Porcelains are actually the fired product of ternary mixture of fine-grained clay (commonly kaolin), flux (usually feldspar) and filler (commonly quartz) [1]. It is a ceramic product of dense, white, translucent character and are usually classified according to firing temperature. So called “hard porcelains” with the standard batch formulation of 50% kaolin, 25% feldspar and 25% quartz have been usually fired at 1380°–1460°C and “soft porcelains” (e.g. feature high content of fluxes) at lower temperatures ~1200°C. Apparently, soft porcelains have lower production cost due to the lower energy consumption during firing, and can be decorated with a wider range of colours. According to the use, there are tableware, sanitary, chemical-technical and electrical porcelains, all made of quartz, feldspar and kaolin. Moreover, there are special types of porcelains, such as “frit porcelains” which is manufactured mainly in France and made of kaolin, quartz and alkali rich frit, or “bone china” which is produced mainly in England and consists of 20 to 30% kaolin, 25 to 30% pegmatite (e.g. Cornish Stone) and 25 to 50% bone ash [2-4]. Composition and processing parameters broadly affect the properties of tableware porcelains, such as densification, firing temperature range, mechanical strength, whiteness, and thermal shock resistance. The most important properties of all these raw materials are sufficient purity, especially low iron content. Kaolin is the most important raw material for the manufacture of porcelain. In the man-
ufacturing kaolin is washed before being used to eliminate the coarse particles which consist mainly of quartz, however very fine silica and mica can remain in the washed kaolin to a certain extent. Ball clay may be added to improve the plasticity of the porcelain body while with regard to the necessary white color of the fired product only few ball clays with a low iron content can be taken into consideration. Quartzite or quartz sand are added to the batch formulation: to avoid thermal shock faults due to the inversion behavior of quartz (e.g. \( \alpha \) to \( \beta \) quartz inversion is accompanied by a linear expansion of 0.45%) cooling rates are not exceeding 50 °C/hour [5,6]

The most used type of feldspar in porcelain bodies is potassium feldspar whilst sodium feldspar is used only occasionally. Potassium feldspar demonstrates good stability against distortion of the porcelain during the firing process due to formation of a melt of great viscosity which decreases only slightly with increasing temperature. Pegmatite is preferred sources to introduce feldspar in the porcelain production.

Porcelain originated in China: although proto-porcelain wares exist dating from the Shang dynasty (1600-1046 B.C.E.) and the gray porcelains surely based on kaolin were manufactured at the time of Zhou dynasty (1027-221 B.C.E.), by the time of the Eastern Han dynasty (206 B.C.E.-220) glazed ceramic wares had developed into proper porcelain. More precisely, it is considered that porcelain was first invented under the Han dynasty in the country of Sin-ping between the years 185 B.C.E. and 88 thus giving it an antiquity of at least 2000 years and a priority of 1600 years over the invention of European porcelain. The first kiln was built in Chan-nan (province of King-si) and, during the eighteenth century, a maximum number of around 3000 kilns was achieved. The production of porcelain became very popular under the Thang dynasty (618-907), so that the poet Tu-Mu was enhancing its beauty by saying that “The porcelain is so light but solid and the wonderful white cups are even more shining than the pure crystals of snow”. Such a better production of porcelain in terms of quantity and quality was mainly due to the discovery and exploitation of the ore located at Kau-ling or Kao-ling (meaning high mountain) or Gaoling according to the Pinyin grammar, located in the province of Kiangsi (or Jangxi) in the South-Eastern China. The Kau-ling mine, next to Kaulin village, gave the name to the exploited kaolin rock, whose hard and no-plastic nature should be more similar to a feldspar-rock rather than the kaolin-clay properly named in Europe and recognized to be softer and with a less content in silica.

In considering the natural resources Chinese potters had available, from loess rock to kaolin and from clay to china stone, creation of porcelain by the Thang period would have been impossible without prolonged experimenting with raw materials, improving furnace design, developing glazing techniques, and learning how to manage the kiln environment. Of course, they employed kaolin as their primary clay, a mineral substance that satisfied all the requirements for such replication since it fired a striking white, shaped to fine tolerances, and with stood the hottest portion of the kiln without melting. Thang dynasty potters thus created the first true porcelain, a new material that nevertheless emerged naturally from the long evolution of high-fired pottery. Thang dynasty potters thus created the first true porcelain, a new material that nevertheless emerged naturally from the long evolution of high-fired pottery, inspired at the last moment by new cultural forces linking China to the rest of the world. Porcelain and other Chinese arts responded to the Thang opening to the west. Oasis communities on the Silk Road played the role of middle area, conveying their versions of Indian and Persian pictorial methods to China, such as rhythmic patterns, rotating arabesques, stylized flowers, geometric shapes, molded relief, interlaced designs, and exuberant colors.

Eventually porcelain and the technique to produce it began to spread into other areas of East Asia. During the Song dynasty (960-1279), artistry and production had reached new heights. The manufacture of porcelain became highly organized, and the kiln sites built in this period could fire as many as 25000 wares. Above all, population growth and foreign trade stimulated the ceramics industry. The Song period accounts for 75 percent of all pottery kilns ever established in China’s history; in particular, porcelain was produced in 130 counties belonging to nineteen provinces. Expansion of seaborne commerce during the Southern Song especially benefited the pottery industry. Maritime traders had a particular liking for porcelain as a cargo: since the ceramic is both heavy and impermeable to fluids, it proved practical as ballast, weighty material packed deep in the ship’s hold to enhance stability in rough seas. Transporting porcelain as ballast was so lucrative that Western merchants speedily adopted the practice when they entered Asian trade networks. Transporting porcelain by the maritime route, rather than by the Silk Road, meant that greater quantities of the ceramic reached Southwest Asia than ever before, by resulting in lowered costs to consumers there [7].

Porcelain gained wider acceptance during the Southern
Song, just as Chinese cuisine took on its distinctive characteristics. Of course, porcelain proved especially practical for drinking tea as it has minimal thermal conductivity, unlike vessels made from metal and glass. Whatever the preparation, color, or tidbit, everyone agreed that tea must be accompanied by porcelain. In becoming a defining aspect of Chinese culture, tea gathered a cluster of associations in which porcelain played a central role, especially among the elite. Beyond its association with tea, porcelain itself also contributed directly to reducing disease: its impermeable surface led to a decrease in bacterial infections stemming from particles of decayed food being retained in the pores and scratches on plates and bowls made of wood, earthenware, pewter, and precious metal. Moreover, after the Thang period, Chinese glazes contained no lead, whereas low fired, lead-glazed pottery used everywhere else released minute amounts of the metal into cooked and stored food, exposing consumers to significant health risk, even death. Song China, early modern Japan, and eighteenth-century Europe all experienced striking population growth. Though obviously impossible to measure or prove, it is likely that widespread use of tea in the three regions and increasing use of porcelain vessels in food preparation, consumption, and storage contributed to improving the health of the general population.

The first clear mention of porcelain in Europe dates back to 1271 in Il Milione by the Venetian Marco Polo. He was the first European traveler on record who penetrated into China. Marco Polo states that “In Kinsai there is nothing further to be observed than that cups or bowls and dishes of porcelain wares, which are there manufactured. The process consists in collecting a certain kind of earth, as it were from a mine, and laying it in a great heap, suffer it to be exposed to the wind, rain and sun, for 30 or 40 years, during which time it is never disturbed. By this means, it becomes refined and fit for being wrought into the vessels above mentioned. Such colors as may be thought proper are then laid on and the ware is afterwards baked in ovens or furnaces. Those persons, therefore, who cause the earth to be dug, collect it for children and grandchildren. Great quantities of the manufacture are sold in the city and for a Venetian groat you may purchase eight porcelain cups. The most beautiful porcelain cups of the world are manufactured in the town of Tenugnise”.

The wares of the Yong-lo period (1403-1424) were highly esteemed; vases of pure white, others with patterns graved in the paste, some ornamented with deep blue flow-

ers, and others of the most vivid red. During this period, the eggshell china was first introduced. Some porcelains were more highly valued than others in the imperial China. China had the world’s most advanced economy throughout much of history, providing goods to an enormous domestic market, as well as to Korea, Japan, Southeast Asia, and countries on the Indian Ocean [7].

Europeans gained direct access to Asian markets just after 1500. Along with Indian cottons and Asian spices, the Chinese merchandise mainly based on tea, silk fabric, lacquer furniture, hand-painted wall hangings and porcelains was required by the most of the Westerners. Only since the seventeenth century, desperate to halt the flow of silver to Asia to pay for the goods, European rulers promoted efforts to replicate chinaware and other manufactured items. Meanwhile, the Tching-te period (1506-1521) in China is marked with an important event in the decoration of porcelain: foreign cobalt blue material, which was worth twice its weight in gold, was first introduced as the blue pigment used before was exhausted. The manufacture of porcelain continued until the present dynasty with equal success by reaching its fame to a peak during the Qing dynasty (1644-1912).

The imitation of old pieces was a very profitable activity during the whole history of porcelain, commencing just in China and continuing intensively across Europe and the rest of the world. On the other hand, all defective pieces were thrown into a heap to be bought by itinerant dealers, some of whom have amassed large fortunes by this trade. Especially in some towns of China, there was a class of workers skillful in the restoration of defective porcelain. It is polished on the wheel for smoothing the uneven surfaces in order to repair that, which is flawed or broken. Others, equally practice in fraud, saturate cracked porcelain in certain liquids, which make it hold together for a time, but when water is poured into it, it flies to pieces. A Portuguese missionary who resided 40 years at Macao wrote a treatise, which was never printed, upon the frauds of the Chinese and among these he enumerates those connected with the sale of old porcelain. It is told that this people, by giving high prices for ancient porcelain, have brought it into high repute. By means of yellow clay and oils of several kinds, some of which are metallic, and by laying the porcelain some months in mud, as soon as it comes from the furnace, they produce the very same sort that is so highly valued by the vulgar as being five or six hundred years old.

The high opinion in which Chinese porcelain was held,
as well as the prices commanded, impelled European princes, potters, scientists, and alchemists to replicate it. From 1664, the fame of porcelain particularly in Europe was so high that the king of France, Louis XIV, grants privileges to a few potters to attempt porcelain. Their experiments lead eventually to the great eighteenth century tradition of French pottery of which Sevres (a factory founded in 1738 and moved to Sevres in 1756) is the leading example [7].

Eager to compete with China, Westerners from the late seventeenth century - soon after porcelains began to arrive in massive quantities - investigated the composition of the ceramic and experimented with formulas that approximated it. The Chinese, however, did not focus on the composition of porcelain itself simply because they regarded the material as a natural extension of their ancient craft of high-fired pottery. For their part, Westerners investigated the nature of the ceramic because of the novelty, excellence, and expense of the exotic commodity.

In 1701, reports circulated around central Europe, telling that a journeyman pharmacist and self-proclaimed alchemist in Berlin, named Johann Friedrich Böttger, had succeeded in transmuting silver coins into gold. Sought after by Frederick William, who desired a treasure-house of gold, the nineteen-year-old charlatan fled for nearby Saxony, where he fell into the hands of August the Strong, Elector of Saxony and King of Poland (1670–1733). Failing to transmute base metal into gold for the king - August demanded sixty million ducats as soon as possible - Böttger instead was forced to work on a formula for porcelain, the new “white gold.” Penned up in a laboratory in the fortifications of Dresden, Böttger bitterly wrote over the door a gold maker has been turned into a pot-maker”. Böttger was obliged to work with other alchemists in the futile research for transmutation and was eventually assigned to assist Tschirnhaus, who was working for 20 years to discover the secret of the true formula of porcelain. Although in 1703, Böttger attempts to escape to Prague for immediately being captured and brought back and in spite of the one-year-interruption of work due to the Swedes occupation of Saxony, one of the first results of the collaboration between the two was the development of a red stoneware in September 1707, made in the laboratory of the fortress [7].

In 1708, Ehrenfried Walther von Tschirnhaus was already able to produce a hard, white, translucent type of porcelain specimen with a combination of ingredients, including kaolin and alabaster, mined from a Saxon mine in Colditz. It was a closely guarded trade secret of the Saxon enterprise. With millions of porcelains pouring into Europe, Ehrenfried Walther von Tschirnhaus (1651-1708), a German man of letters and scientist, declared that the purchase abroad of so great a quantity of goods as the Chinese porcelain represented was a national loss to be advertised. He condemned the Chinese as Saxony’s porcelain bloodsuckers because of the riches, mostly silver from Spanish America that went off to China. He was familiar with the problem, for he served August II by following his passion about amassing porcelains and discovering how to manufacture the ceramic. The Polish king was the most illustrious victim of what critics of Asian luxuries termed “porcelain disease” (la maladie de porcelaine or Porzellankrankheit), a feverish desire to possess the ware. It is not a legend but an historical fact what happened to Augustus II of Saxony when he gave an entire armed regiment of dragoons to the King of Prussia in exchange of 48 pieces of Chinese porcelain right now preserved in the Johanneum museum of Dresden. Augustus’s passion for porcelain matched the scientific interests of Tschirnhaus. A man of formidable intelligence and broad interests, Tschirnhaus seems to have known all the intellectual lights of Europe. Tschirnhaus conducted scientific experiments in London with members of the royal Society, and in Paris soon after, finance minister Colbert hired the budding savant to tutor his son in mathematics. Colbert helped direct Tschirnhaus to the question of applying scientific learning to the development of new technology. Christiaan Huygens (1619-95), the Dutch physicist who discovered Saturn’s rings and pioneered the use of the pendulum in clocks, instructed Tschirnhaus in the grinding and polishing of glass lenses, one of the most exacting craft skills in science. He turned that knowledge to good account by heating potter’s clay using large focused mirrors, an accomplishment that led to his enrollment as the first German member of the French Academy. In 1682, building on his growing reputation, he joined Leibniz in putting out the journal Acta Eruditorum (learned deeds). The question of the secret formula for porcelain, known as the Arcanum, first gripped Tschirnhaus during his studies in Leiden, one of the Dutch towns most inundated with chinaware. Working for August II from the early 1690s, he experimented with optic lenses to achieve the temperatures needed for creating porcelain. He then devoted years to investigate the nature of the ceramic itself, by experimenting with various minerals and clays to come up with the right formula. In 1694, Leibniz’s sec-
tery visited the Dresden laboratory of Tschirnhaus and admired a waxy, porcelain-like material he had concocted. A few years later, the scientist spied out the techniques used in the Delft potteries of Holland and those in the Saint-Cloud pottery manufactory, located to the west of Paris on the road to Versailles [7].

Tschirnhaus welcome Böttger in his team who became the first research and development enterprise in history, driven by visions of enormous profit and haunted by fears of industrial espionage. Clever and industrious, Böttger also was lucky: Tschirnhaus’s death, just when the final breakthrough was made in creating a version of porcelain, allowed the putative alchemist to claim all the credit for the achievement. The first wares produced in 1708 actually consisted of red stoneware, a material similar to that used for the much-admired Yixing teapots, a score of which August held in his collection. Within a short time, beds of kaolin were discovered in Saxony, which improved the product and made for increased production.

Apparently the historical hit occurred when the blacksmith Johann Schnorr proposed to the alchemist to make face powder from a strange white earth found by chance under the his horse’s hoof and brought to the laboratory in a small bag. Even if the amount was very limited, Bottger understood that an interesting application could be tried into the possible porcelain’s formula. Therefore, by using the powder (very pure quality of kaolin) a workshop note records that the first specimen of hard, white and vitrified European porcelain was produced in December 1708. At the time the research was still being supervised by Tschirnhaus; however, he died in October of that year. It was left to Bottger to report to Augustus in March 1709 that he could make porcelain. For this reason, credit for the European discovery of porcelain is traditionally ascribed to him rather than Tschirnhaus. Scale-up production of porcelain begins in the Dresden laboratories in 1709 and just the year later, it appeared for the first time on sale at the Leipzig Easter Fair by 1710 were noted for their great resistance to thermal shock and for the red color known now as Bottger’s stoneware. However, just three years later, Meissen is producing white delicate porcelain. Colored glazes followed within the next few year. Bottger was passionately proud of his creations and therefore was able to inspire Augustus II with his vision of pieces designed by leading artists to outdo even the Chinese, and his achievement in this field gives Saxony its greatest single distinction [7].

Even at the time when he became the Meissen factory’s director, Bottger was confined in Dresden and although his house was luxury into the fortress, there were guards on the door. His tyrannical employer still on occasion resentful that he has been fobbed off with porcelain rather than gold, finally released Bottger in 1714. Although still in his early thirties, he became extremely ill, probably from working with kilns and crucibles in an unventilated laboratory until he died in 1719. A visitor to the factory in Bottger’s time reported having seen a white hot tea pot being removed from the kiln and dropped into cold water without damage. Evidence to support this widely disbelieved story was given in the 1980s when the procedure was repeated in an experiment at the Massachusetts Institute of Technology [7].

Yet despite severe methods of guarding against spies and betrayal, such as locking up his own crafts-men, August failed to keep the secret of porcelain manufacture for himself. Within a few years, workers knowledgeable about the ceramic recipe and the creation of high-temperature kilns escaped from Meissen and peddled the precious information to other princes. Problems with constructing effective kilns and locating sources of kaolin delayed Meissen’s rivals, but by 1760 some thirty porcelain manufactories dotted the map of Europe, about half of them in the states of Germany (Fig.1).
Of course, the Chinese eventually suffered a great deal more than August the Strong from the spread of the secret. They lost their monopoly on porcelain, their longest, dearest-held treasure. There is a certain irony in the consideration that they did so as a direct consequence of the triumphant expansion of their ancient trade in pottery into the new, predatory marketplace of Europe [7].

References