



# Edirne: quel est le secret de leur incomparable beauté?

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## Edirne ancient tiles: where do the secrets of their incomparable beauty come from?

Ph. Colomban

*(Of course the layout of the illustration is to be done by the publisher team as a function of aesthetic and quality of files)*

Unesco World Heritage Site, Edirne, the ancient Adrianopolis founded by Emperor Hadrian in 125 CE became in 1365, after Bursa, the Ottoman capital under Murad I until the conquest of Constantinople in 1453. The city retains many buildings covered with ceramic tiles including the Mosque Sah Melek Pasa, built in 1429 at the same time as the Gazi Mihal bridge, the Mosque of Mourad (Muradiye Cami) built between 1421 and 1451, the mosque with 3 balconies (Üç Serefeli Cami) built between 1410 and 1447, the Yesilce mosque, originally named the Mezid Bey mosque, built as a masjid in 1440-1441, and the mosque of Selim II (Selimiye Camii), built by the famous Mimar Sinan engineer between 1569 and 1575 and covered with typical tiles from Iznik.

### Architectural ceramics

The works on the history of ceramics highlight the initial contribution of China with the invention of stoneware and porcelain in monochrome or with blue-and-white decoration. The characteristics of the white paste, stoneware or porcelain, fired at high temperature ( $\sim > 1400^\circ \text{C}$ ) made it possible to apply high-gloss enamel that could receive a decoration with a design as sophisticated as that placed on a sheet of paper. The drawing was made with a material rich in cobalt, directly on the dry paste, but not fired, then covered with a 'milk' powder of 'glass' (amorphous silicate) which, by melting during heating, encapsulated and protected the drawing (**Fig. 1a**). During the Abbasid Dynasty, the potters of Basra took advantage of the technology of the Roman glassmakers of opacifying a glass by the addition of tin to obtain a 'blank page' on a common coloured clay paste, fired at much more low temperature ( $\sim < 1000^\circ \text{C}$ ) and thus copy Chinese productions, which are very expensive to import (**Fig. 1b**). The knowledge inherited from Mesopotamian potters and the expansion of demand in the Islamic world led to the development of ceramics with important centres in the Seldjuk and Turcomans (Damascus, Tabriz, Kashan), Timurids (Bukhara, Samarcand) and Ottomans (Sivas, Nicea / Nicomedia (now Iznik), Kütahya, Bursa, Konya, etc.) area. These ceramic productions have the particularity of not having been produced only for tableware uses but for architectural decoration, in the Mesopotamian tradition with the famous example of the Ishtar Gate in Babylon (600 BCE) covered with stamped and enamelled bricks (**Fig. 2**).

Figure 3 shows two shards from the Selimiye Mosque Museum (*Kultamis: put the right name*) typical of architectural applications: a carved brick from the exterior decor fall down from the minaret of the Yesilce Mosque and a tile from / analog (*Kultamis can you check at museum*) of the interior decoration of the Sah Melek mosque. The carved brick is covered with traditional turquoise enamel, coloured with copper ( $\text{Cu}^{2+}$ ) ions in an alkaline glass, similar to the bricks of the Ishtar Gate, nearly 2,000 years before! The fractures of these shards show that the paste is reddish, and made of common clay.



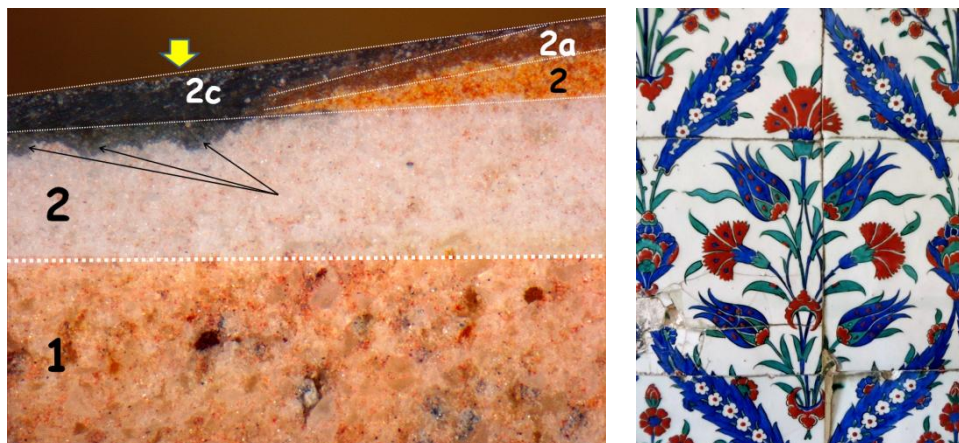
**Fig. 1:** Chinese porcelain with blue-and-white decoration (Ming Dynasty (1368-1644), Coll. Palace Museum, Taipeh, Taiwan) and Abbasid terracotta decorated with green spots on opacified tin enamel (Coll. Islamic History Museum) (*the one next to the blue mosque on the place of the old circus, Kultamis correct with the correct name of the museum*).



**Fig. 2:** Ishtar gate enamelled brick (Coll. Istanbul Archeological Museum).



**Fig. 3:** Shards and original configurations in the Sah Melek Pasa internal wall and bottom of the Yesilce minaret mosques.



**Fig. 4:** Section of an Iznik tile: paste (1) rich in quartz crystals (milky white grains) is covered with a slip very rich in smaller quartz grains (2); on this slip (a few mm thick) was placed a red enamel rich in iron oxide (*"Armenian bole"*, 2a) and a blue enamel rich in cobalt (Photo Courtesy of Dr G. Simsek). As the enamels are fired until melting, a strong reaction and diffusion occurs with the lower layer (arrows). On the left, tiles with blue, red and green enamels at the Seliminiye mosque in Edirne.

The shard of Fig. 3 with a complex decoration with interlacing shows a white intermediate layer covering the red paste on which blue and red enamels are placed to obtain a decoration similar to Timurid productions [1]. The Sah Melek Pasa Mosque retains a few turquoise blue hexagonal tiles surrounded by a frieze with the Timurids pattern. The arrangement of the tiles raises the question of their origin, reuse of a previous building? We will discuss this further.

As shown in Figure 4 with a view of a section of a 16th century Iznik tile, contemporary with the Seliminiye Mosque tiles, the exceptional chromatic quality of these ceramics comes from the layer of crushed quartz crystals (called engobe or slip), which reflects light like a reflector. The paste is strongly siliceous: we see many grains of quartz, larger than in the upper layer of engobe bound by a material rich in iron oxides, which is the origin of the red colour. Quartz grains are cemented by addition of a frit, a lead-rich glass, a technology issued of Damascus pottery (called fritware or stonepaste), and many centuries before of Egyptian potters. Iznik, ancient Nicaea was already a Byzantine ceramic production site, but the technology was different, with unsophisticated decor but without quartz slip. Iznik's earliest productions are blue-and-white, similar to Chinese porcelain (*'Master of the Knots'* style) with blue decoration set on opacified tin enamel, using Islamic technology. These ceramics lack the brilliant gloss of subsequent productions based on quartz slip.

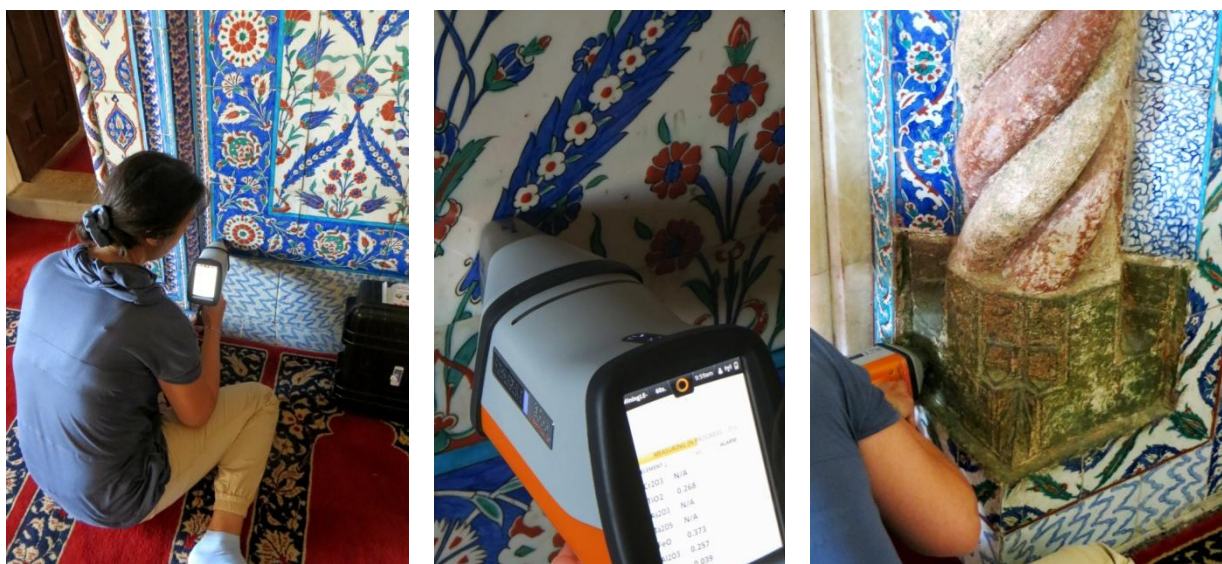
### Cultural Heritage site analysis

The magnificence of Iznik objects and tiles was recognized and appreciated as early as the 19th century and the building up of collections of "Oriental" objects by the European Elite. Famous French potters like Theodore Deck endeavoured to create objects mimicking the various types of Iznik Ottoman ceramics, classified according to the type of decoration and the chromatic palette (Baba Nakas, Rumi-Hatay, Damascus, Rhodian ... styles) [2]. The rapid acquisition of a high technological mastery at the turn of the transition from the 15th to the 16th century (Memet the Conqueror) by Iznik potters has intrigued ceramic historians and continues to motivate scholars to understand the rapid attainment of this remarkable level of technology to identify any transfer of know-how. The



excavations carried out in Iznik on the sites of the old kilns provide irreplaceable data [3,4]. As the dates of construction of buildings are often well documented, the study of the tiles in place is essential. Indeed most of the artefacts in museum collections were obtained on the art market in the 19th and early 20th centuries without documentation.

The prodigious development of performance and the miniaturization of analysis devices, as everyone experiences with smartphones and connected watches capable of analyzing numerous physiological functions, has revolutionized scientific instrumentation for nearly 20 years. Scientific analysis to unravel the "secrets" of masterpieces of the past dates back to the work of Ferchault de Réaumur between 1710 and 1740 on Chinese porcelain and Damascus steel swords, and became widespread at the beginning of the 19th century, in France with Alexandre Brongniart and Georges Bontemps, in England with Humphry Davy, etc. The first methods of analysis sacrificed several objects in order to be able to analyze enamels and it was not until the 1950s to the 1960s that knowledge of the enamels of ancient objects really began. It remains limited for a long time to the study of archaeological fragments and it is only for one or two decades that the masterpieces can be analyzed by limiting themselves to micro-samples, and more recently with mobile instruments in a non-invasive way as we do at Edirne.



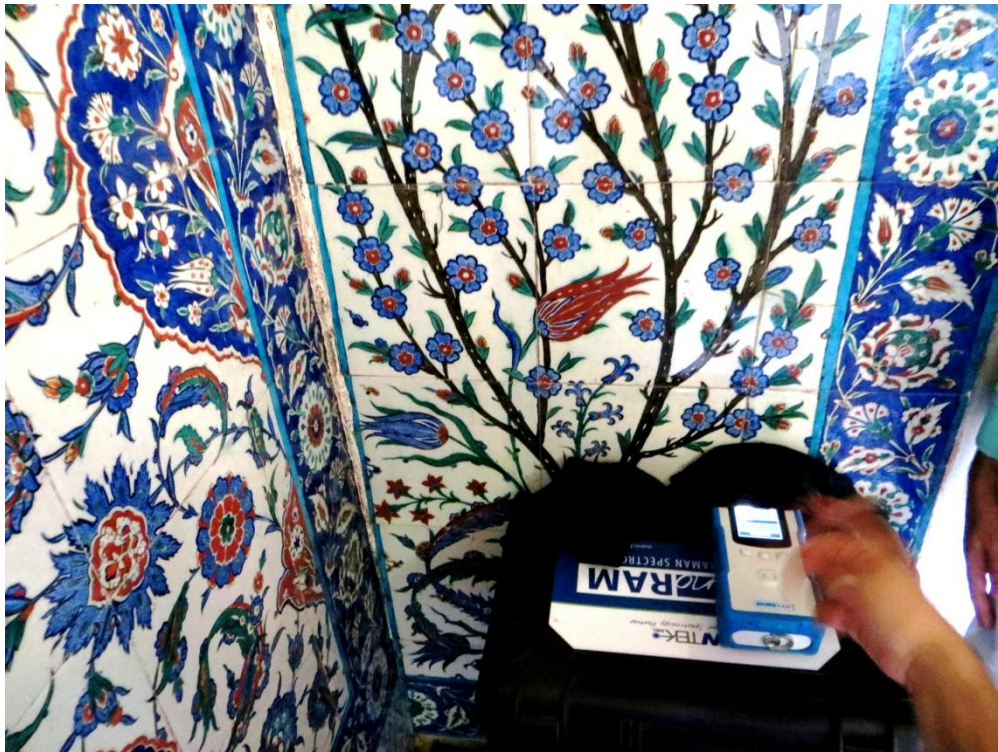
**Fig. 4:** Analysis of the glazes of the tiles of the Sulemaniye mosque: the instrument gives after a few minutes semi-quantitative information on the composition (e.g. on the screen : TiO<sub>2</sub>: 0.268, FeO: 0.373, Al<sub>2</sub>O<sub>3</sub>: 0.257% wt, etc.). The precise exploitation of the data is then carried out in the laboratory. For instance, the instrument detects the gold residue that covered the twisted pillar while no traces are visible to the eye.

Three types of mobile instruments are available, from the least expensive to the most expensive: i) hyperspectral cameras which make it possible to obtain photos in different wavelengths - and for the most sophisticated ones, to record the optical spectrum in each pixel of the image. UV-NIR spectra which identify the colouring ions (indeed, the CCD (Charge Coupled Detector) sensors present in cameras and smartphones are capable, with adaptation of their software, of detecting both radioactivity and infrared emissions, i.e. temperature!); ii) X-ray fluorescence 'guns' (**Figure 4**) which quantitatively measure the composition of surface matter for elements heavier than sodium (air absorbs X-rays too strongly to allow measurement of light elements such as sodium), fluorine,

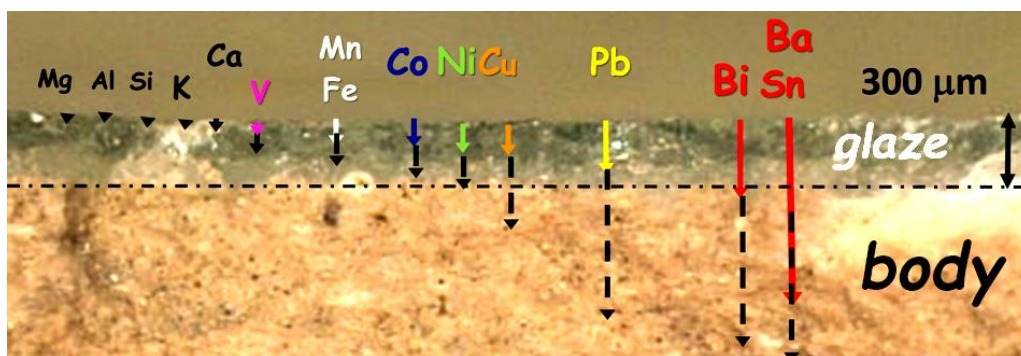
oxygen, carbon, boron, nitrogen, lithium); iii) Raman spectrometers which identify chemical bonds and the structure of matter, amorphous or crystalline (**Figure 5**). For each type of mobile instrument, different devices with varying performance - and cost - are marketed.

The experience acquired in the study of glazed ceramics as well as the constraints of availability of instruments and of the team associating scientists of a French laboratory belonging to the French National Centre for Research (CNRS) and to the Sorbonne University (Paris), of the KUYTAM laboratory of Kos University (Istanbul), of Ege University (Izmir) and of Yedipe University (Istanbul) have led us to favour analysis by X-ray fluorescence. The portable device consists of a pistol with a battery which supplies an X-ray source : a micro tip of metal (rhodium) heated at high temperature under vacuum and subjected to a very strong electric field emits a beam of X-rays over a wide range of energy, the beam is collimated on an area of the order of one cm<sup>2</sup>; the X-rays interact with the electronic layers of the atoms constituting the matter and these atoms emit part of the received energy - this phenomenon is called fluorescence - in the form of new X-rays with characteristic energy related to the atoms. Another part is absorbed and lost for the measurement. This interaction also occurs with atoms in the air (oxygen, nitrogen, argon), which together with absorption means that lighter elements cannot be measured. The absorption depends on the energy of the X-rays and therefore the measurement taken from the surface does not concern exactly the same thickness of material as shown in **Figure 6**: the contents of light elements (magnesium (Mg), aluminium (Al), Silicon (Si), potassium (K) and calcium (Ca) are measured over a few microns in the very surface layer of the enamel; the transition metals (the main colouring agents) are measured over thicknesses of the order of a hundred microns, that is to say a little less than the standard thickness of the enamel; the measurement of heavy elements such as lead (Pb), bismuth (Bi), tin (Sn) is done over a large thickness; the measurement is therefore disturbed or even distorted by the contribution of the layers under the enamel, the paste and if it exists the slip [4]. XRF analysis does not have its weaknesses when it is carried out at laboratory with samples specifically prepared: on polished section the analysis made with a microbeam is not perturbed by the various penetration depth of the X-rays. Other laboratory methods also allow the elemental composition to be obtained in a precise way but all of them require preparation and therefore a more or less significant destruction of the object of study, that prevents the analysis of master pieces.

Raman analysis is an optical method, therefore without contact and without preparation. The beam of a laser emitting in the visible or NIR range interacts with the electronic cloud of chemical bonds modulated by the thermal agitation of atoms (vibrations). This is an optical method so the very good surface quality of the glazed tiles is an advantage. But the performance of the instrument depends on the quality of the laser (power, wavelength), spectrometer (sensitivity, resolution), and illumination and collection optics (microscope objectives), which is in contrast to the miniaturization and mobile Raman spectrometry devices required for amorphous silicate analysis (a glaze/enamel is an amorphous silicate, a glass, in which colouring agents and pigments are dispersed) are quite heavy (15 to 30 kg) which complicates the implementation of measurement campaigns. The light instrument used in Edirne (**Figure 5**) has limited performance in identifying part of the colouring phases only.



**Fig. 5:** Raman measurement with a portable device in the balcony of the Süleymaniye Mosque.



**Fig. 6:** Depth contributing to the pXRF measurement according to the elements considered (after [3]).

**Iznik's precursor tiles: Muradiye and Sah Melek Pasa mosques**





**Fig. 7:** Hexagonal tile wall inside Muradiye Mosque and detail of a tile.



**Fig. 8 :** Detail of the Mihrab of the Muradiye Mosque.

The magnificent and exceptional character of Muradiye's blue-and-white hexagonal tiles caught the interest of specialists very early on. Nowadays, in Kütahya, there are three buildings which have coloured glazed tile decorations, where the production can be related to the period of Beyliks (13th - early 15th-century) [5].<sup>[1]</sup> Some hexagonal, turquoise tiles and gilded decorated ones are similar; technically and compositionally to the tiles of Green Complex in Bursa and border tiles of Şah Melek Paşa Mosque in Edirne (Fig. 3). There were also some blue and brown painted underglaze tiles seen in the *mihrab* of Hisarbey Mosque (Kütahya), which represents the practice of the underglaze technique by the craftsmen of Kütahya at the end of 15th-century. Border tiles of Muradiye were decorated in the same manner, but the colours used were blue and white, unlike Hisarbey Mosque.

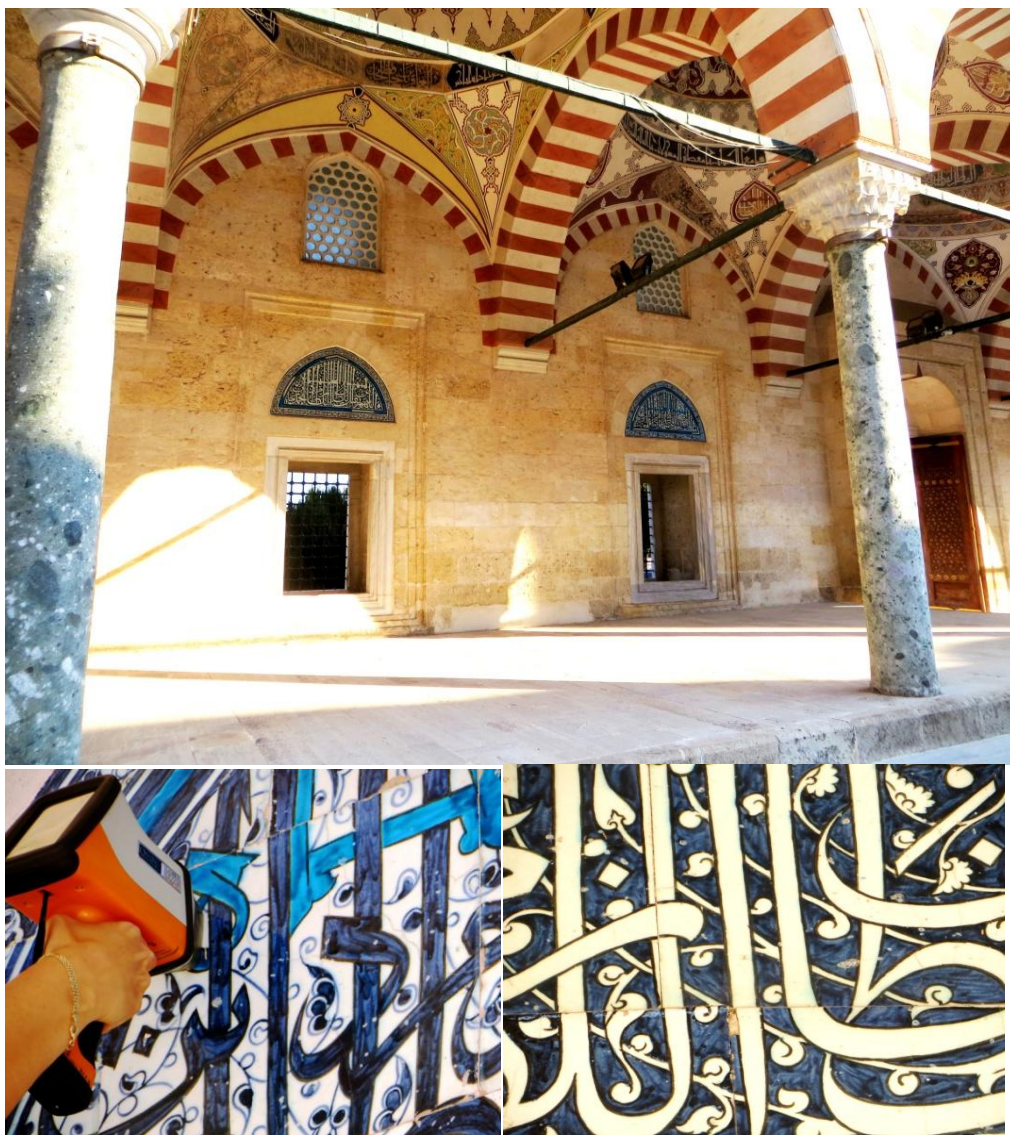
<sup>[1]</sup> According to Necipoglu and Golombek, tiles of Muradiye (**Figure 7**) have a similar design with the porcelain tiles imported from China (Pax Mongolica during Yuan and beginning of Ming Dynasty secured trade along the Silk Road) used in the *Chini-Khaneh* ('porcelain room') pavilion which was built by Ulugh Beg in 1430 in Samarqand and now it has been destroyed [6,7].<sup>[2,3]</sup> Necipoglu also mentions that blue-and-white tile bodies of Muradiye contain lime-alkali frit rather than lead-alkali that Iznik technology uses.<sup>[2]</sup>



The origin of these tiles remains debated: they seem to lay on previous paintings (Figure 7). Was them designed for another place (Edirne Saray built in 1453 and since destroyed) and moved to the mosque? Were they made in another place and which one? Indeed 50 years after, tiles with coloured glazes once again decorated the buildings of Suleiman the Magnificent. Gülru Necipoğlu [6]<sup>[2]</sup> states that a group of immigrant craftsmen from Iran with local assistants were working on the production of 15th-century tile revetments in an unknown ceramic workshop in Istanbul (Iran potters produced also fritware). They were supervised by one of the Tabrizi craftsmen whom Selim I had brought from Tabriz to the Ottoman court following the victory of the battle of Chaldiran in 1514 [8,9].<sup>[4,5]</sup>

Hexagonal tiles are also present at *Şah Melek Paşa Mosque* mosque built on the road that goes to Edirne from Gazi Mihal Bridge in 1429. The rare remaining set of tiles is quasi identical, visually, to the tiles in Green Mosque and Green Tomb in Bursa city as well as being the Ottoman's not-well-investigated artefacts remaining from the 15th century. Most of the tiles are fallen, and some geometric decor made of plaster was painted over the tiles that are covering *mihrab* (altar). These six-cornered turquoise coloured tile plates which are preserved on the left part of the *mihrab* (see Fig. 3), remind us of the Ishak Fakih tombs of Kütahya city dating back from the Germiyanids (1300-1429) [10].<sup>[18]</sup>

The coloured glaze decoration, where a black line surrounds different areas of the decor (Figure 3 and **Figure 8**) serving to keep them separated during the firing. This ornamentation has spread in Timurids Central Asia from the end of the 14th-century to the Ottoman Empire during the 15th and the 16th-century and finally in Iran and India during the Safavid reign [2,7,11].<sup>[2, 3, 6, 7]</sup> Henderson and Raby [12]<sup>[8-11]</sup> identified different phases: firstly, 13th-century Seldjuk pottery linked to Turkistan Iranian fritware technology [2,12-14],<sup>[12-15]</sup> but analysed fragment from the Gök Madrasah in Sivas dated to 1271 reveals that it had a clay body, with no trace of frit [14].<sup>[8]</sup> Then Masters of Tabriz blue-and-white productions are identified, e.g., at Üç Şerefeli (Three Balconies) Mosque, Edirne (**Figure 9**); Henderson stated that “*laboratory analysis [of the paste] has shown that there was considerable technical variation and, most significantly, that they did not use lead frit*”. *The Masters of Tabriz artists who reintroduced the fritware technique into Turkey, but the stonepaste composition they used, was not consistent. It differed visibly in colour, ranging from a brick colour in the 1420 to a buff white for their underglaze tiles in the 1430s* [14]. [8] On the other hand, J. Soustiel [2]<sup>[16]</sup> noted that Muradiye and Üç Şerefeli tiles do not follow the time sequence proposed by A. Lane [15]<sup>[17]</sup> and underlined the high specificity of these tiles. A stylistic similarity does not imply the same place of production, due to ‘à la mode’ style being copied in many places. Most of the analytical studies have been focused on the body and slip examination. Comprehensive analyses of the glazed decoration are still little known, and the literature stays confused about it, a limited number of shards have been studied, and their provenance and date of production are not always well established. The object of our work is to compare characteristics related to the glaze production of tiles during the 15th and first half of the 16th-century. One of the big advantages of on-site measurement of building decor is that the production date of the materials is much more documented than for the tableware ceramics.

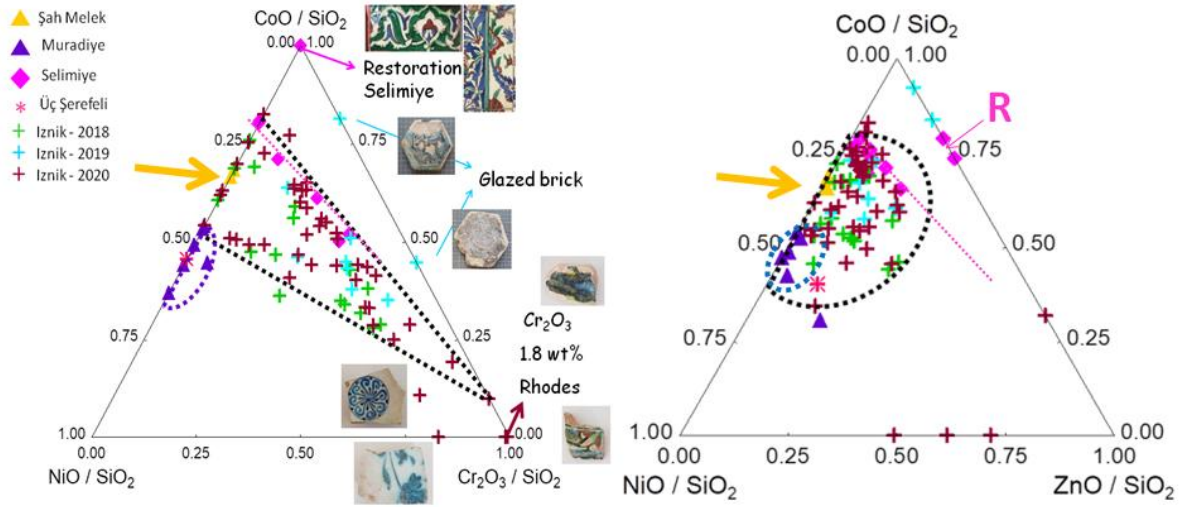


**Fig. 9:** Dedication panels in the courtyard of the Üç Serefeli Cami mosque and detail of the tiles.

## Results

Figure 10 visualizes the first results obtained by the measurement campaign [1]. This figure compares the distribution of the relative contents represented in cobalt oxides and in elements that are found associated with the “cobalt” used to obtain the blue coloration of the enamels. In fact until the middle of the 19th century, the preparative chemistry of cobalt ores, which are geologically rare, was very limited and the 'cobalt' used by potters contained in significant quantities the other transition metals (nickel, chromium, zinc, iron). Other elements such as bismuth and arsenic also trace both the geological context of the mineral and the selection-enrichment process of "cobalt" [1]. In order to average the variations induced by manual positioning (and therefore not perfectly reproducible although facilitated by the flatness of the tiles) the values are normalized with respect to the content of silica ( $\text{SiO}_2$ ), the main component of an enamel. The measurements obtained on the blue zones of the squares of the 3 studied layers are indicated by triangles (yellow and purple respectively for Sah Melek and Muradiye) and pink diamonds for Selimiye. The measures of Üç Serefeli panels are

represented by a star. The crosses correspond to the measurements made on the shards extracted from the excavations of the Iznik sites [3,4].



**Fig. 10 :** Distribution of the relative contents of transition metal oxides measured by pXRF for the blue tile areas of the Edirne mosques in comparison with the data obtained on the shards of tiles from the excavations of the old Iznik kilns.

The data obtained for the blue zones of the Selimiye tiles are distributed in a line within the zones determined from the shards extracted from the Iznik excavations. The distribution comes from the heterogeneity of the cobalt ore used which despite the visual selection made by the miners and certain purification has variable contents of chromium, zinc but also manganese. The measurements on the blue areas of the 'Timurid style' tiles of the Şah Melek mosque are well within the Iznik domain but their purity (almost no Cr and Zn) indicates either a very efficient selection of the cobalt ore, or cobalt from other mines. On the other hand, as on the aesthetic level, the tiles of Muradiye and Üç Şerefeli differ from those of Selimiye (Iznik ovens) and Şah Melek. To go further in identifying their provenance, it will be necessary to study the enamels of sites such as Sivas, Bursa, Kütahya, Damascus, Tabriz, cited above.

### Perspectives

The instruments allowing on-site analysis, without danger or preparation of objects revolutionize the practice and undoubtedly our knowledge of old technologies and the exchange of know-how. Some buildings retain the magnificent coloured glass claustra as shown in Figure 11. While the compositions of the European equivalents - the stained glass windows - are now well known both stylistically and technically due to the cleaning and restoration campaigns carried out for several decades allowing samples and easy access following the degradation of certain potassium glasses by the acid pollution of the 1950s-1970s, the Ottoman claustra have been the subject of little work. It is true that accessibility to these fences is difficult.





**Fig. 11:** Stained glass screens, Suleymania mosque and prayer room of the Bayezit Külliyesi hospital outside the walls (*Kultamis, add the correct name*)

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