Industry and Ideas

Quintessential Blues for the Eighteenth Century

Indigo and Woad, Cobalt, Zaffer, and Smalt

Indigo and cobalt are both names for a color and a coloring source, each characteristically linked to a group of solid blue shades. Even modern references to highlight the close connection between object and coloring process—we speak of indigo textiles or cobalt ceramics, rather than an indigo-colored fabric or ceramics decorated with a cobalt glaze. These conventions almost certainly existed before the eighteenth century but the two substances, indigo and cobalt, hold an especially interesting place among colors and coloring materials during that time.

> 6. Indigo said by *Pliny* to be brought from *India:* a kind of Mud adhering to the Froath about Reeds, and that when tryed with a Coal, the true burns with a Purple-flame, and smells of the Sea: *Linschoten* says it is called *Anil*, that it grows in *Cambaia*, and is a plant like *Rosemary*, which is gathered and dryed, then wetted with fair Water, and beaten to a Mud: this operation being repeated it is dryed and fitted for use.
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> Richard Waller, "A Catalogue of Simple and Mixt Colours," *Philosophical Transactions* 16 (1688), 26.

Michel Pastoureau's recent history of the color blue in the West traces its shift from Roman associations of blue with barbarians through later religious-painting conventions that placed the Virgin Mary in blue and Jesus in red, or vice versa, and then to its status today as the color preferred by a majority of people.[1] Within this history, Pastoureau ascribes a special significance to the eighteenth century. He cites the development of the cobalt industry and the production of blue enamels and pigments, as well as the development of Prussian blue and Saxon blue —and other new sources, materials and techniques for blue colors—as critical events in this overall shift in the taste for and meaning of blue. This significance, together with the ongoing chemical investigations of sources for blue colors, deserves further consideration. In this section, I will consider two sources for this quintessential eighteenth-century color. Study of indigo and cobalt together shows complementary aspects of the relationship of each to both science and the arts. Such understanding was encouraged by governments, academies and improvement societies, and by individuals on behalf of the industries that used them. Efforts at improvement were addressed systematically with some success during the eighteenth century. I will describe their production methods and the processes they used as aspects of chemical understanding applied to natural history subjects and to color-dependent objects.

Indigo

As a color, indigo sits between blue and violet on Newton's color circle. It is darker than the first, less red than the second. As a coloring material, indigo is extracted from the leaves and stems of several families of plants native to Europe, Central and South America, Africa, India, Malaysia, and Japan. During the eighteenth century, indigo was known as a universal source of blue, but there were different varieties. Important sources were *Isatis tinctoria* (woad rather than indigo proper), native to northern Europe and Britain; *Indigofera tinctorium*, imported from India; and *Indigofera suffructicosa*, imported from the Americas. Contemporary authors agreed that the best-quality indigo, that which produced the best color, came from the Spanish West Indies and Central America.

Indigo and Woad

Indig

Weil der Indig nicht alle gut zum färben ist, so will nur bey dem bleiben, so vor uns brauchbar, derselbe heißt *Indigo Corfisau*, wenn man ihn von einander bricht, so siehet er schön kupfrich aus.

G., J. C. [Gülich], *Die rechte und wahrhafte Färbe-Kunst* 4th ed. (Langensalza, 1765), 9.

It is important to understand something of the differences between woad and indigo as, throughout the eighteenth century in Europe, their adoption and abandonment carried noteworthy social and technological connotations. Although similar, and similar in their color palette, the two are not identical. The woad plant contains less indigotin, the coloring material within the source, and it requires higher heats to create color in textiles. Indigo was a more efficient dyestuff, but woad was one native to Europe. As a result, we might expect to find regular resistance to the use of indigo as it began to replace woad in European dyehouses. Substitution patterns were different in every region, however. Woad production was waning throughout Britain by the late seventeenth century, due to changing agricultural patterns as well as the availability of this newer, better source. The decline continued so that later eighteenth- and nineteenth-century efforts to reintroduce woad were complicated by a lack of expertise in its culture and its use.[2] The historic significance of woad cultivation in France, especially in the region around Toulouse, is suggested by references to the *pays de cocagne* (land of plenty), *cocagne* referring to the forms in which pastel was most commonly shipped. French woad-growing traditions disappeared from that region more slowly. Still, late eighteenth-century calls for a return to mixing indigo with woad for blue and black dyeing suggest that, despite protective legislation, the use of the latter had been abandoned.[3] Combined with changes in textile manufacture, the loss of woad-growing and woad-using skills in France was such that, when blockades limited access to indigo in the early nineteenth century, the French government, rather than rely on reestablishment of traditional practices alone, searched for ways to improve the use of Prussian blue as a dyestuff.[4] The history of Saxon blue –in particular, the fact that its changes could be so quickly adapted in Germany—suggests that indigo was a familiar coloring material in dyehouses of that region before the mid-eighteenth century. In the Upper Lusatia

(Oberlausitz) region and in Thuringia, where blue-dyeing was also a specialty, woad cultivation was subject to cycles of activity and disuse that continued into the nineteenth century.[5] As in France, German dyers recommended incorporating woad into the indigo vat for a combination of practical and symbolic reasons. Eighteenth-century German-language manuals of textile practices describe the preparation of woad vats but often give more attention to indigo.[6] It is difficult to determine whether this attention is due to widespread familiarity or lack of use of either substance. In fact, German publications may only acknowledge studies undertaken in France and Britain as well as Germany and have less to do with daily practice.

Creation of Color from Woad or Indigo

Conversion of indigo or woad from coloring source to coloring material required considerable skill, but descriptions of the procedure were not very different from that for other dyestuffs. The initial work usually took place close to its growth site. The plant leaves, and occasionally stalks or stems, were collected, ground, and left to ferment in water. Several hours or days later—the timing depended on temperature, water quality and the variety of indigo plant—the water was stirred vigorously. This released the blue coloring particles, which could then be collected, dried, and sorted for shipment or later use.

Indigo was always exported in bulk, formed into hard dry bricks or balls. The best was between 70 and 90 percent indigo, with the balance being miscellaneous plant matter. The presentation of indigo in this form initially created some confusion in Europe about its classification, despite experience with woad.[7] Was indigo a mineral color or a vegetable color? References to "stone indigo" found in the eighteenth-century literature further suggest this confusion.

Indigo or Woad as a Dyestuff

Dyeing blue on linen

Take half a pound of indigo, and grind it well with a little lime water into an impalpable paste. Put it into 10 gallons of cold water, and add half a pound of Potash. 1 lb green copperas, 3 lbs quicklime. Let the whole stand till there forms on the surface a copper coloured head, and the liquor underneath appears yellow-green. Dip the linen in this liquor till it has acquired the shade of colour desired.

Josiah Wedgwood's Commonplace Book n.d., page 44 Wedgwood MS 39-28408.

Eighteenth-century manuals of practice often classify woad and indigo among direct dyes because they require no mordant or assistants, but their chemistry demanded a dyeing process different from typical direct methods.[8] Modern descriptions classify them as leuco dyes, in which the normally insoluble and nonadherent coloring material is made soluble by the removal of oxygen, a reduction process. The cloth is added to a pale white-green colored (leuco) solution. The blue color forms permanently on the cloth only after it is removed from the dye vat and exposed to oxygen in the air. Because it is first the absence of and then exposure to air that forms the color, deeper colors are more stable when formed from several dippings in the vat rather than from an extended single dyeing. Developing the color, and maintaining a vat over several days' or months' dyeing, as was common, was a specialist skill.[9] As a result, blue-dyers often worked only with woad or indigo, and merchants interested in compound colors that required blue would have to send their cloth, yarns, or fibers to more than one dyehouse.

Textile Printing with Indigo and Woad

Color formation with woad or indigo directly affected its use in textile printing, limiting the use of blue colors in those coloring practices. While the mordant techniques employed in the preparation of many textile colors could be adapted to the creation of multicolored patterns on cloth, and the addition of certain direct dyes further expanded the number of colors available to textile printers, these processes could not easily accommodate the methods indigo or woad required. The color oxidized before it reached the cloth and the result was not permanent. Blue colors, and certain greens and violets that relied on blue as a component, were sometimes added by hand later or do not appear at all on these multicolored eighteenth-century textiles.

Several changes to techniques for processing indigo simplified the addition of blue to multicolored printed or painted cloths to some degree. The first of these changes was the development of the copperas vat, used in England in the 1730s for solid coloring of cloths as well as the creation of resist patterns.[10] In this process, prepared indigo is added to a mixture of copperas (ferrous sulfate) with lime and potash. The reduction to the leuco phase proceeded without the addition of heat. This lowered the overall cost of dyeing, and made it possible to create resist-patterned prints with waxes that had a low melting point, and so were easier to remove. Another change appearing about the same time resulted from the discovery of a combination of materials that slowed the oxidation process enough to paint the indigo solution onto cloth. "Pencil blue" was made by heating finely ground indigo with orpiment and potash. The additives dissolved and reduced the indigo, forming a yellow solution that oxidized to blue. Indigo in this form had to be applied quickly, and so it was generally used to fill in small areas. A third change to the employment of indigo in the eighteenth century came with the introduction of the Saxon-blue vat. Here, again, new combinations of common chemicals altered the production possibilities, in this case shortening production time and creating slightly different color ranges.

It was at least as common, however, to create printed fabrics using resist patterning techniques: Indigo, because it required lower temperatures, was better suited to this process than woad. During much of the eighteenth century the blue-and-white patterned textiles that resulted were popular dress and furnishing fabrics, and a specialty of German dyehouses.[11]

Understanding and Improvement of Indigo Processes and Uses

Basic information about indigo and its processes was widely available to eighteenth- century European artisans and consumers. Nevertheless, it offered a number of mysteries to eighteenth-century scientific investigators and some notable experiments—including the ones I have just described—had a lasting impact on its use. Institutional encouragements played a part in those experiments, as well. Efforts to understand and improve indigo production and use led the Paris Academy of Sciences to sponsor an essay contest in 1777. A prize (1200 livres) was offered for the best description of the nature and use of indigo. The award was shared by the authors of two essays, one half given to Denis-Bernard Quatremère d'Iisjonval, the other to MM. Hecquet d'Orval and de Ribaucour; their work was published by the Academy along with a third essay, submitted by the Swedish chemist Torbern Bergman.[12]

Quatremère began his essay with the details of the culture of indigo, suggesting its problems—poor quality and high price—were due to the exhaustion of the soil and to problems with the indigo process. He attributed a third problem, the loss of color strength, to the practice of forming the partially prepared indigo into balls or stones; as part of his essay, he suggested a different method to store the coloring material.

Quatremère discussed the indigo dyeing processes for all fibers as well, offering the results of some microtests he had conducted. The indigo vat is subject to two significant problems, he found. The dyebath may easily become either over- or under-fermented, resulting in a useless vat or a poor result. To counter this problem, Quatremère recommended the addition of madder and bran (as fermenting agents) to the vat. He further suggested that, rather than risk using an over-fermented but partially exhausted dyebath, dyers could obtain a better light blue color by adding a smaller quantity of indigo.

The chemical examination of the indigo vat and the phenomena that produce good vats were the principal subjects of the essay by Hecquet d'Orval and de Ribaucour. They compared the characteristics of weight and solubility for different kinds of indigo and made nineteen experiments to test its nature in different solvents. They found that volatile alkali was the best solvent, creating the greatest quantity of coloring particles and the most-permanent color. They too discussed the major problems of the indigo vat and suggested remedies.

L'esprit-de-vin bien rectifié détache des parties résineuses	6
Du vinaigre distillé dissout la partie terreuse, mais n'attaque pas le fer, qui est ici en forme de chaux	22
L'acid marin emporte le fer calciné	13
[Total]	53

Les 47 parties restantes, après ces opérations, ne sont que des molécules bleues presque pures.

Torbern Bergman,"Analyse et Examine Chimique de l'Indigo," *Savants étrangers* 9 (1780), 148–9.

Bergman in his essay noted that indigo coloring processes, like all the arts, are dependent on both mechanical operations and on chemistry, however poorly the latter might be understood. He concentrated on experiments to determine the chemical composition of indigo and so better explain coloration. He suggested that the dyeing took place when the indigo was supercharged with phlogiston and he considered the irreversible color-change as the cloth was removed from the vat. How does phlogiston destroy the green color of indigo, as the cloth changes color from pale green to blue? In the first part of his investigation, Bergman determined the composition of indigo, finding that it is about 47 percent pure blue molecules. In the second part or his essay, Bergman considered the applications of his research; he described his studies of other techniques to dye blue through the combination of indigo with alkaline substances. These included a rapid technique for coloring linen or cotton involving orpiment (a highly phlogistic substance) dissolved in soapmakers' lye. This, as Bergman described it, creates liver of sulfur and arsenic from which the phlogiston can easily escape. (The odor on decomposition proves that this is true.) With precipitated indigo, the orpiment doesn't create changes, Bergman continued, because the union of phlogiston is too strong—you need the heat and the alkali to relax it.

Despite the obvious differences between coloring processes for indigo and those for other textile-coloring materials, the characteristics and behavior of indigo were also called on to support general conjectures about chemical combination. Louis-Guillaume de la Follie used the visual examples indigo provided to explain the use of salt in the coloration process. Salts control color, he claimed, because color changes occur when different salts (i.e., mordants) are used or when they are added in differing combinations. De la Follie theorized that mordants were unnecessary with indigo because the coloring material contained the necessary salts within it.[13] That this was true could be confirmed by the color changes observed in the preparation and in the dyeing process—the same green-blue shift that Bergman had explained—proved this. First, the plant itself is a yellowish green because it is full of alkaline salts, drawn from the earth. Denied access to that source at harvesting, the vegetable matter turns a blue color. For use as a coloring material, the indigo is placed into an alkaline solution, which again turns it green. Cloth steeped in the vat is also green until contact with the air, when it immediately becomes a good blue: Introduction of acids changes the direction of the pores in the fibers, allowing only the blue rays pass. Further study of this sequence, de la Follie sugested, might lead to discovery of indigo within other common plants. This conclusion, which may have been acceptable because of the many varieties of indigo available, was offered by other investigators, too. As a result, a number of other yellow and green plants, including carrots, might produce a good-enough indigo-like color.[14]

Indigo as a Pigment

Techniques to prepare indigo or woad for painting and (paper) printing were not as exacting as those involved in its use as a textile color: The coloring material could be finely ground in a liquid and used as a pigment. The earliest records of indigo refer to these uses alone; apparently neither woad nor indigo was a common textile color in the West until about the twelfth century. Water was the preferred vehicle, as oil darkened its already dark tones. Even so, indigo was often tempered with white, mixed into it or applied as a glaze, so that the color appeared brighter. Seventeenth- and eighteenth-century artists' manuals recommended pigment indigo to depict clothing and for shadows, relief and demi-tints.[15]

Of the Use of Indico

The use of the indico is for the dyers and laundresses, serving the last to put among their linen. The painters use it to grind with white, for painting in blue; for, if it is used alone and neat, it turns black; ground with yellow, it makes a green. Some confectioners and apothecaries very preposterously employ this to colour sugars and to make conserves with, and syrup of violets, by adding some orrice.

Malachy Postlthwayt, *Universal Dictionary of Trade and Commerce* (London, 1771), s.v. "Indico."

Indigo had an advantage over the metallic blues such as azurite in that it was not corrosive, but it was not always stable. A skillful painter could make shades of indigo blue that resembled azurite, but it was never considered an adequate substitute for the color range of ultramarine. And, as Prussian blue and cobalt blues became less expensive and easier to obtain, they assumed many of the prior common uses of indigo as a painters' pigment. After the middle of the eighteenth century, recommendations to use indigo were limited to "coarse painting," wallpapers, and proof copies or to other temporary situations where the relatively low price compensated for recognized problems. Indigo was also used to color paper and to "blue" fabrics, techniques to counteract the natural tendency of such vegetable fibers as linen and hemp to turn yellow. Prussian blue and cobalt ultimately took over these uses as well.[16]

Cobalt, Zaffer, Smalt

There are more similarities between the eighteenth-century use and investigations of indigo and those of cobalt than the superficial observations that both substances were used to create blue colors and that frequently designs and patterns were chosen to complement each other.[17] Like indigo, cobalt was both familiar and unknown. A presence in European color production for decades if not centuries, cobalt was subject to intensified scientific and technological investigations during the eighteenth century as researchers sought to understand both color and coloring agent.[18] Interest in indigo coincided with concerns about agriculture in general and, more specifically, with the possibilities and problems of colonial agriculture. Study of the nature of cobalt was a part of the general attention paid to the separation and identification of minerals and to the transfer of that information from the mining regions of Scandinavia and central Europe to England, France, the Americas, and elsewhere. Eighteenth-century investigations of cobalt as a coloring material, like the investigations of indigo as a coloring material, engaged chemistry in its most up-to-date forms.

Raw cobalt is a silvery gray or whitish color often resembling silver, compact and heavy, as Caspar Neumann described it.[19] John Hill noted other general characteristics of the "genus" cobalt: fine, brittle, not fusible. Initially considered a waste product in mining, it was identified as a semimetal by the Swedish chemist and metallurgist Georg Brandt in the 1730s. For about two centuries before that determination, cobalt was prepared in Europe, converted to zaffer to make blue-colored glass and blue enamel, and from zaffer to smalt for painting. It had been used for those purposes, brought from the Near East and Asia, even earlier, but regional production did not begin until early in the sixteenth century.[20]

> Lorsque l'alliage naturel d'arsenic et de cobalt effleurit ou se décompose, il en résulte ce qu'on nomme *fleurs de cobalt*, où le métal est uni à l'acide arsenique. La couleur est d'un rouge violet lie de vin, tirant sur celle de fleurs de pêche, lorsqu'elle est peu intense ; on le trouve quelquefois en aiguilles divergentes, partant d'une centre commun, et formant de jolies rosettes à la surface de la gangue.
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> Jean-Antoine Claude Chaptal "De Cobalt" *Chimie apliquée aux arts* (Paris, 1807), 2:259.

Cobalt was a difficult substance, physically damaging to workers because of the presence of arsenic, complicated and mysterious but obviously useful. Investigations undertaken by or during the eighteenth century located elemental cobalt in southern France, Cornwall, Scotland, and America, but in the eighteenth century cobalt mines and related industries remained closely identified with Scandinavia and Germany, where the richest sources were rumored to be located.[21] The center of the industry was, as it had been since the sixteenth century, Saxony, particularly the mining town of Schneeberg.

In contrast to production techniques for indigo, those for cobalt did not change much during the eighteenth century, while its geology and mineralogy did. As with so many substances, the differentiation of cobalt from other ores, and the subsequent studies of cobalt that were combined with the search for cobalt-bearing veins contributed more immediately to philosophical understanding than to artisan practices. When, at the end of the eighteenth century, August Fürchtgott Winckler, described the process of creating zaffer and smalt from cobalt ore, the steps he outlined were similar to those described by Antoine Fourcroy, Torbern Bergman, Carl Willem Scheele, Caspar Neumann, David Kreig, and earlier investigators who attempted to catalogue this procedure.[22] Nor is Winckler's description it far removed from that described by Birringuccio, or Georgius Agricola.[23]

Winckler described fourteen stages in the process of converting cobalt ore into blue colors. Clearly the most exacting parts of the process were its several roasting stages, because of the dangers associated not only with the extraction of cobalt from arsenic but, as in any other stage of vitreous colormaking, with the effort to achieve and maintain an appropriate degree of heat. According to Winckler's drawings, different kinds of ovens or furnaces were used for different purposes. Notable among these was one with a long horizontal chimney, which could trap the arsenic and other minerals as they sublimed.

Cobalt to Zaffer to Smalt

> Kobalt ein Halbmetall in der Erz und metallischen Gestalt, von weißgrauer, sonst aber von schwarzer oder Pfirsichblüthfarbe, welches mit Sand und Pottasche geschmolzen ein blau Glas . . . von Vitriolöl, Scheide- und Köingswasser aufgelöst aber eine rothe Tinktur giebt.
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> *Jacobssons Technologisches Wörterbuch* (Berlin, 1781): 2: 432.

Cobalt ore is mined as a heavy gray stone, mixed with other elements such as copper, nickel, bismuth and arsenic. In its still-raw state, the stones are washed, roasted, and sorted. They are then further broken up in a stamping mill. These steps, which took several days to complete, separated the cobalt from other elements; those substances and their subsequent processing was generally a task carried out along with cobalt refining. Once separated out, the purified cobalt was roasted and sorted again, and then calcined in a special oven; this would further purify the ore. Stamping and sifting was the next stage, before conversion into zaffer.

Zaffer, an oxide of cobalt, is the name given to the blue glass formed when cobalt is mixed with potash and sand, ground flints or other frits. The proportion of cobalt to frit had an effect on the color of the coloring material: more potash and sand (or soda and sand) would result in a more violet-tinted color. Once prepared, zaffer would be ground again, for use as a vitreous coloring material, in glazes and enamels.

Ground zaffer was also the basis of the painters' material smalt. Here, quality of the coloring material was determined by the degree of fineness to which the smalt was ground. The degree of fineness that could be achieved depended on a combination of characteristics, including the quality of the ore, the proportions of ore to flint and sand in the zaffer mixture, and the degree of fineness to which that mixture was ground before firing. The blue glass that resulted from the cleanest and finest combination could be ground to a correspondingly fine powder, which would be used as a painting pigment in fine-art applications. Less-fine smalt was acceptable for coarse painting or industrial purposes.

For eighteenth-century painters, the mineral origins suggested that smalt would be an especially stable color. This was true in general, but smalt was known to discolor in oil media unless used with small amounts of white lead and, like any coloring material, if poorly made or inexpertly used, it lost color over time. Later, in the early nineteenth century, Louis-Jacques Thénard (in France) and Josef Leithner (in Vienna) used cobalt as the basis for a considerably less expensive substitute for ultramarine pigment; Leithner's blue was also adapted to porcelain manufacture.[24]

It may be coincidence that Saxony was the region that produced new and desirable blues (and the compound colors based on them) for textiles, painting and ceramics. Still, the diffusion of cobalt production techniques, and the indigo process known as Saxon blue, the rapid movement and acceptance of both outside of eastern German regions. The widespread interest in understanding and imitating their color production processes demonstrates the significance of inspiration from other regions, and especially the significance of inspiration transferred through color on specific objects.

Notes:

Note 1: Michel Pastoureau, *Bleu, histoire d'une couleur* (Paris, 2000).

Note 2: Yorkshire Woad Company, Articles of Agreement and Miscellaneous Papers (1800), John Goodchild Collection, Wakefield Library Service, Textile mss., AT/D/8; Jno Olive, in Frome, to John Wheedon, in Taunton, 16 December 1802, Somerset Record Office, DD/SAS/c909 32; J. H. Bettey, "The Cultivation of Woad in the Salisbury Area During the Late Sixteenth Century and Seventeenth Century," *Textile History* 9 (1978): 112–17; Gilly Carr, "Woad, Tattooing, and the Archaeology of Rebellion in Britain," *Dyes in History and Archaeology* 18 (2002): 1–12; N. T. Wills, "Woad Growing and Manufacture in the Lincolnshire and Cambridgeshire Fens and in Northamptonshire," *Dyes in History and Archaeology* 11 (1992): 6–9; Maison Nicéphore Niepce, "Woad," at www.niepce.com/pagus/pastelus1.html (accessed 9 January 2005).

Note 3: Rapport sur l'indigo par M. Champeax, 9 May 1788, AdS *pochette*; Centre de la Vieille Charité, *Sublime indigo:* Ouvrage *réalisé à l'occasion de l'exposition Sublime indigo, . . . 22 mars–31 mai 1987* (Marseille, 1987).

Note 4: Agustí Nieto-Galan, *Colouring Textiles: A History of Natural Dyestuffs in Industrial Europe* (Dordrecht, Netherlands, 2001), 17–19.

Note 5: Rudolf Forberger, *Die Manufaktur in Sachsen vom Ende des 16. bis zum Anfang des 19. Jahrhunderts* (Berlin, 1958), 76–120; Christoph Schümann, *Der Anteil deutscher Apotheker and der Entwicklung der technischen Chemie zwischen 1750 und 1850*

(Frankfurt, 1997), 214–24.

Note 6: J. C. G., *Die rechte und wahrhafte Färbe-Kunst* (Erfurt, 1751); Carl Wilhelm Pörner, *Chymische Versuch und Bermmerkungen zum Nutzen der Färbekunst* (Leipzig, 1772).

Note 7: Gosta Sandberg, *Indigo Textiles: Technique and History* (London, 1989); Anne Matson, "Indigo in the Modern World," Trade Products in Early Modern History, at www.bell.lib.umn.edu/Products/Indigo.html (accessed 15 January 2005).

Note 8: Robin J. H. Clark, and others, "Indigo, Woad, and Tyrian Purple: Important Vat Dyes from Antiquity to the Present," *Endeavour*, n.s., 17, no. 4 (1993): 191–99; Helmut Schweppe, "Indigoide Farbstoffe," in *Handbuch der Naturfarbstoffe: Vorkommen, Verwendung, Nachweis* (Landsberg / Lech, Germany, 1992), 282–18.

Note 9: Georg Stark, "Indigo and the 40 Robbers: Romantic Transfiguration of the Blue-Printer's Trade in Modern Society," *Dyes in History and Archaeology* 16 / 17 (2001): 82–86.

Note 10: H. Cassebaum, "Der Ursprung der Indigofärberei," pt. 1, "Das Aufkommen der Orpermentküpe im 17. und 18. Jahrhundert," *Melliand Textilberichte* 46, no. 3 (1965): 289–91; H. Cassebaum, "Der Ursprung der Indigofärberei," pt. 5, "Vitriolküpe und Zeugdruck," *Melliand Textilberichte* 47, no. 3 (1966): 295–97.

Note 11: Christine Bell, "Die Geschichte des Blaudrucks," in *Ein Blaues Wunder: Blaudruck in Europa und Japan*, ed. Hartmut Valravens (Berlin, 1993), 53–68; Christine Bell, "Technik Des Blaudrucks in Europa," in *Ein Blaues Wunder: Blaudruck in Europa und Japan*, ed. Hartmut Valravens (Berlin, 1993), 69–76; Christine Bell, "Verzeichnis der Blaudrucker in Europa," in *Ein Blaues Wunder: Blaudruck in Europa und Japan*, ed. Hartmut Valravens (Berlin, 1993), 173–80; P. C. Floud, "English Contribution to the Early History of Indigo Printing," *Journal of the Society of Dyers and Colourists* 76 (June 1960): 344–49; Dena Katzenberg, *Blue Traditions: Indigo Dyed Textiles and Related Cobalt Glazed Ceramics from the Seventeenth through the Nineteenth Century* (Baltimore, 1973); Florence M. Montgomery, *Printed Textiles: English and American Cottons and Linens, 1700–1850* (New York, 1970).

Note 12: Torbern Bergman, "Analyse et Examine Chimique de l'Indigo, Tel qu'il Est Dans le Commerce Pour l'Usage de la Teinture. Piece qui a Concouru Pour le Prix sur la Nature & l'Usage de l'Indigo," *Mémoires de mathématique et de physique, présentés à l'Académie royale des Sciences, par divers sçavans, et lûs dans ses assembles* [*Savants étrangers*] 9 (1780): 121–64; Hecquet d'Orval and Ribaucour, *Savants étrangers* 9 (1780): 81–120; Denis-Bernard Quatremère-Disjonval, "Analyse et examine chimique de l'indigo, tel qu'il est dans le commerce pour l'usage de la teinture," *Savants étrangers* 9 (1780): 1–80.

Note 13: Louis-Guillaume de la Follie, "Réflexions sur la Théorie de la Teinture, Suivies d'Expériences Utiles Pour les Manufactures," *Observations sur la physique sur l'histoire naturelle et les arts* 12, pt. 1 (January 1778): 66–78.

Note 14: "The Manufacturing and Preparation of a New Vegetable Preparation Applicable to Dyeing Blues and Other Colours," English Patent no. 7660 issued to George Nussey (31 May 1838); and John Graham, "On the History of Invention as Applied to the Dyeing and Printing of Fabrics: Part 1st, Chemistry," *Proceedings of the Manchester Literary and Philosophical Society*, 3d ser., 1 (1857–60): 216–18.

Note 15: [C.B.], *Traité de peinture en mignature* (The Hague, 1708).

Note 16: . "A Process to Make Indigo Blue and Prussian Blue Appropriate for Whitening Cloths Etc.," French Patent No. 922 issued to George Steigen Berger (1 September 1814); "Dyeing Green and Blue Saxon Colours," English Patent no. 635 issued to George Spence, Charles Dolby and John Christopher Weguelin (8 August 1748); "An Entire New Method of Manufacturing Paper for Hanging and Ornamenting of Rooms, and Other Purposes, and That the Same Will Be of Greate Use and Benefit to the Publick," English Patent no.685 issued to Edward Deighton (2 September 1753); "Liquid Blue, Which by Experience had been Found to be Greatly Preferable to Other Blews in Blewing of Linnens Cottons, etc.," English Patent 694 issued to Robert Maw and Thomas Bishop (26 November1754); "A Method of Dying Paper, Card Paper, and White Leather on the Grain

Side, of Verious Colours, Different in Quality, Superior in Many Respects to Any Hitherto Used for Those Purposes," English Patent no. 951 issued to Charles Fearne and James Gray (25 January 1770); "An Improved Method for Preparing Indigo for Dyeing Wool, Silk, Linen, Cotton, and Goods Made from Linen," English Patent no. 2176 issued to Joseph Barton (25 March 1797); "Purifying Refining and Preparing Indigo for the Use of Dyers," English Patent no. 2259 issued to William Birch and Richard Comyns Birch (11 August 1798). See also Françoise Viatte, "Lavis d'Indigo et Papiers Bleus," in *Sublime Indigo*, 75–78

Note 17: Katzenberg, *Blue Traditions.*

Note 18: De Gensanne, "Sur l'Exploitation des Mines d'Alsace et Comté de Bourgogne," *Savants étrangers* 4 (1763): 141–82; Saur, "Mémoire sur un Minéral Nommé Cobalt, ou Mine Arsénicale que l'on Trouve en France," *Savants étrangers* 1 (1750): 329–44. Philippe-Frédéric Dietrich, baron de Holbach, *Description des gîtes de minerai, des forges et des salines des Pyrénées, suivie d'observations sur le fer mazé et sur les mines des Sards en Poitou*, (Paris, 1786).

Note 19: Caspar Neumann, *The Chemical Works of Caspar Neumann, . . . Abridged and Methodized: With Large Additions, Containing the Later Discoveries and Improvements Made in Chemistry . . . by William Lewis, . . .* (London, 1759), Gale Group, Eighteenth Century Collections Online, at http://galenet.galegroup.com/servlet/ECCO (accessed 7 March 2004). See also *Kirk-Othmer Concise Encyclopedia of Chemical Technology* (New York, 1985), s.v. "Cobalt and Cobalt Alloys."

Note 20: Bruno Mühlethaler and Jean Thissen, "Smalt," in *Artists' Pigments: A Handbook of Their History and Characteristics*, ed. Robert L. Feller, vol. 2, ed. Ashok Roy (Washington, D.C., 1993), 114.

Note 21: Francis Beauchamp to the Society of Arts, 2 January 1755, [R]SA PR.GE/110/1/10, 6 June 1755, [R]SA PR.GE/110/1/27, and 23 June 1755, [R]SA PR.GE/110/1/28; Nicholas Crisp, 14 April 1755, [R]SA PR.GE/110/1/20; Dr. Linden to Dr. Hales, 25 February 1756, [R]SA PR.GE/110/2/107; "Notes on cobalt, zaffer and smalt," 1756, [R]SA PR.GE/110/2/97; Samuel More's statement about experiments made on British cobalt, 11 February 1756, [R]SA PR.GE/110/16/106; J Peat, 24 August 1756, [R]SA PR.GE/110/5/21; J Peat, 18 September 1756, [R]SA PR.GE/110/5/28; Paper by Henry Baker on premiums for cobalt, madder, buff leather, tinning vessels and drawings, 1 December 1756, [R]SA PR.GE/110/5/58; Letter of Emanuel Mendes da Costa regarding cobalt and other minerals, 1756, [R]SA PR.GE/110/5/72; J Peat to the Chemistry Committee, 3 November 1762, [R]SA PR.GE/110/13/38; Experiments on cobalt ore, 16 February 1764, [R]SA PR.GE/110/15/28. This is partial list; further information can be accessed through the RSA Archive Catalogue, at www.rsa.org.uk/archive/archiveSearch.asp. See also "Pieces relatif à la gratification annuel de 2000 # et puis 2400 # à l'comte de Beust, Chamberlain de l' Elector of Saxony entitulé pour la encouragemen d'établir une manufacture des couleurs bleues ou azures faits de cobalt qu'il formée en Bagnières, 1786–1791, AN F/12/1507/V/4. Stefan Jacob, *Chemische Vor-und Frühindustrie in Franken die vorindustrielle Produktion wichtiger chemikalien und die Anfänge der chemischen Industrie in fränkischen territorien des 17., 18. und frühen 19. Jahrhunderts* (Düsseldorf, 1968); Schümann, *Der Anteil deutscher Apotheker*.

Note 22: Alfred Lange, *Das sächsische Blaufarbenwesen um 1790 in Bildern*, (Berlin, 1959), 26; David Kreig, "VIII. Part of a Letter from Dr. David Krieg, F. R. S., to the Publisher, Concerning Cobalt, and the Preparations of Smalt and Arsenic," *Philosophical Transactions* No. 293 (1737): 1753–56; Torbern Bergman, "Of Metals," *An Essay on the Usefulness of Chemistry, and its Application to the Various Occasions of Life* (London, 1783), 117–8; Neumann, *The Chemical Works of Caspar Neumann,* 148–52.

Note 23: Georg Agricola, *Georgius Agricola: De Re Metallica* [1556] . . ., tr. Herbert Clark Hoover and Lou Henry Hoover, (1912; reprint, New York, 1950), 112–13, 353–55, 542. Vannuccio Birringuccio's *De la pirotechnica* (1540) is cited in this work (p. 112, note 8).

Note 24: R. D. Harley, *Artists' Pigments c. 1600–1835: A Study in Documentary Sources*, 2d ed. (London, 1982), 56–7; Ralph Mayer, *The Artist's Handbook of Materials and Techniques* rev. ed. (New York, 1957), 56, 88.