Chapter 2: Egyptian faience contextual review

A contextual review of Egyptian faience is presented in this chapter to provide important compositional information and an aesthetic appraisal, essential for the practical enquiry investigating the use faience and faience-inspired materials with 3D printing technologies. Section 1 looks at Egyptian faience within its historical context, covering faience composition, uses, glazing methods and the significance of this material. Section 2 presents faience within its modern-day context, including examples of how it is currently used as well as the factors that limit the way it can be used. A visual assessment of both ancient and modern-day faience artefacts is presented in section 3 of this chapter. These are discussed in terms of their visual properties in order to establish the benchmark qualities for the practical enquiry presented in chapters 4 and 5.
Section 1: Historical context

What is Egyptian faience?

Egyptian faience is an ancient ceramic ware that was produced in Egypt and the near east around the 4th millennia BC. [Tite and Shortland, 2008].

Unlike most ancient ceramic wares, faience contained very little or no clay and instead was mainly composed of silica with traces of calcium and sodium. The main advantage of faience was that it could be glazed, which was something that was not done to clay pottery until roman times. [Friedman, 1998]. Moreover, the unique composition of Egyptian faience enabled this material to be vitrified and glazed in one firing, compared to at least two firings required for most clay-based pottery.

It is generally accepted that three glazing techniques were used to produce Egyptian faience; application, efflorescence and cementation glazing. Efflorescence and cementation are known as self-glazing techniques. The use of the term self-glazing is convenient as it points out that the glaze has not been applied directly (as is the case for application glazing) and instead suggests that glazing occurs as an inherent part of the material composition and process steps.

Also of interest to this research is a ceramic-glass hybrid material that was initially identified as a variant of faience by Victorian archaeologists Lucas and Harris [1948]. Characteristics of this material include a homogenous structure, with no separate glaze or body layer. Like efflorescence and cementation glazing, this material only requires one firing to produce a highly glossy finish.

Terminology

The term ‘faience’ can appear misleading, as it is sometimes used to describe another ceramic ware that was produced in northern Italy during the 16th and 17th century. This Italian ware is a tin-glazed earthenware that is fundamentally different to faience in its composition. Fortunately, today the Italian ware is more commonly known as Majolica [Nicholson, 2009]. For the purposes of this research, faience refers to a glazed ceramic, whose body is composed of powdered quartz or sand which is coated in a soda-lime-silica

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2 Clay is a mineral that is the end product of a long process of weathering and erosion acting on the original rocks of the earth.

Vitrification occurs as a ceramic body reaches its maturing (peak) temperature. It is the furthest stage to which a body can be taken without deformation [Hammer and Hammer, 1997, pg353]
The Egyptians referred to faience as ‘tjehnet’, meaning that which is brilliant and scintillating like the sun, the moon, and the stars. [Friedman, 1998, pg15]. The sun was a symbol of resurrection in ancient Egyptian culture and its link to faience explains its extensive use for the production of funerary statuettes (shabti’s) to accompany the dead.
and assist in the afterlife [Bianchi, 1998]. The turquoise blue colour that is characteristic of early faience was deemed to have magical properties symbolising life, good health, fertility and rebirth [Shortland and Tite, 2008, pg57]. The appeal of glazed materials in the ancient world was most probably associated with their brightly coloured, smooth and shiny surfaces that were similar in appearance to semi-precious stones such as lapis lazuli and turquoise. [Tite, Shorthand and Paynter, 2002]. It has been proposed that the ancient Egyptians were not interested in “art for art’s sake”, and that faience was not simply prized for aesthetic values, but also for symbolic and religious reasons [Bianchi, 1998]. Faience was used to produce a variety of artefacts, most typically beads, tiles, scarabs, amulets and vessels (typical examples shown in figure 3 - 8). Advances in production techniques in the New Kingdom (1570-1070 BC) led to more experimentation and attempts to make larger scale pieces. Many objects from this period exceed 20cm in height. The largest known ancient Egyptian faience object was found by Sir Flinders Petrie in 1894. The was-sceptre of Set measures 215.8 cm height and weighs 65 Kg (see figure 8). It is now on display at the Victoria and Albert museum.
Figure 3: Jewellery elements for a broad collar faience necklace ca. 1353-1336 B.C. Height 430 mm, width 130 mm.


Figure 4: Djoser faience tile, Old Kingdom. Height 60 mm width 40 mm

[Image credit: Los Angeles Museum of Art, Wikimedia Commons, (2015)]
Figure 5: Scarab amulet with wings. Made in Egyptian faience. Size not specified
[Image credit: australianmuseum.net.au. ©Australian museum]

Figure 6: Faience Djed Pillar ca.688-332 B.C. Height 45 mm, width 17 mm
Figure 7: Lotiform Cup, 945–715 B.C. Height 14.5cm.
Figure 8: Was-sceptre, Egyptian faience, c. 1425 BC. Height 2158 mm
Image source: www.vam.ac.u © Victoria and Albert Museum, London
**Egyptian faience development**

The earliest examples of Egyptian faience date back to the 4th millennium B.C. Subsequently, its production spread to Rhodes, Crete, Cyprus, Russia, Italy, France and Britain [Matin and Matin, 2012]. The production of Egyptian faience continued until around the late 7th century AD. Gradually its use declined and many of the production techniques were lost.

The exact sequence of events that lead to the development of faience are unknown, however there have been several theories put forward by archaeological scholars that are worth noting.

Albert Lucas (1867 – 1945) a British Egyptologist believed that the accidental discovery of glazed quartz pebbles led to the development of faience. He believed that this discovery was the result of a simple chain of events that could be easily understood and repeated. Malachite is a copper carbonate mineral that was well known to the ancient Egyptians for its use as an eye paint. Hard stones such as quartz would have been used to grind the malachite into a fine powder. Lucas suggested that in the presence of an alkali (in the form of wood ash) and if strongly heated (in a fire) such grinding stones would emerge coated in a blue glaze. Lucas thought it possible that the quartz pebbles coloured green by the malachite residue may have been placed in a fire, possibly to act as a support for a cooking pot [Lucas, 1948]. Lucas tested his theory and found that he was able to successfully produce glazed quartz pebbles using this method.

Sir Flinders Petrie (1853 – 1942) a British archaeologist also believed that quartz pebbles were the first substrates to be glazed. It was his theory that quartz pebbles from a hot fire had been fluxed by the wood ashes present in the fire. Lucas put Petrie’s theory to the test found that it failed to produce any noticeable glaze on the quartz pebbles [Lucas, A. 1948]. This theory also failed to explain the production of blue glazes in the earliest known examples of faience due to the presence of a copper compound.

A possible order of occurrence of Egyptian faience might have been first glazed quartz pebbles, produced accidently by the application of powdered malachite to the surface of quartz grinding stones. Successful repetition and subsequent understanding of the glazed quartz pebbles could have led to the development of glazed steatite. Current evidence suggests that glazed steatite pre-dates the production of faience, (5th millennium BC) [Shortland and Tite, 2008]. Steatite is a metamorphic rock that is largely formed of the mineral talc. A major advantage of steatite for the production of small objects is that unlike quartz, steatite is soft and easy to carve. Furthermore, when steatite is fired, the chemically
combined water is driven off and the talc is converted to a mixture of enstatite and cristobolite, which results in a material that is hard and durable. The limited variety of shapes and objects produced by carving steatite might explain the driving force that led to the development of faience. If quartz could be ground into a fine powder, with the addition of water and small amounts of lime and plant ash (added initially as an impurity) this material could be modelled into a greater variety of shapes, either by hand modelling or using moulds.

**What was it made of?**

Egyptian faience production can be characterised as the heat treatment of specific natural minerals, which form oxides of sodium, calcium and silicon when fired between 800 - 1000°C. [Noble, 1969], [Binns, Myrtle, and Hazel, 1932] and [Kiefer, and Allibert, 1971].

Generally, these materials are referred to as soda-lime-silicates. The raw materials from which the soda-lime-silicates are formed are as follows;

It is thought that the silicate source was most likely obtained from ground quartz pebbles, sandstone or desert sand [Lucas, 1948, pg493], the latter being the less pure source that was likely to contain some impurities\(^3\) such as Iron or limestone. The source of lime is likely to have been gathered from limestone (a sedimentary rock that is largely composed of calcium carbonate), or added unintentionally as an impurity in the desert sand (if used).

Soda was sourced from a mixture of alkalis\(^4\), most notably natron\(^5\) [Lucas, A. 1948, pg493] or from the burnt ashes of salt loving (halophytic) plants [Oppenheim, Brill, Barag, and Saldern, 1970]. Colour was added to this composition and is most typically attributed to the use of copper obtained from either crushed malachite\(^6\) or copper scale\(^7\).

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\(^3\) These impurities would mainly bring about undesirable qualities such as discolouration of the glaze.

\(^4\) In the literature and in some parts of this thesis, the soda component is also referred to as an alkali or an alkaline salt.

\(^5\) Natron, a naturally occurring mixture of sodium carbonate and sodium bicarbonate along with small quantities of sodium chloride and sodium sulphate [Natron, 2015].

\(^6\) A relatively pure copper ore

\(^7\) Resulting from the oxidation of copper metal or a copper alloy [Shortland and Tite, 2008, pg44]
Vandiver [1983, pgA18] states that a fairly typical faience composition is;

- Silica: 92-99%
- Soda: 0-5%
- Lime: 1-5%

The purpose of silica is to form the bulk of the body and it is essentially the material from which the object is formed. The addition of lime and soda help to cement the grains of silica together during the drying stage, providing degree of green (unfired) strength. The main strengthening role of the lime and soda occur during the firing, where the lime and soda react with the silica to form small amounts of interparticle glass that bind the grains of silica together and hold them in a glassy matrix.

**Physical properties of faience paste**

It is well documented that faience is a difficult material to work with in paste form. To make a typical faience paste, water is added to the raw powdered ingredients. The resultant paste is difficult to form as it tends to flow if it is too wet and will crack and crumble if it is too dry [Shortland and Tite, 2008, pg46]. Several researchers in the field [Griffin, 2001], [Nicholson 2009], [Riccardelli, Mass and Thornton, 2002] have described faience as a thixotropic material. Thixotropy is a property commonly attributed to certain gels or suspensions that are viscous under static conditions, but will become less viscous when shaken, agitated or otherwise stressed [Thixotropy, 2015]. Whilst this description adequately explains some of the physical properties of faience, it also contradicts other physical properties that have been observed.

When forming faience, Vandiver noted that ‘if pressed vigorously this material will resist flow until it yields and cracks’. She added, ‘faience bodies generally crack if pushed too vigorously into a mould, their low plasticity being exceeded by their yield strength’. [1983 pgA21]. This characteristic is more a-kin to dilatancy. A dilatant material is one whose viscosity increases with the rate of shear strain [Dilatant, 2015]. This is contrary behaviour to that of thixotropy, yet both observations correctly describe the characteristics exhibited when faience is worked. To avoid this confusion, it is better to describe faience in terms of its workability. Workability is a term that is more frequently used to describe the properties of a clay body. The workability of a clay is characterised by a combination of strength, plasticity and thixotropy. Having explained the contradictory behaviour of faience in terms of its thixotropy, the properties of plasticity and strength will now be discussed. It is
necessary to first explain the factors affecting the workability of clay bodies in order to understand how a faience body compares.

Plasticity is a unique property held by clays which combine the strength of a solid with the fluidity of a liquid [Hammer and Hammer, 1997 pg252]. Plasticity enables the solid to be reformed without rupture and enables the new shape to remain without returning to its original form. There is no definitive way to measure the plasticity of a clay, however a simple test can be used to provide an indication of plasticity. Experienced ceramicists Frank and Janet Hamer, provide the following instructions on how to determine a clays plasticity, in the so called ‘tie-the-knot test’. ‘A piece of clay is rolled between the palms to give a strip about the thickness of a pencil. The strip is then tied in a knot. A good clay will accept this exercise without rupture, a poor clay will rupture or break apart’ [Hammer and Hammer, 1997 pg362]. The mechanisms at work that give clay its plastic qualities can be explained in part by the shape and size of the particles. Clay particles are plate-like in shape, with a negative surface charge and a positive edge charge [Peña del Olmo, 2011]. The surface charge found on the mineral structure attracts and absorbs water in layers which lubricates the particles whilst holding them together. When a force is applied, the plate-like shape of the particles allows them to slide easily over one another, but then to retain their shape when the force is removed. The size of clay particles also determines its plasticity in that smaller particles will have a larger surface area with which to absorb water compared to coarse particles.

The opposite of plastic clays are short clays. The particles in short clays have little capacity to slide over one another and have a high resistance to pressure (yield strength) [Hammer and Hammer, 1997, pg302]. The material also has a flabby feel and the poor strength associated with short clays often results in the material sagging under its own weight. The plasticity of faience is even less than that of a short clay. A major reason for this is that a faience body traditionally contains little or no clay and has a high silica content (present in the form of desert sand or crushed quartz). The angular shape of silica particles means that they do not slide easily over one another like clay particles do. The size of silica particles is dependent on the source of acquisition and the extent of grinding and processing. If fine enough, silica particles exhibit mutual forces of attraction that improve plasticity, however this is nothing or still very low compared to that displayed by a clay body [Hammer and Hammer, 1997, pg255].

If the same ‘tie-the-knot’ test was applied to a typical faience paste, the strip of material rolled between the palms would elongate under its own weight, to such a point that it may
rupture at this early stage. If the strip remains intact, the material is likely to rupture before a knot has been formed.

**Forming methods**

The primary methods used to form faience were; modelling the paste by hand using tools for shaping and adding detail, using a male mould to form an object over a core and moulding into an open faced mould [Shortland and Tite, 2008, pg46]. Due to the lack of plasticity in a faience body, throwing was very difficult however it has been suggested by Vandiver and Kingery, [1986, pg122] and Griffin [2002] that clay might have been added to the faience mixture improve workability to the extent that it could have been thrown. To improve the surface of an object formed using all of the techniques, the surfaces were frequently modified by a combination of scraping or grinding [Shortland and Tite, 2008 pg46] As a result of this, evidence of the primary forming method was often removed, making it difficult to detect the surface makings indicative of a particular forming technique. Due to the lack of plasticity, only limited forms and sizes were possible to achieve. This disadvantage caused the faience workers to explore different additions to the paste or changes in forming methods to improve the workability of the material.

**Organic binders**

It is thought that organic binders such as starch, gum Arabic and gum tragacanth\(^8\) were added to faience pastes in order to improve workability. This cannot be proven due to the fact that organic materials do not leave behind any trace in the faience body once fired. However, in the 1960’s, Wulff observed faience workers adding gum tragacanth to their pastes [Wulff, Wulff, and Koch, 1968] and 2011, Tajeddin witnessed a different workshop adding serish\(^9\) to their paste made of powdered quartz [2014]. Alternatively, it has been suggested that small amounts of clay might have been added to improve plasticity. An experimental study by Griffin [2002] demonstrated minor amounts of clay, between 1-3% gave good results.

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\(^8\)Tragacanth is a natural gum obtained from the dried sap of several species of Middle Eastern legumes of the genus Astragalus [Tragacanth, 2015]

\(^9\)Serish is the Persian name for the powdered root tuber of Asphodelus sphaer-oerarpus, whose aqueous solution was commonly used as an adhesive in many traditional crafts in Persia, such as bookbinding and textile crafts [Wulff, 1966]
How was it glazed?

Three glazing techniques have been identified for producing faience. These are application, efflorescence and cementation glazing [Vandiver, 1983]. The key parts of each glazing technique will now be described along with some of the common visual characterises. An SEM photograph showing the typical microstructure of the body material that is characteristic for each method will also be discussed. However, it is important to note that these microstructures are representative and significant variation can be observed from these typical examples due to changes in composition and differences in firing conditions.

Application is the earliest glazing technique [Tajeddin, 2014, pg42] and is very similar in principal to the way in which glaze is applied to pottery today. This technique involves the application of a glaze slurry that is composed of silica, lime and soda. The glaze components are ground to a fine particle size and mixed with water to form a slurry which is then usually applied to an unfired quartz body. Unlike most modern day glazing techniques, faience did not require an initial firing before the glaze slurry was applied [Friedman, 1998, pg54]. The glaze ingredients may have been ground together in their raw state or possibly partially fritted and then ground as is common practice in the making of modern day glazes. [Friedman, F. 1998, pg54]. Glaze slurries were applied by dipping, pouring or painting on to the surface. Characteristics of this technique include the presence of brush or drip marks from the slurry application and variable glaze thickness, the glaze being thickest at the base where the wet slurry has flowed and collected.

Efflorescence is a self-glazing technique that was first identified by Binns et al (1932). Efflorescence occurs due to the inclusion of soluble salts\(^{10}\) in a body composed of silica lime and soda. To the raw powdered ingredients, water is added, and objects are formed from the resultant paste. The water acts by dissolving the soluble salts which are drawn out of the body through capillary action\(^{11}\) as the water evaporates (during drying). A layer of soluble salt forms on the surface of the objects and once fired to around 950°C, this layer reacts with the other body components to form a glaze [Shortland and Tite, 2008, pg47]. Objects glazed using the efflorescence method characteristically have a variable glaze thickness, the glaze being thickest on the outer surface and the rims where airflow (during drying) was greatest [Shortland and Tite, 2008, pg46]. Also, characteristic of this technique

\(^{10}\) Sodium carbonate and sodium bicarbonate are both common examples of soluble salts used to produce faience.

\(^{11}\) Capillary action is the ability of a liquid to flow in narrow spaces, without the assistance of and in opposition to, external forces (such as gravity) [Capillary action, 2015]. It occurs due to intermolecular forces between the liquid and surrounding solid surfaces.
is the presence of rough or raised places on the bottom face as a result of contact with kiln supports during the firing.

**Cementation** is the third faience glazing technique used to produce faience and like efflorescence this method is also a self-glazing process. In the 1960’s Dr Hans E Wulff visited the holy city of Qom (Iran) and discovered this previously unreported technique that local craftsmen were using to produce faience beads. Known as the cementation method or the “Qom technique” [Vandiver, 1983], it is believed that this method (witnessed by Wulff) had changed very little since ancient times [Tajeddin, 2014]. Wulff observed that desired objects were modelled from a high silica paste, the source of which came from carefully selected quartz pebbles that were processed into a fine powder. The silica was then mixed with water and a binding agent to produce a sticky paste that was then either hand formed into small bead sized balls, or pushed into moulds. Once dry the object was then placed in a saggar (a ceramic container) and surrounded by a specially formulated glaze power. The glaze powder was composed of a mixture of silica, soda\(^2\), lime and copper compounds. During the firing process a series of chemical reactions occur\(^3\), resulting in the formation of a glaze on external surfaces of the object only. Once cooled, the glaze powder is transformed into a friable mass that can be crumbled away easily to reveal the glazed object inside. Until relatively recently researchers knew very little regarding the glazing mechanisms at work in the cementation process. In 2012 an experimental study by Matin and Matin shed more light on the process, demonstrating the glazing mechanisms at work and providing hypotheses for the different functions of the raw materials used. Also in 2011, an anthropological study by Tajeddin revealed that two workshops were still in existence in Qom. Tajeddin’s report revealed the recipe used by the faience workshop he visited as well as some of the advances made (since Wulff’s report) in terms of production techniques and material acquisition.

This technique does not require the use of kiln props to assist in the firing, therefore small objects are characterised by the absence of any firing marks. For larger objects, the presence of rough patches on the underside where the object has been in contact with the glaze powder during the firing can be a feature of this technique [Matin and Matin, 2012]. Based on archaeological evidence, this technique does not seem to have been used before

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\(^2\) Possible sources include plant ash, natron and cow dung. The essential component for this technique is sodium chloride (NaCl), which is present in all three sources.

\(^3\) These chemical reactions are complex. There is still much research needed to uncover more about this technique. Based on current evidence and hypotheses this process will be explained in greater detail in chapter 5.
the middle kingdom (2040-1640 BC) [Friedman, 1998, pg53]. Figure 9 shows the three different glazing techniques used to create faience artefacts. The schematic shows the movement of glazing material as the object dries or as it is fired on the left hand side and the distribution of the glaze on the surface of the object once it has been fired on the right hand side.
Figure 9: The movement of glaze material for all three faience glazing techniques

**Colour palette**

Early faience was generally blue-green in colour due to the addition of a copper colourant. By the time of the New Kingdom (1500BC) the colour palette had been extended to include shades of black, brown, purple, red, yellow, white, blue and green. Table 1 lists common compounds and the typical range of colours that they imparted.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Colours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>Light blue, green and turquoise</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Dark blue and violet</td>
</tr>
<tr>
<td>Manganese</td>
<td>Black, purple and brown</td>
</tr>
<tr>
<td>Iron</td>
<td>Red, black and brown</td>
</tr>
<tr>
<td>Lead antimonite</td>
<td>Yellow and green</td>
</tr>
</tbody>
</table>

A major factor that is thought to have contributed to the widening colour palette of faience artefacts is the link between faience and early glass production. Nicholson believes it is possible that coloured frit may have been added to a faience body, as frits contain essentially the same ingredients of glass, however they have not been subject to the same high temperatures required for total fusion [2009]. This is a view also shared by Kühne who believed that ground glass might have been added to a faience body to increase the range of colours and also improve the strength of the material [Kühne, 1969].

**Why was faience significant?**

Ancient Egyptian faience is believed to be the first glazed material invented man. The soda-lime-silica composition resulted in a material with a low firing temperature (between 850 - 1000°C [Nicholson, 1998]. This material often required only a single firing to produce glazed objects that were highly prized for their visual similarities to precious stones such as turquoise and lapis lazuli. The difficulties experienced when forming faience as a paste resulted from the composition containing very little/no clay. This begs the question, why did the ancient Egyptians not use clay as a major component in their faience bodies in order to improve workability? The reason for this was certainly not due to a lack of locally available clay nor was it due to a lack of knowledge in how to use it. Clay was known to the ancient Egyptians and had been used to produce containers with an intended range of properties for thousands of years prior to the production of faience. In Egypt and the Near
east, the use of clay containers began between 7000 and 6000 BC [Watson, 1965] and by 5000 BC, methods of preparing and tempering clay, making slips, firing in controlled atmospheres and surface enhancements were all common practice. [Vandiver, 1985]. After conducting replication studies, Vandiver, hypothesised faience has optical properties that could not have been achieved with clay bodies of the period. She notes that if the same alkaline glazes used to produce faience were applied to Egyptian clays, the underlying body would have given the glaze a muddy appearance. Vandiver also notes that, the high thermal expansion rate\(^\text{14}\) which is a characteristic of vitreous alkaline glazes would have had a strong tendency to craze and flake off a clay-based body [Vandiver and Kingery, 1986, pg20]. These observations suggest that clay was not added, or kept to a minimum in faience bodies despite the improvements it would bring about in terms of workability, as too much would result in an unsuitable glaze fit and even a little could affect the brilliance of the glaze. However, later on in the development of faience, more complex forms were achieved which is thought to have been made possible by the addition of small amounts of clay to the body [Vandiver, 1998] & [Griffin, 2002], which are likely to have come from more pure sources resulting in a whiter appearance.

\(^{14}\) Thermal expansion is the tendency for matter to change in volume in response to a change in temperature [Thermal expansion, 2015]
Section 2: Faience in current contexts

Modern adaptations of Egyptian faience are used by potters today, however within this context, this material is more commonly known as Egyptian paste [Rhodes and Hopper 2000, pg130]. Egyptian pastes generally include a significant amount of china clay (up to about 20%) [Hopper, 2010] which is added to extend the workability range\textsuperscript{15} of the material. Whilst these pastes are easier to work with when compared to traditional faience formulations, the workability range\textsuperscript{16} of the resultant paste is still far narrower than most clay-based bodies (such as terracotta, earthenware or stoneware). Today, Egyptian paste is generally used to make beads, jewellery and small sculptures, as well as being a popular/novel material that is frequently explored in pottery workshops [Koop, 2014].

Ceramic stains

Modern Egyptian paste recipes sometimes contain ceramic stains to impart colour to the glaze and body. Stains are blends of metal and ceramic oxides that have been fired and then ground into a fine powder. Stains containing otherwise toxic oxides can be used without significant dangers [Hansen, 2003]. In ceramics, colour is related to the chemistry of the stain as well as the glaze within which it is mixed. This means that a single stain can impart many different shades depending on the glaze it is added to. Prepared stains change very little in colour when fired and therefore provide good indication of colour in their original form. [Hammer and Hammer, 1997, pg71]. Stains offer many advantages over raw oxide colours some of which include lower toxicity and solubility levels and colour reliability.

Individual stain manufacturers offer huge ranges of different colours and colour systems as the same colour can often be made using different combinations of oxides, each having its own advantages and disadvantages.

What is appealing about Egyptian paste?

Contemporary Egyptian paste appeals to the modern potter for many of the same reasons that that it appealed to the ancient Egyptian craftsman. Egyptian paste is a low-fire body

\textsuperscript{15} This refers to how easily ceramic pastes can be formed. Highly plastic bodies (such as terracotta or earthenware) generally have a wide workability range whereas low-plastic bodies (such as faience) have a narrow workability range.

\textsuperscript{16} This is due to high proportion of non-plastic materials in the body and their inability to attract and absorb water. This is a property of given to clay, which enables the clay particles to slide readily over one another when a force is applied but when the force is removed the mass will retain the shape that has been given to it.
(compared to common clay-based bodies) and it only requires a single firing to become vitrified and glazed. The result of this is a significant reduction in the amount of time it takes to produce a finished, glazed object compared to clay pottery bodies. Like ancient faience, Egyptian paste has an attractive surface appearance that is usually rich turquoise in colour as a result of a copper colourant. Commercially bought ceramic stains may also be used which makes a wide range of colours readily available. Figures 10-12 show some examples of current day practitioners who have worked with Egyptian pastes.

Figure 10: Faience Jewellery by Amy Waller
[Image credit: Amy Waller Pottery, with permission from Waller, A. (2015), photographed by Mary Vogel]
Figure 11: Isabel K-J Denyer: Egyptian paste, porcelain and silver necklace
[Image credit: Isabel K-J Denyer, Ceramics and Necklaces, with permission from Denyer I. K-J (2015)]
What are the limitations of faience?

Two major limitations of faience relate to the poor working properties of the paste material and to the alkaline nature of the glaze. These two factors mean that faience pastes can only produce a limited range of forms and the high alkaline glaze limits the ultimate application of faience objects. This research aims to address the former issue; as the low plasticity of a faience paste is not an issue when using powder binder 3D printing. Faience pastes typically have a narrow workability range which makes the amount of water added to the dry components critical for successful material manipulation. When manipulating faience pastes the worker has to operate against gravity to restrain the paste and prevent it from collapsing under its own weight. This is due to heavy silica particles which constitute the majority of the paste and the runny consistency that this can produce when mixed with water. The margin of error between too much and too little water is narrow, and the lack of
plasticity limits the potential forming method and subsequent range of shapes that can be produced in this material. However, the powder binder printing processes uses much less liquid comparatively, so in essence the issues encountered when forming faience as a paste can be avoided. This additive technique opens up the potential to produce geometrically complex forms in faience that would be extremely difficult or impossible to produce using standard faience forming techniques.

This research does not aim to change the nature of the alkaline glaze which limits the end application of the object made in faience. The reason for this is that changing the nature of the glaze would require the chemistry of both the glaze and the body to be significantly altered. The glaze mechanisms involved in making faience requires the presence of alkaline components in order to successfully produce a glaze. Therefore, its absence, reduction or substitution for something else would be likely to result in glazes that are either unsuccessful, poorly formed or that do not resemble the visual characteristics of faience. High alkaline glazes such as faience characteristically result in crazing due to high thermal expansion rates. Crazing is a glaze defect that results in a network of cracks forming in the glaze. Whilst this can be a sought after finish for some decorative applications, it is not suitable for ware that is required to be watertight as liquid is able to pass through the glaze surface through the cracks in the glaze. Additionally, faience glazes are water soluble and are therefore not safe for the production of any vessel that is to contain/come into contact with things for human consumption. This means that the application of faience objects is reserved for the production of mainly decorative items, rather than objects that have a specific function, such as a ceramic mug that must be chemically inert and impervious to liquid.

Another limitation of faience relates to the soft, friable nature of the body. This is a result of; 1) the chemistry of the components that make up the material and 2) the resultant low firing temperature that the material matures at. Whilst a soft and friable body is characteristic of faience, it can be improved by increasing the alkali addition in the body and extending the firing time or peak temperature. It is interesting to note that these alterations can result in the formation of glassy faience or Variant E (as it is sometimes referred to in archaeological literature). This research only aims to make improvements to the body strength where the object shape and glaze finish are not significantly compromised.
Section 3: Visual assessment

In order to establish the visual benchmarks for this work, an appraisal of historic and contemporary faience artefacts was undertaken. One or more artefacts were selected for discussion from the following categories; a museum artefact, a contemporary artwork and a faience workshop. The choice of artefacts discussed here was influenced by the requirement to represent the different glazing techniques used to produce faience (i.e. efflorescence cementation and application glazing). Examples were selected from the following settings;

A faience workshop in Iran was selected to discuss the visual properties of faience made using the cementation technique. This workshop is one of only two known in the world that produces large batches of beads, buttons and small ornaments using the cementation technique. These they sell both locally and abroad.

A contemporary artwork that demonstrates a wide range of visual properties achievable using the efflorescence technique was selected to discuss this method of making faience. The artwork also proves that it is possible to produce very large and technically complex objects in faience if the maker possesses a detailed understanding of both the material and the making method.

A museum artefact that is believed to combine application and efflorescence glazing was selected to discuss the visual properties achievable using these two techniques.

Each object is discussed in terms of; the possible glazing technique and forming method used to create it, the approximate size of the object, possible colourants used and the surface detail and quality. It important to note that the historical examples discussed in this study will not be directly comparable to the modern examples in terms of surface quality and detail due to surface degradation over time.

This section will conclude with a summary of common faience characteristics produced using cementation, efflorescence and application glazing. Typical characteristics that relate to colour(s), glaze, surface appearance, object size and shape capabilities, as well as any other features will be outlined. This information will be used to determine the (visual) success or failure of the ceramic bodies under development throughout this research as well as providing a basis for comparison between objects produced using paste forming techniques and powder binder 3D printing.
Faience workshop

The Qom technique is another name given to the art of producing faience objects using the cementation glazing method. Today, these beads are still produced in large numbers at two sites in the holy city of Qom in Iran. One of the workshops is run by the Saadatmand family, who claim to have been making beads using this technique for generations. The other site is run by Ustad Saed Mustafa Radawy, also an employee of the Saadatmand workshop. In 2011, Zahed Tajeddin (a PhD researcher from UCL) visited Qom and reported that the blue beads were sold everywhere in the marketplace and in the shops nearby Qom’s holy shrines, which reflects the cultural significance and existing demand for these objects [2014]. Tajeddin was allowed to visit Ustad’s workshop and witnessed first-hand the cementation process that he uses. Figures 13 -18 show various stages of the process and figures 19 - 22 show some typical examples of objects produced at this site.
Figure 13: 19th century pill making machine used to make spherical bead for cementation glazing
[Image credit: Zahed Tajeddin PhD thesis, permission given by Tajeddin, Z (2015)]

Figure 14: Small and large beads made from silica paste
[Image credit: Zahed Tajeddin PhD thesis, permission given by Tajeddin, Z (2015)]
Figure 15: A slab of silica paste rolled out ready for modelling.

Figure 16: The workers use metal frame moulds to make various designs.
Figure 17: Multiple negative steel moulds for buttons
[Image credit: Zahed Tajeddin PhD thesis, permission given by Tajeddin, Z (2015)]

Figure 18: Unfired buttons made from silica paste
[Image credit: Zahed Tajeddin PhD thesis, permission given by Tajeddin, Z (2015)]
Figure 19: Cementation glazed spherical beads
[Image credit: Zahed Tajeddin PhD thesis, permission given by Tajeddin, Z (2015)]

Figure 20: Cementation glazed buttons, small and large sizes
[Image credit: Zahed Tajeddin PhD thesis, permission given by Tajeddin, Z (2015)]
Figure 21: Cementation glazed amulets and ornaments
[Image credit: Zahed Tajeddin PhD thesis, permission given by Tajeddin, Z (2015)]

Figure 22: Cementation glazed salt dishes and ornaments
[Image credit: Zahed Tajeddin PhD thesis, permission given by Tajeddin, Z (2015)]
The most striking characteristic of the objects created through this process is the rich turquoise blue glaze resulting from the addition of a copper compound. It is interesting to note, that turquoise seems to be the only colour known to be produced using this technique which suggests that either the cementation process does not work with other colourants, or that they produce inferior results.

Another feature of this technique is that the glaze covers all parts of the objects i.e. even the undersides and the holes running through many of these objects. This is due to the contact between the glazing powder and the object and how the glaze powder surrounds the object and fills the voided space. During the firing, a reaction between the glaze powder and the object surface results in the formation of a glaze. This all-over glazing is another characteristic of cementation glazing and distinguishes it from efflorescence and application glazing where unglazed parts such as holes (efflorescence) and undersides (application) are common. In terms of glaze formation, these objects were reportedly glazed all over, with a slightly rougher finish on the undersides, especially for the larger pieces. All were said to display darker blue dots where the glaze had pooled and for some, drip marks of thicker glaze was present. The surface appears bumpy and cratered which is especially evident in the spherical bead and button examples in figure 19 and figure 20.

Objects produced using the cementation method vary in size, and typically fall between 1-10cm in length and 1-3cm in width. Despite the simplicity of these forms, variation can be seen between objects produced using identical moulds. This signifies the unpredictable nature of the paste and the degree of control that the shaping methods used here has on the ultimate form. Figure 23 shows a cross section of a bead obtained by Tajeddin in 2011. The composition of the fired body is homogenous throughout, with no separate glaze or core layer. In archaeological texts, a core structure such as this would be classified as a variant of faience (variant E). However, Tite and Shortland state that “glassy faience should most probably not be treated as real variants. Instead, they should be regarded as the end members of a sequence of faience objects in which increasing proportions of glazing mixture have been added resulting in increasing amounts of interparticle glass” [2008, p55]. This point is demonstrated well by the variation seen in structural composition between cementation glazed objects obtained from different sources. Figures 23 -25 show how the core structure ranges from homogenous and glassy to a distinctive core and glaze layer. Based on his findings, Tajeddin reported that the bead obtained from Ustad’s workshop in 2011 (figure 23) was likely to have been subject to a more intense firing
regime and a higher level of alkali and copper in the glaze powder compared to the older beads obtained from other sources.
Figure 23: Cross section of a Qom bead obtained in 2011 and its capsule
[Image credit: Zahed Tajeddin PhD thesis, permission given by Tajeddin, Z (2015)]

Figure 24: Iranian faience bead thought to have been glazed through the cementation method. These beads have a distinctive glaze on top of a lightly coloured core.
Figure 25: Cementation glazed bead from Qom obtained in the 1980's.
[Image credit: Zahed Tajeddin PhD thesis, permission given by Tajeddin, Z (2015)]
Tajeddin [2014] reported the following glaze powder recipe was used at this site;

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Number of parts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finely ground cattle dung ash</td>
<td>20</td>
</tr>
<tr>
<td>Sodium carbonate</td>
<td>16</td>
</tr>
<tr>
<td>Finely crushed hydrated lime</td>
<td>10</td>
</tr>
<tr>
<td>Crushed copper scale</td>
<td>3% of the total weight</td>
</tr>
</tbody>
</table>

An important glaze powder constituent for the cementation process is an alkaline chloride component as its presence is essential for the chloride glazing mechanism to occur. At first sight it appears to be absent from this recipe, however analysis of the dung ash component revealed that this substance provides the crucial salts (sodium and potassium chlorides) in the glaze powder.

Almost two thirds of the glaze powder is comprised of alkaline components, which is likely to be the reason for the homogenous and glassy microstructure of the objects produced at this site.

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17 The chloride glazing mechanism involves the vaporisation of sodium chloride and copper during the firing which results in the characteristic blue glossy surface. The cementation glazing mechanisms are explained in greater detail in chapter 5.
Contemporary artwork: Zahed Tajeddin: *Nu Shabtis*
For the concluding part of his PhD research Zahed Tajeddin produced a body of artwork that was exhibited at the Petrie Museum London alongside ancient Egyptian faience artefacts. Tajeddin’s research was primarily concerned with understanding how ancient craftsmen were able to create such ‘fabulous objects of art’ [2014 pg3] despite using a material that is known for its poor plasticity and friable nature (faience). Tajeddin explored how this might have been possible through his own sculptural practice. Using a two-part terracotta mould and various efflorescent paste formulations, he produced dozens of shabti figurines. These objects demonstrate the broad range of surfaces and visual characteristics that can be achieved using the efflorescence method, which Tajeddin achieved through extensive experimentation into the effect of altering the composition of the efflorescence paste.

Through his experimental work, Tajeddin observed how the particle sizes of the silica grains played a crucial role in both glaze formation and the workability of the efflorescent paste. The fine grains of silica were important for glaze formation, however a paste composed only of fine silica particles (300’s mesh) produced a paste with thixotropic characteristics that was difficult to form. The inclusion of some coarser particles (90’s mesh) in a 60:40 ration (fine: coarse) was found to produce a paste with good workability and satisfactory glaze results.

Figures 26 – 28 show some examples of Tajeddin’s work.
Figure 26: Two-part terracotta mould used to produce Nu Shabtis by Z. Tajeddin
[Image credit: Zahed Tajeddin PhD thesis, permission given by Tajeddin, Z (2015)]

Figure 27: Nu shabtis by Z. Tajeddin. Fired pieces glazed through efflorescence
[Image credit: Zahed Tajeddin PhD thesis, permission given by Tajeddin, Z (2015)]
The approximate height of the *Nu Shabti* figurines measures about 220 mm, demonstrating that medium sized objects can be consistently produced using efflorescence pastes and mould making techniques. Tajeddin has demonstrated that a good degree of control over the form of the objects can also be achieved. The level of detail on these objects is acceptable, although generally speaking the more glaze on the object surface the less surface detail there is.

Objects have been fabricated in a range of colours that have been achieved using both raw oxides and commercially bought ceramic stains. The body texture varies from smooth, to rough and the glaze/surface finish ranges from shiny to matte. On many of the figurines crazing was evident. This is a known characteristic of faience and other high-alkaline glazes. Residual efflorescence was also apparent on many of the figurines which is likely to have occurred due to the presence of unreacted soda in the body (soluble salts). This left over soda may have been drawn out by the moisture in the air, which was able to penetrate the fired body via the cracks in the glaze (caused by crazing). Tajeddin reported that this may be combatted by reducing the amount of soda in the initial recipe [2014 pg71].

Another characteristic of faience glazed through the efflorescence technique is that the structure (once fired) has a separate glaze layer which is easily distinguished from the core. Unlike the glaze, the core is usually light in colour and friable (soft). [Lucas 1948].

Additionally, it is important to note here that another well documented characteristic of faience glazed through efflorescence is that the side where an object has rested during the drying stage is usually absent of a glaze layer due to lack of air flow and subsequent build-up of efflorescence salts. If for some reason an object has effloresced on all faces, kiln props would have to be used during the firing to prevent the object from sticking to the kiln furniture. This would result in the presence of marks on the object surface.

For the centre piece of the *Nu Shabti* exhibition, Tajeddin produced a huge faience sculpture that rivalled the size of the largest known faience object ever produced (the *was-sceptre of set* shown in figure 8). Tajeddin modelled this sculpture on the Djed-pillar, which is an ancient Egyptian symbol of stability. Once complete it measured 2200 mm high and weighed around 80Kg.
Figure 28: The Djed-pillar by Z. Tajeddin. Fired and glazed through efflorescence. 
[Image credit: Zahed Tajeddin PhD thesis, permission given by Tajeddin, Z (2015)]
The Djed-pillar (figure 28) was made using a specially formulated efflorescence paste that Tajeddin had developed for this particular purpose. A 3D model of the pillar and its mould was designed using the CAD software Rhino 3D. This file was then used to digitally fabricate the mould out of Styrofoam using a computer-controlled hotwire cutting technique. The pillar was made in multiple sections which were joined together in one piece in the final firing. Each section was built around a core made of cardboard which was filled with canes of reed. Coils of faience paste were packed into the voids between the core and the Styrofoam mould. This operation was repeated until the mould of each pillar section was filled completely. The mould was then placed in a drying chamber (50°C) for 48 hours and was removed once the material had sufficient strength to stand without the support of the mould or the core structure. Next the surface of the pillar was abraded to remove any seams created by the mould, and sprayed with water to render the surface smooth using a metal trowel. The faience pillar was then returned to the drying chamber to allow the soda to effloresce and after 48 hours it was ready to be fired.

The fabrication of this piece required a range specialist skills, experience and equipment to be executed. Using the experience he had gathered from his PhD research, Tajeddin designed a faience paste with working properties that were suitable for the production of this piece, and that once fired would produce a brilliant turquoise glaze. His skills as a sculptor enabled him to shape the faience paste using carefully considered moulds and core structures and his knowledge of faience pastes enabled him to dry and post process the piece under controlled conditions. Access to specialist equipment, such as a large gas kiln enabled the multiple sections to be joined together to produce one large sculpture. This piece demonstrates that it is possible to produce very large and technically complex objects using faience pastes. It also highlights the level of skill required to produce such an exceptional faience sculpture.
This two coloured cosmetic faience jar is from the reign of Amenhotep III (1386 -1349). The bulk of this jar has been coloured dark blue, most likely due to the addition of cobalt oxide. A characteristic of this period is the use of inlaying techniques that were used to produce decoration in a different colour. Inlaying involves pressing a wet paste into an incised groove made in a wet/partially dried body. It is likely that application glazing was used to glaze the bulk of the object and efflorescence glazing was used to create the inlays. It is possible that the jar was thrown on a potter’s wheel as this technique became popular during this period, or it seems equally as possible that form may have been made using a former/modelled around a core.
Despite the objects age the glaze remains mostly glossy and mostly smooth especially on the inlays. Although it is not clear from this image, it is likely that this object is crazed due to its alkaline nature of the glaze.

The image shows that the surface is covered in lots of little pinholes. If an object has been glazed before the gases in the body (that occur due to the decomposition of organic materials) have had time to escape, then pinholing can occur. This suggests that (if used), the glaze slurry might have been applied to an unfired body.
Table 2: Characteristics of faience glazed through cementation, efflorescence and application

<table>
<thead>
<tr>
<th>Cementation glazing characteristics</th>
<th>Efflorescence glazing characteristics</th>
<th>Application glazing characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Colour(s)</strong> – The only conclusive evidence of the colours achieved using the cementation technique suggest that turquoise (imparted by a copper compound) was and still is used exclusively [private communication between the author and Tajeddin]. Despite this limitation, the colour is rich, bright and highly attractive.</td>
<td><strong>Colour(s)</strong> – In addition to turquoise (by far the most iconic and popular colour used to produce ancient and contemporary faience), a wide range of colours can be achieved. Metal oxides and commercially bought ceramic stains can be used to impart a huge range of colours to efflorescence bodies.</td>
<td><strong>Colour(s)</strong> – Multiple colours can be achieved using application glazing. In addition to metal oxides, colour may be imparted by the use of frits/ceramic stains which can be included in the bodies and the glaze slurry.</td>
</tr>
<tr>
<td><strong>Surface appearance</strong> – Objects produced using this technique typically have an underside that is slightly rough due to glaze powder adhesion which may also be present on other parts of the object.</td>
<td><strong>Surface appearance</strong> – Surfaces range from smooth to rough depending on amount of coarse particles included in the body constituents. These may have been added for textural effect of to increase the green strength, drying rate and fired porosity of the material.</td>
<td><strong>Surface appearance</strong> – The surface may be rough or smooth, depending on the texture of the underlying body and/or the reaction/interaction between the underlying body and the glaze.</td>
</tr>
<tr>
<td><strong>Glaze appearance</strong> – It is typical to see darker patches/pools of glaze on objects produced using the cementation method, due the glass transformation property acting on the surface of the object. As a result of this, the glaze surface should be classed as generally un-even. This technique characteristically produces objects that are glazed all-over, including through holes/voids due to being surrounded by the glazing powder during the firing.</td>
<td><strong>Glaze appearance</strong> – The glaze on objects produced using this technique ranges from highly glossy to matte depending on the material constituents used and the amount of efflorescence that occurs during the drying. Typically, the areas where there has not been sufficient airflow to draw the soda to the surface have very little/no glaze when fired. Due to the high thermal expansion rate of alkaline glazes such as that produced using this technique, the glaze tends to craze and it is therefore characteristic to see a network of cracks within the glaze.</td>
<td><strong>Glaze appearance</strong> – Due to the high alkaline nature of faience glazes, crazing is likely to be present on objects glazed using application techniques. Pinholing may also be present especially if the underlying body has not been fired prior to the application of the glaze. Applied glazes are typically glossy and can be rough or smooth depending on the interactions/reactions that occur between the glaze and underlying body. The presence of marks left by kiln props is often indicative of application glazing. Glaze layers can range from even to uneven depending on their method of application (i.e. spraying or painting).</td>
</tr>
</tbody>
</table>
**Cementation glazing characteristics**

Object size and shape - The size of objects produced using this technique are typically limited to small, simple shapes, which is likely to be due to the extremely poor working properties of the siliceous paste. Even when devices such as moulds or cutters are used, variation should be expected between identically formed objects due to the unpredictable nature of the paste.

**Efflorescence glazing characteristics**

Object size and shape - Generally speaking, efflorescence pastes are difficult to form due to their poor working properties (as a result of a virtually clay-free body). However, knowledge of how to manipulate the working properties of faience pastes so that they become suitable for a particular forming method, (such as moulding) can make it possible to produce large and small objects of relative complexity. In exceptional cases, where the craftsman/sculptor possesses specialist skills and experience in manipulating the material for a particular fabrication technique, very large and technically complex pieces can be produced.

**Application glazing characteristics**

Object size and shape – Application glazing offers the most options in terms of object shape and size. Like efflorescence bodies, the composition of objects glazed through application can manipulated so that they become more suitable for a particular forming method. Unlike efflorescence, application bodies have more freedom in terms of compositional changes as the glazing component is not contained within the body. With the addition of small amounts of a pure clay (such as china clay) and attention the particle size distribution in the body, a skilled craftsman could produce forms as complex as the method of forming allowed i.e. skilful hand building, using moulds, formers and even the potter’s wheel.

**Other characteristics**

- The core structure of objects made using this technique varies from homogenous and glass-like, to soft and clearly distinguishable from the outer glaze layer. The more glass-like in structure the greater the alkaline component is likely to have been in the glaze powder and/or the longer the firing schedule used.

- Objects glazed through efflorescence have a distinctive glaze layer that sits on top of the light, friable core. It has been observed in modern day uses of efflorescence bodies, that after a certain period of time objects continue to effloresce once fired. It is likely that this is due to an excess of unreacted soda in the body that is dissolved by moisture in the air and drawn to the surface. Atmospheric moisture would be able to reach the soda in the body via the cracks present in the glaze surface (due to crazing). Subsequent mention of this phenomenon shall be referred to residual efflorescence.

- Application and efflorescent glazing may be used in combination as each formulation can withstand multiple firings if necessary as long as the highest temperature components are applied and fired first and so on.
Summary
A historical and contextual review of faience has been presented in this chapter which provides valuable information on the composition of faience, forming techniques, glazing methods and ultimate applications of this material. A visual assessment of faience artefacts was also conducted, the results of which were presented in section three of this chapter. This information has been used to inform discuss and assess the visual properties of objects produced using the 3D printing techniques and materials developed within this research.