayed in Anatolian kilims are observed in none of the kilim weaving

countries is accepted by numerous foreign scholars. The abundance and diversity of the cultural accumulation in Anatolia have created a very rich common language of motifs. The extraordinary artistic and technical level achieved by the women who probably have never left their villages or regions is met with worldwide excitement and appreciation.

There is a widespread view that motifs used on kilims have certain meanings and contain symbolic expressions. This quality assigned to kilim motifs suggests that numerous values which has an importance for the people living in Anatolian rural settlements are reflected on kilims through motifs symbolizing concepts pertaining to life such as birth, marriage, and death, as well as the desires to defend and protect themselves against malice, and secure fertility.

Some researchers trace the origins of motifs and their meaning back to the pre-historic period and ancient civilizations, while some hold the view that they are transferred to Anatolia via the migration of the Turkic groups. In spite of the fact that the debate on the origins of motifs and compositions are not yet concluded, the researchers do not object the view that kilim motifs have names or meanings. Some scientific circles accept the view that kilim motifs are symbolic expressions reflecting universal concepts like birth, life and death which have been used since the oldest times in Anatolia.

It is also observed that some motifs are assigned religious meanings. According to some researchers Anatolian women display a unique power of observation and a great skill in creating symbols. Due to traditions, they usually prefer to express their expectations and also themselves through symbols.

*Elibelinde* motif symbolizing women, fertility and abundance, is still used in all regions of Anatolia under different names yet similar meanings. Elibelinde is a stylized female figure. It has been given various names, some of which are elibelinde (hands on hips), eliböğünde (hands on flank), eli göğsünde (hands on breasts), gelin kız (bride), çocuklu kız (girl with child), aman kız (the mercy girl), seleser, kaküllü kız (girl with fringes). No other motif is known to be so widespread yet to carry a single meaning. Some scholars believe that elibelinde motif is the equivalent of the mother goddess and maintain that it is being used since the ancient cultures where woman was dominant and important to symbolize motherhood and fertility.

Koçboynuzu, though not as frequent as elibelinde, is another motif which frequently appear on kilims. It is said to be a symbol of heroism, fertility, power and masculinity. It is also called by various names; koçboynuzu (ram's horn), koç (ram), boynuzlu yanış (horn motif), koçlu yanış (ram motif), gözlü koç başı (ram's head with eyes) etc.

According to some scholars, the wide use of protective motifs on kilims results from the fact that the house, grain, animals and family are the most valuable assets of rural people. Protective motifs have a special place in Anatolian kilims. Special motifs are used on the kilims to protect marriages, spouses, family members, children, houses and grain, and animals against the evil eye and malice in the environment; such motifs include amulets, charms, scorpions, hands, fingers, eyes, crosses, hooks, burdocks, dragons and snakes.

There are also views which suggest claim that fertility is one of the prominent themes used on

Anatolian kilims. Sometimes with the aid of the male and female symbols, they express reproduction in marriage and family, other times they symbolize fertility of the grain and an increase in family income.

*The tree of life*, which appears in many cultures, is a motif frequently used on Anatolian kilims. Some experts believe that it symbolizes the uniqueness of the god, paradise and immortality. It is generally depicted with birds on it. According to the belief the birds will fly off the tree at the time of death.

It is suggested that the bird motifs carry various meanings. Good wishes, bad chance, death, soul, power, strength, happiness and many other concepts are symbolized with the several bird motifs on kilims.

Currently, Anatolian women are interested in the names identifying the motifs rather than the meanings of motifs decorating their kilims. However, with an instinct to protect the tradition they claim the rights of the designs attributed to their region and their culture and avoid reflecting the changes which inevitably take place in time, on the basic design.

Contemporary weavers have almost forgotten the ancient, and once widespread, belief that “kilims bring good luck”. When the weaving women are asked about the meanings of the motifs, they tend to say, “this is our tradition, custom, that’s how we’ve seen from our elders, that’s what we’ve learned” and state that they name the motifs after the objects they see around them. Names such as frog, cat, lamp, apple etc. is a terminology they use among themselves to indicate which motif should be used where and these terms usually tend to change from one region to another.

## **X-ray diffraction and fluorescence analysis of archaeological Anatolian artifacts by portable equipments**

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X-ray fluorescence (XRF) analysis and X-ray powder diffraction (XRD) analysis are nondestructive and are therefore suitable for characterization of archaeological materials. Chemical composition of the artifacts can be analyzed by XRF, while crystal structural information of the artifacts can be revealed by the XRD. The obtained information is useful for identification, provenance analysis, and understanding the production technology of the artifacts as well as the understanding of their cultural background. Especially, recent advances of portable instruments greatly expand the possibility of the techniques: on site analysis at an excavation field or a museum is easily carried out. The targets of the analyses are wide including stone, metal, glass, pottery, paintings, fabrics, building materials, etc. Therefore, these techniques are extremely useful for archaeologists and conservators. In my lecture, principles of the X-ray analytical techniques are explained and their recent advances will be reviewed. As a case study, on site analysis of archaeological materials excavated from Kaman-Kalehöyük, Turkey is introduced. As an example of analysis at museum, study of the iron dagger with golden haft excavated from Alacahöyük carried out at the Ankara Museum of Anatolian Civilizations will be introduced.

We have been developing a portable powder diffractometer and XRF spectrometer since 2001 suitable for on site analyses with enough sensitivity, accuracy, and durability. The latest version of our diffractometer (weight 15kg) adopted Si-PIN as a detector, which enable us to obtain EDX spectrum of the sample as well as a good powder diffraction pattern with low background. The XRF spectrometer (15kg) is equipped with SDD detector and monochromatic/white X-ray sources.

Application example includes quantitative analysis of a series of archaeological glass artifacts excavated from Kaman-Kalehöyük site, which locates in central Anatolia, approximately 100 km southeast to Ankara. The excavation has been conducted by Dr. S. Omura, the Middle East Culture Center in Japan since 1986. The instruments were brought to the site. A total of 188 glass beads unearthed were analyzed. A flat surface without or less corrosion by effect of weathering has been chosen for analysis. The entire glass sample proved to be plant ash soda-lime silicate glass with MgO and K<sub>2</sub>O content ranges between 2-4 wt%. A comparison of ribbed rectangular glass beads excavated from the site with those of the collections of MIHO MUSEUM and Okayama Oriented Museum in Japan show that the excavated glass objects are possible to be made in Mesopotamia region. This is the first scientific evidence that show the possibility of cultural exchange between Kaman-Kalehöyük and Mesopotamia during Middle-Late Bronze Age.

# **The Monetary History of the Ottoman Empire**

## **The Silver Content of the Akce Coins During the Reigns of Murad III, Mehmed III and Ahmed I**

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**Keywords:** Ottoman silver coins, monetary history, x-ray analysis, x-ray and neutron diffraction

In summer 2000 a great number of coins (approx. 60.000) could be found during excavations carried out by a team of archaeologists from Izmir University in Turkey, headed by Prof. Rahmi Ünal, at the medieval site of Becin Kalesi (close to the ancient city of Efes/Selcuk). It is the most important findings of coins and the most important Ottoman treasure ever discovered, as most of the coins stem from the Ottoman Empire and were produced during the 16<sup>th</sup> and 17<sup>th</sup> centuries under the Sultans Murad III, Mehmed III and Ahmed I in 18 different workshops.

In a co-operation between the Turkish and the Austrian Academies of Sciences a project was initiated in order to catalogue all the coins. Additionally, chemical analysis of the material used for the production of the silver coins was performed in order to confirm the geographic assignment suggested by the numismatists. It was agreed to take small samples of approx. 450 objects (mainly Akce coins), embed the specimen in epoxy resin for cross-sectioning and polishing in order to achieve flat surfaces. Investigations were carried out by means of micro-x-ray fluorescence analysis (XRF), energy dispersive analysis in a scanning electron microscope (SEM/EDX), particle induced X-ray emission spectroscopy (PIXE) as well as micro-XRF with synchrotron radiation (Sy-XRF). Additionally, X-ray and neutron diffraction analysis (XRD, NDA) could be carried out on specific samples.

An overview of these techniques used in art and archaeology, especially in cooperation between scientists and numismatists is presented and the applicability of the methods as a tool for non-destructive investigations is discussed. Air path systems and instruments with the micro-beam of x-ray and even synchrotron radiation must be applied in order to fulfill the requirements for the analysis of such findings.

XRF can give us an overview of the chemical composition, whereas PIXE as well as Sy-XRF are mainly applied for non-invasive determination of the minor and trace elements. The coins analyzed were found to have a very high fineness (about 92 %Ag) and the varying content of the minor and trace elements Au, Pb, Bi, Fe, Ni, Zn, As, Hg, Sn and Sb a local assignment to the various mints could be explored [1].

In contrast to these methods, XRD and especially Neutron diffraction can be utilized to determine the orientation distribution of crystallites in a polycrystalline material and therefore

conclusions about the manufacturing process (cast or mint coins) can be drawn [2].

A polycrystal with a preferred orientation of crystallites is said to have a texture. If the grains in an object are oriented at random and if all grain orientations are equally realized then the material is said to be free of texture. Texture is an important material characteristic of metals, alloys and ceramics. It is the result of the solidification and manufacturing process and thus texture contains detailed information about the production history of a work piece. Well defined textures are produced by specific conditions during primary crystallization from a melt, and by thermal and mechanical treatments of the cast such as annealing, drawing, rolling and hammering. Neutron diffraction can therefore provide information on the creation and deformation history of an object, be it a modern engineering component, a mechanically deformed work of archaeological interest or a geological sample deformed by tectonic processes.

Neutron texture analysis is an elegant method to determine the orientations of grains in an object. The presence of texture manifests itself as intensity variation of each Bragg peak as a function of the detector angle. This orientation dependence of intensities originates from two experimental conditions:

- crystallites have to be oriented according to Bragg's equation in order for a particular  $hkl$  peak to be recorded in the detector
- the measured Bragg intensity depends on the number of grains that meet Bragg's law.

For a texture-free material the detector position does not matter because the number of contributing grains is always the same in contrast to a material with texture. The grain orientation distribution can be measured by recording diffraction patterns from many different angles either by rotating the sample or by moving or building a detector around the sample. The first option is the classical texture set-up where a sample is mounted on a goniometer in order to realize a multitude of orientations. Owing to the high penetration power of neutrons and to the large beam sizes in neutron diffraction, textures with high grain statistics and grain sizes up to millimeters can be achieved, even for coarse-grained materials.

The texture information is displayed in so-called pole figures. The pole figures are the maps of the grain distribution and, as such, are fingerprints of the historic making techniques. In case the methods of production are known, the pole figures can be used as signatures to distinguish genuine from fake objects.

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## **Guide to the excursion**

OTTOMAN TILES AND THE MOSQUES *SOKOLLU MEHMET PAŞA CAMII*, *SULTAN AHMET CAMII* AND *RÜSTEM PAŞA CAMII* – Short notes for the excursion

Compiled by Emil Makovicky, Copenhagen

*Orthography versus phonetics*

In *Turkish*, Ş is read as **sh**; Ç is read as **dj** (you need to write Ç if you want to express **ch/cz**); Ğ is almost unpronounced.

*On tiles*

The early Islamic tiles were fired from clay. In 12<sup>th</sup> century, however, as an imitation of Chinese porcelain of the Song dynasty, a *stonepaste* was developed. According to the recipes in the old records, it consisted of ten parts of ground quartz, one part of glaze frit (a mixture of pounded quartz and soda plant ashes heated until clear glass was produced), and one part of fine white clay (Porter 1999). When the pottery body was fired in a kiln, the glass (frit) and clay fused together producing a glassy network between the grains of ground quartz (Henderson 2000). Based on microprobe data, Henderson suggests that all Iznik samples examined contained also lead in the frit.

The stone-paste is more difficult to throw but it is stronger, more malleable and accepts a stable alkaline-based glaze well. This glaze is fluxed with soda or with potash. Underglaze paints do not run on firing using this glaze; they did under the traditional lead-based glaze. However, Henderson suggests that all samples of Iznik pottery had a lead oxide – soda – silica glaze whereas pigments were perfected enough not to run any more. The lead content in Turkish glazes was sporadic or absent before. According to Henderson, it should help to adjust thermal expansion coefficients of the body and glazes and prevent cracking of the latter on cooling. The perfected glaze and body are the principles behind the fabulous *IZNIK CERAMICS*.

In 14<sup>th</sup> century, a technique of separating glaze fields of different colour by unglazed line boundaries was developed in Central Asia, known today under the Spanish name '*cuerva seca*': fields to be painted by different coloured pigments were separated by lines traced out using an oily mixture of Mn oxides. This mixture does not get wetted by, and separates, the adjacent fields of molten glaze on firing. This technique was introduced, and later reintroduced, by masters of Tabriz, after the Ottoman conquest of that region. This technique was abandoned only in the mid sixteenth century.

*Iznik*

After the defeat of Seljuqs (1307), the art of their tilework ceased. The next prominent period of tile working and application starts about 1420, in connection with not-so-peaceful relations of the Ottoman empire with Persia and beyond, as the first influx of Timurid style, by masters schooled in Samarkand and Tabriz. This influence upon Ottoman tile style lasted until about 1470's. Another influx of Iranian influence, by masters of Tabriz, took place in 1520-1550's; they all used the

*cuerva seca* technique.

Although Iznik (Nicaea) had been a production centre for earthenware long before its times of glory, only about 1470's the Iznik potters began making high-quality vessels from a pure white stone paste. They practised underglaze painting, producing thus the finest Islamic pottery ever made (Porter 1999).

Fine pottery was the principal Iznik production; the first tiles from (presumably) Iznik are known from about 1507-1513, reaching perfection at ~1520-1540, with the famous gamut of flower compositions and ornaments (Yerasimos 2000). The traditional cobalt blue-and-white combination was enriched by turquoise after about 1530, and by olive green after 1540, as well as by mauve after 1550 (all these colours were used in combination). The Chinese motifs disappeared in favour of naturalistic motifs – nature-true flowers, pomegranates, artichokes, and leaves in the serrate *Saz* style.

The green and mauve were scarcely used in tiling. Here, the introduction of 'Armenian bole' (βολος = lump of earth), iron-rich clay that fires into intense 'coral red' or, more prosaically, 'tomato red', was the true revolution that happened in the second half of 16<sup>th</sup> century (e.g. Rüstem Paşa Camii, completed in 1561). Around 1560 the court architect Sinan took over the administration of Iznik works and they were converted more and more to a production of tiles for wall revetment.

Popularity of the bright red colour lasted only for ~25 years. After 1580 it was replaced by orange or dark brown (some put blame on a decline in firing techniques) and by ~1600 it disappeared completely. Since 1577, Turkey was at war with the Persian Safavids and in 1603 it lost Yerevan, Kars and Tabriz – I cannot escape a conclusion that *this* meant the end of supplies of the 'Armenian bole'. Moreover - do these statements (Porter 1999) agree with the Blue Mosque (1609-1617)? Let us investigate on the spot.... This is the time when a decline of Iznik works started; the last great achievement were the wall revetments of the Blue Mosque in Istanbul; the 'late blue and white' style should be typical for this period (Henderson 2000). In 17<sup>th</sup> century the workshops of Iznik were replaced completely by those at Kütahya which, however, never reached the same glory (Yerasimos 2000).

### *Style and chemistry*

There are two types of ornamental elements discerned by specialists in Ottoman art: *rumi* – arabesque decoration, including leaves and palmettes, referring to the art of the Seljuqs of Rum, and *hatai* (originally Khata'i – 'Chinese-like') – floral motifs of the Far Eastern origin (Chinese-style blossoms and their garlands).

As a rule, individual tiles are painted by a complex design of swirls, tendrils and flowers. The relationship between tile repetition and periodicity of the painted pattern is complex – from a simple one-tile repetition through two-tile repeats to more complex fits.

Prepare yourself for wonderful examples of plane groups  $p2$ ,  $cm$ ,  $pm$ ,  $pmm$ ,  $cmm$ ,  $p4$ ,  $p4mm$ ,  $p4gm$ , etc., as well as wonderful one-dimensional  $pg$  scrolls. A sensitive use of (nearly) identical motifs in different Wyckoff positions, and cases of hypersymmetry give additional subtlety to these patterns. Intriguing cases of occupational disorder will keep you busy for quite a while as well. All this is found especially in the Rüstem Paşa Camii....

The widely used cobalt blue is aluminate of cobalt, ideally  $CoAl_2O_4$  (a cobalt-aluminium spinel). Preparation temperatures in the present-day dye industry are 1000-1300°C (Hansen & Jensen 1991). In its pure form, before firing, the starting material is pale-pink to violet. Turquoise is produced by a combination of alkaline glaze, tin and copper (Porter 1999). In the mosaics of Rüstem Paşa Mosque, the branches are manganese-based purple. This was a rather short-lasting vogue. Green (combination of iron and copper) is absent from this mosque, always replaced by turquoise. The coral red of Iznik wares of second half of 16<sup>th</sup> century is the firing product of the above mentioned Armenian bole (*kil-i ermeni*), a clay rich in iron oxide, rather thickly applied as a slip (Cimok 1998, Porter 1999).

A traditional opacifying agent of Islamic tiles, applied to achieve white glaze is tin oxide. Low-fired alkaline glaze could be opaque white without additives, due to incomplete dissolution of particles of primary white components on firing (Porter 1999). The Iznik glaze is transparent, however, although it nearly always contains a bit of Sn, and the white background is that of the stonepaste body itself (Henderson 2000). In order to achieve this, the principal body was first covered by a slip, representing a finer edition of the material used for the ceramic body itself.

#### *The Sokollu Mehmet Paşa Camii*

This impressive mosque was built by the Turkish top architect, Sinan, in years 1570-1572, on the orders of the Grand Vizier Sokollu Mehmet Paşa under the rule of Selim II. Its central dome is built on a hexagonal principle, with four semidomes distributed at 120 degrees against one another. Prayer hall is modest in size (14 by 18 meters) but there is 25 m to the keystone. The *quibla* (wall in the direction of Mecca) is adorned by a monumental presentation of Iznik tiles in its central portion, above and around a sober mihrab. 'Vines' and tendrils predominate; Armenian bole rules the colour spectrum used. The stone *minbar* (raised pulpit) and the squinches supporting the dome are covered by polychrome Iznik tiles as well. The domes have painted ornamental decoration. The unified hexagonal space possesses unusual lightness and balance of form (Stierlin 1998). One enters the complex through a tunnel opening into a courtyard of a medresa that offers a spectacular view of the mosque.

#### *The Blue Mosque*

The Blue Mosque (*Sultan Ahmet I Camii*) was built on the orders of the young sultan Ahmet I (1603-1617) after unsuccessful wars with Austria and the Persian Empire. It was built in 1609-1617 under the chief architect Sedefkar Mehmet Ağa. The mosque is crowned by a dome, measuring 23.5 m in radius and 43 m in key-stone height. The prayer room is a square with sides 49 m long. The

central dome is buttressed by four semidomes and there are small domes at the corners.

Although impressive by its setting and by six minarets, architecturally this mosque follows the kanons established by the ingenious architect of the Turkish classical age, Sinan. The light character and luminous beauty of the mosque come from the – in Ottoman art unusual – profusion of colourful tiles (>20 000) that cover walls, drums of the domes, semidomes, and arches of the mosque. They are *raison d'être* of our visit to the Blue Mosque. Its name, however, comes more from the blue painted decoration rather than from the tile revetment.

### *Rüstem Paşa Camii*

The Rüstem Paşa Mosque (completed in 1562) was built by Sinan, the most ingenious architect of the Ottoman Empire, as one of the six mosques in Istanbul that he created in the time span between his two masterpieces, Süleymaniya in Istanbul (1557) and Selimiya in Edirne (1575). Vizier Rüstem Paşa has not lived long enough to see his mosque completed.

The mosque is built using a limited space available for the architect. In order to maximize the space, he placed the dome (diameter of 15.2 m) on an octagonal support. The entire space is covered by a revetment of tiles up to the level of white-and-red arches; tiles are also placed in the triangular fields between the arches whereas the painted ornaments are situated above them.

The perfection of Iznik tiles used in the mosque heralds a beginning of the classical Ottoman style. No other Ottoman mosque, however, can rival this richness of tiles. Perhaps, it was meant to compensate for the rather modest size of the mosque or was it a result of the enchantment with the recent perfecting of the tile art? The single-dome structure is situated in a busy market street and it is accessed by a narrow stairway leading to an arcade portico inset with blue-and-white faience. Lamentably, this mosque is not a part of the excursion route.

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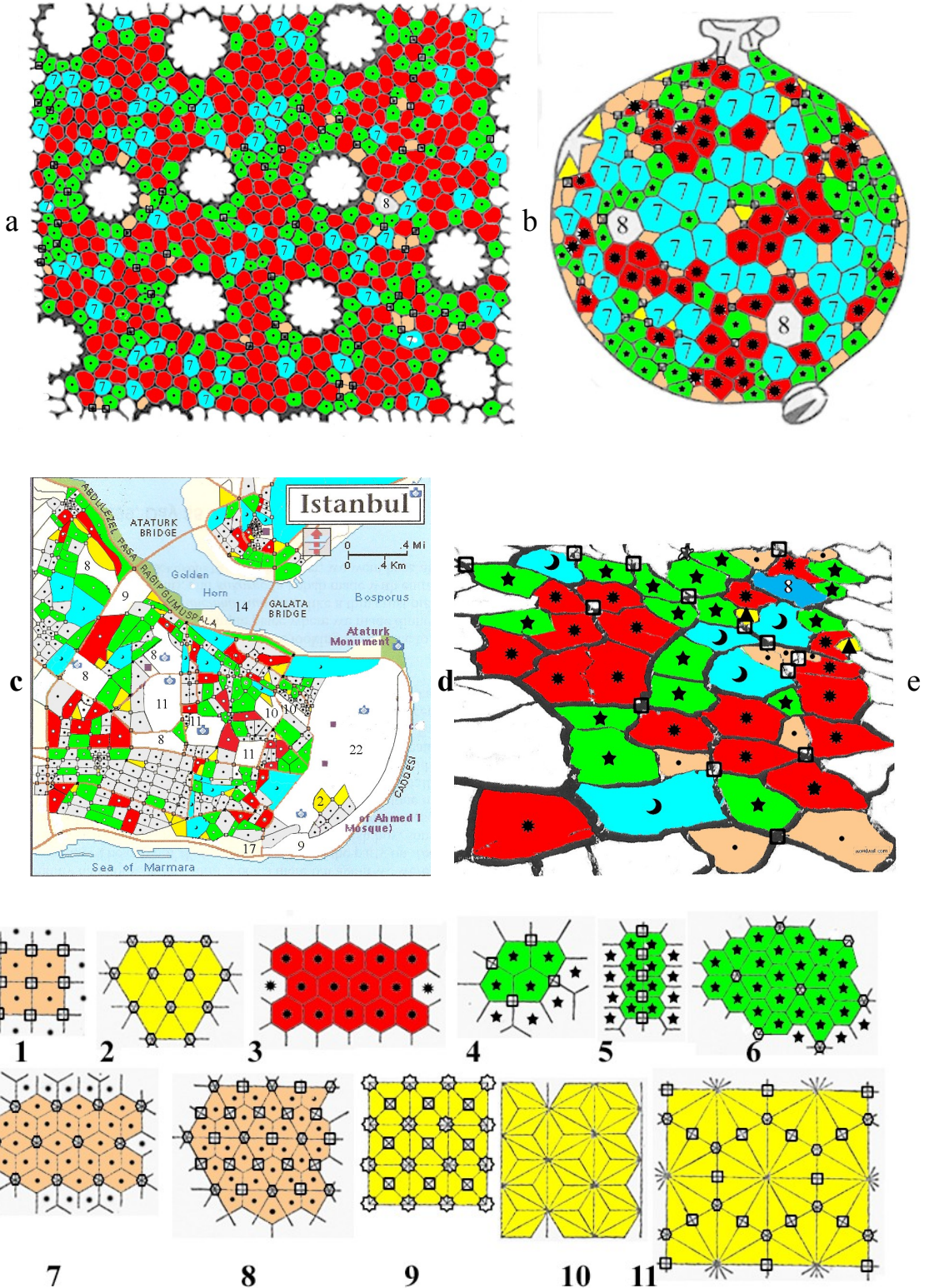


## Poster presentations

## Ordered and disordered multiscale ornaments of nature

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All of these polygonal nets and all other ones obey the same universal law of small integers.  
 1-4/ Local vertex,  $n$ -gon coordination sphere formulas consist of 1-6 different letters [1].



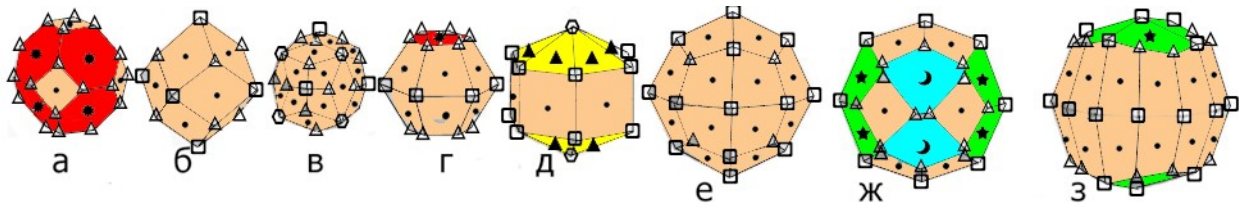


Fig. a, b – organism, c – Istanbul, d – takyr, e – Laves nets, f – Brillouin zones.

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## Symmetry of the Nabeshima dishes.

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The symmetrical aspect of the Nabeshima ware has been represented at ES session, IUCr 2008 Osaka. Later several peoples asked to see and appreciate the patterns and designs of the Nabeshima ware with calm mind. So even though I understand this meeting is the Turkish art and culture, I would like to show photographs of Nabeshima dishes (unfortunately not real dishes) again in this opportunity.

The Nabeshima ware was Japanese porcelain produced in Arita, Saga Prefecture, under the feudal load of Nabeshima, in Edo period for some 200 years until 1871. The original form of it is Imari ware, which were produced in Arita region, and exported to Europe. Since the Nabeshima ware was produced by a clan klin, it was not sold on the open market and used mainly as gift among shougun and feudal loads. The majority of Nabeshima ware are footeddishes (Koudai) in standard size of 3, 5 and 7 sun and 1 shaku (roughly 9, 15, 21 and 30 cm respectively in diameter). The decorations of these dishes feature familiar flowers and plants, landscape and other items of natures as well as continuous patterns such as shippou-tunagi and bisshamon-kikkou.

The patterns are investigated by symmetry, chiefly in two dimensions using point group, plane group and color group. Usually almost pattern shows point group 1, apparently no symmetry. However some dishes show point groups;  $16$ ,  $8mm$  symmetry, and also crystallographic plane groups; Seikaiha  $cm$ , Shitihoutunagari  $p4mm$ ,  $c2mm$  or  $p6mm$  and Bishamon  $p31m$ . Some show polychromatic groups, dichromatic and tricolor groups.

In this conference, several photographs will be shown.

I thank Toguri Museum of Art, Tokyo and Dr. Yumi Mori of it for giving photos and information of Nabeshima ware.

## X-Ray powder diffraction investigations of some historical green pigments

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Green earths belongs to the group of pigments used worldwide since antiquity. It was often applied due to its high colouring capacity, stability and availability. Green earths was used by monks in Ajanta caves in India and by Amerindians artists [1]. It is often found in medieval easel paintings and frescoes. The pigment was extensively used in Pompeii wall paintings [2] and was found among the very first collections of pigments, in pots in the ruins of Pompeii. It was also a favourite Vermeer's green pigment and can be found in some of his paintings. In the past the pigment was collected by mining. The most famous deposits of green earths could be found near Verona (Italy), in Tyrol, Bohemia, Saxony, Poland, Hungary, France, Cypress and in England.

Historical green earths is considered to be composed of two clay micas: celadonite or glauconite. These minerals have a complex chemical structure. In general their chemical formula can be written as  $K(Mg,Fe^{2+})(Fe^{3+},Al)[Si_4O_{10}](OH)_2$  for celadonite and  $(K,Na)(Fe^{3+},Al,Mg)_2(Si,Al)_4O_{10}(OH)_2$  for glauconite.

In the literature, however, one can find many variations of the chemical compositions of these minerals. Celadonite and glauconite produce colors that vary from cold bluish greens to warmer yellow and olive hues. In many cases the color is determined by the specific ratio of divalent and trivalent iron in their structures. Except of celadonite and glauconite, smectite group minerals, chlorites and serpentine group minerals can be also responsible for the green colour. In the case of smectites and chlorites the hue may be altered by minor goethite admixtures [3].

Even though there are numerous studies on clayey minerals, mineralogical studies are rare in the field of cultural heritage and are often limited to identification of the generic class 'green earths' without specific characterization of its mineralogical composition. Due to the fact that such data can be helpful in the field of conservation science, in the poster we will present the results of determination of mineralogical composition of some artistic, historical, commercially available pigments from Kremer-Pigments and other suppliers.

We have studied the following pigments: green earths from Verona, from Germany, from Thuringen, from France. We have also investigated Bavarian, Bohemian and Terre Verte green earths. All the measurements were carried out with the use of X'PERT MPD diffractometer.  $CuK\alpha$  radiation at 40kV and 30mA, graphite monochromator and scintillation or X'Celerator detectors were used. The measurements were performed in the  $2\Theta$  range 5-80° with the step size of 0.02°. The obtained diffraction patterns were interpreted with the use of diffractometer software and PDF-2 or PDF-4 databases.

Since the natural glauconite and celadonite are scarcely obtainable nowadays, it was found that the commercially accessible green earths is chiefly a durable mixture of various minerals. The results indicate also that in some investigated samples glauconite or celadonite does not occur at all.

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