

Technology and Provenancing of French faience

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Abstract

An overview is given of the recipe and the “chaîne opératoire” of French faiences, as revealed in ancient textbooks and archives of the 18th and 19th century. The preparation of the calx, the glaze, the glazing, the decoration with in-glaze and on-glaze colours, the kiln and the three firings (first, second, third) are described and the chemical, mineralogical and technological aspects assessed. Archaeometric analyses of French faiences are scarce. Scientific analyses of such crockery, mainly from the workshops of Le Bois d'Épense/Les Islettes and Granges-le-Bourg, constrain the nature of the clay, the firing temperatures, the glaze composition and the colour pigments. Successful attributions of faience objects are shown. However, such provenancing need much more robust and wellknown chemical reference groups.

Resumen

Se presenta una visión general de la receta y la “cadena operativa” de la Fayenza francesa, tal como se concebía en antiguos manuales y archivos de los siglos XVIII y XIX. Se describen los procesos de preparación de cenizas, vidriado, la aplicación del vidriado, la decoración con colores en el vidriado o post-vidriado así como los aspectos químicos, mineralógicos y tecnológicos involucrados en el proceso. Hay poca información arqueométrica de fayenza francesa. Los análisis científicos de vajillas vidriadas, principalmente de los talleres de Le Bois d'Épense/Les Islettes y Granges-le-Bourg, ponen de manifiesto la naturaleza de la arcilla, temperaturas de cocción y composición de los vidriados y pigmentos. Se muestran los resultados de asignar piezas de fayenza a los talleres de procedencia. Sin embargo, los estudios de proveniencia necesitan consolidarse aún más y disponer de grupos de referencia químicos conocidos.

Key-words: Tin glazed earthenware, French faience, calcareous clay, glaze, biscuit, firing temperatures, archaeometry.

1. Introduction

Ancient and modern ceramic products can be studied from different perspectives. To the petrologist, they are artificial rocks subjected to relatively high temperatures and recrystallized to become thermometamorphic products, analogue to those naturally formed through metamorphism (Maggetti 2001). In contrast to natural rock forming processes, pressure is insignificant in the genesis of such objects, because the kiln can be considered as a technical system. In such open systems, neither pore solutions, present before firing, nor gaseous reaction products, which may have been produced during the high temperature process, have an influence on the transformation, because they can leave the system at any time. Similar to natural rocks, ceramic objects consist of an assemblage of crystalline and amorphous phases, which can be analysed with the same petrographic, mineralogical and chemical methods such as micaschists, which are formed from clay during metamorphism.

Faience is, in the French nomenclature, an earthenware body coated with a white glaze opacified by tin oxide (SnO₂) crystals (Fig. 1). These cassiterites are present as small particles up to 10 µm across or as bigger clusters. The finely distributed tiny crystals refract and reflect light almost without absorption losses (Vendrell et al. 2000). Hence the ceramic object takes on a white and opaque appearance even though it is coloured in the bulk. Tin-glazed earthenware pottery resembles therefore, from the outside, porcelain.

This paper deals with the technique and the origin of 17th to 19th century French faience tableware. Faience tiles and older faiences of this country are not addressed.

2. Discovery and spreading of tin-glaze technique

2.1. Mesopotamia and China

The origin of the tin glaze technique can be traced to what today is Iraq (*Caiger-Smith 1973, Soustiel 1985*). An important production centre was Baghdad, the palace city erected by the second Abbasid Caliph Abu Ja'far al-Mansur in 762 AD in the location where the Silk Road crosses the Tigris River (*Fig. 2*).

It is still a matter of debate if the tin-glaze technique was invented as reaction of Islamic potters from Mesopotamia and Persia to the Chinese competition, trying to emulate the gleaming white surface and the hard, compact body of Chinese porcelain (*Watson 1987*) or if this technology appeared in Basra as a genuine local invention already during 700-750 AD, several decades prior to the known import date of Chinese ware (*Mason & Tite 1997, Mason 2004*).

At the end of the 9th century, in Baghdad, Basra, Samarra and other places, the tin-glazed pottery technique was well established. This novel glaze technique resulted in two advantages. On the one hand, the off-white colour of the ceramic body was masked by the opaque glaze and on the other hand, the white glaze surface provided an ideal canvas for painted decorations. Consequently, the Islamic

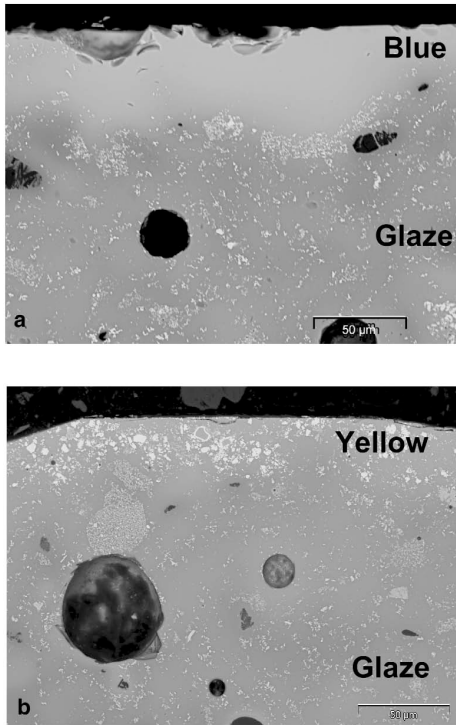


Fig. 1. Backscattered electron images of end 18th century faiences from the workshop Le Bois d'Épense/Les Islettes. (a) Sample BEI 6a showing on top of the tin oxide opacified glaze a stroke of blue in-glaze painting; (b) Sample BEI 54 with a yellow in-glaze painting on top of the glaze. Photo M. Maggetti.

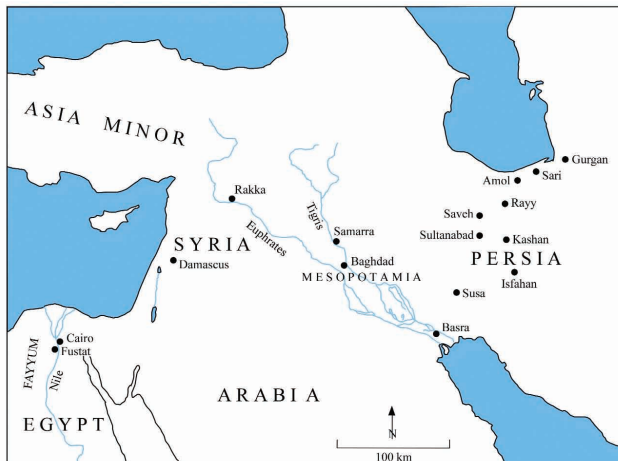


Fig. 2. Major centres of Islamic pottery manufacture in the Middle East.

craftspeople discovered the inglaze blue, brown, green and yellow colours, which were later adopted by the Chinese potters.

A further innovation of the Islamic crafts people was the lustre decoration, possibly inspired by the religious ban on using gold for profane purposes. Hence only gold-like lustre vessels conformed to the religious commandments and statutory laws. In terms of technology, lustre ware was a transfer from glass to ceramic technology, invented in Basra and Fustat during the 8th and 9th centuries AD (Caiger Smith 1985).

At the end of the 12th century AD the first ceramic objects appeared in Iran, showing overglaze decoration, a technique called 'painting with seven colours' (blue, green, brown, violet, red, black and white) (Weiss 1970, Soustiel 1985) and known as *mina'i* or *ladjvardina* wares. Analyses by Mason & Tite (1997) and Mason (2004) throw much light on the development of Mesopotamian tin glazes. The oldest (c. 700-750 AD) tin-opacified glazes from Basra were an improvement of the traditional local opaque glazes that owed their opacity to gas bubbles and fine crystallites of quartz, feldspar, wollastonite and diopside. Cassiterites are concentrated in a slip-like layer at the interface ceramic body/glaze. PbO is very low (around 1 wt.%, Fig. 3). Slightly younger (750-800 AD) glazes contain like earlier glazes gas bubbles, silicates and cassiterites as opacifying agents. The latter, however, are spread throughout the entire glaze and SnO₂ contents are slightly elevated (3-4 wt.%, Fig. 3). The glassy coatings are alkali-lime glazes with 1-2 wt.% PbO. Tin oxide concentrations of later glazes (800-975 AD) reach 4-8 wt.%, sufficiently high to eschew additional opacifying agents. Owing to the elevated PbO content (3-11 wt.%) these glazes can be classified as alkali-lead-lime glazes. Glazes from Baghdad dated c. 800-900 AD show substantially increased PbO (31-41 wt.%) and SnO₂ (6-8 wt.%) contents. Tin-opacified lead-alkali glazes with 25-35 wt.% PbO from Egyptian Fustat of 975-1025 AD show even higher SnO₂ contents (9-16 wt.%) compared to the Basra or Baghdad glazes.

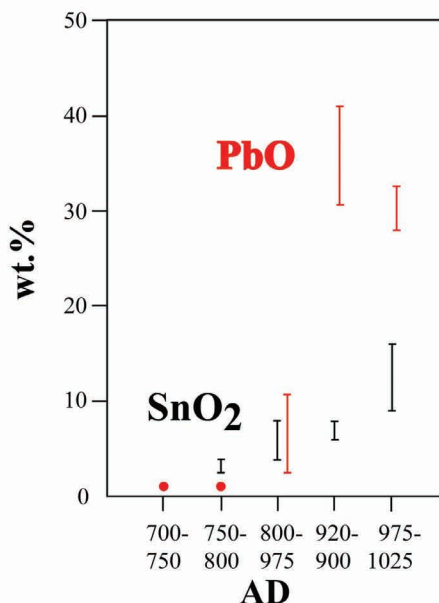


Fig. 3. SnO₂ and PbO concentrations in Mesopotamian tin glazes (Mason & Tite 1997, Mason 2004).

The Mesopotamian Islamic tin-glazed wares, painted or not, with or without lustre, were all produced from calcareous (16-22 wt.% CaO) clays very similar in composition (50-55 wt.% SiO₂, 10-12 wt.% Al₂O₃, 5-7 wt.% MgO, 5-6 wt.% FeO and 1-2 wt.% Na₂O; Mason, 2004). Firing temperatures of blue-painted wares from Basra were estimated at 850-1050°C (Tite 1988). Since Baghdad paste contains in addition some glass fragments it is conceivable that this ceramic production centre used a technology different from Basra. Mesopotamian lustres were studied by Pradell *et al.* (2008 a, b) and Colomban & Truon (2004).

2.2. Spread of tin-glazed pottery

Very early the Arabian westward expansion reached via North Africa Spain that was conquered between 711 and 719. In the wake of the new rulers Islamic potters settled in Spain and introduced this technology. However, it is unknown when the first Spanish tin-glazed ceramic objects were produced. From the 12th to the 15th centuries tin glazing flourished in pottery centres such as Talavera-Puente, Paterna-Manises and

Sevilla. In the 13th century the Hispano-Moresque lustre decoration technique was developed to high perfection, in particular in manufactories of Malaga and Manises. These potters combined the cobalt-blue painted decoration with the metallic lustre coating and thus revived a technique that had been lost in 1224 by the destruction of Raji in Persia by the advancing Mongols.

Many lustre-decorated ceramic plates and cups display the coat-of-arms of French and Italian noble families thus showing how highly esteemed this tableware was. These objects did not serve their foreign clients as dinnerware for daily use anymore but were considered prestigious objects of art fit to grace their ostentatious sideboards. From Spain this type of ceramic ware was introduced to France where in mid-13th century in Marseille tin glazed pottery was made, and eventually to Italy. From there the knowledge of production of tin-glazed ceramic crossed the Alps and extended into the northern parts of Europe. In its wake a continuous stream of new manufactories was established in France, Germany, The Netherlands, England, Switzerland etc. Eventually the faience technology reached the New World (Olin *et al.* 1978, Maggetti *et al.* 1984, Olin and Blackman 1989, Jamieson and Hancock 2004). Tin glazed ware is called Hispano-Moresque ware in Spain, maiolica in Italy, faience in France and delftware in Northern Europe.

3. Archaeometric studies of French faïences

Such studies are very scarce. Some show no chemical analyses at all (Démians d'Archimbaud & Picon 1972, Picon & Démians d'Archimbaud 1978, Vallauri *et al.* 1978, Picon 1993, Rosen 1997a,b), other only mean values (Vallauri & Leenhardt 1997, Picon 2000, Rosen 2001, 2007) and few the complete list of analyses (Carette *et Deroeux* 1985, Dufournier & Deroeux 1986, 1987, Dufournier 1989, Schmitt 1990, Pellet 1993, Rosen 2000b, Bernier 2003, Meunier & Bouquillon 2004, Maggetti *et al.* 2009a, b, Rosen 2009, Rosen *et al.* 2009). Glaze and pigment analyses are discussed in these and other papers (Bouquillon 2000, Oger *et al.*

2002, Dufournier *et al.* 2004, Marco de Lucas *et al.* 2006, Rosen *et al.* 2007, Maggetti *et al.* 2009a, b).

4. Technology of French faience

4.1. First French faience productions

The first French tin-glazed earthenware was produced in Marseille at the beginnings of the 13th century (Marchesi *et al.* 1997, Rosen 2000a). Local workshops created there glaze-less objects or objects with a transparent lead-glaze, both in a Middle-Age tradition, as well as tin-glazed pieces in a new, Islamic technique. This technology spread rapidly throughout France. But during the first 300 years (end of the 13th until the early 16th century), only tin-glazed tiles were produced for a wealthy clientele (Rosen 2000a). Italian potters moved ca. 1550 to France and opened before the end of the 16th century tin glaze pottery workshops in Lyon, Montpellier, Nevers and Cosne-sur-Loire.

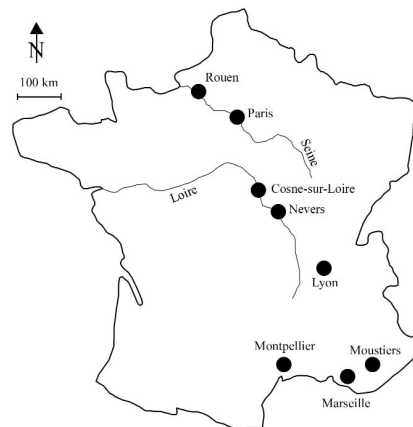


Fig. 4. Map of 17th century French faience manufactories. Redrawn from Fay-Hallé & Lahaussais (2003) and completed.

These establishments were the starting point for the extraordinary expansion and success of French faience in the 17th and 18th centuries (Figs. 4, 5). Around the mid-16th century in Faenza the biscuits were coated with a particularly thick pure white and matt glaze. These *bianchi di Faenza* were so popular and commanding throughout Europe that to this day in France the name of the city became the synonym for French tin-glazed pottery,



Fig. 5. Map of 18th century French faïence manufactures. Redrawn from Rosen (2001)

faïence. In the time span 1550-1600, Lyon's tin glaze potters were named 'white earth potters' or 'vase makers in the style of Venice', and those from Nevers 'white crockery makers in the style of Venice' (Rosen 2000a). The term faïence appeared for the first time in 1604 in Nevers (France) where the ceramist Jean-Baptiste Conrade was labelled 'sculpteur en terre de fayence' (sculptor of faïence earth) (Rosen 2000a).

4.2. Technical treatises of the 18th and 19th centuries

The manufacturing techniques of this special kind of pottery are well known thanks to contemporary publications (*Diderot 1756, Bosc d'Antic 1780, Anonymous 1783, Boussemart 1786, Boyer 1827, Bastenaire-Daudenart 1828, Harlé 1831, Brongniart, 1844*), more recent papers (*Deck 1887, Munier 1957, Montagnon 1987, Rosen 1995, 2009, Peiffer 2000, Bastian 2002-2003, Maggetti 2007a*) and the mid 18th century *Caussy manuscript (de la Hubaudière & Soudée Lacombe 2007)*.

4.3. 'Chaîne opératoire' of French faïence

4.3.1. Nature and treatment of the clays

18th and 19th centuries French faïence is

manufactured from clays in several production steps (Fig. 6). The composition of ideal faïence clays is 58 wt.% SiO₂, 30 wt.% Al₂O₃, 5 wt.% Fe₂O₃ and 7 wt.% CaCO₃ (*Bastenaire-Daudenart 1828*). In order to obtain the calcareous body typical of tin-glazed potteries (*Caiger-Smith 1973, Tite et al. 2008, Tite 2009*), either clays which already contain the ideal amount of carbonates (calcite and dolomite), or artificial mixtures of several kinds of clay are used. The French faïence makers of the 18th and 19th centuries preferred mixtures by far, ranging from two as in the case of Le Bois d'Épense (*Liénard 1877*), Nevers (*Bosc d'Antic 1780*) and Rouen (*de la Hubaudière & Soudée-Lacombe 2007*) to three (*Aprey, Froidos, Lavoye, Paris, Rarecourt, Salvange, Thionville, Tours and Waly, Bosc d'Antic 1780, Brongniart 1844, Liénard 1877*) or even four clays (*Paris, Bastenaire-Daudenart 1828*). French faïences with non or low calcareous paste are rare and show technical drawbacks (*Munier 1957, Caiger-Smith 1973, Picon et al. 1995, Thornton 1997*).

Archaeometric analyses confirmed the blending of two clays, a low and a high calcareous one, for Meillonas (*Rosen 2000b*) and Nevers (*Rosen 2009*), and the use of one clay in Granges-le-Bourg (*Maggetti et al. 2009c*). Chemical analyses proved the calcareous nature of faïences from Arthé (25-32 wt.% CaO, *Pellet 1993, Rosen 2001*), Dijon (14-26 wt.%, *Rosen 2001*), Le Bois d'Épense (17-24 wt.%, *Maggetti et al. 2009a*), Montpellier (17-28 wt.%, *Rosen et al. 2009*), Moustiers (15-32 wt.%, *Rosen et al. 2009*), Nevers (19-30 wt.%, *Rosen et al. 2009, Rosen 2009*), La Rochelle (11-21 wt.%, *Rosen et al. 2009*), Villers-le-Pot (21-28 wt.%, *Rosen 2001*). CaO mean values of faïences from Ancy-le-Franc (20 wt.%, *Rosen 2001*), Chevannes (17 wt.%, *Rosen 2001*), Meillonas (17 wt.%, *Rosen 2000b*) and Vausse (23 wt.%, *Rosen 2001*) fit well in this scheme. Faïences from Granges-le-Bourg are magnesium-rich (MgO 5-10 wt.%) and were made from dolomitic marls (*Maggetti et al. 2009c, d*). Five faïences from Varages (South of France) have more than 11 wt.% MgO (*Schmitt 1990*).

There are five reasons why calcareous clays were widely used (*Tite 2009*):

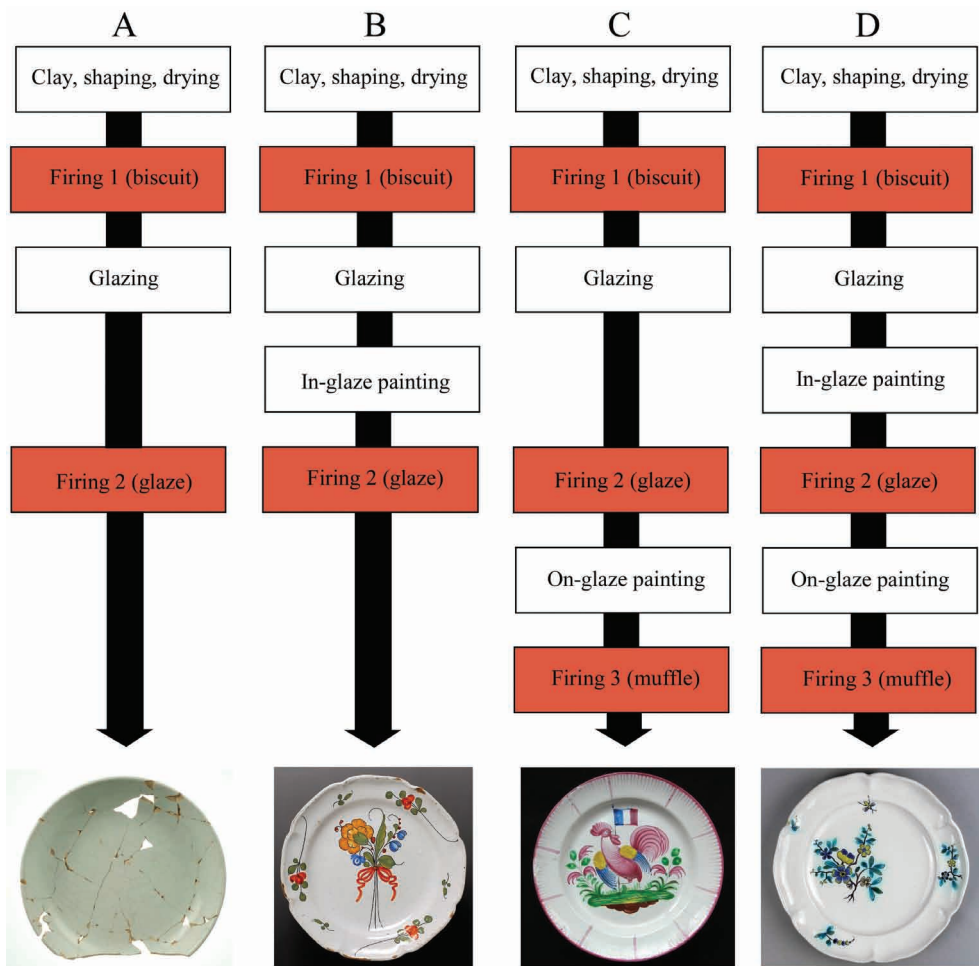


Fig. 6. "Chaîne opératoire" of the four faïence types (without lustred faïence). (A) White faïence. Below, photo of a plate from the faïence manufacture Du passage de la Cour-Robert in Fribourg, Switzerland, ~1790-1810. Archaeological Survey of the Canton Fribourg, Switzerland, inv. FPL-CRI No 1646. Photo G. Bourgarel. (Bourgarel, 2007); (B) Faïence with in-glaze decoration. Below plate from the faïence workshop of Le Bois d'Épense/Les Islettes, France, ~ 1800, diam. 22,5 cm, inv. 943.1.32. Collection and photo of the Museum Bar-le-Duc (Rosen, 2007a); (C) Faïence with on-glaze decoration. Below plate with a cock, after 1830 (?), from a Lorraine manufacture, most probably Lunéville or Saint-Clément. (pers. coll.). Photo M. Maggetti; (D) Faïence with in- and on-glaze decoration. Below plate with stamp Paul Hannong from Strasbourg, ~ 1735-1748, diameter 24,8 cm. Collection and photo J. Bastian.

- (1) They are very common;
 - (2) High CaO-bodies shrink considerably during cooling, putting the glaze under compression;
 - (3) CaO acts like a bleach during firing, giving pale buff colours;
 - (4) The thermal expansion coefficient of calcareous bodies matches those of lead-alkali glazes and
 - (5) Microstructures remain essentially unchanged over the 850-1050°C firing range.
- Calcareous bodies show significantly less firing shrinkage and have a greater rigidity and compressive strength as non calcareous wares.
- The raw materials extracted from river sediments or a quarry must undergo several operations to remove the rougher elements and to make them homogeneous. Finely ground

temper can also be added, or two or more clays mixed. The clay was first ground, then placed in suspension in water in vats or barrels and well stirred to separate the grains (washing). The suspension was filtered, poured into a large earthen pit and once again well stirred. The suspension was then allowed to decant, the unwanted coarse particles settled to the bottom to form a coarse inferior layer. Specialized workers removed the finer superior layers and poured them into another vat. This decanting process was repeated several times.



Fig. 7. Clay washing pools. Faience manufacture of Les Auges, middle of the 19th century (Langres, France). Excavations J. J. Thévenard. Photo M. Maggetti

The excavations made by Jean-Jacques Thévenard in the faience manufacture of Les Auges in Langres, revealed the presence of a whole series of clay pools (Fig. 7). The paste was then stocked in a cellar and allowed to rot for several weeks, even months. Before the material taken from these rotting-cellars could be used, it had to have the exact amount of water necessary, obtained either through drying to remove a surplus, or by adding liquid.

Homogenization was the following step, during a process called marching (Fig. 8). The paste was spread on a hard surface, in the shape of a circle a few centimeters thick. A specialized worker, trained in this delicate task, tread on the clay, walked it, going from the center out, and then the reverse. The effect of this operation was not only to homogenize the clay, but made it also possible for the worker to detect numerous undesirable tiny particles and foreign bodies. Then the paste, shaped into balls of different sizes was forcibly beaten with wooden bats or iron bars in order to extract

any air it could still contain.

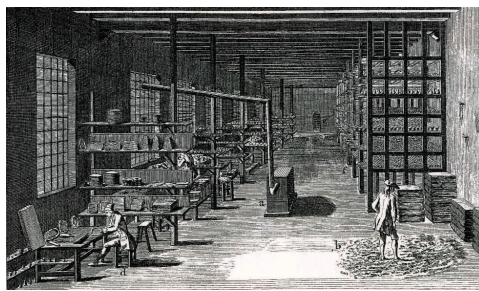


Fig. 8. Schematic view of the inside of a manufacture with a worker "walking" the clay (b), mounds of kneaded clay (c), a worker shaping an object (d) and long shelves to dry the moulds and the objects either thrown or moulded. Diderot (1756, plate II).



Fig. 9. Wheel throwing. The worker in front is shaping and his colleague behind is turning, i.e. finishing the object (Brongniart, 1844, plate XLV).

4.3.2. Shaping, drying and first firing

Once prepared, the mass of plastic clay could be shaped according to two main techniques, throwing and moulding. The first makes it possible to obtain symmetrical objects such as platters, jugs, etc. (Fig. 9). The second is used to shape non-symmetrical objects such as handles, spouts, decorations but also for symmetrical shapes (Fig. 10).

In order that they may dry, the objects thrown on the wheel or moulded were placed on long wooden planks, placed on shelving in a specific, well-aired room, or even in the shaping workshop (Fig. 8). Consequently, a lot of space was necessary for this important and delicate phase, as in the case of the drying of the moulds, whose aim it was to remove as much water as possible from the objects to prevent their shattering during firing.



Fig. 10. Different gypsum moulds from the Bois d'Épense/Les Islettes manufacture with a few biscuits from these moulds (pers. coll.). Early 19th century. Photo M. Maggetti.



Fig. 11. Biscuits from the faïence manufacture Le Bois d'Épense/Les Islettes, France (pers. coll.). Photo M. Maggetti.

During the drying process, water evaporation progresses outward in and its consequence is a loss in volume, called drying shrinkage. The pieces are thus subjected to tensions and it was necessary to ensure that this evaporation took place very slowly and uniformly, without any risk of cracking or distortion.

The usual procedure, in the production line of fine ceramics, is to examine the objects to detect any cracking before placing them in the kiln, because even a very fine crack can turn into breakage of the raw (green) object during firing (Casadio 1998). These dry and cracked pieces are not rejected, but recycled in the shaping phase, as the raw mass can be crushed and rehumidified. This type of discard leaves no trace and is not quantifiable. After forming and drying, the green leather-hard ceramic bodies were fired in a kiln giving a porous, coloured biscuit (Fig. 11). During firing water and other volatile compounds will evaporate.

Mineralogical changes and textural evolutions of calcareous illitic clays during oxidative firing were studied by many authors (Peters & Jenni 1973, Maniatis & Tite 1975, Tite & Maniatis 1975, Heimann 1982, Maggetti 1982, Shoval 1988, Echallier & Mery 1992, Diminuoco et al. 1998, Cultrone et al. 2001, Trindade et al. 2009 and literature therein). X-ray diffraction analysis of experimentally fired samples of a given clay is a popular method to estimate ancient firing temperatures. Such heat related phase changes of a dolomitic clay with a chemical composition matching

those of the faïences from the manufacture of Granges-le-Bourg are shown in Fig. 12.

The X-ray diffraction patterns of biscuits from the manufactures of Le Bois d'Épense/Les Islettes (Maggetti 2007b) and Granges-le-Bourg (Maggetti et al., 2009c) were compared with published results (and Fig. 12), giving estimated maximum firing temperatures of 950°C for the first (or biscuit) firing. This holds most probably for all other French manufactures, as a highly fired biscuit wouldn't be enough porous to adsorb sufficient tin glaze suspension (Bastenaire-Daudenart 1828, p. 395).

4.3.3. Preparing the tin oxide bearing glaze

This lead glaze, opacified with tin oxide, begins to melt at low temperatures around 900°C and should show a thermal dilatation coefficient similar to that of the biscuitted ware to avoid crazing or scaling. The raw material is always quartz sand (SiO_2), as pure as possible, with a significantly low iron content, to avoid the development of a yellowish color during the oxidative second firing. In order to lower the melting point of quartz from 1713°C to approximately 900-950°C, it is necessary to add fluxes such as lead oxide and alkalis (potassium, sodium). French faïence makers in the 18th and 19th centuries used sodium rich fluxes, mostly sea salt (NaCl) and less soda (Na_2CO_3), as indicated in contemporaneous glaze recipes, which vary greatly from one manufacture to the next.

The tin glaze, in its final stage, is a whitish powder obtained through a series of complex ope-

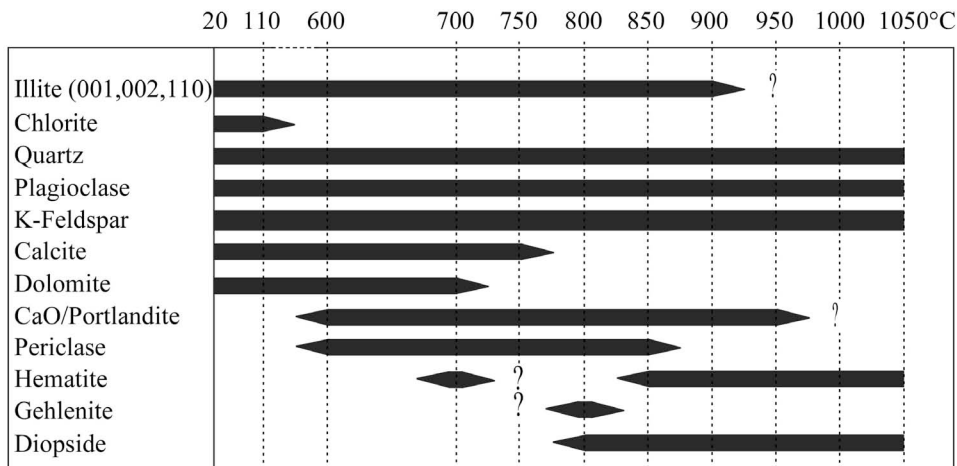


Fig. 12. Mineral stability in experimental firing of a dolomitic marl (sample GLB 1) from the manufacture Granges-le-Bourg. Portlandite is a post-firing hydrate of lime CaO.

rations. This begins with the preparation of a calx or calcine which consists in merging and oxidizing tin with lead in proportions going roughly from 1/3 tin to 2/3 lead up to 1/5 tin to 4/ 5 lead (in weight), which means 50 to 16 kg of tin for 100 kg of lead. To cut down on tin, a costly metal, it was even possible to go down to 10 kg of tin for 100 kg of lead, by adding quartz to the frit (see below). The quantity of tin bears a direct influence on the quality of the vitreous glaze, which becomes whiter and shinier as the amount of tin increases. Both metals were heated together in a small oven of a specific type. Tin melts at 232°C, lead at 327°C. When both metals are melted, the heating process is continued, the oven door is opened allowing air to enter. The liquid becomes oxidized, producing yellowish ash, pushed to the back of the kiln by a worker with an appropriate tool. The oxidation process continues as soon as the surface of the metallic liquid comes once more in contact with the oxygen in the air and the process of ash raking is continued until there is no more liquid.

X-ray diffraction analyses of a calcine from the manufacture of Arthé detected three phases: massicot (PbO, 64.55%), lead stannate (Pb₂SnO₄, 31.46%) and cerussite (PbCO₃, 3.52%). The chemical composition is 91.01 wt.% PbO, 7.94 wt.% SnO₂ and 0.58 wt.% CO₂ (Total 99.53 wt.%, Pellet 1993). Lead stannate is a well-known yellow pigment in artist painting (Maggetti et al. 2009b).

Alkaline fluxes are highly soluble in the aqueous suspension of the tin glaze. They therefore have to be stabilized, like the lead oxides, harmful to the workers' health. This is the second stage consisting in preparing a vitreous mass called frit. The lead stannate ashes, that is the calcine, are removed from the oven, mixed with very pure sand and flux. The proportions vary greatly according to the place where the production occurs and even inside the same factory. As an example, a recipe of Bastenaire-Daudenart (1828, p. 330) shows 100 parts calcine (Sn:Pb = 30:100 parts) + 100 parts Nevers sand (SiO₂) + 12 parts salt (NaCl) + 6 parts minium (Pb₃O₄) + 5 parts Alicante soda (Na₂CO₃), or recalculated by Brongniart (1844, vol. II, p. 25) 44 calcine + 44 sand + 8 salt + 2 minium + 2 soda (Total 100%). Bosc d'Antic (1780) gives three recipes without any supplementary flux, estimating that the calcine's PbO acts as flux. Some recipes mention the addition of a colouring metallic oxide to lightly tint the glaze, such as cobalt for example or copper.

The mixture calcine + sand + fluxes was finely ground and then placed on a sand layer in the lower part, that is on the hearth of the faience kiln. The exception is the workshop of Clermont-en-Argonne where the mixture was fired in ceramic containers at the hearth of the kiln (Liénard 1877, p. 169). It melted almost completely thanks to the high temperatures in this area. These were estimated 60 or 70

degrees of the Wedgwood pyrometer (*Brongniart (1844, II, p. 26)*), corresponding to ca. 1100°C. After cooling, the frit was seen as a whitish vitrous product, where the grains of the sand bed stuck to its base can still be seen (*Fig. 13*). Scanning electron microscopy revealed the inhomogeneous granulometry and distribution of the cassiterite particles. X-ray fluorescence analyses of three representative samples from Granges-le-Bourg show rather constant SnO₂ concentrations (9-12 wt.%), and wider variations in SiO₂ (38-51 wt.%) and PbO (26-40 wt.%). A sample from the manufacture of Prè d'Auge has 10 wt.% SnO₂ (*Dufournier et al. 2004*). Such concentrations match those of the faience tin glazes. The frit was then crushed, extracted from the place where it was fired, kneaded by hand to separate it from impurities and very finely ground in mills to obtain powdered opaque and white tin glaze.

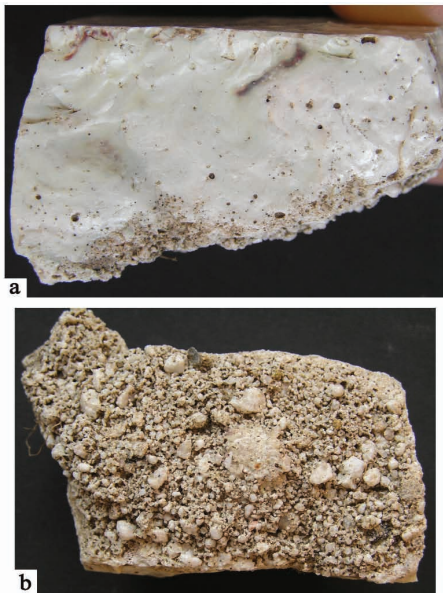


Fig. 13. A piece of tin-glaze frit showing a smooth vitrous break (a) and the rough base (b). To the latter, grains of quartz are stuck from the sand bed on which the powdered mixture was deposited before the firing. Sample GLB 80. Width 3 cm. Faience manufacture of Granges-le-Bourg (France), excavations D. Morin. Photo M. Maggetti

4.3.4. Glazing

The powdered raw glaze was then diluted in water, in which clay or other substances could be added to maintain the frit particles in suspension and to ensure adhesion between the glaze powder and the body after drying

(*Parmelee 1948*). "Often, potters would add to the glaze some organic product such as flour-based glue, gum or honey to make its suspension in water easier, since the high density of these coatings drove them speedily to the bottom. In other cases, clay is added to the suspension; it will act in the forming of the glaze during the firing. All these additions give, moreover, greater cohesion to the film deposited on the surface of the ceramic. [...] When a transparent or opaque glaze has to be tinted throughout, the coloring agent, carefully crushed, can be added to the aqueous suspension, but it can also be mixed to the lead and tin oxides in the frit." (*Picon et al. 1995, p. 49*).

The tin glaze suspension can theoretically be added to the leather-hard, unfired object, as is the case for other glazes, but French treatises only mentions the application of the glaze onto biscuitted ware. Powdered tin-lead glaze, placed directly onto a dry and unfired clayey objet, tends to shrink when fired. To avoid this, the glaze must be applied in a thick, costly layer. The advantage of a biscuit is that it does not react when the aqueous suspension is placed on its surface, and that the dissociation of the carbonates already took place during the first firing. A well fired, calcareous biscuit will theoretically no longer give off carbon dioxide during the second firing. On the other hand, an unfired calcareous paste will give off a lot of CO₂, which appears after firing in the shape of gas bubbles in the vitrous tin glaze.

The bisquitted pieces were dipped either by hand or with pincers (*Fig. 14*). To glaze the interior of an object, the aqueous glaze slurry was poured inside and the surplus poured out after a certain time. Another technique consisted in using brushes or cloths dipped in the suspension. Thanks to the high degree of porosity of the biscuits, the water was rapidly absorbed and a layer of powdered glazed formed on the surface of the ware.

The objects were removed and let dry (*Fig. 15*). The traces left by fingers or holes due to the use of pincers then had to be smoothed over with a brush. The objects were ready for the second firing, if the aim was to produce white dishes (*Fig. 6A*). Uniformly white tableware was in all French manufactures the gre-



Fig. 14. Glazing and touching up. Two workers are dipping biscuit plates in the liquid containing the glaze powder. In the background, two female workers are touching up the raw glazed objects. The one in front is removing the glaze powder from the bottom of a plate with a brush or a piece of felt, so that it will not adhere to the support during firing, the other is removing with a blade the excess thickness of the glaze or their drops. (Brongniart, 1844, Plate XLVI).



Fig. 15. Faience biscuits covered with raw white tin glaze, drying in the sun. Grottaglie, Italy. Photo M. Maggetti.

atest part of the production.

SEM-EDS analyses of 23 tin-glazes from Le Bois d'Épense revealed an overall content of 46 wt.% SiO_2 , 9 wt.% SnO_2 , 31 wt.% PbO , 4 wt.% K_2O and 2 wt.% Na_2O (Maggetti et al. 2009a). Chlorine (1 wt.%) indicates the addition of salt, a common practice in this manufacture. The relatively high alumina content indicates the addition of a clay phase to the aqueous glaze suspension, which was totally dissolved in the tin-glaze during the firing. However, it cannot be ruled out that some alumina present in the glaze results from diffusion processes occurring from the body into the glaze (Tite et al. 1998, Molera et al. 2001).

The tin-opacified lead-alkali glaze shows very few bubbles and relictic quartz grains, as well as newly crystallized phases, such as potash

feldspars and a SiO_2 polymorph, probably cristobalite according to its shape (Fig. 1). Cassiterite particles are not homogeneously dispersed, but form small SnO_2 -clusters. The glazes of Granges-le-Bourg have similar chemical compositions with SnO_2 around 9.1 wt.% (Maggetti et al. 2009d).

4.3.5. Decorating

Painters decorated the pieces freehand, basing themselves on illustrations, often engravings, or by using the technique of stencilling (Bastian 2002, p. 99). The use of stencils, generally made of metal, became widespread only in the 19th century (Rosen 1995, p. 41). The drawing, first made on paper and pierced through by a needle, was rubbed with a stamp containing a powder which disappeared during the firing, such as wood charcoal, and made it possible, by transfer, to obtain a preliminary outline which would guide the painter's hand. As Rosen (1995, p. 41-42) notes: "Only a few pieces received elaborate designs. Most of them only bore elementary patterns executed rapidly by workers who were not always qualified painters. In that case, they could place the object on the girelle of the wheel, and traced with an unmoving hand the outlines which they then filled in with different patterns."

The printed design, a process started in England towards the middle of the 18th century, was not used very much for tin-glaze faience, even though it appeared early on in France on porcelain (ca. 1759, Préaud & d'Albis 2003, p. 346) and white earthenware or terre de pipe (Garric 2006, p. 16-17).

4.3.6. Ceramic colours

French ceramic colours of the 17th and 18th century were, with few exceptions, coloured glass, finely crushed, in order to make it possible to draw lines, even very fine ones. Their colour is due to:

- (1) The addition of colouring metallic oxides to a colourless glass melt;
- (2) The incorporation of natural or synthetic crystals in a colourless or coloured glass melt;



Fig. 16. Test pieces from the faience manufacture Le Bois d'Épense / Les Islettes manufacture (pers. coll.). Width of the clay balls 2-3 cm. Photo M. Maggetti.

- 3) A mixing of milled, coloured crystals with a colourless or coloured glass powder.

Thus we can divide ceramic colours into two large categories, transparent colours and opaque colours. *D'Albis (2003, p. 162)* characterizes them as follows: "If a colouring oxide is melted into a colourless substance and has passed on its colour to it, the colour is then *transparent*. It is said that the colour is "*in solution*" (in the glass). If on the other hand, the colouring oxide or the blend of colouring oxides is merely mixed in its powder state to the colourless substance and if the latter, then called flux, only agglomerates the colouring grains between themselves and on the porcelain during the firing, without as a rule becoming coloured itself, then the colour is *opaque*. The colouring grains themselves are responsible for this. It is then said that the colour is "*in suspension*" (in the glass)".

One of the methods for preparing transparent colours consisted in putting transparent glass powder in a crucible, adding a low percentage of a colouring oxide, melting the whole in a kiln, crushing the newly formed glass, reducing to a powder in the colour mill, washing it and filtering it. This process of fritting-crushing-washing-filtering was usually repeated several times.

For opaque colours, one could either use naturally refractory substances, with low solu-

bility in a glass such as the Armenian bole or synthetic refractory products prepared on the spot or that could be purchased. They were mixed in a crucible with a transparent or coloured crushed glass, then placed in a kiln and melted. After cooling, the procedure was the same as for transparent colours.

Brongniart (1844, II, p. 505-688) devotes a large part of his treatise to the technique and the preparation of ceramic pigments and colouring agents, which shows how important he felt this technological aspect was. In the 18th and at the beginning of the 19th centuries, each workshop normally prepared its own colours and kept its secret very closely. The archive sources and the treatises published reveal countless recipes and numerous trials, whether successful or unsuccessful. These essays are brought forth by archaeological excavations as test pieces, that is to say small tumblers or ceramic objects (*Fig. 16*).

It is easy to understand the reticence there was to reveal these recipes because the colours, these transparent or opaque vitreous powders, the tin glaze and the biscuit, all three submitted to the same second or third firing temperatures, must have had thermal dilation coefficients which were comparable among themselves. Moreover, if the objects were used for culinary purposes, there was the need to find on-glaze colours with a che-

mical composition which would resist liquids such as vinegar, tea or coffee and with a high resistance to abrasion to avoid being scratched by metallic objects such as knives or forks. All these requirements were not easy to bring together and one understands that each factory needed a lot of time, energy and financial backing to put the finishing touches to their recipes, using local and foreign resources to prepare the paste, the tin glaze and the colours, while at the same time keeping in mind their specific physicochemical properties.

4.3.7. In-glaze painting

In this decoration technique (*Bastian 2002, p. 95 ff.*), painters worked directly onto the dry tin glaze powder of the biscuitted pieces, which was very fragile (*Fig. 17*).



Fig. 17. In-glaze painting on tiles at the manufacture Schreiber Keramik AG, Matzingen, Switzerland. Photo M. Maggetti.

It took someone with a steady and well-trained hand, because it was almost impossible to repair an erratic brushstroke. When corrections were required the faulty part had to be carefully scraped off and the glaze including the colour pigments reapplied.

Considering the high temperature and the long time of the second (glaze) firing, in-glaze colours become closely fixed to the tin glaze. But very few colours resist at such high temperatures, the palette contains but few colours: blue, green, brown to violet, yellow, black, red and white. The first three are transparent and their hue is due to the "diluted" presence of cobalt in the case of blue, copper for green and manganese for brown to violet.

Yellow (Normally $Pb_2Sb_2O_7$) is a very ancient opaque colouring agent used by the Egyptians as early as 1600 BC (*Clark et al. 1995*). Its synthesis is a result of a dry mixture of powdered antimony and lead oxides, obtained by oxidizing antimony and lead sulphides (Stibnite Sb_2S_3 and galena PbS), the whole melted in a crucible at temperatures around $900^\circ C$ (*Shortland 2002*). These yellow crystals, finely crushed, are then mixed to powdered colourless, transparent glass, or coloured glass, if the painter wanted other shades and tones for the desired colour. Black is often obtained through manganese and iron oxide crystals, either alone, or mixed. Red, a delicate colour to obtain because it is not very stable at high temperatures such as those of a second firing and turns into drab brown, is therefore little used in faience. What were used instead were calcined ferruginous sands such as *Armenian bole* or, later on, *Thiviers red* (*Rosen 1995, Rosen et al. 2007*). White is a colour containing more tin oxide as the tin glaze, used for example in the technique called *Bianco sopra Bianco*.

The powdered ceramic in-glaze colours were mixed with water and a binder, for example starch, in small bowls. During glaze firing the pigment particles were coated by a thin sheath of molten glaze.

In-glaze colours of the manufacture Le Bois d'Épene were studied by *Maggetti et al. (2009 a, b)*. Electron microscope examination showed that the blue drawings are inclusion-free glazes with wavy boundaries to the underlying tin-glaze (*Fig. 1a*). They are lead-alkali glazes with a small amount of dissolved cobalt (0.2-0.8 wt.%). NaCl was used to make the blue glass, as evidenced by the presence of chlorine. Significant arsenic concentrations classify these blue pigments (smalts) into group 4 of *Gratuze et al. (1997)*, deriving from cobalt ores of the Saxonian Schneeberg (Germany). Purple colours contain minor amounts of cassiterite and relictic Mn-Fe-crystals. Manganese and iron contents in these transparent colours lie between 2.5 and 4.6 wt.% respectively.

The black colour is an association of very tiny

and rounded particles. Elemental mappings show that the latter consist of distinct iron-, manganese- or iron + manganese-rich pigments.

The rare opaque red colour is a complex mixture of: (1) very rare cassiterites; (2) rare, large corroded potash feldspars; (3) large (up to 10 μm "crumbly" pigments (fired yellow or red ochre); and (4) small (approximately 1 μm) rectangular or square particles (Pb feldspars?) (Molera et al. 1993, Fortina et al. 2005).

Early 19th century antimony-based opaque ceramic colours are yellow, tawny and green (Maggetti et al. 2009b). The first is generated by lead antimonate crystals ($\text{Pb}_2\text{Sb}_2\text{O}_7$), which are incorporated into an uncoloured glassmatrix (Fig. 1b). According to SEM-EDS measurements, these pigments contain iron. The tawny colour is the optical result of the combined presence of similar yellow, iron-bearing lead antimonate particles in a Fe-rich, brownish glass matrix. The green opaque colour is produced by the combination of a blue cobalt glass and yellow Pb-Sn-Fe-antimonate crystals. Relictic cores of zoned pigments lighten the recipes, according to which the pigments were produced. First, they were synthesised by calcination, ground and then mixed with a colourless, brown or blue glass powder. The resulting powder mixture was added to a liquid agent and used as high temperature ceramic colour.

Analytical studies of red decorations from four production centers (Argonnes, Nevers, Rouen and Thiviers) showed a complex situation (Marco de Lucas et al. 2006, Rosen et al. 2007). Thiviers used a particular, locally available reddish sandstone called *Grès de Thiviers* or *Thiviers Red*. This rock is composed of α -quartz grains cemented by goethite (α - FeOOH). During firing, the latter transforms to red hematite (α - Fe_2O_3). Raman spectra of different Nevers red hues revealed that the 18th century pigments were a mixture of lead antimonate $\text{Pb}_2\text{Sb}_2\text{O}_7$ with iron oxide and that *Thiviers Red* was used for the mid 19th century faïences. The manufactories of Rouen and *Le Bois d'Épense/Les Islettes* didn't employ *Thiviers Red*, but *Armenian bole* for the former and lead antimonate with

an iron-rich glaze matrix for the latter.

4.3.8. The faïence kiln

The kiln is an essential structure in a faïence workshop. At the time under study here, wood-burning kilns were used, intermittent, with a vertical draught and direct flame (horizontal semi-cylindrical kilns). The kilns in French faïence workshops in the 18th and 19th centuries were made of refractory bricks (Rosen 1995, p. 47). In the Middle Ages, kilns had only one laboratory in which green, leather-hard objects for the first firing and raw glazed biscuits for the second firing were placed simultaneously. The latter were stucked in saggars. These kilns can still be found today (Caiger-Smith 1973, Amigues 2002). French kilns of the 18th and 19th centuries could have two floors or laboratories, separated by a perforated platform to let hot air through (Fig. 18).

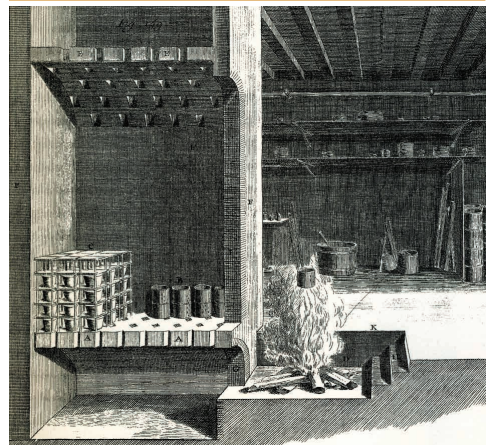


Fig. 18. Schematic aspect of a faïence kiln with its fireplace, the sole and the laboratory for second firing. In the latter two different methods of placing the wares are shown, that is with saggars or rafters and the biscuit laboratory upon it. Diderot (1756, plate IX).

The bigger was used for the second firing of raw glazed pieces and was situated in the lower part of the kiln. The smaller, named "globe" or first firing room was for biscuit firing. There, the green leather-hard object was thoroughly dried and became ceramised, that is, it was transformed into a hard object—the biscuit—and its shape was thus consolidated. The unfired pieces were normally simply piled up "in charge" in the top laboratory where the temperature was not so high,

and fired at the same time as the raw glazed biscuit pieces placed in the lower laboratory. When these objects were placed in the kiln it had to be in such a way as to guarantee they would not touch to avoid becoming stuck together with the molten glaze. It was also necessary that the pieces be kept away from the flames and substances resulting from the combustion, such as ashes and smokes, or from projections, to avoid the deterioration of glaze and decoration.

To this purpose, potters used very specific refractory materials when placing their wares in the kiln, by using two techniques: rafters, also called *en chapelle* (Fig. 18, to the left of the second firing laboratory) and saggars, also called *encastage* (Fig. 18, to the right of the second firing laboratory). The first consists in placing the objects to be fired on rafters or on slabs separated by pegs or reels (Fig. 19). These scaffoldings were wedged with bits of clay of different shapes, named *accots*.



Fig. 19. Slabs, firing plates or shelves for placing wares in the kiln and columnar props or reels from the faience manufacture Le Bois d'Épense/Les Islettes (pers. coll.). Width of the slabs ca. 20 cm. Photo M. Maggetti.

In the second technique, the pieces were placed, according to their shape, in box-like containers either round, or oval, or rectangular, called saggars (Fig. 20) where they rested on triangular supports, the saggars-pins (they can also have other shapes, named cockspurs or trivets). The latter had to be as sharp-edged as possible so as to leave only a very small trace when in contact with the fired object. The inside of the saggars was usually glazed to protect

as much as possible the objects to be fired from the projection of particles. The saggars were piled up in the kiln, isolated from gases and flames by round tiles pierced with a hole and having all cracks filled in with clay putty.

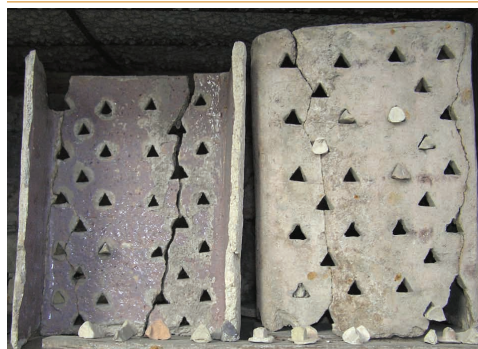


Fig. 20. Saggars and triangular, nail-like saggars-pins or pegs from the faience manufacture Le Bois d'Épense/Les Islettes (pers. coll.). Height of the saggars ca. 16 cm. Photo M. Maggetti.

These technical or kiln ceramics which came in direct contact with the flames and the atmosphere of the kiln, that is the saggars, the rafters used to place the objects in the kiln and the reels had to be resistant at high temperatures, go through as many firing cycles as possible, and bear the weight of the pile up. Refractory mixtures with a high mechanical resistance had to be made. Each manufacture had its own recipe. Non-calcareous clays were commonly used, to which were added a temper in the form of coarse sand and crushed ceramics (*grog*).

There is only one archaeometric study of kiln furnitures from a French faience workshop. Maggetti et al. (2009d) studied thirty-nine samples (firing plates, saggars, spacers, props and *accots/wads*) from the manufacture of Granges-le-Bourg. The kiln furniture is chemically inhomogeneous. Firing plates and saggars belong to a CaO + MgO-poor group, well suited to support high firing temperatures as well as several firing cycles. They correspond to decarbonatised top layers of local dolomitic Triassic marls, tempered with local quartz sands. Contrasting, props, spacers and wads show markedly higher CaO and MgO, and were made using local dolomitic marls, which were probably not as well processed as the faience paste.

The potters obviously employed two major

recipes, based on refractory and non-refractory clays. Ceramic objects with high fluxes will melt around 1100°C and are therefore not very well suited to resist the firing temperatures of a faience kiln or to support many firing cycles. The use of such clays for the second group of kiln furniture is therefore puzzling and not yet understood. Plate and saggars are covered inside with a tin glaze. For obvious financial reasons, the potters used significantly less tin oxide (< 6 wt.% SnO₂), added much more crushed quartz and applied the watery glaze suspension with a much thinner stroke as for the faience. The absence of any significant reaction zone at the body/glaze interface indicates that the glaze suspension was applied on already fired (biscuit fired) plates and saggars.

4.3.9. Second (glost or glaze) firing

Each ceramic firing is divided up into two phases, the firing phase proper which includes the rise in temperature up to the maturing temperature of 950-1050°C, and a second cooling phase in which the kiln is no longer stoked (Picon 2002). In the first, reducing atmospheres alternate with oxidizing ones while in the case of faience, the second phase is throughout oxidizing because air is allowed to penetrate inside the kiln. A vivid description of such a faience firing is given by Amigues (2002). According to Bastenaire-Daudenart (1828, p. 390-391) a French kiln would continuously fire for 25-27 hours, with a first *slow fire* stage (5-6 h), a second more sustained fire stage (5h) and a *long sustained fire* stage at maximum temperatures (15-16h).

The firing, the crowning step in the faience-making process, is not an easy matter, but full of risks, because the distribution of the heat inside a kiln is often very uneven, as much as several hundred degrees difference depending on the specific spot in the kiln (Flame ΔT up to 550°C, Wolf 2002), yielding misfired pieces, either under or over fired, or because the piled up objects crumbled as a result of a poor sagger recipe or through excessive heat. Therefore, one must not be surprised at the large quantity of waste found during workshop excavations. Biscuit wasters could be used as testing material (drawing,

painting, glazing), while the faience of lesser quality were sold at lower prices or incorporated into building materials (Amigues 2002, p. 197). Even the very worst quality was not lost because it was used to fill in ditches or to level the ground. The end products of the glost firing were white faience tableware (Fig. 6A) or in-glaze decorated pottery (Fig. 6B).

Experimental firings in kilns with one firing chamber, built and functioning according to ancient techniques, have given reliable temperature-time curves (see Amigues 2002; Wolf 2002). On the other hand, no experimental firing was carried out in a two-chamber kiln. It can be guessed that the temperature-time curve of the second firing is quite similar to that of a one-laboratory kiln, but precise experimental data for the temperatures of the biscuit laboratory are lacking. "The firing is in two parts, first the objects are fired as biscuit at a temperature ranging from cherry red to whitish red, and then with the glaze at a slightly higher temperature." (Brongniart 1844, 1877 tome II, p. 20).

Inferred second firing temperatures in the kilns from Le Bois d'Épense/Les Islettes and Granges-le-Bourg were, according to X-ray diffraction analyses, between 950 and 1050°C (Maggetti 2007b, Maggetti et al. 2009c). These results are in good agreement with the microstructure of the well sintered bodies with voids due to the dissociation of carbonates (Fig. 21) and tiny calcsilicate phases (diopside, gehlenite, plagioclase) crystallized during firing (Fig. 22).

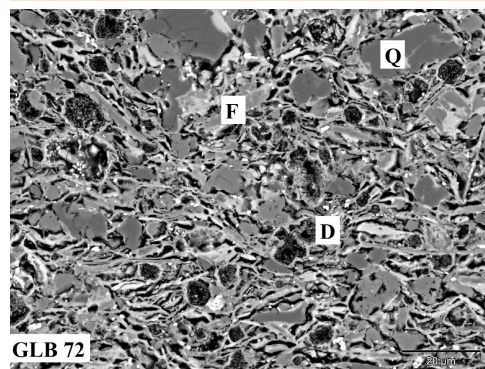


Fig. 21. Backscattered electron images of the body of a faience from Granges-le-Bourg. D = void, former dolomitic grain, F = K-feldspar, Q = quartz. Photo M. Maggetti.

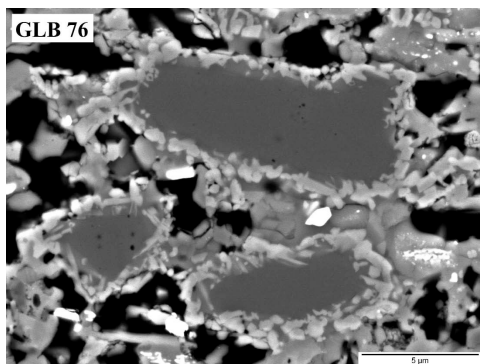


Fig. 22. Closer view of a well fired faience body from Granges-le-Bourg. The tiny crystals around the quartzes and in the glassy matrix are calc silicates (diopside, gehlenite, plagioclase). Photo M. Maggetti.

It has often been observed that the firing triggers the building up of a reaction zone between body and glaze, called *interface body-glaze* or *body-glaze layer*. A detailed discussion of this phenomenon can be found in technical handbooks (Munier 1957, Hamer & Hamer 2004). With progressing firing, glaze melt will soak into the porous biscuit. The fluxes of the glaze (and the body) will selectively attack and dissolve refractory particles of the body, especially clay minerals. This is the reason for the Al-richness of the reaction zone. On cooling, Pb-feldspar will therefore crystallize in the body-glaze layer (Molera et al. 1999). The thickness of this interface depends on several factors (Molera et al. 2001, Ben Amara 2002):

- (1) Mineralogical nature of the clay;
- (2) CaO-content of the body;
- (3) Na-content of the glaze;
- (4) Green, leather-hard body or biscuitted body;
- (5) Firing conditions (T max., soaking time, cooling time).

Modern industrial applications favour the development of such an interface as it prevent to a certain degree crazing and shivering. In the glaze, wollastonite and diopside crystals can be concentrated in a small layer close to the interface body-glaze (Mason & Tite 1997, Molera et al. 2001, Bobin et al. 2003, Fortina et al. 2005, Zucchiatti et al. 2006). Body-lead glaze reactions (up to 300-400 µm from the body/glaze contact into the glaze) are documented by conspicuous ele-

mental diffusion profiles, for instance for alumina and lead oxides (Molera et al. 2001). These phenomena must be taken into account when measuring the chemical composition of a glaze.

4.3.10. On-glaze painting

This technique was introduced into the French faience community around 1740 by Paul Hannong of Strasbourg (Blondel 2001, p. 261). For the on-glaze painting, a binder was added to the powdered colour such as, for example, natural gum or turpentine and turpentine oil (Bastian 1986, p.134, Bastian 2003, p. 106) so as to obtain a more or less viscous mixture. It was possible to use on the one hand powders with pure tints and on the other hand blends, for example blue and green, which gave different colours. During the firing process, the organic substances evaporated, the powder melted and bound with the mollified tin glaze. The applying of colours on the glost fired tin glazed objects, in-glaze decorated (Fig. 6D) or not (Fig. 6C), needed a third firing intended to fix the pattern, in a special reverberatory furnace, also known as muffle furnace. Temperatures in this furnace used to be lower (estimated 400 to 850°C, Rada 1989, p. 83, Endres et al. 1991, p. 42, De Plinval de Guillebon 1995, p. 20, Peiffer 2000, p. 97) than those of the second high temperature firing (inferred 950-1050°C) and allowed for a much larger colour palette to be used.

In rare cases, for the same object, artists used the mixed technique (Fig. 6D). To do this, they applied in a first step, certain in-glaze colours on the unfired tin glaze, and in a second step, after the glost firing, the on-glaze colours which were then fired in the muffle furnace. If the thermal dilatation coefficients or the fixation temperatures of the on-glaze colours were too far apart, it was possible to fire each colour individually, which meant placing the object several times in the muffle furnace. Obviously, these techniques entailed a higher cost.

In order to obtain special effects, the painter can use the luster technique which requires a fourth firing under reducing conditions. This

technique was not used in France in the period studied here.

5. Provenancing of French faïences: two case studies

Attributions of ceramics to a pottery workshop must be based on so-called chemical reference groups. Each reference group comprises a minimum of 20-30 chemical analyses of unequivocally local products (biscuits, wasters) from a specific manufacture. Up to date, there are only four reference groups of French faïence workshops which fulfil all requisites, i. e. (1) enough chemical analyses; and (2) all analyses published. These are Granges-le-Bourg (Maggetti et al. 2009c), Montpellier (Rosen et al. 2009), Moustiers (Rosen et al. 2009) and Nevers (Rosen 2009). Three new reference groups (Le Bois d'Épense, Lunéville and Saint-Clément) will be published very soon.

5.1. 17th century faïences: Nevers or “Le Croisic”?

France had only few faïence manufactures in the 17th century (Fig. 4). A characteristic product painted in the compendiario style (Fig. 23) is attributed by many specialists without any real proofs to the “Le Croisic” workshop (Vince 1982).



Fig. 23. Faïence plate attributed to the “Le Croisic” manufacture (Vince 1982). Photo J. Rosen.

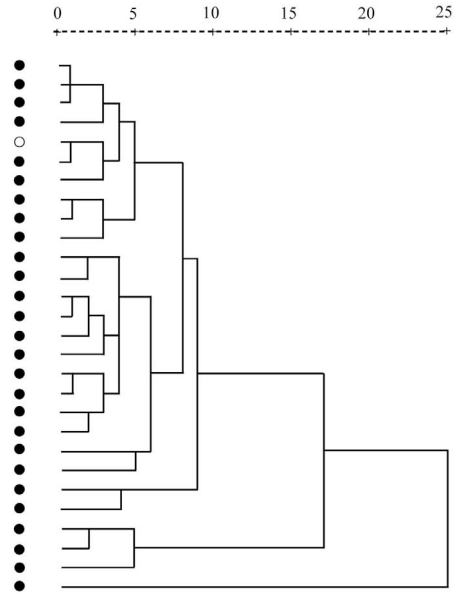


Fig. 24. Result of the cluster analysis of the 17th century Nevers reference group (Rosen, 2009) and the “Le Croisic” faïence piece of Fig. 21. Redrawn and simplified from Rosen et al. (2009).

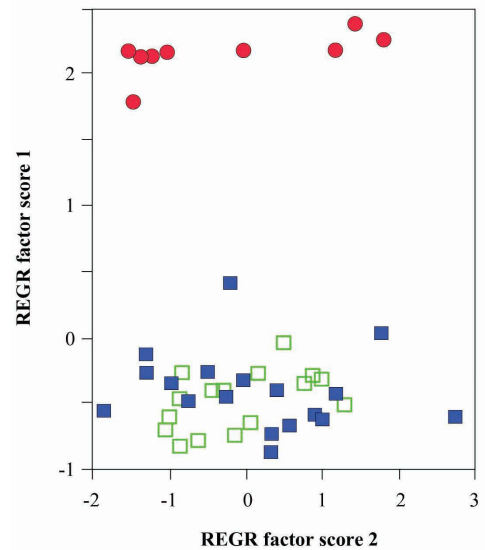


Fig. 25. Factor analysis of the 18th century Nevers reference group (blue rectangles), genuine La Rochelle faïences (from the excavations of the La Rochelle manufacture, red dots) and faïences attributed to La Rochelle, found in the waste dumps of the Nevers manufactures (green rectangles). Redrawn from Rosen et al. (2009).

The authors situated this hypothetical workshop at the estuary of the river Loire in the Atlantic. Using the reference group of 17th century faiences from Nevers (Rosen 2009) it could be shown that this sample of so-called typical “Le Croisic” faience from the *Musée du château des Ducs de Bretagne* in Nantes (French Brittany) match the chemical composition of the Nevers faiences (Fig. 24, Rosen et al. 2009). It was therefore made in Nevers and shipped on the navigable Loire to Nantes and the Atlantic. Faiences from Nevers eventually reached Canada and were found in excavations in Quebec.

5.2. 18th century faiences: Nevers or La Rochelle?

A comparative factor analysis using a Nevers 18th century reference group against a reference group from the manufacture of La Rochelle, a harbour on the West coast of France, clearly distinguishes both (Fig. 25). A whole set of faience pieces with so-called “La Rochelle” decorations (Morin 1990, p. 104), found in the waste dumps of Nevers manufactures, definitely belong to the Nevers reference group (Rosen 2007b, Rosen et al. 2009).

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