THE EARLY HISTORY OF GEMSTONE TREATMENTS

By Kurt Nassau

This article examines the origins of gemstone treatment. Using such primary sources as Pliny's History *and the relatively unknown* Stockholm Papyrus, *the author has uncovered many ancient references to, and even recipes for, the simulation or enhancement of gemstones. Among the processes described are crackling and dyeing quartz, foilbacking, the making of doublets and triplets, boiling amber in oil, and heat treating sapphire to simulate diamond. Although some of the ingredients, such as goat's blood and leek juice, have been replaced by less exotic elements, it is interesting to note that through their crude experimentation, the ancient forerunners of modern science discovered basic methods and principles of gemstone treatment that are still in use today.*

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Acknowledgments: The author is grateful to Dr. John Sinkankas for access to his superb library, and to A. Hanson for helpful advice on the translation from Greek of P. Holm. *Bob Kane was instrumental in gathering many of the photographs.*

This article is based in part on chapter 2 of the author's book Gemstone Enhancement, *which is being published by Butterworths, London, in July 1984.*

Evidence for the use of gemstone treatments points back many thousands of years: heated carnelian, for example, was found in Tutankhamen's tomb—dating to at least 1300 B.C. Even the written accounts of treatments extend back almost 2,000 years. Yet surprisingly little has been published on some of these earlier accounts, especially the "recipes" from which the earliest gemological chemists worked, although many of these recipes are virtually duplicated by techniques in use today.

As part of my research into all aspects of gem treatment, I have studied, and in some cases updated translations of, many of these early references to gem treatment. The realization that so many treatment practices—crackling and dyeing quartz, foilbacking, oiling of emeralds, among others—were acknowledged and even recorded in detail by ancient chemists and historians is both fascinating and highly relevant in this decade when treatment has become a major focal point of gemology.

This article looks into these early documents, especially those that stand out as landmarks in the development of this most ancient practice. Following detailed examinations of Pliny's *History* and the almost totally neglected *Stockholm Papyrus* (*P. Holm.*), I will concentrate on a number of relevant books, only occasionally using secondary sources and references from other fields to highlight specific points. The period covered extends from the first century A.D., which produced the earliest known writings on this topic, to the mid-17th century, coinciding with the publication of the first work on gems written by an experimental scientist.

FIRST CENTURY A.D.: PLINY

As in so many areas of historical interest, the earliest primary source is C. Plinius Secundus (born 23 A.D. and died 79 A.D., during the eruption of Mt. Vesuvius), the busy compiler of all that was known in his time. His

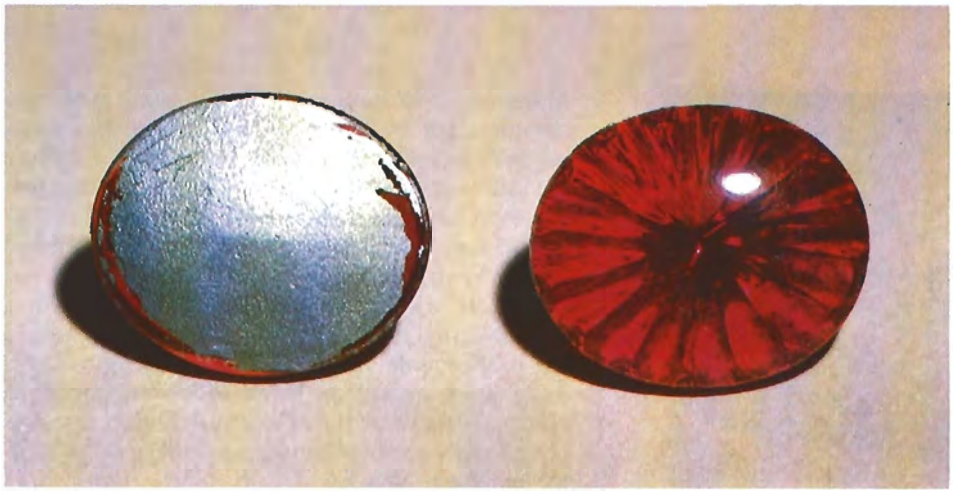


Figure 1. Today, foilbacking of rubies is still practiced, although more commonly (as illustrated here) a special foil paint is used on synthetic ruby to provide greater brilliance. Photo by Tino Hammid.

account of contemporary knowledge, published in 37 books, was based on notes that he professed to have made while reading more than 2,000 books. Some of these books dealt with gemstone alterations:

> I have in my library certain books by authors now living, whom I would under no circumstances name, wherein there are descriptions as to how to give the color of *smaragdus* [emerald, in part] to *crystallus* [rock crystal] and how to imitate other transparent gems: for example, how to make *sardonychus* [sardonyx] from a *sarda* [carnelian, in part sard]: in a word, to transform one stone into another. To tell the truth, there is no fraud or deceit in the world which yields greater gain and profit than that of counterfeiting gems. (Pliny, Book 37, Chap. 75; from Ball, 1950, p. 195[1])

Pliny discusses many gemstone-enhancement techniques that are still in use today, almost 2,000 years later, including foils, oiling, dyeing, and composite stones. The use of shiny metal foils to make stones appear more brilliant (figure 1) or to modify their color goes back at least to Minoan times (2000–1600 B.C.), according to Ball (1950). Pliny mentions their use on "*carbunculi* [red stones, including garnet, ruby, etc.] . . . for the exercise of cunning, when craftsmen force the opaque stones to become translucent by placing foil beneath them" (Vol. 10, p. 243); on "*sard* [carnelian, in part sard]. . . . that is backed with silver foil" (Vol. 10, pp. 249, 251); and with "*hyacinthus* [sapphire] and *chrysolithus* [topaz]" of quality less than the best, which "are backed with brass foil" (Vol. 10, pp. 267, 269).

Vinegar is used to make dull stones shiny (Vol. 10, p. 243), and "*smaragdi* [emeralds in part] . . . in spite of their varied colours, seem to be green by nature, since they may be improved by being steeped in oil" (Vol. 10, pp. 219, 221). One may assume that this refers to white or brown-appearing badly cracked stones which become an improved green on oiling, as is still done today. He also reported the well-known behavior of "*callaina* [turquoise]. . . . The finer specimens lose their colour if they are touched by oil, unguents or even undiluted wine" (Vol. 10, p. 255). In addition, amber "is dressed by being boiled in the fat of a suckling pig" (Vol. 10, p. 199); this is undoubtedly the clarification process rediscovered so much later (figure 2).

Dyeing and staining were widely used in ancient times as they are today. Even pigments made from ground-up malachite and azurite were thus improved: "*Armenian* [azurite] is a mineral that is dyed like malachite . . . " (Vol. 9, p. 297). Then there was: "the green called *Appian*, which counterfeits malachite; just as if there were too few spurious varieties of it already!" (Vol. 9, p. 297). This complaint is still being made today of new

[1] *All notes in brackets within quotations are additions I have given for clarification. Several original spellings have been preserved to retain the flavor of the original account.*

In this quotation, the gemstone identifications are based on those given by Ball (1950). Apart from this elegant passage taken from the rather archaic 1601 translation by Philemon Holland which Ball used, and passing over the frequently used 1898 Bostock and Riley translation, we will hereafter cite only the modern Harvard University translation, begun by Rackham (Vols. 1–5 and 9, 1938–1952), continued by Jones (Vols. 6–8, 1951–1963), and completed by Eichholz (Vol. 10, 1962). They had access to more source manuscripts as well as to more sophisticated scholarship than previous translators, including the guidance of Ball's volume in gemological matters.

Figure 2. Stress fractures are common by-products when amber is heated in some form of oil, a practice reported by Pliny in the first century A.D. In modern times, this is done purposely to produce the brightly spangled amber shown here. Photo by Shane McClure.

imitations as well as of gemstone names. In addition: "it ought to be generally known that *amber* can be tinted, as desired, with kid-suet and the root of *alkanet* [a natural dye]. Indeed it is now stained even with purple dye [Tyrian purple]. . . . *Amber* plays an important part also in the making of artificial transparent gems, particularly artificial amethyst, although, as I have mentioned, it can be dyed any colour" (Vol. 10, pp. 201, 203).

The sugar-acid process for dyeing agates and other porous stones is apparently reported by Pliny (Vol. 10, p. 323), although the description has not always been accepted as such:

> Moreover, *Cochlides* or *shell stones* are now very common, but are really artificial rather than natural. In Arabia they are found as huge lumps and these are said to be boiled in honey without interruption for seven days and nights. Thus all earthy and other impurities are eliminated; and the lump, cleaned and purified, is divided into various shapes by clever craftsmen, who are careful to follow up the veins and elongated markings in such a way as to ensure the readiest sale. . . . In general, all gems are rendered more colorful by being boiled thoroughly in honey, particularly if it is Corsican honey, *which is unsuitable for any other purpose owing to its acidity* (emphasis added).

Ball (1950) interpreted *cochlides* as being shell ornaments, but the "huge lumps" argues against this interpretation. Eichholz (1962, p. 323) more reasonably interprets these as large, inferior agates, boiled in acidic honey in order to bring out their color. Consider, now, the possibility of the use of an unmentioned final, slightly higher temperature heating step and one obtains something not too different from the modern sugar and heating or sugar-acid processes (figure 3). Also note that Pliny's description of how the patterns of "veins and elongated markings" are carefully followed, which is as true of clever craftsmen working with chalcedony and related materials today as it was almost two thousand years ago. This description could hardly apply to material derived from sea shells.

Finally, there is this passage on the making of triplets (figure 4):

Figure 3. This slab illustrates some of the many colors in which agate is dyed in Idar-Oberstein today. The brown section is typical of the color produced by the sugar-acid method Pliny describes. Photo courtesy of J. S. White, Smithsonian Institution.

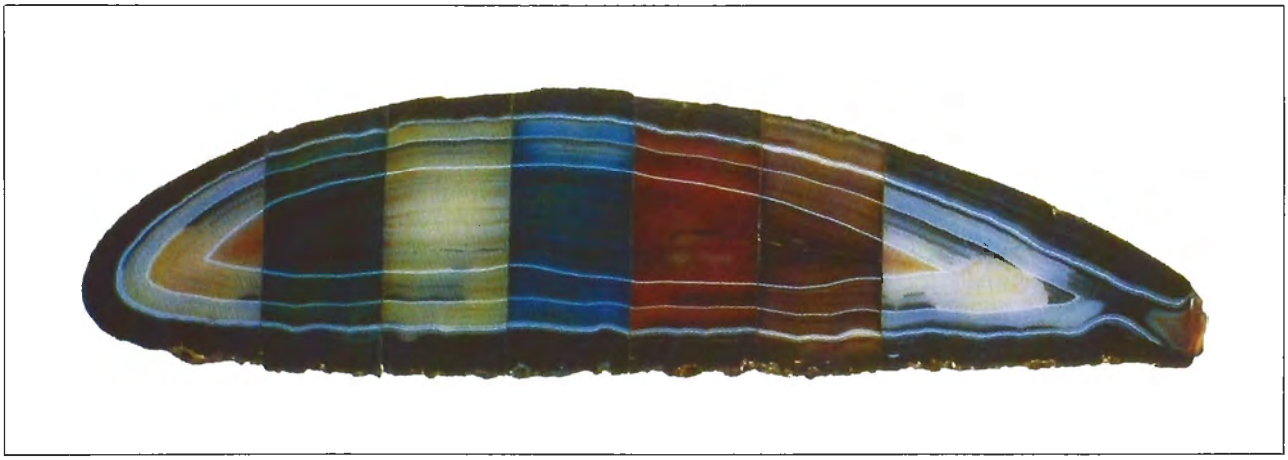


Figure 4. The piece on the right is an interesting adaptation of the technique described by Pliny: a "three-layer" cameo has been manufactured by gluing a white material to a reddish brown material and then painting the top figure in the white material black. The result is a convincing imitation of the natural, unassembled cameo on the left. The imitation piece measures 16.17 × 12.12 × 5.64 mm; the natural, 19.79 × 15.02 × 7.38 mm. Photo by Shane McClure.

> Men have discovered how to make genuine stones of one variety into false stones of another. For example, a *sardonyx* can be manufactured so convincingly by sticking three gems together that the artifice cannot be detected: a black stone is taken from one species, a white from another, and a vermillion-coloured stone from a third, all being excellent in their own way. (Vol. 10, p. 325)

Ball (1950) cites the report by the Chinese ambassador to Antioch, the capital of Roman Syria, in 97 A.D.: "The articles made of rare precious stones produced in this country are sham curiosities and mostly not genuine. . ." (p. 81). The poet Martial, of about the same era, mentions *real* sardonyx, implying the existence of the false. Pliny also describes the use of glass to imitate valuable gemstones (figure 5). When one considers that almost nothing was known in Pliny's day about gemological testing, other than perhaps a very crude estimation of hardness, it is surprising that there were any authentic gemstones at all noticeable among the many fakes.

About 300 A.D. Emperor Diocletian became so outraged by alchemy and related activities (such as the alteration and imitation of gemstones) that he ordered all books on these subjects to be burned (Ball, 1950). It is doubtful that this edict had much effect on such activities, although it may account for the relative scarcity of surviving documents on the subject.

For the reader interested in placing these activities into the framework of the science and technology of the period, Thorndike's (1923–1958) *History of Magic and Experimental Science* (extending from Pliny through the end of the 17th century), the Oxford *History of Technology* (Singer et al., 1954–1978), and F. S. Taylor's *The Alchemists* (1936) are detailed studies that can be recommended.

Figure 5. Glass has been used as a substitute for emerald and other fine gemstones since at least the days of ancient Rome, as mentioned by Pliny and illustrated by the earrings (third century A.D.) shown here. Photo courtesy of B. Zucker Precious Stones.

FOURTH TO FIFTH CENTURIES: THE STOCKHOLM PAPYRUS

In 1832 the Swedish Academy received a metal box containing 14 numbered papyrus sheets plus an unrelated fragment, all covered with early Greek handwriting. The gift came from Johann d'Anastasy, the Swedish-Norwegian Vice-Consul in Alexandria, Egypt, and an inveterate collector of early Egyptian documents. The 14 sheets had originally been a codex, a handwritten "book" consisting of seven folded sheets which had later been cut in half. These documents were subsequently examined by Otto Lagercrantz, who published the text with a German translation and commentary in 1913. Lagercrantz named it the *Papyrus Graecus Holmiensis*, abbreviated *P. Holm.*, and gave it the subtitle "Recipes for Silver, Stones and Purple." This papyrus is also known as the *Stockholm Papyrus*, under which title it was translated into English in 1927 by Caley. Neither Lagercrantz, a classicist, nor Caley, a chemist, was aware of the implications to gemology of this fascinating text.

From a variety of circumstances, Lagercrantz deduced that this papyrus was a copy made by a scribe about 400 A.D. in Greek-speaking Egypt. It was probably made for the purpose of accompanying the remains of a "chemist" in his mummy case, where it survived some 15 centuries in excellent condition. In all probability it was a copy of his laboratory working notes, no doubt in turn taken from an older document.

The small fragment contains a short magical incantation of no obvious meaning. The 14-page main text consists of three parts. The first part deals with metals and gives nine recipes for making copper look like silver, extending silver to double its quantity, and the like. The last part contains 70 recipes for the dyeing of wool and other substances, with emphasis on imitating the costly Tyrian purple dye.

The middle, and longest, section contains 73 recipes which deal with the falsification of pearls and gemstones; it represents the oldest extended recipe collection dealing with gems. Several examples from this virtually inaccessible text are cited here. There is in these recipes no attempt to duplicate anything but the color—or lack of it—of the desired gemstone. The counterfeiting is sometimes very simplistic, as in this recipe:

Bleaching Crystals

> Dissolve rice in water, put the crystal in, and together with it, boil again the solution (Caley, 1927, no. 56; Lagercrantz, 1913, pp. 187–188).[2]

Ten of the recipes deal with improving pearls or imitating them; for example:

Cleaning a Pearl

> When a real pearl becomes dull and dirty from use, the natives of India are accustomed to clean it in the following way. They give the pearl to a rooster to eat in the evening. In the morning they search the droppings and verify that the pearl has become clean in the crop of the bird; and moreover, has acquired a whiteness which is not inferior to the original.

Another Recipe

> Quick lime, when it is not yet slaked in water, after having been burnt in the oven, carries hidden within it the fire; this is slaked with the milk of a dog, but that from a white bitch. Knead the lime and coat it in layers on the pearl and leave it there one day. After stripping off the lime, observe that the pearl has become white." (Caley, 1927, nos. 60 and 61; Lagercrantz, 1913, p. 189)

The first of these recipes presumably relied on the acidic digestive juices of the rooster to remove a thin layer of pearl; in another version (Caley, 1927,

[2]*All quotations from* P. Holm. *are the author's based on the English translation by Caley (1927), using his recipe numbering, and on the German translation by Lagercrantz (1913), giving his pages, as well as on the Greek version given by Lagercrantz. A full translation and a detailed interpretation are being prepared for publication.*

Figure 6. These two pieces of quartz have been heated and then dyed to imitate emerald (1.77) and ruby (0.91 ct). The crackling of quartz and similar stones is one of the oldest gem treatment processes practiced by man.

no. 25; Lagercrantz, 1913, p. 172), the cock is cut open directly after feeding him the pearl. Some version of this technique reappears every few centuries, still frequently attributed to India.

With regard to the dyeing of gemstones, two separate steps are involved; these steps frequently appear as separate recipes, although they are sometimes combined. First the stone, usually crystal (i.e., rock crystal or quartz), has to be made receptive to the color. Four different Greek words are used for this preparatory step: *stufis,* which means "mordanting,"[3] but which could also mean corroding or etching (used 23 times in 14 recipes connected with stones); *araiosis,* which means "softening," "loosening up," or "opening up" (used 6 times in 5 recipes); and *malaksis* (used 4 times in 2 recipes) and *liosis* (used once) which both mean "softening." A detailed examination of the recipes indicates that all of these terms probably referred to the same process, namely cracking of the heated quartz or other stone as the first step so that the dye used in the second step could then penetrate into the cracks to produce the change in color—a practice still common in the 20th century (figure 6). Mention of the heating itself is often omitted, as might be expected for something so self-evident to an expert practitioner; indeed, many of the recipes are abbreviated as in the following extreme, where three recipes are telescoped into one with only the essential ingredients given:

Another [Recipe for the Preparation of Green Stones]

Verdigris and vinegar, verdigris and oil, verdigris and calve's bile; these form emerald." (Caley, 1927, no. 21; Lagercrantz, 1913, p. 170)

Sometimes the crystal is first cleaned before the preparation step:

Cleaning of Crystal

Cleaning of smoky crystal. Put it into a willow basket, place the basket into the cauldron of the [public] baths and leave the crystal there seven days. Then, when it is clean, take and mix warm lime with vinegar. Place the stone in this and let it be mordanted. Finally: color it as you wish. (Caley, 1927, no. 16; Lagercrantz, 1913, p. 164)

In the next two recipes, the only piece of information missing is the exact temperature the stones should be when they contact the liquid so they will crack nicely without falling apart:

Another [Recipe for Mordanting and Opening up Stones]

Put the stones into a bowl, put on it another bowl as a lid, seal the joint with clay, and let the stones be roasted under supervision for a while. Then by degrees remove the lid and pour vinegar and alum on the stones. After this, color the stones with whatever dye you desire. (Caley, 1927, no. 54; Lagercrantz, 1913, p. 186)

Softening Crystal

To soften crystal take goat's blood and dip into this the crystal which you have first heated over a gentle fire, until it is to your liking. (Caley, 1927, no. 36; Lagercrantz, 1913, p. 179)

[3]*This designation also occurs widely in the wool-dyeing section of the papyrus (e.g., Caley, 1927, no. 135; Lagercrantz, 1913, p. 226). The process there described is essentially the same as that used in modern mordant dyeing, whereby an aluminum salt is precipitated on the fiber and a dye is then attached to this precipitate, as one example.*

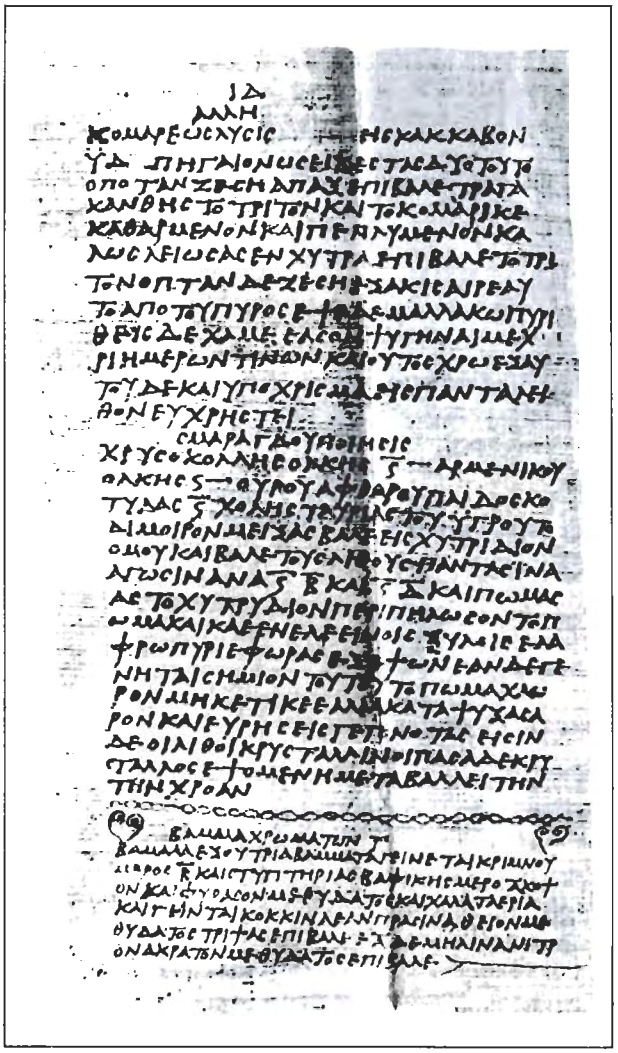


Figure 7. A page from Papyrus Graecus Holmiensis, *written about 400 A.D., the first manuscript to provide detailed gemstone treatment recipes.*

In this recipe is almost certainly found the origin of the curious fable that stones in general and diamonds specifically can be softened with goat's blood. Apparently the intent of the original process was merely to "loosen" or "soften" the stones by cracking them for dye penetration.

The two processes, preparation and dyeing, are sometimes combined into one:

Mordanting for Stones

Let the stone stand for 30 days in putrid urine and alum. Remove the stones and insert them into soft figs or dates. These should now be treated on the coals. Blow therefore with the bellows, till the figs or the dates burn and become charred. Then seize the stone, not with the hand but with tongs, and while it is still warm place it directly into the dye bath and let it cool there. Use as many stones as you wish, however not more than 2 drachmas [each in weight]. The dye, however, should be as thick as paste. (Caley, 1927, no. 29; Lagercrantz, 1913, p. 173)

Note particularly that the stone is so hot that it cannot be picked up by hand.

A wide variety of substances are used to provide the coloration itself. Some are based on copper and other metal salts, at times combined with the bile fluid from tortoises or cattle. The following recipe is the center one of the three on the back of papyrus sheet seven, which is reproduced in figure 7.

Preparation of Emerald

Mix together in a small jar 1/2 drachma of copper green [verdigris], 1/2 drachma of Armenian blue [chrysocolla], 1/2 cup of the urine of an uncorrupted youth, and 2/3 the fluid of a steer's gall. Put into this the stones, about 24 pieces weighing 1/2 obolus each. Put the lid on the jar, seal the lid all around with clay, and heat for 6 hours over a gentle fire made of olive-wood. When there is this sign, that the lid has turned green, then heat no more, but let it cool and remove the stones. You will find that they have become emeralds. The stones are [originally] of crystal. . . . (Caley, 1927, no. 83; Lagercrantz, 1913, pp. 199–200)

Other colorants are based on biological substances such as alkanet red, archille, bile, cochineal, "dragon's blood," heliotrope juice, indigo, leek juice, mulberry juice, and pigeon's blood. In some instances, the coloring matter is added in an oily form. Following are two of these oil impregnations, one based on a copper salt and the other on leek juice:

Another [Recipe for Preparation of Emerald]

Grind scraped-off verdigris and soak it in oil one day and one night. Cook the stones in this over a gentle flame as long as desired. (Caley, 1927, no. 77; Lagercrantz, 1913, p. 196)

Softening of Emerald

Put hard emerald into wax for 14 days. After this time grate garlic and make a cake out of it. Take out the stone and place it into the garlic cake for 7 days. Take leeks and squeeze out the juice. Mix with the leek juice an equal amount of oil, put this into

a new pot, add the stones, and boil for 3 days, until they are to your liking. The stones should be in a basket, so that they do not touch the bottom of the pot. (Caley, 1927, no. 37; Lagercrantz, 1913, p. 179)

Note that there are no instructions to take the stone out of the cake. Once again, one suspects that the garlic cakes are baked or rather charred, just as are the figs or dates in the recipe given above, and that the stones are hot when they are dropped into the oily green leek juice to become cracked and absorb the green color at the same time.

The oily substances used are balsam sap, Canada balsam, cedar oil, liquid pitch, resin, and wax. Oiling with colored oil is still being practiced today by processes not too different from the following:

Cooking of Stones

If you wish to make ruby from Crystal, which has been prepared for this purpose at your pleasure [i.e., precracked], then take and place it in a *kerotakis* [a vessel usually used for melting wax with pigments] and stir in turpentine balsam [Canada balsam] and a little powdered alkanet [a red botanical dye], until the color sauce rises [bubbles?]. And then take care of the stone. (Caley, 1927, no. 31; Lagercrantz, 1913, p. 175).

It is interesting to note that with the exception of the pearl recipes, which deal for the most part with improving the pearl, almost all the other gemstone recipes in *P. Holm.* involve making one gemstone look like another. Only in the last-cited recipe dealing with what we would now call the colored oiling of emerald (and in a variant of it, no. 72 in Caley, 1927, and on p. 194 of Lagercrantz, 1913), does *P. Holm.* describe specifically a gemstone that is being improved as itself. Some of the other recipes dealing with nonspecific "stones" could, of course, be used for such improvements, yet the spirit of the work is clearly one of substitution rather than enhancement.

This unique manuscript represents the earliest comprehensive technical text giving explicit laboratory details. It is invaluable for the light it throws both on early chemistry and on early gemstone knowledge and techniques. Although Pliny, writing a few hundred years earlier, does mention some treatments, he provides none of the detail that makes the processes come alive in *P. Holm.* To Pliny, this was mere theory; to the user of the papyrus, this was clearly his life's work.

THIRTEENTH TO SIXTEENTH CENTURIES

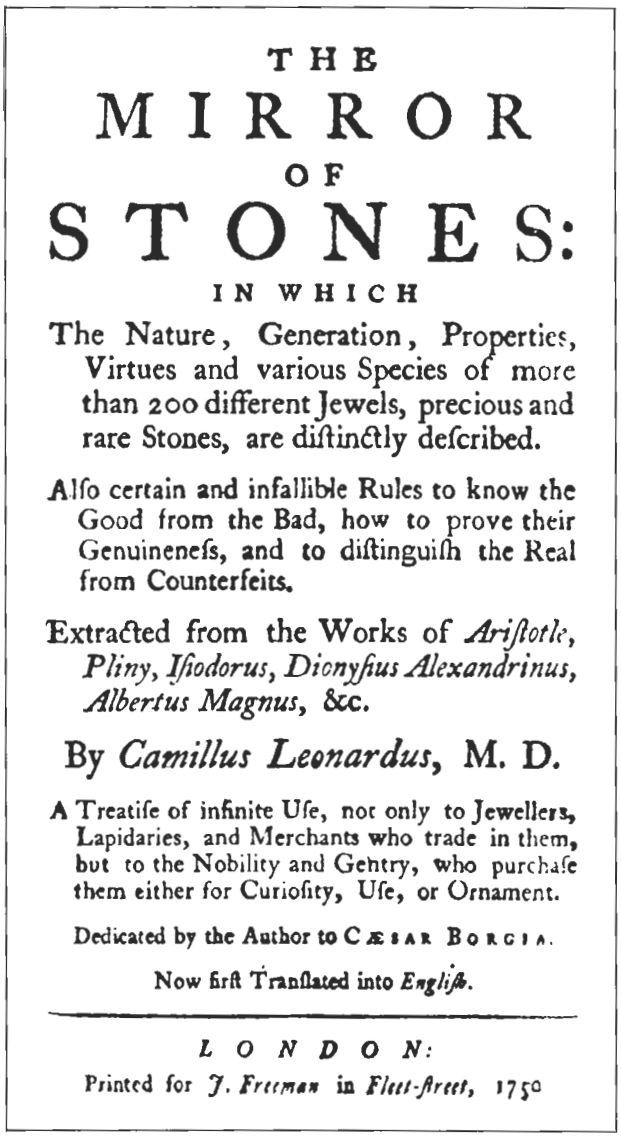
For the next millenium and a half, through the Dark Ages and well into the Renaissance, Pliny's work, often containing many errors from repeated copying, served as the authoritative text for matters mineralogical and gemological.

Writing *On Stones* in about 1260, Albertus Magnus (Albert the Great), a clergyman and emissary of Popes, gives but a single sentence of relevance to treatments. Discussing the color of precious stones in Chapter 2 of Tract 2 of Book 1, he says: " . . . there is also found a stone having a great many colours . . . all its colours are caused by the different substances of which its parts are composed. The same explanation holds, more or less completely, so far as the dyeing of bodies is concerned." This statement seems quite straightforward when viewed in the context of precious stones and the dyeing processes as revealed by Pliny and others, but apparently puzzled the translator (Wyckoff, 1967, p. 43).

In 1502 was published *The Mirror of Stones*, a fascinating book by Camillus Leonardus (also known as Camillo Leonardi or Lunardi), a physician and astrologer of Pesaro, Italy. It is particularly interesting that it discusses not only gem treatments and simulants, but also how to identify those stones that are "not true" and the importance of experience and knowledge in this subject. The title page, shown in figure 8, acknowledges his sources, including Pliny. Excerpts from Chapter 9 of Book 1, from the 1750 translation, follow:

How to know whether Jewels are natural or artificial

Since these Times abound with Counterfeits in every Thing, but especially in the Jewelling Art . . . ; and as there are few unless such as have been long practis'd in them, can judge of them . . . we shall close the First Book with a few Things upon this Head. We say then, that these deceitful Artists in Stones have many Ways of Imposition. As first, when they make Stones of a less Value, and of a particular Species, appear of another Species and consequently of a higher Price; as the *Balasius* of the *Amethist*, which they perforate, and fill the Hole with a Tincture, or bind it with a Ring, or more subtilly, when they work up the Leaves of the *Balasius*, either with *Citron Sapphire* or *Beril*, into the Form of Diamonds, and by adding a Tincture to bind them, sell



THE
MIRROR
OF
STONES:
IN WHICH
The Nature, Generation, Properties, Virtues and various Species of more than 200 different Jewels, precious and rare Stones, are diſtinctly deſcribed.

Alſo certain and infallible Rules to know the Good from the Bad, how to prove their Genuineneſs, and to diſtinguiſh the Real from Counterfeits.

Extracted from the Works of *Ariſtotle*, *Pliny*, *Iſiodorus*, *Dionyſius Alexandrinus*, *Albertus Magnus*, &c.

By *Camillus Leonardus*, M. D.

A Treatiſe of infinite Uſe, not only to Jewellers, Lapidaries, and Merchants who trade in them, but to the Nobility and Gentry, who purchaſe them either for Curioſity, Uſe, or Ornament.

Dedicated by the Author to CÆSAR BORGIA.

Now firſt Tranſlated into *Engliſh*.

LONDON:
Printed for *J. Freeman* in *Fleet-ſtreet*, 1750

Figure 8. The title page of the Leonardus work on gemstones, published in 1502 and translated into English in 1750.

them for true Diamond. Or, very often they fabricate the upper Superficies of the *Granate*, and the lower of Chrystal, which they cement with a certain Glew or Tincture; so that when they are set in Rings they appear like *Rubies*. . . . A Deception may happen in another Manner; as when they make the Form and Colour of a true Stone from one that is not true. And this Deception is made from many Things, and chiefly from smelted Glass, or of a certain Stone, with which our Glass-makers whiten their Vessels, by adding divers permanent Colours to the Fire, as the Potters know; and as I have often seen *Emeralds*, far from bad ones, at least for Use, made out of these Stones. These counterfeit Stones may be known many Ways, as first by the File, to which all false Stones give Way, and all natural ones are Proof against, except the *Emerald* and the Western *Topaz*. . . . The second Way to prove them is by the Aspect; for such as are natural, the more they are look'd at, the more the Eye is delighted with them; and when they are held up to the Light of the Candle, they shine and look fulgent. Whereas the Non-naturals, or artificial, the more they are beheld, the more the Sight is wearied and displeas'd, and their Splendor seems continually decaying, especially when they are oppos'd to the Light of a Candle. They are also known by their weight when they are out of the Rings; for those which are natural are ponderous, except the Emerald, but the Artificial are light. There is one Proof yet remaining, which is infallible, and is preferable to all the rest; namely, that the Artificial do not resist the Fire, but are liquified in it, and lose their Colour and Form when they are dissolved by the Fierceness of the Fire; and it is impossible but that in some Parts of them, some Points like small Bubbles must be seen in their Substance, produc'd by the igneous Heat, and will discover the Disproportion in their Composition, and their Difference from Nature in true Stones. Such false Stones may likewise be compounded of other Things than of Glass, namely, of many Minerals; as of Salt, Copperas, Metals, and other Things. . . . The Knowledge of Stones, and their Species, is acquired by great Experience, and from continual Uses, as they well know who employ themselves in this Kind of Exercise.

The range of treatments here alluded to includes an astonishing variety of colorations and assembled stones. His testing techniques, especially heating in fire, no doubt destroyed many genuine gemstones. Particularly noteworthy is his astute observation of the presence of small bubbles in imitations made of glass.

Next we consider the accounts of two master craftsmen in metallurgy and related arts: the *Pirotechnia* of Vannoccio Biringuccio, printed in 1540 in Venice, and the *Treatise on Goldsmithing* of Benvenuto Cellini, published in Florence in 1568 and translated in 1898. Both mention the use of colored foils placed behind gemstones, the use of a black backing or coating on diamond, and the heat treatment of a sapphire to turn it colorless. Biringuccio says of sapphire: "The best are the oriental ones. It can be made to lose its color by keeping it in molten gold over a fire for twenty-

four hours. With these baths they disguise it in the form of a diamond and try to deceive people" (p. 125). Cellini puts it thus: "There are certain sapphires, which the ingenuity of man can turn white, by putting them in a crucible in which gold is to be melted ['*Nel quale sia dell'oro che s'abbia a struggere.*'], and if not at the first heating, then at the second or third" (pp. 40–41).

Cellini gives highly detailed accounts of various treatment processes, particularly the use of shiny foils, some colored ones, and even colored cloth behind the gemstone in the cavity of the setting (pp. 24–29). In Italy at that time such activities were permitted with all gemstones, but tinting colored gemstones such as emerald, ruby, and sapphire was strictly forbidden by law. Curiously enough, the tinting of diamonds was permitted. There are details of a large diamond given by Emperor Charles V to Pope Paul, who gave it to Cellini to make an elaborate setting and to tint it. Using a clear undercoat of carefully selected pieces of gum mastic followed by a smoky layer consisting of a mixture of freshly prepared soot, selected gum mastic, freshly pressed linseed oil, almond oil, and turpentine, he almost doubled the value of the stone from 12,000 scudi to 20,000 scudi (pp. 31–39).

Cellini also reports that others used the blue dye indigo for tinting diamond, particularly for yellow ones, which "they make green, hence the yellow diamond with the blue tint made an admirable water; and, if it be well applied, it becomes one colour, neither yellow as heretofore nor blue owing to the virtue of the tint, but a variation, in truth, most gracious to the eye" (p. 36). Here he uses the quality term *water of the diamond* in the sense of achieving the most desirable pale blue-green or smoky colors, not in the usually attributed colorless sense. Could this perhaps have been the origin of this designation? Another technique was to use a black backing on diamond. In the words of Biringuccio (p. 122): "diamond . . . is . . . harder and much more lustrous and transparent than any other thing. If the skin of its earthiness is cleaned with art and then it is given its polish, it becomes very brilliant when a lustrous black color is placed underneath."

Illegal falsification was also achieved by the coating of pale stones, according to Cellini: "I once saw a ruby of this nature falsified ever so cleverly by one of these cheats. He had done it by smearing its base with dragon's blood[4]. . . . You would gladly have given 100 golden scudi for it; but without the colour it wouldn't have fetched 10. . . . The color looked so fine and the stone seemed so cunningly set, that no one unless very careful, would have spotted it" (p. 26). Doublets were also widely made (p. 27):

> I mind me also of having seen rubies and emeralds made double, like red & green crystals, stuck together, the stone being in two pieces, and their usual name is 'doppie' or doublets. These false stones are made in Milan, set in silver, and are much in vogue among the peasant folk; the ingenuity of man has devised them to satisfy the wants of these poor people when they wish to make presents at weddings, ceremonies, and so forth, to their wives, who of course don't know any difference between the real and the sham stone, and whom the little deceit makes very happy. Certain avaricious men however, have taken advantage of a form of industry, made partly for a useful, and partly for a good end, & have very cunningly turned it to great evil. For instance, they have taken a thin piece of Indian ruby, and with very cunning setting have twisted and pieced together beneath it bits of glass which they then fixed in this manner in an elaborate & beautiful setting for the ring or whatever it was. And these they have subsequently sold for a good and first-class stone . . . . there was in my time a Milanese jeweller who had so cleverly counterfeited an emerald in this way that he sold it for a genuine stone and got 9000 golden scudi for it. And this all happened because the purchaser—who was no less a person than the King of England—put rather more faith in the jeweller than he ought to have done. The fraud was not found out till several years after.

In his *De Natura Fossilium*, published in 1546, Georgius Agricola discusses metal foils and their detection ("take the stone out of the ring and remove the coloring substance") as well as doublets (triplets in modern terminology) that are made of glass, of quartz, or of garnet and quartz, with a layer of dye. There are also doublets consisting of a diamond top with a base of quartz, corundum, or beryl (emerald). Then there are "filled" gemstones: "Certain amethysts are perforated and filled with minium or are deeply engraved and thin sheets of foil cemented beneath them so that they may be passed as carbunculi" (p. 116). Finally there is

[4] *"Dragon's blood" is a natural vegetable dye, but the name was also applied to the red lead compound* minium, Pb_3O_4, *according to Agricola (1546).*

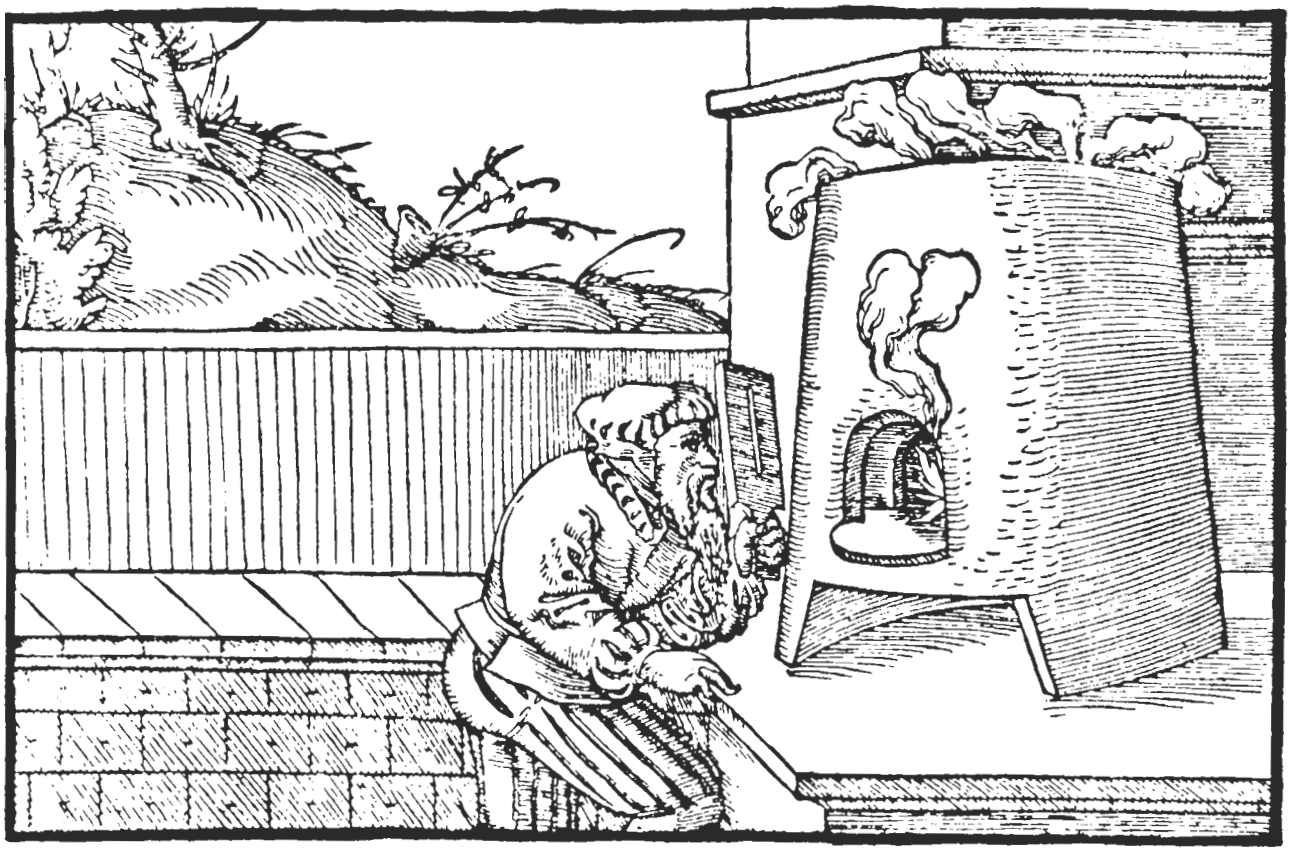


Figure 9. An assay furnace illustrated in Agricola's 1556 book on metallurgy.

dyeing: "The light-coloured or feminine sapphires can be darkened by dyeing. A king of Egypt was the first to dye this stone. Quartz and glass are also dyed to imitate sapphire . . . " (p.130).

There is no discussion of gemstone treatments in Agricola's *De Re Metallica*, but there are many illustrations of the types of furnaces used in metallurgy at the time, shown in figure 9; these same types of furnaces were undoubtedly also used for heat treating gemstones.

In the 17th century, we have the *Gemmarum et Lapidum Historia* of 1609 by Boetius de Boot, a physician of Bruges, which appeared in a number of different forms over the next 40-plus years. In the French translation of 1644, there is discussion in Chapters 20 to 22 of the decolorizing by heat of sapphire, topaz, amethyst, and the like, to produce diamond imitations; the dyeing of stones, mostly with metal compounds (the use of gum mastic is considered to be "trivial and vulgar"); an extended discussion of metal foils; and an obscure description on how to harden gemstones. Several of the techniques are attributed to Baptiste de la Porte or de Porta, presumably derived from personal contact or from an earlier version of John Baptista Porta's *Natural Magic*, which was published in London in 1658.

In Book 6, "Of counterfeiting Precious Sones (sic)," Porta covers a variety of topics, including the making of colored glass imitations and various treatments. Chapter 5, "How Gems are coloured," is devoted to dyeing sapphire, amethyst, topaz, chrysolite, and emerald. In a detailed passage, Porta teaches how:

> **To turn a Saphire [sic] into a Diamond**
>
> This stone, as all others, being put in the fire, loseth his colour. . . . Many do it several ways: for some melt gold, and put the Saphire in the middle of it; others put it on a plate of iron, and set it in the middle of the fornace of reverberation; others bury it in the middle of a heap of iron dust. I am want to do it a safer way, thus: I fill an earthen pot with unkill'd lime, in the middle of which I place my Saphire, and cover it over with coals, which being kindled, I stop the bellows from blowing, for they will make it flie in pieces. When I think it changed, I take a care that the fire may go out it self [that is, he does not pour water on it]: and then taking out

> the stone, I see whether it hath contracted a sufficient whiteness; if it have, I put it again in its former place, and let it cool with the fire; if not, I cover it again, often looking on it until the force of the fire have consumed all the colour, which it will do in five or six hours; if you find that the colour be not quite vanished, do again as before, until it be perfect white. You must be very diligent, that the fire do heat by degrees, and also cool; for it often happeneth, that sudden cold doth either make it congeal, or flie in pieces. All other stones lose their colour, like the Saphire; some sooner, some later, according to their hardness. For the Amethist you must use but a soft and gentle fire; for a vehement one will over-harden it, and turn it to dust. This is the art we use, to turn other precious stones into Diamonds, which being cut in the middle, and coloured, maketh another kind of adulterating Gems; which by this experiment we will make known. . . .

He then proceeds to describe "How to make a stone white on one side, and red or blew on the other," by a special heating process (pp. 183–184.)

Porta's Chapters 10 and 11 deal with "Of leaves of Metal to be put under Gems" and "How leaves of Metals are to be polished." Porta's book appears to have been one of the first of a continuing series of recipe books. Such books were intended to give the general public detailed instruction. They are particularly valuable in our investigation: since they were written for nonprofessionals, the directions tend to be much more detailed than are texts intended for the professional reader.

THE ADVENT OF THE SCIENTIFIC APPROACH

The publication in 1672 of *An Essay About the Origins and Virtues of Gems*, by Robert Boyle, represented the first work on gems written by a professional scientist who based his deductions on his own experiments and observations. In the 300 years that followed, techniques developed in the laboratory were used with increasing frequency and sophistication. By 1820, agate dyeing in Idar-Oberstein had been perfected to the point that it was practiced on a large scale and the agate sold as treated stone. For the first time, a gemstone material was altered commercially and marketed as such and not as a natural material.

By the middle of the 19th century, gemology had turned into a science. As authors studied each other's books and techniques, a certain uniformity appeared in the literature. The works of King (1883) and Bauer (first published in German in 1896, then in English in 1904, and still an important sourcebook for the working gemologist) are representative of the level of knowledge and understanding of gemstone treatments from this period until well into the 20th century, when the discovery of irradiation provided a new approach to gemstone enhancement. Yet while the literature shows great advances during the last few years, many of the treatment methods in use today have their origins in the crude techniques practiced by Pliny's contemporaries and the master of *P. Holm.*

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