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Historical and Technological Studies of the Khwārazmshāhid Brickwork and Glazed Decorations in Khorāsān (North-Eastern of Iran)

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To

Negar Eftekhari and Parviz Holakooei

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Contents

List of figures

List of tables

Guidelines for the readers

Transliterations

This thesis uses British English spelling and punctuation. Technical and local terms, from languages using non-Roman alphabets, have been transliterated with diacritics. Persian, or Farsi, like other languages, comprises of 23 consonants and 6 vowels (Table 0.1). However, these phonemes vowels and consonants have always been a subject of discussion to transliterate due to their complicacy. In this thesis, a system for transliteration of Persian and Arabic terms is suggested based on some other transliteration systems. Here, long vowels are transliterated as **ā** (/ɒ:/), **i** (/i:/) and **u** (/u:/) and short vowels, however, are transliterated as **a** (/æ/), **e** (/e/) and **o** (/o/).

Table 0.1. Persian/Arabic characters versus International Phonetic Alphabet (IPA) phonetics together with their transliterations

Persian/Arabic	*Transliteration*	*IPA*
ا	ʾ, a, ā	ʔ, æ, ɒ:
ب	b	b
پ	p	p
ت	t	t
ث	th	s
ج	j	dʒ
چ	ch	tʃ
ح	h	h
خ	kh	x
د	d	d
ذ	z	z
ر	r	r
ز	z	z
ژ	zh	ʒ
س	s	s
ش	sh	ʃ

Persian/Arabic	*Transliteration*	*IPA*
ص	s	s
ض	ż	z
ط	t	t
ظ	z	z
ع	ʿ	ʔ, :
غ	gh	ɣ, ɢ
ف	f	f
ق	q	ɣ, ɢ
ک	k	k
گ	g	g
ل	l	l
م	m	m
ن	n	n
و	v, u	v, u:, o
ه	h, a	h, e, æ
ی	y	j, i:, e

Silent final **–h** in Arabic and Persian is transliterated as **– a**, such as *khāna*, *qeṭʿa*. There are also some compound vowels, such as **ow** (in Persian words like Ferdows and in Arabic words like *Majd al-Dowla*), **ey** (in Persian words like *Joveyn*) and **ey** (in Arabic words like *Ḥoseyn*). Moreover, 'al' before Arabic proper names, except in constructs is dropped, such as *Biruni*, *Moqaddasi*, but *Ghiyath al-Din*.

Whenever possible, English forms and translations are used instead of Persian or other foreign place names, offices, institutions, *etc*. (a transliteration and/or gloss, if appropriate, might be followed in parentheses). Moreover, non-Latin names (author, book, institute, *etc.*) which have been romanised by the authors or publishers themselves have not been transliterated.

Punctuation, etc.

Italics are used for titles of books and non-Latin materials' and techniques' names. The names that are originally in a non-Latin alphabet names are also transliterated. Double quotation marks are used for titles of articles and dissertations. Single quotes are used for quotations within quotations, and for glosses

immediately following foreign words or phrases; a following comma or stop goes outside; e.g., *kotob* ‘books’.

Citations and referencing

Parenthetical referencing, also known as Harvard referencing, is a citation style of this thesis. Here, the citations are enclosed within parentheses (round brackets) and embedded in the text, either within or after a sentence.

Dates

Dates are given in European style without internal punctuation like **1827**. Centuries are given for the Common Era. Eras are abbreviated as BC and AD. However, years of publication in the citations for non-Gregorian calendar articles and books are transferred to Gregorian calendar in order to unify all the dates.

Capitalization

Titles and epithets are not capitalised except when appended to a name. Persons’ titles or names are hyphenated and capitalised both elements (*ʿAbd al-Ḥoseyn*, *Fatḥ ʿAli*, *Zinat al-Nesā*). In book titles, institutions, *etc*. the pattern *Borj-e Lājim*, *Beyt al-Māl* is used. The first character of each word in books’ and articles’ titles is capitalised. The names of cities, mines, geographical places are also capitalised.

Chapter One: Brickwork and Glazed Decorations in Khorāsān

1.1 Geographical zone and historical background

The term "*Khorāsān*" (or *Khurāsān*), that literally means the Eastern Land (Le Strange, 1905, p. 382), has been used for centuries to name a vast territory covering northern Afghanistan, north-eastern Iran and some parts of Central Asia. During the Sassanid period (224 – 651 AD), Khorāsān included the eastern part of the empire, the known Parthian land (Kasaeei, 1997), that "over the centuries was the scene of battles and the target of invasions" (Saadat, 1976, p. 15).

After seizing Khorāsān by the Islamic Arab army in 651 AD, the territory remained in the hands of the Umayyads and the Abbasids until 820 AD. Afterwards, the Taherids (820 – 873 AD), the Saffarids (861 – 1002 AD), the Samanids (874 – 999 AD), the Ghaznavids (962 – 1186 AD), the Seljuks (1037 – 1194 AD), the Khwārazshāhids (1077 – 1231 AD), the Ghurids (1154 – 1212 AD), the Mongols (1220 – 1258 AD), the Il-khānids (1258 – 1336 AD), the Timurids (1369 – 1500 AD), the Safavids (1502 – 1736 AD), the Afsharids (1736 – 1796 AD), the Qajars (1779 – 1926 AD) and the Afghans, the Turkmens and the Uzbeks, occupied, ruled and brought changes to all or some parts of the Great Khorāsān (Saadat, 1976; Wilkinson, 1987, pp. 39-44; Kasaeei, 1997; Nuraei, 2005; Bakhtiyari, 2007; Hajianpoor, 2007). Thus, depending on who was ruling Khorāsān, it comprised of different regions in a period spanning from the middle of the seventh century to the twentieth century AD. Nishābur (in today's Iran), Merv (in today's Turkmenistan), Herat and Balkh (in today's Afghanistan) are mentioned as four main regions of Khorāsān in most of literature describing the geography of Khorāsān (Le Strange, 1905, pp. 384, 385; Khalili Afghan, 1930, p. 162; Monajjem, 910, pp. 72, 74, 77, 79, 82; Qazvini, 1994, p. 426; Kasaeei, 1997; Fedorov, 2000; Roosta, 2012) (Figure 1.1). However, some have located Samarkand and Bukhara in Transoxiana (Narshakhi, 935; Juvayni, 1286, p. 1), Khwārazm in Uzbekistan (Saadat, 1976, p. 16; Monajjem, 910, p. 79), Qohestān (east of Iran, either as a part of Nishābur or as a separate region) (Le Strange, 1905, p. 352; Saadat, 1976, p. 15; Kasaeei, 1997), Tabarestān (north of Iran) and Jorjān (west of Turkmenistan) (Monajjem, 910, pp. 69, 70) in Khorāsān.

During the Qajar period, according to the Treaty of Paris (signed in 1857), the eastern parts of Khorāssan (in today's Afghanistan) were separated from Iran (Jafarian, 2013). Afterwards, the northern and north-eastern parts of this territory, including those that were occupied by the Russians (Kasaeei, 1997), were separated from Iran by the Ākhāl Treaty in 1881 AD (Zargarinezhad & Alipoor, 2009). As a result of previous events, Khorāsān became a province in the modern-day Iran to which this thesis refers as Khorāsān (Figure 1.1). Khorāsān, the largest province of Iran, was divided into three provinces; i.e., Razavi Khorāsān, North Khorāsān and South Khorāsān in 2004[1].

At the beginning of the thirteen century, Khorāsān (Khorāsān in its former sense) was under control of the Khwārazmshāhids. The *Khwārazmshāh* literately means the King of "Khwārazm" (also Khorezm and Choresmia), a historic region in modern Turkmenistan and Uzbekistan. The first known Khwārazmshāhs, i.e., Banu Iraq, ruled Khwārazm in the tenth century and their capital was Kāth (Fedorov, 2000). Afterwards, three other Khwārazmshāhs ruled Khwārazm, i.e. Maʿmunid (995 – 1017 AD), Altuntash and his sons (1017 – 1041 AD) and Anush Tigins (Mamedov & Muradov, 2001, p. 19).

[1] Islamic Parliament Research Centre (http://rc.majlis.ir/fa/law/show/94006)

The latter who conquered all Central Asia, Afghanistan and most parts of Iran are known as the Great Khwārazmshāhs (Sheykh Nouri & Khosrobeigi, 2005). Hence, the Khwārazmshāhid period is recognised as a short interval between the Seljuk (1037 – 1194 AD) and the Il-khānid (1258 – 1336 AD) dynasties.

In 1077 AD, the Seljuk's Sultan appointed Anush Tigin, a former Turkic slave, to be the governor of Khwārazm (Gorganj or Kohna-Urgench in modern Turkmenistan) and by the year 1098 AD, his son, Qotb al-Din Mohammad I, became the first hereditary Khwārazmshāh that ruled the Khwārazm for thirty years as a Seljuk's vassal (Juvayni, 1286, pp. 2-3). As Juvaini (1286, p. 3) suggests, Alā al-Din Atsiz succeeded his father in 1128 AD although this date is given by others as 1127 AD (Modarres, 1990, p. 426; Sheykh Nouri & Khosrobeigi, 2005; Bavafa, 2011).

The next Khwārazmshāh was Atsiz's son, Il-Arsalān, who came to power in 1156 AD. After the death of Sultan Sanjar in 1157 AD, the Seljuk state fell into chaos and Il-Arsalān extended his territory southward and occupied Nishābur in 1162 AD (Juvayni, 1286, p. 16). On the death of Il-Arsalān in 1163 AD, a throne conflict happened between his sons, Takesh and Sultanshah, for years and finally the elder son, Alā al-Din Takesh got the throne (Juvayni, 1286, pp. 17-30). Afterwards, Sultan Takesh defeated and killed the last king of the Great Seljuk Empire, Toghrol III, in 1194 AD and occupied most parts of Iran (Juvayni, 1286, p. 31; Sharafi, 2007). He died in 1200 AD and his son, Qotb al-Din Mohammad II, became the successor (Modarres, 1990, p. 457; Farrokhir & Khosrobeigi, 2011).

During Qotb al-Din's reign, he overthrew the Qarā-Khtāis and occupied all Transoxiana in 1212 AD and also continued the wars between the Ghurids and the Khwārazmshāhids, that was started from Takesh's time and ended by seizing the Ghurid's land and Herat in 1215 AD (Khalili Afghan, 1930, pp. 168-169; Asadi, 2011). Hence, he created a short-lived empire that stretched from the Zagros Mountains (west of Iran) to the border of India. However, the empire did not endure and was defeated by the army of Changiz Khān in 1220 AD (Wilber, 1955, p. 4; Kasaeei, 1997). Sultan Muhammad was defeated by the Mongol army and died some week later after he fled to an island in the Caspian Sea (Wilber, 1955, p. 3). As a result, his son, Jalāl al-Din, became the new Sultan and attempted to re-establish the kingdom. Although he attempted several wars with the Mongol army and struggled against pretenders to his throne, he never consolidated his power and finally was killed by a bandit in 1231 AD (Wilber, 1955, p. 4; Modarres, 1990, p. 458; Hajianpoor, 2007; Bavafa, 2011; Farrokhir & Khosrobeigi, 2011; Roosta, 2012).

Many wars, especially the Mongol Conquest (Juvayni, 1286; Kasaeei, 1997), together with earthquakes and neglect of buildings and sometimes religious reasons caused destruction of many monuments of Khorāsān of which Khwārazmshāhid edifices are not exception. Nonetheless, in modern Khorāsān, there are two dated mosques from Khwārazmshāhid dominion, one in Gonābād that still in use as a mosque, and another one, a semi-ruined building in Zuzan. These mosques based on two-*iwan* plan show a conversion from the common Seljuk four-*iwan* plan (Godard, 1936, p. 289; Godard, 1949, pp. 241, 248-9; O'Kane, 1994; Esmaeil Alam, 2003, p. 121) that is the most significant alteration carried out in this period. Therefore, the Farumad Mosque, according to its plan, is also attached to this so-called "*Khorāsāni-ye do-iwani*" school dated to the Khwārazmshāhid period (Godard, 1949, p. 250; Labbaf Khaniki & Saber Moghaddam, 2006, p. 13). Apart from architectural distinctions, these buildings exhibit different architectural decorations, especially in brickwork (as the most important decorative elements) and glazed elements. As a result of this evidence (plan and decorations), the mosques of Sangān-e Pāʾin, Ferdows and Khosrowshir (Figure 1.1) can also be classified as monuments that either built or decorated in the Khwārazmshāhid period. As very few Khwārazmshāhid monuments are known, it is fairly difficult to track the Khwārazmshāhid architecture in Iran.

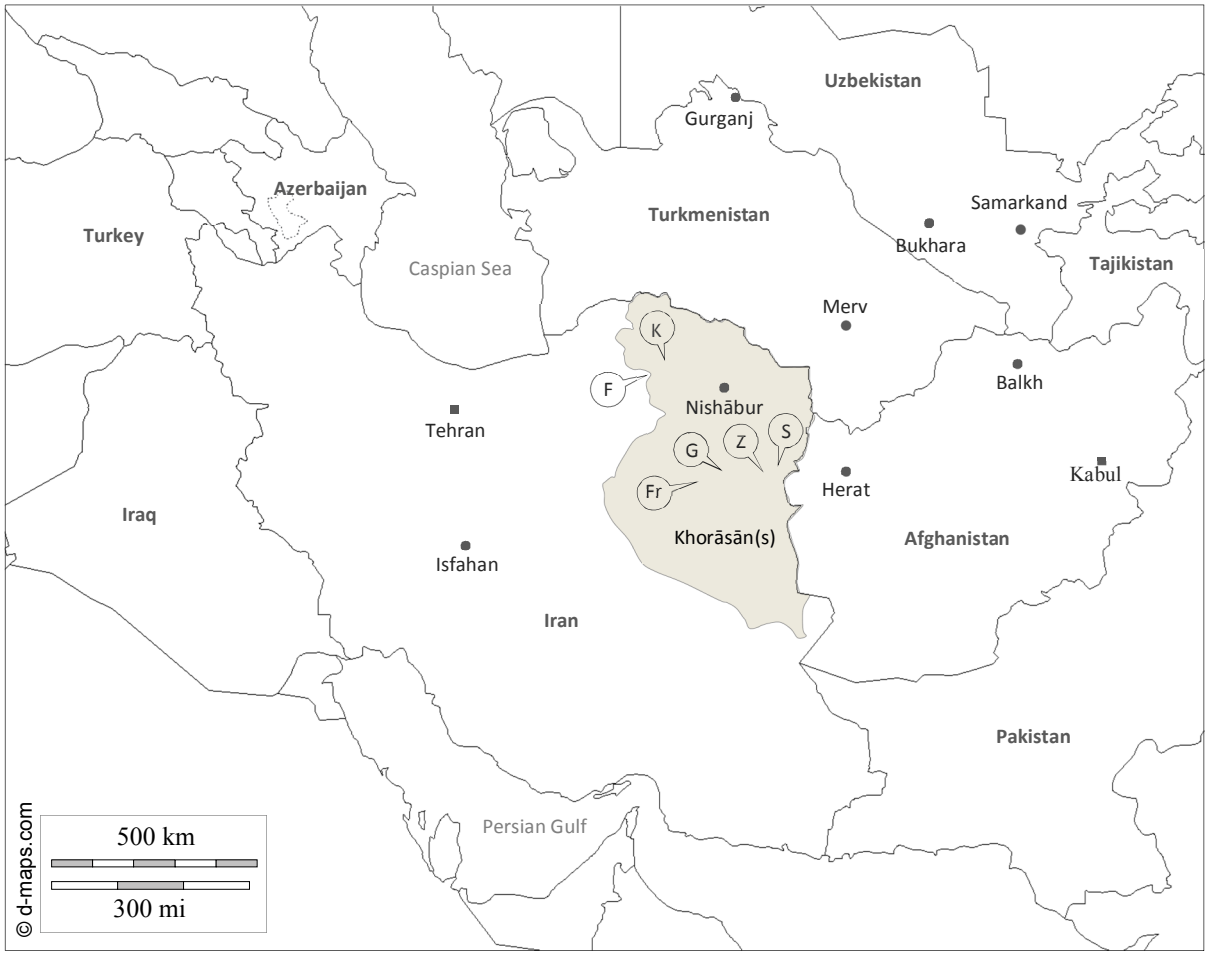


Figure 1.1. Khorāsān(s), the studied area and the location of the selected mosques. Abbreviations: G: Gonāabad, Z: Zuzan, F: Farumad, S: Sangān-e Pā'in, Fr: Ferdows and K: Khosrowshir. (original map from http://d-maps.com)

To provide an overview about using brickwork as a major decorative element, and glazed decorations in their territory (Iran, Afghanistan and Central Asia), these ornaments will be briefly described up to the Mongol conquest, then, the architectural decorations of the monuments will be discussed subsequently.

1.2 Brickwork and glazed decorations in the Khwārazmshāhid territory

Using both glazed elements and brickwork for embellishing architectural façades has a long story in Iran. The panels of moulded bricks from Susa, the brickwork and glazed bricks of the Chogha-Zanbil Ziggurat and polychrome tiles found in Susa are remarkable examples of the Elamite brickwork dated to the second millennium BC (Kiani, 1997, p. 129; Pickett, 1997, p. 17; Campbell & Pryce, 2004, p. 30). In the Achaemenid era, mid-first millennium BC, these traditions were pursued at Susa and Persepolis (Kiani, 1997). During the Parthian (247 BC – 224 AD) and Sassanid (224 – 651 AD) periods, the use of stucco, mural painting and mosaics became a common trend to decorate buildings although some glazed decorative elements from Dura-Europos, a Parthian site, is also reported (Wilber, 1939; Pickett, 1997, p. 17). Moreover, Ṭāq-e Kasrā, constructed of brick in the Sassanid capital, Ctesiphon, is known as one of masterworks in the world (Campbell & Pryce, 2004, p. 72). Unfortunately, our knowledge of the early Islamic architecture in Greater Iran is limited to the manuscripts in which ruins of buildings are described by geographers, historians or travellers. Nonetheless, gradual development of

brickwork in Iran can be followed continuously from the first remained Islamic buildings up to the Mongol conquest. The first glazed elements, after a long period of absence, appeared on the façades of buildings by the second half of eleventh century. The following content provides a description of the history and techniques of brickwork and glazed decorations in the Islamic monuments of Iran, Afghanistan and Central Asia up to the first quarter of the twelfth century.

1.2.1 Brickwork

A- Technical terminology

In the Islamic architecture of Iran both *khesht* (mud-brick, sundried brick or unbaked brick) and *ājor* (backed or fired *khesht*) were the main materials of which the structure of buildings was made (Varjavand, 1997). Moreover, before the adoption of glazed tiles, brick (*ājor*) was the most durable medium to cover and to decorate architectural façades. In other words, bricks were used for both constructtion and ornamental purposes. Brick-based decorative elements can be technically grouped into three main categories as follows.

Ājor chini-ye khās or 'arranged bricks' is the first group in which many patterns (*e.g.*, running bond, herringbone, basket weave, double-stretcher, *etc*.) were used to project the face brick coursing. Using these patterns resulted in a dozen different bonds that could also be decorated by stucco, glazed objects or other brick-based embellishments. Furthermore, sometimes indenting or pulling out part of some bricks from the walls' façades or laying the brick at an angle, created a three-dimensional surface, *gol-andāz-e ājori* in Persian (Varjavand, 1997) that, together with bonds, played an important role to make light and shade, and colour contrast effects.

Borida ('cut and smoothed') or *tarāshida* ('carved') bricks are those bricks which are cut and carved after firing the raw body and can be considered as the second group of brickwork. This kind of brick-working was extensively used to make a wide range of patterns in the Islamic architecture of Iran. The *borida* brick was made by breaking the fired plain bricks up into varied shapes, either flat or curved. As an illustration, the normal shape of traditional Persian/Iranian bricks (either mud or baked) was square in form with different dimensions (depending on the zone and the period in which the bricks used). Therefore, other dimensions of bricks used in architectural decorations of Iran, before the recent centuries that the brick's shape converted to a rectangular form (20 × 10 × 5 cm), demonstrate a proportion (*borida*) of square bricks (Figure 1.2, B). The *tarāshida* bricks, however, are comprised of carved, engraved or trimmed bricks. This technique of decorating bricks can also be applied on *borida* shapes (Figure 1.2, B). The pieces and shapes created by *borida* or *tarāshida* techniques are either used as a bulk form (set into a plaster-base ground), or employed during the brick-laying to create a pattern. Moreover, there are some decorative elements in which, after completing brick courses, carving the face brick surface of wall creates the patterns. Thus, the term *pas-tarāshida* ('post-carved') brick is coined to describe this technique (Figure 1.3, *right column*). The last group of brick-based decorative elements comprises of bricks that are formed before any firing treatment. In this type, moulding, cutting, engraving or stamping are used to create patterns on the wet paste of the brick. In Persian, the term *pish-bor* ('pre-cut') is used to call the square brick that is cut into other shapes before firing, and, the terms *mohri* and *qālebi* has been used for stamped and moulded bricks respectively (Varjavand, 1997). As, in some cases, all these techniques were applied on an entire body of brick on wall, in this thesis, the term *pish-shekli* is coined to refer to all the pre-formed bricks (Figure 1.2, left column).

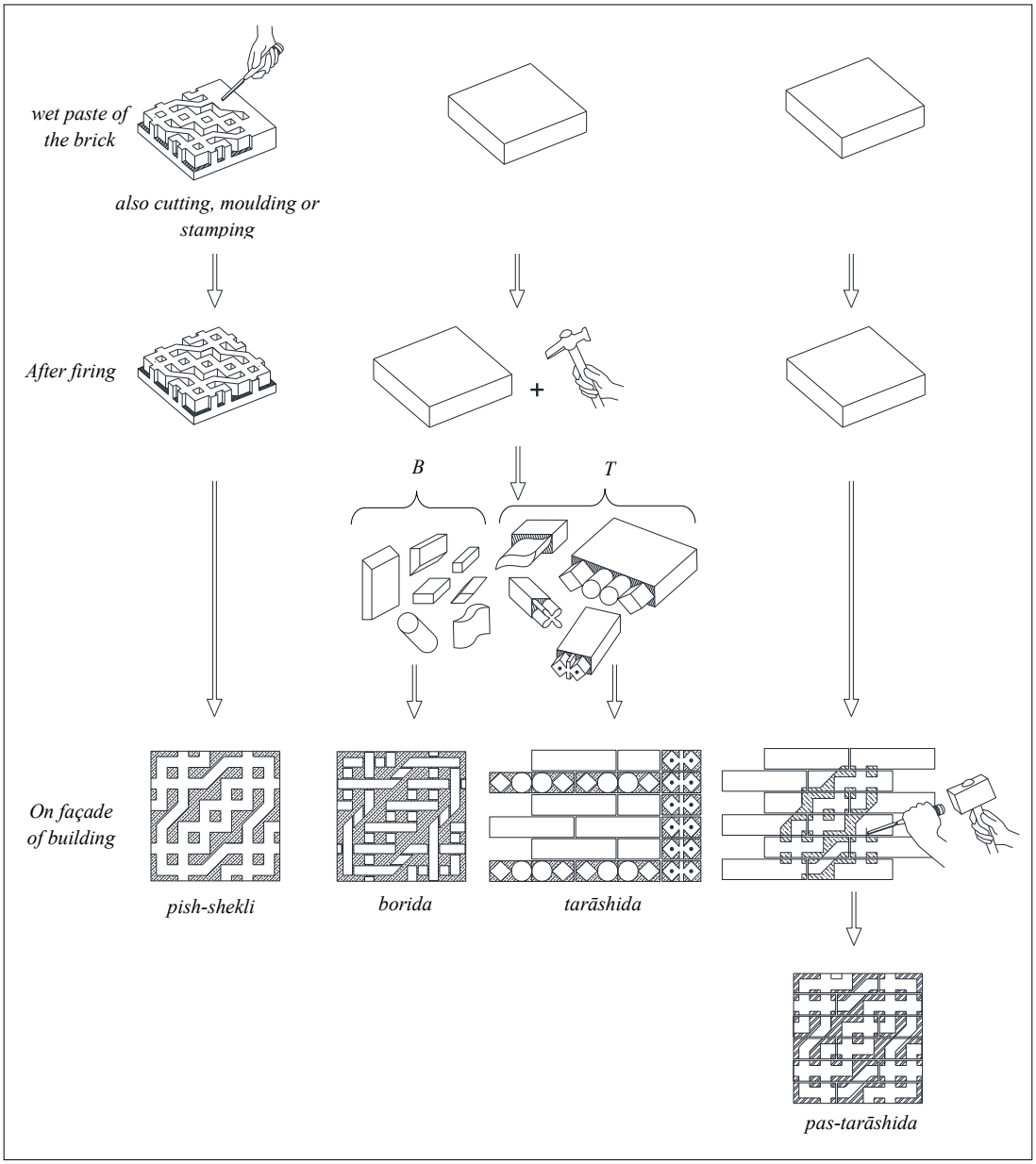


Figure 1.2. Schematic drawing of pish-shekli*,* borida*,* tarāshida *and* pas-tarāshida *brick-based decorations.*

B- *Some examples of the development history*

In Iran, Afghanistan and Central Asia, up to the Mongol conquest, the above-mentioned techniques were employed by architects to decorate the façades of buildings. Initial examples of the use of brickwork are arranged bricks used for both decorative and structural purposes. The Masjed-e Diggaron, dated from the eighth to the tenth centuries (Pugachenkova, 1996), is an example where this kind of brickwork is employed. Moqaddasi (984, p. 316), a tenth century geographer, describes a hypostyle mosque in Nishābur, built in the ninth century (now destroyed) with both wooden columns and rounded brick pillars[1] (Al-Moqaddasi, 984, p. 316). However he does not mention whether the rounded pillars were

[1] The form of these brick pillars, rounded, is not given neither in Persian version (Labbaf Khaniki & Saber Moghaddam, 2006, p. 12) nor in Le Strange's translation (1905, pp. 384-385) but it seems that in recent English version (Al-Moghaddasi (EN), 985, p. 278) the rounded pillar ("أساطين على آجر مدورة") is used correctly.

decorated by brickwork or the brick was only amployed as a structural material like those of the Masjed-e Tāri-Khāna at Damghān, which has rectangular bricks laid in a circular pattern, with plaster evening out the circumference. One of the most remarkable examples of brickwork decorations is embodied in the tomb of the Samanids (907 AD) in Bukhara. In this earliest surviving Islamic monument, the arranged (normal and *borida*) bricks play the main role perfectly although the *pish-shekli* bricks are also used to furnish the building (Pope & Ackerman, 1930, p. 264; Campbell & Pryce, 2004, pp. 75-78).

Figure 1.3. The Minaret of Khosrowgerd (1115 AD), arranged bricks and tarāshida elements in the decorative bands. (Unless otherwise stated, all photograps are by author.)

Excavation at Ṭus (near Mashhad) uncovered the remains of the Masjed-e Tāberān-e Ṭus (Labbaf Khaniki & Saber Moghaddam, 2006, pp. 16-17) where the arranged brick courses cover the remnants of rounded pillars. As the matter of fact, the arranged brick technique is observed in almost all monuments constructed of brick. In addition, the normal and *borida* bricks, combined with stucco bonds, are also employed to make elaborated façades; *e.g.*, the Jurjir Portal of Ḥakim Mosque (977 – 995 AD), the Masjed-e Jāmeʿ-e Naʾin and the Masjed-e Jāmeʿ-e Isfahan (the Buyid part) (Sarafraz, et al., 2012). At approximately the same time, using bricks to create geometric and epigraphic patterns appeared in the portal of the Mausoleum of ʿArab ʿAtā (978 AD) (Blair, 1995), elaborate brickwork in which the motifs are created by *borida* bricks. Later, in 1007 AD, two brick Kufic inscriptions decorate the Gonbad-e Qābus Tower (Figure 1.4). Moreover, a particular type of *pish-shekli* bricks is used to create the structure of this tower (Pope, 1930). The Arsalān Jāẕeb Mausoleum (Figure 1.5), built between 977 and 1026/28 AD (Sourdel & Sourdel-Thomine, 1979; Soucek, 2000), demonstrates another example of using *borida* bricks.

Figure 1.4. A view of the Gonbad-e Qābus Tower (photo: M. Mishmastnehi)

Excavations in the courtyard of the Masjed-e Jāmeʿ-e Isfahan unearthed some special *pish-shekli* elements that are attributed to an early Islamic construction (Jalili, 2003). Moreover, *tarāshida* and *pish-shekli* decorative bricks are used in the Mil-e Rādkān 1016-1020 AD (in Kordkuy). Another example of using brickwork is the Borj-e Lājim (1022 AD), where geometric patterns and a Pahlavi inscription are applied on the top side of the bricks. Unfortunately, the erosive environment has markedly destroyed these bricks so that it is difficult to understand how they are made (*pish-shekli* or *tarāshida?*). Arranged, *borida* and *tarāshida* bricks were also employed to create the Kufic inscription, *muqarnas* and other decorative bands of the Borj-e Lājim (Figure 1.6).

Figure 1.5. Brickwork at the Arsalān Jāẕeb Mausoleum

Figure 1.6. Borj-e Lājim, patterns on top side of bricks together with arranged, borida *and* tarāshida *elements*

Figure 1.7. Pish-sheki pieces at the Mazār-e Niyāzabād

The well-known examples of *pish-shekli* brickwork are the pieces of the Kufic inscription of the Madrasa-ye Neẓāmiya-ye Khargerd, dated to 1058 AD by Godard (1949, pp. 256-297). The remains of this inscription, which were moved to the National Museum of Iran, shows the first floral motifs beside letters (with a curved surface) created by deeply graving the wet clay body. However, an undated *pish-shekli* piece with floral and lettering designs is found at a recent construction in Ghazna, laid upside down in the wall structure, probably from the Ghaznavid period (Flury, 1925, p. PL.XV). Moreover, there were some undated *pish-shekli* pieces in the Mazār-e Niyāzabād, a village at east of Sangān-e Pāʾin close to the Afghanistan border, with floral and epigraphic patterns (now in the Khwāf Museum) (Figure 1.7).

On the other hand, the floral motifs of the Masʿud III Tower (1099 – 1115 AD) are created by *borida*, *tarāshida* and *pas-tarāshida* techniques, probably influenced by the Indian architecture. According to O'Kane (unpublished), the presence of normal face brick courses close to unfinished patterns (Pinder-Wilson, 2001, pp. figs 1-3) demonstrates using *pas-tarāshida* technique in this tower.

During the eleventh and the twelfth centuries up to the Mongol conquest, architects employed arranged, *borida* and *tarāshida* brickwork to decorate the façades of the minarets, mosques, mausoleums, caravansaries, tombs and towers in Iran, Afghanistan and Central Asia. In addition the mausoleums of Imam Dur (1058 AD) at Samarra and Setta Zubayda (or Zummurrud Khatun Tomb), built between 1179 and 1225 AD in Baghdad, are some examples in Iraq where the *borida* and *tarāshida* bricks are used to create geometric motifs.

In the second half of the twelfth and the early thirteenth centuries, the Great Khorāsān was divided between the Khwarazmshahids and the Ghurids while Transoxiana was in the hands of the Qarā-Khatāis. The brick-based architectural decorations in this period were continued based on pre-existing techniques with some local differences in details. The southern portal of the Maghāk-eʿAttari Mosque (1178 AD) in Bukhara bears Qarā-Khatāi brickwork decorations (S. Akiner, 1992). In this portal, besides the arranged, *borida* and *tarāshida* bricks, in the conch of the portal, there is a band of *pish-shekli* bricks containing geometric

patterns (Figure 2.24). These techniques are also employed at three Mausoleums (all are erected in a row) of Uzgen. The Āysha Bibi Mausoleum, attributed to the eleventh and the twelfth centuries, is another Qarā-Khatāi monument where *pish-shekli* bricks are extensively used to cover the façade of the building. However, Kervan (2002) introduces these ornaments as the thirteenth century decorations.

The brickwork of the Ghurid monuments show a close relation with the Ghaznavid architectural decorations. *Borida* and *tarāshida* brick elements are perfectly used in the Masjed-e Jāmeʿ-e Herat (Figures 1.8 and 1.9), two structures at Chisht, the Minaret of Jām and the Ṭāq-e Bost exhibiting floral, geometric and epigraphic patterns however the *pish-shekli* elements from Bost are also reported (Crane & Trousdale, 1972). Moreover, the brick-based embellishments of the Shaykh Sādan Shahīd Tomb (Flood, 2001) and the *mihrab* of Robāṭ-e ʿAli b. Karmākh (Edwards, 1991), the latter two in modern day Pakistan, are performed in *pas-tarāshida* technique.

Figure 1.8. Brickwork at the eastern cloister in the qibla *iwan of the Masjed-e Jāme'-e Herat (covered by new white colour)*

Figure 1.9. Eastern portal of the Masjed-e Jāme'-e Herat showing Ghurid ornamnets (brickwork and glazed inscription) and Timurid alterations.

The Il-Arsalān Mausoleum (or the Mausoleum of Fakhral-Din Razi) is a Khwārazmshāhid monument (Mamedov & Muradov, 2001, pp. 45-48) where the inscription frieze frames three blind pointed arches at the entrance façade (Figure 1.17). Moreover, the spandrels of blind arches, surrounded by a curved brick band, are adorned by floral motifs (Figure 1.10). Although both *pish-shekli* and *tarāshida* brick techniques are reported to create the epigraphic and floral patterns of the principal façade (Mamedov & Muradov, 2001, p. 45), it seems they are *pas-tarāshida* decorations (O'Kane, unpublished). In addition, the brick-based ornaments of the Takesh Mausoleum, another Khwārazmshāhid building (Mamedov & Muradov, 2001, pp. 63-70), include *borida* and arranged bricks combined with glazed tiles. However, the bead motif, carved on the upper side of the bricks (*tarāshida*), is also used in some brick courses and guard bands. Likewise, the

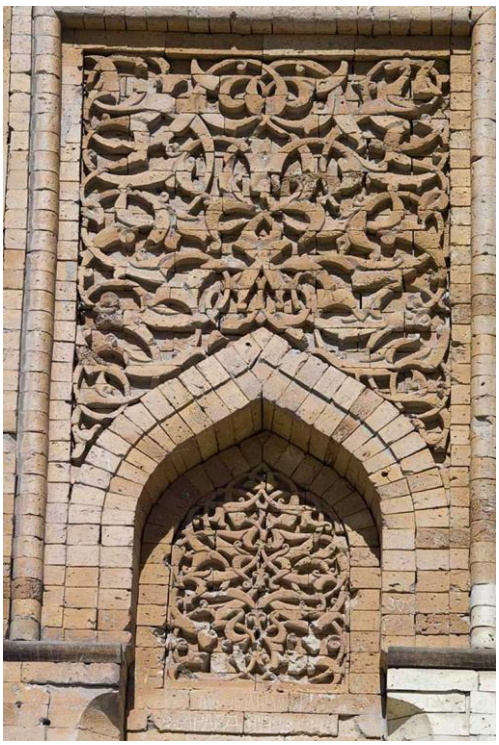


Figure 1.10. Details of floral decoraton, spandrels of the blind arches at Il-Arsalān Mausoleum (photo: Bernard O'Kane)

Figure 1.11. The Minaret of the Negār Mosque, near Bardsir, Kermān province (photo: Jafarzadeh)

remains of an *iwan* (or portal) of the Masjed-e Mohammad-e Khwārazmshāh (Blair, 1985), at Mashhad-e Mesriyān site, shows the floral and geometric patterns created by *borida* and *tarāshida* bricks. The decoration of this monument is similar to Ghurid monuments, e.g. the Minaret of Jam (1174 AD) and the eastern portal of the Masjed-e Jāmeʿ-e Herat (Figure 1.9). In addition, the Minaret of Negār (or Nigār) at Bardsir, dated to 1218 AD (Wilber, 1955; Hutt, 1970; Blair, 1985), is another Khwārazmshāhid monument. The brickwork of this minaret contain *borida* and arranged bricks with inlaid small square glazed decorations in some bounds.

The Masjed-e Jameʿ-e Gonābād and Zuzan Mosque, two dated Khārazmshāhid monument in Khorāsān, show two different styles in both brickwork and glazed ornaments, although *borida*, *tarāshida* and *pish-shekli* bricks are used to decorate the façades of these two monuments. The patterns and designs of the Masjed-e Jāmeʿ-e Gonābād have a close relation with those built in Iran (*e.g.* Borj-e Mihmandust and Robāṭ-e Sharaf), while the brickwork of the Zuzan mosque are heavily influenced by both Khwārazmshāhid monuments in north of Iran and Ghurid architectural decorations in Afghanistan.

1.2.2 Glazed decorations

First, it should be noted that instead of using the term "tile", the well-known term to describe glazed flat decorations, in this thesis other words terms such as glazed ornaments, glazed elements, *etc.* are used to avoid misunderstandings. The term tile (or *kāshi* in Persian) may bring to mind a glazed decoration with standard shape and thickness, for instance *haft rangi* or underglaze tiles while those employed in the studied period are different in shape, form and style and most of them are to be considered as inserted decorations.

As mentioned before, embellishing buildings with glazed objects was abandoned during the Parthian and the Sassanid periods. In Islamic Persia, this technique went into oblivion for centuries. Employing glazed objects (tiles, glazed bricks, *etc*.) in the Islamic architecture of Iran, from early evidence to those extensively covered façades of monuments, are comprehensively discussed (Wilber, 1939; Carboni & Masuya, 1993; Pickett, 1997). The first evidence of the use of tiles in Iran goes back to the 11th century although some earlier examples of using glazed tiles are reported from Iraq and Syria (Wilber, 1939). In addition, some manuscripts describe the glazed decorations used to cover surfaces of buildings and domes in Baghdad and Rayy (Pope & Ackerman, 1930, p. 1549). In Iran, it is difficult to give a certain date to the first example of appearing glazed decorations in buildings. Wilber (1939) and Adle (1982) dates the Minaret of Masjed-e Jāmeʿ-e Dāmghān to 1058 AD. Therefore, the glazed inscription of this minaret (Figure 1.12) can be the first architectural glazed ornaments. Nonetheles, O'Kane (1989)

suggests the first datable glazed elements in Iranian architecture are those of the 999 AD Masjed-e Jāmeʿ-e Naṭanz (Figure 1.13).

On the other hand, the Ṭāq-e Bost is assumed to be erected in 1009 AD (Pickett, 1997, pp. 24, 163) however Pickett (1997, p. 25) discusses about this suggested date and its authentic restoration. Moreover, some scholars assume the Maqbara-ye Khwāja Atābak at Kermān from the eleventh to the middle twelfth centuries, bearing the first glazed ornaments (Javadi, 2000; Javadi, 2003; Poorsafar & Ahmadpanah, 2006). In addition, Pickett (1997) gives the date ca. 1164 AD to this building although Khwāja Atābak, whose name is close to this monument, died in 1186 AD (Poorsafar & Ahmadpanah, 2006).

In the Masjed-e Jāmeʿ-e Isfahan, few *pish-shekli* epigraphic plaques (attributed to the twelfth century) are found whose curved surface of letters is covered by glaze (Godard, 1936). The similar element, *pish-shekli* plaque with glazed letters, is also found in the eleventh/twelfth century site at Nishābur (Wilkinson, 1987, p. 262 fig. 4.3) where some other glazed architectural ornamest were also unearthed (Wilkinson, 1987, pp. 1.6-1-8, 115-117). Moreover, excavations in Jorjān unearthed some glazed ornaments that are attributed to the eleventh century, among them the pieces of an inscription with glazed letters (Kiani, 1997). Interestingly, there are some glazed tiles in the Masjed-e Jājarm, one of them shows the date 1181 AD, although it seems they are not the original decoration of the mosque Yate (Yate, 1900, p. 387; Towḥidi, 1986).

Apart from the above-mentioned samples, the Minarets of Sin (1131 AD), Sārebān (1139 – 1155 AD), Gār (12th c.) and the Minaret of Masjed-e ʿAli in the province of Isfahan, three tombs of the Gonbad-e Sorkh (1147 AD), the Borj-e Modavvar (1168 AD) and the Gonbad-e Kabud (1197 AD) in the city of Marāgha, the Masjed-e Jāmeʿ-e Ardebil (1158 – 1160 AD) and the Se Gonbad Tomb at Orumiya (1184 AD) are some examples where glazed objects are used before the Khwārazmshāhid period in Iran.

The predominant colour, with which the glazed elements of pre-Khwārazmshāhid buildings were decorated, is turquoise although light-blue is also employed at some monuments. The Masjed-e Ḥeydariyya-ye Qazvin, a Seljuk monuments (Wilber, 1939) is an example where

Figure 1.12. The Minaret of Masjed-e Jāmeʿ-e Damghān, ca. 1058 AD

Figure 1.13. Glazed ornaments of the Masjed-e Jāmeʿ-e Naṭanz. 999 AD

Figure 1.14. Glazed ornaments and brickwork of the Minaret of Masjed-e ʿAli, Isfahan, 12th c.

Figure 1.15. Detail of the inscription of the Sin Minaret, 1131 AD., Sin, Isfahan Province

Figure 1.16. Decorations of the Minaret of Ziyār, east of Isfahan, 12th c.

less frequency of using both dark-blue and turquoise colours can be seen although although they are introduced as later additions by Sahebibazaz (2011). In addition, there are two structures at Sangān-e Bālā that Wilber (1937) attributes them to the second half of the eleventh century where the square glazed elements are embedded in arranged bricks (lozenge pattern with normal and *borida* bricks.)

Some above-mentioned Khwārazmshāhid monuments (see *1.2 Brickwork* section) show a gradual development of glazed decorations. Although it is reported (Wilber, 1939) that the dome of the Mausoleum of Sultan Sanjar was covered by glazed ornaments, the two Khwārazmshāhid mausoleums, i.e. the mausoleums of Il-Arsalān and Takesh, can be recorded as early examples where the glazed bricks are still *in situ*. In addition, on top of the drum of the dome in the Mausoleum of Takesh there is an inscription band, extensively destroyed, consisting of two rows of turquoise tiles (Figure 1.17 *right*). It is interesting to pay attention to the remains of these particular tiles that seem are made in an unusual manner. Instead of engraving the surface of wet body paste (or fired brick) or moulding the body to create the epigraphic pattern, in these samples, it is more appropriate to suggest adding an extra paste on the flat bulk body for lettering that were then cut into smaller square pieces to be glazed and fired. On top of this inscription frieze, there is a band including glazed bricks (*borida* or *pish-shekli*), installed in rowlock header course way, that are covered by turquoise and dark-blue glazes, alternatively (Figure 1.17 *right*). The same technique, however, is employed in the Zuzan Mosque; i.e., white and turquoise glazes at the *qibla iwan* and turquoise together with unglazed bricks at the eastern *iwan* (Figures 2.13, 2.19 and 2.23). Accordingly, in the Zuzan Mosque the third colour, white, have added to the palette of tile-maker to create the glazed embellishments; however, it seems that few inlaid white ornaments are also employed in the Takesh Mausoleum beside the blue and turquoise glazed elements. In the Masjed-e Jāmeʿ-e Gonābād, what remained of glazed decorations are some glazed hobnails at centre of *pish-shekli* brickwork elements and some small inset triangular pieces.

The other monuments built in the Khwārazmshāhid period are the portal of the Mashhad-e Mesriyan site and the Minaret of Negār (Figure 1.11). The architectural decorations of the portal at the Mashhad-e Mesriyan show a close relation with Ghurid monuments (e.g. glazed inscription, geometric and floral motifs, using *borida* bricks, *etc*.). On the other hand, the Minaret of Negār is closer to the architecture of central Iran (Figure 1.14-16) that may challenge the Blair's discussion (1985) about the similarity of its inscription with the Ghurid examples. It is interesting to note that the glazed patterns of the stems, letters and upper zones of the Negār inscription are *pish-shekli* pieces (Figure 1.18) while juxtaposing

the individual glazed elements has created the letters and patterns in the Ghurid glazed inscriptions (Figure 1.19). Moreover, the background of the inscription is simply decorated by arranged bricks. The other glazed ornaments of the Negār Minaret are diamond monochrome pieces that decorate the guard bands on the inscription frieze, receiving blue and turquoise glazes alternatively. Moreover, small square turquoise elements, occasionally inserted in arranged bricks, furnish the shaft of the minaret (Figure 1.11).

Figure 1.17. The Il-Arsalān Mausoleum, brickwork at the entrance façade and the glazed decorations of its dome (left) and the inscription and ornaments of the Takesh Mausoleum (right)

Figure 1.19. Details of the glazed iscription of the Negār Minaret (photo: Jafarzadeh)

Figure 1.18. Details of the glazed iscription and the tarāshida *bricks, Masjed-e jameʿ-e Herat*

Apart from the above-mentioned glazed decorations, another technique of glazing came from the pottery industry to be used for decorating the interiors of buildings from the early thirteenth century onwards, i.e. the lustre technique. The *mihrab* of the Imam Reza complex shrine (Motaghedi, 2012), some tiles found in Jorjān (Miri, 1977) and few fragments in the dado of the Abu Saʿid abi al-Kheir Mausoleum (Harrow, 2005) are some examples of this kind of decoration used to furnish the building during the Khwārazmshāhid period. The studies conducted on the history of lustre tiles show no evidence of using these tiles in the Khwārazmshāhid monuments of Khorāsān.

Table 1.1. Brickwork and glazed decorations of some monuments built before the Mongol Conquest [1] *(A: Arranged brick, B:* borida *T:* tarāshida *PT:* pas-tarāshida *PS:* pish-shekli *G: glazed ornamentss)*

Monument	Location	Date	A	B	T	PT	PS	G
Masjed-e Jāmeʿ-e Isfahan	Isfahan-Iran		×	×	-	-	-	-
Masjed-e Diggaron	Khazar, near Samarkand?	8th-11th c.	×	-	-	-	?	-
Tomb of Sāmānid	Bukhara-Uzbekistan	907 / 914-943	×	×	×	-	×	-
Masjed-e Jāmeʿ-e Nāʾin	Nāʾin-Iran	960	×	×	-	-	-	-
Jurjir Portal of Ḥakim Mosque	Isfahan-Iran	977-995	×	×	-	-	-	-
Mausoleum of Arab ʿatā	Turkmanistan	978	×	×	×	-	-	-
Arsalān Jāẕeb Maussoleum	Sang Bast-Iran	977-1026	×	×	-	-	-	-
Masjed-e Jameʿ-e Naṭanz	Naṭanz-Iran	999	?	×	?	-	-	×
Gonbad-e Qābus	Gonbad Qabus-Iran	1007	-	×	-	-	×	-
Mil-e Rādkān (Kordkuy)	Kordkuy-Iran	1016-1020	×	×	×	-	×	-
Robāṭ-e Māhi	On the road of Mashhad to Sarakhs-Iran	1019-1020?	×	×	-	-	-	-
Borj-e Lājim	Lājim-Iran	1022	×	×	×	-	-	-
Tomb Tower of Pir-e ʿalamdār	Dāmghān-Iran	1026-1029	×	×	×	-	-	-
Minaret of Tārikhāne Mosque	Dāmghān-Iran	1026-1029	×	-	-	-	-	-
Gonbad-e Chihl Dokhtarān	Dāmghān-Iran	1054-55	×	-	-	-	-	-
Gonbad-e Ali at Abargu	Abargu-Iran	1058	×	-	-	-	-	-
Madrasa-ye Neẓāmiya at Khargerd	Khwāf-Iran	1058/1068	×	×	-	-	×	-
Minaret of Masjed-e Jāmeʿ-e Dāmghān	Dāmghān-Iran	1058?	×	×	×	-	-	×
Masjed-e Tāberan-e Ṭus	Near Mashahd-Iran	11th century	×	-	-	-	-	-
Masjed-e Robāṭ-e Ziyārat	Near Khwāf -Iran	11th century	?	×	-	-	-	-
Borj-e Kharaqān (Eastern)	Qazvin-Iran	1067	×	×	×	-	-	-
Minaret of Masjed-e Pāmanār	Zavāreh-Iran	1068	×	×	-	-	-	-
Imam Dur Mausoleum	Samarra-Iraq	1085-86	×	×	-	-	-	-
Borj-e Kharaqān (Western)	Qazvin-Iran	1093	×	×	×	-	?	-
Borj-e Mihmāndust	Near Dāmghān-Iran	1097	×	×	×	-	-	-
Imamzāde Jaʿfar	Dāmghān-Iran	11th century	×	-	-	-	-	-

[1] The different given dates in references are separated by «/» and the question mark «?» is used for those with no certain evidence or the latter additions

Table 1.1 Continued

Monument	Location	Date	A	B	T	PT	PS	G
Robāṭ-e Malik	Between Sarakhs and Merv-Turkmenistan	Second Half of 11th c.	×	×	×	-	-	-
Minaret and Mosque of Barsiyān	Barsiyān-Iran	1098 and 1105	×	×	×	-	-	-
Dayakhatyn Caravanserai	Turkmenabat-Turkmenistan	11th/Early 12th c.	×	×	×	-	×	-
Palace of Masʿud Ghaznavi	Ghazna-Afghanistan	?	-	×	-	-	-	×
Mausoleum of Abu Saʿid	Mihna-Turkmenistan	Main Structure 11th c.	×	×	-	-	-	-
Tower of Masʿud III	Ghazna-Afghanistan	1099-1115	×	×	×	×	-	-
Masjed-e Jāmeʿ-e Golpāyegān	Golpāyegān-Iran	1105-1118	×	×	-	-	-	-
Borj-e Resket	Near Sāri-Iran	1106	×	×	×	-	-	-
Gonbad-e Davāzde Imam	Yazd-Iran	1106	×	×	-	-	-	-
Masjed-e Jāmeʿ-e Dāmghān	Dāmghān-Iran	1106	×	×	-	-	-	-
Minaret of Chehl Dokhtarān	Isfahan-Iran	1107	×	×	×	-	-	-
Minaret of Dowlatābād	Balkh-Afhanistan	1108	×	×	-	-	-	-
Minaret at Mashhad-e Meṣriyān	Dehistan-Turkmenistan	1108?	×	-	-	-	-	-
Minaret of Sāveh	Sāveh-Iran	1110	×	×	×	-	-	-
Mil-e Khosrowgerd	Sabzevār-Iran	1111	×	×	×	-	-	-
Mil-e Karāt	Near Tāybāad-Iran	11^{th}-12^{th} c.	×	×	-	-	-	-
Masjed-e Jāmeʿ-e Qazvin	Qazvin-Iran	1113-1115	×	×	-	-	-	×
Robāṭ-e Sharaf	Near Sarakhs-Iran	1114	×	×	×	-	-	-
Do Barār	Near Sarakhs-Iran	12^{th} c.	×	×	-	-	-	-
Namāzgah-e Bukhara	Bukhara-Usbekistan	1119	×	×	-	-	-	-
Mosque of Basṭām	Shāhrud-Iran	1120	×	×	-	-	-	-
Minaret of Gār	East of Isfahan-Iran	1121	×	×	×	-	-	-
Seljuk Portal of Masjed-e Jāmeʿ-e Isfahan	Isfahan-Iran	1121	×	×	×	-	-	-
Minaret of Sin	Sin- near Isfahan-Iran	1131-32	×	×	-	-	-	×
Masjed-e Jāmeʿ-e Zavāreh	Zavāreh-Iran	1136	×	×	×		×	?
Borj-e Ṭoghrol	Tehran-Iran	1139-40	×	×	-	-	-	-
Sārebān Minaret	Isfahan-Iran	1139-1155	×	×	-	-	-	×

Table 1.1 Continued

Monument	Location	Date	A	B	T	PT	PS	G
Gonbad-e Sorkh-e Marāgheh	Marāgheh-Iran	1147	×	×	-	-	-	×
Maqbara-ye Khwaja Atābak	Kermān-Iran	1100-1150	×	×	-	-	-	×
Mausoleom of Soltān Sanjar	Merv-Turkmenistan	1157	×	×	-	-	-	?
Masjed-e Jāmeʿ-e Ardebil	Ardebil-Iran	1158-60	×	×	-	-	-	×
Minaret of the Gaz Mosque	Near Isfahan-Iran	12th c.	×	×	-	-	-	-
Ziyār Minaret	East of Isfahan-Iran	12th c.	×	×	-	-	-	×
Minaret of Masjed-e ʿAli	Isfahan-Iran	12th c.	×	×	-	-	-	×
Madrasa-ye Shāhi Mashhad	Sar Pol-Afghanistan	1166	×	×	×	-	×	-
Ziyārat-e Bābā Ḥātam (or Sālār Khalil Tomb)	Mazār Sharif- Afghanistan	11th / 12th c.?	×	×	×	-	?	-
Gonbad-e Chisht (Eastern)	Bost-Afghanistan	1166	×	×	×	-	-	-
Borj-e Modavvar (Round Tower)	Marāgheh-Iran	1168	×	×	-	-	-	×
Minaret of Jām	Afghanistan	1174-75	×	×	×	-	×	×
Maghak-e 'Attari Mosque	Uzbekistan	1178-79	×	-	-	-	-	-
Masjed-e Jāmeʿ-e Ardestān	Ardestān-Iran	1180	×	×	??	-	-	-
Se Gonbad	Urmia-Iran	1184	×	×	?	-	-	×
Moʾmena Khātun Tomb Tower	Nakhchivan-Azerbaijan	1186-87	×	×	×	-	×	×
Vebkent Minaret	Near Bukhara- Usbekistan	1196	×	-	-	-	-	-
Gonbad-e Kabud	Marāgheh-Iran	1197	×	×	-	-	-	×
Ṭāq-e Bost	Bost-Afghanistan	Late 12th c.	-	×	×	-	-	?
Gonbad-e Chisht (Western)	Bost-Afghanistan	Late 12th c.	×	×	×	-	-	-
Sitta Zubayda Mausoleum	Baghdad-Iraq	Late 12th c.	×	×	×	-	-	-
Masjed-e Moḥammad-e Khwarazmshāh	Balkan Region-Turkmenistan	Early 13th c.	×	×	×	-	-	×
Musoleum of Takesh	Gorganj- Turkmenistan	1200	×	×	×	-	-	×
Il-Arsalān Mausoleum (or Mausoleum of Fakhr al-Din Rāzi)	Gorganj- Turkmenistan	12th c.	×	×	?	×	?	×
Borj-e Radkan-e Sharqi	Near Chanaran-Iran	1205 / 1280-1300	×	×	×	-	×	×
Masjed-e Jāmeʿ-e Herat	Herat-Afghanistan	1201 (Also 1498-9)	×	×	×	-	×	×
Anonymous Mausoleum	Bost-Afghanistan	12th-Early 13th c.	×	×	×	-	-	?

Table 1.1 Continued

Monument	Location	Date	A	B	T	PT	PS	G
Masjed-e Jāmeʿ-e Gonābād	Gonābād-Iran	1212	×	×	×	-	×	×
Robāṭ-e ʿAli b. Karmākh	Near Kabirwala-Pakistan	Late 12th c.	-	-	-	×	-	-
Tomb of Shaykh Sādan Shahīd	Multan-Pakistan	Late 12th c.	-	-	-	×	-	-
Masjed-e Zuzan	Near Khwāf-Iran	1218-1219	×	×	×	-	×	×
Tomb of Āysha Bibi		11th-Early 12th / 13th c.	×	×	×	-	×	

Chapter Two: Studied Monuments

Using the term *khorāsāni-ye do-iwani* style by Godard (1949, p. 250) to call the mosques of Gonābād, Zuzan and Farumad, constructed based on a two-*iwan* plan (Figure 2.1), caused these monuments, for decades, were known as the only Khwārazmshāhid monuments in Khorāsān (Sharifi & Rahnamay, 2007; Kharazmi, et al., 2013). Recent researches and excavations in some other mosques have brought new knowledge that changed the previous given dates to them. As a result, mosques of Sangān-e Pāʾin, Ferdows and Raqqa were also introduced by some scholars (Akbari, 1997; Labbaf Khaniki & Saber Moghaddam, 2006, pp. 38, 42, 44) as Khwārazmshāhid buildings. In addition, the Khosrowshir Mosque bears few *pish-shekli* brick-based ornaments, covered by a later stucco, similar to those in Farumad and Gonābād that can be studied as a building either built or decorated in the Khwārazmshāhid period. Hence, firstly, the brickwork and glazed objects of two dated Khwārazmshāhid mosques are described and the possibility of attributing the other mentioned monuments will then be discussed.

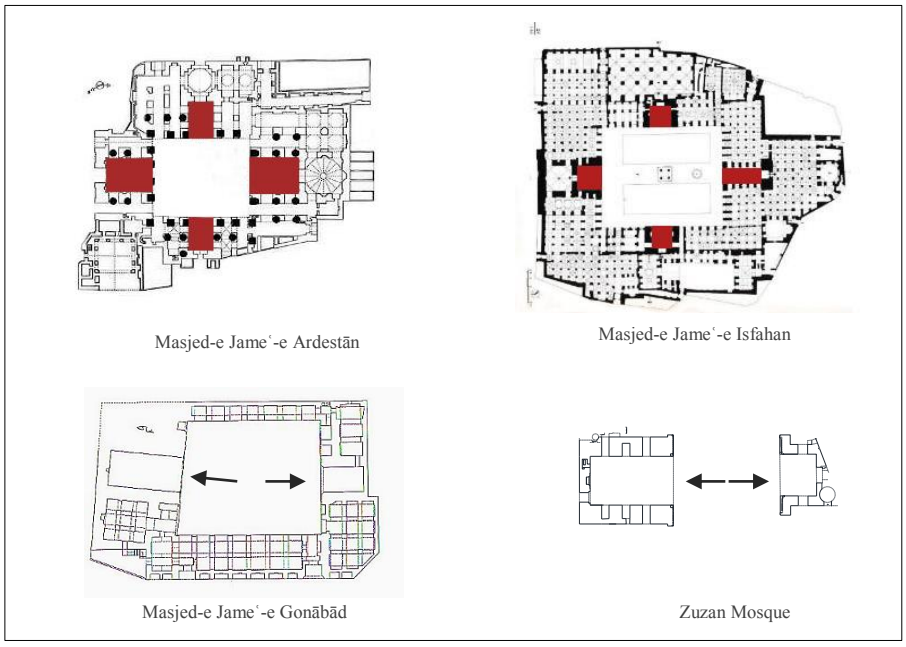


*Figure 2.1. Conversion from the Seljuk four-*iwan *(portico) plan to a two-*iwan *plan in the Khwārazmshahid period. (The scales are diffetent. All plans in this thesis are from Iran's Cultural Heritage, Handicrafts and Tourism Organization, ICHHTO.)*

2.1 Mosque of Gonābād

The city of Gonābād is situated about 270 km southwest of Mashhad, in Khorāsān-e Razavi. The Masjed-e Jāmeʿ-e Gonābād (Shahr), built in the Khwārazmshāhid period, consists of two *iwan*s (north-south oriented), arcades that run along east and west sides of courtyard, and, three hypostyle prayer hall at north-east (now as the Archaeological Museum of Gonābād), east and south-east of the mosque (Figure 2.1). Two cloisters at south-east and northeast corners of the courtyard are the entrances of the

mosque. The building was destroyed and renovated several times because of earthquakes occurred over centuries although Zamani (1970) believes the renovations have not altered the main plan and structure of the mosque. Evidences of an extensive earthquake damage can be seen in the façade's decorative elements of the courtyard proving the brickwork were the predominant ornaments while stucco and glazed elements were also used to furnish the mosque. The half-octagonal *mihrab*, created by moulded panels in the southern *iwan* (*qibla*) and a frieze at the edge of this *iwan*, two spandrel at the transition zone of half-dome in the northern *iwan*, the frieze of the northeast portal and the remains of a new-found *mihrab* at the northeast prayer hall are the stucco decorations of the mosque. The façade of the main *iwan* (*qibla*) (extensively renovated), along the south side of the court (Figure 2.2), consists of two decorative bands with *borida* bricks, a Kufic inscription and a geometric patterned frieze that frame the façade of the *iwan*. The final words of the inscription (at the east side of the *iwan*) show the date 1212 AD (609 A.H.) that was first read and published by Godard (1949). Moreover, there are two decorative columns, with geometric pattern brickwork, at the edges of the *iwan*'s walls.

Figure 2.2. A view of the qibla iwan *of the Gonābād Mosque (left) and the details of its decorations (inscription, geometric frieze and decorative column) at the east side of the façade (right).*

Moreover, there are two other inscription panels on the interior walls of this *iwan*, bordered by *tarāshida* bricks, different from the inscription of the *iwan*'s façade in design and details. In addition, there is another Kufic inscription on the soffit of a vault at the south-eastern prayer hall that has been covered by a latter vault during the renovations (Figure 2.3). This inscription, which seems to be similar with the *iwan*'s façade one in design, has been attributed to the Seljuk period by some scholars despite the lack of any discussion (Mojtabavi, 1995, p. 155; Labbaf Khaniki, 2004, p. 35).

Figure 2.3. The location (left) and details (right) of the inscription at the south-eastern prayer hall

As mentioned previously, the brickwork were employed to decorate the façades of the north, east and west sides of the courtyard. It is quite interesting to pay attention to the technical differences of the brickwork between the southern façade of the courtyard and the other sides, where the remains of ornaments show majority of *pish-shekli* and arranged bricks cover the surfaces, instead of *borida* bricks that are used on the façade of the *qibla iwan*. As few pieces of these ornaments have survived and a previous intervention clearly shows some of these elements are inserted in wrong places, it is difficult to know the exact location of the original *pish-shekli* decorations. Nonetheless, according to old documents available (Zamani, 1970), the spandrel of the northern *iwan* had been decorated by square *pish-shekli* bricks on which the same geometric pattern of the frieze at the *qibla iwan* was created. In addition, the remains of decorations (if they are the original decorations) demonstrate that *pish-shekli* bricks, with triangular and square shapes, were employed to adorn the façade of this *iwan*, where the surface of each side (flank) bears square and rectangular panels alternatively (Figure 2.4 *left*). The rectangular panels of the façade contain blind pointed arches, different in ornaments. The surfaces of the arcades on two lowers panels show special arranged brick decorations but these parts at upper panels are completely destroyed (Figure 2.4).

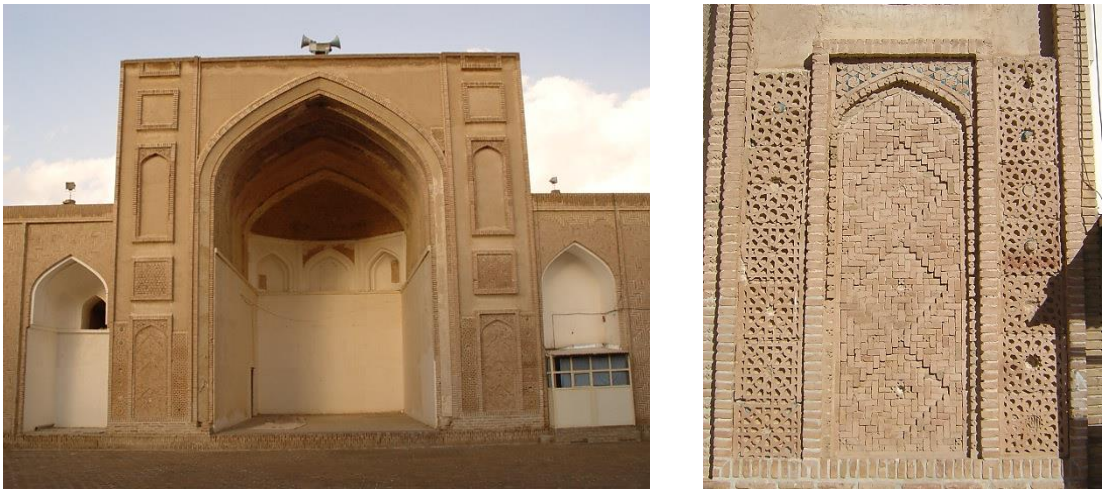


Figure 2.4. The general view of the north iwan *with square and rectangular panels (left, photo:N. Eftekhari) and details of its decorations at lower part of the eastern wall at the Masjed-e Gonābād*

In addition, lozenge (borida) and simple carved hexagonal (*tarāshida* or *pish-shekli*) bricks (Figures 2.4 right, 2.5, 2.6) furnish the spandrels of lower panels, while a geometric patterns, created on triangular *pish-shekli* bricks, decorate the spandrels of the upper panels (Figure 2.6). Furthermore, the same triangular *pish-shekli* bricks adorn one of the square panels at the east side of the façade, but the same panel at west side is furnished by the above-mentioned lozenge and hexagonal bricks, and, the decorative elements of other square panels have now vanished (Figure 2.4 *left*, 2.6). The other interesting decorations of the façade of the north *iwan* are small glazed triangular pieces that are cut and inserted between brickwork at the spandrel of the lower rectangular panel in the east side of the façade (Figures 2.4 *right*, 2.5, 2.6) although there is no evidence of using these glazed ornaments at other parts where the same brickwork are employed.

Figure 2.5. The lozenge and hexagonal bricks and the inset triangular glazed ornaments at spandrel of the blind arch (the eastern façade of the north iwan*)*

Furthermore, the decorative elements remaining *in situ* show two bands, enclosing the panels, that frame all the façade of the *iwan* with square *pish-shekli* bricks with a round perforated hole at the midpoint of each brick (Figures 2.4 and 2.6). Each band features a special geometric motif, hence, a twelve-pointed star design at the centre of bricks in outer band (from the *iwan*'s centre) while the bricks of the inner frieze contain a smaller eight-pointed central star. In addition, a circular glazed curved elements (hobnail shape), that depending on the size of the stars and the round perforated holes have different diameters, adorn the central stars in both friezes (Figure 2.4 *right*) with two exceptions. First, those at the beginning of the outer band (one brick at each side) that the stars are decorated by a engraved inscription (Allah, الله) instead of a glazed hobnail in a perforated hole (Figure 2.7 *left*). The lower brick of the inner band in the east side of the façade is the second anomaly, the most interesting brickwork element of the mosque, on which the centre of brick is not perforated and a turquoise glaze covers inside the central star and even some other motifs (Figure 2.7 *left*).

Figure 2.6. The square and rectangular panels at the eastern façade of the north iwan

Figure 2.7. The different decorations (inscription and glazing) of the central stars on some pish-shekli bricks comparing with those adorned by glazed hobnail, (the façade of the north iwan of the Masjed-e Jameʿ-e Gonābād)

On the eastern and western sides of the courtyard, *pish-shekli* bricks together with glazed hobnails are used to decorate the arcades. Here, again, the glazed elements (similar with outer band of the north *iwan* in size) adorn the stars of a different geometric pattern that created on rectangular bricks instead of square bricks that are employed at the north *iwan* (Figure 2.8).

Apart from the above-mentioned differences of architectural ornaments between *qibla iwan* and other sides of courtyard, there are also some architectural distinctions in the building. There are the remains of two minarets on top of the northern *iwan* alike what were common during the Il-khānid period (1258 – 1336 AD). In addition, the traces of decorative pillars at the edge of the northern *iwan* (most probably similar to those at *qibla iwan*) demonstrate that the mosque has received some changes during the centuries. In addition, covering the above-mentioned inscription at the south-eastern prayer hall and the remains of a *mihrab* executed in stucco at the north-eastern prayer hall are other remarkable examples of altering the building.

As a result of this evidence (distinctions in decorations and structure), it is clear that earthquakes and renovations brought changes to the mosque. Tābanda (1969, pp. 57, 161), who suggests Amir ʻAbd-allah-e Tuni as founder of the Masjed-e Gonābād (Tābanda, 1969, pp. 57, 161), gives some accounts of the strong earthquakes occurred in 1237, 1678 and 1968 AD in Gonābād (Tābanda, 1969, pp. 34, 97). Moreover, Labbaf Khaniki (2004, pp. 35, 45) believes the year 1212 AD, given in the inscription of the façade of the *qibla iwan*, is the date of renovating a Seljuk structure. There are also evidences of some interventions and additions during the Il-khānid period (1258 – 1336 AD) (Labbaf Khaniki & Saber Moghaddam, 2006, p. 32). The *mihrab* at the north-eastern prayer hall, covered by the pillar of the later vault, is attributed to the Il-Khānid period. The Geometric patterns of this *mihrab*, executed in stucco, contain a motif similar to those square *pish-shekli* bricks with glazed hobnails on the façade of the northern *iwan* (outer band). In addition, the stucco decorations of the north-eastern entrance are most probably created in the Qajar period (Akbari, 1997).

Figure 2.8. The pish-shekli *bricks of the eastern side of the courtyard and their central glazed hobnails at the Gonābād mosque*

Using these techniques for creating the decorative elements of the *qibla iwan* was employed to adorn a number of monuments built before 1212 AD (*e.g.*, Robāt Sharaf, Arsalān Jāzeb Tomb, Dowlatābād Minaret, Mil-e Karāt, *etc*.). In addition, at this time, architects were familiar with the motifs on *pish-shekli* bricks. The closest example in design is the Ghurid portal of the Masjed-e Jame'-e Herat (1201 AD), where the glazed hobnails (or bosses) and brickwork decorate the interior walls of the portal. However, the decorations of these two buildings are technically different. At the mosque of Gonābād, the motifs are made of the *pish-shekli* bricks (Figures 2.4 *right*, 2.7 *right and 2*.8) while the *borida* bricks create those at Herat (Figure 2.9). Moreover, the glazed elements of the Ghurid portal are hollow; somewhat like an upside down pottery cup or small jar, but those at the mosque of Gonābād are solid hobnails (Figures 2.9 and 2.10).

Figure 2.9. The geometric patterns combined with glazed hobnails at Ghurid portal of Masjed-e Jāmeʻ-e Herat

Excavations in Nishābur, made by The Metropolitan Museum of Art in 1930s, unearthed some brick-based architectural ornaments at 11th/12th centuries sites (Wilkinson, 1987) that have a close relation with those of the Gonābād Mosque. The same technique of adorning the *qibla iwan* (frieze and decorative pillars) of the Gonābād Mosque was discovered from the Bazaar Tepe (Wilkinson, 1987, pp. 98, 99 and fig. 1.74). Moreover, *pish-shekli* bricks with geometric patterns were found at Tepe Madrasah, whose motifs were also painted with red and blue colours (Wilkinson, 1987, figs. 1 and 1.84). Furthermore, brick-based ornamental bosses with different shapes and design were also unearthed at Tepe Madrasah: one of which decorated by carving, the other bears turquoise-glazed inlays and another is carved and painted (Wilkinson, 1987, figs. 1.76, 1.79 and 1.81). In addition, using the inscription at the central star of the geometric pattern in the Dowlatābād Minaret is an example of employing this technique before 1212 AD (Sourdel-Thomine, 1953, PL.XIX, PL.XX).

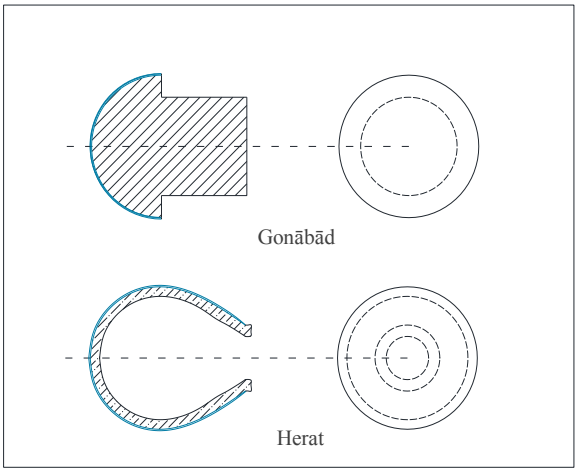


Figure 2.10. The schematc difference of the hobnails of the Gonābād mosque with the Herat mosque

2.2 Mosque of Zuzan

The remains of two *iwan*s (34°21'20.0"N 59°52'38.1"E) are the standing remnants of Zuzan, a medieval city of Khorāsān, among the ruins of the old city. Today Zuzan is a village located some 33 km (direct line) southwest of Khwāf. The importance of Zuzan up until the middle of the thirteenth century, especially before the Mongol conquest, is discussed comprehensively (Le Strange, 1905; Arab Zuzani, 2004; Adle, 2008; Khosh Ahang, 2009). The semi-ruined *iwan*s of Zuzan (Figure 2.1), oriented west-east, were first introduced by Godard (1949) as remnant of a mosque constructed in 1219 AD (according to an inscription at back wall of west *iwan*) based on the two-*iwan* plan. However, in a report for the official register of Persian national monuments, the date 1213 AD is recorded for this building (ICHHTO, 1940) that was then repeated by Kiani (1989, p. 11). Blair (1985) confirmed Godard's dating and read another inscription, a Kufic on the façade of the *qibla* (west) *iwan*, containing the date June 1218 AD Moreover, she brought to the notice that the edifice at Zuzan was a Hanafite Madrasa because of the context of the inscription on the back wall of *qibla iwan* and the orientation of building. Adle (1988; 1988; 2008) believes that it was constructed for both mosque and madrasa purposes. Excavations at this site, carried out by Labbaf Khaniki (1999), unearthed the remains of some structures around and inside the *qibla iwan* (Figure 2.11 *left*) and a number of decorative elements including an almost entire *mihrab*, executed in stucco with painted ornaments, behind the north wall of the *qibla iwan*, and also a lot of brick-based and glazed elements. Labbaf Khaniki (1999) uses the term Masjed-e Jame'-e Zuzan to name this site. The use of some brick-based decorative elements (*pish-shekli*) in brick courses of the standing structure, as normal structural brick, caused to attribute these kind of decoration to the earlier constructions (mosques) that either were destroyed before 1218 AD, or were demolished deliberately to build the present mosque.

Figure 2.11. The unearthed structures at the south of the qibla iwan *(left) and some found decorative elements (right) of the Zuzan mosque*

Overlooking different purposes attributed to this site, the dates of inscriptions enabled scholars to place the building in the reign of 'Alā al-Din Mohammad Khwārazmshāh (1200-20 AD). At this time, Malik of Zuzan (Qavām al-Din Mo'ayyed al-Molk Abu Bakr Ibn Ali Zuzani), the governor of Zuzan (known as the founder of the monument), ruled a vast territory from south of Khorāsān to Oman (Godard, 1949; Blair, 1985; Adle, 1988; Arab Zuzani, 2004; Khosh Ahang, 2009). According to Adle (1988), the semi-ruined *iwan*s are parts of an unfinished mosque-madrasa that was not completed because of the death of the Malik of Zuzan in 1218 or 1219 AD. Labbaf Khaniki (1999) confirmed this and gives some more details about the plan of the building (arcades, entrances, *etc*.). Here, at Zuzan, again like Gonābād, an earthquak was the main reason for the monument's ruin. Berberian (2014, pp. 209-211), according to Majd al-Din Khwāfi (who wrote a book in 1342 AD), gives the details of two strong earthquakes that occurred in October (19th and 21st) 1336 AD at Zuzan district that ruined Zuzan and Jizd:

> *"As with city of Jizd, the city of Zuzan was completely destroyed. Including the palace of Ghiyath al-Din Firuz, the Lord of Zuzan (he died under the collapsed debris.... The only remaining structure was the badley damaged (with collapsed parts of walls and the main vault) Hanafite mosque and School/College of Zuzan built in 1218 AD"* (Berberian, 2014, p. 210)

Although the earthquake affected both the structure and architectural decorations of the mosque, remnants of glazed ornaments on the end wall of the *qibla* iwan show a development of glaze working of pre-Mongol architecture in Khorāsān. The restorations accomplished by the ICHHTO, during recent decades, have been focused on keeping the structures and remnants of the decorations by rebuilding some parts of walls and enclosing the decorations with gypsum plaster.

Disregarding the materials of which the architectural decorations of Zuzan are made, they can be grouped into two main categories. The first group comprises of those employed to decorate the present building, both in situ and similar fallen down elements. Another architectural ornament group includes the decorative elements found during excavations that there is no evidence of their use on the standing structures. The predominant ornaments of the building are brick-based and glazed elements. However, the above-mentioned *mihrab*, attributed to the Seljuk period (Labbaf Khaniki, 1999), and those on remained soffit parts of vaults (ribs) at the *qibla iwan* are the stucco decorations of this site.

As it can be seen in Figure 2.12 ***a***, at the east *iwān*, three friezes frame the façade. The outer one is a concave band containing the geometric patterns made of *borida* bricks and embedded glazed elements (Figure 2.12 ***b***). Furthermore, placing sideway the *tarāshida* bricks, with a grooved decoration, at the middle frieze creates a large Kufic inscription band (Figure 2.12 ***c***). Moreover, the background of this band is furnished by small *tarāshida* pieces and a narrow border of *tarāshida* brick surrounds the

inscription. In addition, it seems that the inner frieze is decorated by *borida* bricks and embedded glazed elements although only some traces remain.

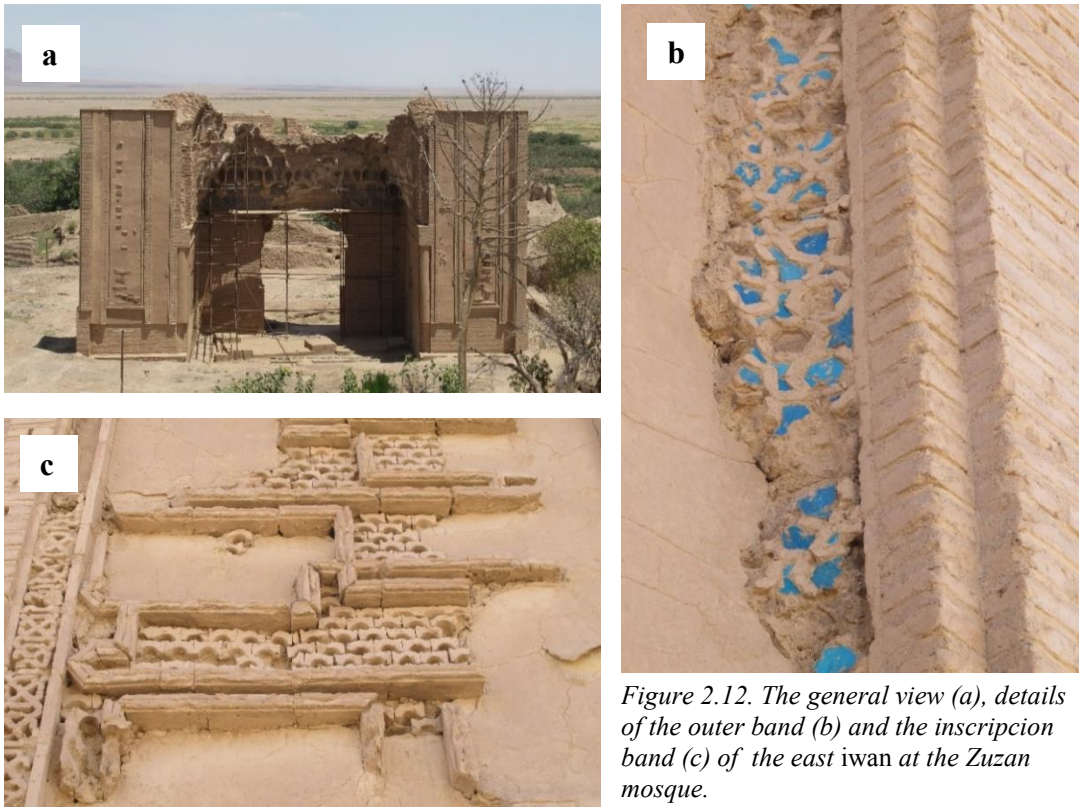


Figure 2.12. The general view (a), details of the outer band (b) and the inscripcion band (c) of the east iwan *at the Zuzan mosque.*

The semi-dome of the east *iwan* is constructed of *muqarnas* ('stalactite vault') where glazed and unglazed *borida* bricks cover the surfaces of tiers (Figures 2.12 **a** and 2.13). In addition, on top of the walls, where the *muqarnas* started, alternatively glazed and unglazed half-bricks create a rowlock header course band (Figure 2.13 *left*). Moreover, on the first row of *muqarnas* (tier) some glazed bricks with curve grooved decoration, like those in the inscription of exterior of the *iwan*, are used as intermediate elements to start the cells of *muqarnas* (Figure 2.13 *left*). The most interesting decorative components of the *muqarnas* are *borida* and engraved bricks that cover the roof parts of some cells. These *borida* bricks, according to the arch of cells, are cut and small squares are then carved on the rest of brick. Finally, the engraved squares are filled by inlaid thin glazed elements (Figure 2.13 *right*).

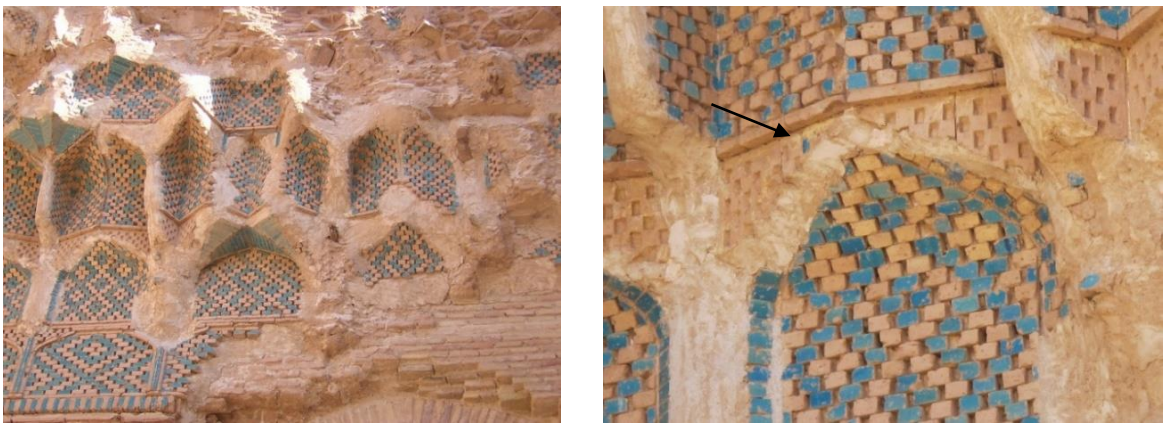
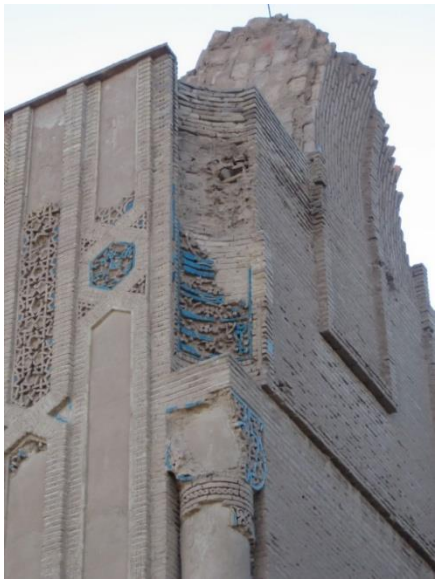


Figure 2.13. The decorations of the muqarnas' *tiers (left) and the detils of carved squares to inlaid glazed ornaments (right), the east* iwan *of the Zuzan mosque*


Figure 2.14. General view of the qibla iwan *(left) and the interlacing bands, vertical sections and the decorations of the compartments on the façade of the* qibla iwan *(right) at the Zuzan mosque.*

Figure 2.15. The decorations of the qibla iwan*'s façade at the Zuzan mosque (photo: Bernard O'Kane)*



In the *qibla iwan* (Figure 2.14 *left*), the façade is divided by interlacing bands (with *tarāshide* decoration on half-brick) where geometric, floral and epigraphic patterns fill the created geometric compartments. As a result, the exterior of each side at the *qibla iwan* is separated into four vertical sections, including the inscription frieze and decorative panels (Figures 2.14-16). The geometric decorations created by both *borida* bricks (with some embedded glazed objects) and combination of glazed and unglazed *borida* bricks are the ornaments of oblong panels (Figures 2.14 right and 2.15). Two different decorations fill the hexagonal panels; those at the inner vertical sections contain a glazed Kufic inscription (the name of architect or designer at the north wall) (Figures 2.14 *right*) while floral motifs (*borida* bricks with some inserted glazed decorations) furnish the panels of other sections (Figure 2.15). The wider section of the façade is the Kufic inscription, surrounded by a narrow border of geometric motifs (like the inscription of the east *iwan* but different in design) (Figures 2.14-16). Here, the *borida* bricks are employed to produce all the letters and the floral patterns (on upper tier of the inscription) together with the small circular and triangular borida bricks that adorn the background (deeper than the level of the letters). In addition, some embedded glazed elements are used to decorate the inscription.

As it can be ssen in Figure 2.16, the decorative columns at the edge of the *iwan* show the traces of floral and geometric patterns that are created by *borida* bricks together with few *tarāshida* elements. Moreover, the glazed *borida* bricks are also employed at its capital. On top of the columns, there are the remains of a *tholth* inscription with glazed letters and an unglazed floral motif background (Figure 2.16).

Figure 2.16. The decorative column at the southern edge of the qibla iwan *and the remnants of the* tholth *inscription*

It is interesting to pay attention to the technique of the glazed elements on the façade of the *qibla iwan* in which both cut and preformed (*pish-shekli*) shapes were used (Figures 2.14-16 and 2.21). Here, the letters of the *tholth* inscription, those employed to create the patterns and most of insets elements were glazed after forming the body, however, there are some glazed elements that were cut after glazing process to be embedded between the brickwork patterns.

Although there is no any evidence of architectural decoration on the north and south walls of the *qibla iwan* (either ruined by earthquakes or unembellished due to leaving the building incomplete), the most interesting architectural decorations at Zuzan appear on the back wall of this *iwan*, where using three turquoise, dark-blue and white glazes shows the development of pre-Mongol tile-working in Khorāsān (Figure 2.17 and 2.20). The applied decorations include three main rows of which almost nothing remained from the upper one. In addition, the inscription that frames the two rows (upper and middle) is destroyed and only the final words, on the vertical part close to the south wall, have remained of the date 1219 AD. Blair (1985) describes (in two different paragraphs of her article) the rest of embellishments as follow:

> *"Measuring approximately thirteen by five meters and executed in light-blue glazed bricks set against a plain reddish-brick ground, the [middle] band is divided into three zones: in the lower zone are the bodies of Kufic letters; in the middle zone the stems of letters braided with hexagrams inserted in the interstices; in the upper zone alternating keyhole and segmented arches decorated with delicate cut stucco growing out of the interlacing below."*

> *"All three parts of the epigraphic band across the south [west] iwan (letters, interlacing, and arcading) are done in light-blue glazed brick [curved surface]. Inserted into the interlacing are white pentagrams and dark-blue hexagons. Guard bands are composed of rectangles of alternating white and light-blue glazed bricks. Below, a row of thirteen roundels encloses decorative patterns in plain and light-blue glazed brick. The central roundel in light-blue glazed brick has an interlaced pentagram, the name Muhammad repeated five times in a circle around the central word, Allah."*

It should be noted that Blair (1985) uses light-blue instead of turquoise (which is used in this thesis) to distinguish the colours. Moreover, at the middle row that contains Kufic inscription, the stars created in interlacing zone are six-pointed stars (not pentagrams) that, as she says, are filled by preformed (*pish-shekli*) white tiles (Figure 2.17 *right*). In addition, the floral decorations of the upper zone, on the background of the arches, are not stucco ornaments but are executed in *borida* bricks (Figure 2.18). However,

Figure 2.17. The decorations of the back wall of the qibla iwan (left) and the details of the middle (stems) and lower (letters) zones of its inscription (right)

Figure 2.18. The alternating keyhole and segmented arches in the upper zone of the inscription on the back wall of the qibla iwan

Figure 2.19. Applying dark-blue glaze on imbrication desings on a brick (inscription row of the back wall of the qibla iwan*)*

some details can be added to her description of the middle row. The glazed (dark-blue) and unglazed elements with special curved shapes (fish scale or imbrication form) adorn the background of the Kufic letters' zone (Figure 2.17 *right*). Likewise, on the upper zone, this kind of embellishment is employed to fill the space between alternating arches, some of them with turquoise glaze (Figure 2.18). In some cases, on both zones, the imbrication design is grooved on the face side of one brick and the dark-blue glaze is then applied on the imbrications alternately (Figure 2.19).

At the lower row of the back wall of *iwan*, contains roundel decorations (medallions), employing ornamental elements with white and turquoise glazes demonstrate that, interestingly, juxtaposing two different glazes on one body re-started at the Mosque of Zuzan after centuries. The guard bands of roundels, with the exception of the central one, are composed of small square pieces with a U-form design on which two glazes, separated by grooving the surface, are applied (Figure 2.20 *right*). Likewise, the same band divides the panel of roundels into three compartments, a square (framing the central roundel) and two rectangulars at its left and right hands. Furthermore, at the corners of the rectangular compartments, the cut pieces of some bichrome glazed elements constitute the geometric patterns of pendentives with embedded turquoise tiles (Figure 2.20 *right*). These glazed elements are created by three glazed strips, two white and one turquoise at the middle, that are applied along the face side of the brick, separated by a groove (Figure 2.20 *right*).

As far as the architectural decorations are concerned, although the influence of Ghurid architecture in the inscriptions and motifs are well-discussed by scholars (Blair, 1985; Adle, 1988; Pickett, 1997), almost nothing is

Figure 2.20. The roundel decorations at the lower row of the back wall of the qibla iwan *(left) and details of bichrome glazed ornaments of this row (right)*

given about the embedded glazed elements and the decorations of the *muqarnas* of the east *iwan*. Comparing the inserted glazed ornamets, between the geometric (and less frequent floral) patterns, on the façades of the *iwan*s of the Zuzan mosque with those found at Nishābur excavations (Wilkinson, 1987, figs. 1.6 and 1.90-1.94) demonstrates a close relation (form, shape and technique) between the ornaments of these two sites . Furthermore, this technique is employed, with less variety of shapes, on the façade of the main portal of the Madrasa-ye Shāhi Mashhad (1166 AD) (Casimir & Glatze, 1971, figs. 9-11) although there is no evidence of the use of this kind of decoration in the other Ghurid monuments.

One example of employing *Muqarna*s in the Khwārazmshāhid period are those at the drum (with inlaid glazed pieces at the edge of its cells) and semi-dome of the portal at the Takesh Mausoleum. Moreover, glazed bricks (cut or normal size) in brick courses, similar to *muqarnas* at the east *iwan* of the Zuzan mosque appeared in the mausoleums of Il-Arsalān where these decorations cover the surfaces of domes and also some bands on the top of its drum (Figure 1.17 *left*). Nonetheless, the inlaid square glazed elements, used in the east *iwan* of the Zuzan mosque, are not employed in any of Ghurid or other Khwārazmshāhid monuments.

As mentioned before, apart from the above-described ornaments of the Zuzan mosque, a number of decorative elements were found during excavations without any evidence of the use on the standing structures that are attributed to destroyed pre-Khwārazmshahid buildings at Zuzan site (Labbaf Khaniki, 1999). The *pish-shekli* elements (different in shape and size), on which the epigraphic and floral motifs are deeply carved, are the majority of found elements at the Zuzan site. Furthermore, there are some individual letters of an inscription executed in *pish-shekli* brick (or terracotta), found inside the *qibla iwan*. The published photo photo of some *pish-shekli* ornaments of the Zuzan site by Adle (Adle, 1988, figs. 4, 5, 7 and 8) shows some decorative elements found in the *qibla iwan*. The fig. 7 (Adle, 1988) presents the *pish-shekli* pieces with geometric motifs that juxtaposing four pieces of these elements create a central star pattern with the round perforated hole. These elements are exactly similar to those at the spandrel of the *qibla iwan* at the Masjed-e Sangān and create the same patten of those at the east and west sides of the courtyard of the Gonābād mosque. Nevertheless, the samples of Zuzan, according to Adle (1988), were also decorated with painting in such a way that above-mentioned examples from Nishābur (Wilkinson, 1987, figs. 1 and 1.84) were adorned.

In addition, among the glazed decorations of the Zuzan site, beside the flat glazed ornaments with different shape, size and thickness (*pish-shekli* bodies and cut elements, Figure 2.21), there are fragments of turquoise monochrome elements with relief motifs (Figure 2.22 *right*). These elements are similar to those found at Nishābur (Wilkinson, 1987, figs. 1.112-1.116) and the inscription of the southern portal of the Moghāk-e ʻAttāri Mosque (Figure 2.22 *left*) (both attributed to the 11th/12th centuries). Therfore they can be recognised as parts of an inscription belonging to the pre-Khwārazmshāhid mosques at Zuzan.

Figure 2.21. The pish-shekli *(left) and cut bodies of the glazed ornaments at the Zuzan site*

Figure 2.22. The glazed inscription and brickwork at the southern portal of the Maghāk-e ʿAttari Mosque (left, photo: Bernard O'Kane) and glazed ornaments with relief decoration found in the Zuzan site (right)

Moreover, there are some bichrome elements (Figure 2.23, *right column*) manufactured in such way, similar in glazing but different in shape, of those at the lower row of the back wall of the *qibla iwan* (Figure 2.22 *right*), definitely contemporary with *in situ* examples. The other bichrome example at Zuzan is a fragment of a panel containing an inscription on which the letters are covered by a white glaze while the glaze used on background (with floral motif) is turquoise in colour (Figure 2.23). Bearing two coloured glazes, it can be ascribed to the same time as other bichrome examples of the Zuzan although nothing of the rest of the inscription was found.

Figure 2.23. The bichrome inscription and pish-shekli *elements found in the Zuzan mosque*

2.3 Farumad Mosque

Farumad (or Faryumad), the old (14th century) capital city of Jovayn district of Khorāssan (Le Strange, 1905, p. 392), is located in the northeast of the province of Semnān (36°30'47.5"N 56°45'00.8"E), very close (some 5 km) to today's border of Khorāsān. As mentioned before, Godard (1949, pp. 250, 256-282) introduced the mosque of Farumad (Figure 2.24) as an edifice built in 12th/13th centuries in so-called "*Khorāsāni-ye Do-iwani*" style because of its similarity with Mosque of Zuzan and Masjed-e Jāmeʿ-e Gonābād. However, the Report of Persian National Monuments shows the date thirteenth century, recorded for the Mosque of Farumad (ICHHTO, 1942). Accordingly, some scholars have gone along with Godard's dating the mosque to the Khwārazmshāhid period (Akbari, 1997; Labbaf Khaniki & Saber Moqaddam, 2006, p. 14; Sharifi & Rahnamay, 2007; Kharazmi, et al., 2013). Nonetheless, Picket records the date ca. 1150 AD for the Masjed-e Jāmeʿ-e Farumad with no discussion (Pickett, 1997, p. 24).

Wilber (1955, pp. 108, 168-169) lists the building as Il-khānid memorial with a Seljuk core, at the south part of the present mosque, that was renovated completely in which the north-eastern structurs and the present decorations were added in circa 1320 AD. In addition, the similarity of its ornaments with some il-khānid building is discussed by Adle (1999) and Shekofteh (2013) claims that the inscription of

Figure 2.24. The Farumad mosque from the east

mihrab, executed in stucco at *qibla iwan*, is an il-khānid ornament. Furthermore, Hoseini (2006) attributes the mosque of Farumad to 1309-1311 AD because of context of some inscriptions that place the building in the reign of Soltān Mohammad Khoda Bande (Oljāytu), when he was a Shiite. From an architectural view, she also believes that both *iwan*s, arcades and decorations were added to a small Seljuk mosque, present at south corner of courtyard, in the early fortheenth century. Nonetheless, the calligraphy of the *tholth* inscriptions in Farumad, especially ending the letters, are close to those at Shāhi Mshhad Madrasa (1166 AD) (Casimir & Glatze, 1971, figs. 33-34; Habibi, 1976, p. 34 'Aks-e Dahom) and the Ghurid Mausoleum of Ghiyath al-Din at Herat (Melikian Chirvani, 1970, PLATE IX), that may challenge Hoseini's comments.

The small square mosque of Farumad consist of two *iwan*s (southwest-northeast), two *iwancha*s ('small portico') at the north side of each *iwan* and the remains of arcades at northwest and southeath sides of courtyard. Besides, there is a prayer hall at the south of *qibla iwan* and the portal of mosque, through a cloister at right hand (south) of the north-eastern *iwan*, opens to the courtyard. Therefore, the cloister and entrance to the prayer hall resuled in two arches at the south of the *iwan*s in the courtyard, alike those at the opposite side (*iwancha*s). In addition, on top of these four small arches, continuing the wall (ca. three meters) along the *iwan*s, is a decorative second storey toward the courtyard, including two blind arches, at north and south of each *iwan* (Figures 2.24, 2.26 *left* and 2.27 *left*). The blind arches at the *qibla* side are trefoil arches (Figure 2.26 *left*) while those on the opposite side are created by triangle arch (Figure 2.27 *left*). Some parts of building were consolidated in 1973-75 however, the continuing restoration recommenced in 1984 (Adle, 1999).

In Masjed-e Jame'-e Farumad nearly the whole construction is delicately adorned either with stucco ornamentation in both incised patterns and high relief, or elaborate brick-based decorations with occasional glazed objects insets. The stucco embellishments cover all surfaces of the portal with an exception, the outer frieze of the façade, that is decorated by brick-based ornaments (Figure 2.25 *left*). Here, in this bands, the rectangular *pish-shekli* bricks (ca. 45×27 cm) with geometric pattern, associated with stamped floral design in jewel form sunken parts, adorn the frieze (Figure 2.27). Moreover, thin molded (or stamped) ten-pointed star bricks with floral reliefs decorate the central stars of created pattern (Figure 2.25 *right*). Inside the Farumad mosque, the stucco decorations are the predominant ornaments used to furnish the interior surfaces and soffits of the *iwan*s, *iwanche*s and arcades. Likewise, the remains show that the façades of *iwanche*s and their upper blind arches (the decorative second storey) are adorned by plaster and stucco ornaments.

Although almost nothing remains of decorations (if there were any) of the façades of the arcades on the north-western and south-eastern sides of the courtyard. The façade of the *qibla iwan* and all surfaces (*iwan* and *iwancha*s) of the north-eastern side are also furnished by *pish-shekli* embellishments. Triangular moulded *pish-shekli* bricks, containing geometric patterns and stamped floral motifs, decorate the spandrels of both *iwan*s and the blind arches of the north-eastern side of the court. Here again the same technique of those on the portal frieze is employed to create *pish-shekli* bricks. In addition the moulded and stamped kite-shaped bricks (Figure 2.28 *left*), made in the above-mentioned technique,

are used to adorn some friezes at the north-eastern façade while the moulded bricks with the same pattern on the façade of the *qibla iwan* are executed on square bricks (Figure 2.28 *right*).

Figure 2.25. The portal of the Farumad mosque (left) and the details of its brickwork frieze

Figure 2.26. The south-western façade (left) and the details of its decoration (right) at the Farumad mosque

Moulded ornaments with different floral and geometric motifs are the other decorative bricks of Farumad mosque that are also employed to adorn the friezes and guard bands of the *iwan* façades, the surfaces of the blind arches of north-eastern side of the courtyard and decorative columns at the edge of the *iwan*s. These moulded *pish-shekli* brick are in square, rectangular and triangular and star (only one) shapes, forming different motifs and designs. On the other hand, interestingly, at the right and left sides of the north-eastern façade (in symmetric points above the south-eastern walls of courtyard) there are decorative bands, containing different ornaments (Figure 2.27 *right*). In spite of the above-mentioned moulded bricks, the floral motifs of *pish-shekli* brickwork of these bands are created by deeply carving the wet rectangular (ca. 10×20 cm) bodies. Unfortunately, the ornaments of the left hand band are almost entire destroyed and only two pieces remain.

Figure 2.27. The north-eastern façade (left) and the details of its decoration (right) at the Farumad mosque

Figure 2.28. The kite-shaped bricks of the north-eastern iwan *(left) and square elements of the* qibla iwan *(right)*

It is interesting to note the glazing of the sunken parts of some moulded bricks on top of the column at the northern edge of the *qibla iwan* by a turquoise glaze that, affected by earthquakes, are placed in wrong positions (Figure 2.29 *left*). Moreover, insets with glazed ornaments are occasionally employed to decorate the façades and spandrels of the two *iwancha*s and the blind arches at the north-eastern side of the courtyard. The majority of these glazed ornaments are small cut turquoise elements however there are some blue monochrome, luster glazed and underglaze painted ornaments (Figure 2.29 *right*).

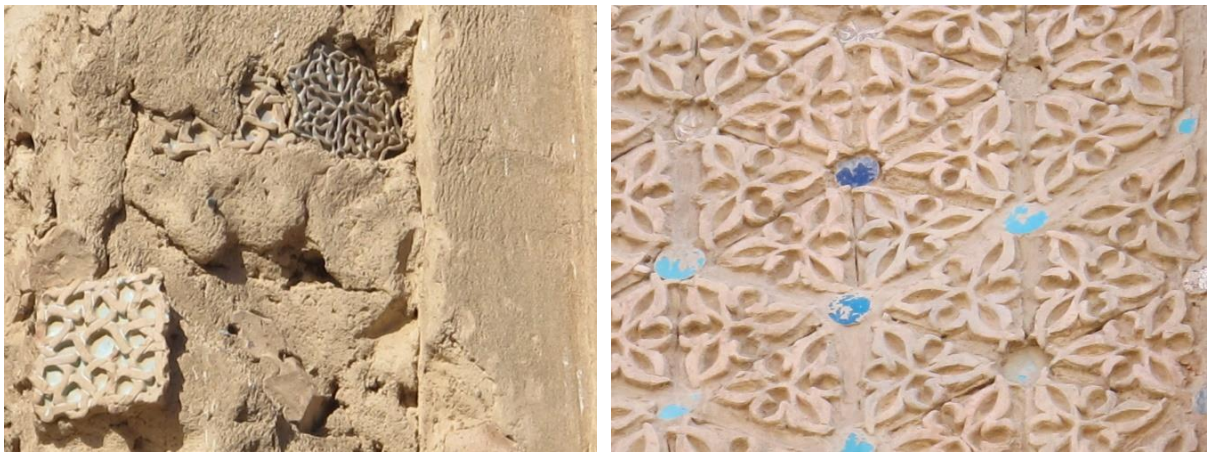


Figure 2.29. Glazed bricks at the column of the northern edge of the qibla iwan *(left) and the glazed decorations at the surface of the blind arch at the right (south side) of the north-eastern* iwan

To compare the decorative brickwork of Farumad mosque, it should be noted that they are manufactured in a completely different way from those at Zuzan and Gonābād. In the Takht-e Soleyman, an Il-khānid site at west of Iran, only one elements was found similar to stamped elements at the Farumad mosque (Kiani, 1997, p. 139). Moreover, in a photo of the Khosrowshir mosque, published by Molavi (1968), the similar element is observable amongst the other presented decorative brickwork (see p.37). However, the employed motifs at the Farumad mosque show a close relation with those at the complexes of Bastām and Natanz, two other Il-khānid sites in Iran. Hence, as a possibility, the decoration of the Farumad mosque could be created after the Khwārazmshāhid period.

2.4 Masjed-e Jāmeʿ-e Ferdows

Some fifty kilometres to the south-west from Gonābād, lise the city of Ferdows. The old name of the city, Tun, was changed to Ferdows at the beginning of twentieth century (Āzari Damirchi, 1971). The Masjed-e Jāmeʿ-e Ferdows (34°00'27.9"N 58°09'31.3"E) is a single-*iwan* (Figure 2.30) mosque with two domed prayer halls to the north and west of the *iwan* and a later rectangular courtyard with two entrances at the shout-west and north-east corners of the court. Moreover, there are two hypostyle prayer halls at the north and south sides of the court, added during the Safavid and Qajar periods (Akbari, 1997; Labbaf Khaniki & Saber Moqaddam, 2006, p. 38). In addition, behind the east wall of court, there are the recently unearthed remnants of pillars, belonging to a large ruined hypostyle prayer hall. Le Strange (1905, p. 353) gives some account of the city and its fine mosque in the tenth century, according to Moqaddasi. However, an eleventh writer, Nāser Khosrow, who visited the city, mentions nothing of the mosque (Āzari Damirchi, 1971). In the Report of Persian National Monuments (Masjed-e Ferdows) (ICHHTO, 1975) it is dated to 1009 and Kiani (1989, p. 11) goes along the report for dating the mosque. Nevertheless, some scholars (Akbari, 1997; Labbaf Khaniki & Saber Moqaddam, 2006, p. 38) believe it was build based on a two-*iwan* plan in thirteenth century. The mosque was affected by earthquakes and several restorations and renovations have carried out during the centuries (Āzari Damirchi, 1971; ICHHTO, 1975; Labbaf Khaniki & Saber Moqaddam, 2006).

Apart from later additions parts (the hypostyle prayer halls and arcades of courtyard), the most important decoration of the Masjed-e Ferdows are those on the façade of the *iwan*. While *pish-shekli* and *tarāshida* ornaments adorn the façade of the *iwan*, the arranged bricks decorate the spandrel of the *iwan*. The *iwan*'s façade of the Masjed-e Ferdows, similar to the façade of the *qibla iwan* at Zuzan, the interlacing bands (*tarāshida* bricks) divide into three vertical sections (Figures 2.30 and 2.31 *right*), where pish-shekli elements with different geometric patterns fill the created geometric compartments (Figure 2.32). Two vertical sections frame the wider middle section at exterior of each side of the *iwan*. The *pish-shekli* bricks at narrower sections are similar (the design and production way) to those of the northern *iwan* of the Gonābād mosque (Figure 2.7 *right*). In other words, it can be said, the square *pish-shekli* brick with eight-pointed central star at the Gonābād is

Figure 2.30. The qibla *side of the Masjed-e Jāmeʿ-e Ferdows*

divided into two equal rectangular bricks to decorate the façade of the *iwan* at the Masjed-e Ferdows.

On the other hand, the middle frieze of *iwan*'s façade at Ferdows is filled by big *pish-shekli* elements (ca. 60×60 cm), containing juxtaposed geometric pattern enclosed in a band on one body (Figure 2.33). In addition, only one glazed ornament fills the jewel form of the geometric pattern of first brick at the south (left) side of *iwan* (Figure 2.31 *left*). The other glazed decoration of *iwan* are some triangular turquoise elements that are placed where the interlaced bands cross over each other (Figure 2.31 *right*). The investigations on these glazed elements demonstrated that they are pieces of an inscription that, unfortunately, were cut and embedded at their present place. The relief decorations, letters and a similar band, on some of these glazed ornaments are the reasons for this idea (Figure 2.32).

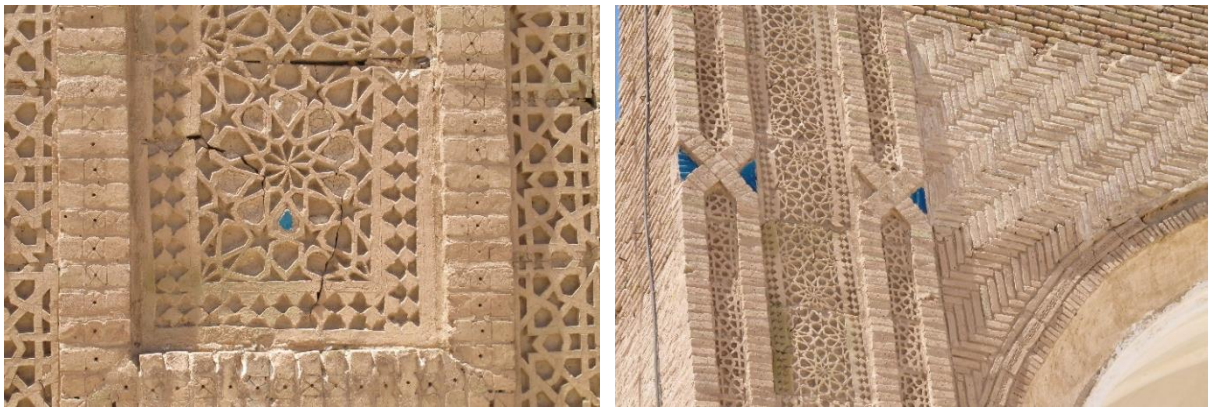


Figure 2.31. The pish-shekli *elements on the façade of the* iwan *in the Masjed-e Ferdows and the inserted glazed ornament in jewel form of the geometric pattern (left) and the embeded triangular turquoise elements on the façade of the* iwan *(right)*

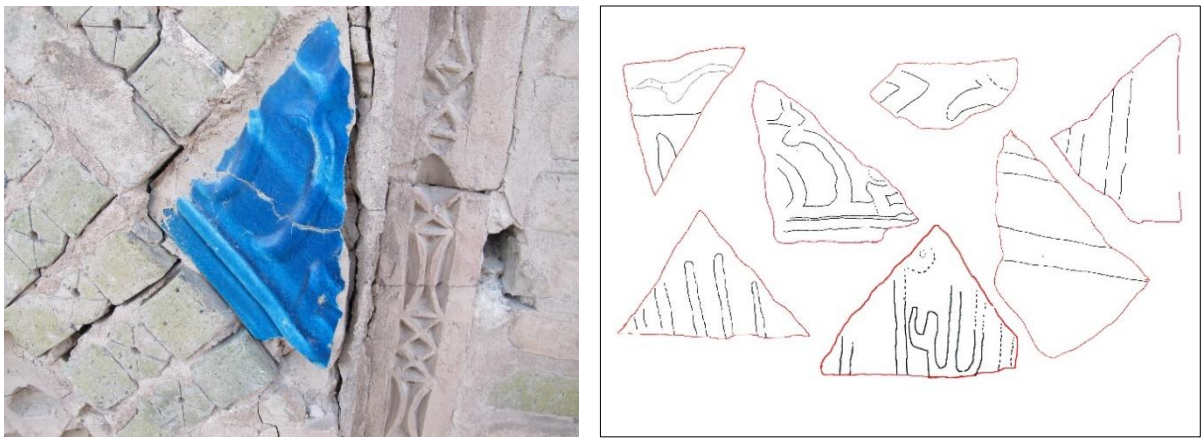


Figure 2.32. The details of the reliefs on a triangular glazed elements (left) and drawing the reliefs of the glazed elements (right) of the Masjed-e Ferdows

2.5 Masjed-e Jāmeʿ-e Sangān-e Pāʾin

Sangān-e Pāʾin is located near the Afghanistan border at the east of Khorāsān (on the old road of Zuzan to Herat). The Masjed-e Jāmeʿ-e Sangān-e Pāʾin (34°23'36.4"N 60°15'22.4"E), is a small mosque erected based on two-*iwan* plan (west-east) although before recent excavations it was known as a single-*iwan* mosque. (Figure 2.33). The main *iwan* and two cloisters *iwancha*s (two decorative storey at front

of them) are the structures of the mosque at the western side of a square courtyard. Symmetrising, at the opposite site (east) there are only the façades of an *iwan* and two *iwancha*s and, the rest are ruined and renovated as a prayer hall that recently excavations (unpublished) unearthed the remnants of some square columns in this altered prayer hall. Moreover, there is a small prayer hall at the south-western corner of mosque and the portal of mosque is located at north-eastern corner of court.

Figure 2.33.The east side of the courtyard at the Masjed-e Sangān in 2006 (left) and 2013 (right)

The Report of Persian National Monuments for the Masjed- e Jāmeʿ-e Sangān (ICHHTO, 1977) introduce this mosque as a Timurid building with the Seljuk ornaments, belonging to other monuments. Nonetheless, some scholars (Akbari, 1997; Labbaf Khaniki & Saber Moqaddam, 2006, p. 44) placed the mosque in Khwārazmshāhid period because of its two-*iwan* plan and the style of decorations.

The decoration of the Masjed-e Sangān-e Pāʾin include *pish-shekli* and *tarāshida* bricks together with few glazed ornaments that adorn the *qibla iwan*, *iwancha*s and arcades. Earthquakes ruined the decorations of the façade of the *qibla iwan* and only the guard bands of the probable frieze, created by *tarāshida* bricks, remain (Figure 2.34 *left*). The *pish-shekli* elements with geometric patterns, similar those at Zuzan site, published by Adle (1988) and Nishābur (Wilkinson, 1987), decorate the spandrel of *qibla iwan*. A circlular glazed decoration with epigraphic design, al-Molk (الملک), adorns the central eight-pointed star of the pattern, created by juxtaposing four pieces of the *pish-shekli* elements (Figure 2.34 *right*). Moreover, a narrow band with vegetal motifs frames the vault of the iwan, close to the spandrel's decorations. In addition, the spandrels of two *iwancha*s are furnished by square *pish-shekli* elements with deeply carved floral motifs, similar to a number of elements at the Zuzan site (Figure 2.35).

Figure 2.34. The qibla *side of the the Masjed-e Sangān (left) and the details of the spandrel of its iwan (right)*

Some *pish-shekli* bricks with epigraphic pattern are wrongly placed at the left hand *iwancha* at the *qibla* side (Figure 2.35 *left*) that seem to be parts of the ruined decoration of the *qibla iwan*'s façade (Figure 2.34 *left*). Inserting the fallen down elements in wrong places demonstrates the later innervations although, as mentioned above, it was the reason to introduce these decoration as non-original elements of Masjed-e Jāmeʿ-e Sangān. The small *pish-shekli* elements with special forms and shapes, adorn the spandrels of the arcades on the other sides of the courtyard (Figure 2.36). The façade of the east iwan is simply renovated by normal brick courses (Figure 2.33).

Figure 2.35. The spandrels of two iwancha*s at the* qibla *side of the Masjed-e Sangān. The inserted elements at wrong place can be seen on the spandrel of the left hand* iwancha *(left)*

Figure 2.36. The special forms of pish-shekli *elements at the spandrels of the arcades in the Masjed-e Sangān*

2.6 Khosrowshir Mosque

The modern Khosrowshir is a small village in the Joveyn district, near the modern city of Joghatāy (north-wetern of Savzevār and north-eastern of Farumad). The only remnants of the Khosrowshir mosque (36°47'24.9"N 57°10'08.0"E) are the semi-ruined walls of an *iwan*, toward the *qibla* (Figure 2.37 *left*). Through the walls, two vaults at each side show the connection of the *iwan* to some other destroyed structures. In addition, the traces of the vaults and the decorative columns at outer edges of the *iwan*'s façade (Figure 2.37 *right*) are the reasons of the existence of ruined *iwancha*s. Moreover, according to Molavi (1968), the minaret of the mosque, which was partially destroyed after an earthquake, was then entirely ruined by the locals in 1940s and its bricks were used in new constructions. Nāderi (1988) places the Khosrowshir Mosque in the Timurid reign while Bakhtiari Shahri (2004),

because of the form and design of the remnants of stucco decorations, dates back this monument to the Il-khānid period.

Figure 2.37. The east view of the Khosrowshir mosque (left) and the divided bands and decorative columns at the outer and inner edges of the iwan*'s façade (right)*

The majority of the remaining decorations of the Khosrowshir mosque are executed in stucco; an inscription frieze on top of the walls, the spandrels of connective vaults, the soffit of the vaults (ribs) of the *iwan* 's arch and upper zone of the columns at the inner edges of the *iwan*. Although the façade of the *iwan* is divided into two bands, all the probable decorations on the façade are ruined (Figure 2.38 *right*). Destroying the stucco layer, because of an earthquake, has been caused to appear some brickwork elements under the stucco layer at soffit of a vault on the west wall of the *iwan* (Figure 2.39). These square *pish-shekli* bricks, with geometric pattern, seem to be the original decorations of the vaults, covered by a later stuccowork. Moreover, the decorative columns at the outer edges of the *iwan*'s façade (ruined *iwancha*s) are executed with special arranged bricks (Figure 2.38 *right*). The published photo by Molavi (1968) presents some other brickwork elements of Khosrowshir mosque, attributed to the destroyed minaret of the mosque (Figure 2.38), that are manufactured by *pish-shekli* (cut, carved and moulded) and *tarāshida* techniques. Interestingly, as it can be seen in the photo, some elements are similar to those at the Farumad mosque, produced by moulding and stamping way. In addition, several *tarāshida* bricks with simple design and two turquoise glazed ornaments were found during the performed surface survey around the mosque that demonstrate the use of glazed decoration in the Khosrowshir Mosque.

Figure 2.38. The photo of the brickwork elements of the Khosrowshir Mosque (Molavi, 1968)

Figure 2.39. The location (left) and details (right) of the remaining pish-shekli *bricks, covered by later stucco decoration at the Khosrowshir mosque*

Chapter Three: Analytical Methods towards the Question of Provenance and Technology

3.1 Introduction

Analytical approaches take an important part of researches conducted on the technological studies of archaeological artefacts. One the other hand, there are studies focused on the provenance of archaeological objects which can only be explored via appropriate analytical studies. The problem of provenance is an important issue which needs accurate and precise methods of analysis. In the case of archaeological tiles, this issue becomes an inevitable problem as tileworks might have been manufactured in a region and have been exported to other regions in order to be applied in architectural façades (Mason, 2003). Numerous analytical studies such as neutron activation analysis (NAA) (Buko, 1984; Neff, et al., 1988; Cogswell, et al., 1996; 1998; Mainfort, et al., 1997; Partha Sarathi, et al., 2008), particle induced X-ray emission (PIXE) (Zucchiatti, et al., 1998; 2003; Robertson, et al., 2002), and various techniques of atomic spectroscopy and spectrometry (ICP-MS, LA-ICP-MS, ICP-AES, *etc*.) (Kennett, et al., 2002; Robertson, et al., 2002; Neff, 2003; Zucchiatti, et al., 2003; Klein, et al., 2004; Tiequan, et al., 2010) have been used to determine the origin of materials. These studies have always been accompanied by statistical methods of data handling to attribute one type of ceramic product to a specific zone. These methods are based on the fact that the quantity of major, minor, and trace elements provides a compositional fingerprint to group together tiles' bodies and to distinguish groups of body made from different raw materials (Tite, 2008). In the present work, wavelength dispersive X-ray fluorescence (WDXRF) is used instead of other methods of quantitative elemental analysis for determining the quantity of the composing elements of the bodies and, moreover, inductively coupled plasma mass spectrometry (ICP-MS) was used to quantitatively measure the elements composed the glazes.

Other than WDXRF and ICP-MS, which encompass the most important analytical studies, micro-Raman spectroscopy (μ-Raman), micro X-ray fluorescence (μ-XRF), scanning electron microscopy-energy dispersive X-ray spectrometry (SEM-EDX) and thin section petrography were used to respond to the occasional technological question. Principal component analysis (PCA) was also used to handle the compositional data of the bodies and glazes.

3.2 Experimental

3.2.1 Samples

The mosques Gonābād, Zuzan, Farumad, Ferdows, Sangān-e Pāʾin and Khosrowshir were subject of sampling. Altogether, more than hundred samples including brickwork decorations, glazed elements, structural bricks and glaze together with local clays from these sites were collected. Table 3.1

summarises the places of sampling and the number of samples collected from each site. The *pish-shekli* elements (two samples) of the main frieze and structural bricks (three samples), all from the *qibla iwan*, are the unglazed samples that were collected from the Masjed-e Jāmeʿ-e Ferdows. Besides, one sample of glazed decorations (of the triangular pieces), and two local clay samples (about one kilometre to the west and and two kilometres to the south-west of the mosque) were selected. Moreover, the samples of the Khosrwoshir mosque included simple, *pish-shekli* and *tarāshida* bricks, from *in situ* and found elements, plus the found glazed objects.

Two *borida* elements from the decorative frieze at the *qibla iwān*, three *pish-shekli* bricks with a central star, one *pish-shekli* decoration (that seems wrongly placed on the south-eastern corner of the courtyard) similar in pattern with those of the decorative frieze of the *qibla iwan*, three samples of letters and guard bands of the Kufic inscription at the south-eastern prayer hall and one structural brick of the north *iwān* are the unglazed samples of the Gonābād mosque. Depending on the accessibility, some glaze, body and both body and glaze samples of the hobnails and the triangular glazed ornaments were also collected (from façade of the north *iwān* and the south-eastern corner of the court). In addition, two local clay samples from the south (ca. 1000 m) and north-west (about 2 km) of the mosque were selected.

Sampling in the Masjed-e Jāmeʿ-e Farumad was performed on the decorative elements, structural bricks (from the *qibla iwan* and the opposite side) and *kāhgel* ('a mixture of clay, straw and water used to cover walls') plaster used for restoration porpuses from local clays. All the decorative bricks, including moulded, stamped and carved (deeper patterns) bricks, were selected from the fallen down elements with no definite location although, according to the *in situ* embellishments, the carved elements only were used on the north-eastern side of the courtyard. Due to the limitations posed by local authorities, the glazed ornaments of the Farumad Mosque were excluded from sampling.

In the Zuzan mosque, all the samples were collected from fallen down elements, from both those that are used on the present structure and the elements ascribed to the destroyed mosques. About 22 samples of the glazed decorations, with different shapes and glazes, were obtained from the Zuzan mosque. Moreover, seventeen samples from unglazed brick-based ornaments (*borida*, *tarāshida* and *pish-shekli* elements) and three local clay samples, between the mosque and an active kiln in north-eastern side of the mosque (2 km distance), were the other collected samples from the Zuzan mosque.

In addition, the structural bricks of the west (*qibla*) and the east sides of the court, as well as the *tarāshida* and *pish-shekli* elements (in situ decorations at *qibla* façade and stored pieces), were gathered from the Masjed-e Jāmeʿ-e Sangān-e Pāʾin.

Table 3.1 The places and the number of samples collected

Site	*labe*	*Brickwork*	*Glazed Decoration*	*Structural Brick*	*Only Glaze*	*Local clay*	*Total*
Masjed-e Jāmeʿ-e Gonābād	**G**	8	3	3	3	2	19
(Malek) Zuzan Mosque	**Z**	15	23	0	1	3	42
Farumad Mosque	**F**	9	0	4	0	1	14
Masjed-e Jāmeʿ-e Sangān	**S**	8	0	5	2	0	15
Khosrowshir Mosque	**K**	6	2	2	0	0	10
Masjed-e Jāmeʿ-e Ferdows	**Fr**	2	1	3	0	2	8

Figure 3.1. The samples of the Zuzan Mosque

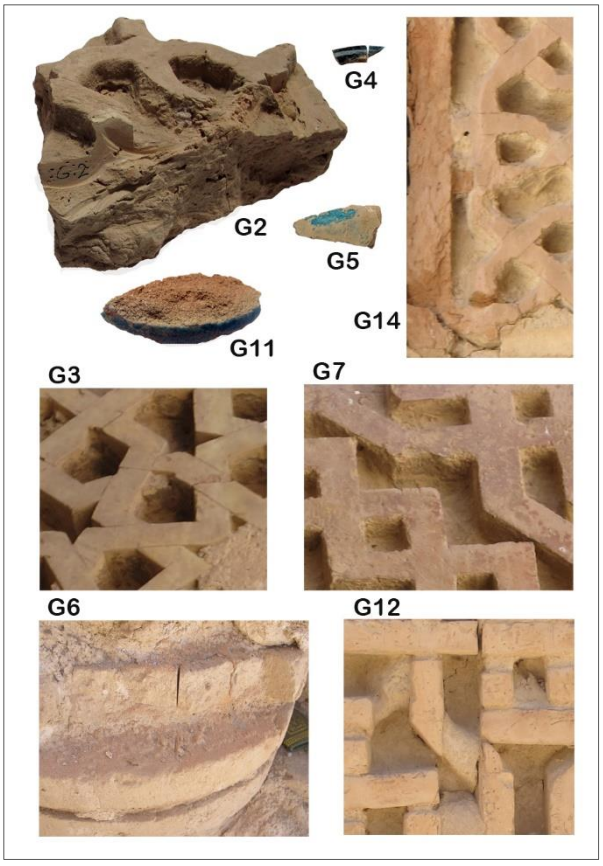


Figure 3.2. The samples of the Masjed-e Jame'-e Gonābād

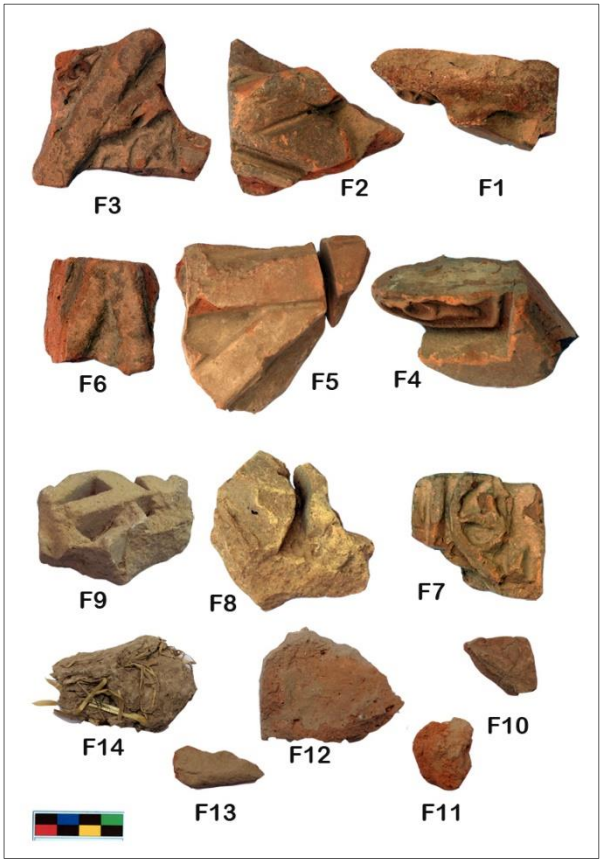


Figure 3.3. The samples of the Frumad Mosque

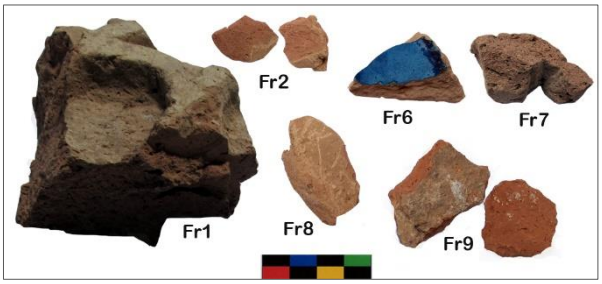


Figure 3.4. The samples of the Masjed-e Jāmeʿ-e Ferdows

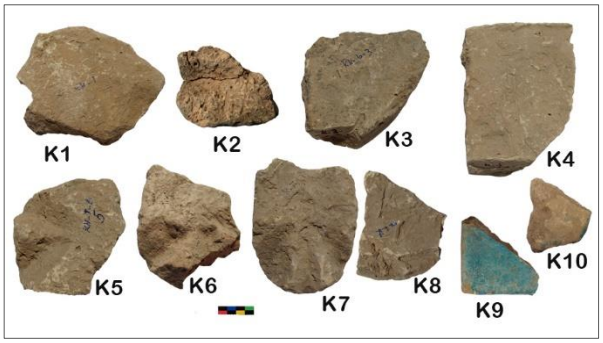


Figure 3.6. The samples of the Khosrowshir Mosque

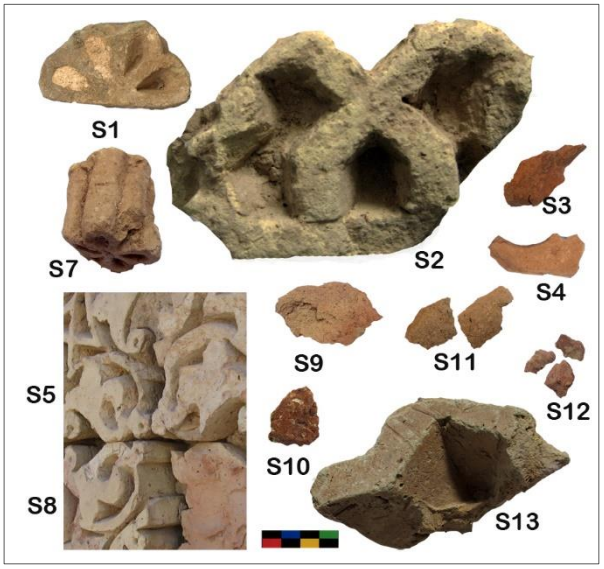


Figure 3.5. The samples of the Masjed-e Jāmeʿ-e Sangān-e Pāʾin

3.2.2 Thin section petrography

Petrographic sections were obtained from a small fragment of the bodies. The fragments were impregnated in vacuum with a mixture from five parts of Hardrock 554 epoxy resin and one part of Hardrock 554 hardener. The mounted sample was then cut and flat surface was then fixed to a glass slide and the rest of the sample was ground down to 30 µm.

3.2.3 WDXRF

The major, minor, and trace elements of the bodies were determined by WDXRF. Depending on the size of samples, a diamond saw was used either to cut samples from the bodies or removing the contaminated surfaces of the bodies (to a depth of about three millimetres) to reduce the possibility of contamination. The prepared specimens were then powdered in an agate mill. WDXRF was performed on the pressed powder pellets using an ARL Advant-XP spectrometer, following the full matrix correction method suggested by Lachance and Traill (1966). Accuracy of the measurements was better than 2% for major oxides and better than 5% for trace element determinations, whereas the detection limits for trace elements range from 1 to 2 ppm. Replicate analyses on trace elements gave a precision better than 5%. The accuracy was calculated based on the difference between the measured values and bibliographic values of international standards and precision was calculated as RSD% (Relative Standard Deviation percent) of replicate analyses (10 measurements) in the course of two years. Loss on ignition (LOI) was determined by weighing the samples before and after heating at 1000°C.

3.2.4 ICP-MS

Major, minor and trace elements of the glazes were determined by inductively coupled plasma-mass spectrometry (ICP-MS) using a Thermo X Series spectrometer equipped with CCT^{ed} (Collision Cell Technology) for the elimination/reduction of the main spectral interferences. The glaze layers were separated from the glazed bodies, and the remnants of bodies were then completely removed from the glaze layer by grinding on a diamond lap. About 200 mg of powdered glazes were dissolved into 50 ml PTFE beakers with 3 ml HNO_3 65% (Suprapur® Merck) and six ml HF 40% (Suprapur® Merck). Each beaker was then covered by Parafilm to put in ultrasonic bath for about 15 minutes. After 20 hours, the Parafilm was removed and the samples evaporated to incipient dryness on hot plate at about 180° C. Three ml of HNO_3 65% and three ml of HF 40% were subsequently added to the beaker and the samples were further evaporated to incipient dryness. The residual HF complete removal was realised through the evaporation with 4 ml of concentrated HNO_3. Finally, the samples were taken into 3 ml HNO_3, and transferred into 100 ml polypropylene volumetric flasks. Solutions of Rh and Re were eventually added as internal standards to the flasks that were then made-up to volume. Accuracy was varied from 1% to 8% and calculated by analysing a number of international standards as unknown.

3.2.5 μ-Raman

A LabRam HR800 spectrometer (Horiba Jobin Yvon, France) with a focal length of 80 mm was used to direct Raman scattering signals via a 600 groove/mm grating to a Peltier-cooled CCD detector (1024 × 256 pixels) at –70 °C. The excitation source was a He-Ne laser (632.8 nm line) with a maximum laser power of 20 mW and an Olympus BXFM microscope together with 50x and 100x objectives were used to collect the Raman signals. The exposure time was about 15 s with 5 accumulations and the spectrometer was calibrated with silicon at 520 cm^{-1}.

3.2.6 μ-XRF

A portable ARTAX^{TM} 200 (Bruker AXS Microanalysis GmbH, Germany) μ-XRF instrument was used to qualitatively analyse the samples. The instrument consisted of an X-ray tube with a Mo target and a SSD Peltier-cooled detector (10 mm^2 active area and resolution of <155 eV at 10 kcps). The maximum voltage and current of 25 kV and 1502 μA, respectively, were used to excite the secondary fluorescence X-rays. A collimator with a diameter of 1 mm was used to collect the emitted secondary X-rays from the samples in air for about 120 s.

3.2.7 SEM-EDX

SEM observations and EDS microanalyses were performed with a Zeiss EVO 40 scanning electron microscope equipped with an INCA Energy 300 Oxford EDS microanalysis system (20 kV and about 8.5 mm working distance). Elemental data were prepared using the INCA Energy 300 software. Samples were not coated and the microanalyses were carried out in variable pressure.

3.2.8 Statistical data handling

The compositional data obtained from WDXRF and ICP-MS were submitted to the multivariate statistical procedure of principal components analysis (PCA) using non log-transformed data following the standardization the data to give an equal weight in the analyses (Baxter, 1995; Baxer & Buck, 2000). Statistical analyses of the samples were developed using IBM SPSS Statistics 20 package.

Chapter Four: Results and Discussion

4.1 Compositional data analysis by PCA on the WDXRF data of the bodies

The results of WDXRF quantitative analyses on the bodies and local clays (100 samples) are represented in Tables 4.1 and 4.2. After removing the outliers and the elements which could be introduced as contamination (such as S, Pb and Cu), the rest of the datasets were standardised and subjected to PCA. The PCA was performed on the correlation matrix of the standardised data accounting 61.99% and 23.28% of total variance for the first and second principal components respectively. Moreover, Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) was calculated to be 0.861 estimating of a good overall of PCA data handling on the dataset. Figure 4.1 presents the biplot of PCA analysis plotted based on the first two components. As Figure 4.1 shows, three main types of body were discriminated amongst the bodies; i.e., the bodies characterised with high concentrations of SiO_2 (the so-called stone-paste bodies), the clay-based bodies with high Mg, Co, Ni and Cr contents and those clay-based associated with relatively low SiO_2 and high Al_2O_3 and CaO contents.

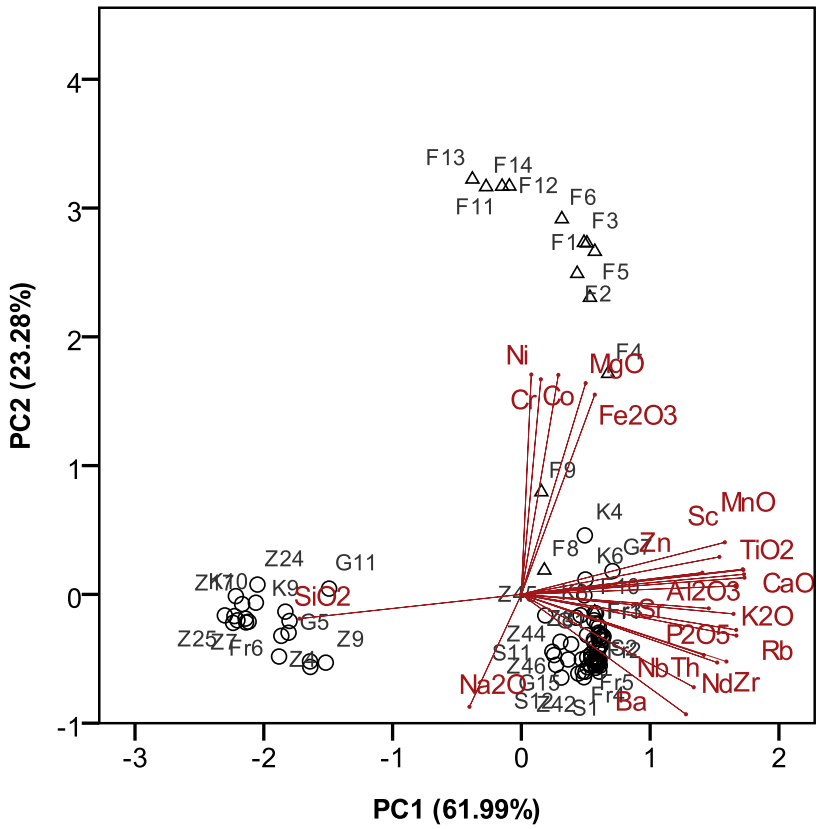


Figure 4.1. PCA bi-plot on the WDXRF quantitative analysis of the bodies

As PCA data handling on the compositional data of the bodies showed (Figure 4.1), 20 glazed samples (out of 94 bodies) were stone-paste bodies. These bodies comprised of a group of the glazed bodies of the Zuzan mosque (Z4, Z7, Z9, Z10, Z15, Z17, Z18, Z19, Z20, Z21, Z22, Z23, Z24, Z25 and Z26), two

bodies from the Gonābād mosque (G5 and G11), one body from the Ferdows mosque (Fr6) and two bodies of the Khosrowshir mosque (K9 and K10). Another PCA bi-plot on the stone-paste bodies (Figure 4.2) showed that most of the stone-paste bodies were basically associated with Ni. This may suggest that the origin of quartz used for manufacturing these bodies would be different from the rest of the stone-paste bodies. Moreover, the Gonābād's samples were separated in terms of high amounts of Fe and Ca.

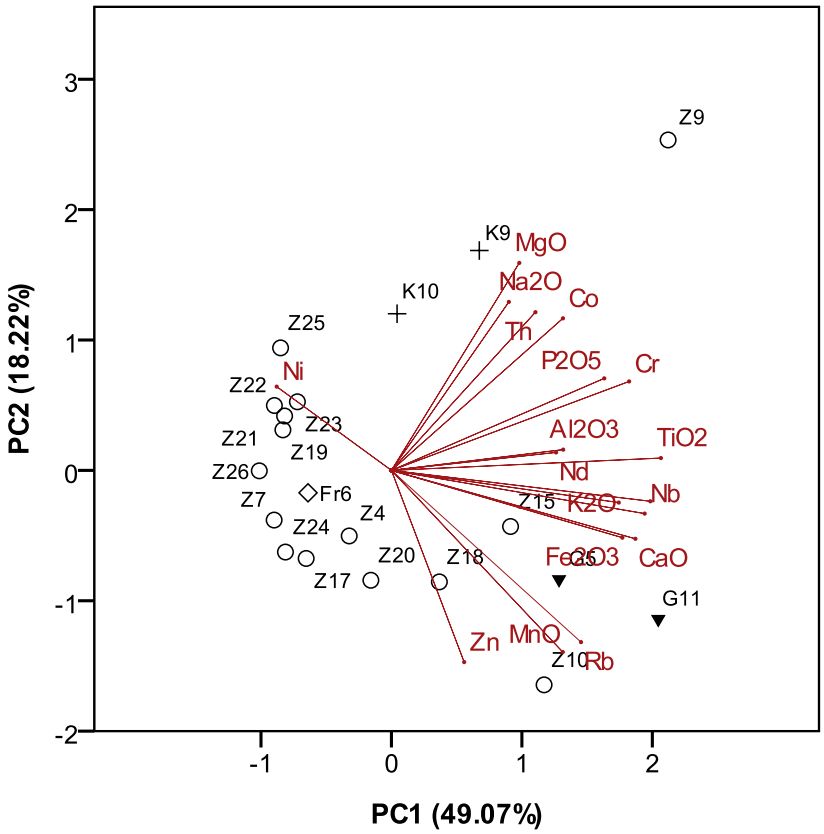


Figure 4.2. PCA bi-plot on the WDXRF quantitative analysis of the stone-paste bodies

As can be seen in Figure 4.1, apart from the stone-paste bodies, the clay-based bodies form a large number of the bodies which can be classified in two main clusters. In the first cluster (with high PC2 values in Figure 4.1), the association of the most of the clay-based bodies of the Farumad mosque (all except F8, F9 and F10) and local clay of Farumad with a high concentration of Mg and Cr was of our major interest as it could establish a local provenance for the clay-based bodies of the Farumad mosque. According to the metallogenic zone where Sabzevar-Farumad zone is placed on, Farumad is located on a metallogenic belt where chromite, huntite, manganese and magnesite deposits are concentrated (Momenzadeh & Walther, 1984). It was very interesting as it would suggest a local provenance for the clays of which the clay-based bodies of the Farumad mosque are manufactured.

As the bodies grouped in the second cluster were very highly correlated, another PCA was run on these bodies in order to see any possible cluster within the bodies (Figure 4.3). About 53.45% of total variance was accounted for the first two PCs (28.71% and 24.74% for PC1 and PC2 respectively). Although about half of the total variance was not appeared in bi-plot of Figure 4.3, it roughly suggested that the clay-bodies of the Khosrowshir mosque had a different provenance in terms of relatively high concentrations of Mg and Cr. This can be explained by a fairly short distance between the Khosrowshir and the Farumad mosques. The mosque of Khosrowshir is located in the town of Joghatāyn in about 50

km north-east Farumad on the same metallogenic zone. This might also suggest that the bodies of which the Khosrowshir mosque's brickwork are made of local clays.

The rest of samples, apart from three local clay samples of the Zuzan mosque (Z44, Z45 and Z46), showed no specific correlation with the composing elements of the bodies.

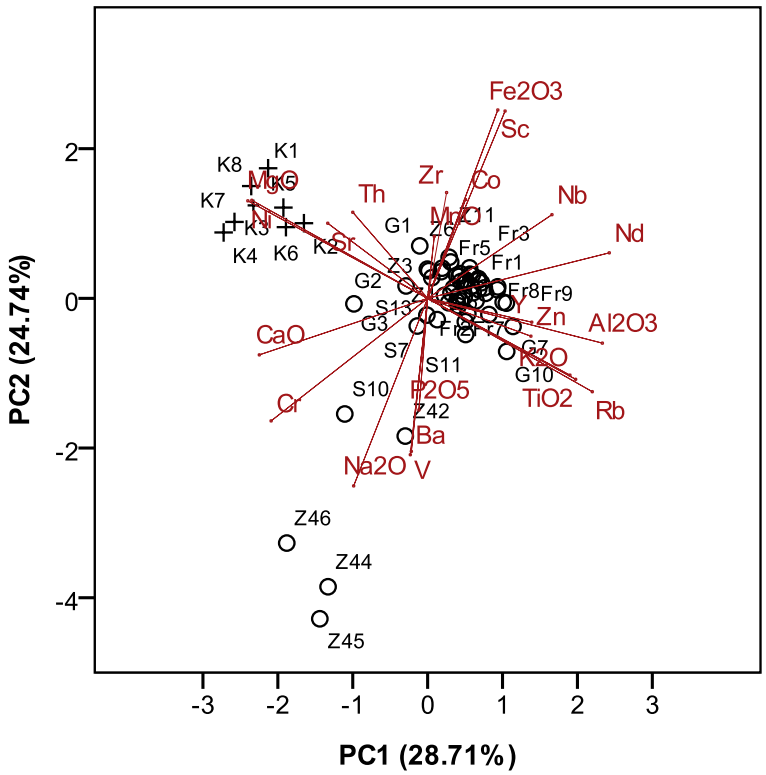


Figure 4.3. PCA bi-plot on the WDXRF quantitative analysis of the clay-based bodies

Another issue of our interest was the colour of the clay-based bodies which can be explained in terms of Fe and Ca contents within the bodies. As Figure 4.4 shows, in the bivariate plot of Fe_2O_3 *vs*. CaO, a relatively high Fe_2O_3 content and a low concentration of CaO may be the reason of the reddish colour of the Farumad's clay bodies. As it is generally well-known, when a body is formed from non-calcareous clays, iron is crystallised in the form of haematite at oxidising atmosphere and, as a result, exhibits a reddish colour (Maniatis, 2009). On the other hand, the rest of the clay-based bodies were calcareous clay-bodies (Tite & Maniatis, 1975) and showed a quite equal amount of CaO (between 8 to 18%) incorporated in the bodies. The buff colour of these bodies may be explained by the reactions take place between CaO and iron oxides present in the clayey matrix. These reactions decrease the size and amount of iron oxide particles and, consequently, bleaches the red colour to a creamy colour (Maniatis, 2009).

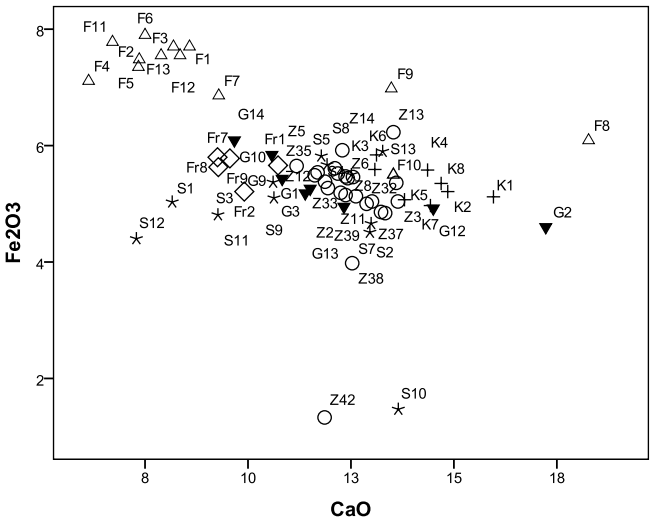


Figure 4.4. Bivariate plot of CaO vs. *Fe_2O_3*

Table 4.1. Major and minor elements of the bodies obtained by WDXRF analysis

n.	Site	Label	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5
1	Farumad	F1	53.0	0.55	10.7	7.70	0.15	15.0	8.58	1.02	1.88	0.15
2	Farumad	F2	54.5	0.58	11.2	7.35	0.12	12.2	7.34	1.17	2.19	0.12
3	Farumad	F3	53.5	0.54	10.8	7.70	0.14	14.8	8.19	0.74	2.00	0.13
4	Farumad	F4	55.6	0.62	11.4	7.11	0.09	10.2	6.13	1.47	2.27	0.14
5	Farumad	F5	53.8	0.58	11.2	7.48	0.13	12.6	7.36	1.44	1.98	0.14
6	Farumad	F6	54.0	0.55	11.0	7.90	0.15	15.2	7.50	0.85	2.00	0.14
7	Farumad	F7	51.2	0.52	10.0	6.86	0.13	14.0	9.29	0.91	1.96	0.11
8	Farumad	F8	47.0	0.58	11.2	6.09	0.17	5.16	18.3	2.28	1.72	0.17
9	Farumad	F9	53.8	0.63	14.1	6.98	0.17	7.05	13.5	2.27	1.97	0.25
10	Farumad	F10	51.2	0.58	10.3	5.50	0.12	8.84	13.5	1.04	2.17	0.15
11	Farumad	F11	51.6	0.50	9.28	7.78	0.14	21.9	6.71	1.34	1.12	0.10
12	Farumad	F12	51.6	0.53	10.3	7.55	0.14	18.2	8.35	1.26	1.14	0.11
13	Farumad	F13	49.6	0.51	9.41	7.55	0.14	19.7	7.89	1.06	1.16	0.09
14	Farumad	F14	49.1	0.38	7.25	7.08	0.12	24.7	7.86	0.75	1.20	0.07
15	Ferdows	Fr1	55.7	0.65	13.9	5.66	0.11	4.73	10.7	1.80	2.51	0.20
16	Ferdows	Fr2	57.2	0.67	12.8	5.21	0.10	6.56	9.91	1.85	2.26	0.30
17	Ferdows	Fr3	60.7	0.72	13.8	5.29	0.09	4.10	10.2	1.61	2.36	0.13
18	Ferdows	Fr5	58.1	0.72	13.9	4.94	0.10	4.24	9.63	3.05	2.42	0.17
19	Ferdows	Fr6	90.1	0.09	3.20	1.55	0.03	0.53	1.06	2.37	0.48	0.07
20	Ferdows	Fr7	59.1	0.70	14.2	5.80	0.11	3.93	9.26	1.90	2.52	0.21
21	Ferdows	Fr8	59.8	0.71	14.4	5.63	0.11	4.11	9.28	2.03	2.60	0.18
22	Ferdows	Fr9	53.7	0.64	14.4	5.78	0.11	5.39	9.56	1.54	3.23	0.20
23	Gonābād	G1	57.7	0.58	10.4	5.26	0.10	3.44	11.5	2.08	1.99	0.17
24	Gonābād	G2	56.5	0.57	11.8	4.60	0.10	4.80	17.2	1.46	2.28	0.18
25	Gonābād	G3	59.8	0.58	10.4	5.18	0.10	3.03	11.4	1.98	2.16	0.19
26	Gonābād	G5	87.5	0.11	4.40	2.77	0.09	1.09	2.53	2.55	0.65	0.08
27	Gonābād	G6	54.3	0.68	13.9	5.79	0.11	4.38	12.5	1.54	2.41	0.13
28	Gonābād	G7	58.6	0.79	17.0	6.76	0.14	4.73	8.58	1.64	3.27	0.46
29	Gonābād	G8	54.0	0.67	13.7	5.22	0.10	4.31	12.5	2.36	2.21	0.13
30	Gonābād	G9	56.5	0.71	14.8	5.43	0.11	3.83	10.8	2.32	2.90	0.15
31	Gonābād	G10	59.0	0.78	16.3	5.84	0.12	4.08	10.6	2.45	2.70	0.16
32	Gonābād	G11	82.8	0.17	5.37	2.92	0.08	1.40	2.97	2.13	0.76	0.11
33	Gonābād	G12	54.8	0.64	11.9	4.92	0.08	3.92	14.5	2.00	2.00	0.14
34	Gonābād	G13	55.3	0.65	11.3	4.95	0.08	4.45	12.3	1.81	2.13	0.14
35	Gonābād	G14	56.8	0.74	15.7	6.09	0.11	4.07	9.67	1.27	3.16	0.16
36	Gonābād	G15	58.4	0.70	13.4	5.30	0.07	3.23	9.25	3.28	2.53	0.12
37	Gonābād	G16	57.9	0.69	13.0	5.66	0.10	3.88	11.3	1.30	2.58	0.13
38	Khosrowshir	K1	51.4	0.57	10.5	5.12	0.11	7.15	16.0	1.07	1.80	0.13
39	Khosrowshir	K2	51.6	0.57	9.88	5.21	0.11	6.44	14.9	0.89	2.25	0.16
40	Khosrowshir	K3	52.7	0.59	10.5	5.59	0.11	8.34	13.1	1.40	1.89	0.16
41	Khosrowshir	K4	52.5	0.56	10.3	5.58	0.12	9.41	14.4	1.24	1.63	0.14
42	Khosrowshir	K5	54.0	0.59	10.1	5.07	0.10	7.26	13.8	1.50	1.87	0.19
43	Khosrowshir	K6	53.1	0.56	10.3	5.84	0.12	8.57	13.1	0.99	2.08	0.14
44	Khosrowshir	K7	53.6	0.58	10.2	4.97	0.11	7.29	14.4	2.35	1.87	0.21
45	Khosrowshir	K8	52.5	0.56	10.2	5.35	0.11	7.11	14.7	0.97	1.73	0.16
46	Khosrowshir	K9	81.5	0.15	5.30	1.53	0.02	1.86	2.13	2.93	0.64	0.12

Table 3.2 Continued

n.	Site	Label	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5
47	Khosrowshir	K10	84.6	0.07	2.72	2.42	0.04	2.36	2.52	2.09	0.49	0.08
48	Zuzan	Z1	55.2	0.63	12.1	5.13	0.11	3.85	12.6	1.66	2.19	0.15
49	Zuzan	Z2	53.3	0.67	12.6	5.27	0.11	4.30	11.9	2.59	2.50	0.18
50	Zuzan	Z3	52.3	0.68	11.0	5.04	0.11	3.66	13.6	1.85	2.27	0.15
51	Zuzan	Z4	74.7	0.10	4.66	2.00	0.02	1.22	2.21	2.16	0.55	0.04
52	Zuzan	Z5	58.4	0.68	13.3	5.65	0.11	4.28	11.2	1.74	2.43	0.19
53	Zuzan	Z6	57.2	0.68	13.2	5.44	0.11	4.41	12.4	2.63	2.07	0.17
54	Zuzan	Z7	86.6	0.05	2.85	0.95	0.03	0.64	2.26	1.08	0.43	0.03
55	Zuzan	Z8	52.6	0.65	12.3	5.15	0.11	4.15	12.4	2.40	2.43	0.19
56	Zuzan	Z9	72.9	0.18	3.94	1.48	0.02	1.75	4.59	3.12	1.01	0.09
57	Zuzan	Z10	73.3	0.13	3.82	1.75	0.06	1.08	4.57	1.96	0.92	0.05
58	Zuzan	Z11	51.8	0.64	11.6	5.04	0.11	4.29	13.0	1.96	2.22	0.15
59	Zuzan	Z12	54.6	0.70	13.0	5.49	0.11	3.70	11.6	2.05	2.99	0.18
60	Zuzan	Z13	53.9	0.75	15.3	6.23	0.11	4.90	13.5	3.10	1.54	0.19
61	Zuzan	Z14	53.8	0.71	13.3	5.92	0.12	4.65	12.3	2.08	2.16	0.21
62	Zuzan	Z15	74.7	0.11	3.81	1.52	0.03	1.04	2.06	2.95	1.15	0.04
63	Zuzan	Z17	85.2	0.06	3.34	1.07	0.03	0.85	2.48	1.65	0.48	0.03
64	Zuzan	Z18	82.8	0.10	3.32	1.85	0.04	1.21	2.92	1.94	0.79	0.06
65	Zuzan	Z19	83.0	0.06	3.40	0.89	0.01	0.86	1.42	2.67	0.69	0.02
66	Zuzan	Z20	86.2	0.09	3.89	1.85	0.03	1.00	2.20	1.99	0.53	0.04
67	Zuzan	Z21	83.5	0.07	3.90	1.14	0.01	1.07	1.59	2.39	0.67	0.03
68	Zuzan	Z22	81.8	0.07	3.05	1.11	0.02	0.83	1.42	2.33	0.58	0.03
69	Zuzan	Z23	87.0	0.07	3.41	1.28	0.02	0.88	1.59	2.72	0.56	0.03
70	Zuzan	Z24	83.8	0.06	2.37	1.41	0.04	0.67	1.73	1.36	0.49	0.04
71	Zuzan	Z25	84.1	0.06	3.09	0.96	0.01	0.78	0.92	2.88	0.49	0.03
72	Zuzan	Z26	82.7	0.05	1.71	1.03	0.02	0.47	1.98	2.42	0.52	0.04
73	Zuzan	Z30	53.7	0.69	12.4	5.19	0.11	4.21	12.3	2.37	2.70	0.16
74	Zuzan	Z31	54.2	0.72	12.3	5.47	0.11	4.70	12.4	2.49	2.42	0.16
75	Zuzan	Z32	54.4	0.70	12.1	4.84	0.12	4.15	13.3	2.91	2.72	0.19
76	Zuzan	Z33	57.1	0.68	13.8	5.38	0.12	4.89	11.9	2.80	2.19	0.20
77	Zuzan	Z34	58.0	0.74	15.5	5.52	0.11	5.25	12.2	3.99	1.81	0.19
78	Zuzan	Z35	57.7	0.66	13.8	5.54	0.11	4.97	11.7	1.78	2.42	0.19
79	Zuzan	Z36	57.9	0.70	14.3	5.61	0.12	5.03	12.1	2.71	1.84	0.20
80	Zuzan	Z37	55.6	0.66	12.1	4.86	0.11	4.16	13.2	2.40	2.26	0.16
81	Zuzan	Z38	50.7	0.65	11.9	3.98	0.11	4.19	12.5	5.27	3.92	0.18
82	Zuzan	Z39	54.4	0.66	12.0	5.00	0.11	4.43	12.9	2.52	2.00	0.15
83	Zuzan	Z40	52.7	0.68	12.7	5.36	0.11	3.97	13.6	2.13	2.76	0.17
84	Zuzan	Z41	52.3	0.67	13.2	5.46	0.11	4.76	12.6	2.47	2.44	0.17
85	Zuzan	Z42	44.5	0.68	9.16	1.33	0.11	2.20	11.9	13.5	5.60	0.21
86	Zuzan	Z44	54.3	0.71	12.6	nd*	0.10	3.37	16.0	20.1	1.95	0.23
87	Zuzan	Z45	54.5	0.83	13.3	nd	0.12	3.40	16.0	24.8	2.05	0.27
88	Zuzan	Z46	53.5	0.67	10.2	0.25	0.08	2.12	15.7	18.5	1.96	0.20
89	Sanāgan	S1	59.2	0.59	12.2	5.03	0.08	3.39	8.16	2.74	2.95	0.12
90	Sanāgan	S2	59.4	0.59	12.7	4.66	0.09	3.90	13.0	3.06	2.34	0.15
91	Sanāgan	S3	58.8	0.61	13.2	5.37	0.08	3.70	10.6	1.33	3.29	0.14
92	Sanāgan	S4	56.3	0.69	14.4	5.50	0.10	4.89	12.5	2.47	2.68	0.18

*not detected

Table 3.2 Continued

n.	Site	Label	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5
93	Sanāgan	S5	55.9	0.69	14.3	5.82	0.10	4.61	11.8	1.77	3.13	0.18
94	Sanāgan	S7	57.2	0.57	12.0	4.51	0.08	3.50	13.0	2.22	2.61	0.16
95	Sanāgan	S8	57.4	0.72	15.1	5.67	0.11	5.45	11.9	2.53	2.76	0.22
96	Sanāgan	S9	54.2	0.61	13.1	5.10	0.09	4.10	10.6	3.88	2.76	0.11
97	Sanāgan	S10	46.2	0.53	11.2	1.47	0.08	3.39	13.7	11.9	4.23	0.14
98	Sanāgan	S11	55.5	0.57	11.7	4.81	0.08	3.07	9.27	3.09	2.67	0.10
99	Sanāgan	S12	52.6	0.61	11.4	4.40	0.06	4.07	7.29	4.31	2.39	0.14
100	Sanāgan	S13	53.4	0.60	13.5	5.90	0.09	4.61	13.3	1.73	2.61	0.14

Table 4.2. Trace elements of the samples quantitatively measured by WDXRF (ppm)

n.	Label	Ba	Ce	Co	Cr	Cu	Ga	Hf	Nb	Nd	Ni	Pb	Rb	S	Sc	Sr	Th	V	Y	Zn	Zr
1	F1	266	40	73	517	42	7	1	6	9	739	16	48	552	12	352	6	85	8	77	80
2	F2	246	46	50	513	41	8	1	6	14	520	15	52	2420	14	259	9	106	9	77	98
3	F3	235	39	67	506	39	7	1	5	10	709	17	49	3010	14	297	7	103	8	75	81
4	F4	270	49	35	515	42	10	3	9	18	320	21	63	2050	14	363	9	118	14	75	146
5	F5	269	46	55	639	40	9	1	5	15	558	18	54	1320	12	285	8	106	11	77	106
6	F6	233	44	70	553	40	6	nd	4	10	724	15	45	2260	10	235	7	106	6	76	67
7	F7	211	40	54	465	35	7	1	6	10	603	17	46	12100	13	445	7	96	9	67	90
8	F8	132	46	26	108	82	9	1	3	9	99	14	29	13900	21	540	6	115	10	63	75
9	F9	188	nd	34	268	94	14	2	5	16	163	11	28	597	22	430	nd	132	11	69	70
10	F10	337	nd	25	149	92	11	3	7	16	203	43	53	1370	18	548	1	107	11	64	112
11	F11	134	nd	67	769	58	9	3	4	5	844	10	24	2060	19	281	nd	115	8	60	56
12	F12	156	nd	60	855	56	11	3	5	6	771	9	24	460	22	354	nd	113	10	54	62
13	F13	144	nd	59	829	54	8	2	2	6	791	7	14	3950	20	241	nd	128	4	52	34
14	F14	130	nd	75	940	42	7	2	4	5	1033	9	26	725	16	447	nd	95	6	54	45
15	Fr1	299	62	17	100	36	11	2	8	16	57	26	75	13000	10	520	11	92	12	74	135
16	Fr2	331	nd	17	98	30	14	4	9	18	53	14	63	12100	15	495	1	85	13	66	131
17	Fr3	326	nd	18	101	27	14	4	10	19	51	22	66	612	13	356	1	93	13	55	150
18	Fr5	325	nd	18	125	31	14	4	9	20	47	18	66	1360	13	279	2	101	13	60	147
19	Fr6	80	nd	5	8	81	1	4	2	3	4	22	6	nd	5	138	nd	12	1	11	29
20	Fr7	340	nd	21	114	36	17	5	11	20	59	28	81	3650	15	406	3	103	16	71	155
21	Fr8	360	nd	19	121	34	16	5	11	20	57	26	81	4370	15	374	2	111	16	74	158
22	Fr9	316	nd	21	102	44	15	5	9	20	65	24	72	24100	17	380	2	106	11	77	103
23	G1	312	64	27	98	17	9	2	66	15	0	11	58	1800	11	117	10	81	14	60	241
24	G2	292	70	16	80	28	9	1	nd	13	53	110	61	1880	9	452	8	93	12	65	134
25	G3	324	64	13	92	28	10	2	10	17	46	21	65	333	9	303	10	82	14	61	194
26	G5	102	nd	8	79	197	4	4	5	5	11	29	17	1336	6	144	nd	17	4	25	57
27	G6	348	nd	22	106	29	17	4	13	18	69	16	84	13900	18	457	3	115	18	69	162
28	G7	411	nd	23	122	38	20	4	13	29	75	29	110	nd	17	309	4	113	16	88	152
29	G8	339	nd	20	124	30	15	4	10	15	56	11	74	20300	17	433	2	111	16	61	142
30	G9	368	nd	21	131	33	16	5	12	21	54	15	87	12300	15	378	3	122	19	72	173
31	G10	393	nd	22	143	26	18	5	12	22	70	8	98	1360	18	286	6	134	20	72	169
32	G11	108	nd	10	272	153	4	4	5	4	14	50	22	704	8	141	1	21	5	39	68
33	G12	335	nd	17	101	23	14	3	11	19	50	15	61	8340	16	357	2	112	17	56	167
34	G13	400	nd	16	101	27	14	5	12	16	69	23	65	1600	15	336	1	93	18	57	275

Table 3.3 Continued

n.	Label	Ba	Ce	Co	Cr	Cu	Ga	Hf	Nb	Nd	Ni	Pb	Rb	S	Sc	Sr	Th	V	Y	Zn	Zr
35	G14	374	nd	21	110	34	16	5	12	20	68	26	95	8680	15	375	3	121	18	71	170
36	G15	332	nd	15	142	30	14	5	10	16	40	22	76	7730	15	238	3	119	16	58	169
37	G16	367	nd	17	121	29	14	5	10	14	61	23	71	nd	17	312	2	107	16	59	171
38	K1	263	56	18	126	26	9	1	9	16	119	11	41	3670	12	626	7	97	12	64	146
39	K2	313	55	20	150	29	8	2	8	17	144	12	47	1330	11	604	8	92	12	60	151
40	K3	325	53	25	199	34	9	2	7	14	185	17	41	3250	11	539	8	100	12	63	139
41	K4	255	48	27	222	35	7	1	7	11	239	13	44	3680	12	482	6	107	12	62	134
42	K5	372	55	16	138	28	9	2	9	14	105	17	48	2170	11	636	8	95	13	61	156
43	K6	270	48	29	202	36	8	2	8	13	255	17	50	1040	12	499	7	105	11	62	128
44	K7	311	60	22	201	32	8	1	7	11	139	21	50	4740	11	569	8	102	11	67	132
45	K8	323	50	20	162	27	8	2	9	13	172	9	38	1740	12	715	7	89	13	60	159
46	K9	50	nd	9	117	175	5	3	2	nd	16	334	6	nd	10	178	nd	23	3	19	41
47	K10	159	nd	22	52	240	2	3	3	4	25	115	6	8	6	197	nd	14	2	34	24
48	Z1	347	72	13	70	33	10	2	10	19	37	136	73	1690	12	432	10	86	12	81	152
49	Z2	329	73	17	84	20	12	2	10	17	40	44	72	6240	10	496	12	89	13	91	143
50	Z3	331	98	15	68	63	12	3	11	17	32	459	66	2910	10	508	7	88	13	89	198
51	Z4	77	87	4	15	118	3	1	2	7	2	636	7	2510	nd	224	3	8	nd	156	46
52	Z5	381	74	17	74	41	13	2	10	20	44	161	72	1400	10	488	10	86	12	86	148
53	Z6	357	74	15	89	20	10	2	9	18	44	61	55	1940	13	510	11	91	11	86	135
54	Z7	211	59	2	1	211	nd	nd	1	nd	2	438	5	392	nd	90	2	4	nd	26	24
55	Z8	407	nd	18	76	133	12	3	6	24	39	329	51	6500	8	348	11	96	2	89	85
56	Z9	119	nd	12	170	169	1	3	4	14	9	3	6	1600	nd	267	6	19	nd	15	78
57	Z10	514	nd	7	33	817	9	1	4	12	4	2080	21	1570	nd	195	nd	17	nd	61	53
58	Z11	328	nd	18	77	39	11	3	10	22	44	70	62	7500	12	517	12	88	11	81	141
59	Z12	378	nd	21	76	29	12	3	10	26	43	17	74	1820	15	502	15	101	10	97	142
60	Z13	323	nd	24	124	35	16	3	10	26	67	4	72	4020	16	486	13	130	13	97	126
61	Z14	362	nd	22	94	197	16	2	9	26	51	621	64	2620	13	410	8	101	3	92	113
62	Z15	157	nd	7	75	501	3	1	4	14	4	445	20	2410	nd	161	6	12	nd	83	50
63	Z17	249	nd	5	9	243	3	3	2	5	5	569	5	1430	5	78	nd	8	nd	36	22
64	Z18	377	nd	9	49	862	11	2	3	nd	19	2350	16	nd	nd	199	nd	15	nd	45	42
65	Z19	113	nd	5	17	216	2	3	2	7	3	276	3	189	4	77	nd	9	nd	15	18
66	Z20	94	nd	6	13	277	8	4	3	5	4	1410	12	nd	7	277	nd	12	nd	145	46
67	Z21	117	nd	6	18	126	5	3	2	8	146	705	7	46	4	112	nd	15	nd	17	27
68	Z22	117	nd	7	44	415	5	3	2	2	268	836	7	253	1	90	nd	7	nd	31	29
69	Z23	140	nd	8	66	597	9	3	3	2	382	1900	9	nd	nd	112	nd	14	nd	28	36
70	Z24	101	nd	7	21	354	3	3	2	3	5	628	6	nd	5	70	nd	16	nd	105	18
71	Z25	119	nd	7	15	140	2	3	3	2	204	339	5	1130	3	89	nd	8	nd	11	24
72	Z26	109	nd	6	16	319	1	4	2	3	4	38	6	2170	5	554	nd	9	nd	22	24
73	Z30	361	nd	18	88	30	14	4	8	16	43	24	61	5460	17	431	3	96	10	92	111
74	Z31	347	nd	20	95	17	15	4	10	20	43	6	63	4830	16	500	1	102	13	88	122
75	Z32	345	nd	17	93	23	15	4	13	16	40	22	69	1520	15	545	2	89	19	87	170
76	Z33	418	nd	20	104	26	16	4	11	20	50	14	71	1400	16	466	3	100	15	93	141
77	Z34	357	nd	21	118	30	18	4	13	21	42	12	56	3970	17	594	3	109	18	99	143
78	Z35	409	nd	19	86	24	16	5	11	16	50	16	82	3240	16	443	3	100	15	70	149
79	Z36	428	nd	21	104	25	18	4	13	21	50	17	72	2290	18	514	3	101	17	103	154
80	Z37	382	nd	19	80	25	15	4	12	18	39	23	77	8790	15	597	2	90	17	83	174
81	Z38	367	nd	20	121	24	14	4	8	19	31	11	62	1230	14	452	2	100	13	86	107

Table 3.3 Continued

n.	Label	Ba	Ce	Co	Cr	Cu	Ga	Hf	Nb	Nd	Ni	Pb	Rb	S	Sc	Sr	Th	V	Y	Zn	Zr
82	Z39	367	nd	18	92	23	14	4	11	16	44	23	59	3970	18	483	2	88	15	81	148
83	Z40	318	nd	19	83	32	15	4	12	19	71	32	75	17500	18	540	2	92	15	100	129
84	Z41	331	nd	18	91	34	16	4	10	18	47	26	67	12800	16	476	2	99	13	98	114
85	Z42	390	nd	15	167	33	14	7	8	15	nd	31	64	3235	8	422	5	103	15	83	135
86	Z44	484	nd	14	293	37	14	3	6	13	nd	22	72	25000	7	428	6	159	13	89	95
87	Z45	511	nd	17	378	46	16	3	4	14	nd	19	66	4060	4	341	4	197	12	108	65
88	Z46	586	nd	11	226	29	13	4	7	8	nd	27	74	23400	5	346	3	121	14	65	153
89	S1	458	70	14	95	22	11	3	9	22	34	7	89	2210	9	373	13	76	15	64	173
90	S2	465	76	14	91	17	12	2	11	17	43	9	77	1780	10	769	12	81	15	65	154
91	S3	484	70	14	69	24	11	3	12	17	50	25	96	1830	8	395	13	89	16	68	187
92	S4	293	69	16	103	28	13	1	8	20	63	14	98	12400	15	443	12	88	13	56	121
93	S5	289	73	21	104	33	12	1	5	19	69	18	72	6940	12	329	11	111	9	78	94
94	S7	499	nd	18	80	25	15	4	11	16	40	21	81	710	16	647	2	75	17	60	171
94	S8	340	nd	22	114	37	17	4	10	24	68	19	80	4080	19	408	2	116	14	77	120
96	S9	470	nd	20	123	27	17	5	10	18	42	8	76	6690	15	532	4	114	14	81	114
97	S10	366	nd	14	174	29	13	5	7	13	nd	18	70	13100	8	616	3	111	12	61	92
98	S11	493	nd	17	120	15	13	5	6	19	38	6	52	739	13	289	3	83	9	45	111
99	S12	464	nd	16	167	23	12	7	8	19	32	9	65	12300	15	290	3	93	17	37	197
100	S13	375	nd	21	92	36	17	4	11	14	67	28	87	10500	18	676	3	108	15	84	129

4.2 Stratigraphy of the glazed tiles

Prior to performing any analysis on the glazes, thin sections of the glazed bodies were studied under polarising light microscope (PLM). The first issue perceived by studying thin sections of the glazed tiles was that the bodies were grouped in two main categories of clay-based and stone-paste bodies. This was entirely consistent with WDXRF results on the bodies (see the previous section). Figure 4.5 *left* demonstrates a stone-paste body on which a transparent glazed is applied. Furthermore, some glazes appeared to be opacified with an opaque substance (Figure 4.5 *right*).

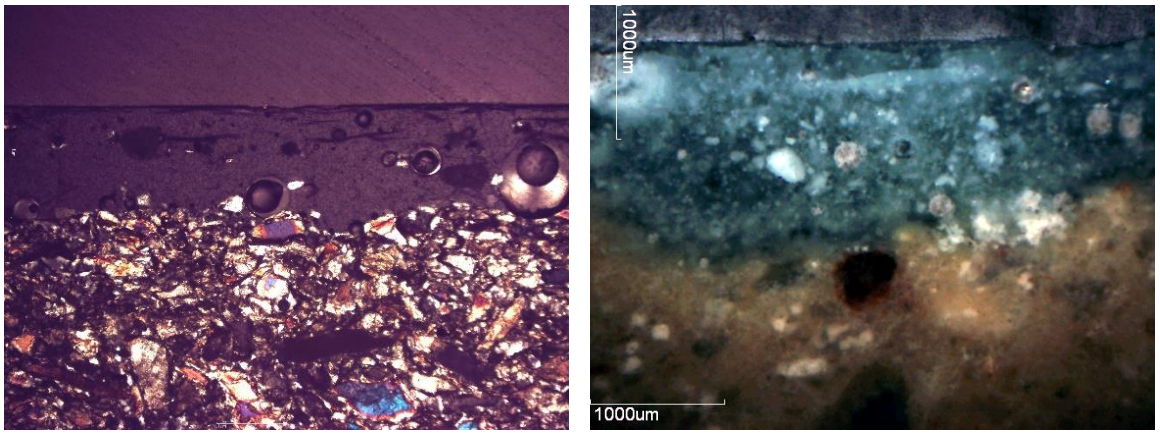


Figure 4.5. Crossed polarised light image of the thin section of K10 shows a quartz-based body on which a transparent glaze is used (left)and the polished cross section of sample M6 shows an opaque substance has opacified the clay-based body (right)

Moreover, PLM revealed that a priming layer was placed between the glaze layer and bodies (Figure 4.6 *left*). This layer was observed in the M10, M20, M4, M21, M18, K10, Fr6, K9 and M22 bodies

which are the stone-paste bodies. The μ-Raman study on this layer showed the Raman bands at 208, 265, 357, 394, 415 and 467 cm^{-1} (Figure 4.6 *right*) confirming quartz (Shapiro, et al., 1967) was the main substance that the priming layer was composed of.

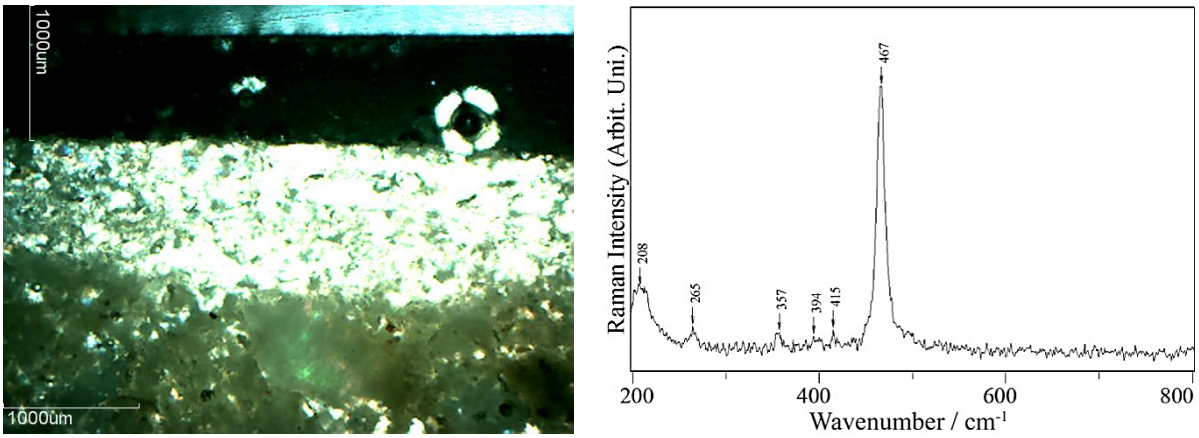


Figure 4.6. Crossed polarised light image of the sample M10 (left) and the Raman spectrum of quartz composing the white priming layer(right)

Another point of interest was that some glazes were revealed to be opacified. The opacified glazes were only used on the clay-based bodies of some selected samples. The backscattered image of SEM on the opacified glazes (Figure 4.7 *left*) showed that the micro-scale opacifier particles were mainly composed of Sn. μ-Raman study with the Raman bands centred at 476, 633 and 769 cm^{-1} (Figure 4.7 *rignt*) showed that cassiterite (SnO_2) (Bouchard & Smith, 2003) was the main constituent of the opacifiers.

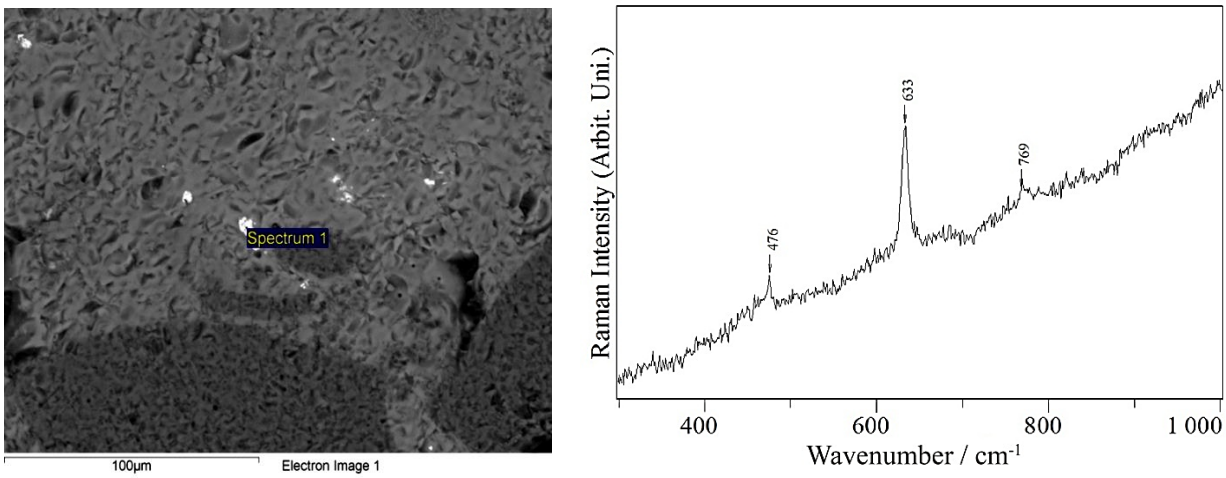


Figure 4.7. Backscattered SEM micrograph of the M1 sample (left) and the Raman spectrum of cassiterite corresponded to the light spots in the left micrograph (right)

The white glaze of M21, however, showed a peculiar multi-layer structure in its cross section (Figure 4.8 *left*). As the back-scattered SEM micrograph of this glaze showed (Figure 4.8 *right*), the multi-layer structure was quite similar to those corroded glassy matrices of the Sassanid glasses studies by Gulmini et al. (2009). As the back-scattered SEM micrograph on this cross section showed, an element with high atomic weight such as Pb and Sn could be deposited fairly deep inside the glaze near the stone paste body. The μ-XRF microanalysis on the white glaze showed no trace of Sn incorporated in the white glaze suggesting an opacifier other than cassiterite embedded in the glassy matrix of the glaze (Figure 4.9). Thus, the heavy atomic weight element appeared in the SEM back-scattered micrograph would be

attributed to Pb. The only possible opacifier whose Raman bands were registered via μ-Raman was quartz with the Raman bands at 203, 263, 390 and 462 cm^{-1} (Figure 4.10).

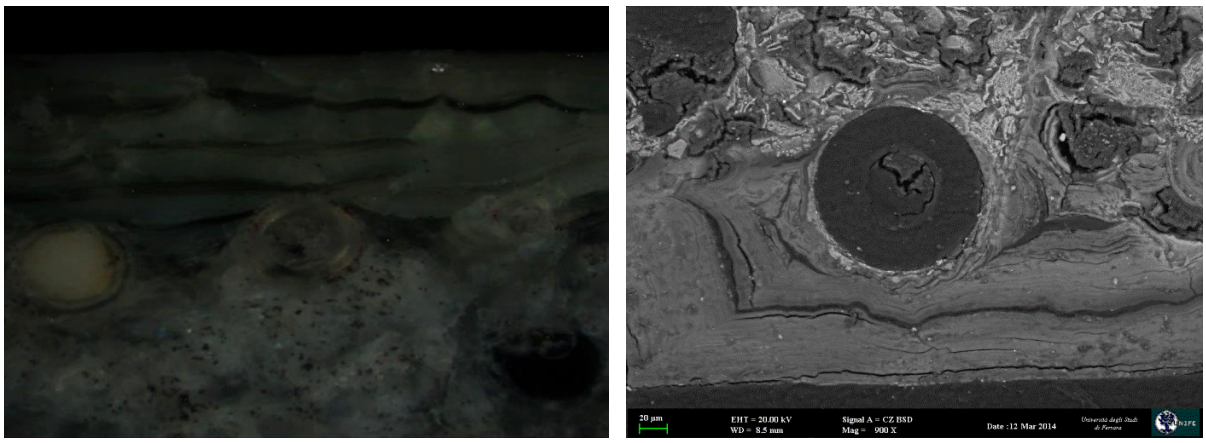


Figure 4.8. Polished cross section of the M21 sample (left) and its SEM back-scattered image showing a multi-layer corroded structure for the white opacified glaze (right)

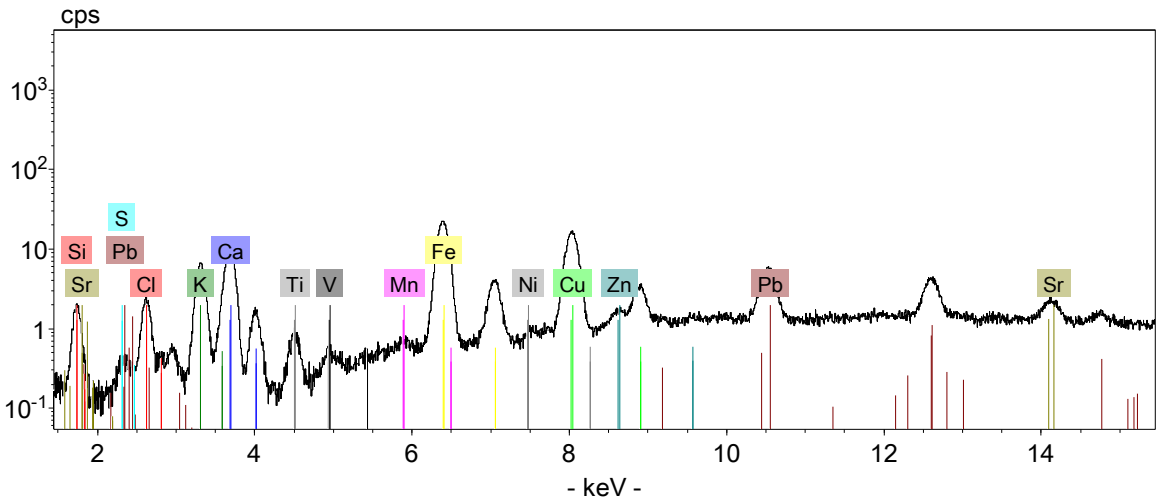


Figure 4.9. μ-XRF spectrum of the M21 white opacified glaze

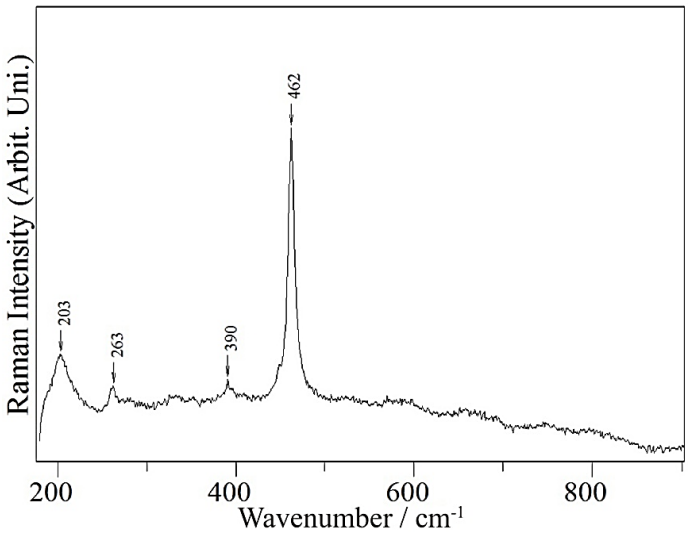


Figure 4.10. Raman spectrum of quartz incorporated as a probable opacifier in the white glaze of M21

Apart from these issues, some unusual aspects of the glazes were revealed in PLM images. For instance, the sample M22 showed an unusual white substance embedded in the glassy matrices of the glaze whose Raman bands were registered at 430, 445, 578, 589, 607, 961, 1049 and 1076 cm^{-1} assignable to hydroxyapatite (Koutsopoulos, 2002), the main constituent of and an essential ingredient of normal bone and teeth (Figure 4.11).

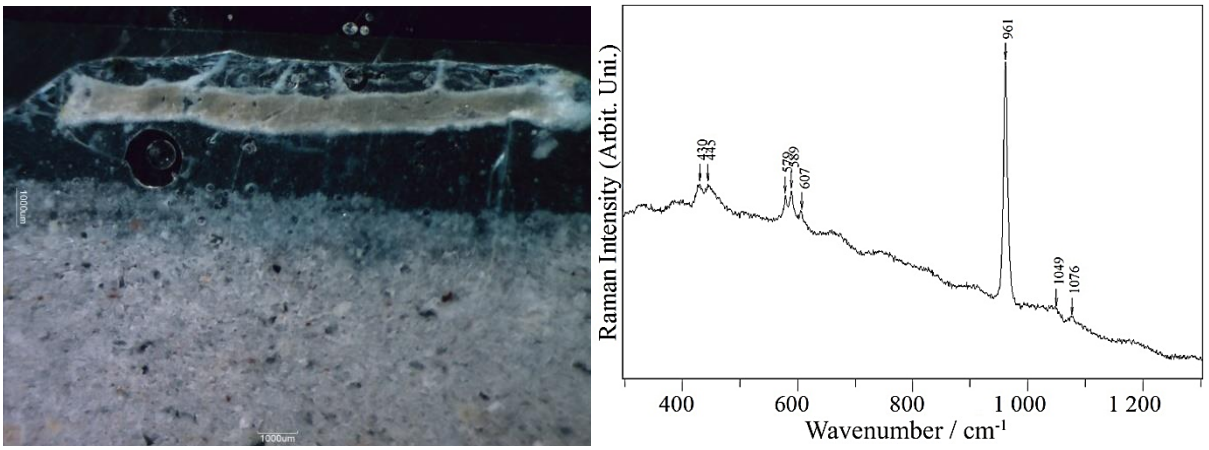


Figure 4.11. Polished cross section of the sample M22 (left) and the Raman spectrum of hydroxyapatite derived from the white substance immersed in the glaze (right)

Moreover, star-like crystals as those demonstrated in Figure 4.12 *left* were appeared in the intermediate layer between the glaze layer and clay bodies. The μ-Raman study on these crystals registered the Raman bands at 227, 328, 357, 391, 668, 894 and 1016 cm^{-1} (Figure 4.12 *right*) which can be assigned to diopside (Huang, et al., 2000). This was consistent with the previous studies where pyroxene crystals were observed in the interface layer formed as a result of firing alkali glazes on calcareous clay-bodies (Mason & Tite, 1997). This may suggest a single firing process for firing the glaze on a raw calcareous clay body.

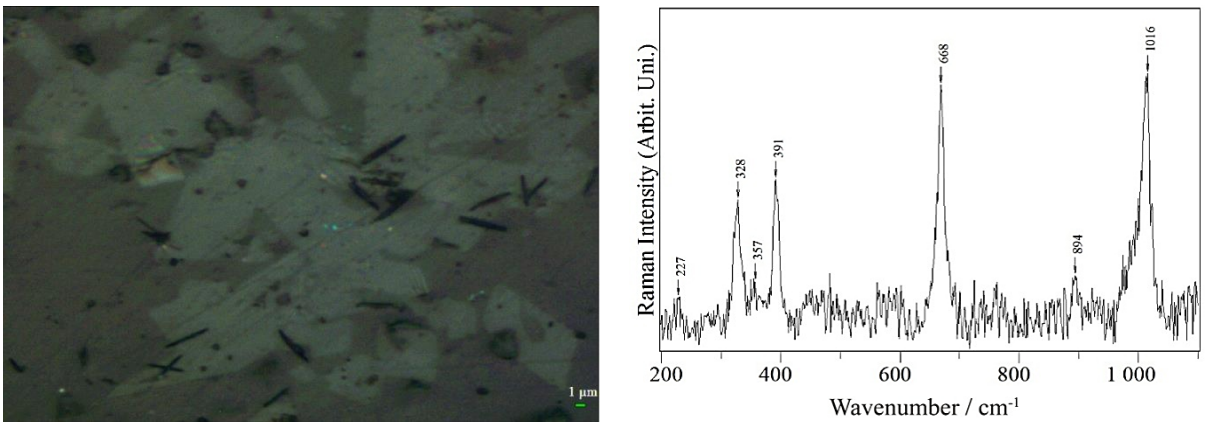


Figure 4.12. Polished cross section of the sample M20 revealing the crystals (left) and their Raman spectrum consistent with diposide (right)

4.3 ICP-MS quantitative analysis of the glazes leading to technological and provenance studies

ICP-MS was mainly performed on the glazes for three main reasons. The first was to shed light on the colouring agents, opacifiers and the chemical composition of the glazes. The second was to investigate any association of the main elements composing the glazes with particular trace elements in order to

have an idea about raw materials used in the glazes. Finally, the quantitative data offered by ICP-MS could be used to explore any particular correlation between various groups clustered within the glazes under study. The data obtained by ICP-MS on the glazes are represented in Table 3.4. To have an overall image on the extensive dataset of ICP-MS, a PCA was run for which about 67.32% of total variance (42.68% and 24.64% for PC1 and PC2 respectively) was accounted. It should be highlighted that some elements, such as Ba, Se, U, Sc, Li, Be, Mo, Cd, Ag, Te, Tl, Hg and Bi, which eather were not detected or showed no contribution in clustering the samples via PCA, were excluded to be handled by PCA.

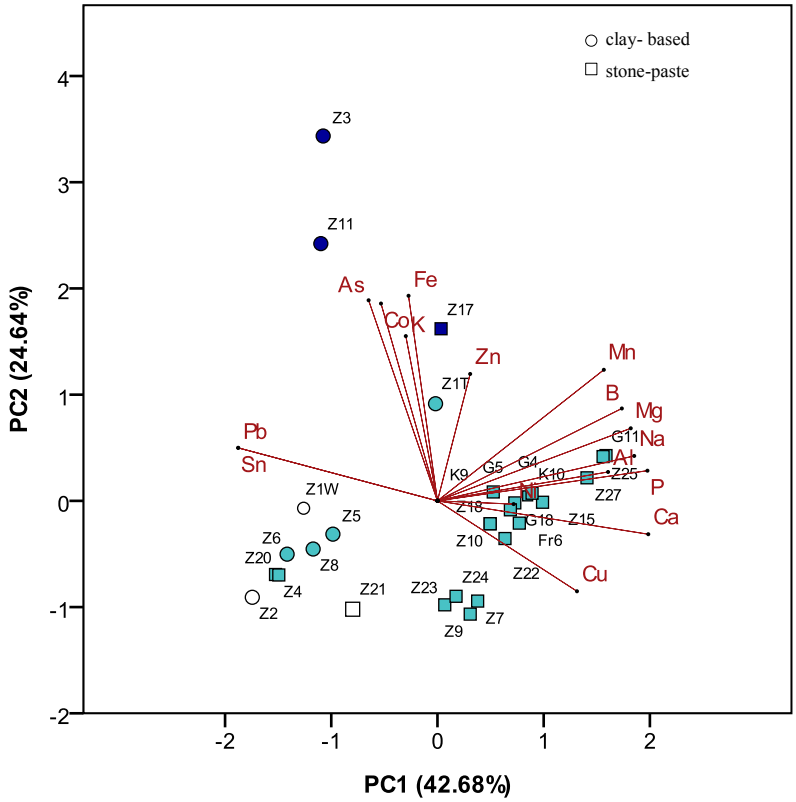


Figure 4.13. PCA bi-plot on the quantitative data of ICP-MS of the glazes

As the PCA bi-plot on the ICP-MS data of the glazes shows (Figure 3.19), three main clusters were discriminated within the glazes. The first group comprises only of three dark-blue glazes of the samples Z3, Z11 and Z17 which are grouped as a result of their high correlation with Co, As, Fe and K. This was of our major interest as it showed, first, that the colouring agent of the dark-blue glazes was Co, the most familiar element of which a dark-blue colour would be expected in an alkali glaze. Second, the association of As was very important as it suggested that the raw Co-bearing material of which cobalt was introduced in the glaze has most probably been supplied from As-bearing ores of cobalt which used to be historically mined from Qamsar, near Kāshān. As the observations of Schindler (Floor, 2003) and Stöllner (2004) suggest, cobalt ores of Qamsar are either cobaltite (CoAsS) or erythrite ($Co_3(AsO_4)_2 \cdot 8H_2O$). This was very interesting as it could suggest that the colouring agent of the blue the studied glazes was most probably supplied from the Qamsar cobalt ores.

The second cluster, which comprised of Z23, Z24, Z9, Z7, Z22, Z10, Z18, G5, G18, K10, G4, G11, Z25, Z27, Z15, Fr6, K9 and Z18, was characterised by a special association with Cu, Na and Mg. As the glazes grouped in this cluster are turquoise in colour, their colour can be attributed to Cu dissolved in the alkali matrix of the glazes. Achieving turquoise colours in alkali glazes has been the most usual way

of achieving turquoise hues in the glazes from the very beginning of glaze-making in the Near East (see the *Discussion* section). What was interesting in the chemical composition of these turquoise glazes was the association of Na with Mg and, to a lesser extent, K. This could be resulted to the fact that the plant ash has most certainly been the source of alkalis used as flux in the glazes (Tite, et al., 2006). Within the second cluster, a four-member group, all from the Zuzan mosque, can also be recognised that includes Z7, Z9, Z23 and Z24 samples.

The third group of the glazes is particularly clustered because of relatively high Pb and Sn contents. All glazes in this group (Z2, Z8, Z1T, Z3, Z5, Z1W, Z6, Z20, Z4 and Z21) are tin opacified glazes of which Z1T, Z5, Z6, Z20, Z4 and Z8 were coloured with Cu. Interestingly, grouping two stone-paste body samples (Z4 and Z20) in this cluster demonstrated the use of tin opacified glaze on both body types at the Zuzan site. The high correlation of Pb and Sn (with 1.0 correlation coefficient) shows that wherever Pb is incorporated in a glaze, Sn is also observed in that glaze. In other words, all the glazes studied by ICP-MS are essentially alkali glazes to which Pb and Sn are only added to opacify the glazes. The Pb/Sn weight ratio of the opacified glazes was varied from 8 to 16 that are significantly higher than the Pb/Sn weight ratio of white glazes described in medieval treatises (Abu'l-Qasim, 1301; Ali Mohamed, 1888), and the values reported for the medieval glazes (Vendrell, et al., 2000) and seventeenth century Persian *haft rang* tiles (Holakooei, et al., 2014). According to Abu'l-Qasim (1301) and Ali Mohamed (1888), Sn should be added in the glaze batch in one-third amount of Pb and, in other words, the Pb/Sn weight ratio should be about 3. The higher Pb/Sn ratio of the studied glazes suggests that Pb might have been deliberately added to the batch of the glazes as fluxing agent. In other words, all the Pb content has not participated in the formation of the opacifier (see the *Discussion* section).

Another important issue which can be seen from the ICP-MS data is that all the glazes studied by ICP-MS are alkali glazes except those tin-opacified glazes. According to the classification suggested by Mason (2004), those glazes which are not opacified can be considered as alkali-lime glazes as their PbO content is lower than 2% wt. The Na/K weight ratio in these glazes varies from 3 to 16. Although the Na/K weight ratio of the most of the glazes fits perfectly within the chemical composition of the plant ashes in the Near East (Tite, et al., 2006), there are some glazes (Z7, Z9, Z15, Z17 and Z24) which show fairly high Na/K weight ratio. This might be indicating that another source of alkalis which is rich in Na and poor in K (probably natron) would have been added to the glazes' batches. One, however, cannot exclude the possible use of an alkali feldspar (i.e., albite $NaAlSi_3O_8$), which is rich in Na and poor in K, for supplying both Si and Na contents of the glazes.

The tin-opacified glazes contained, on the other hand, about 13% to 33% Pb in their composition. This pushes the tin-opacified glazes towards the lead-alkali glazes, according to Mason (2004).

Table 4.3. The ICP-MS data of the glazes (ppm)

	Li	*Be*	*B*	*Na*	*Mg*	*Al*	*P*	*K*	*Ca*	*Sc*	*Ti*	*Na/K*
Fr6	41.2	0.229	79.9	122000	18100	11200	1590	16700	26600	1.94	614	7.30
G4	89.7	0.473	80.1	109000	20200	17500	1790	34700	30400	3.06	835	3.13
G5	79.6	0.417	75.7	111000	16900	16900	1460	25000	24400	2.74	698	4.41
G11	144	0.773	139	169000	30400	29900	2740	38800	26800	7.15	1284	4.35
G18	44.5	0.485	85.1	117000	16900	16800	1600	23800	25600	1.53	793	4.94
K9	19.6	0.167	72.1	103000	20000	17300	750	13900	24500	1.52	706	7.41
K10	29.1	0.207	70.7	129000	29000	8620	1010	12900	36700	7.57	574	10.0
Z3	68.6	0.240	94.1	77000	13500	9220	340	72500	4880	nd	391	1.06
Z4	42.1	0.152	19.2	81000	11300	6250	110	19700	3110	nd	123	4.13
Z5	67.6	0.254	27.4	78000	13700	11300	260	37800	4230	nd	424	2.07
Z8	71.1	0.154	38.4	87000	13600	4530	140	41800	2700	nd	138	2.08
Z9	71.1	4.31	108	123000	24400	6550	720	9440	20700	1.77	591	13.0
Z10	63.7	0.319	61.7	125000	22800	9080	550	13600	16500	1.56	451	9.22
Z11	52.7	0.234	48.0	121000	18500	7090	370	26000	8760	nd	383	4.67
Z1T	124	0.680	74.5	108000	24100	36200	390	52300	4290	7.32	1580	2.06
Z1W	86.2	0.355	36.5	81000	16100	13390	160	35200	2500	2.98	533	2.31
Z2	32.9	0.193	25.0	87000	12800	5110	160	17300	1690	1.21	117	5.04
Z6	49.0	0.315	27.9	68000	12400	14200	170	25700	3070	1.97	603	2.65
Z7	41.9	0.332	45.2	143000	20000	9770	650	8750	15900	2.87	422	16.3
Z15	93.3	0.726	103	215000	35100	19900	910	13000	16900	3.62	811	16.5
Z17	43.3	0.360	57.2	133000	20500	10200	520	11100	19400	2.03	471	12.0
Z18	48.6	0.397	63.3	135000	20300	12800	510	13500	17000	5.55	619	9.95
Z20	42.5	0.194	30.4	69000	10200	6900	130	18800	3010	0.771	186	3.69
Z21	8.45	0.442	20.9	24000	8480	15100	220	8690	5680	1.55	444	2.80
Z22	48.2	0.476	54.2	138000	21400	16600	850	13100	19800	3.05	943	10.5
Z23	39.3	0.493	22.8	77000	14700	16800	600	7180	23100	2.59	754	10.7
Z24	41.9	0.436	42.0	106000	16500	12400	520	9400	26000	1.65	536	11.3
Z25	72.4	0.714	217	264000	41100	22100	1420	38300	17400	15.2	1090	6.88
Z27	120	12.5	181	237000	32300	19300	1430	26900	27000	9.49	936	8.82

Table 3.4 Continued

	V	*Cr*	*Mn*	*Fe*	*Co*	*Ni*	*Cu*	*Zn*	*Ga*	*As*	*Se*	*Rb*
Fr6	12.0	17.7	382	5780	6.87	20.1	25600	64.2	3.61	18.4	0.318	15.6
G4	15.1	22.3	412	7900	11.4	16.3	17500	92.4	6.20	31.1	0.341	71.8
G5	12.0	17.6	395	6220	3.10	17.2	15900	91.1	5.62	21.2	0.182	46.6
G11	15.2	35.5	686	7680	5.78	39.5	23600	184	10.6	15.3	0.253	73.4
G18	15.3	25.9	412	7660	3.19	19.6	17500	112	5.98	20.8	0.333	28.6
K9	13.9	37.2	221	4480	4.48	41.1	10400	628	3.51	70.8	0.237	11.7
K10	14.3	42.6	362	5680	5.42	47.2	8230	98.0	2.94	72.8	0.250	13.2
Z3	8.98	39.2	276	14800	2590	22.4	1960	363	4.23	477	nd	49.9
Z4	11.3	8.85	158	2690	2.14	23.9	11600	154	2.06	29.3	nd	17.0
Z5	12.7	46.8	208	4000	2.69	35.4	17900	113	3.75	42.3	nd	65.9
Z8	3.30	8.53	187	1840	2.71	26.5	13400	135	3.19	11.4	nd	56.1
Z9	5.21	44.4	167	2960	4.89	41.1	9800	31.2	1.63	13.0	nd	16.2
Z10	125	23.2	304	3010	5.95	21.7	17850	154	3.99	36.8	nd	34.1
Z11	8.39	36.1	272	11200	1927	13.9	1090	80.0	3.24	1565	nd	39.8
Z1T	13.6	1105	470	5740	19.6	109	76000	193	12.5	100	nd	98.5
Z1W	7.12	21.6	215	2880	2.94	28.2	1640	89.8	4.89	58.8	nd	66.1
Z2	2.98	7.40	118	1390	1.34	11.4	1030	44.7	2.17	39.5	5.30	23.5
Z6	24.5	27.0	210	3720	3.10	31.6	14500	73.5	4.73	57.4	nd	44.6
Z7	4.23	7.83	237	2050	1.62	19.3	26900	116	3.16	24.7	0.213	14.5
Z15	4.13	30.2	412	2190	3.82	22.1	20400	150	6.83	13.5	0.102	32.8
Z17	6.02	18.0	293	8640	1963	10.8	1760	127	3.85	968	0.402	19.6
Z18	7.21	13.4	284	3370	2.78	30.1	17800	205	6.78	32.6	0.206	29.0
Z20	59.4	9.25	162	2230	2.36	19.9	10600	192	2.45	23.7	nd	25.5
Z21	45.6	13.6	103	2540	2.09	116	2160	71.1	3.77	6.16	0.563	13.8
Z22	10.1	19.6	315	3900	3.39	25.4	25000	235	5.12	26.6	0.334	24.6
Z23	103	13.6	242	4360	2.98	14.2	7050	122	5.45	12.0	0.511	17.3
Z24	21.0	9.74	259	3350	12.9	14.8	12000	118	4.92	30.3	0.422	23.4
Z25	5.36	25.0	617	2760	4.21	41.1	41600	314	7.43	21.3	0.215	46.0
Z27	7.24	26.2	781	3400	4.83	20.2	32300	232	22.3	21.7	0.715	60.4

Table 3.4 Continued

	Sr	*Mo*	*Ag*	*Cd*	*Sn*	*Sb*	*Te*	*Ba*	*Hg*	*Tl*	*Pb*	*Bi*	*U*	*Pb/Sn**
Fr6	372	0.447	3.10	1.07	340	16.3	0.776	71.3	nd	0.023	629	1.70	0.397	-
G4	394	0.433	3.49	1.86	1880	18.3	0.967	137	nd	0.090	1470	3.35	0.681	-
G5	344	0.461	5.34	1.27	2003	17.4	0.762	115	nd	0.176	1160	2.44	0.692	-
G11	645	1.01	4.85	2.82	2060	27.5	1.60	209	nd	0.082	1440	4.84	1.25	-
G18	368	0.470	3.16	1.51	1600	17.3	0.779	129	nd	0.031	800	2.81	0.760	-
K9	310	0.725	4.06	1.07	444	136	0.690	53.5	nd	0.044	3450	3.46	0.414	-
K10	626	0.400	4.21	0.94	432	26.4	0.513	90.8	nd	0.054	920	1.61	0.340	-
Z3	392	1.17	11.5	2.64	13500	117	6.76	140	0.038	0.065	173000	6.30	0.439	12.8
Z4	201	0.145	22.0	1.95	9040	36.9	4.99	73.5	0.003	0.046	149000	2.40	0.311	16.5
Z5	294	0.550	32.3	2.31	18200	106	5.73	138	0.027	0.066	156000	7.51	0.519	8.58
Z8	233	0.193	60.7	2.22	14700	150	6.77	180	0.113	0.071	204000	2.68	0.249	13.9
Z9	544	0.423	2.41	1.10	43.6	17.0	0.304	40.6	nd	0.022	170	0.658	0.590	-
Z10	383	0.410	21.5	1.72	2142	38.5	1.16	164	nd	0.108	26500	3.62	0.710	-
Z11	331	1.56	18.1	1.68	15300	54.8	3.99	145	nd	0.530	79700	5.64	0.397	-
Z1T	441	1.40	46.8	5.61	20200	346	10.9	391	0.786	0.205	339000	32.4	1.49	16.8
Z1W	218	0.664	50.4	2.62	19600	170	7.99	173	0.332	0.146	264000	9.49	0.499	13.5
Z2	148	0.252	119	2.08	11500	151	7.08	96.2	0.117	0.368	243000	6.30	0.229	21.1
Z6	263	1.51	39.2	2.21	15800	146	5.17	151	0.041	0.138	172000	9.34	0.834	10.9
Z7	387	0.253	14.6	1.09	533	46.2	0.575	92.5	nd	0.197	5320	4.76	1.79	-
Z15	1590	1.28	7.24	2.06	314	38.4	1.00	187	nd	0.038	3010	3.48	0.803	-
Z17	399	2.21	6.66	1.12	3230	15.0	1.21	119	nd	0.053	15300	1.83	0.461	-
Z18	467	0.695	16.0	1.39	2900	50.1	1.26	297	nd	0.082	26000	5.21	0.645	-
Z20	225	0.288	17.7	1.69	15200	87.1	3.92	82.1	nd	0.134	136000	3.14	0.412	8.99
Z21	163	1.67	0.98	0.94	1040	3.61	0.306	58.7	nd	0.123	2060	1.12	1.40	-
Z22	431	0.647	8.75	1.53	292	49.8	0.756	132	nd	0.072	4640	5.41	0.646	-
Z23	316	0.621	5.15	1.21	479	11.3	0.543	113	nd	0.072	6530	2.22	1.20	
Z24	399	0.728	5.98	1.48	240	16.4	0.440	139	nd	0.047	3730	1.97	0.980	-
Z25	1160	1.29	34.1	1.78	3440	96.4	1.40	280	nd	0.109	29900	11.3	1.09	-
Z27	946	0.983	32.0	3.11	865	54.2	0.476	1983	nd	10. 5	15900	4.58	0.938	-

* Pb/Sn was only calculated for tin-opacified glazes

4.4 Discussion

4.4.1 Bodies

A- Stone-paste bodies

As thin section petrography and WDXRF quantitative analysis on the bodies of the brickwork and the glazed elements showed both clay-based bodies and stone-paste bodies were used in the studied glazed decoration. As far as the stone-paste bodies are concerned, quartz is the main component of these bodies that, for certain purposes, is associated with other ingredients. Beside the stone paste, to describe quartz-based bodies, the terms such as frit, quartz-frit, faïence, artificial paste, *kāshi* (Mason, 1996), silicate pottery, composite material (Keblow-Bernsted, 2003) and *jesmi* (Nāderi, 1978) have been frequently used. Nonetheless, the term 'processed body', suggested by Holakooei (2013) seems to be more proper covering mentioned terms however, here, in this thesis stone-paste will be used. The ratios of the principal ingredients of processed bodies are 80 wt% quartz, 10 wt% from a white clay and 10 wt% glass powder (Mason, 1996).

In Iran, using stone-paste bodies date back to the Elamite period at Haft Tepe (Negahban, 1991). The friezes of the Apadana palaces at Susa and Persepolis are examples of using this technology during the Achaemenid period (Caubet & Kaczmarczyk, 1998; Tite, et al., 2008). Caubet (1992) states that the main components of the Achaemenid glazed bricks are sand and lime. Stone-paste bodies were also extensively used in the Islamic Persia. According to Abu Dulaf's treatise (950 AD), quartz, glass powder and tin oxide are the main components of a stone-paste body (Morgan, 1994). However, other ingredients are reported to manufacture modern Persian stone-paste bodies; for instance, a combination of flint powder and kaolin in Naṭanz (Wulff, 1966) and in Meybod a combination of 75 wt% silica, 12.5 wt% a white clay and 12.5 wt% glass powder (Centlivres-Demont, 1971). As far as ʿArāyes al-Javāher va Nafāyes al-Atāyeb, the Abu'l-Qasim's treatise (1301), is concerned, the main component of these bodies is quartz, along with *luri* (a white, sticky, strong clay). Ali Mohamed (1888) has also mentioned quartz (flint stone) and a white colour clay called *gil-i buta* as the main components of a stone-paste body. Wulff (1966) refers to the potters of Isfahan, Qum, Naṭanz and Kāshān, that gather, crush and ground the dry riverbed flint stone, found near Naṭanz, and then mix seventy to eighty percent of the powdered flint stone with ten to twenty percent of fine clay and ten percent of glass powder to make a body paste.

The described methods of making stone-paste bodies by Rochechouart (1867) and Ali Mohamed (1888) are more or less similar to that of Abu'l-Qasim's way in which other than quartz and the white clay, glass frit is another component. Nowadays, to make stone-paste bodies, glass powder is also used (Caiger-Smith, 2001) to be molten at high temperature and bind the quartz and clay particles together after cooling (Mason, 1995). Accordingly, alkaline elements in the glass frit react with the quartz grains and clay minerals and modify physical properties of the body (Tite, et al., 2011).

Stone-paste bodies that contain low calcium and iron are usually light in colour (white to pale pink) because of small amount of colouring agents like iron. Moreover, due to low amount of decomposable and combustible materials, stone-paste bodies emit less volatile gases during firing process. Hence, stone-paste body could have been baked together with upper glazes in one individual firing process (Caiger-Smith, 1973).

In addition, lack of decomposable and volatile materials is the reason that the volumetric and linear shrinkage of stone-paste bodies is low. Furthermore, these glazes are not subjected to high tension, due to the almost same coefficient of expansion with alkaline glazes layers, therefore, the risk of crazing and crackling was drastically lessened (Caiger-Smith, 1973; Tite, et al., 2008). Another advantage of using stone-paste bodies is that, in the case of chipping the upper white glaze, the body is not in high contrast with the white glaze (Caiger-Smith, 1973). Also, a possible white upper glaze does not need high percentage of tin oxide to be opacified since the body is already white. Therefore, the tin oxide could be economised in the glazes (Tite, et al., 1998).

B- Clay-based bodies

As far as the clay-based bodies under study are concerned, they are made of calcareous secondary clays. Secondary clays may contain various constituents which are not basically clay minerals e.g. quartz, organic matters, and iron minerals. Moreover, adding some materials to clay to enhance its workability may change the chemical composition of clay (Holakooei, et al., 2013) that is important in the provenance studies of the ceramics. The additives change the chemical composition of the bodies drastically, and introduce new elements that mislead the interpretation of analytical results.

Apart from bricks and *khesht* that were used in Iran, the bricks covered by a vitreous layer at the Choghā Zanbil are, most probably, the first experiences of the use of glazes on a clay body in the Near East (Moorey, 1994). The majority of clay bodies reported in the analytical literature of Persian ceramics have high calcium content with colour variety of creamy to buff (Kamilli & Lamberg-Karlovsky, 1979; Yelon, et al., 1992; Holakooei, 2014; Holakooei, et al., 2014). Sometimes, low Ca-clay bodies have been reported in the literature where iron oxide has yielded an orange to red colour to the bodies (Kamilli & Lamberg-Karlovsky, 1979; Holakooei, et al., 2013). It can be explained by the fact that when a non-calcareous clay is fired, iron is crystallised in the form of hematite and, consequently, become red in colour. On the other hand, when clays containing calcite are fired, calcium carbonate is dissociated to CaO and CO_2. CaO can react with iron oxides decreasing the size of iron oxide particles and, as a result, bleaches the red colour to cream and buff (Maniatis, 2009). The buff colour of the calcareous bodies can be more easily covered by an opacified glaze than in the case of red body with low calcium content. Moreover, due to a higher thermal expansion coefficient of calcareous clay bodies, which is close to those of lead-alkali glazes, the risk of glaze crazing during the cooling following a second firing is lessened (Tite, et al., 1998).

4.4.2 Fluxes

As ICP-MS quantitative analysis on the glazes showed, most of the glazes were alkali in nature and highly correlated with Na and lesser quantities of K and Mg. Sometimes, Pb was also observed in the composition of the glazes as a fluxing agent. The presence of Na associated with K and Mg may suggest the use of plant ash as the possible fluxing agent of the glazes. The evidences of the use of plant ash for making vitreous materials in the ancient Near East (Gadd & Thompson, 1936; Henderson, 1985; Freestone, 1991) and pre-Islamic Persian glasses (Brill, 1992) also support the use of plant ash as the main alkali content in the Khawarazmshahid glazes. Another source of supplying the alkali content of Islamic glazes has been natron (Shortland, et al., 2006) which, according to our observations, cannot be totally ruled out in the case of the sudied glazes because of their relatively low concentrations of K and Mg.

As a substance containing Na, Mg and K, Abu'l-Qasim (1301) quotes mentions *shakhār* as the unifier of glaze ingredients (Ritter, et al., 1935). He describes this substance is made by burning pure, fully-grown *oshnān* plant which has a red-coloured centre when broken, with a strong smell. To produce *shakhār*, Wulff (1966) explains that the plant *oshnān*, which is a variety of *Salsola*, *Kali Solsola* and *Seiditziarosmarinus*, is slowly fired without long flame in a shallow well with two meters in depth. Then, the obtained ash was fired again in a particular furnace for the calcinations of the ash. Then, the glaze-makers used to load the furnace with five to seven kilograms of this ash of which five kilograms *shakhār* would be collected after the calcination. Ali Mohamed (1888) describes *shakhār* is obtained from burning glasswort (*shura*) and to purify it one can dissolve it in water in a kettle and place it on fire and boil it. The crystallised form of *shakhār* will be gathered after boiling and pouring it into an earthen bowl and leaving it all night.

Many parameters determine the compositions of plant ash including the plant species, the stage in the growing season and the component of the plants (woody part or leaves), the composition of the soil and ground water in which the plants are growing and the way in which the plants are ashed (Tite, et al., 2006). Practically, Na and K should be predominantly incorporated in the plant ash in the form of carbonates, bicarbonates, sulphites, sulphides and hydroxides rather than either chlorides or sulphates (Tite, et al., 2006).

4.4.3 Transparent glazes

A transparent glaze should have been an essential part of the glazes under study. It is reported to be prepared by quartz and plant ash. Sometimes, Pb-bearing materials were used in the composition of the transparent glazes as fluxing agent. For instance, al-Biruni (ca.1050) mentions a kind of transparent enamel obtained from powdered flint stone and red lead (Pb_3O_4). Moreover, Nishāburi (1196) describes how to make the transparent frit by mixing and firing the grinded and washed quartz with the plant ash. Abu'l-Qasim (1301), however, describes this frit is prepared by melting 105 parts quartz and 100 parts plant ash in a kiln for a day and suddenly cooling the molten material in the water. The cooled glass is then ground, sifted and used as the transparent frit. Ali Mohamed (1888) suggests equal amounts of quartz and the plant ash should be molten and, like Abu'l-Qasim, describes how to stir the molten glass.

4.4.4 Colouring agents

Various transitional metals could be added to the transparent glaze to make various colours within the glazes. As ICP-MS studies suggested, Co and Cu were the main colouring agents used in the Khwarazmshahid alkali glazes to make dark-blue and turquoise glaze respectively.

A- Cobalt blue glazes

Dark-blue hues have been usually achieved by adding a Co-bearing material into an alkali glaze. The traces of using cobalt together with copper in yielding dark-blue colours date back to the relief glazed bricks of the Achaemenid period (Caubet & Kaczmarczyk, 1998). The use of cobalt blue, nonetheless, was flourished in the Islamic periods. The quotes of Nayshāburi (1196) might be the oldest indications about making dark-blue shades in the alkali glazes when he states it is provided by taking 100 parts quartz, five parts *lājvard* rock [a cobalt compound] and borax of natron. Abu'l-Qasim (1301), however, describes this colour is achieved by adding *sulaymāni lājvard* to the transparent frit. Ali Mohamed (1888) also describes cobalt ores in environs of Kashan which look like blossoms. Allan (1973) suggests

that *solaymāni* stone is sulpharsenide of cobalt, cobaltite (CoAsS), which at high temperatures is transformed to cobalt oxide. The traces of arsenic detected in the cobalt dark-blue glazes may therefore be originated from the cobalt ores of Kashan. This may also suggest a provenance for the colouring agent of the dark-blue glazes.

Ali Mohamed (1888), Olmer (1908), Wulff (1966) and Schindler (Floor, 2003) propose a fairly similar description about the preparation of a key component of a cobalt blue glaze; i.e., earthy cobalt was washed with water, and then fired with potash and borax to obtain a concentrated colourant for blue. Rochechouart (1867) describes another way of making blue glaze. He writes that tile-makers take one part cobalt oxide, one part borax, and one-fourth part grape juice, mix well, and then, melt in a pot in the kiln. Then, they break the pot and take out the contents and powder it. Five grams of this powder is mixed with the following mixture: 100 g powdered glass, 50 g saltpeter, 50 g borax and 50 g caustic soda. They melt the mixture, and after cooling the mixture, they powder it and mix with gum tragacanth and use as a blue glaze. If we consider these ingredients as the probable ingredients of the blue glaze, boron should take an important part of the chemical composition of the blue glaze. However, as the blue Khwarazmshahid glazes showed no significant boron content, the procedure suggested by the above-mentioned modern treatises of making blue glazes may not be the case of the blue glazes under study. The blue Khwarazmshahid glazes may be compositionally closer to the blue glaze that Abul' Qasim describes in his treatise (Abu'l-Qasim, 1301).

B- Turquoise glazes

As it is usually accepted, turquoise hues have been always achieved by bivalent copper ions dissolved in alkaline archaeological glazes. The current thesis also showed that copper was the colouring agent of the turquoise Khwarazmshahid glaze achieved in alkali glazes. Copper has been always known the most important colouring agent in pre-Islamic and Islamic glazes found in Iran. For instance, the application of copper in the Elamite alkaline glazes (Caubet & Pierrat-Bonnefois, 2005; Caubet, 2007) and in the Achaemenid glazed bricks (Caubet & Kaczmarczyk, 1998) towards Parthian and Sassanian periods in pre-Islamic Iran (Hill, et al., 2004) is well-documented. Almost in all old Persian treatises including Neyshaburi (1196) and Abu'l-Qasim (1301), and those modern treatises such Ali Mohamed (1888) and Rochechouart (1867) note that a turquoise colour is achieved by adding copper dross (the pieces which chip off when copper is hammered) to an alkali glaze. This fact is also confirmed by analytical studies performed on the medieval Persian glazes (Holakooei, et al., 2014).

4.4.5 Opacifiers

The presence of any not dissolved materials in the glassy matrix of a transparent frit, that scatter light beam, acts as an opacifier. Dispersed particles with higher refractive index produce the more opaque glaze. Moreover, the size and shape of particles together with their degree of dissolution are the other important factors in opacifying glazes (Mason & Tite, 1997). Lime, air bubbles along with calcium antimonate were the main opacifiers of alkaline glazes in the Middle Elamite period (Caubet, 2007; Holakooei, 2014). However, the opacifiers in the Achaemenid era were calcium antimonate and lead (Caubet & Kaczmarczyk, 1998; Caubet, 2007). Adding diopside, quartz, wollastonite, air bubbles (Mason & Tite, 1997), feldspar together with air bubbles (Mason & Keall, 1991) and undissolved silicates (Pace, et al., 2008), to the transparent glaze, also result the opacified glazes. Nonetheless, tin oxide was largely utilized in the Islamic lands from the ninth century onwards (Mason & Tite, 1997). As μ-Raman study on the opacifiers of the studied glazes showed, cassiterite (SnO_2, tin(IV) oxide) was identified to be the opacifier of the glazes. Moreover, in an unusual sample (the white glaze of M21) no

trace of tin was found in the composition of the white glaze. Using μ-Raman, this glaze was suggested to be most probably opacified with fine-grained quartz particles.

Al-Biruni (ca.1050) describes a white enamel obtained by one part flint-stone powder, equal amount glass powder, one-fourth part natural sodium carbonate (natron), and two-thirds part tin oxide powder. However, Abu'l-Qasim (1301) states that an alkali frit can be opacified in two steps. The first step comprise of melting lead and tin to produce lead and tin oxides and, in the second phase, the mixture of *qamṣari* stone and the plant ash is fired with the product of the first step. To produce lead-tin oxides, as Abu'l-Qasim suggests, three parts white lead and a third part tin should be fired together. Molera et al. (1999) have shown that, during the production of tin-opacified lead glazes, the lead oxide reacts with the tin oxide to produce lead stannate, which then goes into solution as the glaze itself forms. The tin oxide would be subsequently re-crystallised out from the glaze.

4.5 Historical contextualisation of the brickwork based on the analytical data

The analytical studies showed that the majority of brickwork in the Farumad mosque were manufactured from the local clay sources in environs of the town of Farumad. In addition, the different chemical composition of the clay bodies of the Farumad mosque can be assigned to the different periods when extensive constructions and renovations are performed on the building (Godard, 1949; Adle, 1999; Hoseini, 2006). Although all the brickwork of the Farumad mosque are manufactured by *pish-shekli* bricks, the difference observed in their chemical composition may related to the methods by which the motifs are applied on the body. In other words, the samples containing a deep pattern (those carved on a wet clay paste) are different from those manufactured by moulding way. It should be noted that the sampling of the brickwork of the Farumad mosque was performed on the fallen down elements, hence the samples grouped in a distinctive cluster may have origin to the deep-pattern samples of another building. However, due to the presence of decorative friezes in the mosque with deep-pattern elements (see Chapter Two, p. 35), it seems that some older brickwork decorations have been survived when the moulded embellishments were added to the building.

On the other hand, three structural bricks of the Farumad mosque (F11 and F13 from the *qibla* side and F12 from its opposite side) showed similar chemical composition with those moulded decorations. This issue demonstrated that they were manufactured from the same raw materials and, most probably, at the same period. Grouping the F10 sample, another structural brick, with the samples of other studied mosques suggested a different source of clay is used to make the F10 sample. This brick may have been added to the decorations during restoration works.

The analytical studies on the Gonābād mosque's samples demonstrated the use of different raw materials of which the brickwork are made. According to the WDXRF results, the different chemical composition observed within the brickwork (Figure 3.9 and Table 3.2) may be resulted from several renovations and restorations performed on the Gonābād mosque although there is no any significant relation between these samples to hypothesise a certain date for the brickwork decorations. As Figure 3.8 showed, the stone-paste bodies of the Gonābād mosque are different from those of Ferdows, Zuzan and Khosrowshir mosque although they are not grouped together. However, comparing the chemical composition of the glaze and body of the glazed samples of the Gonābād mosque suggests a probable use of the same patterns to create the ornaments during restorations and renovations works. The ICP-MS data (Figure 3.19) showed that the glaze of G11 sample is different from the glazes of G4 and G18 samples although all of them are made in hobnail form. One should consider that the glaze of G5 with triangular shape

has a similar chemical composition with G4 and G18, all three from the façade of the northern *iwan*. Likewise, the glaze and body of G5 are compositionally different from G11 that was collected from the south-eastern corner of the courtyard.

In the Masjed-e Jāmeʿ-e Sangān-e Pāʾin, as mentioned before, some decorative brickwork are placed on a wrong position of the façade of the *qibla iwan* coining these elements as non-original decorations which belong to another building. The WDXRF results showed the square *pish-shekli* bricks with a deep floral motif, placed on the spandrels of the *iwan*chas at the *qibla* side of the Sangān mosque, are chemically close to those (*pish-shekli*) at the Zuzan mosque (Tables 3.1 and 3.2). The attribution of these elements to the Zuzan mosque is the first hypothesis which explains this similarity. The other explanations may be the existence of one production centre for producing this type of elements. In addition, the geometric *pish-shekli* bricks at the spandrel of the *qibla iwan*, *tarāshida* elements with floral pattern (lotus) and all the structural bricks (with one exception S10) have similar chemical composition. This similarity shows that these bricks are produced in the same period and the S10 sample (from on top of the *qibla iwan*) should be a brick added in a restoration work.

Unfortunately, no decorative brick samples of the Khosrowshir mosque were found in situ but around the building. However, their same chemical composition with the structural bricks of the mosque demonstrated the same clay source of which both decorative and structural elements are made. Close to the remains of the *pish-shekli* bricks, under the stucco decorations dated to the Il-Khānid period (Bakhtiari Shahri, 2004), the *tarāshida* bricks are also employed to embellish the Khosrowshir mosque. Likewise, studying the glazed ornaments of the mosque showed that they were manufactured in a similar way that those of the Gonābād, Ferdows and Zuzan (some samples) mosques are made; i.e., the use of a stone-paste body, a white layer between the glaze and the body and transparent glazes on top. Moreover, near the Khosrowshir mosque, in the Joveyn district, there are some other sites

According to the studies performed on the brickwork of the Masjed-e Jameʿ-e Ferdows, a stone-paste body on which a transparent turquoise glaze was used was identified. Moreover, a white priming layer was again observed between the glaze and the body of this sample. Grouping this sample with a majority of the Zuzan mosque's samples within the stone-paste bodies (Figure 3.8) may suggest that the glazed sample of the Ferdows mosque is not a local production. On the other hand, the similar chemical composition of the *pish-shekli* and structural bricks (from the *qibla iwan*) of the Masjed-e Jameʿ-e Ferdows with the local clay samples showed that the brickwork of the Ferdows mosque were made of the local clay source. Also, it can be suggested that the glazed ornaments of the Masjed-e Ferdows, apparently produced in the Zuzan's workshops, were embedded later to the original brickwork of the *qibla iwan*.

As far as the Zuzan mosque is concerned, it contains a variety of brickwork and glazed decorations. As mentioned before, a number of decorative elements (glazed and unglazed) of the Zuzan site are found around the present building. Due to the diversity of form, design, size and shape appeared in the unglazed *pish-shekli* ornaments of the Zuzan mosque, without any in situ evidences, the most of the unglazed samples were collected from the *pish-shekli* brickwork to study any probable difference between their chemical composition and those used in present structure (Z37, Z38 and Z39). The WDXRF results revealed the similarity of the chemical composition of all studied pish-shekli and *tarāshida* samples with one exception, i.e., Z42. As can be seen in Figure 3.10, Z42 sample, that is completely different from the other *pish-shekli* elements (the letters of an inscription), is not grouped with other unglazed samples. In other words, the same raw materials were most probably used to create the unglazed samples (either those observed as *in situ* decorations or found around the mosque) of the Zuzan mosque. This can suggest that the *pish-shekli*, *borida* and *tarāshida* bricks are made in the same period of time. On the

other hand, according to Labbaf Khaniki (1999), the *pish-shekli* ornaments belong to the pre-Khwārazmshāhid mosques at Zuzan, dated to before the 13th century (see Chapter Two, p. 25). Therefore, it is more appropriate to date some of in situ decorative elements of the Zuzan mosque to the 12th century and, on the contrary, to assign the *pish-shekli* samples, which were not used in the present structures, to the Khwārazmshāhid period (Adl, 1988; Labbaf Khaniki, 1999). One should consider that the analytical approaches on the studied local clays (Z44, Z45 and Z46), selected from a modern kiln to the east of the Zuzan mosque, demonstrated they are not the source of supplying the raw materials to create the studied brickwork decoration of the Zuzan mosque (Figure 3.10).

The results of WDXRF on the bodies and ICP-MS on the glazes revealed different ways of manufacturing both the bodies and glazes of the Zuzan mosque. Using clay-based and stone-paste bodies, together with applying tin oxide as opacifier and non-opacified glazes to create glazed ornaments, testifies a significant development of glaze technology at the beginning of the 13th century in Khorāsān. Employing glazed stone-paste ornaments covered with a transparent glaze close to those opacified glazes applied on clay bodies shows an important progress of developing glazed architectural decorations in the Zuzan mosque.

Chapter Five: Conclusions

The current thesis studied both technologically and historically the brickwork and glazed decorations dated back or attributed to the Khwārazmshāhid period. According to the observations provided in this thesis, three types of brickwork have mainly recognised to be used, particularly prior to the use of glazed elements on architectural façades, in Iran over the Islamic period. The particular arrangement of bricks has usually been exploited to create the first type of brickwork which are basically used in most of the historic monuments of Iran, Afghanistan and Central Asia. The second type of brickwork pertains to those bricks formed after firing via carving or cutting normal bricks. This type of brickwork is widely used in the pre-Khwārazmshāhid buildings and includes also a particular technique in which patterns used to be carved on an already plain brick wall. This technique is employed in some Ghurid edifices in Afghanistan and Pakistan and, most probably, in the Il-Arsalān mausoleum erected in the Khwārazmshāhid period. The third type of brickwork, however, includes those brickwork formed prior to firing. Although the evidences of the use of this technique are reported from the pre-Seljuk periods, the most important brickwork achieved by this technique are those of the inscription of the destroyed Nezāmiyya madrasa in Khargerd.

As far as the glazed ornaments are concerned, the first evidences of their use in the Islamic architecture of Iran, Afghanistan and Central Asia go back to the late tenth century. The more recent examples of the glazed decorations, despite their scarcity, are reported until the Khwārazmshāhid period. These glazes are mostly turquoise and, less-frequently, blue in colour. The glazed bricks of the Il-Arsalān Mausoleum, the glazed inscription and the glazed decorations of the Takesh Mausoleum, the glazed ornaments of the Mohammad-e Khwārazmshāh Mosque and the glazed elements of the inscription of the Minaret of Masjed-e Negar's are the examples of the use of glazed elements in the Khwārazmshāhid architecture beyond the Khorāsān's frontiers. Contemporary with these examples, there are the glazed decorations of the Minaret of Jam and the eastern portal of the Masjed-e Jameʿ-e Herat which demonstrate the typical Ghurid glazed decorations.

As the dated inscriptions of the Gonābād and Zuzan mosques demonstrate, these mosques are erected in the last decade of the Khwārazmshāhid reign, before the Mongol conquest. The plan of these mosques and their decorations, particularly those *pish-shekli* bricks of the Gonābād mosque, are the main reasons by which the particular style of the decorations and plan is known as "Khwārazmshāhid style". Accordingly, the similar plan and brickwork of the Farumad and Sangān-e Pāʾin mosques have pushed historians to consider these mosques amongst the Khwārazmshāhid monuments. Moreover, the identical style of brick-working in the Ferdows mosque and the Khosrowshir mosque may attribute the former to the Khwārazmshāhid period. It should be mentioned that although the Raqqa mosque has also been attributed to the Khwārazmshāhid period, it was not studied in this thesis because neither brickwork nor glazed decorations were found at this mosque.

The architectural decorations surrounded the courtyard of the Gonābād mosque are different. While the *qibla iwan* façade contains brickwork and a dated inscription (1212 AD) executed with *borida* bricks, the northern *iwan* and the eastern and western panels are decorated with pish-shekli bricks accompanied with glazed hobnails. This mosque has been subject of various phases of renovation and restoration works due to the earthquakes happened in various historical periods. Moreover, there is another issue

which makes still difficult an accurate dating of the mosque; that is, several brick inscriptions at the *qibla iwan*'s façade, its interior walls and the south-eastern prayer hall show some technical differences. There are other evidences of the extensive changes happened in this mosque of which the remnants of two minarets on top of of the northern *iwan*, the technique of the brick-working that covers the interior walls of the *qibla iwan* and a mihrab, which is uncovered beneath the vaults, in the north-eastern prayer hall are the most important ones.

On the contrary, the Zuzan mosque, where the Ghurid influence is apparently observable, exhibits a different style of decorations respect with that of the Gonābād mosque. The *borida* bricks combined with glazed elements, employed to create the different patterns, make the Zuzan mosque unique amongst the above-mentioned historic buildings of Khorāsān. Many *pish-shekli* bricks discovered from the excavations carried out in environs of the semi-ruined building pushed historians to attribute these remnants to a period prior to the date of the present structure, which is erected in 1218 AD. The predominant use of the white, turquoise and blue glazed decorations at the back wall of the *qibla iwan* is another important architectural decoration of the Zuzan mosque. Moreover, the technique of applying two glazes, one juxtaposed with another, on one single body is a particular achievement observed in this mosque.

A new technique of brick-working is however appeared in the Farumad mosque. *Pish-shekli* moulded bricks with square, rectangular and triangular forms have predominantly decorated the south-western and north-eastern façades with various designs. Stamped decorations with vegetal patterns are primarily observed applied in some geometric motifs. On the north-eastern façade, the glazed decorations are inserted in the brickwork. Turquoise is the predominant colour which the glazed elements of the mosque are made of. Occasionally, blue, underglaze and lustre tiles have also used in the brickwork of the façades. Two bands of brickwork with floral patterns, whose patterns are deeply carved inside the bricks, has also decorated the right side and left side (symmetric points) of the north-eastern façade.

The brickwork in the Khosrowshir mosque are limited to those *pish-shekli* bricks with geometric patterns, which are covered by a later stuccowork. The minaret of the mosque, which was partially destroyed after an earthquake, was then entirely ruined by the locals in the first half of twentieth century and its bricks were used in new constructions. Despite this fact, a close relationship is observed between the stamped and moulded brickwork of the Farumad mosque and those of the Khosrowshir mosque published by Molavi (1968). Apart from these decorations, some tarāshida bricks and two glazed bodies are discovered in the surveys performed on this mosque.

Masjed-e Sangān-e Pāʾin, where *pish-shekli* and tarāshida bricks have decorated the façades of the building, took another part of the survey in this thesis. While the spandrel of *iwancha*s on the *qibla* side are decorated with vegetal patterns composed of square *pish-shekli* bricks, the spandrel of the *qibla iwan* exhibits the use of *pish-shekli* bricks, decorated by geometric patterns, amongst which small circle glazed elements are embedded. The spandrels of the arcades in the northern and southern sides of the courtyard are however decorated with the special forms of *pish-shekli* bricks. It should be noted that the inserted elements, particularly those with epigraphic patterns, are evidences of the changes happened after an earthquake.

In the Ferdows mosque, the *pish-shekli* decorations are worked in interlacing bands of tarāshida bricks at the *iwan*'s façade. This mosque is characterised with large pieces of the *pish-shekli* bricks with geometric patterns and the other pish-shekli bricks of façade are similar to those at north iwan of Masjed-e Gonābād with eight-pointed central star. Moreover, at the *iwan*'s façade there are some triangular

glazed pieces with turquoise colour. The observations showed that these pieces have been cut from a large-piece glazed tile, most probably containing an inscription.

The analytical studies performed on the above-mentioned architectural elements showed more interesting results. As the WDXRF results conveyed, local clays have most certainly been used to manufacture both architectural brickwork and bricks used in the structure of the buildings with one exception, the sample of Zuzan mosque that the selected local clays showed different composition. The particular association of the Farumad mosque's bodies with Mg and Cr from one hand and, on the other hand, the metallogenic zone on which the town of Farumad is constructed established a local provenance for the brickwork decorations of the Farumad mosque. Furthermore, the WDXRF results showed that the chemical composition of the clays used to make moulded bodies and the clays which other types of brick (carved with floral motifs) are made of is significantly different. Thus, it can be deduced that some older brickwork may have been survived during a later intervention when the moulded decorations were added to the building's decorations.

The WDXRF quantitative studies, moreover, showed that the *pish-shekli* bricks and some *tarāshida* decorations on the current façades of the Zuzan mosque are compositionally similar. This may suggest the same source of clay has been used in both decorations. More interestingly, the fairly identical elements composing the *pish-shekli* floral patterns of the Sangān mosque and those of the Zuzan mosque conveyed that these decorations could have been manufactured in the same centre of production.

The WDXRF, further, confirmed a local clay was most probably used to make both the brickwork decorations and the bricks used in the structure of the Ferdows mosque. Moreover, the results showed the *tarāshida* and the plain bricks used on the façades of the Khosrowshir mosque have the same chemical composition suggesting the same provenance for them. However, in the Masjed-e Jameʿ-e Gonābād, the significant differences appeared in the compositional data of the brickwork are most certainly derived from the extensive restoration works performed on the decorations. The original patterns of the brickwork may however have survived during the restorations of Gonābād mosque.

Apart from the provenance of the architectural decorations, the analytical studies shed also light on the technology of the brickwork. Our observations showed that the glazed decorations have been achieved on both clay-based and stone-paste bodies. The glazed decorations on the clay-based bodies were only observed within the glazed samples of the Zuzan mosque although the glazed stone-paste bodies take a part of glazed decorations of the mosque. Moreover, the WDXRF analysis on the bodies showed that the bodies of the Ferdows, Gonābād and Khosrowshir mosques are basically stone-paste bodies.

Studies conducted by polarised light microscope on the cross sections and thin sections of most of the glazed stone-paste bodies, moreover, showed a priming layer was sandwiched between the covering glaze and the stone-paste bodies.

Based on the results of the historical and technological studies performed on the brickwork and glazed decorations the following content would be concluded.

The history of the use of glazed clay and stone-paste bodies goes much further back to the Khwarazmshahid period. The stone-paste bodies were primarily used for making glazed decorations in pre-Khwārazmshāhid monuments an example of which is the glazed decorations of Nishābur, now preserved at the Metropolitan Museum of Art. The Khwārazmshāhid period is deemed to be an overturn point of using glazed bodies in architectural decorations. For instance, the mausoleums of Il-Arsalān and Takesh exhibit the application of glaze on bricks, most probably clay-based body. On the other hand, Scerrato (1962) states that tin oxide as opacifier of the glazed decorations of the Masʿud

Ghaznavi's Palace even though he mentions one underglaze tile on which a transparent glaze cover a brown painted layer. Moreover, Adle (1982) gives an account about the glazed layer of the inscription of the Minaret of the Dāmghān mosque where the buff colour of the body is observable through the glaze layer. This may rule out the idea of not using opacifier in the composition of the glaze.

As it was shown that the *pish-shekli* decorations have not been used in the Khwārazmshāhid mosque of Zuzan and, on the contrary, the mosques of Gonābād, Ferdows and Sangān show the *pish-shekli* bricks as a considerable part of their decorations, it could be concluded that the *pish-shekli* decorations were in dominant use in the beginning of the Khwārazmshāhid period. Thus, the Gonābād mosque, which is constructed earlier than the Zuzan mosque, exhibits the use of *pish-shekli* brickwork. Despite the fact that the Gonābād mosque has undergone an extensive intervention in the Il-khānid period, this intervention does not seem to have markedly changed the general design of the decorations because the traces of the pre-Khwārazmshāhid and Khwārazmshāhid decorations in the façades of the courtyard are evident amongst the Il-khānid interventions. In the Ferdows mosque, using the *pish-shekli* brickwork close to the tarāshida decorations on the *iwan*'s façade may strengthen the idea that the decorations could have been executed in the same period of time of those at the Zuzan and Gonābād mosques. In other words, some elements of the architectural decorations in the *iwan* of the Ferdows mosque are similar to those of the Gonābād mosque and another part of its brickwork are aesthetically close to those of the Zuzan mosque. The similar cases can also be observed in the Sangān mosque where the *pish-shekli* and *tarāshida* brickwork decorate the façades of the courtyard. The Ghurid influence is apparent in the tarāshida brickwork of the Sangān mosque. This may be explained by the fact that the Sangān mosque is geographically close to Herat, the capital city of the Ghurids.

The Farumad mosque, however, demonstrates entirely different type of brickwork, i.e., the stamped brickwork. The close relationship apparently observed between the brickwork of the Farumad mosque and those of the dated Il-khānid decorations, brings these decorations to a period later than the Khwārazmshāhid period. Therefore, Hoseini (2006) may have suggested the most appropriate date for the decorations of the Farumad mosque. This idea can also be challenged as a decorative band of brick-working executed differently from the moulded and stamped bricks and, moreover, showed a different chemical composition respect with the moulded bricks may suggest that the carved *pish-shekli* brickwork, prior to the current decorations, had decorated the mosque.

Finally, the Khosrowshir mosque has possibly been constructed before the Il-khānid period as the pieces of the *tarāshida*, *borida* and *pish-shekli* bricks either carved or stamped were observed in this mosque.

Glossary

ājor	baked (fired) *khesht*
ājor chini-ye khās	arranged bricklaying
borida	Literally meaning ‘cut’; i.e., smaller pieces of normal bricks cut after firing the raw body
borj	tower
gonbad	dome
iwan	arched hall closed on three sides (portico)
iwancha	a smaller *iwan*, usually close to an *iwan*
kāhgel	a mixture of clay, straw and water used to cover walls
khesht	sun-dried brick
madrasa	college of religious educations
maghbara	tomb
Masjed	mosque
Masjed-e Jāme‘	a congregational mosque, also called Friday mosque
mazār	tomb
mihrab	arched niche in the *qibla* wall of religious building
mil	tower
muqarnas	vaulting technique consisting of brackets and dome fragments
pas-tarāshida	Literally meaning ‘post-carved’; i.e., carving the brick surface after completing brick courses to create the patterns on wall
pish-shekli	Literally meaning ‘pre-formed’; i.e., the brick or tile that is formed before any firing treatment
qibla	the direction of Mecca
tarāshida	Literally meaning ‘carved’; engraved brick or *borida* brick
tholth	newer script than Kufic with curved and oblique lines

References

Abu'l-Qasim, A., 1301. *ʿArāʾyes al-Javāher va Nafāyes al-Aṭāyeb.* Tehran (1996): Anjoman-e Āṯhār-e Melli-ye Iran Press.

Adle, C., 1982. Katibe-ye Masjed-e Dāmghān. *Aṯhar,* Volume 7, 8 and 9, pp. 297-300.

Adle, C., 1988. Yaddāshti Bar Masjed Va Madresa-ye Zuzan. *Aṯhar,* Volume 15 and 16, pp. 231-248.

Adle, C., 1999. Faryūmad (modern Farūmad), Monuments of. *Encyclopædia Iranica*.

Adle, C., 2008. Khetta-ye Bāzyāfta-ye Molk-e Zuzan dar Astāna-ye Hamla-ye Moghol. *Bukhara,* Volume 67, pp. 102-120.

Adle, C. & Karimi, A., 1988. Negāhi be Bardāshthā va Didhāye Shomāregāni (Dixhitāli) va Fotogerametri Shoda-ye Zuzan va Bastām. *Aṯhar,* Volume 29, 30, pp. 90-108.

Akbari, P., 1997. Architecture of Mosques Related to Khawrazmshahi Period in Khorassan. *Namāya-ye Paxhuhesh (The Index of Research),* Volume 3 & 4, pp. 56-61.

Ali Mohamed, U., 1888. On the manufacture of modern kashi earthenware tiles and vases in imitation of the ancient. In: W. Furnival, ed. *Leadless Decorative Tiles, Faience, and Mosaic. History, Materials, Manufacture and Use of Ornamental Flooring Tiles, Ceramic Mosaic, and Decorative Tiles and Faience. Recipes for Tile-bodies, and for Leadless Glaze and Art-tile Enamels.* (1904): s.n., pp. 215-223.

Allan, J., 1973. Abu'l Qasim's treatise on ceramics. *Iran,* Volume 11, pp. 111-120.

Al-Moqaddasi, 985. *Ahsan al-Taqāsim fi Maʿrefat al-Aqāalim.* 2 ed. lugduni batavorum (1906): E. G. Brill.

Al-Moghaddasi (EN), 985. *The Best Divisions for Knowledge of the Regions, a Translation of "Ahsan al-Taqāsim fi Maʿrefat al-Aqāalim".* Reading (UK)(1994): Garnet Publishing Limited.

Arab Zuzani, K., 2004. Joghrafiyā-ye Tārikhi-e shahre Zuzan tā Qarn-e Dahom-e H.Q. *Tārikh Paxhuhi,* Volume 21, pp. 85-97.

Asadi, Z., 2011. Study of Ghurid's Situation in Sultan Mohammad Khwarezm Shah Period. *DOĞU ARAŞTIRMALARI A Journal of Oriental Studies,* pp. 231-236.

Āzari Damirchi, A., 1971. Joghrāfiya-ye Tārikhi-ye Ferdows. *Honar va Mardom,* Volume 106, pp. 42-46.

Bakhtiari Shahri, M., 2004. Nazari Ejmāli be Masājed-e Il-Khāni Dar Khorāsān. *Aṯhar,* Volume 40 and 41, pp. 30-44.

Bakhtiyari, S., 2007. from the View of Yaghut al-Himawi A Case Study of 4th to 6th Centuries (A.H.L.). *History of Islam,* 8(31), pp. 5-26.

Bavafa, E., 2011. Kharazm's I'tazila school during Kharazm-shah's Era. *UI-Journals,* 3(2), pp. 17-50.

Baxer, M. & Buck, C., 2000. Data handling and statistical analysis. In: E. Ciliberto & G. Spoto, eds. *Modern Analytical Methods in Art and Archaeology.* New York: John Wiley & Sons, pp. 681-746.

Baxter, M., 1995. Standardization and transformation in principal component analysis, with applications to archaeometry. *Journal of the Royal Statistical Society,* 4(44), pp. 513-527.

Berberian, M., 2014. *Earthquakes and Coseismic Surface Faulting on the Iranian Plateau.* s.l.:Elsevier.

Blair, S., 1985. The Madrasa at Zuzan: Islamic Architecture in Eastern on the Eve of the Mongol Invasion. *Muqarnas,* Volume 3, pp. 75-91.

Blair, S., 1995. Doors and Door Frames (From the medieval through the Safavid periods). *Encyclopædia Iranica*.

Bouchard, M. & Smith, D., 2003. *Catalogue of 45 reference Raman spectra of minerals concerning research in art history or archaeology, especially on corroded metals and coloured glass.* s.l.:s.n.

Brill, R., 1992. Chemical analyses of some glasses from Frattesina. *The Journal of Glass Studies,* Volume 34, pp. 11-22.

Buko, . A., 1984. Problems and research prospects in the determination of the provenance of pottery. *World Archaeology,* 15(3), pp. 348-365.

Caiger-Smith, A., 1973. *Tin-Glaze Pottery in Europe and the Islamic World.* London: Faber and Faber Limited.

Caiger-Smith, A., 2001. *Esfahan: an Unexpected Pottery Workshop, Unpublished Article.* s.l.:s.n.

Campbell, J. W. & Pryce, W., 2004. *Brick, A World History.* London: Thames&Hudson.

Carboni, S. & Masuya, T., 1993. *Persian Tiles.* New York: Metropoliten Museum of Art.

Casimir, M. J. & Glatze, B., 1971. Šāh-i Mašhad, a Recently Discovered Madrasah of the Ghurid Period in Ġarğistān (Afghanistan). *East and West,* 21(1/2), pp. 53-68.

Caubet, A., 1992. *Achaemenid brick decoration, in The Royal City of Susa: Ancient Near Eastern Treasures in the Louvre.* New York: Metropolitan Museum of Art.

Caubet, A., 2007. *Faïences et Matières Vitreuses de l'Orient Ancient.* Paris: Musée du Louvre.

Caubet, A. & Kaczmarczyk, A., 1998. *Les briques glaçurées du palais de Darius.* s.l.:Techne.

Caubet, A. & Pierrat-Bonnefois, G., 2005. *Faïences de l'Antiquité de l'Égypte à l'Iran.* Paris: Musée du Louvre.

Centlivres-Demont, M., 1971. *Une Communauté de Potiers en Iran: Le Centre de Meybod (Yazd).* s.l.:Présentée à la Faculté des Lettres de l'Université de Neuchâtel pour Obtenir le Grade de Docteur es Lettres.

Cogswell, J., Neff, H. & Glascock, M., 1996. The effect of firing temperature on the elemental characterization of pottery. *Journal of Archaeological Science,* Volume 23, pp. 283-287.

Cogswell, J., Neff, H. & Glascock, M., 1998. Analysis of shell-tempered pottery replicates: implications for provenance studies. *American Antiquity,* 63(1), pp. 63-72.

Crane, H. & Trousdale, W., 1972. Helmand-Sistan Project Carved Decorative and Inscribed Bricks from Bust. *East and West,* Volume 22, pp. 215-226.

Dhamija, R., 1975. Use of Brick and Tile in Persian Islamic Architecture. *India International Centre Quarterly,* 2(3), pp. 218-220.

Dold-Samplonius, Y., 2003. Cultur Surface Areas and Volumes in Islamic Architecture. In: J. P. Hogendijk & A. I. Sabra, eds. *The Enterprise of Science in Islam: New Perspectives.* s.l.:MIT Press, pp. 235-268.

Edwards, H., 1991. The Ribāṭ of 'Alī b. Karmākh. *Iran,* Volume 29, pp. 85-94.

Esmaeil Alam, N., 2003. *Funūn al-Sharq al-Awsaṭ fī al-'uṣūr al-Islāmīyah.* Mashhad: BEHNASHR.

Farrokhir, Y. & Khosrobeigi, H., 2011. Study of the Incompetence of the Divan Arz (Ministry of Army) in Khwarazmshahid in the conflict with the Mongols. *Iran History,* Volume 67/5, pp. 55-58.

Fedorov, M., 2000. The Khwarazmshahs of the Banu Iraq (Fourth/Tenth Century). *Iran,* Volume XXXVIII, p. 71–76.

Fehéravàri, G., 2000. *Ceramics in the Islamic world, in the Tareq Rajab Museum.* s.l.:I.B. Tauris.

Flood, F. B., 2001. Ghūrid Architecture in the Indus Valley: The Tomb of Shaykh Sādan Shahīd. *Ars Orientalis,* Volume 31, pp. 129-166.

Floor, W., 2003. *Traditional Crafts in Qajar Iran (1800-1925).* California: Mazda Publishers.

Flury, S., 1925. Le décor épigraphique des monuments de Ghazna. *Syria,* 6(1), pp. 61-90.

Forty, S., 2004. *Arcitecture.* s.l.:The Grange.

Freestone, I., 1991. Technical examination of neo-Assyrian glazed wall plaques. *Iraq,* Volume 53, pp. 55-58.

Gadd, C. & Thompson, . R., 1936. A middle-Babylonian chemical text. *Iraq,* 3(1), pp. 87-96.

Godard, A., 1936. Historique du Masjid-i Djumca. In: *Áthar-e Iran.* Mashhad: Islamic Research Foundation (Astan Quds Razavi), 2006, pp. 283-295.

Godard, A., 1949. Khorasan. In: *Āthār-é Irān.* Mashhad (2006) [in Persian]: Islamic Research Foundation (Astan Quds Razavi), pp. 176-322.

Golombek, L., 2011. The So-Called "TURABEG KHANOM" Mausoleum in Kunya Urgench: Problems of Attribution. *Muqarnas,* 28(1), pp. 133-156.

Gulmini, M. et al., 2009. Morphological and chemical characterization of weathering products on buried Sasanian glass from central Iraq. *Journal of Non-Crystalline Solids 355,* pp. 1613-1621.

Habibi, A. a.-H., 1976. New notices in history of art and science of khorassan, (Mah Malek, Ghurid prances and the Shāh-e Mashhad Madrasa Building, …..). *Honar va Mardom,* Volume 173, pp. 26-35.

Hajianpoor, H., 2007. The Political Conditions of Transoxiana in the Islamic Era up to the Establishment of the Safavid Rule. 8(32).

Harrow, L., 2005. The Tomb Complex of Abū Saʿid Faḍl Allāh b. Abīʾl-Khair at Mihna. *Iran,* Volume 43, pp. 197-215.

Henderson, J., 1985. The raw materials of early glass production. *Oxford Journal of Archaeology,* 4(3), pp. 267-91.

Hill, D., Speakman, R. & Glascock, M., 2004. Chemical and mineralogical characterization of Sasanian and early Islamic glazed ceramics from the Deh Luran Plain, Southwestern Iran. *Archaeometry,* 46(4), pp. 585-605.

Holakooei, P., 2013. *Technological study of the seventeenth century haft rang tiles in Iran with a comparative view to the cuerda seca tiles in Spain.* s.l.:PhD Thesis, University of Ferrara.

Holakooei, P., 2014. A technological study of the Elamite polychrome glazed bricks at Susa, southwestern Iran. *Archaeometry,* 56(5), pp. 764-783.

Holakooei, P., Petrucci, F., Tassinari, R. & Vaccaro, C., 2013. Application of WDXRF in the provenance studies of Persian haft rang tiles: a statistical approach. *X-ray Spectrometry,* 42(2), pp. 105-115.

Holakooei, P., Tisato, F., Vaccaro, C. & Petrucci, F., 2014. Haft rang or cuerda seca? Spectroscopic approaches to the study of overglaze polychrome tiles from seventeenth century Persia. *Journal of Archaeological Science,* Volume 41, pp. 447-460.

Hoseini, S., 2006. Bāzshenāsi-ye Masjed-e Jame'-e Faryumad bar Mabnā-ye Mostanad Negārihā-ye Jadid. In: *Majmu'a Maqālāt-e Sevvomin Kongera-ye TāriKh-e Meʿmāri va Shahrsāzi-ye Iran (Jelde Chāhārom).* s.l.:Iranian Cultural Heritage, Handicraft and Tourism, pp. 41-71.

Huang, E. et al., 2000. Raman spectroscopic characteristics of Mg-Fe-Ca pyroxenes. *American Mineralogist 85,* pp. 473-479.

Hutt, A., 1970. Three minarets in the Kirmān region. *Journal of the Royal Asiatic Society of Great Britain & Ireland (New Series),* 102(2), pp. 172-180.

ICHHTO, 1940. *Report of Persian National Monuments (Masjed-e Malek Zuzan),* s.l.: Iran's Cultural Heritage, Handicraft and Tourism Organization.

ICHHTO, 1942. *Report of Persian National Monuments (Masjed-e Farumad),* s.l.: Iran's Cultural Heritage, Handicraft and Tourism Organization.

ICHHTO, 1975. *Report of Persian National Monuments (Masjed-e Ferdows),* s.l.: Iran's Cultural Heritage, Handicraft and Tourism Organization.

ICHHTO, 1977. *Report of Persian National Monuments (Masjed- e Jāmeʿ-e Sangān),* s.l.: Iran's Cultural Heritage, Handicraft and Tourism Organization.

Jafarian, M. R., 2013. *Islamic Revolution Document Center.* [Online]
Available at: http://www.irdc.ir/fa/content/6620/default.aspx
[Accessed 06 12 2014].

Jalili, S. A., 2003. Moarrefi-ye Noʿ-e Khās va Nāderi az Sofāl. *Athar,* Volume 35, pp. 115-131.

Javadi, S., 2000. Qobba-ye Sabz Qadimitarin Nemuna-ye Kāshi-ye Moarraq Dar Iran. *Honarhā-ye Zibā,* Volume 7, pp. 12-20.

Javadi, S., 2003. Barresi-ye Maqbara-ye Khwaja Atābak, Az Qadimitarin Nemunehā-ye Kāshi-ye Negin Dar Iran. *Modarres-e Honar,* Volume 3, pp. 35-44.

Juvayni, '. M., 1286. *Tārikh-e Jahangosha-ye Juvayni (The History of The World Conqueror).* 4 ed. Tehran (2006): Donyāye Ketāb.

Kamilli, D. & Lamberg-Karlovsky, C., 1979. Petrographic and electron microprobe analysis of ceramics from Tepe Yahya, Iran. *Archaeometry,* 21(1), pp. 47-59.

Kasaeei, N., 1997. Herat from Taherid to Timurid (205-901 H). *Maghalat va Barresiha (Articles and Investigations),* Volume 59-60, pp. 85-102.

Keblow-Bernsted, A., 2003. *Early Islamic Pottery: Materials and Techniques.* London: Archetype.

Kennett, D. et al., 2002. Compositional characterization of prehistoric ceramics: a new approach. *Journal of Archaeological Science,* Volume 29, pp. 443-455.

Kervran, M., 2002. Un monument baroque dans les steppes du Kazakhstan : le tombeau d'Örqina Khatun, princesse Chaghatay. *Tome,* Volume 57, pp. 5-32.

Khalili Afghan, 1930. *Athar-e Harāt.* Herat: Saljughi.

Kharazmi, M., Tavoosi, M., Pourmand, H. & Neyestani, J., 2013. A Study of Geometric Pattern in Architectural Ornament in Gonabad, Malek-Zuzan and Foroumad Mosques. *Honar-Ha-Ye-Ziba: Honar-Ha-Ye-Tajassomi,* 17(3), pp. 13-22.

Khosh Ahang, N., 2009. History of Zuzan and its Historical Mosque. *Pazhohesh Nameye Tarikh (Bojnourd university journals),* Volume 15, pp. 71-109.

Kiani, M. Y., 1989. *Iran Arcitecture (A list of monuments).* Tehran: Jahad Daneshgahi.

Kiani, M. Y., 1997. Kāshi Kāri (The Tile-working). In: A. Sharifi Narani, ed. *Decoration Related with the Iranian Architectur of the Islamic Period.* s.l.:Iranian Cultural Heritage Organization (ICHO), pp. 129-159.

Klein, M., Jesse, . F., Kasper, H. & Golden, A., 2004. Chemical characterization of ancient pottery from Sudan by X-ray fluorescence spectrometry XRF, electron microprobe analysis EMPA and inductively coupled plasma mass spectrometry ICP-MS. *Archaeometry,* Volume 46, pp. 339-356.

Koutsopoulos, S., 2002. *Synthesis and characterization of hydroxyapatite crystals: A review study on the analytical methods.* s.l.:s.n.

Labbaf Khaniki, R., 1999. Seyr-e taḥavol-e masjed-e Jāmeʿ-e Zuzan. In: *Majmuʿa Maqālāt-e Hamāyesh-e asjed, Gozashta, Hāh va Ayanda.* s.l.:Art University, pp. 565-590.

Labbaf Khaniki, R., 2004. *Gonābād Khāstgah-e Hemāsehā-ye Penhān.* Tehran: Sazman-e Mirās-e Farhangi-ye Keshvar.

Labbaf Khaniki, R. & Saber Moghaddam, F., 2006. *Khorasan's Mosques.* Tehran: Head office of culture office and cooperation of khorasan-e Razavi Cultural Heritage, Handicrafts and Tourism organization.

Labbaf Khaniki, R. & Saber Moqaddam, F., 2006. *Khorasan's Mosques.* Tehran: Head office of culture office and cooperation of khorasan-e Razavi Cultural Heritage, Handicrafts and Tourism organization.

Lachance, G. & Traill, R., 1966. A practical solution to the matrix problem in x-ray analysis. *Canadian Journal of Spectroscopy,* Volume 11, pp. 43-48.

Le Strange, G., 1905. *The lands of the eastern caliphate : Mesopotamia, Persia and Central Asia from the Moslem conquest to the time of Timur.* s.l.:Cambridge : University Press.

Mainfort, R. et al., 1997. Neutron-activation analysis of pottery from Pinson mounds and nearby sites in western Tennessee: local production vs. long-distance importation. *Midcontinental Journal of Archaeology,* Volume 22, pp. 43-68.

Mamedov, M. & Muradov, R., 2001. *Gurganj. Architectural and historical guide.* Padova: Il Punto Edizioni.

Maniatis, Y., 2009. The emergence of ceramic technology and its evolution as revealed with the use of scientific techniques, in From Mine to Microscope: Advances in the Study of Ancient Technology. In: A. Shortland, I. Freestone & T. Rehren, eds. Oxbow: Oxford, pp. 11-26.

Mason, R., 1995. New looks at old pots: results of recent multidisciplinary studies of glazed ceramics from the Islamic World. *Muqarnas,* Volume 12, pp. 1-10.

Mason, R., 1996. Petrography and provenance of Timurid ceramics, in Tamerlane's Tableware: a New Approach to the Chinoiserie Ceramics of Fifteenth and Sixteenth Century Iran. In: L. Golombek, R. Mason & G. Bailey, eds. *Royal Ontario Museum and Mazda Press.* s.l.:Costa Mesa, pp. 16-56.

Mason, R., 2003. Petrography of pottery from Kirman. *Iran,* Volume 41, pp. 271-278.

Mason, R. B., 2004. *Shine like the sun.* Toronto: Royal Ontario Museum.

Mason, R. & Keall, E., 1991. The Abbasid glazed wares of Siraf and the Basra connection: petrographic analysis. *Iran,* Volume 29, pp. 51-66.

Mason, R. & Tite, M., 1997. The beginning of tin-opacifications of pottery glazes. *Archaeometry,* Volume 39, pp. 41-58.

Meftah, E., 1997. *Joghrafiyaye Tarikhi Balkh va Jeyhun va Mozafat-i Balkh.* Tehran: Paxhuheshgāh-e ʿOlume Ensāni va Motaleāte Frhangi.

Melikian Chirvani, A. S., 1970. Eastern Iranian Architecture: Apropos of the Ghūrid Parts of the Great Mosque of Harāt. *Bulletin of the School of Oriental and African Studies, University of London,* 33(2), pp. 322-327.

MelikianChirvâni, A. S., 1968. Remarques préliminaires sur un mausolée ghaznévide. *Arts asiatiques,* Volume 17, pp. 59-92.

Miri, R., 1977. Jadval-e Kāshihā-ye Tārikhdar. In: A. Narani Sharifi, ed. *Decoration Related with the Iranian Architectur of the Islamic Period.* s.l.:Iranian Cultural Heritage Organization (ICHO), pp. 153-162.

Modarres, M. A., 1990. *Reyḥānat al-adab Fi tarājem al-Maʿrufin Belkonya-ta ow al-loqab.* Tehran: Khayyam.

Mojtabavi, S. H., 1995. *The Historical Geography of Gonabad.* Gonabad: Marandiz.

Molavi, A., 1968. Athar-e Tārikhi va Rejāl-e Jovayn (Guyān). In: S. M. Hoseini, ed. *Khorassan, Abniya va Mashāhir (Majmu'a Maqālāt).* Mashahad (2010): Islamic Research Foundation (Astan Quds Razavi), pp. 373-387.

Molera, J., Pradell, T., Salvadò, N. & Vendrell-Saz, M., 1999. Evidence of tin oxide recrystallization in opacified lead glazes. *Journal of American Ceramic Society,* Volume 82, pp. 2871-2875.

Momenzadeh, M. & Walther, H., 1984. Mineral Deposits and Metallogenic Epochs in the Area of the Geotraverse across Iran - a Review. In: s.l.:s.n., pp. 468-478.

Monajjem, E. i.-e. H., 910. *Ākam al-Marjan fi Zekr al-Madāin al-Mashhure fi Kolle Makān.* Beirut (1988): ʿĀlam al-Kotob (books-world Co.).

Moorey, R., 1994. *Ancient Mesopotamian Materials and Industries: the Archaeological Evidence.* Oxford; New York: Clarendon Press.

Morgan, P., 1994. *Iranian stone-paste pottery of the Saljuq period: types and techniques, in Cobalt and Lustre.* New York: The Nour Foundation.

Motaghedi, K., 2012. Shokuh-e Kāshihā-ye Zarrin Fām Dar Mehrābhā-ye Haram-e Mottahar. *Astan-e Honar,* Volume 2 and 3, pp. 28-36.

Nāderi, B., 1978. A brief about tile-making in Mashhad. *Hunar va Mardum Magazine,* Volume 188, pp. 58-65.

Nāderi, B., 1988. Joveyn va Banāhā-ye Tarikhi-ye ān (2). *Āgāhināma,* pp. 15-18.

Narshakhi, A., 2005. *Tārikh-e Bukhārā (953AD),* s.l.: Webgāh-e Tārikh.

Narshakhi, A., 935. *Tārikh-e Bukhārā,* s.l.: Webgāh-e Tārikh (2005).

Neff, H., 2003. Analysis of Mesoamerican plumbate pottery surfaces by laser ablation inductively coupled plasma mass spectrometry LA-ICP-MS. *Journal of Archaeological Science,* Volume 30, pp. 21-35.

Neff, H., Bishop, R. & Sayre, E., 1988. A simulation approach to the problem of tempering in compositional studies of archaeological ceramics. *Journal of Archaeological Sciences,* Volume 15, pp. 159-172.

Negahban, E., 1991. Excavations at Haft Tepe, Iran, Vol. 70 of Museum monographs. *Museum of Archaeology.*

Nejati, R., 1351. Yahya inb-i Zeid. *Yaghma,* Volume 283, pp. 29-32.

Neyshāburi, M., 1196. *Javāhir-nāma NiẓāmI.* Tehran (2004): MIrāṯ-e Maktub Press.

Nuraei, M., 2005. The Iranian Political Thought and the capitals of Iran (820-1501). *Journal of the Faculty of Letters and Humanities (University of Isfahan),* Volume 40, pp. 179-202.

O'Kane, B., 1989. The Rise of the Minaret. Review article, of Jonathan Bloom, Minaret: Symbol of Islam. *Oxford Studies in Islamic Art,* Volume VII, pp. 106-113.

O'Kane, B., 1994. Iran and Central Asia. In: M. Frishman & H. Khan, eds. *The Mosque: History, Architectural Development & Regional Diversity.* s.l.:Thames and Hudson, pp. 119-141.

Olmer, M.-J., 1908. *Rapport sur une Mission Scientifique en Perse, Vol XVI.* Paris: Imprimerie Nationale.

Pace, M., Bianco Prevot, A. & Mirti, P., 2008. The technology of production of Sassanian glazed pottery from Veh-Ardashir (Central Iraq). *Archaeometry,* 50(4), pp. 591-605.

Partha Sarathi, D. et al., 2008. Application of instrumental neutron activation analysis for chemical composition analysis of ancient potteries from Buddhist sites of Andhra Pradesh: Part I. *Journal of Nuclear and Radiochemical Sciences,* 9(1), pp. 7-12.

Patel, A., 2007. Architectural Cultures and Empire: The Ghurids in Northern India (ca. 1192–1210). *Bulletin of the Asia Institute,* Volume 21, pp. 35-61.

Pickett, D., 1997. *Early Persian Tilework: The Medieval Flowering of Kāshi.* London: Fairleigh Dickinson.

pinder-wilson, r., 2001. Ghaznavid and Ghūrid Minarets. *Iran,* Volume 39, pp. 155-186.

Pinder-Wilson, R., 2001. Ghaznavid and Ghūrid Minarets. *Iran,* Volume 39, pp. 155-186.

Poorsafar, S. & Ahmadpanah, S. A., 2006. Negāhi Be Zavāyā-ye Honari-ye Maqbara-ye Khwaja Atābak. *Ketab-e Mah-e Honar,* Volume Azar va Dey, pp. 56-63.

Pope, A., 1930. Me'mari-ye Eslāmi: T. Gorgān and Gobad-e Qābus. In: A. U. Pope & P. Ackerman, eds. *A Survey of Persian Art: from Prehistoric Times to the Present.* Tehran (2008): Elmi va Farhangi, pp. 1179-1186.

Pope, A. U., 1930. *An introduction to Persian Arts since seventh century A.D.* London: Peter Davies.

Pope, A. U. & Ackerman, P. eds., 1930. *A Survey of Persian Art From Prehistoric Times To The Present.* Tehran: Manafzadeh Group.

Principe, M. et al., 2012. The Raman spectrum of diopside: a comparison between ab initio calculated and experimentally measured frequencies. *European Journal of Mineralogy,* 24(3), pp. 457-464.

Pugachenkova, G. A., 1996. Urban Development and Architecture: Transoxiana and Khurasan. In: *History of civilizations of Central Asia.* online version ed. s.l.:Unesco, pp. 513-528.

Qazvini, Z. i. M., 1994. *Āthār al-bilād va Akhbār al-ʿIbād.* Tehran: Amirkabir.

Riefstahl, R. M., 1937. Early Turkish Tile Revetments in Edirne. *Ars Islamica,* Volume 4, pp. 249-281.

Ritter, H., Ruska, J. & Winderlich, R., 1935. Orientalische steinbücher und persische fayencetechnik. *Abteilung Istanbul des Archäologischen Institutes des Deutschen Reiches,* Volume 3, pp. 16-56.

Robertson, J., Neff, H. & Higgins, B., 2002. Microanalysis of ceramics with PIXE and LA-ICP-MS. *Nuclear Instruments and Methods in Physics Research B,* Volume 189, pp. 378-381.

Rochechouart, J., 1867. *Souvenirs d'un voyage en Perse.* Paris: Challamel Ainé.

Roosta, J., 2012. Qara-khitai Ambassadors in the Kharezmshahids' Court; Formation of theQara-khitai Dynasty in Kerman. *Iran History,* Issue 70/5, p. 73–102.

S. Akiner, R. U. C. a. R. A. F., 1992. Salt Damage to Islamic Monuments in Uzbekistan. *The Geographical Journal,* 158(3), pp. 257-272.

Saadat, B., 1976. *The Holy Shrine of Imam Reza, Mashhad.* Shiraz: Asia Institute.

Sahebibazaz, M., 2011. Inscription of Plasterwork Mihrabs of The Seljuk Era. *Islamic Art,* 7(13), pp. 69-88.

Sarafraz, A. A., Javadi, S. & Alian, A., 2012. The Influence of Sassanid Art on Shaped and Inscriptions on Façade of Jurjir Mosque. *Bāgh-e Nazar,* 9(22), pp. 3-10.

Scerrato, U., 1962. Islamic Glazed Tiles with Moulded Decoration from Ghazni. *East and West,* 13(4), pp. 263-287.

Shahvari, A., 2009. The Relationship between the Abbasid and Seljuq. *Pazhuhesh Nama-ye Tārikh,* 4(14), pp. 57-76.

Shapiro, S., O'Shea, D. & Cummins, H., 1967. Raman scattering study of the alpha–beta phase transition in quartz. *Physical Review Letters,* Volume 19, pp. 361-364.

Sharafi, M., 2007. Third Seljuk Tohrol and Deline of Iraq Seljuks. *Moskuya,* 1(5), pp. 103-116.

Sharifi, A. & Rahnamay, H., 2007. Barresi-ye Noqush-e Tazyini-e Masājed-e Dora-ye Khwārazmshāhiyan dar Khorāsān (Masjed-e Malek Zuzan, Masjed-e Jame'-e Gonabad va Majed-e Jame'-e Farumad). *Ketāb-e Mah-e Honar,* pp. 32-40.

Shekofteh, A., 2013. The Most Significant Visual Characteristic in Stucco Decorations, Ilkhanid Architecture of Iran. *JIAS,* 1(2), pp. 79-98.

Sheykh Nouri, M. A. & Khosrobeigi, H., 2005. High ranking emirs in the Kharazmshahian's court. *Journal of the Faculty of Letters and Humanities (University of Isfahan),* Volume 40, pp. 17- 40.

Shortland, A., Schachner, L., Freestone, I. & Tite, M., 2006. bNatron as a flux in the early vitreous materials industry: sources, beginnings and reasons for decline. *Journal of Archaeological Science 33,* pp. 521-530.

Soucek, P., 2000. MEMARI IRANI: TAKAMOL YEK SONNAT. In: R. Ettinghousen & E. Yarshater, eds. *Highlights of Persian Art.* Tehran: Agah Publishers, pp. 151-179.

Sourdel, D. & Sourdel-Thomine, J., 1979. A propos des monuments de Sangbast. *Iran,* Volume 17, pp. 109-114.

Sourdel-Thomine, J., 1953. Deux minarets d'époque seljoukide en Afghanistan. *Syria,* 30(1), pp. 108-136.

Stern, S. M., 1966. The Inscriptions of the Kharraqān Mausoleums. *Iran,* Volume 4, pp. 21-27.

Tābanda, S. H., 1969. *Tārikh va Joghrāfiyā-ye Gonābād (The History and Geography of Gonābād).* 2 ed. Tehran: Haqiqat (2000).

Tavassoli, H., 2014. Recognition of principles and characteristics of presenting cities in ancient texts (Case study: the Samanid city). *The Scientific Journal of NAZAR research center (Nrc) for Art, Architecture & Urbanism,* 11(28), pp. 35-42.

Thackston, W. M., 1994. The Role of Calligraphy. In: M. Frishman & H. Khan, eds. *The Mosque: History, Architectural Development & Regional Diversity.* s.l.:Thames and Hudson, pp. 43-55.

Tiequan, Z., Changsui, W., Hongmin, W. & Zhenwei, M., 2010. The preliminary study on kiln identification of Chinese ancient Qingbai wares by ICP-AES,. *Journal of Cultural Heritage,* 11(4), pp. 482-486.

Tite, M., 2008. Ceramic production, provenance and use- a review. *Archaeometry,* 50(2), pp. 216-231.

Tite, M. et al., 1998. Lead glazes in antiquity: methods of production and reasons for use. *Archaeometry,* 40(2), pp. 241-260.

Tite, M. & Maniatis, Y., 1975. *Examination of ancient pottery using the scanning electron microscope.* s.l.:Nature.

Tite, M. et al., 2006. The composition of the sodarich and mixed alkali plant ashes used in the production of glass. *Journal of Archaeological Science,* Volume 33, pp. 1284-1292.

Tite, M., Shortland, A., McCarthy, B. & Paynter, S., 2008. Production of glazed pottery and brickwork in the Near East. In: M. Tite & A. Shortland, eds. *Production Technology of Faience and Related Early Vitreous Materials.* s.l.:Oxford University School of Archaeology Monograph 72, Oxford, pp. 187-198.

Tite, M., Wolf, S. & Mason,, R., 2011. The technological development of stonepaste ceramics from the Islamic Middle East. *Journal of Archaeological Science,* Volume 38, pp. 570-580.

Towḥidi, F., 1986. Masjed-e Jājarm. *Aṯar,* Volume 12, 13 and 14.

Varjavand, P., 1997. Ājor Kāri (The Brickwork). In: A. Sharifi Narani, ed. *Decoration Related with the Iranian Architectur of the Islamic Period.* s.l.:Iranian Cultural Heritage Organization (ICHO), pp. 41-72.

Vendrell, M., Molera, J. & Tite, M., 2000. Optical properties of tin-opacified glazes. *Archaeometry,* Volume 42, pp. 325-340.

Wilber, D. N., 1937. The two structures at Sanjan. *Bulletin of The American Institute For Iranian Art and Archaeology,* 5(1), pp. 33-37.

Wilber, D. N., 1939. The Development of Mosaic Faiënce in Islamic Architecture in Iran. *Ars Islamica,* 6(1), pp. 16-47.

Wilber, D. N., 1955. *The Architecture of Islamic Iran: The Ilkhanid Period.* Tehran (1967): Bongah Tarjome va Nashr-e Ketab. [in Persian]

Wilkinson, C. K., 1987. *Nishapur: Some Early Islamic Buildings and Their Decoration.* New York: The Metropolitan Museum of Art.

Wulff, H., 1966. *The Traditional Crafts of Persia.* Mass: Cambridge.

Yate, C. E., 1900. *Khorasan and sistan.* Nendeln/Liechtenstein (1977): KRAYS-THOMSON ORGANISATION LIMITED.

Yelon, A. et al., 1992. *Thermal analysis of early Neolithic pottery from Tepe Ganj Dareh, Iran.* s.l.:MRS Proceedings.

Zamani, A., 1970. Majed-e Jāme'-e Gonābād. *Honar va Mardom,* Volume 92, pp. 6-14.

Zamani, A., 1972. The art of making pottery in Mend of Gonabad. *Honar va Mardom,* Volume 119 & 120, pp. 10-24.

Zargarinezhad, . G. H. & Alipoor, N., 2009. Turkmens and Slavery of Iranians In Qajarids' Era (From The Beginning to Akhal Treaty). *History of Islam & Iran,* 19(2(77)), pp. 23-45.

Zucchiatti, A., Bouquillon, A., Castaing, J. & Gaborit, J., 2003. Elemental analysis of a group of glazed terracotta angels from the Italian renaissance as a tool for reconstruction of a complex conservation history. *Archaeometry,* Volume 45, pp. 391-404.

Zucchiatti, A. et al., 1998. PIXE analysis of pottery from the recovery of a renaissance wreck. *Nuclear Instruments and Methods in Physics Research B,* pp. 136-138, 893-896.