Quid Medici poſſent manibus? quas iungere plagas
Vlceribus ſordes, ſigna mouere loco?
Extitit hic ſolus qui pondera, viſcera Terræ
Rimatus, nobis bella metalla fodit.

Georgius Agricola

The Geological Society of America
Special Paper 63

DE NATURA FOSSILIUM

(Textbook of Mineralogy)

BY

GEORGIUS AGRICOLA

Translated from the First Latin Edition of 1546
by
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"The philosopher takes pleasure in the contemplation of the nature of these compounds while the miner takes pleasure in the profit and use he obtains from the metals he extracts from them."—AGRICOLA

FOREWORD

In Classical Times knowledge of minerals was based almost entirely upon philosophical speculations. Interesting theories were never tested by direct observations and mining was not a socially acceptable occupation. Little attention was given to mining and minerals, other than gems, and then only as an adjunct to the broader theories concerning the origin of the Universe. Although there may have been earlier writers Aristotle is the first known to us to have presented a comprehensive theory of the origin and nature of minerals. In his *Meteorologica* he advanced the theory that all natural substances consisted of four properties, dryness, dampness, heat and cold, and these were combined in the four primitive elements, water, air, earth and fire, elements that could be transmuted by altering the relative proportions of the properties. This concept dominated the thinking of man for the next two thousand years.

Another early treatise on minerals was *De Mineralibus* by Theophrastus, a contemporary of Aristotle. Theophrastus accepted the theory of four primitive elements and separated mineral substances into two classes, those affected by heat and those not affected.

The next important work on minerals was the monumental Natural History of Pliny, an encyclopedia of the entire field of Nature, written in 77 A.D. In it are collected all the theories, fables and observations of Greek, Latin and Oriental writers up to that time. This work served as the authority and source book for writers on Natural History subjects for sixteen centuries, although it did not dominate or shape the thinking of men as did the works and teachings of Aristotle.

There was no important work on mineralogy from the time of Pliny until Agricola published his *De Natura Fossilium* in 1546 and the shorter introductory work *Bermannus* in 1530. During the intervening fourteen centuries that spanned the rise and fall of the Roman Empire and the Dark and Middle Ages, writers on mineralogical subjects merely elaborated on the information and much of the misinformation contained in Pliny's Natural History. The development of mineralogy, if it could be called development, can be traced through the numerous lapidaries and encyclopedias that began to appear after the time of Pliny. There was no factual foundation to this development. Each writer cited some previous writer as his authority for the most ridiculous and incredible facts and theories and commonly embellished some of the more fanciful. The result was a spreading structure of theories supported by fables, a structure top

heavy with philosophical reasoning directed toward supporting prior authorities and contemporary religious dogmas.

In the course of a thorough classical education in Germany and Italy Agricola became acquainted with the writings of Greek and Roman authors as well as the rather sterile works of the Dark and Middle Ages. Having a professional and natural interest in minerals, rocks and earths, it is particularly fortunate that he was destined to take up residence in a booming mining district. During his study of the mineral wealth opening before his eyes even the most cursory observations could not fail to demonstrate the fallacies of many of the old theories accepted as valid by his contemporaries. Although he held the opinions of many of the older writers in high esteem he was constantly testing them on the touchstone of observation and experience and discarding those proven to be erroneous.

Prior to the publication of *De Natura Fossilium* few writers had attempted to classify minerals. The common practice was to either list all minerals alphabetically or first describe the more common and better known minerals and then list the remaining in alphabetical order. Without the sister sciences of chemistry and crystallography the only basis for a classification in the sixteenth century was the physical properties and, with the exception of color, little attention was given to these properties. Agricola, with the opportunity and desire to study the physical properties of minerals by observation, was able to work backward through the literature and separate many facts about minerals from the mass of fantasies of the earlier writers. The work *De Architectura* by Vitruvius proved to be particularly valuable. As a result of these studies he was the first to propose a systematic mineral classification, one based upon observed physical properties. It is for this contribution in *De Natura Fossilium* that he is justly known as the Father of Mineralogy. Although physical properties can be used for the sight identification of minerals, unfortunately they cannot serve as the basis for an adequate classification and his effort was doomed to failure, particularly since he was confined within the framework of the concept of the four Peripatetic elements. This does not detract, in any manner, from Agricola's contributions, especially when we judge them against the background of the general level of learning in his day and when we realize that it was not until the end of the eighteenth century, over two hundred years later, that the next important advances in mineralogy were to be made.

Agricola recognized and used all the physical properties of minerals known to present day mineralogists. The outline of his classification is as follows:

Non-Composite Minerals
Simple
Earths
Congealed Juices
Harsh

Unctuous
Inflammable
Non-inflammable
Stones
Stones
Gems
Marbles
Rocks
Metals
Mixed
Composite Minerals

As would be expected he had great difficulty placing many so-called minerals in this classification, particularly the fossils and some of the materials considered as gems. Fossils were not generally recognized as such although he recognized coquina as consisting of fossil shells.

It was not possible for him to discard or discredit all the time-honored fantasies regarding minerals, particularly the mythical and magical properties ascribed to so many of them. While some are discarded others are mentioned but in context that indicates serious doubt on his part. It is interesting to note that the one outstanding error he makes is the classification of camphor as a *corpus subterraneum* related to petroleum, an error based on deductive reasoning and not on observation.

De Natura Fossilium was first published by the Forben press at Basel in 1546 and later editions appeared in 1558 (folio), 1612 (12mo), and 1657 (folio). The second edition, also published by the Forben press, appeared three years after his death. The work was translated into Italian in 1612 and into German in 1809–1810.

Agricola uses some 573 Latin mineral names and 115 Greek names. Two minerals are described by concise phrases. Twenty-seven mineral or "fossil" materials are given the same Latin name as some other wholly dissimilar material and three are given Greek names. At least twenty mineral species are described for the first time and several materials or minerals are described but not named. In spite of the scope of the work there are several noteworthy omissions of mineral names undoubtedly well known to him. Apparently Agricola was slow to accept certain changes introduced by his contemporaries, for example, the use of the name *natron* instead of *nitrum.*

Aside from its historical interest this work is of particular value in giving mineral localities and describing the occurrence of many ore minerals for the first time.

GEORGIUS AGRICOLA

Georgius Agricola, the "Father of Mineralogy," was born Georgius Pawer or Bauer at Glauchau, Saxony, March 24, 1494 and died at Chemnitz, Germany, November 21, 1555. Almost nothing is known of his parents and early life.

He entered Leipzig University in 1514 and graduated in 1517 or 1518 with the degree of Bachelor of Arts in the classics. Either during his student days or shortly thereafter he Latinized his name to Agricola.

From 1517 or 1518 until 1522 Agricola taught Latin and Greek at Zwickau and during this period published his first book, a Latin grammar, in 1520. While at Leipzig and Zwickau he studied philology and acquired a wide knowledge of the works of writers of Classic times. Apparently he also developed an interest in political science and medicine for in 1522 he commenced the study of medicine at Leipzig. In 1524 he went to Italy where he studied medicine and philosophy at Bologna and Padua and took his degree in the former at Ferrara University in 1526.

In 1526 he returned to Zwickau to practice medicine and in the following year was appointed Public Physician of the city of Joachimsthal, the center of one of the world famous mining districts which had been discovered, or opened up, some ten years earlier. In 1533 he resigned his post at Joachimsthal and in 1534 was appointed to the same post at Chemnitz, another world famous mining center, where he lived until his death.

It was at Joachimsthal that Agricola's interest was directed toward mining, mineralogy and geology. He visited mines and smelters, first in the discharge of his duties and then because of his growing interest in all phases of the mining industry. Here he had the opportunity to study mines at first hand and his unusual powers of observation together with his broad classical background and keen mind laid the foundations for his later writing which shows him to have been at least a century in advance of his time.

While at Joachimsthal he wrote *Bermannus*, his first work on mining, in 1528, and published it in 1530. In 1545 or 1546 Agricola was appointed Burgemeister of Chemnitz and continued to be appointed to public offices for the rest of his life. Because of his interest in political and natural sciences he attracted the attention of Duke Maurice and Duke Augustus of Saxony who appointed him to several public posts and encouraged and assisted him in publishing his various works. He held public offices in Leipzig, Freiberg, and Dresden and was envoy of Duke Maurice to Austria and Spain. Little is known of his activities in these various posts but it can be assumed that he discharged the duties with credit in view of his numerous appointments. While a student in Italy he met Erasmus and

the two men remained close personal friends throughout their lifetime. Erasmus as director of the famous Forben Press at Basel published most of Agricola's works after 1530.

In 1544 Agricola wrote *De Ortu et Causis Subterraneorum.* and in 1545 *De Natura Quae Effluunt ex Terra,* two works that established him as the "Forefather of Geology."[1] In 1546 he wrote *De Natura Fossilium,* the first textbook of mineralogy in the modern sense, *De Veteribus et Novis Metallis,* and *Interpretatio.* These books, together with the second edition of *Bermannus* were published in a single folio volume in 1546. The date of the first edition of his *De Mensuris et Ponderibus* is not known definitely. Hoover[2] considers the edition published together with the first edition of *De Precio Metallorum et De Monetis.* in 1550, as the second edition. *De Animantibus Subterraneis* was published in 1548 and his most important work, *De Re Metallica,* was written in 1550 and published in 1556, the year following his death.

Other writings in addition to those on mines, mineralogy, and geology were in the fields of political science, medicine, religion and education.

Agricola was one of the founders of a new school of education, the school of observation and study of natural processes and conditions in the field, as a substitute for the older school of philosophical speculations. As a result, many modern concepts of geology and ore deposition were first expressed in his writings and to him must go the credit for the first modern works on mining geology and mineralogy. Even though he belonged to the Peripatetic school he departed from its teachings to a marked degree. While his works were published in several editions apparently they were not widely read and did not have the popular appeal of the contemporary and later editions of lapidaries, herbals, and smaller works on mining. In consequence most writers on the history of mineralogy, mining, and geology have been slow to recognize the importance of his works and given them the credit they merit.

The life and works of Agricola are treated at length by Hofmann, and Darmstaedter[3] and reference should be made to these by anyone interested in his life.

[1] Adams, F. D., The Birth and Development of the Geological Sciences, London, 1938, p. 185.

[2] Hoover, H. C., and L. H., *Da Re Metallica,* London, 1912.

[3] Hofmann, R., Dr. Georg Agricola, Gotha, 1905.
Darmstaedter, E., Georg Agricola Leben und Werk, Munich, 1926.

TRANSLATORS' PREFACE

In writing *De Natura Fossilium* and other works on geology and mining Agricola found difficulty in expressing himself adequately in Latin, a language that had not expanded with the renaissance of learning. In the field of the new sciences of mineralogy and mining geology many new German and English technical terms had come into common use in the mining districts without the development of Latin counterparts. Consequently he was compelled to use older Latin words in strange contexts and to create new words. In many passages one must assume the shade of meaning implied by rather vague expressions and words.

Editing has been reduced to a minimum. Where Agricola departs from the more common spelling of mineral and proper names his spelling has been retained when there is no evidence of misprinting. Examples are Euax, Zactalias, *glessum* and several others. In general the Latin locality names have been retained.

Where possible modern equivalents of mineral names have been substituted for the Latin. The latter are retained where identification is questionable, or where they clarify the text. No effort has been made to quote other authorities or to give a comprehensive review of available background material. Footnotes have been used sparingly, primarily to clarify the text.

Although the second edition of this work, published three years after Agricola's death, is larger, the first edition was selected for translation and the two texts are not compared. In our opinion the first edition of any scientific work that represents an outstanding advance in learning is usually better suited than later and revised editions for evaluating the stature of the author and the plane of knowledge at the time the work was first written. This translation has been made with the sole objective of presenting in English the first textbook of mineralogy, a work that has been considered by Adams[1] as marking "the dawn of the Renaissance in the Geological sciences."

[1] *Op. cit.*, p. 56.

CONTENTS

TO THE ILLUSTRIOUS DUKE OF SAXONY AND OF THURINGIA AND MISENA PRINCE MAURICE

GEORGIUS AGRICOLA S.D.

Philosophy which treats of the origins, causes and natures of things, Illustrious Prince, has been divided into many parts and must explain very difficult things. For example, it expounds the divinity and reality of God, the heavens and stars, the elements, causes, interrelationships between these things, changes in the atmosphere, as well as living and subterranean bodies and their origins. The concept of God has aroused all nations and peoples but the Jews, Egyptians and Greeks were the first to consider the nature of God. The Chalddeans after long observation and the Greeks after careful study came to know the stars and learned to measure the heavens. The Greeks, more than any other people, studied the elements, their causes, and the interrelationship between natural bodies. Aristotle considered the movements and changes in the atmosphere as well as the species, nature and origin of living matter. Theophrastus has discussed the causes and natures of original life. But the subject of subterranean things in which we are most interested has never been properly treated.

We have already considered the origins and causes of subterranean things.[1] Some of these flow from the earth while others are dug out of it. We have discussed the nature of the former in a previous treatise.[2] In the next ten books we will discuss the distinctive features, physical characters and useful properties of those things which are dug up. The first of these books considers the distinctive features and discusses the origins of all mineral matter; the second treats of earths; the third of congealed juices; the fourth treats of congealed juices, amber, and stones which form from bitumen. The fifth book takes up stones; the sixth, gems; the seventh, marbles and rocks; the eighth, metals; the ninth, metallic substances. The tenth book describes mixed and combined substances.

The Greeks discussed the origin of all mineral matter but no one of them has considered their nature. Likewise medical men and writers on agricultural subjects have been concerned only with the earths related to their own fields and have not considered any others. Medical men have written about congealed juices and Theophrastus wrote a book on salt, soda and alum which is not extant. Many have written about amber but in most cases their discourses are very similar. Democritus and Aristotle have both written books about stones. Theophrastus has written a small book

[1] De Ortu & Causis Subterraneorum, Lib. V, 1544.
[2] De Natura Eorum Quae Effluunt Ex Terra, Lib. IV, 1545.

on stones and two books on petrifactions. Others who have written about stones are Socrates Rhodius, Xenocrates, Sudines, Callistratus, Megasthenes, Ismenias, Horus, Satyrus, Archelaus, Bocchus, Nicander, Jacchus, Juba, Zactalias, Agatharchides Samius, Thrasyllus Mendesius, Heraclitus Sicyonius, Nicias Maleotes, Dorotheus Chaldaeus, Theophilus, Dercyllus, Dionysius Afer, Diogenes, Orpheus, Epiphanius, and Didymus Alexandrinus.[3] Each of these wrote so much concerning marbles that it is most surprising that some wrote only about gems. Of all the writings of these men only a small book by Theophrastus and some verses by Orpheus have been preserved. No work on the engraving of gems is extant. Theophrastus, in his small book, mentions many differences in stones and in characteristic style discusses the form of a few of them. The verses of Orpheus are of little value to us. The two books by Theophrastus on metals have not been preserved. Medical men have written only those things concerning minerals which pertain to their particular field and from their writings we see that the older authors knew little or nothing about complex minerals. The medical writers followed some of the older authors as did Theophrastus.[4]

Pliny, in his last five books and in parts of others, is the only writer who has discussed minerals at any length. It is regrettable that he was not able to study the minerals he writes about as I believe that many of them were brought to Rome at that time. In this field, as in others, he brought order out of the disorder he found in the writings of others but since he had no intimate knowledge of minerals he failed to observe that different writers had two or three different names for the same thing and, following other writers, he sometimes gave the same name to two or three different substances. Later on we will take up this question when we consider the more obscure passages of certain writers who treat of subterranean things. Although these errors exist in his writings, nevertheless Pliny has performed a great service in writing with such diligence on so many different subjects and in preserving from loss many notable expositions of other writers. He has given both Latin and Greek names for many things and were it not for his writings these names would surely be lost.

At times I shall make use of his learned explanations, even use his own words. Since the work exists it is proper to select certain material from it although the things whose nature I shall discuss will not be copied entirely from his or other writings. Only in this way can several obscure points be clarified by our own interpretations of the writings of others and scattered and unrelated information arranged in proper order. Pliny gives credit openly and frankly to those whose writings he uses and likewise I shall give credit by name to those whom I quote.

[3] Agricola should have included Solinus, Sotacus, Zenothemis and Zoroaster.

[4] Maecenas and Olympicus Theocrestos who were known to Agricola could have been included.

Although our veins and mines do not produce all varieties of minerals I have attempted to discuss those minerals not found in Germany but in other parts of Europe and certain parts of Asia and Africa. In the discussion of these minerals learned men, traders and miners have been of great assistance to me. As a rule, in connection with each mineral, I shall mention the places where it has been found or is found today. It is well known that certain regions produce famous earths, others congealed juices, stones, gems, marbles and metals. Some of these substances lack names as previous writers have not mentioned them and it will be necessary that I give them new names. As a rule I will give them Greek names as they cannot be named so aptly in Latin.

Most Illustrious Prince. I dedicate these books to you, in part because of the many favors you have bestowed upon me and for which I shall always be grateful, in part because the greatness of your name and reputation will give them added value. Actually your name adds greater honor to these books than any which might come to you through this association. If we consider birth, we see you having been born to that noble family which is one of the oldest and greatest of all Germany, second only in rank of nobility. If we consider favors of fortune, we see you abounding in riches and great and lasting power. You are known to be brave, strong of body, and with a stature becoming to the dignity of a Prince. Your strength of character is shown by the deep understanding with which you treat all people; by your manly courage and your burning zeal. You have become famous and renowned because of these attributes, praised by King Ferdinand and approved of, above all others, by The Most Invincible Emperor Charles. Your kingdom abounds in metals and, since we treat of metals in different sections of these books, it is most appropriate that they be dedicated to you.

In Misena silver, tin, copper, and iron are found; in Thuringia, near Sangerhausen, copper. Moreover Misena is so rich in silver that I need not mention any other metal to illustrate my point. Three hundred years ago the veins of Freiberg alone yielded enough silver annually to Prince Henry, who first annexed Thuringia to Misena, to purchase the kingdom of Bohemia. It was during his reign that a great tree was made from silver and set up near Northausen, Thuringia, not that anyone might sit beneath it as Xerxes once sat beneath a golden tree, but that its leaves, some of which were of gold and some of silver, could be given to nobles of all ranks who might come there to compete in tournaments. Golden leaves were given to those who unseated their opponents, silver leaves to those whose matches were a tie. There were no leaves for the unfortunate one who was unseated.

Garium, Misena, has been an esteemed producer of silver for one hundred and fifty years, Schneeberg for eighty-four years, Annaberg for forty-three years, and Marienberg for sixteen years. In recent years mines in the Joachimstal and Albertham valleys at the base of the Sudetes Mountains

have produced native silver so pure that it requires no refining before use in the arts. Melibocus, Lauterberg, and the Jura mountains of France, near the valley of Hares also produce a little silver.

No one can examine this work carefully and not realize that my studies will become better known and of added value through the greatness of your fortune, honor and virtue.

Be Strong Oh Illustrious Prince.

Chemnitz, February 15, 1546

BOOK I

Mineral substances vary greatly in color, transparency, luster, brilliance, odor, taste, and other properties which are shown by their strength and weakness, shape, and form. They do not have the variety of origins that we find not only in living matter but also in original matter. Moreover they have not been classified like the latter on the basis of the place where they pass their life since mineral substances lack life and with rare exceptions are found only within the earth. They do not have the differences in characters and actions which nature has given to living things alone. Great differences are not the essential features of minerals as they are of living and original matter.

Minerals have no dissimilar portions made up of similar materials. For example, a mineral we call "complex" nature forms from different kinds of simple substances, none of them dissimilar. The substances we call similar the Greeks usually call *ὁμοιομερής* while dissimilar substances are called *ἀνομοιομερής*. Many minerals form from a single species, a few from many similar species. For example, each unit of red ocher is red ocher; each unit of alum, alum; asbestos, asbestos; gold, gold. All species of earth, congealed juice, stone, and metal are composed of single species except certain stones which are composed of two or more species. These stones are recognized by the presence of spots, veins, and areas that glitter like the stars. They may imitate different things by color variations. Thus from the minerals that come to our notice we learn these differences and are able to study their nature.

Color, taste, odor, and qualities of minerals which can be perceived by touch are most widely known because they are more easily recognized by the physical senses than qualities such as strength or weakness. A great many of these qualities are not known to everyone although those qualities which are learned through experience are widely known. For example, everyone knows that fire can be produced by striking flint with iron. On the other hand miners not only know this but also that fire will melt some varieties of flint, shatter others. Many people know that lodestone will pick up iron but only a few know that this power is weakened and destroyed if the stone is immersed in an acid.

In order to show the differences in minerals I shall begin by classifying them according to color, then I shall describe the nature of each form. Minerals vary greatly in color. Chalk, alum, asbestos, and Arabian marble are usually white. Persian marble, quartz, silver, quick silver, and tin are almost always white. *Pnigitis, sory,* smoky quartz, and Lucullian marble are black. Melia earth and one of the Eretria earths are ash-gray. Lapis lazuli and sapphire are blue. Chrysocolla and *smaragdus* are always green while some chalk and *atramentum sutorium* may be green. Ocher and gold

are yellow. A certain variety of earth (*rubrica*) is red whence comes its name. Sard and *carbunculus* are red. Realgar has a ruddy color while amethyst is purple.

There are marked differences in shades of color in all of these minerals. For example, among the green minerals *smaragdus* is an intense green, chalk, pale green and chrysocolla an intermediate shade. Certain minerals have their own distinctive colors such as lead which is neither black nor blue-black and pure copper, between ruddy and red. Some minerals imitate the colors of other minerals and metals. Orpiment and yellow muscovite imitate the color of gold; one variety of *aspilates*, silver; *chalcitis*, copper; one variety of *balanites*, Corinthian copper; galena, lead; *dactylus idaeus* and *basaltes*, iron. Several minerals imitate the color of living things. For example, the gem *icterias* is similar in color to saffron; hematite, to blood; *prasius*, to the leek; *aspilates*, to fire.

Many minerals have two mixed or separate colors. Taking up those with mixed colors first, some are bluish white such as *jaspis* which is also called *borea*. Some are greenish blue such as *armenium*, some whitish red, as *aphrodisiace*. Some minerals are in part yellowish white as *xanthos;* in part blackish red such as the three varieties of *batrachites*. Certain black minerals have a purplish tinge, for example *alabandicus lapis*.

Regarding minerals with two separate colors, those having white and black bands have been used more than all others in our times since they are so admirably suited for carving. These stones occur in nature with alternating white and black bands. *Apsyctos* has a black groundmass cut by red veins while *nasamonites* has a red groundmass cut by black veins. Leek-green *heliotropios* is cut by blood-red veins. Lapis lazuli contains sparkling golden points of light.

Some minerals have three separate colors. Stones found in glass sands are white, red and yellow; white, gray and black; even white, green and blue. The white groundmass of the mineral "Egyptian agate" is cut by black and sard-red veins according to Jacchus. *Eupetalos* and *orca* have four different colors, *eupetalos*, blue, flame-red, vermillion and green; *orca*, black, dark yellow, green and white. *Hexacontalithos* and *panchros* have even a greater number of distinct colors and the names of these stones come from the variety of colors they show. If different color combinations are found in stones such as these latter ones they do not form new varieties but if such variations occur in other minerals they usually do. Finally, several minerals such as the mineral *paederos* show a play of colors similar to that seen on the neck feathers of certain African fowl when ruffled in anger and on the feathers of the peacock or pigeon when spread in the sun. These minerals also show a play of colors when inclined in different directions.

Although certain minerals are transparent most minerals are not. None of the earths, metals, or rocks is transparent. Out of the large number of mixed minerals proustite is the only transparent one, a deep red, and

even this one is not always so. Of all the marbles only some parts of a few pieces of *phengites* marble are transparent and among the stones, properly named, only selenite, *magnetis* formed in thin crusts, and gypsum, the last two minerals only very rarely. Four congealed juices are transparent, halite, *nitrum*, alum, and *atramentum sutorium*. Many gems are transparent and amber commonly so. Some of the transparent gems change color when inclined, for example, *eristalis* (opal), which changes from white to red. Others may become clearer when inclined as does the Carthaginian *smaragdus*. Gems which can be scratched with steel, especially those which are spherical and protrude like the eye appear to be white when held in the sunlight and have the same color as the rest of the mineral, although somewhat lighter, when held in the shadow. But of these some are brilliant, others dull; some are lighter, others dark. These differences can be observed in the *carbunculus*.

Luster, brilliant luster, is found in all genera of minerals and I shall mention only a few. Among the earths *creta argentaria* has a brilliant luster and the same is true of all transparent congealed juices, all transparent stones, all gems, and the native metals. Luster occurs throughout the entire body of the most valuable gems, *magnetis*, and the mineral we call *armatura*. On the other hand some minerals do not have a luster throughout all the body. Certain micas have a luster only within the body of the mineral and similarly *misy* has a golden luster, *creta argentaria*, silver. Also there are stones to which they attach very thin foils of pure gold, silver, copper, and other metals in order to increase their luster. Among the lustrous minerals some reflect an image, for example, *smaragdus*, the *carbunculus* found at Orchomenus, Arcadia, *cepites*, *cepionides*, and *hephaestites*. All hard stones will reflect an image when polished. *Obsidianus lapis* that is called jet reflects an image which resembles a shadow. Although all minerals have this property, the luster we usually see is more often due to art than to nature. The luster of marbles, gems, and metals is the result of polishing. A luster can be given to glutinous earths by merely rubbing them with the finger nail.

I now take up taste. Some minerals have a sweet taste, for example, *melitites* and *galactites;* Samia earth and marl, an oily taste; *nitrum*, a bitter taste; halite, a salty taste; lime and *spodos* which is found in mines, an acrid taste; red ocher, an astringent taste; and certain earths which have absorbed an acidulous juice, an acidulous taste. Some minerals have a mixed or confused taste, for example, *atramentum sutorium* and related species which have both an astringent and acrid taste. One perceives the taste of congealed juices by placing them on the tongue, especially salt, alum, soda, iron sulphates, and related species. Earths which have absorbed these juices, as well as stones, are tested in the same way. Astringent earths adhere to the tongue. Some earths, if not all, when placed in a vessel, covered with sweet water, and then worked with the hands, give their taste to the water. The water will be found to have the same taste

as the earth. A kind of juice is given off by certain stones such as hematite and *schistos* when they are ground in a mortar. Gems and the stones which melt in a fire do not give this kind of juice. Each metal has a distinctive taste which can be ascertained by placing water in a vessel made from the metal and allowing it to stand for a long time. The metal then gives its taste to the water. The taste of copper is very bitter and unpleasant, that of iron less so while the taste of tin is the weakest of all metals.

The odor which minerals give off according to their strength and nature will be considered next. That of *sory* is so foul it causes nausea. Certain minerals have an odor when struck with an iron or stone. Treated in this way the Hildesheim marble gives off an odor of burning horn. Recently a silver vein has been discovered in a prospect named St. Fabius and St. Sebastian near Marienburg and the ore from this vein, when broken in the mine or after it is carried outside, gives off an odor which is pleasing to everyone. Prince Henry, who was present at the time the vein was discovered, was so pleased that he exclaimed, "This is Calcutta, India." Aromatic gums come to us from that city. An odor is also obtained from some minerals by crushing them in a mortar. Realgar, treated in this way, gives off an odor of sulphur. Certain minerals give off an odor when burnt in a fire, for example, realgar has an odor of sulphur; amber, for the most part, of myrrh; jet, of bitumen. Camphor has an acrid odor and the fire which heats it increases its pungency as it is carried upward to the cover of the vessel. Stones and earths which do not contain bitumen give off almost no odor when thrown on a fire. When heated gold has a sweet odor which is detected with difficulty; silver a somewhat fetid odor; copper and iron a fetid odor; lead, bismuth, and zinc a dull odor. Many mixed minerals smell of bitumen, many of sulphur. Some *cadmia fossilis* has an odor of garlic. The geodes from Misena, the stone from Berninger and fragments of a rock from Aldenberg have an odor of violets which comes, not from the stone, but from the adhering moss.

Minerals have warmth and coolness, moisture and dryness. To anyone who touches minerals lightly almost all appear to be cold but there are many which warm the body if they are held against it for a long time. Some minerals are warm, having been heated by the fires which rage within the earth. This genus is commonly found in fiery localities. Sometimes a mild subterranean heat warms them, for example, the vein recently found in the Joachimsthal valley and named the "Stella" and the vein found some years ago at Annaberg and named the "Obliqua." But this mild heat found in minerals is not excessive for the miners working in pits and mines usually do not notice it. But when ore is first brought out to the air, if it is in the form of small pieces so that the hands can be buried in it, the ore not only heats them but burns them painfully for a short time. Any very hard stones which are naturally cool become warm when rubbed or pounded together. The same is true of metals.

Although minerals are naturally dry, often projecting parts can be

completely saturated with water. All earths can be saturated with water and certain congealed juices.

Minerals differ even more in other qualities which are perceived by touch and which reveal the position of some, and in the well-known qualities due to strength and weakness, namely, unctuousness and meagerness, density and porosity, hardness and softness, roughness and smoothness, heaviness and lightness, and many others.

Some minerals are unctuous such as marl, sulphur and jet, while others, such as ocher, salt, sandstone, and almost all stones, are meager. There are many more meager minerals than unctuous but among the latter there are some which are completely unctuous such as sulphur, bitumen, amber, jet, etc., and some which are semi-unctuous such as *spinus* and many others which I shall classify as "mixed." Although most minerals are dense, some are porous, for example, pumice, travertine, and the chalk used by painters. The parts have not been joined and connected, one with the other, on all sides and they contain much air. Many minerals are hard but stones and metals are especially so. *Spodos*, lime, and earths which have been moistened with water are soft. Emery, Melia earth, and the earth they call "tripela" (tripolite) are rough for these have sharp points. Most gems, refined metals, and even native metals, the parts of which are uniform, are smooth. Generally all minerals are heavy although jet, mineral *ebenum*, pumice, and travertine are light. Some minerals have openings too small to be seen by the eye and in these is a quantity of air which mixed with earth and water is contained in the entire body of the mineral. A mineral which is full of openings that can be seen by the eye is called πολύκενος in Greek and *fistulosa* in Latin.

Minerals differ in the degree of the qualities mentioned above, for example, amber is more unctuous than jet, sandstone is more meager than ocher, and another is intermediate between unctuous and meager. The concept of degree in qualities was understood by the older writers on agricultural subjects for they say that one earth is rich, another poor, another intermediate.

Now I shall consider how minerals differ in other well known qualities due to strength or weakness, namely how they resist destruction. Certain minerals dissolve in moisture, such as earths, halite, *nitrum*, alum, *atramentum sutorium*, etc.; others in fire, such as the stones the Greeks call τηκτός and our miners, if I may be allowed to translate the German word, call *fluores*.[1] Many of these are very similar to gems. Transparent gems themselves melt in fire as well as *silex*, stones which produce the sands from which glass is made, metals, and especially many mixed minerals. Some of these melt quickly, some slowly. Earth which if soft, porous, and meager dissolves quickly in liquid while earth which is hard, dense,

[1] Fluorite, Germ., flusse. The Latin name from which fluorite is derived is the verbal noun fluor.

and unctuous dissolves slowly as does halite, *nitrum*, alum, and *atramentum sutorium*. Artifical minerals dissolve quickly. The same is true of natural efflorescences of halite and *nitrum*. These minerals do not occur within the earth. Bismuth, tin, and lead melt quickly in a fire; the other metals with greater difficulty; iron with the greatest difficulty. Stones similar to gems melt more quickly than true gems. Minerals which dissolve in a liquid almost never melt in a fire but are either reduced to a powder or consumed, as I shall discuss a little later. On the other hand, minerals which melt in a fire are not soluble in liquid.

Some minerals such as earths, certain stones, and sulphur become soft in a liquid and iron and copper become soft in a fire. Those minerals which become soft in a fire and correctly called μαλακτά by the Greeks since they can be worked so that, with one blow of the hammer, the surface is spread out and at the same time lowered. However minerals which are softened by a liquid are not called μαλακτά for although they become soft they cannot be flattened or stretched like a sinew, membrane, or piece of leather without breaking. Some of the latter minerals become soft quickly, for example the earths, while others, such as hard stones, soften slowly. All minerals which are not softened in a fire can be softened by water. For example, a portion of the hardest marble buried within the earth may be softened by water while the rest retains its hardness.

Some minerals are damp such as earths and sulphur, while metals and transparent gems are not. Damp or moist minerals are those which become soft when sprinkled with water. Halite, *nitrum*, alum, and *atramentum sutorium* are not moist since they dissolve instead of softening when sprinkled with water. Since all minerals contain earth and water those which dissolve or soften in water consist mostly of earth and those that soften in fire contain an abundance of water. Some minerals are pliant and sticky such as soft bitumen. Some are so coherent that when drawn out it is difficult to separate them from the parent mass. Similarly, unctuous earth which has been softened with water is sticky and, as the poet affirms,

"It sticks to the fingers like pitch"[2]

Certain minerals, having been crushed, are broken down with ease in water. These are called ψαθυρά by the Greeks. Meager earths belong to this class and many varieties are found in mines. A few minerals are flexible, namely asbestos, the only mineral that is spun and woven, and metals that occur in arborescent shapes. If these wires of native metals are straight they can be bent in any direction, and if bent they can be straightened. Other minerals can be neither straightened nor bent.

Most minerals are friable, i.e., they can be pulverized by either pounding or grinding them in a mortar. A very few are cleavable, i.e., capable of being split into two parts such as talc which occurs as tabular aggregates.

[2] Virgil.

Certain minerals are dense such as bitumen, stones, and metals while others are tenuous such as the *spodos* found in mines, natural lime, *melanteria*, and a black mineral which resembles the down from plants and from which we obtain quicksilver (metacinnabarite). We apply the term dense to minerals which, because of strong coherence, occur in large units and apply the term tenuous to minerals which occur in small units because of the lack of coherence. Thus hard and tough minerals, since they occur in large units, are dense and soft and easily crushed minerals which occur in small units are tenuous. Impressions can be made in certain minerals of the latter class such as unctuous, incoherent, soft or moistened earths, bitumen, lead. Stones and most minerals will not take impressions. Some minerals soft enough to take impressions of the hand or blows of a hammer may be worked into various shapes while other minerals which are harder may be cast. Copper can be cast as well as worked by hammering. Some minerals, too hard to take impressions, are soft enough to be scratched by iron, for example, marbles, almost all rocks and many stones known by special names. Other minerals are too hard to be scratched such as flint and almost all transparent gems. Minerals soft enough to be scratched by iron may be engraved and even turned in a lathe, for example the Zeblician marble of Misena and the Comensis stone of Italy. Goblets are turned from the former and, according to Pliny, cooking utensils were turned from the latter. Venetian *tofus* can be cut with iron and rocks and marbles can be split with wedges. Some of the minerals which cannot be scratched with iron are very brittle such as flint while others such as the knots found in *schistos* and *basaltes* can be broken only with great effort. Some minerals, for example the diamond, are not affected by a blow.

Some gems are scratched by a file such as *topazius* (chrysolite) while others are not, such as lapis-lazuli and *carbunculus*. All gems can be engraved with emery except the diamond which can only be scratched by its own fragments.

Certain minerals can be compressed such as native *spodos* and a black mineral similar to the down of plants and which is sometimes argentiferous, sometimes hydrargyriferous (metacinnabarite). Common stones, gems, rocks, marbles, and metals cannot be compressed. Porous, unctuous, soft earths can be compressed and when compressed, remain so. Some can be drawn out, i.e., protuberences of unctuous earths which have been moistened with water, as well as bitumen can be drawn out into a long thin body because these have the essence of movement. Earths which are hard, meager or dry cannot be drawn out. Gold, silver, and copper can be drawn as well as stamped. None of the stones can be drawn. Bitumen can be drawn and compressed. Some minerals are cleavable, for example selenite and talc, for the openings in these minerals have been extended along the length, not the width. Some occur similar to hair such as native silver and alum. A great many do not have a cleavage such as stones and metals. Some minerals burn readily, sulphur, bitumen, and jet, while metals,

stones, and earths do not. Some that burn are entirely consumed such as sulphur and bitumen while others are only partly consumed, for example, *spinos*. All that burn, since they are unctuous, produce soot, and, in fact, soot is obtained from the copious smoke and vapor given off by these unctuous substances when they are burned.

Concerning the minerals which do not burn, some can be set on fire; for example, all metals except gold can be entirely consumed. Some can be melted, such as gems and the stones similar to gems; and some can be reduced to a powder, for example, earths and stones moistened with water. Many gems do not melt in ordinary fires and some stones are hardened, for example, those found on Siphanto and Como, Italy. Fire can be produced from pyrite, *lapis molaris*, flint, quartz, and other hard substances. Some rocks are hardened by exposure to the sun and air while others are softened and when moistened by rain, disintegrate.

Vinegar attacks some minerals such as the gem *astroites*, which our people have named for victory (*sigstein*) and not uncommonly *trochites*. When some minerals are placed in water they swell like a bubble such as certain earths. Some float on water if whole and sink when broken into small pieces, for example, pumice, *lapis thyreus*, and bricks made from pumaceous earth. *Galactites*, goethite, and hematite yield a juice when pulverized. That of *galactites* is white; of goethite, commonly saffron-yellow; and of hematite, blood-red. The juice from *galactites* is sweet while that from goethite and hematite is astringent. Some minerals tint metals, for example, *cadmia*, iron, copper. If *cadmia* (zinc carbonate and silicate) is added to copper it forms brass and if iron is added to copper it forms white copper. Certain genera of earths and stones impart their color to anything. White chalk makes white lines, green chalk called *theodotion*, green lines, black chalk, black lines. Silver, although white, makes a black line on wood. Eretria earth rubbed on copper gives it a violet color. Flint and sandstone sharpen iron. Lodestone attracts iron while *theamedes* repels it. Amber and jet will attract chaff, hair, and straws, while some even acts as lodestone and will pick up light objects. When flint is used to sharpen iron it sacrifices something for, during the process of sharpening, it loses some of its bulk, something is taken away. Likewise chalk, when used to make marks, sacrifices something and since it is entirely consumed with repeated use, something is taken from it. Other minerals have this same property.

Minerals that are taken in food or drink may be either a remedy or a poison and possess a characteristic power that accomplishes something while they themselves suffer some change. Minerals that act as a remedy heal the body in part through an essence that is characteristic of all such minerals and in part through some efficacious quality of purity. Some minerals rich in this peculiar essence counteract poisons, some cure disease. Others, endowed by Nature with the power of counteracting poisons cure people ill with the plague. *Smaragdus*, and Lemnian and Armenian earths have this property. Others counteract a single poison as does lapis-lazuli

which, having been drunk, counteracts the sting of a scorpion; sulphur, having been smeared on a wound counteracts the poison in it; soda and iron sulphates, having been drunk, counteract the poison from toadstools. Some minerals counteract many poisons, for example halite, which is a remedy for the bites of vipers, horned snakes and crocodiles, the stings of scorpions and wasps, the infections from centipedes. The halite is applied as a poultice. Taken internally, halite counteracts the poisons of toadstools and opium.

Among other minerals with healing qualities *hieracites* stops bleeding from deep cuts. *Jaspis*, placed on the stomach, strengthens it and prevents vomiting. A geode tied on the left side of a women's hips maintains and preserves pregnancy and prevents miscarriage. *Jaspis* and geodes bound to the thigh of a pregnant woman cause an early delivery. Magnetite removes excess fat. *Chrysocolla*, *armenium*, and *atramentum sutorium* cause vomiting.

I shall say no more about the medicinal properties of minerals and will now take up the medicinal qualities. All minerals dry. Some warm the body such as alum, *atramentum sutorium*, *chalcitis*, *misy*, *sory*, and *melanteria* while others such as Eretrian earth, galena, and stibnite cool it. Regarding the secondary qualities, jet softens areas of the body which are hard while galena and stibnite harden areas which are soft. Hydrous sodium carbonate minerals such as *nitrum*, *nitri spuma*, and *aphronitrum* open holes too small for the eye to see while Samian *aster* and all other glutinous earths close them. Minerals such as pyrite, *molaris*, and bitumen break up gatherings in the body. *Chalcitis*, *misy*, and cleavable alum heal wounds. The Greeks call minerals which remove fleshy growths καθαιρετικός. These include natural lime, *aerugo*, and if the growths are soft *chalcitis* and *misy*. Some minerals which the Greeks call σηπτικός cause flesh to decay, for example, the *spodos* found in mines, orpiment, realgar, and *chrysocolla*.

Various minerals have been endowed with diverse qualities, for example Cimolia earth (principally cimolite) and halite. Cimolia earth disperses and holds disease in check; halite cleanses and is astringent. *Chrysocolla*, *armenium*, orpiment, realgar, hematite, and goethite have these same qualities as well as *atramentum sutorium*, *misy*, *sory*, *chalcitis*, and *melanteria*. Of these *chrysocolla* is stronger than *armenium;* orpiment, than realgar; hematite, than goethite; *atramentum sutorium*, than the related minerals. Many will cause serious injury and even death to men and animals when taken into the body with food or drink or when placed in close contact to the body. Certain varieties of *spodos* found in mines, *cadmia* and *chrysocolla*, will eat away flesh rapidly. Gypsum and selenite cause constipation.

I shall say nothing concerning the properties which the Persian scholars have attributed to stones and gems. They, and the Arabs who have copied them, have treated the natures and causes of things with such a superficiality and vagueness as to cause one to regard them as of little value as I shall explain at greater length elsewhere.

Nature has given minerals various shapes and forms with the exception of the earths which are either without form or are tabular, for example, Samian *aster*. Some minerals are round. *Thyites* found between Syene and Philae occurs in perfect spheres while stones from veins that are carried along by rivers and deposited on the banks occur as compressed spheres with protuberances and hollows. Turquois and *astroites* occur in hemispheres while beryl and *syenites* are cylindrical. Some are conical and others have the shape of a top. Certain stones and congealed juices similar to icicles which form in caves represent the former; those which hang from the backs of caves, the latter. Some minerals are angular. They may be either triangular such as certain gems; quadratic or cubic as diamond and some pyrite found in rivers and brooks; or pentagonal as the Misena *basaltes*, although this may have a variable number of angles from four to seven. Quartz has six angles and *pangonius* many angles.[3] Some minerals have a hexagonal termination which is common on quartz and found occasionally on diamond. Others with a spindle shape have been twisted into the form of a snail's shell, for example, some stones.

Selenite and *magnetis* are flat; geodes, convex on the inner side; *smaragdus*, concave. Minerals may be covered with wart-like excrescences as is *myrmecias*. Some have forms which imitate those of well known objects. *Ammonis cornu* imitates a horn; *tephrites*, a new moon; alum, asbestos, and native silver, hair; some stones similar to gems, the lobe of the ear; *bucardia*, the heart of an ox; some pyrite, a honeycomb;[4] African sand, pebbles from near the pyramids in Egypt and Cappadocia Hill, lentils; *stelechites*, the trunk of a tree; *belemnites*, an arrow; *chalazias*, hail; *lapis judaicus*, an acorn; *lapis molaris* found near Volsinii, a mill-stone; rocks in Hildesheim, a beam of wood; Misena and Syene *basaltes*, an upright piece of wood. Certain others represent effigies of things, for example, *enorchis*, the testes; *diphyis*, the genitals of both sexes; *entrochos*, a wheel; *enostos*, bones. According to Pliny, when *cyamea* is crushed it breaks into pieces which resemble beans. Certain rocks, when split open, are found to contain shells, for example, the *conchites* beds of Megara and the rocks of France which contain snail shells. Inclusions in transparent amber are conspicuous. These embrace gnats, fleas, ants, spiders, small fish, fish eggs, leaves of trees, stalks of plants, seaweed, and other small things. These were entangled in the amber when it flowed down from higher ground into the sea and even in the sea itself before congelation. This happened by accident and certainly on the surface of the earth.

Going back to minerals, many with lines of various colors running through them resemble various objects as *leucophthalmos* resembles the

[3] Agricola, following the Greeks, gives the name *pangonius* to twelve-sided and complex quartz crystals. In "Interpretatio Germanica Vocum Rei Metallicae" he classifies *pangonius* and quartz as the same mineral.

[4] This is a good description of a well-known and wide-spread pyrite-marcasite texture formed by the primary alteration of pyrrhotite.

human eye; *aegophthalmos*, a goat's eye; *lycophthalmos*, the eye of a wolf; *astroites*, the stars; *lapis eislebanus*, pike, perch, various marine fish, and even a cock and salamander; *pontica*, mountains and valleys; agate and green marble, woods and streams. Under color of minerals I have discussed those that have lines of various colors but which do not resemble other things. Certain minerals are characterized by small spots similar to the stars in the heavens and for that reason are given the common name *stellae*. Lapis-lazuli, *corallachates*, and *acopis* have golden points, *pontica*, blood-red and black points. *Lapis arabicus* resembles bones just as other minerals resemble hair. Clear, white marl resembles the marrow of bones more than the outer portion.

Minerals vary greatly in quantity. Some occur in large masses as do marbles and rocks; others in small units, as certain stones and gems. Although Nature has given all genera of minerals a small and discrete body, nevertheless rocks, marbles, and earths often occur in great masses and it is necessary to separate portions from the parent body.

Thus minerals have differences which we observe by color, taste, odor, place of origin, natural strength and weakness, shape, form, and size. In order to make this knowledge clearer and more obvious, I shall explain which genera are outstanding and most important and which, in general, embrace all minerals.

Writers do not agree on how many and which these may be. Aristotle states that there are only two classes of bodies that form within the earth, namely, minerals, which he calls ὀρυκτά, and those substances from which metals are extracted and which he calls μεταλλευτά. Others believe that there are three classes, stones, metals, and earths, which we cultivate. Avicenna mentions four classes, stones, stones that melt in fire and which are called πηκτός by the Greeks, sulphurous stones, and saline stones. Albertus places minerals in three classes, stones, metals, and an intermediate class. Aristotle is seen to classify subterranean substances in accord with the usage of the common people of Greece. I am of the opinion that he named well-known earths and even stones ὀρυκτά because they have only to be dug up and then they are ready for use and he called metallic materials μεταλλευτά because it is necessary to smelt them. Irrespective of whether Aristotle bases his classification on common usage or not, he fails to recognize that metals are obtained from well-known earths and stones as well as from minerals. Since it is commonly recognized that this is true, the genus "mineral substance" embraces earth, stone, and metal. Even if we say, in order to please some critics, that these substances have been named μεταλλευτά because they are searched for and not because they produce metals, we are not able to defend and support his classification even with this interpretation. Since each is dug up the genus is "mineral substance." These interpretations of his opinion have led us to the next theory. It has been said that we search for metals deep within the earth with little or no hope of finding them while stones and well-known

earths are dug up without careful search. For this reason the former are correctly called μεταλλευτά, the latter ὀρυκτά. Such reasoning is weak and unsupported since we do not prospect for metals alone nor at all times. Actually we prospect for gems, veins of well-known earths, and even marbles, while metals sometimes occur as if they were offering themselves to us. For this reason, by neither of these interpretations are these names characteristic of these things even though Aristotle was able to complete his classification. He classifies those stones that do not melt in a fire as minerals and those stones that do melt and contain a metal as "minerals from which metals are obtained" and then he cannot place those stones that melt and yet contain no metal in either of these groups. Actually some of the stones that melt in a fire do contain a metal and are correctly called μεταλλευτά since metals are recovered from them. Other stones contain no metal but having been formed from exhalations melt in a fire and can be poured. These cannot be called μεταλλευτά. Therefore if all "mineral substances" are formed from vapor, as he himself says, and among all these the ones which have formed from exhalations contain no metal, it follows that there must be three genera of bodies formed within the earth although only two may be formed from exhalations.

Philosophers who believed the "earth" to be composed of the three classes, stone, metal, and cultivated earths, are not correct if they mean by "earth," as did Galen, one of the four elements, a body that is exceedingly cold, dry, dense, and heavy. None of these classes is a simple body for all are mixed. But if they visualize, as they seem to, a body of such combination that the earth surpasses the other elements in weight, they do not see that there are more than these three classes of it. Many forms of such an earthy body are found in living matter such as bones, nails, claws, and shells. Actually there are as many parts of trees and shrubs that are earthy as there are forms of earthy matter, the bark, the wood, the inner bark, the shell and kernel of the nuts, bunches of grapes, and many others. Thus, even if they regard the forms mentioned above as higher forms which are parts of living matter, they still hold that there are three forms of inanimate matter, namely, stone, metal, and earth that is cultivated. But since philosophers have not considered it necessary to classify things in this way, the Peripatetic philosophers force them with this doctrine. Metals contain more water than earth. In which case, even though those philosophers may not be willing to yield to the Peripatetic philosophers nevertheless none of them can place congealed juices and especially mixed bodies in one of these three genera. Even Avicenna himself, although he increased the number of classes, was unable to classify red ocher and other well-known earths that do not contain a metal. Then, since certain stones that contain no metal melt and flow in a fire, he correctly distinguishes stone and metallic material, as he calls it, from that which melts in a fire. Finally, without skill but with the capriciousness of chemists he places the two species sulphur and orpiment under sulphureous things. Actually con-

gealed juices embrace sulphur, bitumen, realgar, and orpiment. Similarly, due to insufficient knowledge and experience, he divides the genus of saline minerals into three species, namely, halite, alum, and *atramentum sutorium*. Halite has a saline taste but alum and *atramentum sutorium* have only a very faint saline taste. Yet the classes of meager congealed juices have been distinguished by taste and other qualities.

Albertus calls minerals which have the properties of both stones and metals by an intermediate name. He recognizes that metals characteristically melt in fire while stones do not. For this reason he considers stones to be dry and earthy, metals moist and aqueous. He regards intermediate minerals as having the properties of both a dry earth and a liquid. Certain of these are composed principally of earth, others of water. The intermediate minerals include halite, *nitrum*, alum, *atramentum sutorium*, orpiment, pyrite which is called *marchasita* by the Moors, *pompholyx*, and slag which is called *σκωρία* in the Greek language. By this classification minerals that have a mixed composition are called intermediate although actually pyrite is the only one that is truly intermediate since in this case stone is mixed and combined with a metal. Halite, *nitrum*, alum, and *atramentum sutorium* have neither a stone nor metal in their composition although they may be united and joined together with semi-stones. *Arsenicum* is rarely metallic, never intermediate. *Pompholyx*, concerning which Albertus has written, and slag are not natural substances but are produced in furnaces. Basing our classification on the above arguments, if we call intermediate only those minerals formed from water and earth, we will have in the intermediate class stones and metals which are composed of these elements. Since, however, some stones melt in fire and some do not, resistance to melting is not a characteristic of stones for if it is, then stones which melt would not be stones but intermediate minerals. No one has dared to say this, not even Albertus himself. Similarly Avicenna is not able to classify earths in any correct genus. Since I am about to discuss each genus of bodies formed in the earth, what it is and its nature, I shall regard earths as mixed minerals and, speaking frankly, disregard the opinions of certain of the Greeks.

There are two forms of subterranean bodies without life, one of which, because it is blown out and flows out from the earth we call by a characteristic name, the other we call mineral. A mineral body may form from portions of a similar substance, for example, gold, every particle of which is gold, or from dissimilar substances such as a clod which is composed of earth, stone, and metal. Actually it is separable into earth, stone, and metal. The former mineral body we call non-composite, the latter, composite. The non-composite bodies we divide still further into simple and mixed. There are four kinds of simple mineral bodies, earth, congealed juice, stone, and metal. There are many kinds of mixed mineral bodies which I shall discuss a little later.

Earth is a simple mineral body which can be worked in the hands when

it is moistened and from which mud can be made when it is saturated with water. True earth may be found in veins and veinlets within the earth as well as on the earth's surface in fields and meadows. Earth is by definition a universal thing. Although the harder earths do not readily form mud when saturated with water nevertheless this is true of even the hardest if they are left in water for a sufficient length of time. There are many species of earth, some of which have been given names.

A congealed juice, called *ὑγρὸς πυκτός* by the Greeks, is a dry, rather hard mineral body which is either not softened in water but dissolves or, if it softens when sprinkled with water, it differs from an earth in unctuousness or in composition. Although sometimes it has the hardness of stone it can be distinguished with ease since it retains the form and appearance of congealed juices which are softer than stone. Congealed juices are divided into harsh and unctuous. There are three species of the harsh because they form from three different things, namely, a liquid mixed with either an earth, a metal, or a mixed substance. In the first we find halite and *nitrum;* in the second, *chrysocolla*, *aerugo*, iron rust, and *caeruleum;* in the third, *atramentum sutorium*, alum, and an unnamed acid juice. *Atramentum sutorium* and alum form from pyrite, the unnamed acid juice from *cadmia.* Unctuous congealed juices include sulphur, bitumen, realgar, and orpiment. Although *atramentum sutorium* and alum may be somewhat unctuous they will not burn. These latter minerals also differ in origin from the unctuous juices. The latter are driven from the earth by the force of heat, the former are produced by the action of moisture on pyrite.

Stone is a dry, hard mineral body that may soften a little after standing in water for a long time and is reduced to a powder in fire or is not softened in water and melts in only the very hottest fire. In the first genus we find stones that have been hardened by heat, in the latter genus those that have been congealed by cold. These two genera are of similar material. Writers on natural subjects who have considered the quantities, qualities and values of stones have divided them into four genera. The first genus, without a special name other than the general name stone, includes magnetite, hematite, and agate. Minerals of the second genus are called gems and embrace unusually hard minerals which are either transparent or sparkle with many beautiful colors. Minerals of the third genus are called marbles and these are only pleasing to the eye when polished. Minerals of the fourth genus are called rocks and are obtained from quarries. Rocks are of indispensable use in buildings and in sculpture. They do not show marked colors or take sharp edges. Few stones are lustrous and even fewer are transparent. At times marble cannot be distinguished from non-transparent gems except by size or quantity. Rocks can always be distinguished from true stones by size. Gems are found, characteristically, in veins and stringers that run through rocks and marbles. There are many species in each of these four genera which I shall describe later.

A metal is a natural mineral body which is either liquid or solid and will

melt in a fire. The molten metal, on cooling, again becomes hard and returns to its original form. In this way it differs from a stone that melts in a fire. The molten stone becomes hard when cool but does not return to its original form and appearance. There are reported to be six species of metals, namely, gold, silver, iron, copper, tin, and lead. Actually there are more. Mercury is a metal although we differ on this point with the chemists. *Plumbum cinereum* (gray lead) which we call *bisemutum* was unknown to the older Greek writers. On the other hand Ammonius writes correctly many metals are unknown to us, as well as many plants and animals. Stibnite, having been smelted and refined in a crucible is seen to belong more properly to the genus of lead minerals, tin, lead, and bismuth, than writers think. Moreover, having been refined in this manner and added to tin in the proper proportions, it produces the alloy *libraria*. *Libraria* is used by printers to make type.[5] Actually each metal has its own characteristic nature which it retains when parted and separated from those metals with which it may have been mixed. Thus, neither *electrum* nor *stannum* is in itself a metal but a mixture of two metals. *Electrum* is a mixture of gold and silver; *stannum*, lead and silver. If the silver is parted from the gold, gold remains, not *electrum*, if parted from the lead, lead remains, not *stannum*. We cannot say whether brass occurs as a native mineral or not. The only brass known to us is the artificial product made from copper having been dyed with the color of *cadmia fossilis*. If any has been mined it has had the characteristic appearances of a metal. *Aes nigrum* and *candidum* are seen to differ from the *rubrum* species. Thus a metal is either solid or liquid. Mercury is the only liquid metal.

Leaving the genera of simple minerals I shall now take up the mixed minerals. I shall not discuss all genera but only those that Nature has created from inanimate substances. In the class of mixed minerals I have placed those which have formed from two or three simple substances which are themselves mineral bodies. These are true minerals but with their constituents so mixed and combined in proper proportions that the smallest particle of the mixed body contains everything found in the body as a whole. They are so combined that if the mixed mineral contains three simple constituents or bodies, one can be separated from another by the force of fire, or a third from the other two, or two from the third. The two or three constituents are commonly combined in the new mineral in such a manner that the original character of none is evident. A composite mineral, even though it contains these same simple constituents, differs from a mixed mineral. The simple constituents almost always retain their form and one can be separated from another, not only by fire but also by water and sometimes even by the hand of man. Since these two things differ so greatly that one may be distinguished from the other I wish to distinguish them by those two names. I realize that Galen called an earth which con-

[5] Type metal is usually an alloy of antimony and lead rather than tin.

tained metallic particles a mixed earth when it is actually a composite earth. But it behooves one who teaches others to give exact names to everything.

An earth and a juice do not form a mixed mineral if the former absorbs the liquid, surrounds the congealed juice, or adheres to it. The juice can always be washed out and at times even removed by hand. But a stone and a juice can produce a mixed mineral when a solid is created from material of each one, even if sometimes if retains the appearance of one of them. Many mixed minerals form from an earth and a metal and even more from a stone and a metal. Several mixed minerals contain a stone, juice, and metal. Thus we see that there are four forms of mixed minerals which again, as genera, are divided into species.

When two simple substances form a mixed mineral they may be combined in equal or unequal proportions. When combined in equal proportions they form one genus and combined in unequal proportions they form two, since sometimes one substance predominates, sometimes the other. According to that reasoning three genera may be found which contain a metal and a stone, however, only one of these genera has been found that contains an earth and a metal, namely, the third genus which contains more metal than earth. I believe that the first genus with equal parts of metal and earth and the second with more earth than metal have never been found. Only the first and third genera of mixed minerals which contain a stone, congealed juice, and metal are found. This class of mixed minerals is formed from these simple things in such a manner that the mixture contains abundant metal and more congealed juice than stone. This refers to mass not weight since the mixture might have a greater mass of congealed juice than metal and yet the metal could have the greater weight.

Since the third genus is divided into three parts, there are six genera of mixed minerals and each of these contains many species. The first genus which forms from stone and congealed juice embraces Tusculum flint, Sabine stone, and many others. The second genus contains a metal and earth, the third has equal parts of stone and metal, the fourth is rich in metal, the fifth, with an abundance of stone embraces gold, silver, and copper ores. The sixth genus includes sulphurous pyrite and bituminous *cadmia* which contain other metals. The older Latin and Greek writers have not recognized the natures of many mixed minerals, or if they did, they have not described them sufficiently. They have called the forms of these either stones, such as pyrite, *cadmia*, and galena, or veins of gold, silver, and copper, since they did not distinguish between composite and mixed. I shall not say more now about these things but will take up the earths, both simple and mixed.

They distinguish one earth from another on the basis of utility and the different uses it offers to artisans. One is useful to farmers for nourishing and supporting plant life. Another is used by physicians, for example, Lemnian, Samian, and Armenian earths. Sculptors and potters use another such as the clay which is called *creta* by the potters. From this each fashions and shapes his works. Some are used by carpenters, for example red ocher which, for that reason, is called *fabrilis*. Painters have used Paraetonian, Melian, and other earths. Fullers use others such as Cimolian. Silversmiths use *creta argentaria* and many other earths are used by other artisans. This classification does not consider the true nature of earths and fails to distinguish sufficiently one earth from another. For example, Egyptian earth is both cultivated and used as a medicament. Red ocher (*rubrica*) is used by physicians, artisans, and painters. Cimolian earth is indispensable to fullers and physicians. Therefore, if we classify earths as medical, potter's, artisan's, etc., we have to place the same earth in several species and genera. Since a substance cannot be transferred from its own genus to another genus, medical earth, potter's earth artisan's earth, etc., cannot be species. While the mass of common people may distinguish one earth from another in this way, the expert in natural history who must treat his subject correctly cannot use this classification. Some earths are classified as distinct species under genera according to the place or region where they are found and from which they take their names, such as Samian, Eretrian, Chian, and Selinusian. Although people sometimes add to the name certain characteristics in which one earth is known to differ from others, nevertheless the true character cannot be satisfactorily described in this manner.

First we must enumerate the principal differences of earths, next make clear to which class each earth belongs and the district from which the name is derived. It will be seen that I accept the common practice of giving locality names to earths because of the lack of another name and I believe that earths from one locality may be worthless while similar ones from another are valuable.

An earth, like other mineral substances, is either simple or composite. I do not say that simple earth is free from the other elements for scarcely any earth is found that does not contain a certain amount of water, fire, or air but it contains no other mineral or liquid juice. A composite earth, on the contrary, contains either one or several minerals or may have absorbed a liquid juice. For example, *ochra* is usually simple even though it has been subjected to fire and has a certain acrid quality, as is usually the case, while Melian earth is composite because it contains alum. Simple

earths are found in one place, composite, in another. The presence of any of the other elements, water, air, or fire, in a simple earth can be determined in the following manner. Earth is essentially heavy but one that contains air throughout its mass is light. Earth is essentially dry but when it contains any cold water it is astringent and if it contains fire it is acrid. When an earth contains both air and water it is glutinous and light while the presence of both air and fire make it light and acrid.

Simple earths are distinguished from one another by qualities and those things that are related to their place of origin. They may be meager, unctuous, or intermediate; porous, dense, or intermediate; soft, hard, or intermediate; and smooth, rough, or intermediate. They are distinguished by variations in color and may be white, black, yellow, red, purple, green, blue, gray, or brown. They differ in taste being sweet, oily, sour, oily-sweet, or oily-sour. Many earths are astringent. Some show differences in odor but this cannot be detected in most cases unless the earth is treated. The odor agrees with the taste and is usually said to be either agreeable and pleasing or disagreeable and foul. Earths differ in form of occurrence being either tabular or non-tabular. In addition, there are certain elemental differences in simple earths. They are usually dry and cool although warm or tepid earths are known and even though these are cooled they will return to their original nature. When any portion of such an earth or even the entire mass is sprinkled or soaked with water and then dried it returns to its former state. Some of these qualities are readily perceived by the physical senses, color by the eyes and taste by the tongue if the earth is not too disagreeable to taste. When an earth has a very disagreeable taste it is better to mix it with some sweet water and then taste the water. By touch we perceive the hardness, softness, smoothness and roughness of earths. To test the meagerness, an earth is softened with water and thoroughly worked by the hands. A small ball of this is then thrown on the ground and if it cracks open it is meager, if not, it is unctuous. Actually some earths are so unctuous that when placed on the tongue they melt like butter. Lightweight earths are porous, heavy earths, dense, while those which are intermediate in weight have an intermediate texture. The weight is determined by either holding it in one's hand or weighing it on scales. In any case it is important that the sample examined be representative of the whole. I do not agree with Pliny who denies that lightness or heaviness can be determined by true weight.

Through the combining of differences various forms of earths are created. While it may not be possible to enumerate all of these as Columella has done with the earths used by artisans and farmers, certainly one who discusses the nature of these things should not only classify them but also describe them very carefully.

A simple earth may be either meager, unctuous, or intermediate. An earth in any one of these classes may be either porous, dense, or intermediate, thus increasing the number of varieties to nine. Any of these

nine varieties may be either soft, hard, or intermediate, thus making twenty-seven varieties. Any of these may be either smooth, harsh, or intermediate, thus increasing the number to eighty-one. Smooth earths, as I use the term, have congealed uniformly, harsh earths, unequally, and intermediate earths in some intermediate manner. For this reason soft and intermediate earths may be harsh; hard, rarely so. Finally, since any of these may be either white, black, yellow, red, green, blue, gray, brown, or even some other color, a vast number of varieties are seen to exist.

Taste increases the varieties of simple earths. They may be oily or oily-sweet, each of which is due to a good juice and true taste. Some are oily and acrid or at the same time astringent. Others are only acrid or astringent.

Although the odor of earths agrees with the taste, Latin writers do not use the same names for both qualities but describe odors by those names mentioned above. Earths that have been dry for a long time have an agreeable odor when they absorb sudden and moderate rains.

Some earths can be broken up with ease, others are glutinous or intermediate. These qualities do not form new varieties since meager earths can always be broken with ease, unctuous earths are glutinous, intermediate earths, intermediate. In the same way light, heavy and intermediate earths do not form new varieties since all porous earths are light, dense earths, heavy, etc. Thus we see that Nature has combined these many differences in such ways as to produce the many species of earths mentioned by the older writers. Many species lack names and the names of some come from either their natural color or the region in which they are found.

I shall now take up the forms of earths, those cultivated by farmers and those used by potters, fullers, painters, carpenters, and other artisans. All prefer simple earths and reject the composite ones except the potters who use some arenaceous earths. Farmers sometimes select unctuous sandy soils for growing sesame. They classify soils first of all according to their fertility, sterility, or intermediate qualities and then according to their denseness or porosity without considering an intermediate class. Finally they consider the taste. Hard, soft, and intermediate classes are not important since all dense earths are usually hard and porous earths soft although any dense, porous, or intermediate earth may be either hard, soft, or intermediate as stated above. But this is a digression from farming.

In cultivated fields only the upper portion is hard and this is only true of unplowed fields before they are moistened by rains. Marl, sometimes used by farmers, is usually hard. It does not matter to a farmer if his soil is harsh, smooth, or intermediate and it is of no importance if it is black, gray, yellow, red, or any other color if it suits his purpose. There are in all twenty-one species of earths which are of interest to the farmer, nine species of rich earths and six each of the poor and intermediate. Rich or unctuous earths are the best since in these, especially in the sweet varieties, there exists a juice which nourishes the grain. Rich porous earths

are the best of all since they yield the finest produce. Porous earths require the least work and afford the greatest yield. Intermediate earths occupy the second place since they require a moderate amount of work while the dense ones which are most abundant in nature are third. However, any fertile soil will produce abundantly.

Wheat, winter wheat, beans, kidney beans, small chick-peas, flax and hemp grow best in rich earths. Wheat, barley, peas, lentils and sesame do best in rich, porous earths. If these are not available the farmer cultivates intermediate earths that, with moderate care, can be worked profitably. The porous intermediate ones are the best while the dense intermediate are inferior. The intermediate produce the same grains as the rich but not in the same quantity. Only turnips do best in loose, plowed, intermediate soils and mustard in similar loose, poor soil. Barley is not planted in intermediate soils, as Columella states, but in the very richest which cannot be injured by intensive cultivation or in poor soils in which nothing else is planted. Intermediate soils, sprinkled with marl or manure, can acquire the fertility of rich soils. No other grain except barley is planted in poor soil and of all the leguminous plants only lupine thrives in a poor, compact soil.

Poor soils are improved by manure and marl (*marga*, lime). A discussion of manures is outside the scope of this work. Marl is nothing other than a very rich, compact earth. It does not matter if it is hard, intermediate, or soft. When dried it changes into sand, *tofus*, or a harder rock and when moistened, into some sort of juice that is known by the same name, *marga*. In regions where the soil is intermediate to poor they use marl as a fertilizer, sprinkling the crushed rock over the plowed fields. Where the soil is fertile as in Campania, Italy, Bohemia, and Thuringia, Germany, marl is never used even though it is abundant in these localities. The word *marga* is derived from *medulla*, marrow of bones, for sometimes the water which flows from marl is as white as marrow and hence has been given this name by the Germans and the Gauls who speak the same language. The white solution is called *Steinomarga* by our German miners. Marl is sometimes found along fractures and joints of rocks but more commonly enclosed within the rock itself. It is usually hard. When drunk it will stop profuse bleeding from wounds and, in general, has the same medicinal properties as Samian earth. The variety of marl found in mines and quarries is not used by farmers since it occurs in small quantities.

Pliny has given an excellent description of this mineral. He emphasizes its aid in increasing the productivity of soils. It is a sort of soft fat of earth and, like the glandular organs in the body, there thickens itself with a nucleus of richness. There are many varieties, the best being found in characteristic veins. It occurs as an earth, usually hard, somewhat sandy, in part tufaceous, in part as hard as solid stone. All of these varieties vary in color being either white, brown, dark red, iridescent, green, gray, yellow, etc. As a rule the tufaceous, arenaceous, and stony varieties feel rough

while the earthy varieties are smooth or intermediate. Marls differ in form. Some form crusts, usually earthy and rarely stony. Tufaceous varieties are porous, sometimes with openings like pipes that extend through the entire body. The purer the marl the better it is for fertilizing and the harder it is the longer its action. Some of the hard varieties are richer than others. Soils can be made fertile for many years by either applying a large amount at one time or small amounts over a period of time. Softer varieties are best for dry soils, harder varieties, arenaceous, tufaceous, or stony, for moist soils. In Greater Germany only the farmers in Saxony use it. Some of the fields in Thuringia and Bohemia are too fertile. When manure is abundant the farmers prefer to use it.

Marl does not occur in some of our mountainous districts. It is quarried in many places in Saxony, namely, between Mundar and Cassel, a town in Hesse, where it has a variety of colors; an iridescent variety in western Hildesheim near the Indersta river at the foot of a hill; white tufaceous marl on the south side of Mt. Alfeld; red and iridescent varieties at localities in Desterus. A pale greenish blue variety is also found at the foot of Mt. Desterus. Two varieties are found at Goslar, one gray, the other whiter, the latter being used to make metal molds. Solid masses of these two varieties are split into thin sheets by the action of frost during the winter months. Two varieties are found between Gandersheim and Sesena, a town about five miles from the Harz forest. One is red, the other white, both being stony, tufaceous, and arenaceous. French and British farmers have used marl within our times. With either a rich, porous, or intermediate soil any farmer would profit greatly by using it since it would increase the fertility of his soil. The Ubii,[1] according to Pliny, covered their fields with a foot of marl and then dug them up to a depth of three feet. This same method is used today by the inhabitants of Juliers and their neighbors. The material they use is rich although not as dense and hard as true marl. Pliny states that a poor soil can be improved by spreading a rich soil over it. Many believe this although it is foolish for the poor soil is not improved as has been proven in France and Britain. Only marl can improve the fertility of compact soil. Columella approved the practice of his uncle in using chalk on sandy soils when manure was not available.

I shall now consider the earths used by potters and sculptors. They, like the farmer, use unctuous earths but the farmer prefers porous earths while they prefer those which are dense and semi-soft, never as hard as marl. Both Theophrastus and Dioscorides write that some of the earths from Samos were suitable for their needs. If dense earths are not available the intermediate varieties are superior to the porous. Intermediate or semi-hard clays are the best, the soft, next. Porous clays are rarely used and those which are incoherent are valueless. When porous varieties are

[1] An ancient German people who dwelt on the east bank of the Rhine near Cologne.

used, those which are soft to intermediate are given preference over the hard. All must be unctuous. Unctuous and dense clays are used to make the crucibles and scorifiers which are not affected by fire and are used in refining ores and metals. These clays are also used to make vessels which neither absorb nor exude liquids. Such vessels are used in mixing and storing the solutions for parting gold and silver. Dense clays are more difficult to work by hand than the intermediate and porous varieties. Harder clays, although more tractable, require a great deal more work to prepare than soft clays. Vessels that do not absorb liquids are made not only from dense clays but also from sand which is mixed and burnt. These vessels such as those from Waldenburg are in great demand by pharmacists for holding liquids and syrups since they last longer than others. These also withstand fire for long periods of time.

Some containers that absorb and even exude liquids are made from unctuous porous clays. These are the only pottery that are not completely burned. They cannot stand a high heat for when the moisture is completely driven off and their unctuousness destroyed they develop flaws and cracks and may even be reduced to a powder. For this reason potters place amphorae, deep dishes, and small pots made from this class of clay in the sun to dry and after decorating them with various colors sell them in the unburned state. When sand and straw are mixed with this class of clay before burning it does not break so easily in the furnace. It is a common practice to mix sand with any clay that is available and use this mixture in making cooking vessels. Loose textured clays, even though mixed with sand, become porous during firing and will exude liquids. The jugs from Gislan, from which we drink new wine, are made by adding sieved sand to clay and thoroughly mixing the two by treading. Clays that are naturally sandy will be discussed later. A little dry sand is often added to Waldenburg pottery before firing to make it rough with the result that some of this pottery has the appearance of a sea urchin.

Since unctuous clays are not of a uniform color the pottery made from them also varies in color. Some clay is white and because of this whiteness it is called ἄργιλλος by the Greeks, *argilla* by certain Latin writers. The Eisleben clay that sparkles with silver-mica belongs to this class. Some clays such as the Waldenburg are grayish-white. The triangular crucibles used by people who coin gold and silver are made from gray clay from Ipsa. Yellow clay is found at Midbeida. Red clay occurs in the silver veins at Annaberg and this is used in making crucibles and scorifiers. Black clays are found at Glogovian in Ligyes. Some clays have variegated colors, for example, the white and yellow clay of Midbeida.

A potter will choose first one clay then another for making different kinds of pottery but the sculptor always chooses an easily worked clay. Potters have made countries, islands, and towns famous, for example, the pottery from Murviedro, Spain; Polenza, Asta, Modena, and Arezzo, Italy; the goblets from Sorrento, Italy; the dishes of Reggio and Cumae,

Italy; and the dolia from the island of Ischia which is also called Pithecusa by the Greeks. The pottery of Pergamon and Tralles has added to the fame of Asia. The pottery from Cos was well known to the ancients and that from Samos has been described repeatedly. The exquisite pottery of Aretina and many other localities in Italy and Persia is still being made today. The vessels made at Askalon are highly prized in Syria. The Greeks brought utensils from Keft, Egypt, that had been mixed with scent and resembled the pottery from Rhodes. They called this pottery "aromatic." The Waldenburg pottery easily holds first place as regards usefulness although it is not beautiful while that from Seburg is second. Neither absorbs liquids. Norinberg produces earthenware furnaces used in refining metals and ores. The crucibles used in making brass are made from a clay found near Roteberg, a fortified city twelve miles from Norinberg. When these crucibles, filled with brass, are withdrawn from the furnace they do not break but can be drawn out and twisted like glass. The triangular crucibles used by the men who coin money come from Ipsa, a town of Upper Pannonia. These are made from the Tasconia clay, in Spain. This clay, according to Pliny, is white and resembles *argilla*. The crucibles cannot be used a second time.

Among the men who work with clay are those who make bricks. They use unctuous, porous clays since these are more coherent and lighter. Although they use clay of any color they prefer that which is either white or red. Plasterers use only those clays which are unctuous. The men, called *fornacei*, who build furnaces and furnace walls prefer an unctuous earth since, according to Pliny, the furnace walls are constructed by tamping earth between two boards instead of building them. If different kinds of earths are available, when constructing high furnaces, heavy earths are placed in the lower portion of the walls, intermediate earths in the middle and light earths at the top. A high furnace of this type can be seen today near Ceruecia, Saxony, and many were built in Spain according to Pliny. Hannibal mentions having seen earthen observation towers that were located on the highest peaks of the mountains in Spain. This class of edifice, although less attractive than one of wood or stone, is more resistant to fire, rain, or wind. Earth tremors damage stone towers more than earthen ones. Rains may destroy wooden and even rough stone towers while earthen towers are little affected, if at all. Winds may blow down wooden and even stone structures while those built of earth are more resistant. For this reason Pliny writes that in Africa and Spain walls made of earth resist fire, wind and rain and last forever, actually becoming more resistant with age. In Thuringia and Saxony they mix hair with the clay, as a rule, and construct walls without first tamping the clay into bricks. Such a wall can be seen today at Cribera, Misena, about five miles from Leipzig.

I shall now take up fuller's earths which are unctuous but, having been dried over a fire, become acrid and, because of this, possess the power to

clean cloth. Only fullers use these earths for cleaning. Some fullers, limited by the unctuousness of their earths, add soap believing that this will increase their cleansing power. Many of these earths derive their names from islands and countries. Cimolia earth, also called Smectis earth because it cleans so well, comes from Cimolus, one of the Cyclades islands; Sarda earth, from Sardinia; Umbrica earth from Umbria. Only the earths from these localities are of value. They are used in the following manner. If the cloth is colored it is washed first in a vessel with soap and Cimolia or Umbrica earth. Theophrastus writes that instead of Cimolia earth the Greeks used gypsum from Tymphrestus. The cloth is then fumigated with sulphur. Finally it is again cleaned with Cimolia earth. If the cloth is white, instead of Cimolia or Umbrica earth, they use Sarda, then fumigate with sulphur and accomplish the final cleaning by beating the cloth on a rock.

Fuller's earths are found today in many parts of Germany, for example, Fulda in Alsace; two varieties, one white similar to tufa, the other gray, at Hildesheim, Saxony; a gray earth at Cadan, Bohemia; a lighter gray earth at Leipzig, Misena. The color of the earth is of no importance, the primary property being the power to remove grease from cloth. According to Galen fullers used one of the three genera of Lemnia earths. It is seen that any unctuous, acrid earth which is not hard can be used by a fuller.

Painters use meager, intermediate, or slightly unctuous earths, the most unctuous being called Paretonium. It does not matter if the earths are porous, intermediate, or dense but they prefer the soft or intermediate varieties since the hard earths require too much work to prepare them. All must be crushed fine. Although they use those which are moist they prefer the dry since these are easier to prepare. Painters are the only artisans who select earths on the basis of their color. Some are white such as the chalk from Paretonium, Melos, and Eretria. Ochers may be various shades of red and yellow. Some earths, commonly found in mines, are realgar-red. Chalk may be green or black. Other earths are found with many different colors.

Similar earths are used by carpenters, for example, red ocher, green, and black chalk. Carpenters can use any color except white since a white line is not readily visible on white wood. Other artisans prefer meager or porous earths which are either soft or intermediate and somewhat acrid. Hard earths are of little value. Silversmiths use a clay[2] called *argentaria* for cleaning silver. The name is derived from its use by silversmiths. The earth used by barbers is called *tripela*.[3] It is used to clean the brass vessels in which they keep the warm water and soap used in washing and shaving. This same earth is used to polish armor and gems. It is yellowish in color and harsh to the touch. Other earths used for polishing and cleaning may

[2] Agricola uses the word *creta*, the name usually applied to chalk. However, since chalk is harder than silver it is doubtful if it would be used to clean it.

[3] A German corruption of the latin spelling, *tripolis*.

be white such as that from the village of Hasda in Hildesheim. This white earth is sometimes stained red. These earths are usually harsh.

I shall discuss now the use of earths in medicine. All, since they are naturally dry, possess the power of drying. Earth, in general, is astringent and cooling and breaks up infections. The most astringent earth is the coolest. Some earths are so astringent that they will tear the skin from the tongue when placed on it. The greenish earth found at Linda, Hanover, belongs to this class. Some earths are not so astringent and others only moderately so. An acrimonious earth has a taste characteristic of heat. It warms the skin and usually the more acrimonious it is the more it heats. One which is so weakly acrimonious that the senses cannot detect it, warms very slightly and produces no biting or pain although it cleanses. Some earths with an oily taste feel like glue on the tongue and while they are neither astringent nor acrid they may be used as an ointment and cool the skin moderately. Any earth that is either warm or cool to the skin and can be spread may be used as an ointment. With an increase in unctuousness it becomes warmer or cooler. An unctuous, astringent earth may be used as an astringent ointment and an unctuous, acrid earth as a cleansing ointment. Only by careful study of the simple earths which come to hand can one judge accurately the uses to which they are best adapted.

I shall now discuss earths which have taken their names either from the locality in which they are found or from their color and shall attempt to describe their various properties. This is not difficult in some instances since various writers describe certain properties by which one earth is distinguished from another. In other instances it is very difficult since writers have described the medicinal properties of the earths and make no mention of any others.

There are two varieties of Samian earth, one called *collyrion* because it is commonly used in eye remedies which are called *collyria* by the Greeks. The other earth is called *aster*. The origin of the latter name is not definitely known but may come from the star (ἀστήρ) with which the earth is stamped when placed on the market just as the Lemnian earth is stamped with a goat. The name may come from the large amount of glistening mica. Mica is also common in the Eisleben clay. Both of the Samian earths are used in medicine. Dioscorides preferred *collyrion* to *aster* while Galen preferred *aster* for some diseases and *collyrion* for others. The latter is an unctuous, porous, white, soft earth with an oily-sweet taste. Being unctuous it is also glutinous; being porous it is light; being soft and dry, friable. Dioscorides writes that it is glutinous and the taste is obvious when placed on the tongue. He observes that glutinous earths are always unctuous and porous earths are light in weight since they can hold a large quantity of air throughout their mass and this is the cause of the lightness. He describes the earth as soft and easily crushed which indicates that it is dry. Finally he says it has a good taste, meaning oily-sweet, which is observed when the earth is placed on the tongue and dis-

solved by the tongue's moisture. Since an earth of this type dries and is moderately cooling it reduces inflammation of the testes and breasts when mixed with rose water. Since this type of earth is glutinous and can be spread over any surface it will stop bleeding from any part of the body, as mentioned by Dioscorides. Galen describes Samian earth somewhat differently. He writes that the Samian *aster* is more glutinous and tenacious and since it is moderately cleansing, as are Chia and Selinusia earths, it is useful in treating skin ulcers and burns. Evidently Dioscorides was acquainted with one kind of Samian earth, Galen another. This is not to be wondered at since Theophrastus mentions that there are many different kinds of earths found on Samia. Since Dioscorides mentions that he prefers the very whitest variety we can conclude that gray and even other colored earths are found there and while they may not differ in other qualities they at least differ in color from the one described by him.

Samian *aster* is unctuous, dense, smooth, and found in thin beds. Since it is unctuous and dense it must be glutinous and heavy. Some of the other qualities are not mentioned in descriptions but Galen writes that it is sticky and glutinous; Dioscorides, that it is dense; Theophrastus, that it is smooth. Although it is dense and hence heavy, it is lighter than Lemnia earth and heavier than *collyrion*. If these earths had been more abundant the ancients would have put them to more uses but they were rare and therefore commanded a very high price. Earths, similar to Samia and other famous ones, are found in different localities and it is a common practice to call these by well known names.

Melinum earth takes its name from the island of Melos, yet Pliny writes that it is found on the island of Samos. Chalk (*creta*) takes its name from the island of Crete, yet today we call any similar material by that name no matter where it comes from.

Chia earth takes its name from the island of Chios where it is found. It is unctuous, porous, soft, white to light gray, with a sharp oily taste and for that reason cleanses better than Samia earth. It is used to cleanse the face as well as the entire body. Galen writes that it is similar to Samia but is less efficacious in reducing inflammations of the breast, groin, and testes.

Selinusia earth resembles Chia very closely, even more closely than Chia resembles Samia. The name comes from Selinus,[4] a town of Sicily. The best is highly lustrous, white, friable, and when moistened dissolves quickly and completely. According to Vitruvius, when it is colored blue it resembles the blue dye of India and according to Pliny when mixed with milk it resembles whitewash.

Melinum earth, called *melia* by Theophrastus, is a white, meager to intermediate earth used by painters. Cimolia earth has a few distinctive characteristics. It is moderately unctuous, according to Dioscorides, white

[4] The modern seaport of Selinonto.

to purplish-white, and cold to the touch. Galen describes it as astringent, moderately acrid, cooling, and useful in reducing swellings. Thus it is similar to most other earths that break up and reduce gatherings. He writes that it is more efficacious than either Chia or Selinusia earths and yet it does not bite. Since it cleans better than Selinusia it is used by fullers. Neither Galen nor Dioscorides mention whether it is porous or dense, light or heavy. A doctor needs only to taste an earth in order to determine its medicinal properties. We can assume this to be soft or intermediate since Pliny, writing about fuller's earths, mentioned a rock which he differentiated from the others by hardness. Dioscorides does not describe Samia *aster* as hard and if this earth had been hard he would have mentioned it. In summation, it is moderately unctuous, loose textured, soft, white or purplish-white, sometimes astringent, sometimes acrid.

The earth which physicians call *cretica* is sometimes meager, sometimes intermediate or even moderately unctuous. A similar earth used in Britain for fertilizer is unctuous since it would have to be in order to make the fields fertile for so many years. That found in Germany is loose-textured and moderately soft although the rock from which it forms is hard. It is white and sufficiently acrid to be detected by the physical senses although some is found that is astringent and can be used for cleaning. It resembles Cimolia in that there are different kinds. *Cretica* earth or chalk, according to Pliny, was placed on the feet of the more important slaves to indicate the ones to be taken home as tokens of victory. Silversmiths use it to clean and polish their wares and for that reason it is sometimes called *argentaria*. Painters and men who make calculations on tablets of stone or wood use this earth as it makes a white line with ease. Physicians use it since it cleanses and yet does not bite or sting. There are regions with hills of chalk in France, Britain, and Muna, a desert island in the Baltic Sea on the route from Pomerania to Copenhagen. The latter rock cannot be used for writing because it is too hard.[5] The wall of Constance is built, in great part, of this rock.

Green chalk is similar but is more acrid and cleans better. According to Vitruvius it is found in many places but the best comes from Smyrna. This variety is called *θεοδότιος* after Theodotus who first discovered it. Today it is found in many ore veins and ranks below *chrysocolla* in color and properties. It is meager, intermediate to slightly unctuous, loose-textured, soft, green, and very slightly acrid. It makes a green line just as white chalk makes a white line.

Paretonium earth is named for a seaport just outside Egypt in Cyrenaica. It is unctuous, dense, and white. Pliny describes this earth when writing about *chrysocolla*. This is the most unctuous of all the white earths, and, on account of its smoothness, the most tenacious of all those

[5] Agricola apparently recognized the relationship between chalk and limestone. Chalk is a soft limestone composed principally of the shells of foraminifera. Limestone is a chemical deposit of calcium carbonate.

used by plasterers. We know it to be dense for Pliny writes that it was adulterated with boiled and compressed Cimolia earth. In *De Ortu et Causis Subterraneorum* I have explained how it was formed since shells are found in it.[6] It is not sea foam for the salt would render it useless to plasterers. It is an earth formed from an unctuous rock such as limestone that has been altered. One can see this type of earth at Alfeld, Saxony, where it is sometimes found containing shells. This earth also occurs in Cyrenaica, Egypt, and on the island of Crete. Since it has never been used in medicine nothing is known regarding its taste for a painter does not use taste in classifying earths.

Lemnia earth takes its name from the island of Lemnos.[7] There it is collected into mounds and burnt near a town named for Hephaestus.[8] This earth has many names, "Red Lemnia Earth" on account of its color, *Lemnium sigillum* or stamped Lemnia earth, *sigillum caprae* since it is sometimes stamped with the sign of Diana, a she-goat, in the same way as it is stamped today with Turkish letters. It is a red, unctuous, soft, dense, astringent earth which is sold in the markets today. Galen describes it as unctuous and when writing about lotions says that "a priest dries the unctuous mud until it has the consistency of wax." We know it is dense for Galen writes that it is the same weight as Samian *aster*. Dioscorides also describes it as being dense. Galen writes that it is slightly astringent and is red in color but differs from the red Samian earth in that it does not soil the hands. There are three varieties. One is sacred, according to Galen, and is not handled by anyone except the priests; another is the red earth used by artisans; the third is a fuller's earth. Since *Lemnium sigillum* is unctuous it is slightly glutinous and gummy; being dense it is heavy; being soft and dry it crushes easily as does Samian *aster*. Drunk with water and vinegar it stops bleeding and mixed with the juice of the plantain[9] it cures colic. It has greater medicinal potency than Samian *aster* and for that reason when placed on an inflamed skin, especially a tender skin, it is irritating.

Eretria earth, according to Pliny, takes its name from the city where it is found, Eretria,[10] on the island of Euboea. This city is near Chalcis, the

[6] Book III, page 41, line 21. "A pure or simple earth is formed along channels in the following manner. Rain, which the outer portion of the earth absorbs, first permeates and passes through the earth itself and is mixed with it. Then it is collected from all sides into veins and stringers. There sometimes this water, sometimes water of another origin tears away the earths from them. Much is worn away if the veins and stringers are in earth, little if in rock. But it does wear away even the rocks themselves, more by continual movement, especially the softer ones. Members of the latter genus are calcareous from which are produced chalks, clays, marls, Paretonium, and other unctuous earths, or arenaceous from which are produced barren earths."

[7] This earth is also known as Lemnian bole, asphragide, etc.

[8] The God of fire and metal working.

[9] A common weed of the genus Plantago.

[10] Modern Aletria.

principal city of the island. This earth is moderately unctuous but whether it is dense or not I cannot say as nothing has been written about this property. There are two varieties, the white used by painters, the gray used by physicians. The gray variety has a variable hardness and physicians prefer the softest. Although other earths are used by copper workers to mark the copper with a violet line, according to Galen, this one makes a better line than Lemnia earth and yet it does not eat the metal. After the line is washed off only a very slight trace remains. An unctuous green earth similar to Eretria is found in a limestone quarry in Hanover and is ground for use as a pigment by copper workers although the color after grinding is an intense bluish gray.

Pnigitis earth takes its name from the village of Pnigeus in Egyptian Libya. According to Dioscorides it has a color similar to Eretria earth which we know to be gray. On the other hand Galen and those who follow him, for example, Paulus Aegineta, describe it as black. It is unctuous, dense, soft, black, sometimes astringent, sometimes acrid. It is certainly unctuous since Galen describes it as no less glutinous than Samia earth and if anything even more so. Dioscorides says it will stick to the tongue with such force that it will hang from it. We know it to be dense since Dioscorides writes that it contains solid lumps and cools the hand considerably when held in it. Since it has properties similar to those of Cimolia earth we known it must be variable, namely, some must be astringent and cooling, some acrid and warming. Dioscorides describes it as somewhat weaker than Cimolian.

Not dissimilar to the above is an earth known as black chalk. This is found in Germany near a town which takes its name from waters (Cologne). It is also similar to red ocher and is used by the carpenters in that vicinity in the place of ocher. There are two varieties, one that is soft and makes a line when dry, one that is hard and makes a line when moistened. They are moderately unctuous, porous, black, acrid, and both hard and soft. Each variety is also found at Hildesheim, Saxony, in the moat of the north wall.

The earth the Greeks call μίλτος is red and for that reason is called red earth or red ocher. It is found in gold, silver, copper, and iron mines and was known to Theophrastus. It is sometimes found in pure veins. At one time the best was mined at Cappadocia and taken to Sinope. An inferior variety was found on Lemnos, as I have said, and was one of the Lemnia earths. This material is found on a hill and is the red ocher used by artisans. Ocher is also found in Egypt, Africa, and the Balearic Islands. Dioscorides calls the African earth "Cartaginian ocher." Today it is found in Greater Germany in ore veins and in veins of pure ocher, for example, near the town of St. Wendelin. All red ocher which adheres to rock is of a uniform color and therefore better than other varieties. That which does not adhere to rock and has congealed in lumps usually has variegated colors. There are three varieties of the latter, a deep red, a light red, and one of an intermediate color. The ocher Theophrastus calls αὐτάρκη i.e.,

from its purity, we call "unadulterated" because it is not mixed since merchants are accustomed to mix it with other inferior earths. Painters use all varieties of ocher. Artisans use those from Egypt and Africa, according to Pliny, and physicians that from Sinope. There are three varieties of this earth, one that is soft and when touched comes off on the hands and soils them, an intermediate variety which soils the hands to a lesser extent, and a hard variety which does not soil the hands unless moistened. Each of these, when moistened, makes an excellent line and is widely used by artisans. From these properties we know this genus of ocher to be moderately unctuous, acrid, sometimes hard, sometimes soft. The loose textured varieties may be either hard or soft and usually are astringent. Some ochers are not unctuous, for example that found in Lydia and in part of Hildesheim. The latter occurs in lumps and has a good red color and good taste. It will adhere readily to the tongue and then melt like butter. The ocher from Sinope, according to Dioscorides and Strabo, is obtained from a cave in Cappadocia and after being cleaned is brought to Sinope, a town in Pontus, and sold there. The best quality is dense, heavy, and uniformly liver-colored but this is adulterated and sent to all parts of the world in large quantities. Strabo writes that a red earth similar in quality to Sinopian ocher came from Spain. An astringent, white to reddish-white earth with properties similar to Lemnia earth is found in Elbogan near the town of Toterbisa and in Hesse between Marburg and Suenisburg. It is not to be wondered at that there are as many varieties of red earth as there are of white and other earths.

Armenia earth which both Paulus Aegineta and Aetius Amidenus call "Armenia Soil" derives its name from Armenia on the border of Cappadocia where it is found. This name is also used by the Arabs. It is pale colored and denser and heavier than Samian *aster*. It has the appearance of a stone, yet is soft and friable. Since it dries so excessively it cures colic and oral ulcers, stops vomiting and bleeding, and reduces inflammation. It is very useful in treating cases of wasting diseases and plagues. Paulus Aegineta says it has properties similar to those of Alana earth.[11]

A yellow earth is found in many parts of Germany but is most abundant in distinctive veins in Bohemia and Hesse near Francoberg. The Hessians use it to tint leather while the Bohemians and Misenians use it as a pigment. Although it is highly astringent the Germans usually call this earth and true ocher by the same name.

Many earths that are extremely acrid are found in mines and since these have been dried by the heat of the earth they have the appearance of having been burnt. They vary in color as much as other earths but in general are either yellow, tawny, red, or purple. All have the property of healing and reducing swellings. They all lack names except ocher which the Latins could have named *lutea* (clay) if the Greek or foreign term *sil*

[11] Agricola also calls this earth *gelerbolus*.

had not appealed to them more.[12] *Sil* is the color of clay and is commonly used by painters instead of orpiment, according to Theophrastus, who writes that there is no difference in their colors. Just as *sil* and orpiment have similar colors, the tawny earth that has no name is similar in color to realgar although they differ widely in other properties. Ocherous earths occur abundantly not only in mines but also in distinctive veins. A variety from Athens is the best. The Athenian deposits, related to silver mines, were not worked in the time of Vitruvius because of the scarcity of slaves. Today this earth comes from a portion of Hungary formerly called Dacia; Raetia; the silver mines of Germany; and from Hildesheim, between that city and a cave named for dwarfs, where it occurs in crusts. It is found between Alfeld and Embecca where it often has the appearance of sea shells. This earth has the appearance of pipes in a deposit in Hildesheim on the road between Hasda and Sarsteda. The painters of Hanover burn the ocher found in limestone quarries and use this instead of red ocher. Red ocher is made from purple ocher by first burning it and then when it is red hot quenching it with vinegar. Ocher has an acrid taste. It is used in medicine to cure tumors, mumps, and to retard swellings. Mixed with wax it fills hollows in the flesh and retards stiffening of the joints.

[12] Pliny uses the name *sil* for yellow ocher.

BOOK III

There are many species of earths which can be used by artisans for various purposes. I have described these earths, as I know them, in the previous book. I shall now take up the next class of minerals, congealed juices, of which, as I have said, there are four genera. The first embraces halite and *nitrum;* the second, alum, *atramentum sutorium,* and related minerals as well as the acrid juices; the third, sulphur, bitumen, realgar, and orpiment; the fourth, *chrysocolla, aerugo, caeruleum, ferrugo,* etc. I shall discuss each species in these four genera beginning with halite.

Sal (halite, salt) is known as both a natural mineral and an artificial product. Halite produced by Nature is found both within the earth and on its surface. When it occurs within the earth it is either quarried out of the mountains, or mined from beneath the fields or sands that cover it. The latter are stripped off before the mineral is recovered. There are many famous mountains of halite in the world. In Germany there is a salt lake just to the north of Seburg and rock salt occurs near the gateway of the Caspian Sea. It is not quarried at either place since, at the former locality, a river flows from the lake and carries particles of halite with it and in the latter region salt pits are common. From these the salt workers draw off liquid so rich that they have no need for the natural mineral. Halite is mined in quantity in the Carpathian Mountains at Salzburg, Torrenburg, Aderhell, etc., areas inhabited by the Siebenberg and Ceculus people. The most famous mine in Germany is near the town of Thusa. Onesicritus writes that it was mined from a certain mountain in Carmania. Other sources are Oromenus, India, and according to Pliny, the mountains of Africa near Ammanien. It comes from three places in the part of Sarmatia that is now called Poland. First, near Cracow, where digging started only recently and where, in contrast to the second locality, no stones are found; second, a place about eight miles from the town of Veliscus; third, about thirty miles from Bochnia. The pits near Veliscus have not been put down in the plains but in rolling ground toward the coast, to the south, and back in the mountains. However, the most important mines are those of Stassfurt, Saxony. In summer a sprinkling of salt can be seen on the plains and salt effloresces at all times. It is mined near Kolomea in the neighborhood of the Rutheni and the Valachi. It is also mined at two places in Cappadocia, one near the towns of Colupena and Camisena near Lesser, Armenia, the other in Ximena near the headwaters of the Kisil-Irmak river, as mentioned by Strabo. Ambrosius mentions the mines in Britain; Pliny, the mines in Spain near Egelasta; Posidonius, the mines in Arabia; and Strabo, the mines on the island of Meroe. Pliny mentions occurrences overlain by sand at Castle of Tineh, Egypt, and in the deserts of Africa

between there and Arabia, in Cyrenaica. While all this latter salt can be called sal ammoniac, the name is usually given only to that from Cyrenaica. So much regarding the occurrence of natural halite within the earth. Natural halite is found also in springs, rivers, lakes and oceans on the surface of the earth. Springs, such as the hot springs at Pegasius, may carry salt. It is often produced from rivers when they are dried up by the sun's heat. The salt plain of Narbonne, France, is of this origin. The plain near the marshy spring at Schönbach in Elboganum becomes white with salt during the summer. A river may carry small grains of salt as do the Oxus and Ochus rivers where they flow out of the mountains opposite Balkh, or rivers may have a crust of salt on the surface and the water will flow out from under this crust as freely as does the water from under a glacier. An example of the latter is the river which flows into the Caspian Sea between Armenia and Mardos. Pliny has written extensively about salt, apparently having taken it from Theophrastus. A lake may be saturated with salt and even turn into solid salt. It turns into salt in different ways. The entire lake may be so converted as at Taranto, Apulia, and at Tragasaeus, Aeolia, which is near Amaxitus not far from the temple of Apollo. One part of the lake may turn to salt as at Tuz Geul, Phrygia, from whence comes the Tattaeus salt; in Cappadocia; at Aspendus, Pamphylia. Only the ends of some lakes are converted into salt as at Cocanicus and Gela, Sicily. The lake near Citium, Cyprus, and the Dead Sea of Palestine have become saturated with salt. The salt from the Dead Sea is called "Salt of Sodom." Other lakes that produce salt are two desolate lakes in Balkh, one near Scythia, the other near Arios; one near Memphis, Egypt; many in Africa. Salt forms in thin crusts on the shores of oceans. In summer when it is hot foam forms and this is driven onto the shore and rocks. This foam, cut off from the ocean, dries and is converted into salt. The material Dioscorides calls ἅλος ἄχνης, Pliny calls "foam" and we, usually, "dry sea foam" or more correctly "salt formed from sea foam." Younger writers call it *salis spuma* (foam of salt). Although they write in this poetic manner nevertheless they understood its origin as I shall explain elsewhere.

I have said enough about the origin of halite and shall now take up briefly the manufacture of salt since I can explain the differences in its natural properties and formation more accurately this way. Salt is produced from marine waters, saline springs, salt wells, and from alkaline solutions. I shall explain the methods of making salt in a book on mining. Halite varies in color. The natural mineral from Sarmatia is transparent and white. Similar material is found in the Carpathians and in Dacia while the mineral from the lakes near Taranto is the finest of all. Our salt works at Luneburg produce white salt. "Flowers of salt" whether it blossoms in mines or brine pits is usually white. Gray halite is often not transparent, as at Sarmatia and Dacia. In these various localities the halite may be white in one place and black or gray in another. Norwegian salt which is

refined in iron vessels is black and for that reason is used by the country people. The black halite found in Sarmatia is as transparent as the white and occurs in veins and stringers. The mineral in the enlarged portions of the veins is cut into blocks. The Arabs write that black halite is found in India. According to Pliny, salt that is refined in wood is black. The natural mineral from Cappadocia is yellow; that from near the Oxus river in Balkh, reddish; that from Dacia and Memphis, Egypt, occasionally red. Some of the halite from Spain is purple but when crushed turns white. That from Centorbi, Sicily, is also purple.

Halite varies in transparency and brilliancy or luster. While all other salt may not be transparent, the crusts which resemble gypsum, such as the natural halite in Cappadocia, and sal ammoniac generally are. The finest halite of Sarmatia and Dacia, which occurs in cubes, is so transparent that it compares favorably with quartz. This quality is correctly named "gem salt." The transparent natural mineral also occurs in Spain. The mineral which forms in the lakes of Sicily near Gela is so brilliant, according to Pliny, that it reflects an image as well as a mirror.

While all salt has a taste which we describe as "salty," the drier the salt the stronger the taste. As a rule the manufactured salt is milder than the natural mineral. The halite from Taranto has a mild taste; sal ammoniac, unpleasant; from the Dead Sea, bitter; that formed from sea foam on cliffs, acrid. The salt from Kolomea has a taste similar to that of a dried egg. This salt, either "flowers" or finely crushed material, is pressed into four sided cakes and various figures are stamped into them on all sides.

Some halite gives off a strong and pleasing odor. The Arabian mineral has a slight odor while the Cappadocian mineral has a very strong odor. Since natural halite is more compact and harder than other salt it is also denser. Marine and lacustrine salt, as a rule, is less compact, softer, and not as dense. Nevertheless in all these salts there are dense portions. On the other hand salt made from brine is tenuous, usually fine-grained and soft. The most tenuous is "flowers of salt." This resembles the finest and lightest ashes and is very white. "Flowers of salt" produced from marine water differs from that produced from brine in that it is moist, unctuous, yellow, and similar to the salt used in baths as I have explained elsewhere.

Halite occurs in various forms. The Sarmatian and Dacian mineral occurs in cubes and is called "gem salt." Some occurs in the form of a pyramid, for example the white salt from India. This salt is either not the natural mineral or, if natural, is formed from "flowers of salt" or fine-grained material since it has a trade-mark stamped in the base. Some salt occurs in crusts as that from Cappadocia, and sal ammoniac. It is even mined in various shapes, the most noted being the cubes of lustrous Sarmatian salt, some of which weigh as much as two thousand pounds. The artificial mineral is obtained sometimes in the form of large pyramids[1] as that from Halle of the Hermunduri; sometimes in medium

[1] This is probably a reference to cavernous or "hopper-shaped" crystals since halite is rarely octahedral.

sized pyramids as at Stassfurt, Saxony; and sometimes in small pyramids as at Aldedorf, Hesse.

Salt has variable natural properties. Some is compact, dense, and when heated in a fire decrepitates and flies apart. This is true of all natural and most marine salt. Fine-grained and dense salt decrepitates even more, especially most of the artificial salt produced from saline solutions. The porous mineral, whether compact or loosely coherent, does not decrepitate or disintegrate in fire. This is true of the halite formed in saline lakes by the drying force of the sun, for example at Agrigentum and Tragasaeus, and a similar salt found on the sea shore at Aeantium, as well as that which comes from India in the form of pyramids and from Colomaeus in cubes. "Flowers of salt" and salt "scale" belong to this class. Loose, fine-grained, uncompacted salt does not decrepitate. The mineral reacts the same when placed on glowing coals. Crushed and powdered it is readily soluble in water. When compact and hard it dissolves slowly although it will dissolve eventually. Of the compact salts artificial salt dissolves the quickest, marine and lacustrine salt more slowly, halite[2] the slowest. In each class some particular salt may be found which is more compact or more loose-textured than the rest and will dissolve more readily or more slowly than the others. A salt from Agrigentum jumps out of the water according to Pliny.

All salt is dried when placed in a crucible over a fire yet the quantity does not decrease or decreases very slightly. The mineral loves dryness since it has congealed as the result of a union with either cold or heat. On the other hand dampness is its enemy since it dissolves and liquefies when left in a damp place. Even when exposed to dampness some of the salt is softened and lost. Therefore when one wishes to preserve salt it is necessary to leave it in a dry place. This is not always true since salt is heaped up on the coast of Africa near Utica until the mounds resemble small hills and the surfaces become so indurated by the sun that they do not dissolve during rains. When needed the salt is broken down with iron bars according to Pliny, and only after great effort.

The carving of vessels and small animals from white salt was unknown to the Greeks. They believed that this mineral did not exist as a solid in the earth but as an exceptionally sticky and glue-like body that, like Paria marble, became hard and solid after having been placed in the sun.

Salt is used in various ways, in buildings, in religious worship, in medicine and most of all in food. The Arabs of Carris and Gerrha build houses, walls and towers from salt which is cut into square blocks like stone and cemented together with water instead of lime. The Ammanientes in Africa build their houses in a similar fashion. The Romans used salt in their temples and never built one without a cornerstone of salt. Fabius Pictor writes that the Vestal Virgins cut the salt for the temples with an iron saw. Hebrew rabbis sprinkled salt on the heads of sacrificial

[2] In general the mineralogical name halite is limited in the English text to natural salt occurring within the earth.

animals. Early Christians collected and preserved sacred salt and believed in sprinkling salt on the bodies of newly born infants in order to make the skin firm and tough. Not only is salt of greatest value to the living as a food and medicine but it is also used by them to preserve the flesh of the dead as well as the flesh of animals that have been butchered. It increases the appetite of man more than most condiments and has a marked taste, recognized by the tongue. Food is never so tasty and delectable when eaten without salt and even if a food can be eaten without it when salt is used the food is more pleasing to the palate. Not only is it a stimulant to the appetite of man but it is also used by shepherds to increase the appetite of a single animal or a herd; by husbandmen and liverymen for beasts of burden; and by sportsmen for game. Animals lick the salt when it is placed in wooden troughs or on the ground and eat it mixed with their fodder. It causes them to graze freely and drink copiously. For these reasons, according to Plutarch, the priests of the Goddess Isis, in Egypt, do not use salt on feast days so that they would not suffer inconveniences if they ate and drank freely and caused humors to abound in the body. Fine-grained salt is used in food because it is not bitter but agreeable to the taste and dissolves readily. Bitter salt does not stimulate the appetite but actually destroys it. Since coarse and hard salt does not dissolve readily it is not used in food, as a rule and when it is used the undissolved particles of salt are gritty. Color indicates the quality of the salt, white being the best. The best cooking salt is refined from brine, for example, in Germany at the salt works of Luneburg and Halle of the Hermunduri, and in Italy at Volterra. Other highly valued salts are the lacustrine salt of Taranto and the marine salt of Euboea and Athens. At Kolomea the salt is made into thin cakes which are used as a flavoring in food and are also eaten like bread. Since every variety of salt is not found in every region, different kinds of salt are used in food in different localities, usually the variety which is most abundant. Marine salt is used in the marine provinces and on almost all islands except those which lie in regions so cold that the sun does not evaporate the sea water even when it is taken into salt works. Natural, as well as artificial salt is especially abundant in Spain. The lacustrine salt from Taranto, the artificial salt from Volterra and the best salt of Hetruria is used in Italy. France has both marine and artificial salt; Sicily and Phrygia, lacustrine salt. In Cappadocia they use artificial, natural, and lacustrine salt while Germany and northwest Epirus use only the artificial. Sarmatia uses both the natural and artificial salt, the latter being produced both from brine and fragments of the mineral. Only lacustrine salt is used in Aeolis and Pamphylia. Halite is very abundant in Africa and India although marine salt is common in the maritime provinces of both countries and lacustrine salt in Africa, especially in Egypt near Memphis.

We use salt to preserve meat since the dryness of the salt takes up the liquids in the meat and may unite the essences so that the meat is pro-

tected from putrefaction. The flesh of fish and other animals that we eat can be preserved unimpaired when sprinkled with this mineral. It is not only used on meat but also on cheese, butter and some fruit such as the caper. Some olives, lemons and other fruits can be preserved for a long time by placing them in brine. The drier, harder less friable and more astringent a salt the more useful it becomes for salting and curing. Halite or rock salt is the best. Among marine salts, that from Megara is considered the best and among artificial salts, that made from Stassfurt brine. The driest salts are the most salty; the hardest dissolve the slowest; the most astringent unite the essence of the salted substance most strongly.

When used in medicine salt dries the body and even when mixed with other substances it retains its drying power. It cleanses and is astringent; the more astringent or bitter it is, the less it cleanses. All salt is only slightly astringent when compared with astringent minerals such as alums, sulphates and related minerals. However various salts differ greatly in this property. Halite is more astringent than any marine, lacustrine, or artificial salt. Certain natural, lacustrine, and artificial salts are more cleansing than astringent although the tongue can detect a certain bitter taste in all of them. This distinguishes these salts from the other two genera. Natural sal ammoniac occurs with halite in the lacustrine salt from the Dead Sea and artificial sal ammoniac (*sal ammoniacus subditicus*) forms with certain manufactured salts. Sometimes, in one and the same ore, salts of both the first and third[3] genera are found together. Dioscorides recommends halite as a remedy and even sal ammoniac. Pliny recommends that Tattaeum or Caunos salt be added to salves and plasters. The Spaniards use it for eyes that have been blackened and discolored by blood, the result of a blow. It is used by the Thebans for itch, leprosy and mange. Its healing properties are known from experience and one learns through conversations the diseases it will cure so further discussion is unecessary. A dram of salt in a glass of wine sooths the stomach. The black Sarmatian salt found in cross-cutting veins is used today for this purpose. Salt was prepared and sold fraudulently in former times and the practice has continued to the present day. Cubes and porous pieces of marine salt are selected and substituted for the white Indian salt that occurs in octahedrons as I have stated above. Sal ammoniac is not only adulterated with Cocanician and Cyprian salt, as mentioned by Pliny, but also with the artificial salt. Each adulteration is easily detected. Marine salt crackles and decrepitates in fire while the Indian mineral does not. Artificial sal ammoniac forms in lozenges[4] and neither crackles nor decrepitates in a fire but is entirely consumed.[5] Native sal ammoniac occurs

[3] Sulphur, bitumen, realgar, etc.

[4] Although native sal ammoniac crystallizes in the isometric system, artificial crystals have been observed with rhombohedral symmetry.

[5] Sal ammoniac, NH_4Cl, sublimes without fusion under certain conditions.

in oblong plates similar in appearance to gypsum and decrepitates in fire. So much regarding salt.

We shall now consider *nitrum* which is related to salt.[6] It is found in nature and is produced artificially similar to salt. *Nitrum* is found within the earth and on the surface. When found in the earth it is dug out like other salts and is hard and dense, similar to stone. The Venetians make *chrysocolla*, the material I call *borax*, from this mineral.[7] Sometimes it is collected from caves where it either hangs down from the roof like icicles or it forms on the floor of the cave from water that drips from the roof. It is soft, incoherent, and white with the appearance of foam. The Greeks call it *aphronitrum* not so much because it is found in the earth as because it occurs in caves and only the soft, foam-like material is so-named. The dense, hard mineral is not true *aphronitrum*. The Greeks indentified these minerals on the basis of quality and uniformity. *Nitrum* is mined or collected in Asia, especially at Alashehr, Lydia, and Manissa, Caria. It is interesting to note that Emperor Gallienus, when he was informed by dispatches and messengers that Asia was to be devastated by the Scythians, exclaimed, with a certain jocular license, "What! We cannot live without *aphronitrum*."

Nitrum is found on the surface of the earth in protected valleys and on flat plains or in lakes. When it occurs as an efflorescence on the surface the Greeks call it *halmirhaga*, a name derived in part from its rather salty taste, in part because it comes up out of the earth. Pliny mentions that the valleys along the Media river become white during the summer and it would appear that the entire surface of the ground around Philippopolis, Thrace, is impregnated with the mineral. Pliny calls the earth of these fields "filthy." A lake in eastern Macedonia in the Letaeus district produces this mineral. The mineral called *chalastraeum* by the old writers came from a bay near the town of Chalastra, whence the name.

There are many varieties of artificial *nitrum*. One variety is made in Egypt from the alkali water of the Nile which is conducted to the plants. These are situated at Naucratis, Nitria, and Memphis. In these plants, as in salt works, the finest and lightest froth may be called "flowers of *nitrum*" but it is more commonly called "*nitrum* foam." The Greeks call this material by two separate names, *ἀφρὸς νίτρου*, in order to distinguish it from the natural mineral which is similar to foam and which they call *ἀφρόνιτρος*. Dioscorides calls both *aphronitrum* and "*nitrum* foam," *ἀφρὸς νίτρου*. He distinguishes one from the other by quality and writes that the finest material comes from Lydia and that this is *aphronitrum* while the second quality mineral, "*nitrum* foam," comes from Egypt. Some artifi-

[6] Until the latter part of the 16th century, there was confusion in the use of the name *nitrum* (Greek, *νίτρον*). In general it included all hydrous sodium carbonates, natron, thermonatrite, trona, etc., as well as other minerals obtained from soda lakes, especially those in Egypt and Asia.

[7] Natron, $Na_2CO_3 \cdot 10H_2O$, borax, $Na_2B_4O_7 \cdot 10H_2O$.

cial *nitrum* is made, even today, from the natural mineral and this is called *tincar* by the Arabs. I call this material by the Greek name *chrysocolla*, which it actually is, or by the Arabic name *borax*.[8] A third form of this mineral is made from burnt oak or hard wood and I shall explain the process of making it in the book De Re Metallica.

One *nitrum* will differ from another in color. That from Chalastra is white; *aphronitrum* looks more like foam than "*nitrum* foam." Dioscorides discusses a red *nitrum* in conjuction with the white. *Aphronitrum* may be purplish white. The inferior variety from Egypt is dark colored. Concerning transparency, native *nitrum* from which they make *chrysocolla* is transparent. The taste is variable. The Egyptian material is bitter and the "foam" quite bitter. Some native *nitrum* is so weakly bitter that the senses cannot detect it, for example, the material used in making *chrysocolla*. The word *halmirhaga* signifies a salty taste and this is detected by the tongue. *Chalastraeum* has a salty bitter taste. *Nitrum* has no odor but when it is burnt an odor can be detected but when it is adulterated with lime it gives off a strong odor.

Some *nitrum* is incoherent and pulverent, for example, "flowers of *nitrum*," foam-like *aphronitrum*, and *halmirhaga*. Some, although compact and dense, is soft and can be crushed with ease, for example, the best variety from Egypt and *chrysocolla*. Some is hard and dense and native *aphronitrum* is similar to stone. The Egyptian mineral that has been allowed to stand in the open in large mounds is hard as a rock and this material is called *βουνός* by the Greeks because they look like hills. All the pulverent, fragile material is loose-textured and light, for example, *halmirhaga* and "*nitrum* foam." Some is compact such as *aphronitrum* and *chrysocolla* while some is dense and heavy such as certain varieties of the native mineral.

Nitrum varies most in form. The native mineral occurs in formless lumps and icicles. The *aphronitrum* of Lydia occurs in the form of lozenges. Artificial *chrysocolla* forms in rectangular crystals with pyramidal terminations. The Egyptain material is sometimes porous, sometimes spongy. *Nitrum* neither decrepitates nor flies out of a fire although the native mineral swells up and intumesces. Artificial *nitrum* and *chrysocolla* are soluble in water, the hard and dense varieties being slowly soluble. *Nitrum*, because it removes dirt, is used by fullers in solutions to clean spots from cloth and dyers treat wool with a similar solution so that it will take the dye evenly. Ancient peoples were accustomed to wash themselves in the public baths in water containing *aphronitrum* so that they would be clean and healthy. Pliny states that the very fine sand of the Nile which contained *nitrum* was used for whitening the bodies of wrestlers from Patrobius who had been freed by Nero. He also writes that dyers used an impure variety. Actually dyers who have no *nitrum* use the

[8] Borax is a French word derived from the Arabic *būraq*.

dregs or tartar in wine casks. Pliny also tells us that utensils were made from the Egyptian mineral that became hard as stone when left in mounds. Macedonians add *chalastraeum* to flour instead of salt when baking bread. Egyptians sprinkle it on radishes just as we use salt. Physicians regard it with the highest esteem. It dries, cleanses, and dissipates. "*Nitrum* foam" is the more valuable while the the finest quality of *aphronitrum*, loose-textured, soft, pulverulent and purplish white is the most valuable. That usually selected by physicians is light, spongy, reddish or white such as is found in the mounds made by the Egyptians, especially the very whitest and lightest of "*nitrum* foam." This, as well as white *nitrum*, may be adulterated with lime but the deception can be detected by both the tongue and nose. According to Pliny the pure mineral dissolves quickly, the adulterated, slowly; the former has only a slight odor, the latter irritates the nose. *Chrysocolla* is used by artisans to solder silver and gold, whence its name.[9] Artificers who make needles from iron use sal ammoniac in a similar manner when they coat the heads with tin. Goldsmiths add a lump of *chrysocolla* when they wish to melt gold fillings since it increases the speed of melting.

Halinitrum whitens the fields of Saxony not far south of Stassfurt on the road to Warmesdorf just as *halmirhaga* whitens the valleys near Medos in summer. In fact the earth is saturated with *halinitrum* at Cervecius and Berneburg, Saxony, Mochela, Thuringia, and other places in Germany. In arid regions storms do not penetrate far below the earth's surface, as a rule, and below the superficial crust definite veins (beds) of white *halinitrum* are common. In the above named sections of Saxony the country is low and flat. *Halinitrum* is made from the material that effloresces on the fields. It is collected in heaps and covered with branches of shrubs. It is salty and slightly acrid. A material similar to this is seen to effloresce on the stone walls of wine cellars and other dark places that are protected from moisture. It has the appearance of flour on the walls. The mineral we call *halinitrum* is made from these two materials no matter whether they are *halmirhaga* or *nitrum*. The finest material in this class is that from which the largest amount of salt has been removed.

True *halinitrum* is produced not only from these two native materials but also from the soft and very tenuous material which exudes from rocks on mountains. Such material adheres to limestone and gypsum on the mountains near Sala. It is also produced from hard and dense icicles that commonly hang down from the backs of underground passages and caves such as the one at Neoschonburg, a stronghold of Bohemia. There they hang in a wine cellar cut out of rock. The material is neither very bitter nor very salty but it is sometimes acrid, sometimes only slightly so. The color is variable, white, yellowish, light red, etc. The material that effloresces on the walls of caves is either gray or white while that which forms

[9] χρυσός, gold; κόλλα, glue.

on the fields is always as white as *halinitrum* itself. When the latter is pure it is transparent, salty, slightly acrid, loose-textured and light. It crystallizes in rectangles with pyramidal terminations. It can be crushed with ease. The mineral catches fire easily and burns. It is found in matted masses which contain much air. For these reasons it is useful in making the powder that throws the round missiles of the pieces of ordnance which they call bombard. Both *halinitrum* and the *nitrum* that effloresces on walls will take fire.[10] Although *halinitrum* cleanses, the degree of bitterness differs considerably from that of *nitrum*.

I shall now take up alum (*alumen*) which is more closely related to *atramentum sutorium*[11] than salt to *nitrum*. Although all of these minerals are cleansing, salt and *nitrum* are only slighly astringent, the others, strongly astringent. *Atramentum sutorium* is more earthy than alum. The two minerals can be separated since alum forms from *atramentum sutorium*. When the latter is mixed with olive oil alum forms since the oil takes up the earth and one particle of alum unites with another. Also earth alone, thoroughly mixed with water, precipitates alum which gradually crystallizes in cubes.

I shall discuss alum first and then take up *chalcitis*, *misy*, *sory*, and *melanteria* which I will associate with *atramentum sutorium* since they are related minerals. Alum occurs as a native mineral and is prepared artificially, in both cases forming from water and aluminous earth. There are many alum mines in the world. In Spain it is found in silver mines. It occurs in many places in Germany, near Brambach, Saxony; at Zuenicius and beyond Radeberg, Misena; near Blava and Salfeld, Vogtland; in Bohemia at Schachic half way between Cometavius and Launa. Also in Noricum near the Julian Alps; in Hetruria near the market place named Claudius, at Bassano and Volterra; in Campania at the market place between Pozzuolo and Naples; in Pontus; in Phrygia Hierapolis; in Judea near Mekaur; in Armenia, Babylon, Egypt, and Africa. It is found on the islands of Sardinia, Melos, Strongyle[12] and Lipari. So numerous are the alum mines known to us or mentioned in the literature. Diodorus Siculus states that the Romans obtained the greater part of their alum from the Liparian mines. In Germany it is rarely found pure and is usually produced artificially from aluminous earths, for example, in Hetruria. A few small white hollow pieces the size of a walnut have been found in the moat on the west side of Hildesheim, Saxony. The liquid that comes from Blancheburg near the Harz forest is produced artificially, not by nature, since it is necessary to remove *chalcitis* or some similar mineral from the latter before it is solidified by heating to produce the pure white alum. Thus all alum is either liquid or solid. The former is common in nature

[10] Agricola apparently includes under *nitrum* not only various hydrous sodium carbonates but also nitrocalcite, $Ca(NO_3)_2 \cdot nH_2O$, etc.

[11] This is a general name for iron sulphates.

[12] The alum from this island was known in commerce as "strongyle."

and rarely produced artificially while the latter is common in nature and equally common as an artificial mineral. There are two genera of the liquid, one is pure, the color of milk, limpid, and may smell of fire. This variety is widely used because of its purity and is called φορίμης by the Greeks. The other genus of liquid is impure, light colored and cloudy and because it is fouled and polluted with foreign matter is called παράφορος. The latter liquid is even adulterated with very fine rock fragments and tinted with oak galls.

The solid mineral occurs in a variety of forms. Since it has been named σχίσις by the Greeks it has a cleavage. It occurs in lumps and as a type of "flower of alum." This type not only exudes from and grows on veins but also on *atramentum sutorium* when they both occur in the same vein. Pyrite, having been altered, is the parent of both minerals. The mineral which can be cleaved either has been compressed and compacted like a lump or it has effloresced in the form of individual whitish-gray hairs. These are called τριχῖτις by the Greeks, *capillaris* by the Latins. Alum may be spherical and this is called στρωγγύλος. There are three species of this form, one which is puffed up like a bubble, another full of pipe-like openings similar to some sponges, while the third is solid. A variety which has the shape of a heel is called ἀστραγαλωτός and that in the form of a brick πλινθιτις. The mineral which occurs in crusts is called πλακίτις by the Greeks. Today it is made in the form of cones from lumps of any kind and this is called *saccharinus*.

Nature has given alum a variety of other distinctive qualities. The color may be either white, grayish-white, or, if in fairly good sized pieces, a dark color which is called black. The best quality is white and dark colors are rare as Pliny has written. It may be reddish white as is that which comes from the Neapolitan region or light colored as the rounded and fibrous mineral mined at Schachic, Bohemia. The artificial mineral is usually more transparent than the native alum. Since the latter is not so dense all tenuous alums are not translucent.

Regarding taste, alum is strongly astringent and for that reason is called στυπτηρία by the Greeks. Regarding the odor, not only the liquid, which has the strongest odor, but also the dry mineral gives off an odor of fire not unlike that given off by stones when struck together. On the other hand the artificial mineral has no odor. The capillary mineral is the softest and most fragile, next hardest is the material that resembles bubbles and that which is porous with a pipe-like appearance. The next hardest is the material that resembles a heel. All the rest are dense and hard, for example, all artificial alums and the native mineral that occurs in the form of blocks, in tabular crusts, and in all other solid forms. Liquid alum is very unctuous, the artificial mineral only slightly so. Some alum is dense, as that congealed from a liquid while some is tenuous such as that which occurs in the form of bubbles or is very porous. The alum that resembles a heel is tenuous since it too is porous. When the mineral is

placed on live coals or in earthenware vessels over a fire it dries and swells into bubbles similar to *nitrum* and loses some of its substance.[13] Like other congealed juices it is soluble in water; the spherical, bubble-like variety dissolving the most rapidly.

Alum is used by goldsmiths, dyers, copyists and physicians. Goldsmiths clean gold with it and use it when covering copper with gold leaf. Dyers prepare their wool as well as cloth by washing it in water in which alum has been dissolved. Wool or cloth, so treated, takes the dye easily and retains the color for a long time. When the wool is to be dyed a light color they use the white liquor and when dying wool black they use the cloudy or dark liquor, according to Pliny. Today dyers always use the white mineral since they do not have the natural liquors. The mineral is also used when they dye hides. Leaves of books that are dipped in water in which alum has been dissolved become strong and tough and can be written on with inks that are acid without having the ink sink into the paper as is often the case with untreated paper.

When used as a medicament, alum has a drying power, drawing together ulcers and wounds. According to Dioscorides, in the olden days they used the broken, nodular, and liquid forms. The rough, cleavable material is the best of all, especially that from Egypt which is pure, fresh, white, and strongly astringent. The best nodular material is the native mineral which intumesces into bubbles when pure. This usually comes from Melos or Egypt and is pale white, moderately unctuous, soft, and strongly astringent. The best liquid is that which is the color of milk, translucent, and with the odor of fire.

I shall now take up the juice the Latins call *atramentum*. Since there are three kinds of *atramentum* and the name of each comes from the black color, it has been named *sutorium* to distinguish it from *librarium* and *metallicum* because it is used by both the shoemaker and leather worker to dye leather black. It is called *χάλκανθος* by the Greeks because it forms as an efflorescence on copper.[14] Cupriferous pyrite, which is also called *chalcitis*, is the parent and source of *sory*, and *melanteria* which is also called *atramentum metallicum*. These minerals, in turn, produce *atramentum sutorium* and other closely related minerals.[15] This can be seen especi-

[13] Alum contains approximately 45.6% water and 13.5% sulphur.

[14] From *χαλκός*, brass or copper, and *ἄνθος*, a flower.

[15] De Ortu et Causis Subterraneorum, Book I, page 13, "When moisture corrodes cupriferous and friable pyrite it produces an acid juice from which *atramentum sutorium* forms and also liquid alum." Idem, Book III, page 46, "When water has covered pyrite it produces *atramentum sutorium* either through being congealed by cold or evaporated by heat." Idem, Book III, page 47, "Not only are *atramentum sutorium* and alum made from an acid juice but also *sory*, *chalcitis*, and *misy*. *Misy* is "flowers" of *atramentum sutorium* just as *sory* is "flowers" of *melanteria*. Experiments show that when porous, friable pyrite is attacked by moisture such an acid juice is produced. Green *atramentum sutorium* in the form of hairs very often appears on this kind of pyrite together with *melanteria* which covers the pyrite."

ally at Goslar where it occurs as dark gray, dull, subrounded masses and is called *atramentum* stone. In the center of these masses pale-colored pyrite is found almost dissolved. Usually the center of pyrite is about the size of a walnut. Either *sory* or *melanteria* envelope these cores of pyrite and spreading through these minerals are pale green stringers of *atramentum* that have the appearance of hairs running out from and at the same time connecting to the minerals.[16] *Atramentum sutorium* is produced both in nature and artificially from water and *sory* or *melanteria* or even *chalcitis*. The natural mineral forms from some kind of humor and has congealed like ice either in viens, fractures or joints of rocks or it has come out from the rock drop by drop and, moving down along channels, has congealed in the form of icicles and hangs from the back of openings or finally it may drop from the back of openings and congeal on the floor. Irrespective of whether it hangs from the back or occurs on the floor the Greeks call it σταλακτικός because it has congealed by dropping. There are two artificial varieties, one the Greeks call, correctly, πηκτός, the Latins, *concretus*. When this variety is either carried from underground workings and poured into rectangular reservoirs or conducted thence along channels it will congeal due to the cold or the heat of the sun. The other variety the Greeks call ἑφθός, the Latins, *coctum* or "cooked." The water containing the *atramentum* is placed in rectangular basins and then boiled away, as I shall explain elsewhere.

These minerals and related varieties have been mined in Spain and many places in Germany. They are found at Goslar, a noted locality; in the Harz forest near the fortified city of Blancheburg six miles from Halberstadt, Saxony; at Zuenicius, Breitenbrunn, in certain underground workings of Annaberg, and above Radeberg, Misena; in Bohemia; at Cuperberg in the Salyes district; and some about four miles from the mine we call Zuckmantel because many travellers are there robbed of their coats by highwaymen. Other localities are the part of Hungary once called Dacia; Smolensk in Cepusk; near caverns at Volterra, Italy; at Solis in Cyprus; and in Egypt and Africa. There are five species of this mineral, *melanteria*, *sory*, *misy*, *chalcitis* and *atramentum sutorium*. Some species

[16] Bermanus, page 464.

Naevius, " . . . The Veneti prefer the *atramentum sutorium* from Cyprus to all others and I have purchased a piece that has been partially altered to *misy*. I have this specimen in my house at present and will send it to you Bermannus at the first opportunity. If this obvious alteration occurs in the mines of Cyprus you can easily find it in our copper mines."

Bermannus. "You will do me a great favor."

Naevius. "I am not denying that Galen wrote about *atramentum sutorium*. I have many pieces of this remedy which I brought back from Cyprus and after almost twenty years the outer portions have changed to *chalcitis* while the interior is *atramentum sutorium*. To this day I have always taken off the outer portion which has altered and observed at the end of each year how this transformation has proceeded, comparing it with the alteration of *chalcitis* to *misy*."

are found in many localities, all in certain localities. Some species are formed from others. *Sory* and *melanteria* form from pyrite which is the source of all the juices; *chalcitis*, from *sory;* varieties of *atramentum sutorium* from *chalcitis, melanteria* and *sory*. Some of these minerals occur as white efflorescences while others are green and even blue. *Misy* forms as an efflorescence, not only on *sory, melanteria* and *chalcitis* but also on all varieties of *atramentum sutorium*, both natural and artificial. We have mentioned all the juices that belong to this group but have said nothing about the earths, stones, etc. that may have absorbed these juices, all of which actually belong here. Even wood may absorb these juices.

These minerals differ among themselves. *Sory, melanteria, chalcitis* and *misy* are always natural minerals and only *atramentum sutorium* may be either an artificial or a natural mineral. *Sory* and *melanteria* have the same color, gray and black; *chalcitis* red and copper colored; *misy*, yellowish and golden; *atramentum sutorium*, various colors. White *atramentum sutorium* is called λευκόϊον because it resembles the color of the white violet. It may also be pale to deep green or blue. The finest white variety occurs in the form of icicles at Goslar and resembles transparent quartz.[17] Both the blue and green varieties may be transparent. Because of this transparency *atramentum sutorium* was given the name *vitriolum* in olden times. The blue mineral is wont to shine in a wonderful manner. All five minerals are astringent and acrid, *atramentum sutorium* being the most strongly astringent. All have a natural odor similar to that given off by a bolt of lightning while the odor of *sory* is the most penetrating. *Atramentum sutorium* is soft and tenuous similar to down or hair; *melanteria*, similar to plant down and with a certain saltiness. While all five minerals may be light and porus *sory, chalcitis* and *misy* may occur massive. *Sory* may be as hard as a stone because of excessive congealing and for that reason is the most dense, *misy* the most tenuous, *chalcitis* intermediate. Although *sory* and *melanteria* have the same color the former is more dense and has a stronger odor. Both artificial and natural *atramentum sutorium* may be dense and hard as well as loose-textured and light. The natural and sometimes the artificial white variety is sub-unctuous. *Sory* may have a certain unctuousness at times.[18]

[17] This is probably the first description of the mineral goslarite.

[18] Sulphate minerals have been classified under one of these five names by miners and mineralogists since the first century and two names, melanterite and misy, are still used by miners in much the same sense as they were in the time of Dioscorides and Pliny. It was not until the last quarter of the nineteenth century that definitive studies of the iron sulphate minerals began to appear. Prior to this period there was confusion in the application of these names and it is evident that in the time of Agricola oxidation minerals other than sulphates were sometimes included in these five species.

Since color was the primary basis of this classification all water-soluble metallic sulphates were placed in one species or the other solely on this basis. Agricola undoubtedly writes of minerals found in the oxide zone of the various veins in the

Regarding the form of these minerals, *sory*, *chalcitis*, *misy*, and *melanteria* usually occur as rounded masses. *Sory* may have many openings and this is a characteristic of the mineral. *Misy*, when it occurs as an efflorescence on another mineral, may have the form of dust, otherwise it occurs as rounded masses. Only *melanteria* occurs like plant down or "foam" of salt. Dioscorides described such a mineral as hanging from the veins in copper mines. However, it should be understood that this mineral does not form in all copper mines but only in those in which pyrite occurs. Native *atramentum sutorium* occurs in the form of hairs or feathers, in icicles or in rounded forms. The artificial mineral forms in groups of small crystals that resemble cubes and grow together like grapes. When the sub-unctuous mineral is dried over a fire it swells into bubbles in the same manner as *nitrum* and alum. When it is not sub-unctuous it merely dries out. Each of these minerals is more easily pulverized after heating.

All five minerals are soluble in water although the hard sub-unctuous varieties are more slowly soluble than the soft and meager. *Atramentum sutorium*, having been dissolved in water, is used widely to dye hides and wool black. Dyers also color cloth with madder root in order to darken the natural color of the cloth and then, to make it liver-colored, boil it again in water in which *atramentum sutorium* has been dissolved. A solution of *atramentum sutorium* may be used to dye the hair and beard black and sometimes solutions of *sory* and *melanteria* are used for the same purpose. In all cases dried *atramentum sutorium* is best. For medicinal purposes the natural, blue, heavy, dense and transparent mineral is best while that which is properly called "congealed" is next best. The blue mineral is the most astringent and will heat the body the most. It will check profuse bleeding when sprinkled on a severed vein. It expels pus from ulcers and dries excrement. When a dram is taken internally mixed with honey and water, wine, or especially olive oil it acts as an emetic. When used in eye salves preference is given to the white transparent variety.[19] Although *sory*, *chalcitis*, *melanteria* and *misy* are less astringent

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Harz district, particularly at Goslar. It is possible that the following minerals are the modern equivalents of those known to Agricola.

Atramentum sutorium caeruleum	chalcanthite
Atramentum sutorium candidum	goslarite
Atramentum sutorium virida	melanterite
Chalcitis	romerite botryogen
Melanteria	melanterite
Misy	copiapite metavoltine
Sory	voltaite melanterite with finely divided pyrite.

[19] Apparently the hydrous zinc silicate calamine is confused with the hydrous zinc sulphate goslarite.

nevertheless they can burn the skin so badly that it appears to have been cauterized. Some natural *atramentum sutorium* has this same property. *Sory* is identified by its black and shiny surface when broken, by its many openings, it sub-unctuous quality, its strong harsh odor of lightning and its power to destroy odors of the gullet, especially the mineral from Egypt which Dioscorides regards as the best.[20] The best *chalcitis* is that which, when fresh, has the color of copper, occurs in long shining fibers and crushes easily. *Misy* can be identified by its hardness, its golden color, its luster which resembles polished gold and its sparkle which resembles the stars. The best *melanteria* has the color of sulphur but blackens rapidly when placed in water.[21]

Since I have discussed natural *atramentum sutorium* and the related minerals that form from cupriferous pyrite it follows that I mention the congealed acid juice which usually produces *cadmia.* This mineral is found in the underground workings of the St. Otto mine at Annaberg. It is white, hard, and so acrid that it can eat away walls, grills and even destroy all living matter. The very tenuous material that exudes from mountain rocks and the dense material that hangs from the back of underground workings and caves, from which they make *halinitrum*, is commonly acrid but it does not produce *cadmia.*

I shall now describe *chrysocolla, caeruleum, armenium* and *aerugo* since these are commonly found in mineral veins, especially copper veins. The Greeks first gave the name *chrysocolla* to the artificial compound used in soldering gold and subsequently natural minerals as well as other artificial compounds were given the same name because of a certain similarity in color. There are two kinds of *chrysocolla*, native and artificial. The native mineral occurs in veins and fractures and is found either pure, similar

[20] Black water-soluble sulphates are rare. There are only two to which he might have reference, voltaite and glockerite. Both minerals occur at Goslar and at other mines in the Harz district. Glockerite has been reported from near Zuckmantel.

These description indicate that Agricola confused, at times, other minerals viz. hydrous oxides, silicates, etc., with sulphates. However his statement that "all five minerals are soluble in water" indicates that he must have observed some black soluble sulphate mineral.

Veins containing porous marcasite and pyrite, especially when they are alteration products of pyrrhotite, oxidize first to a mixture of free sulphuric acid, melanterite and finely divided iron sulphide which gives the mixture an intense black color. It is possible that Agricola may refer to this mixture when speaking of black *melanteria* and in part black *sory.*

[21] Agricola has mentioned these minerals in other works. The following extract is of particular interest. See Footnote 15.

De Natura Eorum Quae Effluunt ex Terra, Book I, p. 108, "*Atramentum sutorium* is rarely white, commonly green or blue. Among the related minerals *misy* is golden yellow; *chalcitis* is copper-colored; *sory* and *melanteria* almost always black although the latter is usually gray when dried. 'Book II, p. 121,' *Atramentum sutorium*, like other acid substances, dyes black and, like other penetrating substances, will produce sneezing."

to sand, or adhering to vein material. When scraped from the vein material the latter mineral resembles the sand, although sometimes the coating is so thin that little or none can be removed. When water removes the mineral from veins it settles out in a fine powder. A green mine water of this kind flows from an ancient underground working at Neusohl in the Carpathian Mountains. A volume sufficient to fill thirty castles is impounded and the mineral permitted to settle out. This is collected each year and sold in lots. The production from Neusohl is obtained without human effort and Pliny describes a similar case where the mineral is obtained artificially. The light summer rains that fall in June were directed into a vein and then collected and allowed to evaporate in the sun during June and July.[22]

There are two species of artificial *chrysocolla*, one made from the hard native mineral then colored with saffron and hence named for this herb. This is the best and is more valuable than the native mineral. Pliny describes how it is made. The native mineral is dried on wool or linen and then crushed in a mortar and sieved. The coarse material is crushed again and this process continued until it all passes through the sieve. It is then ground in a mill. The fine material is placed in a shallow vessel and macerated with vinegar until it becomes soft. It is again ground in a mortar and then washed in shells and dried. After drying it is moistened with a solution of alum and colored with saffron. It is important that it take the color readily and uniformly. If it will not take the color at once scythanum[23] and turbystum are added. These substances will cause the color to be absorbed. Painters call a similar color orobitin. There are two varieties of this made in Cyprus, one a clay that is preserved in unguents, the other a liquid, according to Pliny.

The *chyrsocolla* used by craftsmen and classified by Dioscorides as a variety of *aerugo* is described as a metallic mixture produced from Cyprian *aerugo*, the urine of young boys and *nitrum*. Galen, writing later than Dioscorides, states that it is made only from *aerugo* and urine. Since there is a lack of Cyprian copper this variety of *chrysocolla* cannot be made and the other variety, which I have already mentioned, has replaced it. This is adulterated with powdered chalk that has first been colored with *aerugo* and in this way a large amount is obtained from one pound of pure mineral. This practice, although deceitful, actually is not contrary to nature which also colors chalk green. At one time *chrysocolla* was made from a yellow herb and finely ground *caeruleum*. Neither of these adulterated or falsified products is recommended since each is worthless.

But to return to the natural mineral which is found in copper mines since it forms only from copper. When it occurs in gold, silver or lead mines it is certain that copper also occurs in the same veins. This mineral

[22] This is probably a reference to some green sulphate rather than to either chrysocolla or malachite.

[23] Also written scytanum and scytatum by different authors.

is found abundantly and in many places in Spain according to Pliny; in small amounts in Germany; abundantly at Neusohl, Dacia; in Macedonia, Cyprus, Armenia and on Damonesus, a Carthaginian island. That from Armenia has such a deep color that it resembles prase.[24] Dioscorides gives preference to this material and second place to that from Macedonia. However the quality of the mineral is more properly judged from its color and nature which are related to the place of origin. Although the native mineral is always green there is a wide variation in the tone. It may be a deep green and while it adheres to the metallic vein material it may approach the color of the emerald and this was considered the best for a long time. The mineral with the least value is pale green and that with intermediate tones has an intermediate value. The artificial material which is tinted yellow is the color of the carob tree and for that reason is called ὀροβίτης by the Greeks. Since so much work is put into the preparing, grinding and coloring this *chrysocolla* is sold at a higher price than the rest because of the higher costs. Pliny has given us the relative values of three different grades, *aspera* similar to hard sand, seven denarii a pound, *media* which sinks rapidly in water or can be crumbled in the hand, five denarii, and *attrita* that can be crumbled in the hand and is colored with saffron, thirteen denarii. Today *aspera* and *media* are worth about one and one-half denarii a pound. We do not have the *attrita*.

Painters use *chrysocolla* of all kinds. Metal workers use only that which cements gold to gold and silver to silver.[25] Medical men use both the artificial and natural minerals and the latter, for that reason, is called ἄκέσις by the Greeks. Both are drying and corrosive but even when they eat away the flesh they do not cause excessive pain. For this reason the mineral is used in the treating of ulcers which will not heal. The artificial mineral is more tenuous, dries more and causes less pain than the natural mineral. When burned it becomes more tenuous as do all minerals as Galen has correctly stated. A small quantity causes vomiting and a large quantity is fatal. Pliny writes that Nero spread *chrysocolla* on the great race course of the arena when he was going to compete in a chariot race so that the course would look like a piece of cloth. *Chrysocolla* is so closely related to *caeruleum*, which the Greeks call κύανος, that these two congealed juices are frequently formed at the same time and may be found adhering to the same piece of ore. When they form together one is seen to surround and enclose the other. Sometimes there is more *caeruleum*, as Theophrastus has observed, sometimes more *chrysocolla* and sometimes they occur in equal quantities as I have observed.[26]

[24] This is evidently taken from Dioscorides and probably refers to mineral from the Katara copper mine.

[25] Borax.

[26] According to these descriptions the name *chrysocolla* was given to various natural blue and green minerals which, by definition, contained copper and were not soluble in water. The two principal minerals were the copper silicate, chrysocolla

Caeruleum may be a natural or artificial mineral. Native *caeruleum*, like native *chrysocolla*, is found as the pure mineral in veins or fractures, as gravel or fine sand or is scraped from vein material. There are many varieties of the artificial mineral some of which are more valuable than the natural. I shall explain how the former are made in Book IX. Three distinct genera were used by the Greek people, two natural genera from Scythia and Cyprus and an artificial genus from Egypt. The Romans used these three as well as a native mineral from Spain and an artificial mineral from Pozzuoli. The Greeks did not know of the native mineral of the Carthaginians that was dug from mines on the island of Damonesus. *Caeruleum* is found not only in copper mines but also in gold and silver mines. The caverns of the island of Cyprus formed by the action of sea waves contain veins which produce this mineral although Dioscorides has not explained in what fashion. Today the native mineral is obtained from mines in Germany, Dacia, Noricum and Raetia although in small quantities since the artificial mineral is more widely used. A considerable quantity is produced from the highest peak of the Sudetes mountain which is erroneously called Pine Mountain and from Ligyes near Goldberg. *Caeruleum* is adulterated in India by dissolving the true mineral

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and the basic copper carbonate, malachite. Later, in his *Interpretatio*, Agricola apparently recognized malachite as a distinct mineral with the Latin name *molochites*. The artificial mineral borax, a hydrous sodium borate, was also included under this name. Agricola uses the Latin name *borax* for this mineral and recognized the relationship with hydrous sodium carbonates which he called *nitrum*.

The following quotations are taken from other writings of Agricola.

De Ortu & Causis Subterraneorum, Book III, p. 47. "*Chrysocolla* forms in veins when a metallic substance is moistened with water and then dried. Proof of this is offered by copper pitchers or vessels used in baths. If such a vessel is moistened often and over a long period of time it will have a green efflorescence when it dries." (The basic copper chloride atacamite and the basic copper sulphate brochantite form under these conditions and later may be converted into the basic copper carbonate malachite.)

Bermannus, p. 454.

Naevius. " . . . *Chrysocolla* itself is quite green. Dioscorides says that the finest comes from Armenia, the next best from Macedonia and after that the Cyprus material but this mineral is not obtained from any of these places today.

Bermannus. "The Dacian mineral is good and equally good material can be obtained in our mines, especially our copper mines.

Naevius. "Pliny regards the mineral obtained from copper mines as the best. He writes that the second best *chrysocolla* comes from silver mines, the third quality from gold mines and the poorest from lead mines.

Bermannus. "Speaking of the artificial mineral, Pliny and your Galen have given it the same name while Dioscorides classes it under *aerugo*. I do not care to say anything now concerning the mineral used by goldsmiths.

Naevius. " . . . But the artificial mineral has the same properties as the native mineral since it breaks up and stops gatherings, checks fleshy growths and still does not produce much pain.

Ancon. "The Arabs were familiar with both kinds. They write that it will also retard the decay in teeth and stop toothache."

in water and then infusing the solution into ground chalk. Pliny writes that a pale violet variety is made by dissolving the true mineral and then filtering it through lime on to Eretrian chalk.

The color of *caeruleum* varies from black to white. It has a complex taste, bitter and astringent. Painters use both the native and artificial minerals while physicians use only the former and prefer that with a uniform color. This will reduce and destroy growths on the skin.[27]

Armenium, which Galen and other physicians who follow him call *ameniacum*, some call *armenium color*, others *opandica*. If it is of the very best quality it is *caeruleum* according to Dioscorides. This mineral does not differ from *caeruleum* except in having a lighter color which Pliny describes as more delicate. However, since some *caeruleum* is white it can be substituted fraudulently for *armenium*. Actually if, as Pliny writes, differing from Dioscorides, the best *armenium* is a deep green, by combining this color with *caeruleum*, again for purposes of fraud, that which is found in our mines can be substituted in the place of that of a similar color which is used by painters. Thus it is not to be wondered at that a mineral has been found in the sands of Spain from which a color similar to *armenium* could be made.

Armenium occurs in different localities than *caeruleum* and differs from it in taste and strength. The former comes from Armenia as the name indicates while *caeruleum* is found in many places. The taste is less acrid and astringent. As a remedy it cleanses and for that reason it is used in eye remedies and, having been ground to a very fine powder, is sprinkled on the eyelids where it causes the lashes to grow. Having been drunk it purges the black bile according to the younger Greek writers and the Moors.

[27] *Caeruleum* is, properly, the blue basic copper carbonate azurite. However it was apparently confused with chrysocolla and other cupriferous minerals. The following notes are from Bermannus.

P. 453,

Bermannus. "This is *caeruleum* which together with *chrysocolla* adheres to the cracks in stones.

Naevius. "It has the appearance of fine sand. Theophrastus, who invents the name from a certain divine force of eloquence, evidently knew the mineral since he writes, '*caeruleum* is a natural substance since it contains *chrysocolla*' as is evident here.

Bermannus. "Quite beautiful material is obtained from Goldberg, a town of Silesia named for a mountain yeilding gold. Gold is also obtained from this mineral. There are many genera of the artificial mineral, some of which are very valuable. The methods of making *caeruleum* were in part known to the ancients and in part have been discovered by chemists and their assistants. To mention all of them would take too long now. I have often thought about this because they make your *catapotium* or *pilula*, as you are wont to call them because of their form, from an artificial genus which is made by chemists."

P. 454.

Bermannus. "Tell us of the properties of *caeruleum*.

Naevius. "It has an extraordinary power of dispersing although it is somewhat astringent."

Physicians select *armenium* that is smooth, blue, non-granular and easily pulverized. However the stone that is known today as *armenium* is a mixture of *caeruleum* and *chrysocolla* and, although it is brought from Armenia and is the blue color of *armenium* it is not this stone and the color is so pale that it has a very limited use.[28]

They say, according to Dioscorides, that *aerugo* forms in two ways in copper mines, especially the Cyprian mines. It occurs as an efflorescence in small amounts on copper bearing stones, this being the best variety, or as drippings in certain caves. The latter mineral is of poor quality because it is mixed with gravel and other minerals that make it as hard as stone. This has a deep and pleasing color. First the mineral is pulverized then collected dry.[29]

There are three other closely related minerals, one the Greeks call σκώληξ since it resembles worms, another ἰὸς ξησός because it is obtained by scraping. Likewise there are three artificial genera, one scraped from copper, one with the form of worms and the third made in copper mortars from the urine of old men. As I have said before, the latter is called *chrysocolla*. I will describe how *aerugo* is made in Book IX. *Aerugo* has a pale blue color and an acrid taste. Painters and physicians use all kinds while goldsmiths use only that which will solder gold to gold. In medicine Dioscorides preferred the native mineral with a worm-like form and gave second place to the native mineral obtained by scraping. He regarded the artificial minerals as of little value for he says that they bite more than the native minerals. Goldsmiths use that which has the appearance of scrapings. *Aerugo* destroys growths and although it stings it decreases and dissolves both hard and soft skin ulcers.

Since *ferrugo* constitutes an imperfection in metal I will speak of it here. Pure iron, from which this forms, is rarely found within the earth. Some call this mineral *rubigo* because it forms as a scale on iron which is in contact with moisture, others call it *rubigo* because of its color, blackish red. It is described as red by some, black by others. It is just as astringent as *atramentum sutorium* but less corrosive. For this reason leather workers dissolve it in stronger Zittau solution and use it to dye leather. When a linen cloth has been stained with *rubigo* it is difficult to wash it clean.[30]

I shall now take up two other genera of congealed juices, orpiment

[28] From this description it is evident that *armenium* is a variety of *chrysocolla* probably from the Katara copper mine in Armenia.

[29] The modern equivalent of *aerugo* is copper rust or verdigris. The names *aerugo* and verdigris were and are usually used for various green and blue basic copper acetates. Agricola apparently includes under this name the native green copper carbonate malachite. In *De Ortu et Causis Subterraneorum*, Book III, p. 47, Agricola writes, "If a juice, strongly acid, covers material containing copper, eating it away, it produces *aerugo*." In *Interpretatio* he gives the German equivalents for *aerugo* as *grünspan oder spanschgrün* "because it was first brought to Germany from Spain. Foreigners call it 'green copper'."

[30] Here *ferrugo* and *rubigo* can both be identified with rust.

(*auripigmentum*) and realgar (*sandaraca*). These minerals are very closely related. They form, almost always, in the same veins. They have taken the force of fire in such a fashion as to appear as if having been burnt. Orpiment is more unctuous than realgar. Native orpiment, which the Greeks call ἀρσενικός, varies in color and form. One variety is the color of gold and is composed of many thin layers resembling scales that appear to have been placed one on the other. It cleaves similar to gypsum. This variety, if it is not mixed with other minerals, is considered to be the finest. Dioscorides writes that it occurs at Hellespont, Mysia. Theophrastus has left us a description of another variety that is the color of gold but occurs as a powder. This variety is of second quality. The third quality has a color approaching that of realgar and occurs in the form of lumps. Dioscorides writes that it comes from Pontus and Cappadocia. Orpiment is found in Carmania. There are two artificial species of orpiment, both brilliant. One is white with pale yellow or red veins running through it, the other is yellow but varies from black to pale red with from a few to many yellow veins through it. Each of these is made from cleavages of native orpiment to which measured amounts of native salt have been added. These minerals are first ground and then placed in two earthenware vessels similar to broad dishes and not too deep. They are coated inside with lead. One vessel is placed over the other and where they are joined they are sealed with mud and then heated until all the orpiment is sublimated and adheres to the upper vessel. This is repeated a second and usually a third time until the mixture becomes white. The artificial yellow species is prepared with less work. Orpiment has an acrid taste and when burnt has the odor of sulphur but this is less intense than that from realgar. Painters use the native mineral and binders use it to tint books. Minium was used for this purpose at one time. Doctors use it to remove hair. If it is allowed to remain on the skin too long it will burn and injure it.[31]

Native realgar also varies in color. It may be deep red, similar in color to cinnabar, or less red and in part pale yellow. It may differ in form. Sometimes it is in lumps, the most common form, or in powder according to Theophrastus. Vitruvius writes that it is mined extensively along the the boundary between Ephesus and Magnesia. The best quality does not require grinding or sieving but occurs naturally in a powder just as if it had been crushed and prepared by hand. All realgar has an odor of sulphur which becomes stronger when the mineral is crushed and strongest when it is burnt. Moreover, when burnt it gives off yellow fumes. The very best, when pure, is a deep red and has an odor of sulphur without being crushed or burnt, and can be crushed with ease. This variety comes from Pontus. Realgar can be made from orpiment in the following manner. Medium small particles of the latter are placed in an earthen jar and then

[31] This is an excellent description of orpiment. Agricola was the first to use the German corruption of the Latin name, namely, operment (*Interpretatio*), from which the modern name has evolved.

the mouth of it is sealed. The jar is placed in a furnace for five hours and the mineral will then have the color of realgar. Realgar and orpiment are commonly found in the same veins as Dioscorides has correctly observed, for example, at Hellespont, Mysia; in Pontus on the Hypanis river; in Asia Minor along the boundary between Magnesia and Ephesus; in Cappadocia; in Pimolisenus, a district of Paphlagonia; in Carmania; and on St. John's Island in the sea called Red. Realgar is used by painters, by potters when they wish to draw red lines around their vessels and by physicians since it has the property of burning. Taken internally with liquids or resins it cures the fever of many diseases and mixed with honey it cures purulent expectorations. Mixed with resin it cures asthma and chronic cough if the fumes from the burning mixture are drawn in through the mouth and nose. Mixed with honey it stops hoarseness if the mixture is licked or swallowed.[32]

I shall now take up juices, among which sulphur and bitumen are the more unctuous. There are two kinds of sulphur (*sulfur*), one being the native mineral the Latins call *vivum* and the Greeks ἄπυρος, that is, not having been subjected to fire as correctly interpreted by Celsus. The second variety is the artificial mineral the Greeks call πεπυρωμένος, that is, having been subjected to fire. Native sulphur is obtained in large quantities from the burning mountain of Hekla, Iceland, and is sold by merchants for a low price. A small quantity is found in the Bohemian Bilderz silver mine. A large amount is mined in Italy, particularly at Volterra, in the Cesenatico mountains, at Narni, on the Phlegraean Plain between Pozzuolo and Naples, on the sulphur bearing plain which the Greeks call ἠφαίστος ἀγοράν and in the Leucogaean hills. It is found on Lipari and other Aeolian Islands and on Melos. There is a sulphur mine in Judea near the town of Machaeruntis.

Artificial sulphur is made in a variety of ways. It can be refined from water as in Lower Pannonia near Buda. It can be obtained from earth that is dug up and then heated in vessels as at many places in Italy, for example, Volterra, Cesena and Pozzuolo. It may be distilled from pyrite which is heated in earthen jars as at Brambach and Harzgerode, Saxony, each being in the principality of the Prince of Anhalt, and at Cromena, Bohemia. It is obtained in a similar manner from pyrite-bearing stone that forms in layers along the Werra river of the Suntel Gebirge, Hesse.

There is a second artificial variety that is made by heating sulphur and iron scale in earthenware jugs. This variety is commonly called *caballinus* since it is used to cure scabs on horses. It is also obtained from a sulphur mud found in Pannonia.

[32] Arsenic is used today as a tonic, in the treatment of malaria fever and asthma. Realgar readily alters to orpiment and both minerals will alter to the white oxide, arsenolite. In the *Interpretatio* Agricola gives the two German names reuschgeel and rosgeel in synonyms. He mentions that the so-called *sandaraca* found in mines is not true realgar but red ochre. He identifies the red artificial mineral as the red lead oxide minimum.

Sulphur varies in color. Some is yellow such as that from the sulphur-bearing plain of Terra di Lavoro. This is called "virgin sulphur" because it is pure and also because virgins as well as matrons paint their bodies with it. Artificial sulphur is usually yellow. Some natural sulphur is gray as well as the artificial mineral from Pannonia. Some of the natural gray material is discolored with a blue tinge. Some is red as is the very purest artificial material. This is commonly transparent, as transparent as pyrargyrite. The artificial yellow material is not as transparent as the native mineral.

The taste of sulphur is somewhat oily and unpleasant. It has a characteristic odor and density. The odor is that of thunder and lightning and is similar to the odor that comes from certain ores when they are roasted. When sulphur is burned it is very irritating to the nose. All sulphur is unctuous, porous and light, some more so than the rest depending upon the purity. Native sulphur often contains earth, alum, various iron sulphates, etc. The manufactured mineral obtained by distilling pyrite is no better and may have alum and iron sulphates mixed with it. Some native sulphur is as hard as stone and some is quite dense although portions of both of these may be tenuous. Some is soft, especially the light gray material. Other sulphur is intermediate.

There is little variation in the form of native sulphur. It is dug from the earth in the form of shapeless masses and very rarely stalactites are broken from the roofs of caves or underground workings. Artificial sulphur is produced in the form of cylindrical sticks and in tabular masses. The round form is produced by distilling sulphur, drop by drop, through the openings of jars. Sometimes single drops are made which are similar in size and appearance to a dolichos seed, even with the same rounded tail. Sulphur is a friend of fire for when fragments are sprinkled around burning wood or coal they can entice and draw the fire across the intervening space. The purer the sulphur the easier it burns and the bluer the smoke. When it contains alum or *atramentum sutorium* it catches fire with difficulty and burns with a less brilliant flame. This gives off very little blue smoke.

Fumes from sulphur that has been placed on a fire retard epilepsy according to Pliny. This mineral has many other uses. The Greeks and Romans, who were so superstitious, believed that the smoke from sulphur could purify the temples. Fullers, after first washing cloth in lye and the herb crow's-foot, usually fumigate it with the sulphur that is properly called earthy. Wool dyers use a variety of sulphur they call *egula* the same way since it makes the wool white and soft according to Pliny.

We light candles and dry wood with sulphurous tapers and these are set afire by sparks from flint which has been struck with iron.[33] First we light the tinder and then the tapers from the tinder. The worst invention

[33] These tapers were made of either hemp twine or thin pieces of wood covered with sulphur.

is the use of this same sulphur in a powder compound which, having been ignited, throws out balls of stone, iron or copper from a new kind of military machine. On the other hand the best use is in medicine. Since it has the power of drawing out poison it cures the stings of sea scorpions, marine reptiles and snakes. It can be spread on dry or mixed with saliva, old oil, honey or turpentine according to Galen. Mixed with soda it soothes the itch since it possesses the property of cleansing. Mixed with vinegar it cures skin eruptions and when mixed with turpentine it cures mange and rash. Bright yellow, transparent sulphur that is not as hard as stone is selected for medicinal uses.

BOOK IV

I shall now take up a second unctuous juice which is naturally related to sulphur and is called ἄσφαλτος by the Greeks. The Latins have named it *bitumen*. Included under this name are not only the substances the older writers placed here but also naphtha (*naphtha*), camphor (*camphora*), maltha (*maltha*), pittasphalt (*pissasphaltus*), jet (*gagates*), Samothracian gem, *thracius* stone, *obsidianus* stone and many others classified by Pliny as gems, and natural carbons as well as the earth called ἀμπελῖτις by the Greeks. Amber (*succinum*) is also included here. This juice is known by so many different names because of variations and qualities by which it is distinguished and because of the discourses of the people in whose countries it either originates or is sold.

First of all the liquid (which people experienced in the nature of things correctly call "liquid bitumen" since it is usually distilled from the solid), being similar to olive oil, is especially unctuous and has been named *oleum* (oil) by various writers at different times and is now called *petroleum* (petroleum) because it flows from rocks. This same black juice, when liquid, is called *pix* (pitch) by others because of the similarity in color to that of pitch. From this it is apparent that the name and nature of this substance was evident and well known to some and obscure and unknown to others. Thus many names have been given to one and the same thing and, at the same time, many more names coming from the vocabularies of different races have also been given to this same juice. The Babylonians called it *naphtha*, the Samosatians *maltha*. The Moors, following the Arabs, as did several other races who were influenced by their learning, called it *hafral*.[1]

[1] Agricola makes the following references to bitumen and related substances in De Natura Eorum Quae Effluunt ex Terra, Book I,—

Page 105. "The color of liquid bitumen varies. Some is white, especially the genus naphtha. Posidonius believed this material to be liquid sulphur. It flows from the earth in Babylon near Demetriade, in Parthia, in Mesopotamia and from a mountain they call Gibius on the Mutinian plains. It also flows into the German Sea and from it 'white amber' is made. Some is whitish gray as is that found at the port of Sichres, Arabia. The Arabs call this material 'solidified amber.' 'Solidified amber' is formed from a bitumen of a similar color which is dug up on the shore of the bay of the Sudini. Some is reddish yellow such as that flowing from a spring near Lake Degera in Suebia. It is also found at Salachites, India. Reddish bitumen is found in the fields around Modena. Wax-yellow, honey-yellow, and bitumen the color of Falernian wine is dug up from the German Sea. These are colors common to amber. Black bitumen flows from many springs in Germany, in Saxony two miles from the town of Brunon on the road to Scheninga and in the swamps three miles from Burgedorf; on the border of Apollonia near Nymphaeum; and in Babylon. Reddish black bitumen comes from a spring at the foot of Mt. Dester, fifteen miles southwest of Hanover. This bitumen

Included in this same genus is the substance the Moors, following the

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floats on the very clear spring water. That from Judea is a bright purple and some from near Brunon is blue.

"Bitumen has a variable taste and in this way we can distinguish it from amber. The black, when entirely dry, has a somewhat bitter taste while the white is oily sweet. Bitumen of other colors is less sweet.

"It has a variable odor. The black usually has a heavy odor, the white a pleasant one and material of other colors have odors between these two, sometimes almost the odor of myrrh. A black bitumen flowing from a spring at Cratea, Carthage, is reported to have the odor of citron. That from Nymphaeum Apollonia, has an odor of pitch mixed with bitumen and for that reason was given the name of πισσάσφαλτας.

"Sometimes the material which flows as a spring is cold as at the German localities mentioned above, sometimes it is warm as at Nymphaeum, and sometimes hot as at the asphalt lake in Judea where it flows out at irregular and unpredictable times.

"All bitumen is not the same consistency. Some is as fluid as oil as that from Suebia while some is the consistency of mud as that at Samosata which is called *maltha* and *judaicum*.

"Since bitumen is an unctuous liquid it is light and floats on water like oil."

Page 114. "Bitumen floats on water and when it occurs in abundance can be collected in vessels. When it is in meager quantities it is collected with goose feathers, fine meshed linen cloth—a method known to Pliny—and thin mats made from reeds. It adheres readily to these materials. Bitumen contains a very powerful fire essence so that when any material is saturated with *naphtha* and placed near a fire it will burn strongly. Water will not extinguish it and only seems to make it burn more. It can be smothered with mud, earth, powder and any wholly dry substance. Since it burns so readily it is widely used in lamps for illumination instead of the older olive oil, as for example, in the province of Agrigento, Italy, hence the name 'Sicilian oil'; near Solo, Cilicia; and in Babylon, Ecbatan, India and Ethiopia. The country people of Saxony use it today for illumination and for making funeral torches by dipping the dried stalks of mullein in it and also for greasing the axle-trees of carts."

Page 115. "Medea, according to Pliny, burned herself with bitumen when, after making a sacrifice, she drew too close to the altar, fascinated by the burning circle. For this reason the Greeks call naphtha 'oil of Medea.' This genus of bitumen is quite inflammable and Strabo writes that Alexander experimented with it by having it poured over boys and lighting it so that the boys were set on fire and died at once unless servants poured large quantities of water over them and put out the fire. According to Ammianus Marcellinus the Persians spread it on cloth and after lighting it used it to burn the homes of the enemy as the flame slowly spread over the cloth. . . .

"It is spread on copper and iron to prevent rust and corrosion. Saxons paint wooden posts with it to protect them from rain. For the same reasons it is customary to spread it on statues. . . .

"It is used in medicine. Drunk as bituminous water it breaks up blood clots and causes abortions. Spread on cattle and beasts of burden it cures mange and Pliny writes that the Babylonians believed it to be good for jaundice and for whitening the eyes. They also believed it to be a cure for leprosy, eruptive and itching skin diseases. It is used as an ointment for the gout."

Page 120. "Horses that drink from the Cassinitius River of Thrace are said to become wild and for that reason the water is judged to be bituminous."

Indian usage, called *camphora*. We know this to be true because Averroes writes that amber is a species of camphor; because Serapio writes that it forms abundantly when the earth is shattered with earthquakes and then, commonly, both sulphur and bitumen pour forth with great force; because certain springs of warm water along the Aemilia Road smell of camphor; because merchants say that they have seen a place in India that exudes camphor. Since the native camphor from India is colorless and, in part, tenuous and finely fibrous, it differs from the white naphtha of Babylonia. That which is brought to us in the small cakes is artificial. It is prepared in the following manner. Indian bitumen which effloresces from native camphor is placed in earthenware vessels and heated over burning coals. The more tenuous portions of the bitumen, having been changed to a white color, are carried upward to the lid. It is then collected and given the form we see. For this reason it happens that merchants sometimes bring us pieces of bitumen along with the camphor from India. But this association, in itself, is of little value. Actually if a cotton cloth is moistened with water and placed in the lid of the vessel in which oil is being extracted from amber, the cloth will have the odor of camphor.[2] Not without cause has Avicenna said that amber has a strong camphor odor. It catches fire and burns with the same ease as all other bitumens. Nevertheless the Moors and the younger Greek writers who follow them have another theory regarding the origin of camphor. They say it is the gum or the tears of a tree with such wide-spreading branches that it is able to shade an area large enough to accommodate a hundred men with ease. The wood of the tree is said to be white, ferulaceous, light, and with the camphor contained in the porous heart of the tree. Obviously a dream. The tree is said to grow in mountains near the ocean. When they think camphor to be either tears, resin or gum, the Moors do not consider why it is that the Indians would have any cause to extract the more tenuous parts from it over a fire. No matter from what kind of a tree a juice may come, if it is very pleasing and useful, it is used in the form in which it occurs naturally. For example, myrrh, bdellium, benzoin and other similar tears are brought to us in the same form as that in which they are exuded from the tree. Similarly, frankincense, storax, and other resins and even the gums of ivy, juniper, peach, and other trees are not altered. But, on the other hand, we often extract the more tenuous portions of other mineral substances in this manner, for example, from mercury and calamine. Therefore it is very probable, as certain merchants relate, that camphor is made from a certain genus of bitumen by distillation.[3]

[2] Although camphor and amber have the same general composition, $C_{10}H_{16}O$, they are only distantly related, chemically. There are many organic compounds that have an odor similar to camphor. When heated amber yields succinic acid, often called oil of amber and a bituminous residue. Agricola refers here to this acid

[3] Several closely related terpenes can be produced from bitumen but they were probably not being produced in the time of Agricola. Today these compounds are called camphors.

All Moorish writers do not say that this mineral is the gum of a tree. Neither the Moors nor the Greek authorities have investigated whether or not it was a juice but each has written that it is the tears of the poplar tree without investigating its true nature. Thus Serapio writes that according to certain people there are trees in the mountains of India that yield camphor in abundance. Isaacus, who writes at the same time as Serapio, states definitely that it is the gum of a tree and Pselus, a Greek writer, is not sure whether it is a gum or tears. The Moors write that native camphor is sometimes brought to them mixed with fragments of wood. There are two possible explanations of this. The wood may have adhered to the bitumen, by chance, as it was flowing or exuding from the earth since it is unctuous, or the Indians may have added it to the camphor in order to cheat the Moors or deceive the credulous. This argument that is used to prove that camphor comes from a tree is not sufficiently valid. And it is not the same as if someone said that amber was the juice of a tree because Archelaus writes that it is brought from India in the crude state with bark adhering to it. However, since I have never seen the place where camphor is produced I will not fight with these opinions of the Moors. Also, I wish to keep peace with the learned men who hold that the writings of the Moors are beyond question. Wisely, Ludovicus Vertomannus who sailed to the island of Borneo, having heard this theory of the origin of camphor withheld his assent to an unknown thing since he did not see it with his own eyes. No less correctly M. Paulus Venetus, who sailed to Lower Java to a place called Fansur where the finest camphor is said to be produced, has said nothing about its origin and has ignored the subject completely.

The color of the native mineral is not uniform since it may be white and clear with reddish spots, white and dull, or dark colored. The artificial mineral is always white. The taste is mixed, being both acrid and bitter. The odor is agreeable and varies only slightly. Camphor is, by nature, friendly to fire and when ignited burns at all points until entirely consumed. Even when it is smeared over an icicle and set on fire it will not be extinguished as long as a particle of camphor remains. For this reason it is commonly added to compounds which burn in water. It has a bright and sweet smelling flame. Since it consists of the most tenuous material it gradually melts into the air and disappears.[4] This fact is well known to physicians who place the mineral in vessels and cover it with flax or millet seeds in order to preserve it for many years. The camphor which has been sublimated to the upper portion of an earthenware vessel when placed on a fire is readily dissolved in wine and then burned as incense instead of frankincense and myrrh. The refined mineral is used in medicine to warm and to dry. This is taught by experience and proven by taste. A certain Moor has written, quite correctly, that it is warm and dry in the second

[4] Camphor readily sublimates in air at room temperature. This is an early description of this property of certain solids.

degree. The native mineral is less warm than the refined although it warms in time. Fire would not be able to implant so much heat within it when it is made in this manner if it were cold in the third degree as the Moors write, nor would it produce sleep if it were cold in the third degree as these Moors believe. Even though its odor prevents venery and having been drunk it prevents conception it does not follow that the mineral is cold. Rue, which is very warm, will do the same thing when drunk. Since camphor rises to the head, like all bitumen, it cures colds, produces sleep, and will turn the hair of a young man gray. Regarding all the other cures which are attributed to camphor these are, in most part, not due to the camphor but to the medicines with which it is mixed. However, since it is so tenuous, when added to other medicines it speeds their action. This is much too much concerning camphor.

Bitumen which flows from springs is often so dense that it has the appearance of mud. However, as long as it floats on water it remains soft or flexible. When removed and dried it may become harder than pitch. Even though completely fluid after being kept for a long time in a vessel it usually hardens. Dense bitumen is found floating on the Dead Sea and on the stagnant water of the city of Samosata, Comagene. It flows from the Carpathian Mountains at Siebenburg, is found in Rhaetia near Sefeld and in Epirus near Polina. The latter material is called πιττάσφαλτος by the Greeks, a word derived from pitch and bitumen, not because it contains both of them, as Pliny writes (I do not know whose opinion he follows) but because it smells like each of them, as Dioscorides correctly states. The Moors call this material *mumia*. Serapio gives this name to both this material and the compound used in embalming the bodies of the dead.

There are springs of bitumen on the island of Zante and at many other places. I have described in *De Natura eorum quae effluunt ex Terra* the occurrences, colors, tastes, odors and other qualities and uses of this mineral and will not repeat myself since nothing would be gained.

Liquid bitumen, having been drawn or collected, is heated in brass or iron boilers to thicken it. When it is finished it usually catches fire but the blaze is extinguished by linen cloths soaked in water and thrown over it. The Germans who live in Dacia and Saxony cook it in this way. I do not doubt that the Deximontanians who, as Pliny writes, live on the right bank of the Granicus river flowing through Susiana treat bitumen in this same fashion. Theopompus has written that the bitumen coming from the crater of Nymphaeum is mixed with some tasteless material and is the most dilute of all. Pliny writes that some pitch is mixed with bitumen and is recommended as a remedy for mange on animals and when young animals have injured the mother's teats. The Saxons increase the viscosity of bitumen by mixing it with old animal fat just as others mix it with pitch. It is dug up in a dense or stiff condition on a hill in Apollonia according to both Theopompus and Posidonius. The former calls it mineral pitch and

the latter writes that after removing the pitch the working is filled with earth and after a period of time the earth is changed to bitumen.

All bitumen is unctuous and fire and air are mixed with it in all proportions so that, as a rule, it will catch fire with ease. The more dense varieties catch fire easily when melted and since they possess the quality of denseness they will congeal again when placed in a cool room. Dry bitumen, whether natural or dried artificially, is used in many ways. Semiramis, using bitumen instead of mortar and without doubt before moistening it with water, erected a brick wall around Babylon. The Egyptians used it to preserve the bodies of the dead. The Sabaeans, burning it as incense, inhale the odors as a cure for head ailments. Pliny writes that when burned it is a cure for epilepsy. In medicine it warms and dries in the second degree and therefore coagulates bloody wounds and stops bleeding. Finally bitumen, both within the earth and on the surface, may be hardened and altered until it becomes as hard as a stone.

Let us take up now the earthy mineral to which writers have given various names. Galen called it stone, not realizing that it was the same as the pharmacist's earth he had just discussed. It is called *ampelitis* earth by those who have written on rural subjects. The Greeks call it *κνίπας* because, according to Galen, it harasses the worms gnawing the buds of vines. It is given the same name by physicians and pharmacists because, more than any other earth, it has the efficacious power of healing and curing. Theophrastus calls it *carbo* because it has the same color as coal; because it catches fire and burns in the same way; and because it is used in the same way as coal. The German name is made up of the words for stone and coal.[5] Actually it is just as easy to make up new words in our language as in Greek.

If bitumen is sufficiently hard to take a polish it is called *gagates* (jet). According to Dioscorides the name comes from the Gagas river in Lycia which empties into the ocean not far from Plagiopolis. It is found near the mouth of this river. However, Galen, who travelled along the entire coast of Lycia in a small boat and should have seen all the known things that have been found there, writes that he himself did not see the mouth of this river. Other writers have related that there was a town of Gagas in Lycia. According to Stephanus, in his first book on Lycia, Alexander called an ancient wall by that name. It is probable that when the town was deserted the name was transferred from the town to the river. Phocion Grammaticus writes that the Rhodians hid in this town. Pliny mentions Gagas and Rhodiopolin as towns of Lycia, each of which is likely to have been founded by the Rhodians. Nicander the grammarian says that this town in Lycia was called Ganga and Gangis and he refers to jet as *ἐγγάγγιδα πέτρος*. Strabo calls it *gangitis*. This same hard polished bitumen is called *samothracia* (gem of Samothrace) by Pliny—again I do not know

[5] Steinkohle.

his authority—because it is said to be found on the island of Samothrace. Nicander calls it *lapis thracius* because farmers bring it from a Thracian river that they call Pontus. An unknown Greek writer states that the Pontus river which carries down this genus of stone is between Scytha and Medos. There is still a question whether *lapis thracius* may be the same stone as that which Theophrastus calls *spinus* or the same as another stone which I shall now describe. Each of these stones is bituminous but the latter is simple, *spinus* complex. I shall discuss the complex minerals in the tenth book.

Obsidianus lapis is a hard bitumen which is so named because it is found in Ethiopia near Obsidius. The gem called *obsidiana* is made from it. We see that one and the same thing, namely black earthy bitumen that is often hard when it comes from the earth, is known by all of these names. It is necessary that I be able to defend my opinion with the words of the writers themselves. But first may I describe this kind of bitumen.

This bitumen is black, pitchy and resembles a poor quality of coal. It has the luster of pitch and is sometimes soft, sometimes hard. Broken into splinters and set on fire it burns. When the soft variety is pulverized and placed in olive oil it dissolves rapidly, as Galen has written. I have purchased many of these stones, tabular and black and similar to the tablets that come from Coele, Syria, which, when placed in a fire, burn with a meager flame. These come from the hills around the Dead Sea and from the same locality that produces bitumen. Their odor is similar to that of bitumen. However, without doubt the hot waters flowing deep beneath those bituminous hills have abraded and liquefied the bitumen and carried it into the lake or sea in which these waters have welled up as springs. This black bitumen is later cast up by the raging and seething of the sea and is found on the shores. It differs from the true Judean bitumen only in hardness. The more broken material is not tabular but differs only in this respect.

Ampelitis earth, which is also called pharmacist's earth (*pharmacitis*) is the best. It is pitch black and when broken into small splinters has the same luster as small pieces of coal. It dissolves when crushed and mixed with olive oil, according to Dioscorides. Galen says that it differs greatly from other earths and comes near to being the essence of stone. From this we know it to be hard. It is known to consist of bitumen, not so much from the writings of Pliny who says that it is very similar to bitumen as from the writings of Posidonius who says that it is bituminous. Since it is such a material it burns readily. From all of these facts it is evident that *ampelitis* earth is native bitumen of the finest quality and for that reason is given preference by physicians. Bitumen that has been mixed with too much earth is usually of another color and does not belong to this group.

It is obvious to the eyes that native coal does not differ from *ampelitis* earth. Theophrastus who has referred to coal makes no reference to *ampelitis* and, on the other hand, those who have written about *ampelitis* have

made no reference to coal. Theophrastus writes that native coals are those earthy substances which we regard as varieties of stone and earth and which, for that reason, we call by a name formed from stone and coal. Certainly some are much harder than others. It is obvious that every writer should have given a reason for the selection and meaning of his name, for example, those who have called this native bitumen, earth, or have said that it is an earthy coal and those who call it stone or λιθώδια coal because they regard coal as being soft and this material as being hard. For the same reason some have called a similar hard bitumen jet because they classify it as a stone. The Germans call it by a name composed of a corruption of the original name to which they have added the name for stone.[6] Since it actually belongs to this genus a description of it will suffice.

Jet, according to various writers, is black, tabular, quite light, inflammable and with an odor similar to bitumen. The most inflammable is the best. If sprinkled with water it will burn stronger but sprinkling with oil extinguishes the fire. Nicander writes that it is not consumed by fire either because bitumen burns continuously within the earth in many places or because the Magi, who use it in what they call divination, according to Pliny, deny that it is consumed if they so wish it for any reason. Serpents are driven away by its fumes. Having been warmed by rubbing it will pick up small light objects as does amber. It will not do this unless it has a natural brilliancy or has been polished. Solinus says that this property is limited to gemmy jet while Dioscorides, on the other hand, says that rough unpolished jet has the same property. Pliny writes that jet does not differ greatly from wood and since it is by nature tabular it has this type of fracture. It breaks with ease when dropped. The gem *samothracia* is seen to be nothing other than polished jet since Pliny writes that it has the same color, lightness and resemblance to wood. He writes, a black gem with a weight similar to that of wood is given the name of the island of Samothrace.

Lapis thracius is identical with jet. According to Euax Maurus it is black. According to Nicander and Dioscorides when it is sprinkled with water it burns with a very clear flame and is entirely consumed the same as bitumen and when sprinkled with oil it will not burn. An unknown Greek writer states that when burned it has an odor similar to that of bitumen but so acrid and unpleasant that no serpent will remain near it. In addition, a follower of Nicander correctly observes that it is bitumen because it has hardened after the manner of a stone. *Lapis obsidianus* is the same as jet since it is very black; because it gives a shadowy reflection similar to the image in a mirror; and because small statues have been made from it. In fact these and other similar criteria are those by which jet is distinguished from stones. Moreover we know this concerning

[6] Agat stein or Aidstein.

obsidianus since Pliny writes as follows concerning glass. *Obsidianus* is classified as a glass because of a similarity to a stone found at Obsidius, Ethiopia, which is very black and sometimes transparent. It has a dense appearance and reflects a dark shadowy image like a mirror. They make many gems from it and the statue of Saint Augustus was cut from the massive dense material as well as the four elephants in the temple of Concordia which was consecrated by a miracle. Tiberius Caesar, when placed over Egypt, sent back an obsidian statue of Menelaus that came into his possession, to the priests of Heliopolis. This shows the ancient origin of the material that is now falsified with glass. Xenocrates writes that *lapis obsidianus* occurs in India; Samnium, Italy; and near the ocean in Spain. Pliny, when writing about this mineral, says that it comes from India.[7]

I shall mention the places where this bituminous earth occurs. It is mined in that part of Britain or Albion which we call Scotland because of the Scotch Germans who emigrated there. It is found most abundantly about twenty miles from Edinburgh on the Deisert heath at a place they call Carbon. Some of this material burns as I have described elsewhere. Solinus writes that jet is also found in Britain. The hard variety that the Romans called *lapis obsidianus* is mined in northern Spain. Even today they still make statues from this material and many of these have been brought to us from Galicia by travellers. It is mined at Sion, France and in Lower Germany, especially near Leodiensis. The hard material from the latter locality is used to make the best beads with which we calculate prices. It is found in Lower Germany at Aquisgranus and in Greater Germany in many places, especially in Saxony at the town which is named Oberbach because of the white poplars, about twenty miles north of Munder. It is found in Misena in a mountain famous for its coal, two and one-half miles from Zuicca. There the miners worked the earth to a depth of six feet and then having enlarged the diggings they discovered a vein of soft coal almost eighteen feet thick when completely exposed. Below this was a very dense rock and below the rock a second vein of coal so hard they have given it the name "pitch" which it resembles in color and luster.[8] Below this vein bituminous *cadmia* was found and below that aluminous pyrite, pure copper and coal. There are burning mountains in certain localities and the coal that feeds the fire is changed into a black powder when earth falls into the fire and extinguishes it. Such a place is found along the distant Black river that flows through the solitudes of Africa where jagged, burnt-out rocks jut from the river. Pliny writes that Suetonium Paulinum was his authority for the above statement. This same genus of bituminous earth is found five miles from Dresden, Misena, on the road to Freiberg. It also occurs at three places

[7] These descriptions refer to the volcanic glass called obsidian and not to a bituminous material or jet.

[8] This probably refers to anthracite coal.

in Elboganus near the little town of Satelus. It is found near a town whose name is derived from that of a variety of hawk which we call falcon, along the road to Culma at a very high place which is called "The Burning Hill" because it burned once. The same is dug up at Samnius, Italy, according to Xenocrates; near Liguria, according to Theophrastus; in Thesprotia; and in Elis, along the road over Mt. Olympus.

When polished we give coal a new name and call it jet (*gagates*). Not all coal can be polished, only the hardest, and not all jet is coal since some is bitumen. This same name is given to black bitumen that has been indurated in the sea and thrown up on the shore near the Vistula river in a manner similar to amber but in much smaller quantities. According to Pliny it is thrown up by the sea in Leucola where it is collected over an area a mile and a half long. It is found along the Pontus river in Thrace and hence called Thracian stone by Nicander and Dioscorides (*lapis thracius*). Samothracian gem (*samothracia*), so-called by Pliny, is found on the island of Samothrace. The material found in Lycia near the town of Gagas was called *gagates* by Dioscorides and the material from Mesopotamia was called *gangitis* by Strabo. According to Galen *gangitis* is found around an asphalt lake in Judea and at Seleucia Pieria, the most prominent town of Syria. Strabo and Dioscorides called the material from the latter locality *ampelitis* earth. We know from the writings of Galen that some of it was hard and thus similar to hard coal and rough jet and some soft and similar to soft coal. This same hard bitumen is found in India and Ethiopia according to Xenocrates and Pliny has called these materials *lapis obsidianus*. This is enough concerning the places where this mineral is found.

I shall now consider the uses and these are many. Copper and iron workers sometimes use it in the place of charcoal but it will corrupt iron and make it brittle and for this reason those who do fine iron work do not use it. They use only iron obtained with charcoal except when it is not available. When wood is not available people use this bitumen to cook food, to heat their homes in winter and to burn lime. Farmers put it on vines because it blinds and kills worms and rodents. It is used to dye the eyelids and hair various pleasing shades. In medicine it is used to dry and dispel. The hard, polished varieties are carved into statues of people, into round balls used in calculating prices and into gems to be placed in rings or to be used as a base.[9]

We shall now consider the mineral called *succinum* (amber), what it is, where it occurs, localities where it is mined and where it is cast up on beaches, and finally its distinguishing qualities. To begin with, the Romans correctly called it *succinum* since it is a congealed juice although not the juice of a tree as they thought. The Greeks called it ἤλεκτρον

[9] Although jet has been used as the backing material in doublets, Agricola undoubtedly refers here to obsidian and chalcedony which have enjoyed a much wider use in doublets because of their superior physical properties.

because when it is rubbed it will attract chaff and other small light objects. For the same reason they called it ἄρπαγα. If it comes from Germany the Moors call it by the Persian name *caraben*, a name that has the same significance as ἄρπαγα, and if it comes from Arabia or India it is known by the Arabian name *ambra*. Serapio calls the German mineral *ambra*. The younger Greek writers, like the Moors, call the Indian and Arabian amber *ambra* but they had no cause to employ a foreign name since their language was full of words which were easily adapted to new things. The older Greek writers called all bitumen that had been hardened into stone of any color except black ἤλεκτρον. The black bitumen was known to them by the names mentioned previously. The older German writers called it *glessum* (glessite) which in our language signifies glass since some of the yellowish-brown and reddish-brown amber is as transparent as glass. The Greeks call this latter ὕαλος and the German term is seen to be an imitation of the Greek. Today we call it two different names, one of which is *gagates* since it is, actually, a form of bitumen and the other name comes from the fact that it burns.[10] It is called *gentarus* by the Prussians. The Scythians call all amber *sacrium* and the reddish yellow varieties *sualternicum*. The Egyptians call it *sacal*. Amber is known by a great many names but since I am interested in things and not in words I have mentioned only a few since I have no wish to make several minerals from one and the same mineral. The Moors are in the habit of doing this and they are often in error.

There are no fewer opinions as to what amber may be than there are names for it. Pliny has discussed almost all of these theories. Sophocles was of the opinion that it was the congealed tears of guinea fowls crying for Meleagar.[11] A poet is allowed to use his imagination and hence no one who is unprejudiced would give this idea any credulity for it is obviously false. Demostratus thought that amber was the frozen urine of the lynx and he named it *lyncurium*. For this same reason others have called it *langurium* after the langur monkeys or, following Zenothemis, *langa*. It is obvious that this theory is as false as that of the tragic poet. Many say that it is the sap of a tree. Since there are three kinds of amber, namely, tears or drops, gum and resin, none of the writers has ever described in detail the sap or the tree from which it exuded. The writers who have believed that amber is the juice of a tree are the Greeks, Sudines, Metrodorus, Ctesias, Theomenes, Sotacus and the Latin writer Cornelius Tacitus. Ctesias wrote that the tree was called *aphytacora;* Sotacus, *electrida*. Some writers have described one of these three juices, for example, Aristotle, who apparently believed that the original juice dropped from a tree. The poets Aeschylus, Philoxenus, Nicander, Euripides, Satyrus and Dionysius write that amber was the tears of a certain poplar tree and Dioscorides mentions these opinions. The Latin poets follow the Greeks

[10] Bernstein.

[11] The sisters of Meleagar were changed into guinea fowls when he died.

in this belief. Some poets believed that amber was a gum but Pliny has not written who they might have been nor has he named the tree that, in their belief, produced this gum. Actually the poplar does not give off drops or tears but a resin according to the belief of Dioscorides. Pliny who decided it was a pine tree which produced the juice and Mithridates who though it was a cedar have left the following description "for each tree produces resin." There is seen to be considerable conflict in these statements hence we know one and all to be false since neither on our shores nor on the opposite shores nor on the intermediate islands do we find trees on the high cliffs, of which there are many along the seashores, that drop resin into the sea so that amber can be formed from it. Amber is usually thrown onto the shores by waves and storms and since it is soft both outside and inside it cannot have come from any great distance nor can it have lurked in the depths of the sea since some ancient time when trees might have dropped it. Therefore trees do not exude amber.[12]

Some say that it is a juice of the earth and they believe that the rays of the sun, penetrating with great force, bring forth an unctuous sweat from which amber is produced. Nicias is seen to have been of this opinion. What juice could be produced by the rays of the sun which are both hot and dry? Nicias was correct in believing that amber is an unctuous juice of the earth or, as he called it, a sweat but he is wrong in believing that it is produced from the earth by the rays of the sun. Either the intense heat of the earth squeezes out a liquid from the unctuous earths or, liquifying an already congealed mass, causes it to flow forth, or waters which moisten and dissolve the congealed matter bring it forth as a liquid from the veins of the earth. How could the sun draw out a juice from the frozen regions toward the north that are turned away from it? Why does it not draw out this juice from the many hot places that are directly beneath its course? Certainly the heat is greatest in the latter regions in summer and only moderately so in the former regions. If the sun is able to throw such vehement rays on our country that they can liquify congealed juices they should certainly liquify those juices that have been exposed to the air but the juice from which amber is made is very rarely so exposed being almost always buried in the earth where, having been liquified, it flows out with water. Therefore the rays of the sun do not produce this juice. Nevertheless Nicias has come closer to the actual method of origin of amber than any of the other Greeks or Latins. Even Asarubas and our own writers who say that it is formed from slime have added something. But neither the latter have explained what kind of slime it may be nor Nicias what kind of juice. Since amber is unctuous and inflammable it is obvious that it must be related to either sulphur or bitumen. The variety of colors shown by bitumen as it flows from fountains, white, yellow, reddish, black, purplish red and bluish black indicate that it is more

[12] Agricola's logic, based upon his inability to see a tree that produced amber, led him to err.

probably a bitumen than sulphur. Additional evidence is found when bitumen is cooked artificially and part of it turned into oil of a characteristic color, part into black bitumen which is purple when finely ground and so similar to the material found in Judea that it cannot be distinguished from it, part into black ashes and finally part into a white tenuous substance that bears a certain similarity and appearance to salt. This, having been set on fire, decrepitates similar to any other tenuous juice.

Now may we consider what has been written about the places where amber forms and the regions where it is found. The Greeks, especially the Greek poets, were of the opinion that it formed most abundantly in Italy. Some say along the Po river, others on the islands they call Electridas, still others along the cliffs on the shore of the Adriatic Gulf. Sudines and Metrodorus say that it formed in Liguria and that the amber trees can be seen there. Zenothemis writes that it is formed near the Po but says it is the urine of beasts he calls "*langae*." Theophrastus writes in *De Lapidibus* that it is found in Liguria. Strabo writes that Liguria abounds in *lyncurium* which certain ones call *electrum*, a proper use of the term. As a result of a false idea certain ones have given this mineral the name *lyncurium* derived from the name lynx,

> "From which, as they relate, whatever comes from the bladder
> It is turned into stone, and it congeals when it touches the air."

At no time has any amber congealed from the urine of the lynx as Pliny correctly believed. The older Roman writers did not have a correct theory concerning amber although it formed in Italy, nor have our own writers, with their superior mental ability, profited by the formers' thinking when considering natural things. Pliny accepted the creation theory because the peasant women north of the Po wear amber as a necklace both for the sake of beauty (I use his words) and as a remedy since they believed that it prevented tonsilitis and throat troubles by soothing the throat and adjacent flesh. Theophrastus and Xenocrates believed that it was formed in Spain since storms threw it on the beach of a promontory of the Pyrenees. However in Spain as in southern Germany we find jet but no amber. Black bitumen that has been changed into stone is not an amber as the Moors and we Germans have falsely believed. Likewise Sotacus, who believed that it flowed from trees in Britain, is also in error.

The European localities where amber is found have been mentioned by following writers, Pytheas, Timaeus, Nicias, Mithridates, C. Pliny and Cornelius Tacitus. Pytheas and Timaeus have written that the waves of the ocean carry it, in the spring, to an island and that it is the dregs of the sea. Pytheas calls the island Abulus and Timaeus, Bannomanna. The former says that the island is one day's sail from the Mentonomus estuary where the Guttones of Germany live, the latter, the same distance from Scythia. Neither writer says what these congealed dregs of the sea are or whence they come. They only indicate that they are cast up by the sea.

Actually amber is not only cast up on islands where it can be collected but also upon the shores of both peninsulas and continents. Therefore neither Pytheas nor Timaeus writes anything which is definite and we have no knowledge of the existence of either of these islands today. The last three writers believed that the place in which amber originates deserves a description. Nicias, with excessive frankness, wrote only that it was land to the west and Cornelius Tacitus, islands and lands to the west. Each writer gives reasons why it originates in the west. The former considered Greece since anything coming from there, no matter what it was, was considered to have come from the west. Tacitus considered the eastern countries where the forests and trees exude incense and balsam and these actually are in the west. Pliny is correct when he writes that it forms on islands in the North Sea and one of these has been named Glessaria by the soldiers of Germanicus Caesar who fought there since *glessum* is the German name for amber. The island is called Austrauia by the barbarians. Mithridates calls the island where it originates, Osterica, both of these latter names being of German origin. Austrauia signifies to us a plain situated in a low region to the east, Osterica an eastern kingdom. The Germans who live at the mouth of the Rhine along the shore call the islands where amber would form by these same names because they are to the east. However, if we study the shores upon which amber is thrown, we find them situated in the west and facing to the north. Mithridates believed that amber formed from a variety of cedar and fell in a petrified form but how this was effected he does not say. After falling it rolled to the sea and was picked up from the shore. Others write that it was cast on to the shore having been torn from both the land and the islands. Nicias writes that it is cast up on the coast of Germany. Pliny is seen to be in agreement with this since he writes of the distance from the German shore where it is found to a town of Pannonia. Although it is found in Germany along the coast between the Suebi river and the mouth of the Vistula this is a small amount compared to that which is found on the famous peninsula. Cornelius Tacitus writes, correctly, that the people of Aestyus collect it on their shores. A certain priest has written recently, for posterity, that amber flows from the cliffs along our shore into the sea. Some of the Germans, although very few, know that it is spread abroad from the cliffs of this peninsula. The uncouth Prussians have no knowledge of this. The amber that is cast up on the shore in this particular area, by west and north winds, is a golden-yellow. This part of the peninsula belongs to Samaidensis, called Sambiensis by some, Samlandia by others. This portion of Prussia extends from the Pregala river, which Ptolomaeus calls Chronus, to the sea. There it is called Sudavia and hence the racial name Sudini. This maritime province, which faces to the north, extends approximately thirty-five miles from the west promontory of the peninsula, called Brusta, to another promontory which takes its name from the Curis people. Actually it is but little larger than Sudavia and

comes to a very narrow point to the east. The shore bends a little to the north toward the peninsula which faces the west and extends thirty-two miles from Brusta to Lochsteda. Amber is cast on the shore of the peninsula, especially around Brusta. Sometimes it is driven farther to the east by western winds, even to the shore of the country of the Curi and beyond. A portion of this adjacent country is under the rule of the Prince of Livonia. In the same manner, an eastern wind will drive it to the west, and during northern storms it is thrown on the shore near the promontory of Friesland which extends as a narrow strip from the right side of the Vistula toward the peninsula. These same winds cast amber on the shores of Germany today, as always, at a place once inhabited by the Gotthones and Suebi, a small peninsula on which the towns of Puceca and Hela are situated, and along the shores of Pomerania. Almost all of these localities are near the mouth of the Vistula. Amber is found abundantly in Sudavia, in small quantities in Livonia and in smaller quantities in other places. Although the Germans rule all of these places which extend as far as the Narva river that separates Germany from Muscovy, the older Prussians, the Sudini, Curi and others, use a language which Cornelius Tacitus says is more closely related to that of the Britains than to ours. Many Greek words have been intermixed with it but these are used in such an untutored fashion that one cannot understand them unless one listens very carefully. There are about thirty villages of the Sudini who live on that portion of the peninsula near Brusta and these people today, as in the most ancient times, gather amber in small nets in the same manner as they catch fish. When they were freemen and had their own laws they gathered amber of their own free will but now as slaves under the alien laws of the Germans they, having been handed over to the holy military class, are ruled by them and are driven to their work by commands. Practical experience has taught these people the best method for collecting this mineral and this knowledge has been passed down from hand to hand as they say.

When Favonius, Corus or Trascias is shaken by storms at sea all the people of Sudini rush eagerly from their villages, at night as well as during the day, to the beach upon which the waves are driven by the winds. The men bring with them their nets woven from linen cord and fastened to the ends of long poles with two prongs. When spread out these nets are as long as a man's arm. The women act as helpers. When the wind dies down but with the sea still running high the men, completely naked, run into the sea in the wake of each wave and gather in their nets the amber which has been carried along the bottom. At the same time they pull up the plants, not unlike penny-royal, that grow on the bottom. They collect the amber and any plants as quickly as possible and when the next wave comes in they run for the beach where the wives empty the debris from the net and remove the seaweed and other materials. If they have children they help also. During the winter months of the year the wife warms the

cold body of her nude husband with cloths that have been warmed by the fire so that he will not suffer too much from the cold and can go back into the sea refreshed. He goes back again and again until he can find no more material. He must take everything that he finds to an overseer who gives him an equal measure of salt for the amber. This is the only compensation he receives for so much work and such irksome labor yet he is bound to this by old and long established custom. The Sudini are not allowed the liberty of travelling nor are they allowed to conceal amber. When anyone is caught concealing it his civil liberties are taken from him, he is soon brought to trial and hanged from a tree. However, these Germans get as much pleasure from gathering amber as they do from fishing. In any one year with more than a thousand merchants along the Rhine less than ten will sell amber which, having been shaped into various forms, is sold in lots. White amber is the most esteemed today because it has the most pleasing odor, is most efficacious as a remedy and is rarest. The next most prized amber is the transparent reddish yellow and deep red and next the whitish variety which is the pale color of cooked honey. The other amber is of little value. A large piece sells for more than many small pieces of the same weight.

In other localities where amber is found on sea shores it is rarely collected in nets. It is either picked up on the dry sand where it has been left by the waves when they have subsided or when the sea is calm. The larger pieces are located with a three pronged fork and dug up from the beach or the sea bottom. It is sometimes found when sand is taken from the shore. Recently amber has been found on the beach near Dantiscus where it has the appearance of having been thrown away and later covered with sand. Obviously Philemon was not entirely wrong when he wrote that this mineral is dug up at two places in Scythia. The regions beyond the Vistula river were called Scythia by some Greek writers among them Xenocrates and Sarmatia by others. Philemon writes that white and wax colored amber is dug up at one place and dark reddish brown in another, but this does not agree with the facts. Actually all colors of amber are found in one and the same place, whitish, wax colored, reddish brown, deep red and that which is the color of cooked honey. Gray amber usually has a crass or cloudy appearance due to the sea salt it has picked up. Reddish brown and deep red are commonly transparent and sometimes contain small flying insects such as flies, gnats, bees and rustic animals such as ants, small red worms, spiders, lizards and vipers according to Martialis. Other inclusions are swimming things such as fish, the parts of small animals such as the wings of flies and fish roe, inanimate substances such as the stalks of plants and leaves with branches, all of which are either picked up by, crawl into or fall into the liquid bitumen when it flows out of the earth or swim into it when it flows down into the sea and once having been included in this manner they are changed into stone along with the amber.

Amber varies in taste. The white is oily sweet while the other colors are

less sweet. It varies in odor and while all of it has a pleasant odor and sometimes may smell like myrrh, the white is the best. When we fumigate rooms with shavings of amber during the plague the odor will last for three days. It is rarely soft and although hard it is considerably less so than stone. All is light but the white is the lightest and they use this to make the dice with which our people play. It is worked into a variety of forms. The beads with which we say our prayers are made from it as well as rings, small dishes, small statues and effigies of many things especially of men. Those things made from the white are the most valued today. Once amber was so highly esteemed by the Romans, as Pliny writes, that any small statue of a man made from the reddish brown or deep red material was of greater value than a living healthy man. Just as we value the whiteness and beauty of our statues the Romans preferred statues of these other colors because of their beauty and transparency. However dice are made only from the white so that they will resemble those made from the bones of animals. When placed on a flame it catches fire readily and burns as do all other genera of bitumen. For this reason the old Prussians who Cornelius Tacitus calls Aestii used it in the place of wood for fires.

Having been warmed by rubbing amber will draw and support feathers, chaff, balls, leaves and other small light substances in the same manner as lodestone attracts iron. Although Theophrastus claims this is not true, it does attract ocimum. It will pick up metal shavings and some writers attribute this power to the lynx. When the fragments of amber that are left over from cutting are set on fire they blaze up in the same fashion as does the powder they use to throw balls from cannons. When a solid piece is rubbed it takes up some heat from the fingers but it will become warmer when rubbed with a rough cloth, a piece of wool, stone, iron or some other hard substance. Recently some gray amber was dug up on the beach near Puceca on this side of the Vistula which, when rubbed with iron, would draw leaves that had fallen to the ground even when held in the hand a distance of two feet above them.

Amber offers a multitude of uses. Fragments are used in the place of incense for fumigating and for clearing fetid or contaminated air. It is used in lamps to make them burn brighter and for a longer time. The African peoples who burn their dead break pieces from the crude material and boil them in oil until they form a solid mass. This is then thrown on the burning pyre. Writers mix fragments with their ink and then warm it. In medicine it has the property of coating and having been drunk stops bleeding no matter where it occurs. It will stop vomiting, flux of the womb, discharge from ulcers, head discharges, and cure tonsilitis and throat irritations. It strengthens the viscera and other parts of the body. Since it is sweet smelling it is good for the heart and will stop heart tremors. The fumes of white amber will drive away epilepsy. So much regarding European amber.

I shall now take up African amber. Writers are not of one opinion re-

garding the places where it occurs. Nicias writes that it occurs in Egypt in the same way as in Europe. Theophrastus says that it occurs in Ethiopia and Xenocrates, someplace in Numidia. Asarubas, who lived in the time of Pliny, writes that it comes from Lake Cephisida, called Electrum by the Moors, near the Atlantic ocean. When this lake was heated by the sun the amber would rise from the slime on the bottom. Mnesias says it occurs in the same fashion in an African lake near Sicyon from which flows the Cratis river. Theomenes says it is collected from a swamp near Sidra on the north coast of Africa and he was of the opinion that it was the juice of trees. Certainly it occurs in Africa but where, I am not sure. A rough piece was brought from Africa and when broken open was found to be reddish yellow and transparent.

Amber occurs in Asia since Nicias writes that it is found in Syria but he does not give the name of the locality. Pselus says it is found at Silachitis and has a reddish yellow color. He writes that the Moors call both the Arabian and Indian material *ambra*. In the works of Serapio amber is said to grow out of an earth which is under the sea, in no way different from the manner in which fungus grows out of things that project above the sea. In part it is cast up on the shore along with small pebbles by the waves and storms and then collected and in part it is eaten by fish and when they are killed it is found inside them. That which is found in the stomach is misshapen, the best being found near the spine.[13] Avicenna and Pselus are more correct in believing that it flows from springs in the ocean although neither denies that it is found in fish. M. Paulus Venetus asserts that it comes from whales near the island of Madagascar and is found through good fortune. I do not know if amber is to be found in the stomachs of our fish. Even Asiatic amber flows from fountains in the sea and when hardened is cast on the shore in the same fashion as the European mineral. The Asiatic material is not brought to us. Instead we receive an artificial substance which smells of musk or civit. This is made either from benzoin, white wax of a new swarm of bees, rotten ashwood and moss of trees, or from storax, labdanum and shavings of aloe wood. Musk or civit is added to each mixture and all is mixed with rose water. It is easy to detect this fraud. Natural amber does not soften in water as readily as does the artificial and it has a different color and odor. So much for amber.

Not far from the place where the Vistula empties into the Gulf of Pucicus and near the monastery called Oliva they find quite hard lumps of congealed bitumen with a form more or less resembling eggs and with either a yellow, gray, reddish or even some other color. It is neither sweet nor pleasant and burns readily. Small shrubs that have a fish-like

[13] This is probably a reference to ambergris or a related substance. The Arabian term *anbar* was first given to ambergris, a gray waxy substance secreted by the sperm whale. Later the name amber was derived from this term through the French, and given to the fossil resin.

odor, evidently either oak or boxwood, occur with it. These are three or at the most four feet high. They lack roots and adhering to the bitumen have the appearance of the shallow wooden dishes or platters the Greeks call λεπάδας. These stones are similar to those described by Theophrastus that formed in the sea along with oaks and firs. However, Theophrastus writes that the oak and fir grew on oyster shells hence if this genus of shrub can grow on bituminous stones it is obvious that it could not grow very well on oyster shells.

Anatachates smells like myrrh when it is burned and is either amber or some bituminous stone of another color.[14] *Aromatites* takes its name from its very pleasing odor. It smells like myrrh and forms from bitumen. As Pliny states, it is reported to have its origin in Arabia but it occurs in Egypt near Pisa. Since it is like stone and with the color and odor of myrrh it is widely collected for royal ladies. Similarly *myrrhites* is the color of myrrh and although called *gemma* it bears little resemblence to a gem. Having been crushed it has the odor of nard ointment and is seen to be bituminous. *Zanthenes* also belongs to this genus since it can be softened like wax and is sweet smelling. Democritus records that it occurs in Media and is the color of amber. If ground with palm wine and saffron it becomes soft like wax and has a very pleasing odor.

Today gems are not made from amber that has been dyed but at one time they were made from material that had been dyed with the root of alkanet.[15] *Baptes* is seen to have been such a gem for its name signifies dyeing[16] and the soft varieties had a distinctive odor. Pliny has not told us with which color this material was dyed. Megasthenes writes about stones that are mined in India with the color of frankincense and sweeter than figs and honey. We know that these belong to this same genus since amber is definitely sweet and at times has a color that closely approaches that of frankincense. Among these stones Pliny makes special mention of *libanochrus*, a gem. Actually *atizoe* which Democritus records as occurring in India, Persia and Mt. Ida, shining with a silvery beauty, three inches in size, lenticular in shape and with a pleasant odor, is a bituminous gem. What could be the origin of such an odor in a stone unless it were bituminous?

Finally, *catochites*, a stone of Corsica, is of this same genus. When placed in the hand it sticks to it like a gum, hence the name. *Lipare* belongs to this genus and when burnt draws all animals to it.[17] The stone is unctuous, hence the name. Amber, especially the rough, unctuous, genu-

[14] The name means "non-agate" and may be identified with the natural resin retinite.

[15] Alkanet yields anchusin, a red coloring material.

[16] The Greek word βαπταός from which this name is derived signifies imitation.

[17] A favorite mineral of the writers of ancient and medieval lapidaries. Many fantastic magical properties were ascribed to it, all with a central theme of its irresistibility to animals.

ine mineral, if held tightly in the hand for some time is observed to adhere to it. In the same fashion, soft bituminous stones are seen to be of such a nature that they become soft and adhere to the hand even more. There is some doubt as to what *myrsinites*, a gem, may be. It is the color of honey and has the odor of myrtle. Amber may have this color but not this odor.

Before I leave the sea may I mention certain other minerals that occur there. Since the water of the sea is salt, when the foam is mixed with very fine dust it congeals and forms *halcyonium*. This mineral is named for the birds the Greeks call ἀλκυών, the Latins *alcedona*, since it used this mineral in building its nest which floats on the sea. Both Dioscorides and Galen agree that there are five species of this mineral. The first has a form similar to a sponge but is dense and heavy with an odor of decomposed fish. It is found abundantly on the sea shore. Another species is rather long, full of holes, smooth and with an odor similar to seaweed. A third species closely resembles worms and has a purple color and is soft. This is called Milesian *halcyonium*. The fourth has an unctuousness similar to unwashed wool, is full of holes and smooth. The fifth is as light as fungus and is as rough inside as pumice. It is acrid but has no odor. This occurs on the island of Besbicus in the sea of Marmora according to Dioscorides and is called ἅλος ἀχνη, which is to say sea foam. This name is now given to all *halcyonium* except the rounded variety which we usually call a "marine ball." The last species cleans and, through exhalations, breaks up gatherings, as do all the rest. It is very corrosive and eats away the skin and destroys the hair.[18]

Adarce, also called *calamochnus* which means reed foam, is related to *halcyonium*. It is a variety of *halcyonium* that forms in a marsh on the dry portions of reeds and twigs. It is somewhat salty with a color similar to that of "flowers of Assius" but with a form characteristic of all *halcyonium*, soft and full of holes. The whitest is the most acrid and for that reason cannot be used by itself in medicine but when mixed with other substances which reduce its power it is applied only to the outside of the body. *Lapis spongia* and *spongites* are commonly found in sponges and hence the name. These are perforated like a snail shell and each, when drunk with wine, breaks up gall-stones and for that reason are also known as *tecolithos*. Although not one of these three minerals forms within the earth I must mention them since two of them form from saline juices and because Theophrastus calls *halcyonium*, *pumex*, Pliny, *spongites*. Pliny regards *spongites* as a stone and has classified it as a gem. Just as amber forms from an unctuous juice that flows into the sea, *halcyonium* forms from a saline juice peculiar to the sea and when this is changed into a stone it forms *corallium* (coral) or, according to Theophrastus, *curallium*. It has been called *lithodendres*, partly because it has been changed to stone and

[18] Halcyonium embraces coral and a variety of calcareous skeletons and shells of marine life.

partly because it is arborescent. Because of its arborescent form it has also been called *dendrites*. Actually the coral itself can be seen as a soft green bush growing under the sea. It has berries which are similar in appearance and size to those of the cornel tree. They are soft and white and when left in the air they soon harden as cleverly described by Ovid,

> "In this way coral, when first it touches air,
> In time it hardens, soft was the plant under the waves."

Since it begins to harden as soon as it is exposed to the air it has been named *gorgonia*. The poets picture the Gorgones as turning people into stone. Pliny writes thus concerning gems, "*gorgonia* is nothing other than coral, the reason for the name being because it is changed into the hardness of stone." The Persians, according to Pliny, call it *jaces*. Coral is not of one color nor are the other stones of this genus that have congealed within the earth from a juice. If the juice was red the coral is red; if reddish, reddish; if white, white; if black, black; and if greenish, greenish.However, as I have said previously, all coral before it is torn away with nets or broken off with pieces of iron is green. When a single stone forms from juices of different colors it has several colors and for this reason the stalk and branches of a single coral may be red, white, black and other colors, Black coral has been named *antipathes* by some, according to Dioscorides and by others *isidis plocamos*, according to Juba. Coral has a moderately astringent taste and an odor very similar to algae. Some is hard, such as that from Gaul, some soft such as that from Terra di Lavoro, while that from Erythra is even softer. All coral will break when it falls. Some is solid, some tube-like, some scaly, some with many branches and some with only a few.

Coral occurs in many places. It is found around the Orkneys north of the British Isles, in the Hetruscus Gulf near Gravisca, at Terra di Lavoro near Naples, in Sicily near Helia and Trapani, in Africa near Erythra, in the Persian Gulf. Black coral occurs in the Red Sea around the islands of the Troglodytae.

We wear the perforated berries of coral as ornaments and use them in calculating prices as do the Indians. Pliny writes that the Indian prophets and priests, being especially superstituous, believe that when they are worn as an amulet they have the power to ward off danger and hence the people take a decorous and religious pleasure in wearing them. Unless it is a coral berry I do not know what the mineral might be that Pliny calls a gem nor whom he has followed when he writes that it has the appearance of a cherry. The common people believe that if young sprouts of coral are worn suspended from the neck they will protect infants and children from being bewitched. The people of Gaul decorate their swords, shields and helmets with it. As a remedy it dries and cools and is astringent. For that reason, having been drunk in water, it stops the coughing of blood and cures severe cases of colic. Physicians select

the coral that is red, has an odor of algae, is easily crushed, has congealed uniformily and is branching.

Stalks form from a petrifying juice[19] in other places than in the sea. For example, thyme, a variety of laurel, and other similar species are found petrified near the mountains of Calpe and Abyla at the Straits of Gibraltar, reeds and bulrushes in India and fungus in the Red Sea. Both Theophrastus and Pliny are the authorities for these things that have been changed into stone. *Calamites* named from *κάλαμος*, a reed, belongs to this genus and *syringites* which was a hollow stem like a pipe between joints. Also *phycites* which derives its name from a resemblance to algae.

Enough of this. I shall now take up the stones that are formed within the earth.

[19] To explain and rationalize the origin of minerals and certain rocks Agricola developed the theory of a petrifying juice (*succus lapidescens*, *De Ortu et Causis Subterraneorum*, pp. 51–57). This was a revolutionary concept, far in advance of the contemporary and earlier theories of petrific seed, *vis formativa*, celestial influence, and many others. In developing his theory of the origin of this juice and its action within the earth in producing stones and minerals, particularly in veins, Agricola apparently had the germ of the modern concepts of mineral formation. In many passages the proper translation would be "mineralizing solution."

BOOK V

I have said that there are four genera of stones, the first, in brief review, is called common stone and embraces lodestone, hematite, geodes and a great many other species. Minerals of the second genera are called gems and include diamond, *smaragdus*, *carbunculus* and similar species. The third genus is much larger and since the species may have the brilliancy of polished gems it is called marble. Members of this genera are identified principally by color and place of origin, typical species being *phyrites*, *ophites*, Parian and Laconian marbles and others. Species of the fourth genus are called rocks and differ from stones. This genus embrances sandstone, limestone and others.

May I speak first of the stones of the first genera and first of all about lodestone since it is the most famous and noted of all because of its singular and chracteristic power of drawing iron to itself. Because of this property the Greeks have many names for it. It is known as *magnes*, *magnetis*, *heraclius* and *sideritis*. The name *magnes* comes either from the name of the man who first found it on Mt. Ida, according to Pliny who took this story from Nicander, or from the district Magnesia in which lodestone is found. Lucretius writes in these words,

> "The Magnesians call it by the patriotic name of the Greeks,
> *Magnes* because it is found within the borders of their country."

It is called *magnetis* by others for the same reason. The name *heraclius* comes either from the town of Heracleia or from Hercules. Just as Hercules conquered and destroyed the hideous and fierce monsters of the earth through his strength, in the same way lodestone overcomes the natural essence of the things it draws to itself. Because of this power it is also called *sideritis*. It has the appearance of rough iron and is commonly found in iron mines although in only a few such mines since there are a great number of iron mines. Sometimes a large amount of the mineral is distributed at random through the iron ore and sometimes it may be found in a continuous mass. It is found in Cantabrian, Spain, and on an island north of Lapland that takes its name from the mineral. It is found in Germany in the following places: in the Harz Forest beyond Harzburg about seven miles from Goslar, where it is obtained from a single opening; in an iron vein on Mt. Meissen near Swarzburg; especially near Eibestock in a mine named Magnes; near the village of Pela on the right hand side of the road to the valley of St. Joachim and in an iron mine that takes its name from the discoverer Burcardus and the sloping ground. It is also found in the country of the Franks and likewise in Bohemia in iron mines near the town of Lessa, about halfway between the town of Slaccheuerda and the hot springs of Charles IV. Lodestone occurs especially in Mace-

donia in the district of Magnesia that has the same boundary as Macedonia and lies to the right of Lake Boebe. It is found at Echius in Boeotia; at Troas near Alexander; in India near the Indus river and in certain rough rocky districts along the ocean and near Zimirus in Ethiopia, concerning which Pliny has written, following Sotacus.

Lodestone varies in color being either black, bluish black, reddish black and sometimes even dark red. It varies in density and porosity. Some is as dense as emery, some is in part as porous as though it had been eaten away and may even resemble pumice. It differs in weight since it may be heavy, light or intermediate. It varies in strength. Some will draw iron to itself with force and is called "male" while some is weak and is known as "female." The best not only draws and holds iron but also transfers its power into the iron so that it in turn is able to pick up and hold other iron they may lay near it. Thus it may draw to itself many rings and these are so held that they are all suspended from the lodestone since it will draw some iron to itself and then communicate its force to other iron which in turn passes on its force and holds still more material. In this manner we can see rings fastened to other rings as though forming a chain although one ring is not fastened into the other in the manner common to chains. The force draws and holds the first ring most closely and strongly, the succeeding ones loosely and less strongly. Since this phenomenon produces the greatest astonishment among the common people the iron to which this stone has given its power is called "living iron" according to Pliny and Empedocles of Agrigentum writes in his philosophy that lodestone is alive. Theologians attribute the powers this mineral possesses to divine origin, scientists to natural origins, the nature of which cannot be interpreted. I have seen a round mirror nine inches in diameter and six inches high with a lodestone placed under the convex portion. It drew to itself an iron ball placed on the lowest part of the mirror so that not even the dense body of the mirror was able to break up and destroy its powers. The iron ball which would usually fall was here raised up to the amazement of those ignorant of the nature of this mineral. A similar phenomenon is not inconsistent with the truth nor is it absurd simply because it is related by a certain sacred writer. This writer states that iron, having been placed beside silver and then approached with a piece of lodestone held in the hand of a man, will move toward the stone while the silver remains quiet. It is related in Greek literature that lodestone was placed in the panels of the ceiling of the temple of Serapis in Alexandria, Egypt, and that in this same temple there was a brass statue with a piece of iron in the head. The statue was held in such a fashion by the lodestone that it was suspended in mid-air and neither the head nor feet touched anything. Pliny writes that Dinocrates, the architect of Alexandria, began the arch in the temple of Arsinoes with lodestone so that an image of Arsinoes, made from iron, would hang in the air beneath

it. His death and that of Ptolemy who ordered that the statue should be of his sister intervened. Dinocrates has been copied by the Arabs for in this same manner they have made the iron bier, in which Mohammed is said to be preserved, hang in the air in his temple in Mecca, according to certain people. Pliny also relates that this power of lodestone to attract iron was revealed to its discoverer when the iron nails of his sandals and the ferrule of his staff adhered to a lodestone when he was tending his flock. In a similar fashion it was demonstrated to our own miners who worked in the iron mine called Magnes, mentioned above, when they quit work. After a hard day's work the miners were accustomed to throw their hammers and wedges on the floor of the mine working and on the following day when they would return to work the tools were not found in the places where they had been left but on the backs of the workings where they would be suspended, having been drawn there by the strength of this mineral. The miners, ignorant of this natural phenomenon, believed it to be an indication of the approval of the Gods. After they found out that it was a vein of lodestone they would amuse themselves by hanging their tools from the ore. This same power reveals the mineral to sailors. The Moors relate that abundant lodestone is found on certain rugged shores of India and that it will draw the nails from a vessel that approaches these places and will even draw vessels loaded with iron to the shore and stop the journey. Pliny relates that the Ethiopian mineral is so strong that it will draw all other lodestone to itself. Lodestone will not attract iron that is covered with rust, impure iron or iron that has been smeared with the juice of onion or garlic.

To no less degree, diamond resists its power. If a diamond is placed next to iron a lodestone cannot draw it or if iron has been attracted to the stone as soon as a diamond is placed along side of it the iron will drop. When lodestone is removed from iron ore for a long time it loses part of its strength and to prevent this it must be covered with iron filings. There have been periods when glass workers have used this mineral because they believed that it, in itself, influenced the fluidity of the glass just as it influenced iron, according to Pliny. Even doctors have used it. Dioscorides relates that when one-half dram is drunk in water sweetened with honey it will draw out a dense humor. Galen states that it has properties similar to hematite. Since it has the same color as hematite after it is burnt, the latter is sometimes sold for lodestone. Dioscorides preferred that which attracted iron with ease, had a color inclined to blue, was dense and not very heavy.

Theamedes has the opposite power to lodestone since the latter attracts iron, the former repels it. It occurs in a mountain of Ethiopia not far from the mountain where lodestone is found. If the memory of Pliny was not at fault and the source from which he copied it correct, there are two similar mountains in India near the Indus river. The nature of the one

composed of lodestone is such that it holds iron, of the other composed of *theamedes*, that it repels iron.[1] Can we then believe that if we had the nails pulled from our shoes on one mountain we could go to the other and have them put back? Even today stones are found composed in part of lodestone, in part of *theamedes*. These two minerals do not differ in color although they have different properties. Albertus Magnus writes that during his lifetime he found such a mineral, a portion of which would attract iron, another portion repel it. Since I have no intent of writing about mythical stones I will not discuss those said to be attracted by iron nor those that are supposed to attract human flesh. I will omit *pantarbe* which Philostratus describes as attracting other stones as well as *amphitane* which Pliny writes is also known as *chrysocolla*. The latter is said to have an appearance similar to gold and to be found in a cubic form in a part of India where the ants dig up gold. It is affirmed to have the same properties as lodestone except that it also attracts gold.[2]

Related stones are often found in iron mines, especially hematite (*haematites*) and *schistos*.[3] These are produced from the same material and differ only in form and certain other properties. Hematite is so-called either because it is the color of blood, as Galen rightly believes, following Theophrastus; because it stops the flow of blood; or because, having been ground on a wet whetstone, it imitates a bloody juice.[4] *Schistos* is so-named not because it has been split nor because it can always be split with ease for it cannot, but, because it is cleavable in a certain manner. Due to the mutual arrangement of its parts it has formed like wood in straight lines and is similar to sal ammoniac.

These stones are found in many parts of Germany, in Saxony, in the Hildesheim forest on the farther side of Mt. Maurice in a wide and oblique vein; four miles from Goslar on the road to a mountain the miners call Silver Birch but which we will call Goslar. *Schistos* is found in several places in the Harz forest, especially near Harzgerode. It occurs in the Hass Berg which is in the district of the Chatti in the mountains of Gladenbach, also in Misena in the mine of the Hermunduri called Goldekrona, i.e., Gold Crown. It is abundant about five miles from the town of Marienburg. Both minerals occur in the iron mines of Bohemia near the town of Lessa. They are also found in the silver mines of Joachimsthal, although always in small amounts, and in the iron mines of Noricum south of the Danube which are two miles from Amberg on the road to the west toward

[1] This myth probably developed from the fact that a piece of lodestone shows polarity.

[2] This probably refers to pyrite. Although it will not attract gold it is often auriferous, the possible basis of the myth.

[3] *Schistos* is a synonym for goethite, as used by Agricola, but due to incomplete knowledge of the character of the various hydrous iron oxides he has included some limonite as well as hematite and other minerals in this group.

[4] The name comes from the Greek *αἱματίτης*, blood-like.

Sulzbach. In any locality where one finds hematite and *schistos* one will also find red rocks and earths from which, as a source, these minerals are formed. Dioscorides writes that hematite is found in the red ocher of Sinope. *Schistos* occurs in Spain, hematite in Arabia, Egypt, Africa and Ethiopia.

Each mineral varies in color. They may be similar in color to dried blood, hence the name, or they may imitate the color of iron and at times the surface may even have the color of saffron. The latter material is found in Misena. A variety that is entirely black is mined not far from the mountain named for the silver birch, as I have just mentioned. Sotacus relates that a variety of black *schistos* is found in Africa and from its resemblance to quenched coal is known as *anthracites*. *Schistos* is usually smooth on the outside and as brilliant as polished iron, for example, that from Misena which is the hardest of all. It is less brilliant inside. Some is not brilliant externally but sparkes on the inside like the artificial minium the painters call *cinnabaris*. Mineral of this variety occurs in the Harz forest. This same material, when pulverized, sparkles as though it had been adulterated with mercury.

I shall now take up the colors produced by both of these minerals when rubbed on flint and the colors they have after being burnt. Some produce a streak with ease, as is usually the case, while others, for example the material from Arabia and Misena, give a streak with difficulty because of their excessive hardness. Although they commonly give a blood-red streak the material from Africa called *anthracites* gives a black streak from the bottom portion and a yellow streak from the rest. Similarly the material from Goslar that has congealed in the form of grapes gives a black streak from one part and a dark yellow streak from another. The Arabian hematite has a color similar to saffron. Both *schistos* and hematite, if they have congealed with a color similar to blood, imitate the color of cinnabar after they are burnt and if they are black burning will deepen the color. Burning turns all other varieties of *schistos* to a florid color. Both hematite and *schistos* draw the tongue together. Although each is dense and usually hard the more the luster of *schistos* approaches the luster of iron the harder it is, for example, that found in Misena and the Harz forest. Some knots are found in Misena the size of walnuts and so hard that when placed upon an anvil they are unaffected when struck. Silversmiths polish these hard pieces and then, in turn, use them to polish very thin pieces of gold foil by drawing the foil over the stones. They also use them to polish the foils they place beneath gems in order to improve the color of the gem with the color of the foil. In each case the stones are fashioned into various shapes.

Hematite almost always occurs in the form of lumps and may be full of little hollows as is that from Hildesheim. The Harz mineral sometimes congeals in the form of grapes. *Schistos* shows a much greater variety of forms. It may be wedge-shaped at either end or both. Sometimes it is

found as a narrow wedge, sometimes broad, sometimes little, sometimes large. Pieces from Misena may weigh as much as fourteen pounds. It may congeal with the form of an icicle or a belemnite, for example, that found at times in Goslar and common in the iron mines of Bohemia near the village of Lessa. It may have the appearance of grapes as in the case of the mineral from the Harz forest and some of the very black mineral from Goslar. The Harz mineral often has the appearance of a brain since it sometimes occurs in hemispherical forms. Finally it may be broader than long, for example, the Harz mineral that sparkles like artificial minium.

Physicians use hematite since it dries and is astringent. The powder, after the mineral is completely pulverized in a mortar, reduces roughness of the eyelids, a disease the Greeks call *τράχωμα*, when mixed with egg and smeared on the inflamed lid. If mixed with water it stops bleeding from an open vein. It is beneficial in the treatment of all ulcers. The powder reduces all fleshy growths. *Schistos* of the same color as hematite has the same properties while that of other colors is less efficacious. The best hematite is the color of dried blood, friable, uniform and pure. Similarly, the best *schistos* has the same properties although Dioscorides preferred the variety that was yellow at the ends but he is mistaken in this since the very finest differs only in form from hematite.

Nature produces hematite from *ostracites* in the Hildesheim district at a place between a cave and a water course and it is produced artificially from lodestone, in each case by burning. The gem *antipathes* which is black and opaque is nothing other than black hematite. The latter mineral, as well as hematite, if cooked in milk becomes similar to myrrh. The black *trichrus* from Africa belongs to this same genus and yields three juices, black from the base, red from the middle and white from the top. This is a compound mineral consisting of two kinds of hematite, red and black, and apparently *galactites* or some similar mineral.

Just as hematite and *schistos* form from red rocks, *morochthus* forms from white and similar calcareous rocks. Since this mineral makes white lines in the same manner as chalk it is also called *leucographis* and since it is also white and soft it is called *leucogaea*, i.e., white earth. It is called *galaxias* by some because it gives a milky streak. This mineral is found in Egypt and is mined in Saxony, Germany, along with the earth of Alfeld. The pit is to the south on the road to the wooded mountain. *Morochthus* is white, soft and readily soluble. Textile workers use it to whiten linen. Since it possesses the property of spreading and reduces bleeding physicians use it to relieve menstruation. Since it dries and is not astringent and does not draw nor bite when taken internally it relieves pains in the abdomen and bladder. It is used in eye remedies, causes hollow ulcers to fill and stops the flow of humors. It covers up scars from ulcers, especially soft ulcers.

Galactites and *melititis* form from the same calcareous rocks. Each is

gray and when pulverized with flint yields a milky powder from which *galactites* takes its name. Both powders are sweet although that from *melitites* is sweeter and the mineral takes its name from honey because of the similarity of taste. The Achelous river yields *galactites* and it is found along the rivers in Goslar, Saxony. In Hildesheim it is found in a sandstone pit where it is deposited each year from a milky, glue-like juice. Masses several times the size of a boy's head are often found here. Each cleanses because it contains some heat but *melitites* is the better since it contains the most. Each is beneficial when applied as an ointment to running eyes and ulcers. *Galactites*, having been pulverized and drunk with water or sweet wine, is said to produce abundant breast milk. The stones from Argaeus, Cappadocia, when dissolved produce a milk-like solution. Galen reports that these destroy gall-stones.

Calcareous rock is the parent of gypsum (*gypsum*). Veins of gypsum cut the calcareous rocks of the mountains of Misena near Sala. The nature of gypsum, although unusual, is closer to a stone than an earth as Theophrastus rightly believed. It occurs in many places and we shall mention only the most noted, for example, Galicia, Spain; Hildesheim, Saxony, beyond Mt. Maurice; in the Harz forest at Stolberg; among the Chatti between the towns of Aldedorf and Eschuega not far from the citadel of Pilstein; among the Thuringians in Northusa where there are mountains of gypsum and in the same district near Gotha where it is mined on Mt. Seberg; in Misena between Sala and Jena, a town of Thuringia where many wide veins are found in the mountains. It occurs in Italy at Thuriae, Thessaly, Perrhaebia and Thesprotia toward Tymphaea; in Cyprus where it is mined after a thin crust of earth is removed. It occurs in Phoenicia, Syria and Caesarian Mauritania where, if I am not mistaken, the port of Gypsaria takes its name from this mineral.

Gypsum varies in color. It is found white in many places but the whitest comes from Northusa and Hildesheim where it resembles ivory. It also occurs grayish-white at Hildesheim; gray covered with black spots like the Rochlicens marble, in Misena near Sala; and gray in Northusa where it occurs in abundance. Light red and green varieties are also found in Misena.

The luster of gypsum is variable. Some twinkles like stars such as that commonly in the form of lumps; some glistens like marble such as the grayish-white material from Hildesheim and the light red from Misena; some is translucent such as the material which comes occasionally from Galicia. The mineral also has a variable form. The light red from Misena and the gray with black spots occurs in lumps. The gray from Northusa occurs in crusts while the white and green from Misena occurs as cleavages resembling sal ammoniac. Although all gypsum has a certain hardness, as I have mentioned, that found in Thuringia between Northusa and Elder and in Saxony in the district of Hildesheim is soft and resembles sugar and has more the appearance of an earth than a stone. This is so

friable that it can be pulverized between the fingers. Hard material is burned by the inhabitants of the Harz forest and Thuringia and after being burnt is ground. They then mix this with water and use it instead of chalk since it is more tenacious. The Phoenicians, Syrians and others have all burnt and used gypsum at various times. Irrespective of the original color it is always white after burning. Since it is glutinous it retains heat within itself for a long time after being burnt as does limestone. In the same manner gypsum is made from selenite (*lapis specularis*) after having been burnt and this is the best. When burnt gypsum is mixed with water it has the color of milk. When preparing it they pour the water over the powder and stir it with wooden spoons in order to mix it well. They do not use their hands as one cannot stand the heat. Having been wetted, Pliny writes, it is used immediately since it sets and dries very rapidly. It can be crushed and reduced to a powder a second time. If moistened and allowed to stand over night it becomes so hard that an ax must be used to break it. After wetting it a second time with water it can be used to cement rough stones, as a whitewash and in arenas. The small figures for buildings and the images of saints are made both from burnt and wetted gypsum and carved from the natural mineral, especially that which is similar in color to ivory. Pliny writes that Lysistratus of Sicyon, brother of Lysippus, was the first to sculpture the figure of man from this mineral and then cover the figure with wax to free it from any imperfections.[5] At Northusa in Thuringia a gray wall has been built from the gypsum that occurs in beds in the vicinity and the wall of the port of Algiers, a town of Mauretania, Africa, is of similar material. Pliny writes that the sourness of wine is reduced through the use of African gypsum. Theophrastus writes that fullers have used this mineral instead of cimolian earth at various times for preparing animal skins. It dries when used as a remedy and has the power of producing a film over anything. For that reason it stops the flow of blood when mixed with the white of an egg. Having been burnt and thus made more tenuous it dries more but is less able to produce a film over anything. When drunk it is fatal since it blocks the veins and causes acute constipation.

Selenite (*lapis specularis*) is related to gypsum.[6] It forms from limestone

[5] Lysippus was a celebrated metal worker who lived in the latter part of the 4th century, B.C.

[6] In modern usage gypsum is a generic name and selenite a specific name given to gypsum occurring in transparent discrete crystals. Agricola uses these names in much the same sense in his writings. Many of the older writers confused gypsum and mica and Agricola is probably the first to clearly distinguish the two minerals. It is interesting to note that in *Interpretatio* he describes *lapis specularis* as *unser lieben frawen eis-spar. Itali lumen de scaiola.* Today the name *eis-spath* is given to mica and Werner gave this name to sanidine feldspar. The following reference to gypsum is given in Bermannus, page 456,—

Naevius. "But you do not recognize gypsum and *lapis specularis* which you have already mentioned.

in the same manner but has less admixed water. While man, through his ingenuity, makes gypsum from *lapis specularis*, nature on the other hand sometimes makes *lapis specularis* from gypsum. Its name comes from *speculum* because it is transparent and, having been polished, will reflect the image of anything on one side. It is called σεληνίτης by certain Greeks either because it was usually found at night when the moon was increasing in size or because it drew within itself the image of the moon at night or because it was pellucid and reflected the exact image of the moon each day showing the increase and decrease in size. Others called it αφροσέληνος because many had become convinced that the moon was made of this mineral just as the ignorant have become convinced of the even greater absurdity that it is foam of the moon. According to Aetius Amidenus it is called διαφανής because it is transparent and for the same reason σφεκλάριος from a corruption of the Latin name. Certain Germans have given it the name *glacies* or ice because of the marked resemblance of the two materials.

Bermannus. "You are referring to native gypsum?

Naevius. "Of course. Pliny copies Theophrastus and writes, "And it is dug from the earth, as in Cyprus, at the surface. For Theophrastus says that the miners remove little earth."

Bermannus. "That is the way it is found. *Lapis specularis* from which gypsum is made is thus described by Pliny, "The best of all is known to be made from *lapis specularis* or material having such scales."

Naevius. "You have mentioned these under things that are found here and which can be used in medicine and in our buildings.

Bermannus. "They are found in several places and along the Elbe river for when it overflows it sometimes carries these minerals. Gypsum is sold by the common people and we use their name. They call *lapis specularis* 'Mary's Ice,' concerning which Pliny has written most exhaustively, it seems to me. Selenite is well named since it splits with exceptional ease into very thin sheets. At one time Spain produced a large amount of this mineral from an area within one hundred miles of the town of Segovia. Today it is produced in Cyprus, Cappadocia, Sicily and especially Africa. The softest and largest pieces from Spain and Cappadocia are the most valuable although they are dark. There are, in a part of Bononia, Italy, small spotted pieces bound together with the surrounding hard stone that have an appearance very similar to the material which is dug from the deepest parts of the mines in Spain. Also it is found included in rock within the earth and is mined. To date pieces which occur free in nature have not been found that are longer than five feet. Certain ones say that, just as a humor of the earth is frozen into quartz and congealed into a stone, the marrow of the bones of wild animals that fall into certain pits is changed into this mineral by nature after a winter. Occasionally it is found black but it is usually an intense white, when it is quite soft, from the effects of sun and weather. It will not deteriorate, if it is not injured, when it is taken from rocks of many genera. They have found a use for the fine material for sprinkling around the outer part of the circus during the games in order to give it a dazzling white color. Pliny writes this about selenite and nothing could be more clear.

Naevius. "He expresses our opinion when he says that it is frozen like quartz and for that reason is called 'Mary's Ice' (*Marieneis*).

Bermannus. "That is right. A blackish variety is found in this vicinity which is not

Julius Caesar noticed this same thing for he writes that *lapis phrygius* resembles the ice he observed in the Sequana river. He calls selenite by this name because it is found in Phrygia.

Selenite is mined in many places. It is abundant in eastern Spain near the town of Segovia and less abundant in Gaul; in small quantities in Saxony near Hildesheim and toward the base of Mt. Desterus beyond Bunsedorf; abundant in Thuringia two miles from Northusa in the Steigerwald valley; abundant in the mountains where the Vicelebii have built their famous and strong fortress of Stein; in small quantities in Misena toward Sala; at Bononia, Italy, where a portion of the walls is made from it and where it is found in many foundations; in Sicily, Cyprus, Phrygia, Cappadocia, Arabia, Egypt and Africa.

It is either all white, all black or half white and half black as that mined in Hanover in the vicinity of Francisca at the foot of Mt. Desterus. Some of the white is similar to ophite because of its black spots. This variety is found even today and Theophrastus writes that it came from Egypt in ancient times. The honey-white variety is rare. Most of the white is transparent while all other varieties are either less transparent or opaque. All are splendent. Most selenite is soft, the softest being from Cappadocia. Some is hard but this is the same species as the soft differing only in hardness which may equal that of marble. The hard is not common in beds while the soft is often found in quite thin beds. Both hard and soft are found in Germany. Since they consist of the same material gypsum is made from both by burning. Each is light the softer being the lighter. Numerous beds of selenite are common such places as Spain, Thuringia and Cappadocia, although Pliny writes that they are never found more than five feet thick. In some places the beds are small as in

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sufficiently clear and white but which is very transparent. For that reason it is used in windows the same as glass. Such a window can be seen in a certain old church of Marieburg.

Ancon. "Albertus writes the same and says that in the place of the lead which is used to strengthen the glass, smooth pieces of wood are used.

Bermannus. "That is right.

Ancon. "Moreover he writes that he himself had seen such large quantities of it in Germany that they filled wagons with it. He says that it is found in France together with gypsum, a part of which is of the very highest quality.

Bermannus. "Albertus is right. When our people suffer from dysentery they take a piece the size of a walnut, powder it, place it in sour wine and drink it. Many people have been cured of sickness in this way.

Ancon. "It is obviously related to gypsum since the Arabs drink the latter to stop the expectoration of blood, to stop menstrual flow and to cure dysentery.

Naevius. "Dioscorides writes that gypsum will stop the flow of blood but when drunk causes strangulation. Galen does not give it as a drink but recommends that a plaster be made from gypsum, the white of an egg, fine wheat flour and some pleasant binder and used to stop bleeding.

Bermannus. "Then it is safer to drink selenite without wine. Up to now it has injured no one and I have seen and heard of many people being helped by it."

Misena near Sala and in Bononia, Italy. This mineral withstands the heat of the sun and the cold of the winter but cannot withstand rain since it is destroyed whenever placed in large heaps. Since it is transparent they made panes of it, even within the memory of Seneca, and these were placed in windows since they shut out the air and transmitted light. A church in Cosuicus, Saxony, and another in Merseburg, Thuringia, have window panes of this mineral. Later the people made their window panes from round or square pieces of glass joined with lead, also from paper or linen smeared with white wax or goat tallow. Nevertheless they have retained the ancient Latin name. Today certain people take the rough stone from a selenite quarry and after burning it use it in the place of lime. Fragments drunk in sour wine relieve dysentery. If the powder, after burning, is sprinkled on fistulas and ulcers it promotes the growth of flesh.

Asbestos (*amiantus*) follows. This does not form from limestone or gypsum but from a juice of its own genus which, however, is of a special nature. It is named *amiantus* because fire does not destroy its luster and even if an impurity is mixed with it this is removed with no loss of brilliancy or luster.[7] It is also called *asbestos* because they make wicks for lamps from it and when once these are set on fire they will continue to burn as long as any oil touches them and yet they are not consumed by the fire.[8] It is called *bostrychites* by Zoroaster because it is braided like the hair of women (it is usually sold in this braided form). Because it is the whitish gray color of man it is called *polia* by some, *corsoides* by others, and because it may have the whitish gray color of esparto grass some call it *spartopolios*. Some call it *linon* since it is spun and woven by hand like linen. The cloth is called *asbestinum* by the Greeks because it is made from asbestos. Pliny calls it *vivum* because it is not affected by fire. Pausanias calls it *carystium* because it is mined near Carystos.[9] It is called *alumen* by Quadrigarius because it has a fracture similar to alum.

Asbestos occurs in the mines of Suacium in Noricum in the Arcadian mountains; near Carystos, a town of Euboea; in Scythia, India and Egypt. It is either white, gray, red or the color of iron. It differs in taste from alum since the latter is astringent, asbestos is only slightly astringent although it may sting the tongue a little. Concerning its form, asbestos resembles hair and can be separated into fine fibers. It is by nature dry externally but has a humor internally. Fire is unable to consume this humor since it is more powerful than the heat of the fire. However the fire is able to consume impurities adhering to the mineral. Pliny says that napkins made from it are burned in the fireplace after a banquet when they are soiled in order to clean them since the fire is better than water.

[7] From ἀ, not; μιαίνειν, to stain.

[8] From ἄσβεστος, not extinguished.

[9] A town on the south coast of Euboea, once famous for its marble, a white stone veined with green mica and also called *carystium*.

Quadrigarius writes that during the seige of Athens Lucius Sulla discovered that things covered with asbestos did not take fire. But, as I have said, he called it alum. Strabo is seen to have used the same name for this mineral since he writes that burning bitumen can be extinguished by alum. Pausanias writes that in Athens the wick of the golden lamp of Minerva made by Callimachus was made from Carystian *linon*. This is obviously ancient and this practice of the Athenians of making wicks from asbestos is followed today by many peoples. The mineral is washed, combed, spun and woven, although with difficulty because of the shortness of the fibers, and not only are napkins made from it, as in Rome, but also towels, as in Vereberg, Saxony. Hierocles writes that the clothes of the Brahman philosophers of India were made of this material. Sometimes funereal robes of royalty are made from it for when the body is wrapped in this cloth and then placed on the burning pyre the ashes of the body can be kept separate from those of the wood and later preserved in a sepulcher. Although Pliny writes that this cloth is very rare and when met with has a value equal to that of the finest pearls, nevertheless since pieces of it can be seen today in the mines of Noricum it has obviously been sold at a low price.

When either the "cleavable stone" of Eisleben or the pyrite of Goslar is roasted they exude a light green, dry, harsh and tenuous material on the top of the pyre. After forming this is not entirely consumed by the fire and thus is similar to asbestos. The "cleavable stone" yields this mineral more copiously than pyrite.

Magnetis (mica), not the stone which draws iron to itself but the one that is similar to silver, differs from asbestos in form but not in natural qualities. Actually it forms in beds in the same way as selenite but these are very tenuous. Like asbestos it withstands fire to such an extent that it cannot be consumed. It is of such a nature that they can make wicks of it by joining several layers together with an iron thread.

It is found in many places, for example, the Goldekrona mine, Misena, about five miles from Marienburg, and in another mine near the town of Sleta; at Wildestein, Bohemia; at Miltenberg, Franconia; in Livonia. The color may be silvery, the most common color, and for that reason our potters call it by a name compounded from *argentum* and *album*, a very appropriate name.[10] It resembles silver so closely that it may deceive those who do not examine it carefully. Although it has this resemblance to silver they are not joined by any natural relationship as Theophrastus correctly states. It may be the color of iron, e.g., the mineral sometimes found at the Goldekrona mine, Misena. A lead colored variety is also found in this same mine. It may have a mixed lead and silver color although it is usually silver or iron colored. It may be mixed with a red earth, a yellow earth and even at times with some other earth. Some is found in very thin beds and some is not. The latter usually has a lead or silver-lead color since

[10] Silberweis.

it occurs in thick beds. In Livonia they make lamps of the very thin beds since they are not affected by fire. Today chemists mix the silver colored mineral with copper and other materials and make it so white that it resembles silver. Potters sprinkle this mineral on their jars to give them a silvery luster. They make table tops out of the silver-lead colored mineral that occurs in thick beds. These can be cleansed by both water and fire when soiled.

Mica is similar in color to *magnetis* but has dissimilar qualities. It is the color of silver but is destroyed by fire. It occurs in stones, marbles and sands and having originated in these it cannot be separated. Our miners sometimes call it by a name signifying its luster[11] and at times by a name derived from the names *feles* and *argentum*.[12] Some call it *magnetis*.[13]

Just as mica is the color of silver, *ammochrysos* (phlogopite) is the color of gold. The sand is more the color of gold than the solid mineral, hence the name and not as Pliny writes because it resembles sand mixed with gold. Our miners call this mineral by a name derived from the words *feles* and *aurum*[14] although it contains no gold. The golden powder that writers use instead of sand is made from it.

A similar mineral is that which the miners call *armatura* (slickenside) because it polishes iron and resembles copper. However, it contains neither of these metals, in fact not even a trace of any metal can be produced from it. From its appearance it might have been the result of an unsuccessful attempt on the part of nature to make a metal. A stone that is clothed with this "armour" might be called *hoplites*, from the Greek. A cleavable stone is often so "armoured" and sometimes one side of a vein, for six feet or more, may shine like polished iron.[15] Similarly *ammonis cornu* and other things are "armoured" but the "armour" of these is seen to be made, as a rule, from polished gold or brass, as I shall mention later.[16]

[11] Glimmer.

[12] Katzensilber.

[13] It would appear that *magnetis* and *mica* were distinguished primarily by mode of occurrence, the latter occurring in veins and hence consumed when the ores were smelted. It should be noted that Agricola distinguished talc and mica. The following description of *mica* is given in Bermannus, p. 454,

Ancon. ". . . and a third mineral is white and sparkles in this rock like stars.

Bermannus. "It is as you say and I believe that this is the mineral the Latins called *mica* and the German miners *mica* and 'cat's silver' or in their language 'katzensilber.' It is called silver because it is so similar in color to that metal that it often deceives boys and people who do not know about mines. The term 'cat' is used either because of the similarity of this mineral to the shine of a cat's eye at night or because they wish to compare it to the uselessness and worthlessness of a cat's voice. Nothing valuable is ever obtained from this mineral when it is smelted since it is entirely consumed in the fire."

[14] Katzengold.

[15] Agricola is describing a slickenside or wall of a fault that has been polished by movement. Slickensides often have a high luster and are common in shales that have been folded.

[16] *Ammonis cornu* is an ammonite which here has been replaced by pyrite or marcasite.

A certain black stone is found with a uniform color similar to the stone from which tin is smelted but so light that one readily perceives that it is barren and contains no metal. We call this *spuma lupi*.[17]

When lodestone is mixed with copper it is changed so that it resembles silver and if *cadmia* (calamine) is mixed with it, it will resemble gold and is called *orichalcum* (brass).[18] There are three varieties of *cadmia* two of which are obtained from mines. One of these contains no metal and we will speak of it now. The second one contains an abundance of metal. The former we refer to by the common name *fossilis* (native), the latter we call *metallica* (metallic). The third variety which forms in furnaces we call *cadmia fornacum*. Since the *cadmia* that forms on the iron rods in a furnace is in hollow masses it first took its name from the hollow reed *calamus*. Today it is only given to the natural mineral.[19] This stone is of a light yellow color, sometimes not very hard. Festus Pompeius writes that this is an earth. It gives off yellow fumes when burnt.[20] It is found in Lower Germany at a locality between Cologne and that important town which takes its name from waters; in Greater Germany in Westphalia near the town of Lemming and in the iron mines of Sauerland; in Raetia where it was first mined; and in Altenberg where it is mined. In our tongue the latter locality signifies an old mountain. But this is enough concerning those substances that are seen to have natural qualities which lie between those of an earth, a stone and a metal.

I shall take up now the remaining stones that form from marbles or rocks. *Lapis judaicus*, *trochites*, *dactylus idaeus* and related stones belong to this genus. *Lapis judaicus* is known by a number of names, this being due principally to the number of places where it occurs. Since it occurs in Judea from whence it is brought, even today, Dioscorides named it *judaicus*. Aetius Amidenus called it *syriacus* because Judea itself is in Palestine Syria.[21] Concerning its form some say it is similar to an acorn or palm nut while others say it resembles an olive pit. For that reason the former is called *phoenicites* and the latter *pyren*.[22] Having been heated it has the power to liquify stones and because of this it has been called *tecolithos* by some. It is also called *eurrhoeus* because it removes gall-stones and permits easy urination. It usually occurs in the form of symmetrical acorns. Prominent lines run from the blunt to the pointed end and these are so regular they appear to have been made in a lathe and resemble the striae on a shell. The people who call this mineral *pyren* liken these lines to the bones of a fish that extend from the back down to the belly. If it

[17] Froth of the wolf.

[18] This term includes both brass and several alloys of similar composition.

[19] Calamine was used for both zinc silicate (U.S.) and carbonate (England) until recently, and is still widely used for oxide zinc ores.

[20] This is typical of hemimorphite which may occur in light yellow earthy masses and gives off yellow fumes when heated.

[21] *Lapis judaicus* is a fossil, probably a pentremites.

[22] Probably from φοινιξ, an emblem of immortality and πυρήν, stone of a fruit.

is free from all adhering earth it may be as white outside as inside. When split open it is light inside and glistens like marble and in some cases the outside also has a high luster. Having been powdered on a whetstone, as is customary since it is used in medicine, it has no taste. A piece the size of a chick-pea drunk with about a half ounce of hot water is prescribed in cases of difficult urination since it destroys gall-stones, more especially those in the kidneys than in the bladder.

Trochites is related to *lapis judaicus* and takes its name from a wheel. Since nature has given it the form of a drum the round part of it is smooth and each side has a certain degree of smoothness. Radii, so prominent they form striations, extend in all directions from the center to the outer rim like spokes in a wheel. It varies much in size but the smallest is about one tenth the size of the largest. The largest is the width of a finger in diameter and a third as thick. The color varies being either gray, black or yellow. This variety of colors is due to the contamination of earth since in the interior it is whiter than the rest of the material. It breaks, similar to *lapis judaicus*, along the length, width and obliquely and is smooth and brilliant inside. Having been placed in vinegar it gives off bubbles like *astroites* and sometimes possesses the same power to move itself from one place to another. *Entrochos* is sometimes formed from *trochites* by being built up of two, three, four or even more since as many as twenty are found joined together. There are two species of *entrochos*, one evenly rounded, the other evenly rounded but with the central part thickened and the edges constricted. These have the prominent radiating lines characteristic of *trochites* where two parts join on the curve of the girdle although the lower portions lack a girdle and are entirely smooth. The *trochites* are joined in such a fashion that the radii of one fits into the striae of the other. The thickened species usually have radii extending almost to the center. Often a shapeless stone is found associated with these minerals which contains within itself the form of a wheel which has remained in the stone as though it were the root of the mineral that had been broken off. These minerals occur in Saxony near Hildesheim on the last peak of Mt. Maurice in groups in a whitish yellow marble and in a glutinous earth; between Alfeld and Embach; in Hesse on that part of the Cnoreberg hill which is near the mountain where the fortified city of Spangenberg is located.[23]

Some stones found in the fields may have prominent lines and striae and the ignorant believe that these fall when it thunders. For this reason the Greeks call them *brontia*. They resemble the head of a tortoise. If they fall when it rains they are called *ombria*. Ours are light yellow, green, red, yellowish red and even with variegated colors. When polished they will reflect an image like a mirror. They are almost always in the form of a hemisphere, rarely oblong, sometimes the size of an egg but usually smaller. Some have two circles which appear to be units of measure. Five promi-

[23] These minerals are fossil crinoid stems.

nent lines, equally spaced, extend from the upper circle to the lower and each line has striae on both sides. Transverse lines join the vertical striae. Between these there are always shallow quadrangular areas. Some have only the five vertical lines with many transverse lines and spaces that are not very large. The entire middle area stands out and may lack lines and striae. Some are the same as this except that they have striae instead of lines and have prominent transverse areas.[24]

Ceraunia received its name in the same manner as the above minerals for the ignorant believe it falls during flashes of lightening. It is found not only in Carmania but also in our own fields. It lacks striae and lines and differs from *brontia*. It is usually smooth and either round or oblong. Different species are distinguished by color. Some are black, others red and others white and pellucid in part and in part black.

Just as a species of *entrochos* has the form of a wheel, *encrinos* has the form of a lily.[25] When one angular portion is separated from another one may obtain five lilies. The ridges of one fit into the striae of the other. The five portions have five angles, five sides and on both top and bottom five lilies, hence the Greek name *pentacrinus*. Just as *entrochos* sometimes forms from many *trochites*, *encrinos* forms from many *pentacrinus*. It occurs in reddish black stones but the mineral is red. The latter, when broken, has the same color, smoothness and luster as *lapis judaicus*. It has the same medicinal properties. It is found in the moat of the town of Hildesheim. Stones with palm fronds are found, as Pliny writes, near Munda, Spain, where Caesar conquered Dictator Pompeius. These can be obtained as often as one will break a stone.

Enostos, when broken, resembles a variety of bone as I shall mention under flint. *Enorchis* resembles the testicles but is white, as Pliny writes. In the district of the Treveri, while they were digging for cement to repair the defective structures of the fortified city of Erebreitestein, they found black hard stones that produced menstruation.

Diphyis[26] resemble the genitals of both sexes with a dividing line, hence the name. There are two species, according to Pliny, one white the other black. *Glossopetra* resembles the human tongue. *Dactyli idaei* occur in Crete, have the color of iron and the shape of a human thumb. Pliny classes these three minerals as precious stones. He writes that *ammonis cornu* has the form of a ram's horn and a golden color. It is found in Ethiopia. When it has a golden color it is seen to have been covered with *armatura*. In all the district of Hildesheim from the fortress of Marienburg through the lower city and on to the town of Hasda, an area that has the appearance of a long hill, this stone is found in the form of a new moon twisted into a horn and covered with *armatura* of a golden color. It

[24] This is an excellent description of a fossil sea urchin. Agricola is probably the first writer to give these names to a specific material.

[25] This is the body of the crinoid which is attached to the stem.

[26] Concretions.

may be large or small, sometimes striated and moderately hard. Sometimes the *armatura* is the color of iron and even diamond. When it is found in an aluminous earth it has a golden copiapite-like color and when found in other types of earth it has the color of iron or some other material. Iron sulphates and alum can change the iron color to that of brass which is similar to gold. In this same locality a gray stone is found with the same shape but entirely free of *armatura*. Pliny calls this *tephritis*. Pliny writes that *hephaestites* found in Corycus has the properties of a glass in that it will reflect an image even though it is red. The name comes from the fact that it will set fire to dry material when held in the sun just as a concave glass sets fire to sulphurous material, straw and small twigs. Stones of this genus, with a dark red color, are found in the moat on the north side of Hildesheim. They have been found the size of a dish with the red gleam of golden *armatura*. This material also reflects an image and when held in the rays of the sun will set fire to dry material. Stones are found in this same place ornamented with *armatura* in such a manner that it appears to be sprinkled with gold.

Myrmecias, a black stone, derives its name from the fact that it has protuberances similar to warts. Pliny classifies it as a gemstone.[27] Some stones have markings which resemble the feathers of birds, for example *hieracites* which Paulus Aegineta classes as a stone and is more correct than Pliny who regards it as a gem.[28] This, the latter affirms, shows variable shades of black similar to the feathers of a kite. It is found in the Hildesheim district where the road goes from the west moat through the hills on both sides of the river and is similar in appearance and color to the softer feathers on the breast of hawks. Another stone is found in this same place that resembles the feathers from the breast of a partridge, having the same ridges and colors. *Hieracites* bound to the right thigh is said to stop profuse bleeding from a severed vein. *Ammonites* is formed from sand in such a manner that it has the appearance of fish roe and inside it sometimes has the same form and even the same color and texture.

A certain genus of stone is found in Saxony near Alfeld and Hildesheim the size of a walnut or even larger. They belong to the same genus that I shall describe in Book Seven. *Lepidotes* (mica) is similar to the scales of fish with variable colors.

I shall describe now certain stones found in the district of Hildesheim. A stone is found in a water course inside a cave that takes its name from dwarfs, with a dark color, tabular form, as harsh as sal ammoniac and having protuberances on the upper surface that resemble the heads of nails. Another stone is found near Hasda which is similar except that it is white and has no protuberances. In the mountainous region where the tem-

[27] Pliny, Book 37, Chapter 72, describes this mineral as amber, or a mineral containing an ant. He makes no mention of protuberances. The name is derived from the word for ant, *myrmeois*.

[28] Probably arborescent coatings on rocks.

ple dedicated to St. Maurice is located a stone is found in a marble quarry that is called *pentagonos* because it has five angles and a similar stone which has six angles is called *hexagonos*. Each is white, one and one-half inches wide, tabular but having a hollow in the middle and the rim raised as on a gaming board. There is a hole in the middle of the hollow from which radii extend to the outer rim as on *trochites*. In the same place they find *rhombites* (calcite) the size of a chestnut or walnut. This mineral is white, covered on all sides with small conspicuous scales and with each side oblique giving it the appearance of a rhomb from which the mineral takes its name. Another variety of *rhombites* is found at Galgenberg. It is commonly four and one-half inches long, one and one-half inches wide and three-quarters of an inch thick. It has the form of a compressed cylinder but the striae of both the upper and lower portions intersect in such a way that they produce more ridges in the center that also have the form of a rhomb.[29]

At a depth of one hundred and thirty feet in a mine at Salfeld, Thuringia, a stone was found that had the appearance of a solid breast bone, one and one-half feet long, eight and one-half inches wide, four and one-half inches thick at the front part where the ribs were fastened, two inches thick at the back where the middle perforated vertebra occurred. The spine was missing from it because the marrow of the bone was squeezed out. On the outside the stone was either black or gray, on the inside the color of Arabian marble. Nature had produced this extraordinary thing.

I shall return now to those substances which Nature produces abundantly in one place or in many places with the same characteristics. To this class belong the stones that resemble fish roe and occur in the glutinous earths found in veins, stringers and lenses in rocks. Earth, being denser than water, produces more imperfect forms that lack life. Stones of this genus are found in Germany at Hildesheim, Saxony, and enclosed in rocks in many localities which I shall mention in their proper place.

Strombites (fossil gastropoda) resembles the shell of a snail since it tapers from a wide to a narrow coil in the form of a top with a right-handed spiral. It is sometimes short, sometimes nine inches long. It is white inside but assumes the same color on the outside as that of the earth in which it forms. It is found at Hildesheim, Saxony, in the quarries of Galgenberg and in the new portion of that city where they were digging wine cellars, between the watch tower of Alfeld and the road to Embecca and in the limestone quarries of Hanover.

Ctenites[30] is striated and has the general form of a comb. It is usually gray and is found in the quarries of Hildesheim on the far side of Mt. Mortiz.

[29] This is probably the first description of a vicinal form on a crystal.
[30] Probably a fossil pecten.

Myites, because it is not striated, resembles a mouse. There are two species both oblong and rounded like a scallop. One, colored gray, is found in Hesse near the fortified city of Spangenberg associated with *trochites* and in the quarries of Hildesheim, Saxony, as already mentioned. The other species, sometimes gray sometimes light yellow, is found in the moat on the north side of Hildesheim.

Onychites has an odor similar to finger-nails which the Greeks call *onyx*. It resembles them in both color and form and is found in the quarries near Hildesheim.

Ostracites (fossil ostrea shells) is a stone that takes its name from *ostreum* which it resembles. There are two species, the larger found in the moat on the north side of Hildesheim has a cleavage similar to selenite. The smaller species is found not far from Hanover on a cliff near the village of Linda in an unctuous light green earth.

Porphyroides with a gray color and shaped like the pointed stinger of the purple fish is found in the same moat of Hildesheim but it is not cone-shaped as is the purple fish. A similar substance is found in this same place without the point but having instead transverse striae.

Conchites is found in the same moat. It has curved ridges running back to the shoulder and decorated with *armatura* of a golden color. It is commonly six inches long and three inches wide. Marine shells, according to Paulanias, are scattered throughout the stone at Megara and for that reason the stone is called *conchites*.

Since *philogynos* is also covered with *armatura* it has been called *chrysites*. It is found in Egypt, according to Pliny, and resembles the oyster of Athens. Valerius Cordus, who recently suffered a most untimely death in Rome, has brought me a very large number of stones from Hildesheim. This young man not only made an intensive study of these natural objects but also studied a great many herbs. But I have said enough about this genus of stones and shall now take up the rest.

Stelechites has the appearance of the trunk of a tree from which the branches have been cut. It is found with a gray color in Hesse near the fortified city of Spangenberg on the Cnorenberg hill. *Belemnites* has the shape of an arrow and for that reason the Saxons call it by a name compounded from *ephialtis* and *sagitta*. When drunk it is said to cure nightmare and hallucinations and prevent bewitchment. Certain physicians have and use this stone today instead of *lyncurium* (amber). This is neither congealed urine of the lynx nor any similar substance. The older writers have called amber by this name as I have said because they believed it to be of this origin. If anyone has seen the *lyncurium* of the Greeks at any time which was not amber I believe that he has seen *belemnites*. Some has the color of Falernian amber and is transparent. Some will attract chaff and other light objects as does amber. It is found in Germany in many places, in Saxony in the west moat of Hildesheim and on the banks of the Lanus river near Neustadt, a town about twelve miles from Han-

over. It is found in the vicinity of Brunon associated with bitumen; near Stettin, Pomerania; near Marienberg, Prussia; on the banks of the Vistula river; near Hoching in the district of the Suebi not far from the Alps. *Belemnites* from Hildesheim is either gray, whitish or dark red. That found in Prussia is the color of Falernian amber. At first the material which was almost always transparent and similar to amber was the only variety called "lynx-stone" by our physicans but later the name was given to non-transparent *belemnites* of other colors. When burnt it becomes white or grayish white. Each variety is found between Hildesheim and Marienburg on the left hand wall of a limestone cave named for dwarfs. This locality has every appearance of having been burnt except for the odor of the stone. A golden *armatura* not only covers the outside of the material found in the east moat of Hildesheim but also the enclosing rock. This *armatura* has a natural high luster and reflects an image like a window glass. When rubbed *belemnites* gives off an odor similar to that produced by polishing or burning the horn of an ox. The material found in the marbles of Hildesheim has this odor while that from other localities has no odor. It varies in size, the largest being three-quarters of an inch long as a rule although that found in the north moat of Hildesheim is six inches long and as thick as the arm. It always has the form of an arrow, a broad base which tapers to a very sharp point. It has a natural fissure and as a result is split with ease along the length. The variation in transparency is striking and it is sometimes covered with a golden *armatura* on the inside. It may contain earth, sand or stone which is itself in the form of an acute cone. The rock that contains the material with the golden *armatura* occurs in beds that resemble certain membranes when first stretched and then more and more drawn together.[31] Since it dries the physicians of Prussia and Pomerania use it to heal wounds while both they and the physicans of Saxony use it the same as *lapis judaicus* to remove stones.

Just as *belemnites* contains earth, sand and stone, *gaeodes* (chalcedony geode) enclose earth, *aetites* (geode and concretion) stone and sand, and *enhydros* (enhydros) liquid. However these latter differ in form. All of them are commonly formed into a ball that resembles the earth. Sometimes they are perfect, sometimes compressed. Pliny classifies some under *aetites*, certainly any that enclose earth, and describes others separately calling them *gaeodes*. Dioscorides distinguishes *gaeodes* from *aetites* since the former contains an earth, hence the name,[32] the latter, stone. Actually they are closely related since they consist of the same material and like *belemnites* contain different things since they both originate in almost the same places. They occur in Hildesheim, Saxony; in the mountains of

[31] Thin bedded calcareous shale.

[32] From the Greek γῆ εἶδος, earthlike.

Misena near Sala not far from Aldenberg and also below the fortress of Motestha; on Gargano a mountain of Apulia; and in Taphiusa near Leucadia, Cyprus. They are also found in Arabia, India and Africa. They are usually found when torrents, due to heavy steady rains, wash away the earth. The name *aetites* comes either from the similarity of color to that of the eagle with a white tail, as Pliny believes, or because it is found in the nest of eagles for it is found built into the nests of four kinds of eagles according to Pliny. It is either white, as that from Taphiusa; the color of a gall-nut or light red as some from Arabia; or a very dark red as that from Misena which is found near Aldenberg. The material from Apulia shows a variety of colors being whitish, yellowish, light reddish brown and of more than one color, for example, part yellow, part a dark color. The Hildesheim material may be stained with ochre and that from Misena smells like violets because of the moss which adheres to it. When this moss is removed the odor disappears. This is not the only material which smells so agreeably for the rocks found in fragments in Calenberg near Aldenberg and the flint on Mt. Berninger on the border of Misena and Bohemia may sometimes have just as pleasant an odor. Although commonly round, the material from near Sala, Misena, is irregular. That from Arabia is disk shaped as is some from near Aldenberg, Misena. Some are angular but these are rarer. *Aetites* varies more in size than in shape. It may be the size of Armenian, Persian, Phoenician or Nile apples. The African material is very small, that from Cyprus larger while the Motestha mineral is the largest. The Arabian, whitish Apulian and the Misenian mineral which they call "male" is hard, the Cyprian and African material they call "female" is soft and friable. Much of the Apulian material is smooth while that found in Misena near Sala is rough. In the concave interior, just as in the stomach, one finds earth, sand or stone. Only those that contain earth are called *gaeodes*. This earth is either white as in the African stones, of a pale shade as in those stones found near Aldenberg, Misena, or yellow as in those from Hildesheim. Sand is found in some of our stones and in those from Apulia and Cyprus. When they contain stones they either contain one as those from Taphiusa and Arabia or a number as those from Cyprus and Apulia. All of these contain small free and loose grains and when the *aetites* is shaken vigorously they make a noise. However the material from Sala, Misena, Motescha and Hildesheim has these grains attached to the walls and so gives no sound when shaken. The material found in the mountains near Sala has grains adhering to the inside wall that are small and white and sparkle like quartz while the grains in the material from Motescha are of different colors and similar to gems although soft. The very small pebbles in the Hildesheim material are stained with ochre. Among the filled *aetites* certain ones have both earth and small stones together in the center, as those from Hildesheim. *Aetites* from Cyprus has both sand and small stones and perhaps some have earth and

sand, others earth, sand and small stones. The stone in Taphiusa *aetites* is called *callimus* and not *tenerius* according to Pliny.[33] *Paeantides* and *gemonides* found in Macedonia near the monument of Tiresias, *cissites* found in Egypt near Copton and *gasidane* from the Medos and Erbil are all names for white *aetites*. *Paeantides* is so called because it stops labor pains, *gemonides*[34] because it appears to become pregnant and produce another stone, *cissites* because it conceives. We are ignorant of the actual meaning of the name *gasidane* but since the mineral is said to conceive and to have loose parts within itself which are detected by shaking we know that it is *aetites*. *Paeantides* has the appearance of glacial water, *gasidane*, a swan or colored flowers. *Cissites* is white and does not differ in color from *aetites* which is often this color. Different writers have described these varieties of geodes in many ways. Since some of them are angular they obviously differ from *aetites* just as *belemnites* that contains an earth is distinguished by form from *gaeodes*. Nevertheless one cannot exclude them from the class of *aetites* since the latter may be angular when compressed. We cannot ascertain from Pliny whether they were angular or not and the writers he has copied have said nothing concerning the form of these stones. Some have been described more carefully than others. All the stones mentioned so far are those that Theophrastus and Mutianus believed to be distinct species.

All geodes dry and certain ones are astringent. A geode will purge matter which may cover the eyes and when mixed with water and used as a salve it reduces inflammation of the breast and testes. When it contained small pebbles the Greeks believed that it would keep the fetus in place and prevent miscarriage if fastened to the left forearm of a pregnant woman and when bound to her left thigh would reduce labor pains and permit a painless delivery. Pliny writes, however, that it is effiacious only when it has been newly taken from the earth.

Enhydros is a variety of geode. The name comes from the water it contains. It is always round, smooth and very white but will sway back and forth when moved. Inside it is a liquid just as in an egg, as Pliny, our Albertus and others believed, and it may even drip water. Liquid bitumen, sometimes with a pleasant odor, is found enclosed in rock just as in a vase.[35] *Belemnites* and geodes contain earth as I have mentioned.

Samius lapis is found enclosed in the Samian earth that artisans use to polish their work. Dioscorides states that the best is white and sometimes

[33] Agricola includes under geodes hollow nodules of chalcedony and carbonate minerals, usually calcite with or without crystal lined interiors and ironstone concretions. Most of the earth and sand filled geodes belong to this latter group. Undoubtedly vugs which had weathered intact from veins were included here. One may assume that Agricola did not believe the myth universally accepted at that time, that *aetites* gave birth to young.

[34] A more correct form would be *geminides*.

[35] This may be a reference to light hydrocarbons sometimes found in vesicles in igneous rocks that have traversed bituminous sediments.

hard and from this we can conclude that it is also found soft and having other colors. It probably resembles stones found at Hildesheim near a mill on a cliff not far from the village of Hasda. Here they occur in veinlets of a glutinous sticky earth similar to Samian earth. They are gray or some pale shade, soft to somewhat hard, sparkling inside and rough outside. They are used to polish gold. The white Samian stones have been made into gems because of their beauty and these were called *exhebenus* by Zoroaster. *Samius lapis* since it is astringent and cooling, having been ground in a mortar with milk, can be used advantageously in curing ulcers and reducing watering of the eyes. Artisans polish gold and silver with *samius lapis* in the same manner as ring makers clean and polish hard gems with emery. Glass workers use it to cut sheets of glass. It is found in the silver mines of Annaberg, Misena, and other localities and has the appearance and hardness of iron.[36] It is used to harden the gums and as a dentifrice. The stone occurs in Armenia where they use it to engrave gems and cut small images according to Stephanus but he does not state whether it is emery, Armenian flint or some other stone.

Ostracites, so named because it resembles an oyster shell, is accepted as the best material to remove skin and hair. The younger Greek writers have called it λιθόστρεος in order to distinguish it from the oyster shell. The older writers have called it *ceramites* since it has the color of the shell and also *cheramides* because it has a band of dark colored protuberances. It forms in strata that are conspicuous. When tapped with the finger it has the sound of a jug. Today a light red variety is found in Hildesheim near a cave named for dwarfs. The area, as I have said, shows that it has been on fire at some time or other. *Ostracites* dries and is astringent and, for that reason, will repress menstruation when a dram is drunk with wine. Moistened with water it reduces inflammation of the breasts, heals ulcers and is poisonous to crawling insects.[37]

Phrygius stone takes its name from Phrygia where dyers color cloth with it although it is also found in Cappadocia. It is a spongy substance with a mixed taste. Some is astringent and biting. The best has a pale color with white veins similar to calamine and a body structure that is not strong. The weight is moderate. When sprinkled with wine and burnt it becomes a darker yellow. Some of this is sold today for *lyncurium* just as *belemnites* is sometimes substituted for it. It is used in medicine as a desiccant. It possesses mixed qualities for it also repels and disperses. It is used to treat decomposed ulcers and as an eye remedy. According to Galen dyers use *phrygius* just as tanners use *ageratus*. Since it is both astringent and biting it is impossible to assign to it a definite taste. Since it represses and disperses it is used to cure inflammation of dog's teeth.

[36] Apparently quartz, chalcedony, and other minerals are included in this group.

[37] Although other writers have given this name to a variety of minerals Agricola limits its use to a particular variety of fossil shell.

Cos (quartzite), that is used to sharpen tools, is the next mineral to be considered. Certainly every man has sharpened his knife on a whetstone as well as the mower his scythe, the barber his razor and the carpenter his saw. And what is more important all iron tools made or used by artisans are sharpened on a whetstone. There are many species, some classified according to the kind of liquid they require, others according to the country where they are found. Oil is spread on some stones and these produce the finest edge. They are called *olearia.* In Germany these are used only by barbers for sharpening their razors. In Italy at one time, according to Pliny, the men who did the mowing were in the habit of carrying a horn of oil fastened to their leg and this was used when sharpening their sythes. The finest of these stones is found today in Germany in the district of that famous town which takes its name from waters. Second quality stones are found in Saxony not far from Garleba. The third quality are found in Bohemia. Pliny writes that for a long time the finest were obtained from Crete and the second quality from Laconia on Mt. Taygeta.

Certain whetstones are moistened with water and these are called *aquaria.* They are found most abundantly along the rivers of Hesse, especially the Lanus river near Marburg and the Eder near Francoberg. They were found in Italy and beyond the Alps in Passernices according to Pliny. They are found on Cyprus, Naxos, Arsinoe and in Armenia. At one time the Naxos stones were considered to be the best, the Armenian, second.

A third variety of whetstone is most efficient when moistened with both water and oil. These come from Cilicia. A fourth variety is moistened with saliva. According to Pliny these were used at one time by barbers instead of the oil stones used today and he states that the finest of these are the Flamin stones from Upper Spain.

Whetstones vary in color. They are either black, as those from Saxony and some from lower Germany, or green as are some of the Italian and many of the Bohemian stones some of which have a distinctive white vein. Some of the stones from Lower Germany have conspicuous alternating black and white bands. Those found in the rivers of Hesse are usually dark colored. The large blocks from which they make the drum-shaped millstones have various colors, some being white or gray, others whitish-gray, yellow or red. Regarding softness or hardness the oil stones are soft, softer than the saliva stones used by most men. If they slip from the hand and fall these usually break Water stones, on the other hand are hard. The green stones from Bohemia are usually harder than other oil stones and can be used for the same purposes as the water stones. Stones are not discarded if the white veins running through them have the same hardness as the rest of the stone. These veins may be so soft that oil spread on the rest of the stone will exude from them. Some stones have a natural cubic form. Some are long and need only to be smoothed and perforated. When they are broad they are cut into two or more stones. Each type is found

in Hesse. Some stones are given a square form after quarrying, for example the Naxian stones from the marble quarries and the stones from the Armenian quarries. Recently a few water stones have been fashioned into triangular shapes about six inches long. These are found near the Krakow fortress in Bohemia and consist of wood that has been turned into stone. Only the largest blocks are shaped into the form of a drum and used with water to sharpen tools, being turned either by a water wheel or by a man. Mill-stones are made from large and hard blocks. Some are made from the black and white banded rocks brought from Lower Germany and from the stones that have the appearance of broken bones. These latter are called ἐνοσέοως by the Greeks. All of these stones can be used to sharpen iron and some of the hardest are used as hearthstones, for example, in Hesse. Finally, since an edge is restored to iron by water stones through a wearing away of each it follows that whetstones are cooling and therefore when spread over the breasts of a virgin or the testes of a young boy will stop their growth. Whetstone is useful for the gout. Since an oil stone restores an edge to iron because the iron is worn away it follows that the stone cleanses and, for that reason, is used as an ointment to stop falling hair. The Greeks call this disease *alopecia*.[38]

Gold and silver are tested on *coticula* (touchstone). The reason for this will be given in the book De Re Metallica. This stone is called βάσανος by many Greeks, for example, Pindarus, Sophocles, Antiphon and Theognides because the quality of the gold can be determined from its streak as well as with a balance. For the same reason others have called the stone χρυσῖτις. Some call it *lydius* stone because it is found in Lydia; others *heracleus* stone from the town of Heraclea in Lydia. All touchstone in the time of Theophrastus was found in the Tmolus river, in the time of Pliny in a number of places and today we get our touchstones from the rivers of Hildesheim and Goslar and from the town of Visa between Egra and Eredorf. Usually it is very dark with a characteristic smoothness. Although Pliny writes that the largest is less than four inches long by two inches wide it is found today six inches long and three inches wide and even larger, especially near the village of Visa. Theophrastus writes that experience has shown that the stone which has been partially exposed to the sun is the best while that which has lain in water is inferior because it is not as dry as the former. Moisture prevents the stone from taking the color of either gold or silver. A good test cannot be made when the stone is hot for then the moisture that is given off acts as a lubricant.

Pumex (pumice) is found in localities that have been on fire at some time or are burning now. It has been melted down from earth or stone and changed into its present form. Typical pumice is found on Mt. Moderna and Mt. Vesuvius in Campania; on the islands of Ischia and Aeoliae; in Sicily near Aetna; on Melos and Nisida and on the sun-baked hills of

[38] From the Greek ἀλώπηξ, a fox. Mange and loss of fur is very common among foxes.

Mysia. It is quarried at the town of Confluentia, so-called because it is at the confluence of the Moselle and Rhine rivers. It is found in Lower Germany near the famous town which takes its name from waters. Since pumice is as full of open channels as a sponge it is called *lapis spongia,* according to Vitruvius. It is called κίσσηρις by the Greeks. This name, according to certain writers, comes from the name of the worm that eats grain and is called κίς by the Greeks and *gurgulius* (weevil) by the Latins. It makes holes in the grain until it has the appearance of pumice. Theophrastus called the rock *halcyonium* because he thought it had congealed from sea foam but we have already discussed this mineral.

There are varieties of pumice. They are not all of one color since they may be black, gray or white. Some are so soft they can be ground to a sand in the hands, for example, that found on Nisida, according to Theophrastus. Others are hard. All are porous and light because of the internal cavities filled with air. Due to its porosity it will float on water as do other pumaceous stones no matter how large they may be. A pumaceous stone of this lightness is found on Thyrrae and another on the island of Nisida and these may be true pumice. Pumice which floats when whole will sink when crushed. Although all are light and porous the black varieties are denser and heavier while the white and gray varieties are lighter. Although it contains a large amount of air it will neither take fire nor burn because it lacks moisture. The force of fire destroys it. Because of its roughness pumice is cleansing and women use it chiefly to beautify the skin and for thinning hair. Both men and women use it as a dentifrice and men use it for many other purposes. Transcribers smooth books with it. Physicians mix it with substances that produce flesh. When wine workers put in it casks of new heating wine the heating ceases immediately. The drinkers in a drinking contest take a powder of pumice but Theophrastus warns that this is a dangerous practice unless they become satiated with the immense draught. Physicians prefer that which is white, rather light, porous, harsh, fragile and free of stones.

Finally I shall discuss the remaining stones—those to which we have given names which come from the fact that when thrown into a furnace they liquify with ease and flow freely. There are three genera of these, one similar to transparent gems and a second that does not resemble gems. The latter is not transparent as a rule, rarely partially so. The former is found in small quantities in silver and other mines. The latter is found in veins characteristic of the mineral and often in abundance. Material of the third genus is used in making glass although glass can be made from the other two genera. Small pebbles of the first genus are not only transparent but brilliant and with the same colors as those found in gems. Some of the pebbles resemble quartz, others *smaragdus,* prase, sapphire, amethyst, *hyacinthus, carbunculus, chrysolithus* and other gems. However they are markedly different from gems in degree of hardness. If we

classify chrysolite and *sandastros* as soft gems, following Pliny who says that they are too soft to take a polish, especially the material from Thebes, then some of these stones may be classed, properly, as gems. Nevertheless any mineral that is too soft to take a polish cannot be regarded as a true gem. Goldsmiths sometimes take these stones when they are naturally smooth and suitably shaped and set them in jewelry and rings. Apothecaries commonly use them in the place of *hyacinthus*, lapis lazuli, *smaragdus* and *carbunculus*. Certain painters use the violet-colored ones.[39]

Alabandicus lapis belongs to the first genus provided that it is not the same as Alabandian garnet. Pliny writes that it melts in a fire and can be poured and used as a glass. It is black with a tendency toward a purple hue. It occurs in Caria near Alabanda and Miletus.[40]

Stones of the second genus do not have as many colors and are rarely pleasing to the eye. They are commonly white, gray or light yellow. Since

[39] This passage refers to fluorite (*fluores*); Agricola was the first to use this name, in Bermannus, page 466,

Ancon. "———. What is this Bermannus?

Bermannus. "They are stones similar to gems but not so hard and called by our miners *fluores*. This is not inappropriate, I would say, since the fire melts them and makes them as fluid as ice in the sun. They are found with a variety of pleasing colors.

Naevius. "Theophrastus would call them ἐκ σύρροος, i.e., 'to flow together in the earth.' This red fluorite, if I may now use your name, is it the ruby silver you showed us before?

Bermannus. "They do have a similar appearance at first but they are not the same. Transparent red fluorite is not rare.

Naevius. "Then it is *carbunculus*.

Bermannus. "Certainly not that.

Naevius. "Then how can you tell them apart?

Bermannus. "That is very easy. Fluorite does not have as brilliant a luster. If it is not transparent that distinguishes it from *carbunculus*. Finally all varieties of fluorite melt as soon as they are placed in a fire while *carbunculus* does not.

Naevius. "You distinguish them very well.

Bermannus. "You see another species with a pale purple color.

Naevius. "It looks like a poor quality amethyst such as that found in many places in Bohemia.

Bermannus. "Certainly they are not dissimilar and for that reason fluorite can be set in rings and sold readily as a good stone to the ordinary person who does not know good amethysts. A third species is colorless as you see.

Naevius. "I would think it quartz.

Bermannus. "This variety is yellow, that gray and the other blackish.

Ancon. "What use has fluorite?

Bermannus. "During smelting it is often added to the charge for it makes it more fluid just as the genus of stone we have said is produced from pyrite. It is found near Breitenbornn which is near Swartzenberg. Pigments can be made from fluorite."

[40] This description probably refers to the manganese sulphide alabandite and the vein material containing this mineral.

they melt quickly in the furnace they are added to ore from which metals are to be extracted.

Glass is made from stones of the third genus, especially when they are found as sand. The sand melts when thrown into the furnace and for that reason the Greeks call it ὑαλῖτις ἄμμος. These stones are sometimes in solid veins, sometimes in more extensive deposits and sometimes found sparingly in metalliferous veins. They are not as hard as *silex*[41] and on that account fire cannot be struck from them. They are not transparent but occur in a variety of colors, for example, white, light yellow, gray, dark blue, black, green blue, reddish brown and red. Although stones of this genus are found in mountainous regions, on the banks of streams and scattered here and there in certain fields, those that are black inside as well as on the surface are rarer.[42] No matter what the color of the stone they are all criss-crossed with veins of other colors, for example red veins in a white stone. White spots are often found in the green stones, black spots in the gray and reddish-brown spots in the white. Pieces are often found on the surface. They are polished by being rubbed on stones of the same or other genera in stream beds. In this way the pieces are often shaped into spheres that are usually flattened. Light reddish brown stones of this genus are found in the silver mines of Annaberg having the form of a cross, one such stone being four and one-half inches high and three inches wide.[43] The vertical portion was three-quarters inch wide, the cross arm one-third inch, both being an inch thick. Material has been found at Freiberg with the silhouette of a monkey as well as other material the size of a red chestnut. The latter material had a whitish upper surface with a small red shield with four lines running around it, the first and third being white, the other two red.

A yellowish stone from the Bochantian district of the Carpathian Mountains appears to be eaten. This offers a great variety of uses. The colored stones are spread on the highways. The blue is added to the ashes of the wood of the fir tree and after being burnt is used by dyers. The white is burned, seived and then glass is made from this sand. The whiter the stone the more useful. The Belus river that rises at the foot of Mt.Carmel in Phoenicia between the district of Ptolemais and the city of Tyre carries abundant glass sand to the ocean where the waves wear away all impurities and polish it, according to Pliny. The Volturno river also carries sand to the ocean where, after being reworked by the waves, it is cast on the beach between Cuma and Lucrino. Actually glass is not made from this sand alone. Three parts are mixed with one of *nitrum* and then, when melted, the material is called *ammonitrum*. If *nitrum* is not available

[41] Bermannus, page 467,—"The fourth genus (of rocks) is by far the hardest of all and is named for horn which it resembles in color (German, *hornstein*). This is called *silex* by the Latins."

[42] Flint.

[43] Staurolite, possibly.

an equal quantity of rock salt is added to the sand and if there is no rock salt, marine salt can be used. When none of these salts is available either artificial salts or salts obtained from leaching the ashes of anthyllis and some even add the ashes of burnt trees. According to Pliny the first glass was made in India from crushed quartz. It can also be made from a genus of small pebbles very similar to gem stones that melt in a fire in the same fashion as the materials mentioned above.

At one time Sidon was famous for the glass produced there but within our times the finest glass is made in Murano and made famous by the Venetians who live in a city renowned for its beauty and spaciousness. The glass which is as colorless and transparent as quartz is the most highly esteemed. The clearest and finest glass is tinted in two ways. Sometimes a small or large amount of natural coloring material is ground with the glass and then both are melted together and it is only in this way that glass with the true color of gems is produced, for example, diamond, *smaragdus*, *carbunculus*, amethyst, *hyacinthus*, sapphire, jet and others having a single color as well as some of the multicolored gems such as opal. By another method an apparently black glass is produced which, if held to the sun will show the true color that this glass will give to another glass when used as a dye. Silver is used to color glass white, black, green or part blue and part purple. In the same manner a famous variety of dyeing glass is made from gold and this is used to tint glass a clear ruby red. Black glass is called *obsidianus* because of *obsidanus lapis* which is also called jet. According to Pliny all red glass which is not transparent is called *haematinon*. The small jugs from which we drink malt liquors and the vessels from which we eat belong to this class. But this is enough concerning this and the stones that melt in fire. I shall now take up the gems.

BOOK VI

A gem, as I have said, is exceptionally hard and transparent, as the diamond and *smaragdus*, or it is exceptionally beautiful because it is adorned with pleasing or variable colors as most species of *jaspis*. Transparency, unusual beauty of color, luster and brilliancy are, in great part, responsible for the value. However, even though some congealed juices such as salt, *nitrum*, *alumen* and *atramentum sutorium* are transparent they cannot be numbered among the gems because they are not hard and for the same reason gypsum and silver-colored mica which are also transparent. Nor the stones which melt in a fire although they have the same colors and are as transparent as gems. *Tephrites*, *diphyes*, *enorchis*, *cryptopetra*, *tecolithos* and similar stones are not classed as gems because they cannot be cut, they are not brilliant, nor are they adorned with beautiful or variable colors. For the same reasons asbestos, *bostrychites*, *corsoides*, *polia* and *spartopolios* which are names for asbestos are not regarded as gems. On the other hand hematite, *lysimachia*, *arabica*, *alabastrites*, *meroctes*, *obsidianus*, *siderites* and similar stones are classed as gems because these stones as well as small fragments of marble are cut and polished and to a limited extent set in rings. However we will not treat these minerals here. A small piece of hematite does not differ from a large mass either in color or porperties, only in size. *Lysimachia* is the same as Rhodian marble; *arabica*, as Arabian marble; *capnites*, as marble with smoky spirals; *alabastros*, as *alabastrites*; *exhebenus*, as *samius lapis*; *obsidiana* which is also called *samothracia*, as *obsidianus*; *meroctes*, as *thyites*; and *siderites*, as *basaltes*. I have already discussed amber, which Pliny correctly classifies as a gem, in Book IV as well as those minerals which are either amber or at least consist of bitumen. In this genus are *anatachates*, *aromatites*, *myrrhites*, *zanthenes*, *baptes*, *atizoe*, *catochites* and *lipare*. I have discussed coral which Pliny calls *gorgonia* and, as it appears to me, *crocallis*. I have mentioned *spongites*, *syringites* and *phycites* and therefore will say nothing about them here.

Certain minerals having the distinct qualities of gems do not deserve to be placed among the gems because they do not form definite species, for example, it falls to many gems to be distinguished by one line or more. Thus *jaspis* is called *grammatias* when one line runs through it and *polygrammos* when there are many lines running through it. Any other gem could be called by these same names if marked the same way. If a white line runs through the middle of any colored gem this is called *mesoleucos*, if a black line, *mesomelas*, if a green line it could be called *mesochloros* and if of some other color, by any similarly appropriate name. When a thin white line runs from the top to the base of a gem it is called *perileucos*, with a black line it could be called *perimelas* and with a line of another

color, by some name signifying the color. When a white gem has a black top it is called *epimelas* and when, like the Median *smaragdus*, it resembles a poppy it is called *meconites*. On the other hand, when *chrysolithus* is cut by a white vein it is called *leucochrysos* and this name is only given to this one gem since other gems having this white line do not have a golden color. Thus *grammatias*, *polygrammos*, *mesoleucos* and *mesomelas* are not in themselves gems nor are *perileucos*, *meconites*, *epimelas* and *leucochrysos*.

Gems are found in many ways. With us they occur either as if by their own free will or they are picked out of washed sand or they are dug out of the mountains. When they occur as if by their own free will they may be turned up by the plow as are the garnets in the fields of Bohemia and Lygius or exposed by the etesian winds which remove the surrounding sand as is the case with the *smaragdus* which the Bactrian horsemen collect into small piles. They may be exposed by torrents as are the sardonyx they gather from the *charadrae*[1] of India, or they are carried to the banks of rivers together with other pebbles as are the agates found along the Choaspes river in Persia. Some project from massive rock as do the crystals of quartz found in the highest part of Mt. Melibocus which the people of the Harz Wood call Blochenberg, having changed the letters. By these methods transparent gems are sought for so widely because they seize the sparkle of the stars and give it back, by day reflecting the splendor of the sun, by night the beauty of the moon.

But the rest, and those more properly called stones, are found by chance. Having been found in this way a small number are collected but this requires more labor, especially when the stones are attached to the rough parent rock. For example, the country people who live on Mt. Melibocus and in the Alps climb these mountains or hang from ropes in order to find crystals of quartz. The horsemen of Carmania find their turquois in moss at the base of cliffs. It adheres lightly to the moss, not as to the parent rock, as Pliny writes, but as if it had been placed in it.

The sands of springs and rivers are washed for gems. Garnets are obtained in this way from a spring in Bohemia between the fortress we call The Royal Watchtower and the town of Plana. The finest *carbunculi* and *hyacinthi* are obtained from a river in Misena above the walled city of Hoestein, five miles from Stolpa. *Hyacinthus*, with the bluish gray color and unctuousness of *jaspis*, is mined in Misena near Volchestein. Sometimes another stone called *borea* is mined from the two mountains of Ligyes near the town of Striga. In India the finest *carbunculi* are mined from a mountain on the island of Ceylon. Gems are sometimes found in veins, stringers or vugs in rocks. Some are found in the actual heart of a rock, for example, the sard found near Babylon, according to Pliny. There it was exposed in a stone quarry.

[1] A *charadra* was a canal built for the purpose of carrying water to a place where it was used to wash dirt and other waste materials from metals, minerals or gems.

However, irrespective of the manner in which gems occur they are never as brilliant and transparent in the natural state as when polished. They are first polished with an earth called tripoli.[2] This earth is sprinkled on a lead wheel which is rotated with the right hand while the gem is held firmly against it with the left. Whether the gem is polished or engraved it is always cemented, with a variety of pitch, to the end of a wooden spindle which is held in the hand. In order to give the gem a higher polish it is held tightly against a wooden wheel covered with the hide of an elk or some equally thick skin. Thus the old method of polishing gems on Naxian or Armenian whetstones has been changed. Artisans usually give an angular shape to certain massive gems before they are polished. Although the hexagonal *smaragdus*, *carbunculus*, sapphire and even the diamond have natural faces their brilliancy is enhanced by cutting new facets on them. The dull color of the hexagonal beryl of India is enlivened by the reflections of the angles. Many facets are added to European quartz and *jaspis* in order to make them more becoming as ornaments. Powdered emery is sprinkled on brass wheels when these are used instead of lead and first one part of a stone is held firmly aganist the wheel and then another part until it is faceted. All gems can be cut with emery powder except diamond which can only be cut with the diamond powder brought from India by the Lusitanians. Gems are also suitable for relief engraving and the finest figures are carved on them. Some gems can be engraved more easily than others, for example, carnelian, *onyx*, sardonyx, amethyst, *jaspis*, *molochites* and smoky quartz. Certain others stubbornly resist efforts to engrave them, for example, Indian diamond, Scythian and Egyptian *smaragdus*,[3] *sapphirus*,[4] sapphire and the *carbunculus* which holds part of the wax in the signet. Archelaus writes that the Carthaginian garnet (*carchedonius*) can melt the wax from signets, even the deepest part. Although the diamond is the most difficult of all stones to engrave this is sometimes done to conceal a flaw in a prominent part but because of the hardness and the difficulty in cutting it, the stone is usually hollowed out with the sharp point of another diamond or with diamond fragments set in iron. This iron is set in a square hole in a brass shaft. A heavy cord goes around this shaft and down around a wheel. The engraver, turning the wheel with the right hand and at the same time rotating the shaft, applies the gem set in pitch to the diamond point with the left hand. The diamond which is to be engraved is cemented with pitch to the end of a wooden spindle. In this way figures are engraved on a gem. Stones

[2] A siliceous deposit formed from the shells of diatoms.

[3] It is of interest that Agricola places the emerald (Egyptian *smaragdus*), a relatively soft gem, in this class.

[4] In general Agricola uses this name for lapis-lazuli, a gem which is softer than any of those mentioned above. This must refer to the true sapphire which he usually calls *cyanus*. The name sapphire is of Oriental origin and this may be the first time it is used in its modern sense.

that are not as hard as a diamond are engraved more easily with a fine iron wire that is first coated with oil and then with emery powder. They are cut more quickly by this method than with a diamond point since the engraver can use different wires, sharp and dull, large and small. It costs the engraver little to use emery: a considerable sum to use diamond. But this is enough concerning the relief engraving of gems.

Not only is a pleasing angular form given to transparent gems in order to increase their brilliancy but when they are set in rings it is customary to place bright thin foil of almost the same color beneath the stone and this adds its color to that of the stone. This foil is made in the following way. Gold, silver and copper are melted together into a bar. This is then drawn out into very thin sheets. These are held by pinchers over burning coals in such a way that they do not touch the coals yet absorb some of their heat. This heat stains them various colors depending upon whether gold predominates over silver and copper, silver over gold and copper, or copper over silver and gold. Yellow foil is placed under *topazius;* green under *smaragdus* and *chrysoberyllus;* blue under *sapphirus*[5] and sapphire; red under *carbunculus.* If one suspects that a gem has been embellished and enlightened with foil and wishes to know the true color of the gem he must take the stone out of the ring and remove the coloring substance. Since fraud begins with a single act and once begun is hard to stop, I shall mention a few of the many ways in which gems are falsified as well as a few ways in which true gems can be distinguished from the false so that anyone may detect them and thus protect himself against fraud.

Glass, as I have said, is dyed many colors and may have the same color as *smaragdus,* turquois, amethyst, *hyacinthus, chrysolithus* and *topazius.* This genus of artificial stones cannot be recognized by their appearance but can be detected by drawing a file across them. The glass, because it is soft and fragile, is scratched by the file while the true gem, being hard, is not affected, except *topazius* and *smaragdus* and even these stones are not scratched if they are Scythian or Egyptian. True gems may also be distinguished by touch since glass is warmer when compared with a gem. Glass is lighter than a gem. By these two methods true *topazius* and *smaragdus* can be distinguished from false. The eye may detect bubbles in the glass which sometimes shine like silver in the depth of the stone. The permanent brilliancy of the true gem is always appearent to the eye and is very soothing while any brilliancy of glass fades or dies before it ever reaches the eye. This can be readily observed if we examine the gems in early morning light or at night by the light of a lamp. Glass is usually rough on the surface.

Transparent gems are sometimes made from dyed quartz but this fraud is detected by using a file and by sharp eyesight. These false gems have

[5] Here *sapphirus* must refer to the modern sapphire and be synonymous with *cyanus.* Foil would add nothing to the color of lapis-lazuli.

a weaker brilliancy than the true and are scratched by a file. Less cleverly they attempt to produce a false *carbunculus* by cementing two pieces of glass together, or better two pieces of quartz, with a thin layer of minium between them. Minium is called "dragon's blood" in their workshops. Since both quartz and glass are scratched by a file this deception is not difficult to detect even when the stone is in a ring or closed setting. When it is taken out of its setting the cementing can be seen and one part separated from the other. These gems are made in a number of different ways and are called doublets. By using two pieces of glass or quartz with different dyes between them rogues produce all manner of colored transparent gems. The finest *carbunculus*, which we call *rubinus* (spinel), is made from a piece of Carthaginian garnet and quartz cemented together with the garnet on top, the quartz on the bottom and a dye between them. Since the garnet is not scratched by a file this fraud cannot be detected unless the gem is taken from its setting. In a similar fashion, according to Pliny, sardonyx is made form *ceraunia* which is cemented to gems, sometimes white, sometimes black, sometimes red. True but worthless gems are sometimes made into valuable gems in this way, for example, *amethystizon* from amethyst; diamond from quartz, colorless corundum, or *beryllus* similar to quartz. 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*. Quartz, corundum and *beryllus* are given the hexagonal form of diamond and true diamond is cemented on top of them since it is a common practice to make diamond doublets. These artificial diamonds and *carbunculi* are very similar to true gems when set in a ring but when they are taken from the setting and the foils or dyes removed the fraud is apparent. Quartz is scratched with a file even when set in a ring and can be readily identified in this way. Moreover, with transparent gems, the portion that receives the light appears to be brilliant clear, the portion that reflects the light, if it only reflects it, appears to be even clearer. With all other gems, of whatever color they may be, they reflect the same color. The varicolored gems are even more brilliant. This property is best observed in gems that are angular or rounded like a shield.

Gems have one, two or more colors as was mentioned in Book One and I shall review them here in a few words. Many gems have only one color, for example, quartz, *asterios* and diamond are colorless; *smaragdus*, *beryllus* and prase, green; sapphire, blue; *carbunculus* and sard, red; *sandastros* and *chrysolithos*, yellow. When a gem has two colors these may be distinct or mixed. Several have the colors mixed, *aphrodisiace* being reddish white, *xanthos*, yellowish white and the three species of *batrachites*, reddish black. Examples of stones with two distinct colors are, *apsyctos* with reddish veins in a black stone, *nasamonites* with black veins in a red stone, heliotrope, with blood-red veins in a leek-green stone. The opal has three intermingled colors, flame, purple and green. According to Jacchus the

gem *aegyptilla* has sard-red and black veins through a white stone. *Paederos*[6] has four intermingled colors, white, purple, copper-red and golden yellow. Four distinct colors are found in *eupetalos*, blue, flame-red, vermillion and apple-green. *Hexacontalithos* and *panchros* have many colors.

Gems, especially transparent gems, have many different types of flaws. Some flaws have a color similar to smoke, clouds, shadows, etc. Some have a solid body similar to scales, hairs, salt, dots, shavings, lead rust, iron rust, rust and hidden ulcers. Just as the clear blue of the heavens may be marred when a black, white or streaked cloud crosses it, in the same fashion the beauty of a gem is marred when it contains a smoky or shadowy flaw, is lightened by a white or cloudy area or is disfigured by dark spots. When they are tinted with a smoky flaw they lose their transparency and brilliancy. Transparent *chrysolithos* is often smoky and the Greeks call this and the *jaspis* which is not transparent *capnias* (καπνίας). Shadows and clouds are only found in transparent gems. Shadows have a dark color, clouds a white or spotted color. When these flaws occur the gem loses its true color. These flaws may be inside the gem or appear to lie on the edge. They may darken the stone as is common with quartz and some *smaragdus* or whiten it as in the case of other *smaragdus*. They may spot the stone as in some quartz. In some stones the flaws may have the same exotic color as the gem in which they occur. Scales appear to be irregularities; hairs look like cracks. Dots of an alien color are called "salt" because of the similarity to white mica. Points have variable colors. "Salt" is conspicuous in quartz, points in sapphire and certain crystals. Any of these flaws may be harder or softer than the rest of the gem. The points which are called "drops" and "stars" we will not regard as flaws since the golden points that sparkle in lapis-lazuli are highly prized as are the golden "drops" that sparkle in *sandastros*. Shavings do not have an alien color. *Chrysolithos*, especially that from Arabia, is sometimes filled with shavings according to Pliny. When they are white they differ from "salt" in being much smaller. Iron rust has an iron color; rust, red; lead, a lead color. Pliny writes that the *smaragdus* from Athens frequently contains lead rust since the lead color can be seen in the sun. They call a gem ulcerous when it is so filthy that the interior seems to be filled with corrupt material. If the flaws occur on the surface of a gem they can be concealed by smearing some substance over them or they can be removed by engraving but when they occur within the body of the gem they can neither be concealed nor cut away. For that reason gems that contain such objectionable flaws are neither engraved or cut further. If a sapphire contains a point within the crystal it is valueless to the gem cutter. The Greeks call these stones κέντρον. On the other hand *beryllus* is per-

[6] *Paederos* is a general term for opals and other gems showing a play of colors. The name is also given to purple amethyst.

forated in order to make it more attractive by removing the whiter marrow. When gold is added, according to Pliny, the beauty of this gem is improved since much of its brilliancy may be lost when it is thick.

I shall now discuss the form of gems, both the natural form and that given to them by artisans. There is a great variety of forms. They may be round like a sphere or hemisphere; sometimes solid, sometimes hollow. Some are angular and the angles either project or are flat and level. When a diamond has a natural hexagonal form, and this is the most highly prized, it is set in a ring in such a fashion that a sharp point projects from the setting. If it is oblong or rounded like a shield it is cut to a hexagonal form, as are all other gems, but the angular portion is set in the ring while the flat portion stands above the setting. This form which is given artificially to all transparent gems is most highly esteemed. The next most popular form is the oblong gem with facets that are all equally prominent. Lens shaped gems are less popular. Least popular are gems that are rounded like a shield and of these the solid gems are more popular than the hollow ones. It is possible to give a hexagonal form to the solid ones, not to those that are hollow. In some districts valuable gems are found while in other districts gems of the same form are valueless. Nevertheless among the valuable gems some worthless ones are always found and likewise among worthless gems some valuable ones may be expected.

Since gems may be classified chiefly by color, I shall speak first of the (colorless) ones. The Greek name for quartz comes from its close resemblance to ice and the Latins have translated the Greek name into their own language and call it *crystallus*.[7] Indeed certain people believe that quartz is ice, i.e., rain water that has been solidified by extreme cold, but this is not true. It is actually a juice that has been congealed by cold. If it were water solidified by extreme cold it would be most abundant in regions where extreme cold prevails, where the brooks and even the largest rivers are frozen to the bottom and it would melt when brought into the warm sunlight. Both are contrary to facts. Not even the ice on the highest Alps which has become hard from the perpetual cold which has existed there for years, actually hundreds of years, is changed into quartz. Even this ice, although it may be hard as stone, melts when it falls from the heights into the warm sunshine. We must conclude that quartz is a juice which, as I have written in *De Ortu & Causis Subterraneorum*, has been coagulated by the cold within the earth and for that reason has been found in openings in marbles and rocks. Sometimes it is turned up by the plow and it may be carried along by streams but in each case it has come originally from veins or stringers. Actually, when a crystal projects outward from the rough rock, as can be observed in the Alps and the highest part of Mt. Melibocus, it is certain that the force of the waters has washed away the minerals that were around it. Those who gather these from inaccessi-

[7] Greek, κρύσταλλος from κρύος, icy cold, frost.

ble rough rocks commonly, according to Pliny, hang from a rope. It is also found in metalliferous veins and veins of the pure mineral. It occurs in many places, in Spain, France, Germany, the Alps, Scythia, Cyprus, Asia, Carmania, India and on two islands in the Red Sea near Arabia, one island being called Neron, the other Chitis.

The best quartz is colorless and as transparent as limpid water. Flaws are common, those that have a color are spotted or similar to black clouds while those that have a body resemble scales, "salt," ulcers, hairs, rust, iron rust and lead rust. Sometimes quartz crystals contain silver minerals of a lead or reddish color (probably argentite and proustite). The former is the more valuable and the best. The silver is usually in the body of the quartz, rarely on the end.

Quartz crystals vary in size and consequently in weight. While the shortest crystals may be less than half an inch high Juba writes that he remembers a crystal eight inches long that was dug up on the island of Chitis by Pythagoras, prefect of king Ptolemaeus. Crystals may be less than a quarter of an inch thick yet Pliny describes a crystal found in India that was so thick that a vase which could hold three quarts of liquid was cut from it. Xenocrates describes a vase similar to an amphora cut from a single crystal. While the smallest crystal may weigh only a scruple, Pliny writes that Livia Augusta placed one in the temple to Jupiter which weighed approximately fifty pounds.

Quartz crystals are rarely found single. Usually a number occur together growing from a common base, sometimes standing up separately, sometimes united. Some crystals stand vertically, some are inclined, some lie on the base adhering to it so that they cannot be removed easily. Sometimes a number grow on a common base and are so united that they can only be separated with the greatest difficulty. A single large and perfect crystal may form surrounded on all sides by many small and imperfect crystals which are seen to have only three sides as if they were half crystals since quartz is hexagonal although the sides are usually unequal. Quartz crystals often have two broad and four narrow sides while rarely there are four broad and two narrow sides. Moreover a narrow side may taper and a broad side become broader.

The sharp termination of the crystal is hexagonal similar to the body. The point differs in that the narrow pyramid is not always above the narrow side and sometimes the broad pyramid may be above the narrow side. Only a small portion of the mass of the crystal is in the point, the greater part being in the angular body although some crystals found on the cliffs of Blocheberg have a large point and a small body. The faces of the point are so much smoother than those of the rest of the body, unless they contain flaws, that they can be polished only with great effort.

Since quartz cannot withstand heat, cold liquids can be poured into quartz goblets without injury to them but if a hot liquid is poured into them they break. Not only are goblets made from this mineral, such as

the two in Nero's possession, but even wine ladles such as the one Pliny mentions which was purchased for eight hundred and fifty pieces of gold from a none too wealthy woman H———s, as well as the faceted spheres with which we calculate prices. It is also cut into the faceted hemispheres from which they make the clusters that are set in rings. Quartz can be used for relief engraving, especially for coats of arms although it is rarely employed for this purpose since it wears rapidly with use being softer than a file. It is also used for the lenses that were employed by physicians in times gone by to burn people when held in the sun's rays. These lenses produce a dazzling white point of light that can shatter quartz itself and set fire to material. *Hephaestites* is also used for these lenses. Quartz itself is cold and dry. When an object is placed before it, it will illuminate the portion nearest it with its brilliancy. The more transparent and brilliant the quartz the greater its heating power.

Quartz is used in medicine. Having been ground very fine and taken in sour wine it stops dysentery since it is so drying.

The finest quartz is free from all flaws, transparent and heavy. This variety is found in the Alps near Sion and the finest crystals of Germany come from Gombezanus. All other quartz is of inferior quality. Actually writers judge the beauty of quartz according to its place of origin. Pliny writes that the finest comes from India and praises the groups of crystals found in the Alps. He writes that the very poorest comes from Asia near Alabanda and Orthosia. Solinus writes that the Scythian crystals are the most valuable. When the rays of the sun coming through an open door, window or crack are allowed to fall on a crystal of Scythian quartz it will reflect the rays on a nearby wall with all the colors of the rainbow and for that reason it is called *iris*. This can only be done with colorless, transparent, natural hexagonal crystals. Indeed it is because of its angles that it can take the rays of the sun and reflect them on a wall as a rainbow. The crystal that will produce the largest rainbow with the brightest colors is regarded as the best. If any one of the angles of the crystal is turned toward the light and observed carefully a rainbow can be seen within the crystal. *Iris* is found in the localities mentioned above along with other quartz but it is especially abundant along the Weser river near the town of Hoxer; in Westphalia near Erz on the estate called Hildeschespred; in Hesse near Halleberg; and in the mountains between Trier and the Rhine. Pliny writes that it is dug up on an island in the Red Sea forty miles from the town of Berenice.

There is another variety of *iris* that is not as colorless as quartz and when turned toward the light has a color as yellow as citron. For this reason gem dealers call it *citrina*.[8] Older writers have described this variety as resembling wax. Since it is not as transparent as quartz it is not as brilliant and the colors of the rainbow it throws on the wall of a room are

[8] This is the first use of the name citrine for yellow quartz. The name *citrina* should not be confused with *citrinus* a variety of *chrysolithos*.

darker. It is found in the mines of Misena and Bohemia and in many quartz localities. According to Horus it occurs in Persia and is much harder than our mineral, in fact, by comparison, our mineral is soft and fragile. Horus writes that it is a remedy for mongoose bite when burned and pulverized. Quartz that does not have an angular form will not throw a rainbow on a nearby wall but does throw a similar group of colors. This is sufficient concerning quartz and *iris.*[9]

Nature sometimes produces a gem from the same essence as that of quartz but with more than six angles and for that reason it is called *pangonius* by the Greeks (from *πᾶν*, all, *γωνία*, angle). This mineral is rarely found in the same places as quartz but when it is, it has the same color and transparency but is smoother. When found by itself it is usually dark and full of small pits like a honeycomb. Crystals having twelve sides and terminated with a point, like quartz, are found along the Aller and Ochus rivers. Pliny writes that it is never found longer than three-quarters of an inch but some are found longer than this, although they are usually shorter.

Diamond is formed from an essence not dissimilar to that of quartz but having been congealed by a more intense cold. It takes its name, *adamas*, from the fact that it cannot be affected by either iron or fire. It is also called *anachites* because it sets one free from idle fears by its constant sparkle according to the belief of some. It forms in mines in Ethiopia, India, Arabia, Macedonia and Cyprus. It is found with gold between the temple of Mercury and the Island of Meroe, Ethiopia. The Arabian stones are found with the very purest gold; the Macedonian stones, at Philippi. The Cyprian stones are found in copper mines while the Indian stones are found unassociated with other minerals. The color of both the Ethiopian and Macedonian crystals is similar to cucumber seeds; the Indian, colorless; the Arabian, tinted; the Cyprian, inclined toward brass-yellow. The Indian stones are the most transparent. Diamonds that have the same luster as iron are called *siderites*. Pliny does not mention the place where these occur.

The Indian stones are sometimes found the size of a hazelnut; the Arabian diamonds are smaller; the Ethiopian and Macedonian no larger than a cucumber seed. A stone no larger than a millet seed is called *cenchros*. Diamond often has the same color and smoothness as quartz. It is often found in colorless hexagonal crystals that terminate in a point. According to Pliny the Indian stones are sometimes found having the appearance of two cones joined together at their bases. They may be perfectly smooth.

[9] Agricola distinguishes between crystals of quartz, *crystallus*, and massive crystalline quartzose rocks, *quarzum*. It is rather unusual that no mention of the name *quarzum* is made in this work since he wrote as follows in Bermannus in 1529.

Ancon. "I see several kinds of rocks here.

Bermannus. "A large number. . . . Another genus is this one which is seen to be transparent at times, at times very white, light yellow or bluish gray. Our people call it *quarzum*."

Diamond differs from quartz in hardness. The former is actually so hard that if placed on an anvil and struck with an iron hammer, the hammer and anvil will break before the diamond can be fractured or crushed.[10] It will not only withstand the blows of a hammer but also fire. If we are to believe Pliny it will not melt or even glow in the hottest fire. According to Xenocrates it is not fouled in a fire but is purified. Nevertheless the exceptional hardness of this remarkable stone can be reduced by placing it in the blood of a male goat or lion, after which it can be broken. When placed in liquid lead in a very hot furnace it will melt. Actually all diamonds are not of the same hardness. Those from Cyprus and the variety *siderites* are broken by the blow of a hammer and holes can be drilled through them with other diamonds. Pliny writes that he was the first to call these stones "degenerate." The very finest diamonds can destroy the force of lodestone just as the blood of a male goat or lion can reduce the hardness of a diamond. When the diamond is placed next to the iron the lodestone cannot attract it, or if eventually it does attract the iron it is drawn away violently from the diamond. A diamond can detect poison and render it harmless. For this reason it has always been highly prized by royalty and therefore has always commanded a high price. It is reported to prevent insanity but this is hard to believe. Finally, gem engravers set broken fragments of diamond in iron and because of the superior hardness use them to engrave all other gems.

Androdamas also forms from a colorless essence. The name, as many believe, comes from its power to subdue the violence of men and to cool anger (*ἀνδρός*, man, *δάμασν*, subduing). It is found in Arabia. With the color and luster of silver it has the appearance of a diamond although it has a different form. It occurs as a cube. Although it may be cubical and without the same properties nevertheless it is today called diamond, a hexagonal mineral.

The following gems are white and multicolored, that is, they change color when inclined just as does a variety of silk cloth when viewed from different directions. The Greeks call these gems *paederos*, the name being derived from the passionate love of youth, because of its exceptional charm (*παιδίον*, boy; *ἔρος*, love). In this group of gems the finest is the *opalus*. When it is inclined one sees in it the weaker fire of the *carbunculus*, the gleaming purple of the amethyst, the sea green of the *smaragdus*, and all of these colors sparkling in an incredible intermixture. Masses are found the size of a hazelnut. It is found only in India and is more valuable than the *smaragdus*. It is brought to us only rarely. The gem that takes second place is called *sangenis* by the Indians, *semites* by the Egyptians. When inclined this shows the colors copper-red, purple, and wine-yellow. The wine-yellow color always occurs around the outer edge while the purple, according to Pliny, spreads to the yellow and mixes with all the other colors. This gem, pleasing and delightful to the eye, occurs in India,

[10] A fallacy widely held in ancient and medieval times.

Egypt, Arabia, Pontus, Galatia, Thasos and Cyprus. The Indian gem is the best, then the Egyptian and last the Arabian. The Pontian stone is of little value because it lacks brilliancy. The Galatian, Thasian and Cyprian stones are dull and of little value.

A third variety is called *eristalis*. This has a red color when inclined. Ophesus calls this variety *opalius*, unless I have made a mistake, and writes that it has the delicate coloring of a young boy, i.e., white tinted with red. There are many other varieties of *paederos* since by merely inclining the gem one can add to it's white luster either the golden yellow of wine, the blue of the heliotrope, the pale color of quartz which has less luster or a kind of blackness that darkens the gem. Pliny classes some of these as defective opals, hence it can be understood why one writer calls all gems of this genus *opali*, another *paederotae*. Species of *paederos* are also found in the localities mentioned above. The flaws found in these gems are usually scales, "salt" or hairs.

Another gem also forms from the colorless quartz essence that has a white internal gleam which resembles that of a star. For this reason it has been called *asteria*, *asterios*, *astroites*, *astrios*, *astrobolos* and *solis gemma* by different writers, names which Pliny has collected from almost all writers. Pliny himself prefers the names *asteria*, because the gem reflects the dazzling white rays of the sun, and *astrios* because it receives and reflects the brightness of the stars. But each of these properties is common to all of the others. We know this to be one and not several gems because the names are almost identical; the places they occur are the same, for example, Carmania and India; they are the same white color; they have the same white brightness; when they are rounded one writer says they resemble the pupil of the eye, another the full moon, another the round disk of the sun. Pliny writes that when inclined the gem reflects the light from the interior as though it were moving from one point to another and it is not unlike the *carbunculus* in this respect. The gems that reflect a white light are the best. Those that reflect a blue light are inferior and are called *ceraunia* because of the belief that the place where they may have been found had been struck by lightning although this has been proven to be false. The gems reflecting a light similar to that of a lamp are the least valuable. The beauty and value of these gems is judged according to the place where they are found and on this basis the gems from Carmania are regarded as the finest and less subject to flaws. Second quality gems come from India and the third from Pallene on the shores of the Thracian peninsula. This gem is quite hard and for that reason difficult to engrave. When polished it is usually given the form of a hemisphere. Sudines writes that *astrobolos* resembles the eye of a fish.[11]

[11] Agricola is without doubt here describing various adularescent gems, chalcedony moonstone, feldspar moonstone, girasol opal and sapphire, and he has probably included aventurine feldspar and labradorite. Some of these names embrace other minerals. *Asteria* may have embraced all the asteriated gems. *Astroites* is coral and is probably included here because of the radiating structure of certain species.

In conclusion we may say that the white or colorless gems are quartz, *pangonius*, diamond, *androdamas*, opal and *asterios*. Regarding the form and features that distinguish one from the other, quartz, *pangonius* and *androdamas* are always angular, diamond, sometimes. Opal and *asterios* are not angular but usually rounded. *Pangonius* is distinguished from the other angular gems by the large number of angles. The others are either hexagonal or cubic. *Androdamas* being cubic is easily distinguished from quartz and diamond, in fact from all angular white stones because all the others terminate in a point if they have their natural form. Diamond can be distinguished from quartz by hardness. Opal is distinguished from *asterios* by inclining the gem. The former will change color while the latter will reflect a round inner light. Diamond is the most valuable of all these gems. A king of the Turks bought one twenty-three years ago for nine hundred and fifty pieces of gold. Next in value is the opal and third, the *sangenis*. After these comes *asterios* and then *pangonius* because of its rarity. However, quartz, if it is in crystals large enough that a vase can be cut from them, commands a high price for Pliny writes that a wine ladle was purchased from a not too wealthy lady, H———s, for eight hundred and fifty pieces of gold. I have said enough concerning the white and multicolored gems and will not take up the green gems.[12]

The first green gem to come to our mind is *smaragdus*. The Greeks have given it this name because of its brilliancy. According to Pliny it is called *limoniates* (λειμωνιάτης), a moist green pasture). It is found in Asiatic Scythia; Bactria; Media; Perseis; the gold mines of Arabia; in the mountains and rocky wastes of Egypt near Keft, a town of Thebes; in the copper mines of Carthaginia that are on Mt. Smaragdites; in Sicily; on Mt. Tagyetus, Laconia; near Kastri, a town of Greece; in the silver mines of Attica; at a place called Thoricus; and in the copper mines of Cyprus. The color of the finest *smaragdus* is a dense bright green and the body of the gem is not only brilliant but as transparent as water. Gems of this quality are found in Scythia, Bactris, Egypt and Ethiopia. Those from Kastri are an oily-green as are the finest from Cyprus which, if examined carefully, are seen to have the translucency of the sea. While this gem can scarcely be said to sparkle nevertheless it does have the apparent property of tinting the air around it, especially when it is lighted by the brilliancy of the sun or a lamp or when a shadow darkens it. For that reason, when

[12] There is some confusion in the use of these various names. Quartz and *pangonius* are the same mineral, the latter being a crystal with twelve prismatic faces. There is a certain confusion in the identification of quartz and diamond since the hexagonal crystal terminating in a point is obviously quartz. *Androdamas* which is described as cubic may be diamond since this is one of the forms of this mineral. It is impossible to identify *siderites* but it must be some mineral other than diamond. Since it was believed that the hardness of diamond could be materially reduced by soaking the stone in goat's blood it was easy to consider any transparent, colorless stone as a treated diamond. Asteriated gems have long been a source of wonder and it is strange that Agricola should apply this name and its variations to the gem now known as moonstone.

placed in water and viewed from a distance, it appears to be larger than it actually is. Gold and silver coins placed in water show this same phenomenon for the brilliancy of the metal tints the surrounding water just as the *smaragdus* tints the surrounding air. Stones of poorer quality are not so green in the sun although they are transparent. Such stones came from Attica according to Pliny. Some stones, when inclined, are more or less green and bright such as those mentioned by Pliny from the copper mines of Carthaginia as well as the *smaragdus* surrounded by white veins of the mineral they call *galactites.*

Smaragdus contains a great many flaws. First, the color is not uniform being bright green in one part and either dark or light green in another or the green color does not extend through the entire crystal. The interior or the edges may be white. These gems are called clouded. The transparency may vary and one part may be completely transparent another part not. Pliny says that the Persian crystals are not absolutely transparent, assuming that the crystals he mentions are *smaragdi*, as he himself believed. These may have belonged to a translucent species of *smaragdus* which includes the Median stones. As described by Pliny these latter stones contain images of various objects such as the poppy, birds, feathers, small animals as well as the images shown by other translucent gems and marbles, for example, agates and green marble. As regards the body of the stone, it is not always perfect and may contain flaws such as hair, "salt," lead rust, pulp and flaws peculiar to this gem. Some of the Cyprian gems are various shades of bluish gray. The stones from Attica gradually lose their green color and appear to die of old age. These stones are also injured by the sun. On the other hand the stones from Media that are not uniformly green can have their color improved by placing them in wine or oil.

Although *smaragdus* is rarely hard Pliny writes that the stones from Scythia and Egypt are so hard they cannot be injured. The Cyprian stones are not so hard. The Carchedonian stones, as well as all the rest, are so fragile that gem artisans are more reluctant to set these stones in rings than any other. The gems are cut cabochon, flat or concave. One very famous gem is in Genoa with the shape of a small shallow dish. A similar *smaragdus* is in the monastery of Narbo, Gaul, on the plain of Lyons. These are certainly very large gems. The gem in the small shrine to Wenceslaus at Prague, Bohemia, is not small since it is over nine inches long. There is a longer gem at Magdeburg which forms the base for the small tower-shaped golden chest in which the sacrament is carried. They say that the handle of the dagger of Otto I was a *smaragdus*. Although some *smaragdi* have been perforated as a rule they are not so large. The largest are the Cyprian stones which very rarely are found large enough to carve into small figures. According to Theophrastus they are usually small. A most extraordinary gem was found in Cyprus which was half *smaragdus* and half *jaspis*. This, as well as all other gems that have formed from different essences, contains an unusual number of flaws.

Smaragdus transmits images as if it were glass and a piece of it was used by Nero when he watched gladiatorial combats. Concave gems are the best for focusing an image. These sooth eyes that have been strained but do not cure them according to Pliny. It does restore keen sight to eyes that see indistinctly as a result of strain. The gentle green of this gem is most soothing to the strained eyes of the gem engraver. Any lewd act is very dangerous to a *smaragdus*. If either a man or a woman wears this gem during cohabitation and it touches the flesh, even when set in a ring, it will be shattered.[13] It combats epilepsy as though it were a deadly enemy until it either overcomes the lesser power of the disease or is overcome by a greater power. In the former case the stone remains whole and intact but in the latter case it is fractured into many small pieces. For this reason kings and priests suspend it from the necks of boys and wear it in rings in order to test whether it will have the power to expel this horrible disease. Theophrastus writes that the *smaragdus* from Cyprus can solder gold the same as borax. These two minerals have a similar color and are seen to have similar properties.[14]

From the above remarks one may know which *smaragdi* are the best yet some judge the quality of these gems solely by their place of origin. Judged in this manner the Scythian stones are the best, the Bactrian second, the Egyptian third, the Ethiopian stones of pure uniform color fourth and the Cyprian fifth. The other stones are worthless.[15]

Beryllus is also green. It is found in India; in Arabia according to Strabo; in Phoenicia in veins of *ophites* according to Dionysius Afer; and accordihg to Pliny it was found in our own world at one time around the Black Sea. The color is green but lighter than that of *smaragdus* and often the *fulgor*[16] is of another color. For this reason there are eight species of *beryllus*. The most highly prized has the pure green color of the sea and takes its name from this. The next species is called *chrysoberyllus* because

[13] There is a superstition today that if a wife wears an emerald and her husband is unfaithful to her the stone will turn white.

[14] See under *chrysocolla*. Agricola recognizes two species of this mineral, the natural which includes malachite, chrysocolla, etc., and the artificial which is borax. He is speaking here of borax which is white and confusing it with green malachite and chrysocolla.

[15] Several green minerals are included under *smaragdus*. This is due in great part to confused descriptions and the lack of comparison of the minerals described by the different writers. Primarily *smaragdus* was the modern emerald, a variety of beryl. The following characteristics must refer to the emerald,—the gem is not brilliant but transparent; found in Egypt and Ethiopia; the Scythian stones are the best; contains many flaws; the green color is not uniform and may grade into white. The gem from Cyprus which is described as half *smaragdus* and half *jaspis* is probably red and green jasper. The gem that appears to die of old age and can have the color improved by placing it in wine or oil probably refers to turquois. The *smaragdus* of Theophrastus from Cyprus was probably chrysocolla.

[16] Agricola uses the term *fulgor* in a sense which cannot be translated directly in many instances. Literally *fulgor* is brilliancy but it is meaningless in this association since color is not a quality of brilliancy. A possible translation is "flash."

the *fulgor* of the gem is the color of gold. *Chrysoberyllus* is also named *choaspitis* from a river.[17] This gem is also said to have a golden-green *fulgor*. *Chrysoprasius* is the third species and its name comes from gold and the juice of the leek. It is lighter colored than *chrysoberyllus*. The fourth species is *hyacinthizontes*, so named because it is similar in color to the *hyacinthus;* the fifth, *aerodes*, because it is similar in color to the sky;[18] the sixth, *cerinus*, because it is similar in color to wax; the seventh, *oleagenus*, because the color is similar to that of oil; and the eighth, *crystallinus*, because it is colorless.

Beryllus may contain the same flaws as *smaragdus* as well as the characteristic flaws called "membranes." Because of its color beryl tends to be dull unless the dead and lifeless appearance is enlivened by reflection from the angles. For this reason gem cutters give a hexagonal form to all of these stones and make cylinders from them more often than other gems. The *cymbia* (goblets) of India are made from *chrysoprasius*. The finest gems have the golden center in the top of the stone. The others are usually drilled to remove any white core and if they are only moderately transparent they are strung on elephant's hair. If they are even less transparent gold is added to increase the transparency.[19] *Diadochos* is similar to, if not actually the same as, *beryllus* since the writers who describe this stone do not say in what way it differs from the latter.[20]

Prasius (prase) which is called *prasitis* by Theophrastus is a lighter green than the beryl which has the pure green color of the sea. It has the color of the juice of the leek and the name comes from this (πράσον, a leek). *Eumetre*, which the Assyrians call the gem of Belus after their most sacred God, is leek-green and is seen to be the same mineral as prase. This stone is translucent but not very brilliant. For this reason it is classed among the valueless gems. There are three species. The first is moderately green, the second characterized by blood-red spots (bloodstone) and the third by three white twigs. Prase has the same flaws as beryl. It is found in the silver and copper mines of Germany.

Heliotropios (heliotrope) is another species of prase which is also leek-green.[21] It differs from one species of prase in that it has blood-red veins through it instead of spots. It is found in Cyprus, Africa and Ethiopia.

[17] The Choaspes river in Persia.

[18] Pliny and other writers give this name as *aeroides*. This would be called aquamarine today.

[19] This is a good description of beryl and of the numerous varieties including the bluish-green aquamarine, the golden-yellow heliodor, etc. Crystals are found of extraordinary size. Flaws are common and the color is often irregular.

[20] For more than 2000 years *diadochos* was a mineral noted for its magical properties. It is interesting to note that the name (diadochite) is given today to an entirely different mineral, one with properties that are unusual if not unique.

[21] Prase and plasma are more or less identical varieties of cryptocrystalline quartz, plasma being slightly less translucent than prase and somewhat brighter green. Heliotrope is identical with bloodstone, essentially prase or plasma containing spots of red jasper.

The name comes from a property of the stone (ἥλιος, the sun, τρέπειν, to turn). According to Pliny when placed in a glass of water it changes the brilliance of the sun, as it approaches it, into a blood-red color, especially the Ethiopian stones. Outside the water the stone will reflect the sun's rays like a mirror and it shows the eclipse of the sun when the moon passes in front of it.

Although *topazius* also has a leek-green color it is transparent and extraordinarily brilliant. It has a golden *fulgor* and is classed among the precious gems. The name comes from the Topazius Island of Arabia (modern St. John's Island in the Red Sea). Archelaus calls it Chitis[22] and writes that the Troglodyte pirates found the stone long ago when digging for herbs and roots having been shut in by storms and suffering from hunger. Since it has a *fulgor* similar to gold it is not easily seen in the daytime for it resembles the rays of the sun. It is conspicuous at night and is sought for at that time.[23]

This same gem is called *chrysolampis* for Pliny says it is found in Ethiopia and has a pale color by day and a flaming color at night. Strabo writes that at one time the kings of Egypt supported a multitude of men who collected and guarded this *topazius*. According to Pliny, the most recent writers say it is found near Alabaster, a town of Thebes, Egypt, and they describe two species. One is *prasoides*, the other, *chrysopteros* similar to *chrysoprasius*. The one evidently has a *fulgor* that is deep golden yellow, the other a paler *fulgor*. A third species, according to our gem workers, is found in Dacia and since it contains no green is pale yellow and has a *fulgor* of the same color.[24]

Topazius is known to occur in larger masses than any other precious stone for Juba writes that a statue six feet high of the wife of Ptolemy Philadelphus was made from it and placed in a sacred shrine named Aureus. Hadrianus Guilielmus of Naples has a *topazius* which is engraved with these old Roman words,

Nature fails,
Fortune changes,
God decides all.[25]

[22] Obscure references in the older literature to Topazius and Chitis have raised the question of whether there were two islands in the Red Sea that were ancient sources of peridot. Agricola believes them to be one and the same island.

[23] This description would apply to the modern peridot or chrysolite and not to topaz.

[24] These species are probably chrysolite in part. From these descriptions it is impossible to identify them with any accuracy. *Chrysolampis* could be the modern gem alexandrite, a variety of chrysoberyl but this gem has never been found in Egypt, Africa or Asia Minor.

[25] This is freely translated by Thomas Nicols in his Faithful Lapidary, London, 1659, page 107, as follows,

Nature by fraility doth dayly waste away,
Fortune is turned and changed every day,
In all these there is an eye knows no decay.

Topazius is soft and the only one of the precious stones that wears away with use. It can be scratched by a file and is polished with other rocks and flint.

Nilios that is found on the banks of the Nile and takes its name from this river is not as beautiful as *topazius*. It has a smoky *topazius* or honey color. When looked at carefully it has a dull, shallow and false luster. According to Pliny it is found in India, according to Juba in Ethiopia and according to Sudines along the Severus river in Attica. The *callais* or *augites* gem is of less value than the *topazius*, according to Pliny, who has written in detail regarding it. This stone is pale green and, characteristically, occurs with *topazius*. It is found in large masses, full of holes and dirt, in the hinterland of India in parts of the Caucasian mountains inhabited by the Phicari and Asdathae. The stones from Carmania are purer and better. Here they are found on the sides of unscalable and icy cliffs standing out like eyes and adhering loosely to the cliffs as if they had been placed there and not as if they had formed with the rock. To climb these cliffs tires the people, whether they are on foot or horseback, and the danger frightens them. Therefore they work around the base, at some distance from the cliffs, and shake the stones from the moss found there. Luck varies in the search. Sometimes with one blow they may recover many fine stones and at other times with many blows they recover none. The *callais* is prepared for market in the following manner. They are shaped by cutting since they are fragile and the best have the color of *smaragdus*. It would appear that this stone is regarded so highly because it is foreign. It is usually set in gold and is no more pleasing than the gold itself. Oil, ointment or wine will destroy the color of the more beautiful of these stones. The poor stones are not affected. This gem can be imitated with glass.

There are stones they say are found in the nests of birds in Arabia that are called *melancoryphus*. Only that.

In summary, the green transparent gems are *smaragdus*, *beryllus*, prase, *topazius*, *nilios* and *callais*. They are distinguished from one another by color, brilliancy and form. *Smaragdus*, because of its deep green color, is easily distinguished from prase, *topazius*, *nilios*, almost all varieties of *beryllus* and from the pale green *callais*. Since it tints the surrounding air with its brilliancy it can be distinguished from the finest *beryllus* and *callais*. They can be identified by form. Artificers give a hexagonal form to *beryllus*, the form of an eye to *callais* while *smaragdus* has neither of these forms being cut usually in a high cabochon. The first species of *beryllus* has a different color than all other green gems and has a different form than *callais*. *Chrysoberyllus* and *chrysoprasius* are not always hexagonal and the small stones are cut with a tabular form today. They are easily distinguished from *topazius* since they do not have as high a luster. Prase may be either pure leek-green in color or have blood-red spots or distinctive white veins through it and thus differs from all the other

stones. The golden luster of *topazius* distinguishes it from the pale green *callais* and from *nilios* which has a honey-yellow or smoky-yellow color. The *smaragdus* commands the highest price of all green gems and is followed by *topazius*, *beryllus*, *callais*, *nilios* and finally prase. However, the largest *topazius* will sell, no doubt, for more than a small *smaragdus*.[26]

Sapphirus (lapis-lazuli) and *cyanus* (sapphire) are dark blue, hence the name of the latter gem (κύανος, a dark blue substance). Lapis-lazuli is enlivened by small golden points. Both gems are as blue as the heavens but lapis-lazuli especially resembles the heavens because of the golden points which represent the stars. For this reason Dionysius Afer describes the mineral as blue and gold. Although sapphire may contain a golden powder it is not completely tinged with it. The blue color of lapis-lazuli rarely has purple mixed with it and often has black areas within it. Sapphire, on the other hand, approaches the blue color of the ocean.

There are two varieties of sapphire, one dark the other light. The former is called masculine, the latter feminine.[27] The feminine variety sometimes has so little color that it is almost like quartz although it is always somewhat darker. The darker the sapphire the greater its value. Also, the more brilliant and the more transparent the stone the more prized it will be. Sapphire contains flaws such as hairs and phantoms and a golden powder in masculine sapphires decreases their value. The form of both lapis-lazuli and sapphire varies, being tabular like a board, round and even oblong. Lapis-lazuli occurs in the territory of the Arieni in Media, in India[28] and Africa. The dark sapphires are found in Scythia, Cyprus and Egypt, the light sapphires in Narbonensis, Gaul, not far from the Rhone river.

The light colored 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 but this fraud can be detected readily by the feel, especially to the tongue. Sapphire is colder than glass. For this same reason lapis-lazuli is advantageously set with *carbunculi* and other stones that give off warmth. Gem dealers today call each of these gems *sapphirus*.

Hyacinthus and *amethystus* (amethyst) are purple gems. Amethyst has

[26] These descriptions of green gems, while showing some confusion, indicate a quite definite nomenclature. Although other gems and minerals are included on the basis of similarity of color the species are, in general, quite clearly defined. *Smaragdus* is our emerald; *beryllus*, beryl; *prasius*, prase; *topazius*, chrysolite or peridot; *callais*, turquois. Since the first description by Pliny *nilios* has been an unidentified species. The description given here would indicate jasper although Pliny may have referred to corundum from India.

[27] The idea of sex in minerals was first advanced by Theophrastus. It was long held that stones and minerals possessed the power of reproduction. A logical development of this concept was the effort to distinguish the male and female minerals, in the case of gems on the basis of color. Female gems were always lighter and brighter colored than the male.

[28] This probably refers to the mines in Badakshan, Afghanistan, near the Oxus river.

the color of wine before it is tested while it still retains a certain shade of violet, according to Pliny. He writes that it was named amethyst because of the ignorance of some learned men who believed that it would prevent drunkeness (derived from ἀ, not; μεθύειν, to be drunk). It is also called *ion* because of its violet color (ἴον, the blue violet). Because of its beauty the very best grade is called the "gem of Venus" and for the same reason *paederos* and *anteros* (both words derived from ἔρως, love). It is found in Thasos, Cyprus, Galatia, Armenia Minor, Petraea, Arabia, India and Egypt. The *hyacinthus* is found in Ethiopia. Amethyst is also found in the Amethyst Mine, Volchestein, Misena. It is found in large crystals with a hexagonal base and terminated in a point similar to quartz. Most of the crystals come from this mine and the silver mines of Bohemia although it is also collected from a Misenian river above the fortified city of Hoestein, five miles from Stolpa. It is found in the district inhabited by the Gombesani who migrated from Germany into the Alpine valleys of the Seduni. The poorest amethyst comes from Thasos and Cyprus, ordinary quality from the other localities and the best from India. Stones of a deep rich color are found very rarely anywhere.

The color of amethyst is redder, that of *hyacinthus* blacker. The purple brilliancy shining from an amethyst is not found throughout the entire crystal but fades into the color of wine and gives it a delicate rose color. In *hyacinthus* the color is weaker and with the first look the beauty vanishes, I use the words of Pliny, before one is satisfied and does not completely fill the eye, actually hardly touches it, fading even more rapidly than the flower for which it is named. Each is transparent and without form when found but artificers cut facets on them in order to increase their brilliancy. Some stones are cut en cabochon similar to the natural shape of some *smaragdus*. They are easy to engrave. Pliny describes five species of amethyst. The first species includes the gems from India that are the pure purple that is the despair of the dyers. This color emanates from the gem in a soft caressing manner, not with the glitter of the *carbunculus*. The next species includes the *hyacinthus*. The Indian calls the color of this gem "sacon" and the gem itself *sacodion*. The stones of lighter color are called *sapinos*, a name that is derived likewise from the color. The next species includes the stones called *paranitis* that come from a district of the same name adjoining Arabia. Stones of the fourth species are the color of wine. Those of the fifth species are a very pale purple approaching the color of quartz. This latter species has little value although it should be as highly prized as the light rose tint in the purple of the *carbunculus*.

There are two kinds of *hyacinthus*. The dark variety we call masculine and the lighter, feminine. The Venetian artificers polish the valueless and false German *hyacinthus* and call it the true gem. These are sent to Constantinople and sold to the Turkish women. The more recent writers place three different gems under *hyacinthus* and divide this genus into three

species. The first species they call *granatus* and these are *chrysolithus*. The second species, which is also *chrysolithus*, they call *citrinus*. The third they call *venetus* and these are sapphires. Solinus also confused sapphire with *hyacinthus* and gem merchants always call *sandastros* and *chrysolithos*, *hyacinthus*. This is enough concerning the purple gems.[29]

Sard is red. It is called *sarda*, *sardo* and *sardius* in Latin. This name was given to the stone by the Sardians after the place where it was first found. The gem merchants call it *carneolus* (carnelian), because it has a color similar to flesh (Latin, *carneus*, fleshy).[30] It is found in many places, in Germany along the Rhine near Marburg; at Ephyra; in Troy, Asia; at Sardis, Lydia; in Armenia, Babylon, Persia, Arabia, India, and near Egypt. Sard is not a single color. It may be redder than the cooked shell of a marine crab, dark red, light red, honey-yellow, or similar in color to the dirty dregs from a wine cask. Sometimes it has a very unusual color due to some foreign substance. The more brilliant stones are called masculine, the duller ones feminine. The masculine stones may be translucent, such as those from Babylon, the Rhine and the first quality stones from India. The feminine stone is so dense and gross that one cannot see into it, such as those from Arabia and the second quality stones from India. These are called *δήμιος* by the Greeks because of their grossness. The most prized stones are very red while the darker and lighter tones are of less value. Stones of other colors are worthless. Sard is improved by the artisans. In Egypt they back the stones with gold foil and in India they back the third quality stones with silver foil. The gem has always had a wide use because it can be engraved with ease and is excellent for seals since the wax will not stick to it. It will make a sharp imprint longer than any other of the transparent gems because the hot wax wears it away very slowly. Oil will wear it away faster than any other material, according to Pliny. Pulverized and drunk with sour wine it stops menstruation and profuse bleeding from a severed vein.

Sometimes a mass of red sard is underlain with white onyx and from these two gems a third is created which is called *sardonyx* (sardonyx). When the white portion of the stone is turned up it has the appearance of a human fingernail with the flesh underneath it. The colors of the upper and lower layers of this mineral vary greatly. The upper layer may be the color of the finest sard, darker, lighter, brighter, honey-yellow, a dirty red or some other shade of red produced by foreign material. The lower layer may be the color of the human fingernail, wax-colored or horn-colored. It may have different colors, be ornamented with circles or resemble the rainbow. Although sardonyx is usually translucent some is found that

[29] Agricola, and later De Boot and De Laet, regarded *hyacinthus* as a variety of amethyst. There is an obvious confusion in the description of this gem and different writers applied the name to different gems. It takes its name from the hyacinth flower but this name was given to a number of different flowers by the older writers.

[30] Carnelian and sard are translucent varieties of chalcedony which are distinguished by color. Carnelian is a light orange-red; sard, a reddish to dark brown.

is not and this is called *caeca*. The best of the translucent material is a fine red on top and white on the bottom. This is found in India as many writers have recorded. A stone is judged to be the very finest when, having been turned toward the light and carefully examined, it shows a uniform red color. Certain stones are, in part, honey-yellow. The stones with circles on the bottom are most highly prized when the white zones of the circles are narrow. On the other hand stones with broad or pale colored zones are considered valueless. Good stones of this type are found in Armenia. Sardonyx is found, not only in India, but, in almost all the other localities where sard occurs. Moreover, any gem with sard on top, even though it is worthless, and a base of white onyx is properly called sardonyx. It is not proper to use this name when the other layer is not white onyx, for example, when the lower layer is not similar in color to the human fingernail but is the color of wax or horn or is of some other color even though the top layer is sard. Another case where this name is not properly used is when the sardonyx has a white upper layer but with a lower layer that is not sard-red, for example, black or sky-blue. However we do call gems sardonyx which, when turned over, have the attractive appearance of onyx, not of sard. It is even more improper to call gems sardonyx that contain no trace of sard nor a whiteness similar to that of the fingernail but have a top layer ornamented with either white circles or with white grading into red and the bottom layer black or blue, such as the stones found in Arabia. The Arabian stones, according to Pliny, are famous for the brilliant whiteness of the circles and not for their thin banding. They have no brilliancy in the recesses or concave portions of the stone but only on the convex portions. These stones have a very black lower layer. We engrave this gem and set it in rings for, like sard, it can be used as a seal since wax does not stick to it. In India caskets are made from it since it is found in large masses and the common people, after perforating pieces of it, wear them around their necks. The Greeks believed that this gem possessed great powers as is shown by the following story of Pliny's. Polycrates, a tyrant of Samia, valued this gem so highly that when satiated and disgusted with continuing prosperity and good fortune and wishing to suffer adversity and misfortune he threw his ring set with sardonyx into the sea.[31] I am not ignorant of the fact that several Greek writers, including Herodotus, state that this ring was set with a *smaragdus*.

Since sardonyx is formed of sard and onyx and I have already described sard I will describe onyx before taking up the fiery red gems. The name onyx (Latin, *onyx*) comes from the white color of the stone which resembles that of the fingernails. Very often it is milky white, especially some of the layers. This is called *onychites* and *lapis onychinus*. It is found in northern Germany near the shrine of Vendelinus and according to

[31] Polycrates' wishes were granted. A few years later he was crucified by the Persian Prince Orontes. Several writers have identified the stone as an emerald.

Albertus among the Sequani between Basilea and Strasbourg. It is found in Greater Germany in many places, for example, in a deserted mine of Mittelbach five miles from Chemnitz, Misena; in a second mine five miles from the first near the town of Langovicius; in a valley between the town of Zuicca and a mountain containing coal. In the latter place it occurs in veins of pure onyx as well as in a black breccia. It is found in Cappadocia near Galatia; in many parts of Scythia; and according to Pliny especially in Carmania, Arabia and India. The onyx found among the Germans and Sequanians as well as other stones similar to it is called *chalcedonius* (chalcedony). The name is derived from Chalcedon, Bithynia, a town to which this mineral was brought from either Cappadocia or from some other nearby place. All the rest is known by the old name onyx although Pliny calls the mineral from Carmania both *onyx* and *murrhina*.[32]

The color of onyx varies greatly. It may have veins that are fiery red, red and purple with layers that are milk-white such as the German material. It may be fiery red, black, horn-yellow with white circles which resemble the white portion of the eye, according to Pliny, such as the stones from India. The Arabian stones are black with white layers. The stones from Scythia and Carmania have fire-red, purple and milk-white layers. As I have said, Pliny calls these latter stones *murrhina*. Certain gray stones are found with whitish zones that give them the appearance of an eye. Some have blue layers while the German stones rarely have black, often bluish black and, besides the colors already mentioned, blue and blackish red. The veins or bands found in these stones may be broad or narrow. They may curve smoothly or crookedly and even form eddies which resemble waves. Some of these stones reflect colors such as those seen in the rainbow, according to Pliny. In the shrine of The Three Wise Men, or as we call them, The Three Kings, at Cologne there is a piece of onyx three inches wide with milk-white bands that run in all directions in such a manner that they portray the heads of two youths with a black band resembling a serpent running from the forehead of one to that of the other and the head of an Ethiopian with a black beard. The beard is on top of the jaw bone of one of the white heads. The rest of the gem has the same color as a fingernail. Albertus has also described this same gem. The layers of onyx, no matter what their color, are usually translucent except the black and milky white layers which are opaque. Very often coats of arms are engraved on pieces of white German onyx and these are highly prized by the nobility since they are more transparent than any other onyx and harder than quartz although less transparent. In addition, these stones are backed with colors that tint the coat of arms with the proper colors. The German stones are sometimes used for the little spheres with which we calculate prices as well as for the hilts of swords, goblets and the small mortars in which they grind emery. They

[32] Chalcedony is a variety of cryptocrystalline quartz and onyx a variety of chalcedony with straight parallel banding. Some of the "onyx" mentioned here is banded calcite, the Egyptian alabaster of the ancients.

make drinking vessels from the onyx from Carmania which is called *murrhina*[33] as well as the feet for beds, seats and pillars just as if it were marble. These are made by rubbing two pieces of onyx together on a table until they are so hot they almost glow and cannot be held in the hand.

I shall now take up the gems that have a fiery glow or color. Gems which are especially fiery were called *ἀνθράκια* by the Greeks. Theophrastus called them *ἄνθρακας* and also *ἀνθρακίτιδας* because, when exposed to the sun's rays they appear to glow like burning coals. For the same reason these stones are called *carbunculus* in Latin.[34] Some of these stones which are not affected by fire certain Greek writers have called *ἀπύρωτος* (*ἀ*, not; *πῦρ*, fire). They are found in many places, in Spain near Olisipo; in Gaul near Massilia; in Germany along the Misena river above the fortified city of Hoestein where they are associated with *hyacinthus*; in Bohemia five miles from Litomerice in the fields along the road to Trebenice, also near Schelkowitz about three miles from this locality and in the fields of Lotedorf about ten miles from Most on the road to Mount St. Catherine. They are found also in Bohemia in a spring between the fortified city which is known by our name for a royal watchtower and the city of Plana. Other localities are Riseberg, Lygius; Thrace; Corinth and Troezen, Peloponnesus; Orchomenus, Arcadia; the island of Scio; the promontory of Orthosia and near the town of Miletus, Caria. They are also found in India, especially in the mountains of the fabulous island of Ceylon; at Thebes, Egypt; near the city of Syene near the island of Elephantina; in the interior of Ethiopia in the district of Pselcis; among the Garamantes and Nasamones.[35]

All *carbunculi* are red and brilliant but variations in this gem have given rise to several species. Stones that are especially red and brilliant but usually small are called *spinellus* (spinel). Stones with a pure bright red color and brilliancy but found in large sizes are called *rubinus* by the Italians, after the color, and *pyropus* by the Greeks and Ovid because they appear to be burning. These same names are given also to *carbunculi* with colors similar to the amethyst. The older Greek writers called these latter stones *amethystizon* although they are distinct from the amethyst. The latter stone has a purple tint that is mildly alluring while the *carbunculus* dazzles the eye. Some *carbunculi* have a lighter color and luster and these the younger writers have called *ballagius* because of the color and the older writers *candidus* because of the luster.[36] The luster of the *carbunculi* of the second species approaches the rose-like luster peculiar to the amethyst

[33] Some of these vessels were exceptionally beautiful and commanded very high prices.

[34] The Greek names are derived from the word *ἄνθραξ*, coal; the Latin from *carbo*, a little coal.

[35] Tribes of interior and northern Africa.

[36] The derivation of the name *ballagius* or balas is uncertain. Some believe the name to come from Ballaheia, a mountain in India mentioned by Marco Polo as being the source of the balas-spinel; King believes that the name may come from

and the color of the stones of the third species approaches the color of this same gem. The stones the younger writers call *granatus* and the older writers *carchedonius* have a darker appearance, especially those found among the Garamantes and Nasamones and in Syrtis Major and brought to Carthage for sale. Another and darker variety is that called *almandinus* and at times *alabandicus*, the former a corruption of the name Alabanda because these stones were polished at one time in the city of Alabanda although they came from a cliff in Orthosia. Some of these gems are part white, part red and with white spots scattered through the red. The older writers called these *troezenius*, the younger writers *amandinus*.[37]

The first and second species come from India and Misena; the third from Egypt; the fourth from Ethiopia, Bohemia, Lygius, Syrtis Major, and from among the Nasamones and Garamantes; the fifth from Caria, Thrace, Chios and Arcadia, the darkest ones coming from Chios; the sixth from Troezen and Corinth, the lightest ones coming from Troezen. I believe that different species of *carbunculus* can be found in one and the same region.

These gems differ in brilliancy just as they differ in color. The *amethystizon* and *spinellus* have a bright, clear, flaming red luster; the *candidus* a more liquid luster; the *carchedonius* and *alabandicus* a darker luster. Several of these have a tinge of blue such as those from India called *lithizon*. Even within a single species some stones are better colored than others and these are called masculine while the duller stones are called feminine. According to Satyrus the Ethiopian stones do not give off a clear light but rather glow like the wavering light of a fire. Stars glow within the masculine *carchedonius* while the feminine stones give off a brilliancy entirely outside themselves. This is true of the *alabandicus*. Thus these stones differ, one from the other, since the color of each species of *carbunculus* may be deeper or lighter and the brilliancy brighter or weaker.

The gems called *amethystizon* are the most highly prized today as in former times because the clear flame-red is superior to all others. However, if the *spinellus* were large they would compare favorably with the best but they are so small that they are usually classed among the least valuable. The *candidus* stone holds second place because the limpid luster is more pleasing than that of the darker stones. The *carchedonius* comes third because the flaming red color is not as dark as that of the *alabandicus*. The older writers placed *carchedonius* second since some of the gems of this species have a gleaming feather-like brilliancy such as those called *syrtites*, having been named for Syrtis Major where they are found.[38]

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the Phrygian name for a certain fiery stone, ballen; the seventh edition of Dana offers the possible derivation from Balakhsh, a district of Ceylon where the spinel is found. Bauer and Spencer state that the present district of Badakshan was known as Balascia in the time of Marco Polo and believe the name to be derived from this.

[37] This is probably a typographic error and should be *almandinus* (almandite).

[38] Agricola includes spinel and garnet under *carbunculus* and suprisingly enough

Glass can be dyed a red color which imitates that of the *carbunculus*. The same color can also be obtained by cementing two pieces of quartz together with a red dye between them which gives a flame color to the entire stone. If two pieces of hexagonal quartz are cemented together with red between them and the rays of the sun allowed to fall upon this doublet in a shaded place it will throw red tones upon an adjacent wall. The outermost zone of these tones is often blue however, having been retained from the rainbow which can be produced with any hexagonal quartz crystal. Brilliant metal foil is placed under *carbunculi* in order to give them a bright flaming color. The *carbunculus* has fewer flaws than any other gem. *Alabandicus* sometimes contains scales and some of the Indian gems are dirty. As a rule *carbunculi* are small although some of the Indian stones are so large that goblets can be made from them that will hold a little less than a pint. Pliny writes that he collected drinking goblets made from the Egyptian stones. Theophrastus writes that the Arcadian stones were so large that window panes could be made from them.

The form of the *carbunculus*, as well as that of other gems, varies. The stones from Miletus, Caria, are hexagonal according to Theophrastus. As a rule they do not melt in a fire and this is especially true of the *carchedonii* and the Thracian stones that have the same hardness as diamond.[39] Archelaus writes that the *carchedonius* found by the Garamantes and Nasamones when engraved, no matter how dark the stone may be, will melt wax.

Lychnites and *lychnis* have a glow similar to the flame of an oil lamp whence their names (λύχνος, a lamp). This gem is found in the cliffs of Pallene, a peninsula of Thrace; near the cliffs of Orthosia and in all parts of Caria and neighboring regions and in India. The Indian stones are the best. Pliny, as well as others, regarded them as pale *carbunculi*.[40]

Sandastros is another stone that glows with a reddish gold color. Some call this gem *garamantites* because it is found in the country of the Garamantes in Ethiopia. The gem dealers call it *hyacinthus*, not having followed the writers. Pliny says that it is found in India at a place with the same name. The younger writers say that it comes from the mountains of Ceylon where it is found with the *carbunculus*. The stones found in southern Arabia are quite dark as though full of smoke. Within the body of *sandastros* and not on the surface golden points are seen to shine like the stars in the heavens, using the words of Pliny. The more golden points there are the more valuable the gem. Since this gem has the same number

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does not include ruby. His *ballagius*, *candidus* and *spinellus* are spinel; *alabandicus*, *syrtites* and *troezenius*, almandine; *granatus* and *carchedonius*, pyrope; *amethystizon* and *lithizon*, rhodolite.

[39] The references to resistance to fire must refer to the spinel and possibly to the ruby, not to the garnet.

[40] This passage probably refers to the ruby although the description is inadequate.

of stars set in almost the same position as the stars of the Hyades,[41] according to Pliny, it was used in Chaldean ceremonies. These points are not as conspicuous when the gem is examined in the sunlight as when it is set in a ring. The more brilliant gems are called masculine, the less brilliant, feminine. Like the *carchedonius* species of *carbunculus* this gem is not injured in a fire.[42]

The *chrysolithus* which the gem dealers today call *hyacinthus* differs from *sandastros* in the number of golden points it contains. The latter has only a few, the former a large number. It is found in Spain, Pontus, Bactria, India, Arabia and Ethiopia. The color of the stone may be golden yellow, hence the name, reddish yellow or similar in color to the *carchedonius carbunculus* which they call *granatus* but with a golden luster. Some of the stones have a color similar to amber and are called *chryselectros*. When the finest stones are placed next to gold they become whitened and have a silvery appearance. The less valuable and worthless stones have a variable color due to white and black spots. The stones that appear to have smoke through them are called *capniae* by the Greeks; those with a honey-yellow color, *melichrysos* because, according to Pliny, they have the appearance of gold shining through clear honey.[43] When a stone has a white band through it they called it *leucochrysos*. The stones that are full of scales, hairs or are not clear have a luster similar to saffron-yellow glass. Only the transparent stones are placed in open settings while those containing a cloud of spots that spoil the brilliancy are set in rings. Formerly gem setters were in the habit of placing brass foil on the back of these stones but now they use foil with a color which almost matches that of the stone. Pliny writes that the first quality stones come from India, the second quality from Bactria if they are not variegated while those from Arabia are the poorest. Some are hard, some soft. The *melichrysos* from India is very fragile. The Pontician stones are very light. Bocchus writes that he had seen Spanish stones weighing twelve pounds. I myself have seen masses taken from our own mines that weighed more than sixty pounds. These stones have a rectangular shape, especially those stones about one inch wide and two inches long. They are all so soft that they cannot be polished.[44]

Craterites is very hard with a color between *chrysolithus* and amber.[45]

[41] A group of seven stars in the constellation Taurus.

[42] There is obvious confusion in this description. The reddish yellow color, dark smoky appearance and infusibility indicate that it is garnet or sapphire with solid mineral inclusions or aventurine quartz. The "infusible garnets" mentioned by Agricola and older writers were probably our corundum.

[43] This is an excellent description of a stone backed with foil.

[44] From this description one could identify a number of minerals with *chrysolithus*, topaz, barite, smithsonite, etc. Undoubtedly many of the descriptions by older writers referred primarily to the topaz. Agricola undoubtedly saw crystals of topaz but since this mineral is uncommonly hard one can only speculate as to the identity of the soft mineral. It may have been barite, fluorite, etc.

[45] Probably the golden yellow sapphire.

Hormesion has the shape of an eye, a golden luster and, as Pliny states, a white line around the edge. *Syrtites* has a honey-yellow to saffron color and contains pale stars within the body of the stone. It is found on the shores of Syrtis and Lucania. But this is enough concerning the gems that glow.

Morion is black and transparent. It is found in Misena, the lower Alps, Cyprus, Tyre, Galatia and India. It may be very black and is then called *pramnion* or it may have some other color mixed with the black. When the red of the *carbunculus* is mixed with it, it is called *alexandrinus* because these stones are carried to Alexandria. When mixed with the color of sard it is called *cyprius* since it is usually found on Cyprus. When mixed with the color of *hyacinthus* it is called *misenus* since it is mined at Volchenstein, Misena. *Morion* is seen to occur in the lower portion of these stones and to be formed from a denser essence which has settled to the bottom. However the variety I have described as *pramnion* has been found in this vicinity with the bottom portion quartz and only the end very black. This also has the hexagonal form of quartz, especially that found at Volchenstein with *hyacinthus* in the end. This gem is engraved the same as quartz.[46]

Cepionides is transparent, sometimes glassy, sometimes crystalline, sometimes similar to green *jaspis*. They are found at Atarnea, in Aeolis. Pliny writes that when full of inclusions these stones are so splendent they will reflect an image the same as a mirror. This concludes the transparent gems.

I shall now take up those gems with such variations in color that different species are seen to be included under a single name. Among these gems is *jaspis*. This may be as green as the emerald, for example, the abundant dark green material found in Noricum, Thrace and India. It may have an oily bluish gray color similar to that obtained by mixing green pigment in milk. This variety is found in the district of the Lygii near the town of Striga and on the island of Cyprus. Some has a pale green color similar to *callais* and this, according to Dioscorides, is called *terebinthizusa*. Pliny also uses this same inappropriate name. Sometimes it is as blue as the clear sky such as that found in Cappadocia near the Terma river. Sometimes it resembles the autumnal sky early in the morning, a color that is obtained when mixing blue in milk and for that reason it has been called *ἀερίζουσα* by some of the older writers, *borea* by others and *turcica* by the younger writers. This variety is found around the Caspian Sea, especially around Lake Neusis in Spain, at Hircanus and in the mountains near the town of Crerma. It is found in Scythia beyond Imau in the district called Cuniclus. Very rarely it is the color of the stones from the Strigian district or purple as is the Phrygian material. Equally rare are the rose-colored stones which appear to have been tinted with flowers. These are obtained from the deepest caves of Mt. Ida. Other rare colors

[46] Agricola identifies *morion* with the modern smoky quartz or cairngorm. Today the name morion is given to the nearly black variety. Here *hyacinthus* is identified with amethyst.

are the blackish purple stones from Cappadocia, the blackish red from the mountains near Sala, Misena, the liver-brown and sard-red. Rarely is it crystalline and similar in color to phlegm. All of these rare colored stones are brought from Misena to the village situated between Chemnitz and Glauca, a town we call Langovicius from the Latin *longa alba*. Stones similar in color to *smaragdus* with a single white line through them are called *grammatias* by the Greeks and with more than one white line the stone is called *polygrammos* as well as *assyria* after that country. Those stones with a rich liver color usually have circular color bands of a lighter or black color. Certain snow-white gems contain red points as though set with stars. Some stones contain onyx or *jasponyx* (jasponyx). These may be half onyx and half jasper and are found near Mittelbach between Chemnitz and Langovicius. We have even seen jasper with one part purple and opaque, the other green and transparent. Some appears to be filled with smoke and this is called *capnias*, some encloses a cloud, some is turbid and variable such as the Chalcidian and some of the Misenian stones. It contains such imperfections as "salt," hairs, etc. Jasper has a notable brilliancy, very often is not transparent and in this respect differs from the transparent gems it may resemble. For example, green jasper differs from *smaragdus* in transparency although Pliny says that this jasper is often translucent. In this same respect the pale green differs from transparent *callais;* the purple from amethyst and *hyacinthus;* the blue from sapphire; the sard-red from sard; and the crystalline stones resembling phlegm, from quartz. Although these varieties of jasper sometimes have small transparent areas they are very rarely entirely transparent. When they are entirely transparent they are far more desirable than any of the gems they resemble. The older writers give first place to the purple stones of any shade, second to the rose-colored, third to the emerald-green and fourth to the jasper. Today, without question, first place is given to the variety of jasper called *borea*, second to the green *polygrammos*, third to stones of any shade of purple, fourth to rose-colored stones and fifth to emerald-green stones, either the pure green stones or those with white lines crossing them. The other stones are of no great value.

Jasper is either rounded like an eye, for example *borea* which is an oily bluish gray, or it is without form such as that found near Langovicius from which they make the small balls we use to calculate prices and the fine pebbles used to put out fires. Such large masses are found that Pliny was not astonished to have seen a piece weighing eleven ounces from which had been carved an image of Nero with a breastplate. Jasper is usually found here in a siliceous rock with a blue color nine feet thick followed by a dark sandstone about twelve feet thick that carries no jasper. *Molochites* does not differ greatly from green jasper. The name comes from *malva*[47] which has leaves of the same color. The deep green varieties are not transparent and are best adapted to relief engraving.

[47] A genus of plants commonly known as mallow.

We shall take up *achates* (agate) next. The name is derived from a river of the same name in Sicily[48] where the mineral was first found. It not only varies in color but also in the images of things seen in it, images which are not the result of artificial treatment but have been formed within the stone by nature. Sometimes veins and spots are scattered through a stone in such a manner that they represent a wood-pigeon and are called *phassachates* by the Greeks. Stones that show a horn are called *cerachates*.[49] These stones may show one, two or more trees and sometimes they seem to contain an entire forest and hence are called *dendrachates* (dendritic agate). This is the variety that Camillus, the Pisaurian,[50] describes when he writes that it appears to be a plain with seven trees. Some portray rivers, chariots and horses. They do not contain as many images of birds as of beasts of burden and men. In the agate belonging to Pyrrhus, king of Epirus, there appeared the nine Muses together with Apollo holding a cithara, a gem not produced by art but created by nature. According to Pliny spots were scattered here and there through the stone in such a manner that each Muse stood out individually. This particular agate came from India.[51]

Agate is either black, dark blue, gray, coral-red, the color of the pelt of a hyena, lion, panther or the color of the flowers that grow in the fields. The Greeks call the stones that are the color of a lion pelt *leontios* or *leontodora* and that of the panther, *pardalios*. Stones of these colors, especially the first-named color, often have white veins running through them and are called *leucachates*, those with blood-red veins, *haemachates* and those with sard-red veins, *sardachates*. The coral-red agate is called *corallachates*. Agates with golden points similar to lapis-lazuli are found most abundantly on the island of Crete where they are regarded as sacred, according to Pliny; in India and at Syene. The stones that are the color of field flowers are found in Thrace; Thessaly near Oeta; on Mt. Parnassus, Greece; at Achia, Messenia; on Lesbos and Rhodes. The other agates are found in Sicily, Cyprus, Phrygia, Persia and at Thebes, Egypt. Pliny writes that the stones from Cyprus have the same transparency as glass. The Egyptian stones lack the red and white veins. Dionysius Afer writes that the Persian streams carry agates down to the banks of the Choaspes river after they have been removed from rock by torrents. These Persian

[48] This river is now known as the Drillo river.

[49] Today this name, ceragate, is given to yellow or wax-colored agate or chalcedony.

[50] This is the sole reference to the popular lapidary *Speculum Lapidum* (The Mirror of Stones) by Camillus Leonardus Pisaurensis. This most interesting and valuable work was first published in Venice in 1502, in Latin, and later editions in other languages appeared for over 250 years. Since Agricola makes no reference to the many and popular lapidaries written in the Middle Ages and earlier we may conclude that he gave little credulence to the marvellous virtues and properties their authors ascribed to gems and stones.

[51] This is an excellent description of the mocha-stone or dendritic agate which presents an endless variety of markings resembling profiles, plants and trees.

stones are large and often have a cylindrical form. The Sicilian, Cretian, Indian and Egyptian stones are a remedy for the sting of spiders and scorpions. The Phrygian stones have no such power. Physicians make a variety of touchstone from the Indian agates. These are used in examining the eyes and when placed in the mouth will allay thirst.

Although similar to agate *ostracias altera* is harder unless, as Pliny states, agate becomes more unctuous when polished. This gem is transparent with a color that is green mixed with black. Fragments of it are sometimes used to engrave other gems.[52]

The gem that some call *thracia* from the place where it occurs and others *pontica* from a river of the same district I believe to be related to agate. These gems contain likenesses of mountains and valleys. They have red and dark lines running through them and are decorated with star-like drops of the same color. They may be green or pale green and are non-transparent. They are distinguished from heliotrope which has blood-red veins and from prase which has blood-red drops similar to stars. When they lack veins and drops they are distinguished from green translucent jasper by their lighter green color.

Cepites is white, according to Pliny, with knots joined together in such a fashion as to give the appearance of veins. It reflects a dazzling white image. Just as agates and *ponticae* contain images of various objects, the gem the older writers call "the eye of Bel" portrays an eye. The name is derived from Bel, a god of the Assyrians who was usually portrayed as an eye. The younger writers call this stone *beli oculus*, a corruption. They call the gem by this name because it is beautiful and has a certain similarity to the eye. According to Pliny it is white with a black pupil and in the center there is a golden tint.[53] *Lycophthalmos*, although it is brownish or blood-red, also has the appearance of a round white eye with a dark pupil but lacks the golden tint. This name comes from the gem's resemblance to the eye of a wolf. *Aegophthalmos* resembles the eye of a goat, *hyophthalmos*, the eye of a pig and *triophthalmos* is a name derived from three eyes of a man.

The stone the Greeks call *encardia* or *cardisca* has the appearance of a heart. The former is black, the latter green. A third variety is black but is surrounded with white. The stone *bucardia* derives its name from its resemblance to the heart of a beef just as *sarcites* derives its name from its resemblance to the heart of a fish. *Telicardios* is the color of the heart and is found in Persia. It takes its name from the word for a spot. *Nymph-arena* resembles the teeth of a hippopotamus and takes its name from a

[52] In *Interpretatio* the German equivalent for this mineral is given as "luxsaphir." Lux sapphire or leuco sapphire are modern equivalents of colorless sapphire. Prior to the Middle Ages this name was given to our sapphirine quartz and any form of pale blue to bluish gray cryptocrystalline quartz. Agricola appears to include both sapphire and chalcedony under this name.

[53] An eye-agate usually has a dark central portion surrounded by concentric white, or lighter rings and often bears a close resemblance to the eye.

city and people of Persia. Black *glossopetra* resembles the tongue and takes its name from this resemblance. The Germans call this stone "tongue of the water snake" (watter zungelien) which it does not resemble while it is similar to the tongue of the woodpecker. It is found in an aluminous earth at Luneburg, Saxony.[54]

White or light gray *astroites* gives off black rays resembling those from stars and is very abundant. It takes its name from this property. Our people call it by a name derived from victory (sigstein) because they believe that if it is worn, it will aid them to stand their ground and conquer the enemy. Usually it has the shape of an eye although in rare cases it is oblong. Having been placed in oil it sets itself in motion and not uncommonly it will turn in a circle.[55]

Chelonitis is so named because it resembles a tortoise and is hollow. The Germans have named it with a compound word derived from the words toad and stone because they believe that it forms in the head of this poisonous animal (krottenstein). Some of these stones are black, some dark blue and some are white in part. Some of the black stones are blood-red with white spots in the concave hollow, others are golden yellow. All are rounded in the form of an eye but not all are concave. All are of the same genus, rarely larger than a wolf's eye, commonly smaller.[56]

Veneris crines (sagenitic quartz) has a very black *fulgor* with red hair-like inclusions. Certain gems have a pleasing variety of colors, for example, *eupetalos*, with blue, flame, vermillion and apple-green; *orca*, with black, reddish yellow, green and white; and *nebrites*, with colors similar to those on the pelt of a deer. Because of the colors the latter stone is sacred to Bacchus.[57] A certain darker stone is of this same genus. *Hexacontalithos* takes its name from the multitude of colors found in it. *Panchros* is so named for the same reason and actually almost every color can be found in it. Some of these are similar to spheres of glass that vary greatly in color because of the contents. Some have characteristic veins with a different color than that of the rest of the body. Thus blood-red *nasamonites* has black veins and black *medea*, golden veins. Two white bands in a black groundmass is characteristic of *ophicardelus*. In a similar fashion a white band cuts across the black groundmass of the gem *veientana* found at Veii. The Germans have named a similar stone for lard because it has a more unctuous white color. A gem that is either black or gray with white lines is called *huia*.

The best material of this genus, especially that with broad white and

[54] These are all fossils or concretions. None would be considered a gem stone today.

[55] *Astroites* is massive coral, a stone that can be polished. The rays are the septa of the polyp.

[56] *Chelonitis* is a concretion and would not be classed as a gem stone today.

[57] It is difficult if not impossible to identify these three stones. They are probably varieties of quartz. It is difficult to understand why the last stone was sacred to Bacchus since he was more commonly associated with the panther.

sard-red bands has been most popular with relief engravers in our time. The snow-white bands of *leucopetalos* contrast well with the golden yellow color. A black and sard-red vein passes through *aegyptilla*. *Apsyctos* is so named because having been heated to redness in a fire it will hold the heat for seven days. *Horminodes* is so named, according to Pliny, because it is a white, black and sometimes pale colored gem with a green tint surrounded by a golden yellow band. Golden *acopis* is set with star-like points and is as pumiceous as *nitrum*. It is so called, if we are to believe Pliny, because when heated with oil and then used as an ointment it drives away weariness. Some of these stones contain spots, for example, *dionysias* which contains red spots.

Certain of these stones have mixed colors as I have mentioned. *Aphrodisiace* has reddish yellow mixed with white and *xanthos*, which the people of India call *hemus*, has white mixed with dark yellow. Some have the upper portion of one color, the lower portion of another, for example, *telirrhizos* which is either gray or reddish with a white base hence the name, in part.

Sometimes different species are given the same name, for example, the two species of *botryites* both of which have the form of grapes but one is black, the other the green shade of a young plant. There are two species of *balanites*, the one from Coptos being a light green, the other from the region of the Troglodytes being the red of Corinth copper. There are two species of *indica*, one light reddish, the other white. The former gives off a purple "sweat" when pulverized while the latter has a dusty appearance. There are three species of *batrachites*, the first the color of a frog from which it derives its name (*βάτραχος*, a frog), the second the color of ivory and the third a reddish black. Although the latter two species are not the color of a frog they are called *batrachites* because they are found in Coptos together with the first species. *Icterias*, regarded as an excellent cure for the Royal sickness, is named for a pale yellow bird and embraces four species. One is the color of the bird, another a lighter yellow, a third the color of the first broad green leaves and it is almost without weight and has green veins through it, while the fourth is the same green color but with black veins running down the stone. Pliny classifies *memnonia* as a gem but does not describe it.

Daphnia and *paneros* also belong here. Zoroaster shows that the former is a remedy for epilepsy, the latter, according to a poem of Timaeus quoted by Metrodorus, bestows fecundity and for that reason was deified by the queens of the Venetians.

This calls to mind the gems of the Magi.[58] *Zoronisios* comes from the Indus river and belongs to this group as well as *geniane* which has the power to punish an enemy. *Erotylos*, *mepicoros* and *hieromnemon* are all praised by Democritus in discussions of divination.[59] Democritus writes

[58] The Magi were an ancient priestly cast skilled in Oriental magic and astrology.

[59] It is suprising that Agricola does not include *amphicomos*, a third varietal name for *erotylos* mentioned by Democritus.

that *aspilates* is found in Arabia and has a flame-red color. Black *baroptes* is said to have an outer band of blood-red and white knots giving it a supernatural appearance. *Eumetris*, from Balk, is similar to flint and having been placed on the head produces nocturnal dreams resembling visions.[60] Although *zoronisios* is found along the Indus river and *eumetris* in Balk nevertheless *xistios* appears to be the gem of the lower classes of India. *Lesbia* which takes its name from Lesbos is another gem of the Magi that is also found in India. *Catopyrites* comes from Cappadocia. This is all Democritus writes concerning these gems.

Democritus writes that *mithrax* is popular with the Persians. It has the multicolored brilliance of the mountains of the Red Sea against the sun. He has described the color of certain other gems, for example, that of *cerites* which is similar to wax; *eurotias*, a blackness that is not evident when the stone is first found; *chrysophis*, golden yellow. He also describes the form of other gems, for example, *bolenia* which is found as lumps only during storms. Both the form and other qualities are mentioned in the descriptions of some stones since he writes that *orites* is an earthy species which is so-named because, like *siderites*, it is not affected by fire. Since Pliny does not write more than this concerning these same species it is evident that he had not seen them himself nor did he know what they were. Actually we cannot say whether the Magi named these stones or gems with appropriate names, descriptive of what they are, or if they too were as ignorant of these facts since both the Greeks and Latins are seen to have been as ignorant of them as are we.

Chloritis has the green color of emerald when transparent and that of *jaspis* when non-transparent, or the color of Persian, Median and similar *smaragdi*. This stone, according to the Magi, is found in the stomach of the Scylla bird.[61] They believed that since it contains iron this was an indication of its supernatural origin. *Sagda* is also green, prase-green when transparent, jasper-green when not. The Chaldean soothsayers believed that it adhered to the bottom of ships. It is impossible to discuss the other stones since the writers Democritus has followed give no descriptions of differences between these stones and the green gems. *Zmilaces*,[62] found in the Euphrates river, is similar to the blue-gray Proconnesian marble and is seen to consist of pieces of marble of that genus that have been carried along by the river. *Eusebes* is a similar stone and, it is related, a seat was made from it, for the Temple of Hercules in Tyre, from which a person would rise God-like. However Pliny does not say what kind of stone it is.

Stones that form in living bodies are placed among the gems. These stones are found in birds, fish and shell-fish. *Alectorius* takes its name from

[60] No mineral name has been spelled as many different ways as this one. The more proper form would be *eumitres*.

[61] The daughter of Nisus, king of Megara, was turned into the Scylla bird or sea-monster by Ciris for cutting off her father's hair upon which depended his happiness.

[62] Pliny calls this gem *zimilampis* and describes it as having a sea-green color.

a cock. This is a rare stone that is found in the craw and liver of cocks and capons, occurring most commonly in the liver. Recently one was found in a capon that measured one inch by three-quarters of an inch by one and one-half inches. The widest surface contained shallow hollows. The narrower upper portion protruded to the right, the left was flatter and darker and the rest of the stone was light grayish black. When these stones are found in the craw they are usually the shape of a lupine seed and about the same size or the size of a bean. They may be light gray or grayish black but not of intense colors. Sometimes a quartz-like species is found that is dark in color and may contain light red veinlets. Pliny writes that Milo of Crotona used these in contests in which he wished to appear as invincible. When highly polished the stones that resemble quartz can be placed between the eyeball and the lower eyelid and moved from one place to another without injury to the eye. This same thing can be done with other gems such as lapis-lazuli, onyx, etc. but only if the stones are small.[63]

Chelidonius takes its name from swallows since it is found in the craws of these birds. They have a symmetrical form and are always hollow and for this reason are quite fragile. They are usually light gray on top while the hollow convex portion is a dark purple, often with irregular spots. There are two species of this stone both of which are used in eye salves. They are hung about the necks of boys to cure epilepsy.[64]

Pliny writes that *hyenia* comes from the eye of a hyena and for that reason they are said to be found in hunting utensils. He certainly did not see one of these. *Chelonia* is the eye of an Indian tortoise. *Cinaedia* is a white, oblong stone found in the brain of a fish of the same name. Actually in our own small fish with large heads two small, flat, white, oblong stones are found with one part divided into small teeth. Likewise *synodontites* comes from the brain of the fish called "*synodus*." According to Pliny there is no such gem or fish. Two hemispherical stones are found in the head of the river crab which some people set in jewelry. These produce abundant urine when taken internally.[65]

Pearls (*unio*) are found in mollusks. When they are white, round, large, smooth and heavy, such as those sometimes found in India and Arabia, they command a higher price than any gem except the diamond. *Conchiliae* that are small, white and with a navel are sometimes set in jewelry.

[63] The *alectorius* or "cock-stone" was one of the most widely known animal concretions in ancient times. It was supposed to transfer the fighting qualities of the cock to one who held the stone in his mouth. The name embraces calcareous concretions and siliceous pebbles.

[64] A legendary stone that enjoyed wide popularity as a remedy in ancient and medieval times. In medieval times varieties of quartz were sold as this stone.

[65] No mention is made of several other mystical and fabulous stones that were well known in Medieval Europe, particularly bezoar and kenne. The bezoar stone was the subject of scientific investigations and learned papers until well into the eighteenth century.

Draconites or *dracontias* is said to come from the brain of a dragon. *Saurites* is reported to come from the stomach of a green lizard that is caught in traps. Even though the former may be artificial and the latter could be found I have never seen either one offered to us. Since I have said that *margaritas* (pearls) command a high price it occurs to me that I should say something regarding the relative value of the precious gems.

Diamond is the most valuable gem and is followed in turn by the Indian pearl, emerald, opal, ruby, jasper, lapis-lazuli, sapphire, *asterios* and chrysolite. Next comes *chrysolithus*, amethyst, *hyacinthus*, prase, agate, *beli oculus* and finally the other gems. However, a poor diamond will command a lower price than a fine ruby (*carbunculus*), a large chrysolite will sell for more than a small emerald and an agate that contains an exceptional image is more highly prized than an inferior opal. The inhabitants of the region in which a certain gem is found regard it as of little value since it is so common and yet these same people regard the gems that occur in other regions as having a great value since, to them, they are rare and unusual. As a rule, great and noble men attach great importance to the gems they possess. Gems are not only set in rings, brooches, necklaces and bracelets but they also embellish the crowns of nobility and even the statues of them, for example, the copper statue of Caesar of Saxony at Goslar. They may adorn the statues of saints as that of Saint Valerius of Goslar, They are set in the statues of famous men, for example, the one of Pega Vipertus of Misena. Anyone who wishes to study gems should examine these statues and the royal crowns whenever the opportunity arises. In the magnificent temple of St. Mark in Venice the tablet of the high altar is set with precious gems and since the temple is open daily one can examine it as well as the crown of Cyprus and other gems that are placed on display.

BOOK VII

In the previous book I spoke at length about gems. I will now consider marbles. The name comes from the fact that it has a fine luster when polished.[1] Marbles have been classified as gems and actually small polished pieces are sometimes set in rings. The gem *lysimachia* is cut from Rhodian marble; *arabica*, from Arabian marble; and *meroctes*, from *thyites*. These cut stones differ from marble however in color and markings and these features have given rise to a large number of species. True marbles are usually named from the place they are found, with a few exceptions such as Luculleum, Augustum, Tiberium, etc. Luculleum marble is named for L. Lucullus, Consul, who was the first to bring this particular marble to Rome from an island in the Nile. The latter two were named in deference to the importance of these two men. The former, found in Egypt, is an ophite with markings similar to a snake. The latter resembles Ethiopian *basaltes* with the color and hardness of iron.

I shall consider first the white marbles since these embrace the most famous varieties used by sculptors in statues, for example, Parian, Chian, Cretan, etc. The first comes from the island of Paros and was called *lapis lychnites* by the Greeks, according to Varro, because it was first mined and used for lamps. Pausanias writes that Phidias carved his statue of Nemesis at Rhamnus, Attica, from this stone. However the statue above the temple is of Parian marble and was sculptured by the sons of Anthermus. The magnificent and rich Laurentine temple in Picenum is built of a white marble in which various historical events have been cut. It contains a shrine built of rough stones. Part of the temple of Florence, at one time dedicated to Mars but now sacred to St. John the Baptist, is built of this same stone. A fountain with this same stone is found in the villa of Prince Fr. Maria of Urbinum, a mile from Pesaro. White marble is quarried in lower Rhetia some ten miles above Augusta Tiberius and this we call Reginoburgian marble; in Thasos dug up with ram's horn and discovered by Paxadorus; in Lesbos where the stone is a little darker than the Thasian; in Proconnesos, one of the Sporades Islands in the Marmora Sea from whence comes the highly prized Proconnesian marble. Lygdinian marble found in Arabia and on Mt. Taurus in Asia is another famous variety. Pliny calls the latter *lygdinus lapis* and writes that it is never obtained in pieces larger than platters and punch bowls. Some call it *lygdus* and use polished slabs of it in tables.

Lapis coraliticus is a white marble similar in color to ivory and so-called, as I believe, because it is found near the Coralius river in Phrygia. This is also known as the Sangarius river. The Arabian marble from Arabia is

[1] From the Greek μαρμαίρειν, to sparkle; Latin, *marmor*.

ivory-white and from it they cut the gem *arabica*. Pliny writes that this gem is the color of ivory and might be confused with it if it were not for the hardness.[2]

Chernites, from which they made the sepulcher of Darius according to Theophrastus, is said to be white marble. It is found in small quantities in Cappadocia on the border of Galatia and is commonly used to make the hilts of swords. It is found in Hildesheim and in the Harz forest near Elbingerode and near the village of Bentechestein as well as in neighboring places. Some is found in the silver mines of Misena. The Asiatic material is found in even smaller masses than the German since Pliny writes that it is never larger than three feet across. Some of the German material has hardened into stalactites that are often translucent and with a fine luster even though they have not been polished. This mineral often contains many wavy lines that resemble smoke, especially that found in Cappadocia and Phrygia which is considered the finest. According to Pliny they cut gems from this and if it is similar to ivory but suffused with smoke it is called *capnites*. So much concerning white marble.

I now come to gray and black marbles. A whitish gray stone is quarried in Hildesheim beyond Mt. Saint Mark with a luster similar to *lapis judaicus* on freshly broken surfaces. The Saxons use this stone to surface roads. A varicolored marble is found on a hill in this same region, particularly at the foot of the hill, not far from the Indersta river. The bulk of this rock is gray to dark colored. This occurs in thin beds whose surfaces are usually full of holes. In the same district a black marble containing narrow white veins is found on the left side of the entrance to a cave named for dwarfs. The Saxons do not use the ordinary marble found on each side of this. Taenarian marble is black and comes from Taenarus, a promontory of Laconia. Part of the temple of Florentia, mentioned above, is built of this marble. Lucullean marble is a dull black and came from an island in the Nile, according to Pliny, from whence it was taken to Rome. Two columns forty feet high were made from it and placed in the open court of the home of Scaurus. The Lydian marble is also a dull black.[3] Two enormous lions that stand on the steps of the Capitol in Rome are sculptured from this stone as well as a head of Cybele in the house of an attendant of Magdalona in Naples. Recently a sepulchre for Caelius of Rome was cut from this rock and placed in the Church of the Sacred Cross.

Some marble is iron-gray, for example, the *basaltes* from Egypt that is found in Ethiopia.[4] A similar marble from Misena is not inferior to *basaltes* either in color which is a deep iron-gray, or in hardness since iron workers use it as an anvil. The castle of the governor of Misena at Stolpa

[2] Marble has a hardness of 3 in the Mohr scale, ivory, approximately 5.

[3] It is possible that Agricola is describing an igneous rock and not a marble.

[4] Both igneous and sedimentary rocks are included here.

is built of this stone and has square pillars. But this is enough concerning gray and black marbles and *basaltes.*

Marbles from Crocea, Lacedaemon, and Mt. Taygetus are green. The Pulpit of the cathedral of St. Lawrence in Rome outside the Esquiline Gate and the temple in Florence dedicated to St. John the Baptist are built, in part, from this or some similar stone. The latter temple is built of white, black and green marbles.

Porphyrites is a red marble found in Egypt. When there are white spots in the stone it is called *leucostictos.* This stone has been used in many places, e.g., in Constantinople in the large columns of the very famous Temple of Wisdom called Σοφίας by the Greeks because it was built by Justinian; in many columns near St. Mark's, Venice; in the beautiful columns near the Temple of Apollo in Ravenna; in the columns of the shrine of St. John the Baptist in Florence as well as in those outside the largest bronze, gold-covered gate. Three columns were made from it by the Pisans and sent to Florence in gratitude for a victory over the Tyrians. While the people of Pisa had been carrying on a campaign against the Lucans their city had been defended by the people of Florence. Some of the large urns in Rome are made from *porphyrites,* one in the Temple of St. Bartholomew on an island is used as a receptacle for the remains of saints. The very large and beautiful top of the latter is made of white marble. There is another urn in the Temple of the Sacred Cross in Jerusalem which also has a cover but is not as large as the one mentioned above. There is a second urn in Jerusalem in the Shrine of Saints John and Paul with the cover surrounded by a protection that is so highly polished it reflects an image like a mirror. There is an enormous sepulcher made from this stone in the Temple of St. Constance on the Numentana Way, a temple formerly dedicated to Bacchus. Three boys are shown on the side of this sepulcher crushing grapes with their feet. The boys are winged and nude and the oldest has an amulet about his neck. The two others hold staffs in their hands. There are other boys beside these three, some carrying grapes, others carrying them accompanied by butterflies and a shaggy ram. The rostrum of the very holy temple of St. Mark in Venice and a part of the rostrum of the shrine of St. Lawrence in Rome outside the Esquiline Gate are made from this marble. A portion of the latter, as I have mentioned above, is made of green marble with hieroglyphics cut in the base.[5]

Some marble is reddish such as that found on the left of the entrance to the cave in Hildesheim named for dwarfs. So much concerning marbles of a single color.

I shall now take up those marbles that are spotted or that have more

[5] The Egyptian *porphyrites* is a syenite porphyry and not a marble. The name is derived from the Greek word meaning purple. The use of the term broadened until it became meaningless. Currently the name has been redefined to describe an igneous rock texture characteristic of the original Egyptian rock.

than one color. I shall start with the white marbles. Some are white permeated with gray spots. In Rome the columns near the altar in the Temple of St. Bartholomew, at one time sacred to Jove, which is on an island, are of this type of material. Some white marbles are discolored with gray spots such as that found in the mountains between Northusa, Thuringia, and the town of Elderica. This rock is similar to *alabastrites*. In the Temple of Wisdom in Constantinople there are two bas-reliefs cut from white marble with the gray areas so distributed by nature that the image of St. John the Baptist appears to be covered with a camel's hide. The other shows Turks with Christians.

When a block of stone was broken free with wedges in the marble quarries at Paria, it was found to contain the image of Silenus[6] while in the Chian quarries the likeness of the head of Pan has been observed upon a fracture surface. It is difficult to understand how these have been produced. There is a gray marble in the Temple of St. Vitalis in Ravenna in which Nature has portrayed the image of a Franciscan monk. This is one of the famous vari-colored marbles from the Palace of Senator Pintius that stood on the magnificent hill of Gardena in Rome. This was brought to Ravenna by Theodoricus, King of the Ostrogoths, according to the letters of Cassiodorus.

Some marble is white with veins of different colors, for example, that from Noricum which we call Salburgian marble. Another has dark yellow veins through it and since it is in great part translucent is called *lapis phengites*. According to Pliny this was used by Nero to build the gambling house that was called Sejes since it was dedicated to King Servius. This house was famous for its golden cupola and lighting. During the day, light was let into the building through concealed openings that made it as light as if windows had been used and yet the source of light appeared to have been within it. There is a vase of the type known as buccal in the house of Tiberius in Naples made from this stone. Large pellucid pieces of *lapis phengites* have been found in Cappadocia near Galatia.

Some marbles are gray with a slightly bluish tint and with white and black spots. One variety, quarried in Misena near the town of Rochlitz, is as lustrous as silver. Another variety which comes from Numidia is gray with yellow spots. Two basins in front of the Pantheon in Rome are said to be made from this variety as well as the twenty foot column erected to C. Ceasar by Antonius and torn down by Dolobella. There are three other basins of the same shape and almost the same size in front of the Pantheon that were cut from a stone similar to the Numidian marble. One stands before a shrine of St. Mark at the end of a wide road, another seventeen feet long, seven feet wide and five feet high before a shrine of St. Peter in chains, and the third before a shrine of St. Salvatori of the Laurel near the hill now called Jordan.

[6] Silenus was the tutor of Bacchus who is always portrayed with a bald head, riding on an ass and drunk.

Some marbles contain black veins streaked with white resembling certain dark streams. The columns in the shrine of St. Michael in Hildesheim are cut from this variety. Other marbles contain characteristic white but very thin veins. A red variety is found in Hildesheim with the upper portion of the stone black.

Marble may contain distinctive white spots such as that in the famous columns in the shrine of St. Sabina and the shrine of St. Saba on Mt. Aventine, Rome. Some are a very dark green with numerous pale green spots. This variety is found in thin beds in Rome. A tablet of green marble with the appearance of wood is found in a monastery between Venice and Murano where it has been placed in the wall near the high altar.

As stated above, *porphyrites* is called *leucostictos* when it contains small white spots. A vessel in Hildesheim of the oval shape commonly known as a Canaanian urn is cut from this variety and, having been inlaid with silver, hangs in the shrine of St. Michael. Some of the columns mentioned above are cut, in part, from this material.

Certain marbles are reddish brown with numerous spots of a lighter color.

Ophites is a mottled stone with three varieties. One is white, the second black and the third gray. The Greeks call the latter *tephrias* because of its color. Augustian and Tiberian marbles differ from *ophites* in that the former are mottled like a serpent while the latter, to use the words of Pliny, has the spots of color arranged in a different pattern. The mottling in Augustian marble is in lines resembling the crests of waves, in the Tiberian stone, in scattered grayish white whorls. The two columns at the shrine of St. Lawrence in Lucina on the Plain of Mars near the Tiber river are of *ophites*.

A light gray marble with very narrow interrupted black veinlets and numerous minute white spots is quarried in Misena not far from the castle of Lauterstein near the village of Zeblich. The marble we call *serpentaria* may contain spots or numerous broad black veins. The rostrum of the cathedral of the Holy Spirit in Hildesheim is of this material while the columns have a reddish black color with curly undulations.

Chian marble contains varicolored spots, Rhodan marble golden-yellow veins, both being found on the islands from which they take their names. Theban marble is black with golden spots while *syenites* has reddish spots.[7] Because of the reddish spots the latter is also called *pyrrhopoecilos*. Both *pyrrhopoecilos* and *syenites* are found at Thebes, Egypt, between Phila and Syene, whence comes the latter name. Other varigated marbles are Carystan from Carystus, Euboea; Deucalan from Deucalion, Phthia; Scyran from the island of Scyros; Hierapolan from Hierapolis, Phrygia; and a marble found in Phrygia at Docimium near Synnada that the Romans called Synnadic, *lapis phryges*, Docimites, and Docimian marble. The latter has a variable color similar to *lapis alabastrites*.

[7] *Syenites* was a hornblende granite with reddish feldspar.

Lapis alabastrites (onyx marble) comes from the town of Alabastros in either Phrygia or Thebes, whence the name. It is called *onyx* because of its similarity to gem onyx. It is found in Cappadocia, Syria, Carminia and India. The finest comes from Carminia, according to Pliny, the second quality from India. A whiter variety comes from Damascus, Syria, and the least valuable, which is without luster, from Cappadocia. The non-tranlucent honey-yellow variety with whorls or specks is considered the finest. Imperfections are either horn-yellow, white or glassy. There are two large columns in Rome in the chapel of St. Agnes on the Numentana Way beyond Viminalis, two small columns before a shrine near the bath house of Constantine near St. John Lateran, and the columns in the Temple of St. Mark in Venice cut from this stone. The material from Carminia is similar to this. Material of gem quality occurs in masses the size of deposits of marble since Cornelius Nepos relates that he had seen columns thirty-one feet long made from it. Cornelius Balbus, after being freed by Claudius, placed four small columns in his theater and Callistus had thirty amphoras in his dining hall cut from this marble. Today the high altar of St. Peter's in Rome has six onyx marble columns placed to the right and left and four other columns in different places in the altar.

Some *jaspis* is found in similarly large pieces, pieces of such size that large basins can be cut from them, for example, the basin which is said to stand in the arcade near St. Mary's, Ravenna. It is similar in color to the jasper we mine in Misena. *Smaragdus* is sometimes found in large pieces if, as Theophrastus writes, one can place faith in the commentaries written about the Egyptian kings. It is written that a piece of *smaragdus* was sent as a present to their king by a king of Babylon which was six feet long, four and one-half feet wide. It is also written that four pieces were placed in the obelisk of Jove that had a total length of sixty feet and were six feet wide in one place, three feet wide in another. Theophrastus writes that the largest *smaragdus* has been seen by many people in Tyre where there was a very large column in the temple of Hercules. Herodotus also mentions this column but Theophrastus has doubts concerning this and did not know if it were true *smaragdus* or not. Pliny writes that Apion Plistonices has left a manuscript written a little before this in which he mentions a colossal Serapis thirteen and one-half feet high in the Egyptian labyrinth cut from *smaragdus*. Juba writes that the *smaragdus* they called *cholas* was used to decorate buildings in Arabia. There may be some doubt as to the truth of this statement since Juba has also written that a statue six feet high of the wife of Ptolemaeus Philadelphus was cut from a *topazius* from the island of Arsinoe.[8]

Thus we see, on one hand, marble cut into small pieces and made into gems that are set in rings and on the other hand, gems that occur in large masses substituted for marble. So much concerning the size of these gem materials.

[8] The name *smaragdus* is here given to various altered igneous rocks, principally serpentine.

Lunense marble is variegated and, according to Strabo, passes to a bluish gray color. Some marbles have not been described properly by the writers who mention them, for example, Spanish marble; Traguran from near Tragurium, Liburnus or Croatia; Hymettan from Mt. Hymettus, Attica; Pentellican also from Mr. Hymettus, Attica; and Cyzicene from the island of Elaphonnesus near Cyzicus. So much concerning the color and markings of marbles.

I shall now take up the varieties of marbles which have been brought to the cities. The Romans not only carried away marbles from the quarries of Greece, Asia, Egypt and other regions but also robbed the temples and holy places in these regions of their statues and columns.

I shall now discuss some of the other qualities of marbles. There is one in Hildesheim that, as I have said, is gray or somewhat darker. When rubbed against another stone or even against another piece of the same stone it has a strong odor of burnt horn. In this same locality there is a black to reddish variety with distinctive white veins that has an even stronger odor. Some marble is hard such as the black *ophites*, some soft such as the white *ophites* and the Zeblican marble from Misena. The surface of some of the Hildesheim stones is very porous. The Rochlican material is often rough even after polishing.

Concerning the form of marbles they are rarely found in the small lumps that are characteristic of the material from a town called Crocea. They sometimes occur in such large masses that the longest pillars which the Greeks call *στήλας* can be cut from them as well as the very wide slabs or blocks they call *πλάκος*. Actually marble is commonly found in slabs that are wider than they are thick and these the Greeks call *πλαταμών*. These are found in Rhodes; in Rhetia where it is known as Reginobergan marble; and in Saxony near Hildesheim where the various gray and black marbles I have mentioned are found. The latter are rarely more than two inches thick. Nature also produces columns which may be rounded such as the *syenites* that are found along the road between Syene and Phila, Thebes. Some natural columns are angular such as the *basaltes* in Misena which was used, as I have mentioned before, to build the castle of Stolpa where the governor of Misena lives. All angular columns are not alike but have a minimum of four corners and a maximum of seven. These columns usually occur tightly packed together. Those from Thebes may occur as single columns. Sometimes one occurs on another, even a small one on a larger one. The largest ones from Misena are one and one-half feet thick and fourteen feet long while those from Thebes may be as much as twelve feet thick and over one hundred feet long. We know this to be true because of the size of the obelisks erected by the kings of Egypt. Near these columnar stones they find the spherical stones from which they make the mortars and pestles used in preparing eye salves.

Artisans make many other objects from marble. The older workers used the white *ophites* for vases and jugs. The Zeblican marble is used

today in Germany for making spoons and goblets since it is supposed to reveal the presence of poison, and the small balls the women use in drying the linen shawls they wear over their heads. It is also used to make the tabular and curved stones with which we warm ourselves in winter, especially those usually placed in beds.[9] Tabular stones are used to warm the chest and stomach and arched stones for the side, feet and arms. From early periods to the present, artisans have made the ointment jars they call *alabastra* from alabaster and Lygdinan marble. Statues, columns, obelisks, sepulchers, altars, chapels, shrines and temples are made from all varieties of marble. Basins are cut from large thick blocks and gaming boards and table tops from thin tabular pieces. Rough brick and stone walls are sometimes covered with thin tabular pieces. This type of work is especially common in Sena where the walls of the temple of the Blessed Virgin are faced with marble both inside and outside as well as the altar floor, the basin for holy water, the floor of the temple, the high altar, the candelabrum and the tower. There are seven varieties of marble on the top of the altar, white, black, green, gray, light brownish red and two mottled varieties. There are marble images of all the Roman priests in the vault of the temple. A most magnificent temple in Florence has marble facings as do the rectangular towers of St. Mark's in Venice and the Temple of Wisdom in Constantinople. The walls of the home of Augustus Tiberius were also faced with marble. Tiles are made from this material and used in floors, for example, the floor in the living quarters of the house used by Caesar in Goslar, Saxony, as well as in the three temples mentioned above. The consecrated portion of the cathedral of Pisa where they have the burial vaults at the Shrine of St. John is paved with these tiles. Marble surpasses all other stones for use in *lithostroton* (mosaic pavement). A particularly fine example is found in the Temple of St. Agapetus in Preneste. This work, done by Sulla, consists of very small pieces put together in such a manner as to depict the exploits of Sulla. There is another mosaic pavement in the shrine of St. John the Baptist which portrays the dome of heaven with twelve images and in the center the sun, shown as a charioteer. They also make mosaics which picture animals and events by fitting together polished chips of marbles of different colors. Heliogabalus paved streets on Palatine Hill with Laconian marble and *porphyrites*, covering the walls of the houses as well. Some of the finest inlay work was done in the time of Nero, according to Pliny, when spots were produced in the marbles by inserting small pieces to relieve the monotony of color and produce an effect similar to the spots in Numidian and the purple in Synnadan marbles. Since there is not a sufficient quantity of naturally tabular pieces found in quarries they must be made by cutting irregular masses. Pliny writes that they were cut with sand and we see them cut with iron. The saw is a very thin wire that picks up sand and when this is

[9] This refers probably to a variety of soapstone.

moved back and forth it cuts the stone. The sand must be soft and fine, not coarse and hard. The finer sand cuts the stone into thinner pieces while coarser sand is used for coarser work. The former makes a thinner cut and cuts away less marble and produces a surface that is easier to polish. Soft sand produces a smoother surface. The finest and softest sand came, at one time, from Ethiopia and from a shallow inlet of the Adriatic which has dried up recently because of the summer sun. Hard sands come from India, Naxos, and near Keft, Egypt. Coarse sand is abundant in rivers.

Marble is polished with sand and flint. At one time a sand from Thebes and finely ground pumice was used. Today *tofus* and sandstone are used. The flint formerly came from Naxos or Armenia but today any hard material is used in its place, usually either very hard marble or rock.

Certain marbles are used in medicine. *Lapis arabicus*, having been pulverized and mixed with flax down will stop bleeding when placed on hemorrhoids. A dentifrice is made from burnt marble. *Alabastrites*, having been burnt and mixed with either pitch or resin will soften hard swellings and when dissolved in wax will relieve pains in the stomach. When unadulterated it shrinks the gums. Mixed with rock salt it destroys unpleasant odors of the mouth and teeth.

Pieces of marble found in gold, silver, and other veins are dense and have a natural luster equal to that of polished material. This may be white, gray, dark red, reddish brown and even liver-colored. So much concerning marbles.

Tofus, called πῶρος by the Greeks, is similar in color and hardness to Parian marble according to Theophrastus. It is as light as pumice and was much used for interior walls in large buildings in Egypt. It was also used to connect one building with another. Since it is so light it added little weight to the building. It is found in France about a mile from Coburg in the fields near the Thuringian forest. It is carried by the Elba, a small river of Thuringia. It is found in the province of Mansfeld where it is used to build walls and fortifications. The *tofus* from the Harz Forest of Stolberg is used to build furnaces. There are quarries on Mt. Dester, Saxony. All these localities produce white *tofus*. Whitish material is found at Pisa, Venice and Umbria, Italy, and was known to Vitruvius. When notched it can be used to cut wood. Red and black varieties are found in Campania.

Tofus is not always hard. It does not melt in a fire, as a rule, nor harden but falls into a powder instead. Stones which form in caves from juices that drip from the back and harden, because of the cold, are also called *tofus*.[10]

Silex is the next mineral to be considered. It is my opinion that the name

[10] This term is given primarily to tufa, both siliceous and calcareous, but probably embraces some tuff.

has been given the mineral because it flies into splinters when struck a heavy blow with a hammer. According to certain philologists the name is derived from the verb *salio*,[11] not because the mineral possesses any natural power to fly apart but because it is shattered by fire. Others believe the name comes from the verb *sileo*[12] because they believe the mineral contains within itself a latent fire that is brought to life by the blow of a piece of iron. Among the Germans the name comes from the word "horn" and we call it hornstone.[13] Some of the older writers have given this name to marbles, rocks of other genera and mixed stones. M. Varro called Lunan marble "Lunan *silex*." Vitruvius called hard calcareous rock *silex* while Varro called this same rock "Sabinian *silex*." The true *silex* I am describing is harder than marble and often as brilliant. Since it flakes badly when an iron point is pressed against it, it is not suitable for use in engraving. Since it is hard fire can be struck from it with iron with ease. *Silex* occurs in both metal veins and in veins composed of this mineral alone. Species are distinguished by color. It may occur the color of horn, white, gray, dark blue, black, brownish red, liver-colored or blue. It occurs on each wall of a vein of jasper at Langovicius. All *silex* will melt in a fire but only in the hottest furnaces. Otherwise it withstands fire, rain and extreme cold. If it could be dressed with iron tools it would be most useful as a building stone. It is used as road metal and for lining furnaces.

So much concerning stones that are found in veins and stringers. Actually *silex* and *tofus* may contain veins and then they should be classed as rocks. Veins spread through the rocks that form mountains. The quarries in these mountains contain many angular masses of rock. This is softer than either gems, *silex* or marble. It can be sculptured into statues but cannot be polished to a lustrous surface. Even when it is so hard that it can be sculptured only with difficulty it will not take a polish because it lacks denseness. It differs from *tofus* in weight. It will not melt in a fire but decomposes to a powder and in this way differs from hornstone. There are two genera of rock that can be sculptured. One is rough and makes a harsh sound when rubbed with the fingers. Sand is obtained from the pieces that are cut away during the shaping and for that reason I call it "sandy." The other genus is entirely different and the pieces that are cut away are larger. There are different species of the "sandy" rock that are easily distinguished by color. The white is found at Pirna and Zuicca, Misena; gray at Querfurd, Saxony; yellow at Freiberg, Saxony; red at Rochlitz, Saxony; and a blackish red species at Embach, Saxony. Some is

[11] *Salio*, to leap, spring. The name "salt" is derived from this verb since the mineral decrepitates when placed on a fire.

[12] *Sileo*, to be silent. The verb and the participial noun connote secret or mysterious.

[13] Hornstone, in modern usage, is an impure flint or chalcedony. It is closely related to chert. Flint breaks with a conchoidal fracture and is tougher than hornstone which breaks with a splintery fracture.

soft as that from Zuicca, Misena, some medium hard as that from Pirna, while some is hard as that from Norinberg across the Danube. The latter material is soft when it is first broken in the quarry and therefore is worked at once since it becomes quite hard after standing in the air for some time. The rock from Zuicca will not withstand rain or cold weather. Cliffs of this rock in France between Colebach and Cuperberg, when exposed to the air, gradually disintegrate to sand. One variety from Pirna is composed of a very fine sand and has a smooth surface when sculptured. The rock from Rochlitz is so coarse that it cannot be given a smooth surface. Some rock is similar in appearance to fish roe such as that found between Eisleben and Seberg and within the sovereignty of Bruno at Noteberg. This resembles salmon roe which is about the size of rape seed. Another variety found between Eisleben and Seberg is composed of sand the size of coriander seed, blackish red in color and covered with a sweetish efflorescence.

Rock usually occurs in large masses and in quarries large angular blocks can be obtained. More rarely it occurs in thinner beds as near Bodeberder and Embach, Saxony. Rock from these thin beds is spread on roads in many places and is used in both private and public buildings. At both Embach and Bodeberder they spread it on the roofs of houses. The rectangular masses are used to build shrines and temples and especially for columns, windows and door posts. Material which will harden in air is preferred, for example that from Norinberg mentioned above. The well known wall of the fortified city of Dresden is built of this stone and the road to the famous bridge of the Elbe passes through an arch of this wall. A portion of the fortress of Berlin is built of the same rock. It is carried to distant and foreign countries via the Elbe river.

They make millstones from harder and denser rocks and for that reason the Greeks call them μυλίας or μυλίτης, and the Latins, following the Greeks call them *lapis molaris*. Such rocks are found in Saxony near the town of Munda; in Misena near the fortress of Loma some three miles from Pirna. The millstones are transported from the former locality via the Weser river and from the latter via the Elbe. Another type of millstone is found in places that are burning. This rock forms from molten stone and was called *lutum* by Strabo and since it contains an admixed portion of a burning substance it has a moderate unctuousness. When these burning places erupt they throw out this molten stone and rivers of it flow away as can be seen at Etna. This soon congeals in the cold air and is changed into rock which can be quarried just as any other rock, although Pliny writes that this is a stone, not a rock. It is only found in those places that were burning at one time or are burning today. Even when the molten material is not thrown out it is congealed by the cold of the earth and changed into rock. Such a material is quarried in Italy near Lake Vulsiniis and in the district of Statonius; on the island of Nisida; and on Cape Melaena, Ionia. We do not know if the rock found in Mesopotamia near the Euphrates belonged to this genus or some other.

According to Xenophon it was made into millstones by the inhabitants of that district and brought to Babylon.

Lapis molaris which melts in a fire is called μύλη by Aristotle and Varro who has described the revolving millstones of Vulsiniis. The stones that do not melt are called μυλίαν. Theophrastus and Strabo called the stones that melted μυλίαν, physicians called them μυλίτης, and those who followed the Latin nomenclature *molaris*. Certain Greek writers called them *pyrites* since fire can be drawn from them just as from hard pyrite. Usually these stones are quite hard. The black gem that burns the fingers when heated by rubbing is evidently *pyrites*. Since this stone is unaffected by rain, heat or cold it can be used as a building stone. Millstones are made from it whence comes the name. According to Pliny there are certain millstones belonging to this genus that, when polished with flint and viewed from a distance, have the appearance of *ophites*. Commonly *molaris* is black and sometimes spotted since it has formed from a liquid material of this color. Actually if a reddish stone is melted to a liquid the part that will flow becomes black when it congeals. Aristotle writes that this material is similar to limestone and of course limestone can be used as a building stone but as Pliny writes, this has a certain natural unctuousness. When free of pyrite it is used for millstones. It reduces swellings that may have come on any external part of the body.

But to return to arenaceous rocks. Sand can be obtained from them when they are crushed finely but this is not the only source of sand. It is also obtained from the stones used in the manufacture of glass as I have explained in Book V, from stony marl, from unctuous limestone, and, in fact, from almost all stones and rocks that have a similar hardness. They make a variety of sand that is called *carbunculus* from bituminous earth that has been changed into a rather soft rock.

There are three genera of sand. The first is sedimentary sand that is dug from pits such as those at Pelgrana, Misena, and Glogova, Lygius. The second is fluvial that is found along rivers and streams. The third, marine that is found on beaches and seashores. Pliny describes sand that was obtained from the shallows of the Adriatic Sea when exposed during the summer. Sands vary in color according to the color of the rocks from which they are derived. That from Pelgrana is white, that from Glogova, yellow. The sand from Mt. Peribolos, Rome, is a golden color and for that reason they have come to call the mountain Motorius, i.e., golden mountain. Fluvial sand is usually gray although red, black and other colored sands do occur.

Some sand is fine, some coarse. The fine usually comes from pits. The fluvial and marine is usually coarse and mixed with gravel that must be separated with a sieve. It may even contain a large amount of coarse gravel. The sand that is to be mixed with lime must be free, not only of fine and coarse gravel but also of all earth and congealed juices. Earth affects the tenacity and toughness of lime and destroys its power to hold

rough stones together. If such lime is used in a wall it will not stand, especially when it carries a heavy load. If the sand contains congealed juices they will exude from the wall and dissolve the plaster. Bitumen is the only impurity that will make the mortar stronger and the structure firmer. The presence of a congealed juice can be detected readily by taste. If sand contains earth it is too harsh and when rubbed between the hands it does not make a creaking noise. Earthy sand will stain a white cloth passed through it. Some sands are dry and these are the most useful in buildings. They are usually sedimentary while fluvial and marine are usually moist and not as useful. Each sand is difficult to dry. When perfectly dry they will neither stand with a vertical wall nor arch as Vitruvius has observed. Sedimentary sands are usually unctuous, fluvial and marine, meager.

Sedimentary sand should not be used in plaster because of its unctuousness, marine, because of its saltiness. Both will produce cracks in the plaster. The sedimentary is the more useful of the two since it will harden without cracking if some binder is placed in the plaster and also because it does not contain salt.

Pliny writers that the sand from many parts of Africa resembles a lentil and that from near the pyramids, Egypt, has both the form and size of a lentil. Also, on a certain long hill of Cappadocia located in a field, the pebbles resemble a lentil.[14]

Sand is used not only as a building material but also in cutting marble as I have already mentioned. Coarse *sabulum*[15] is also sand. It may be either hard or soft, the former being called male, the latter female. The male is more useful as a road surfacing material. It is spread beneath layers of flint and rock and also between layers of these materials. We call fragments of stone, marble, flint, and *tofus* that are not large enough to be called rocks *glarea*. But this is enough concerning sandstone, sand, *sabulum*, and *glarea*.

I shall now take up another genus of rock. Artificers use this as they use sandstone, namely in columns, blocks, and any other forms that are needed in buildings. The tabular blocks are artificially smoothed and then laid in floors and in courtyards such as one in Hesse. These floors are found both in public buildings and private homes of the wealthy. This rock is also used for roofing tiles. The Romans made no distinction between this rock and sandstone but as soon as an iron tool is applied to it the difference is apparent. This genus is found in a variety of colors as is sandstone, white, red, mottled, i.e., white and red, etc. The white is found in Chemnitz in two quarries in the forest on the eastern side, the red and mottled in two quarries near a town on the western side, one in an oblong moun-

[14] This is probably a reference to "dreikanters," lenticular stones facetted by the wind.

[15] *Sabulum* is sand in the sense of a species of earth as contrasted to *arena*, sand as the barren material of deserts.

tain named for virgins, the other behind the shrine of St. Nicholas. It may be gray, black, liver-colored, yellow, etc., but these are worthless.

This rock varies in hardness. The Chemnitz material from the oblong mountain is soft, as is the material from the red quarries of the Pallienians, Fidenae and Albans. Some is moderately hard as that from the deep quarry behind the shrine of St. Nicholas and the quarry in the woods to the right. This rock was used to build the famous monastery of St. Benedict on a small mountain outside the town. The Tiburtian, Amiternian and Soractian quarries have produced this same type of rock. That from the mountains near Mulde between Penica and Roseburg is hard. The temple of Cosus under the sovereignty of Anhalt is made from blocks of a very hard rock, in fact it is so hard it can only be dressed with iron tools and even then only with the greatest of difficulty. This genus, especially when it is soft or moderately hard, usually contains impurities. Sometimes it contains marl that makes holes since the marl falls out when the stone is dressed. Sometimes it contains flint, especially black flint that tends to break from the rock when struck with a hammer and thus make the surface uneven. Sometimes it contains small pebbles similar to gems and although these appear, at first, to enhance the beauty of the stone, during dressing these tend to drop out leaving holes. These can be observed in Elboganun and especially in the walled city of Herzberg.

The very white rock of Megara and other softer varieties contain marine shells throughout and for that reason are called *lapis conchites*.[16] This rock was used, according to Pausanias, in the monument of Phoroneus and in many buildings in the city of Megara. The same genus is found in Thessalia, Haemon, Macedonia, and the mountains of Calabria. Similar rocks quarried near Paris often contain snail shells. Recently a rock was quarried that carried an impression similar to a crown of laurel.

The soft rocks can be dressed with ease with an iron tool but the hard rocks can be dressed only with the greatest difficulty even after they have been left exposed to the air for some time. The moderately hard rocks are dressed with moderate ease. When the soft varieties are exposed to the weather they crumble and dissolve in the rain while the ice and frost break them into small pieces. Some cannot stand the heat of the sun and near the ocean they crumble because of the salt air. In protected places, however, they can sustain heavy loads. The moderately hard rocks sustain heavy loads in exposed places and withstand rain and cold but break up in a fire. The hard stones are not even injured by fire. Copper workers use this genus to make the appropriate molds for casting molten copper. Some varieties are soft and easy to work and still withstand fire and these are the ones most suited for molds. Some rocks, dark gray in color, are found in Hesse and are worked into all types of molds for casting different metals. The same species is found in Siphnos and in Italy near Como

[16] Coquina and coquina marble.

where it is fashioned into cooking vessels which are then bound with iron hoops. The hard rocks should be dressed with iron tools as soon as they are taken from the quarries since they become much harder after standing in the air. These are used in making mortars in which druggists compound medicaments and whetstones on which other stones are ground. For these purposes they use the beds of rocks found in Misena between Penica and the fortified city of Roseburg, as well as *lapis thebaicus* with yellow spots, *chrysites* from Chalazius, and *basanites*. The Ancients made mortars from these rocks and also from hard marbles, for example, the greenish marble from Ethiopia, from *haematites*, from each of the marbles of Taenarius, from Parian marble, Egyptian *alabastrites*, and from white *ophites*. Today they make the small mortars used in grinding and pulverizing emery and other hard stones from our jasper and onyx. Remedies for the eyes are ground and mixed in mortars made from Ethiopian marble since this stone itself, when pulverized on a flint, will destroy the mists that form in front of the eyes.

There are two other genera of rocks but square blocks are not cut from them. One is called "fissile," the other "calcareous." The strata of "fissile" rocks (slate) differ from those of other rocks in that they can be split with ease. They differ in color since the former may be white, yellow, red or some other color while the latter are either gray, whitish gray, light or dark bluish gray, dark blue or black. "Fissile" rock is found in many places but the very best with a dark color, distinctly tabular form, and with golden veins comes to Lipsia from Norinberg. "Fissile" rock will usually split in a fire and the thin pieces produced in this way are used in Germany to cover churches and large buildings.

"Calcareous" rocks are so-called because lime may be produced from them when burnt in a furnace. This genus varies in color. Some is white and the whitest is found in the vicinity of the village of Bruno, especially in the fields of Lichtenberg and even under the walled city of Wolfenbüttel. Some is light gray or gray such as that about two miles from Chemnitz on the road to Waldenburg. Some is dark blue as that from the lime quarry of the village of Averswald five miles from Chemnitz. In the mountains near Sala it is found white, light yellow and light red. A rock that is part white and part light gray is found near the Moecheta river not far from Pirna. The river is used to transport the rock to the country along its course.

The "calcareous" rocks are divided into hard and soft varieties. The rock from near Bruno is soft and easy to work while that from Chemnitz is hard. The Hanover variety is similar to Pirnian marble and when struck gives a resonant sound similar to that of black copper chalcophones. One of these stones in the walled city of Alcathea, Megara, gives a tone similar to the cithara when struck with a pebble but this is obviously due to the artificial carving. Although "calcareous" rock is commonly dense the rock from Sala is loose-textured and full of small holes. It has a variable unc-

tuousness but is always unctuous. Only the pure true material is of any value since the mixed material is full of impurities. They make white lime from the pure varieties and the whitest rock is found near Bruno. Dark lime is made from dark "calcareous" rocks and varicolored lime from varicolored varieties. The white lime is given preference if it is of good quality otherwise. Neither the whitewashers nor plasterers find the dark lime suited to their needs. Lime from soft rock is more useful to plasterers and that from hard rock more useful to builders. Lime from unctuous rocks is more tenaceous than that from meager while that from loose-textured and porous varieties is lighter than that from dense. In each case the first named lime is more suited to the needs of plasterers, the latter to construction. It can be obtained from rocks suitable for millstones, not the sandstones but the unctuous rocks. The lime from siliceous rocks is not good because a large part of the rock goes into a glassy slag when burnt. Better lime is made from the shells of marine mollusks. The fire in burnt lime is so concealed that when it cools it appears to be cold yet this fire is rapidly aroused with water. For this reason it is usually reduced to the very finest powders.

Lime is used in a great many ways. It is used in preparing olive oil and on vines. The Hedui and Pictores fertilize their fields with it. Certain African peoples treat wine with it in order to neutralize the sharp taste. It is collected by the living from arched vaults and mixed with water so that a cadaver thrown into it may be entirely consumed. Dyers, tanners and medical men use it but they require fresh lime that has not been slacked. It burns so violently that it forms thin crusts. In a short time after it dries it will not burn further but still is capable of warming and drying the flesh and even eating it away. After it has been washed three or four times it will not bite but will dry effectively. However, the principal use is in constructing buildings. According to Vitruvius if the sand with which it is mixed is natural or pit sand the proportions are three of sand to one of lime; if fluvial or marine, two to one. These are the best proportions. If a third part of shells, tufa or impure chalk, is added to fluvial or marine sand a better mixture is obtained. A better mortar is obtained if the lime and sand are mixed together and allowed to stand for a period of three years. Certain buildings are not firm and stable because the mortar was prepared too soon after mixing the lime and sand.

Lime is used in making the *maltha* the Romans used to cement their aqueducts, castles and reservoirs. According to Pliny this material was extremely tenacious and had a hardness equal to that of the rocks mentioned above. It can be seen in Rome today. The name is derived from *maltha*, a genus of bitumen. The natural material will produce the firmest of walls and the artificial cement is used in the same manner. The latter is used to plug cracks in aqueducts and reservoirs since it is as tenacious as natural bitumen. The older writers have described two genera of the artificial cement, each being made of lime and lard. The sap of the fig tree is

added to one, pitch to the other. A lump of lime is first quenched in wine then crushed in a mortar with lard and either the sap of the fig tree or pitch. That made with pitch is darker and readily distinguished from the other. According to Pliny when a surface is coated with maltha, oil is rubbed over it. Metal workers also have a genus of maltha with which they fill cracks in the bottom of large crucibles so that the molten metal will not be lost through them. If the crucible is made of ash the molten metal produces flaws that eventually break it. Fresh maltha will hold molten metal just as old maltha holds water. The maltha of the metal workers is made from unslacked lime, ox blood and meal.

Lithocolla differs in composition and use from the two older malthas. The former is made from powdered marble and beef glue and is used to cement fragments of marble or rock to the parent mass. Today two kinds are in use each containing powdered marble or rock similar to the fragments of marble or rock that are to be cemented. White of egg is added to one variety, pitch to another. Some people add other ingredients. Lapidaries have their own variety that is used to cement rough stones to the dorp. This is usually made from powdered brick and pitch.

Since I have discussed sand, lime, maltha and *lithocolla* I should say something about artificial stones. There are two genera of these. One is made from stones and lacks a name, the other is made from earth and is called *later* (brick). The former can be made from any stone by simply giving it a new shape although the original color is lost. Thus one large stone can be made from a number of small ones and a small stone from several smaller ones as *aetites*, from the small pebbles found in a geode and flint from small pieces of flint. Similarly a whetstone can be made from silicious fragments to which silver or other materials are added. First the stone is crushed to a powder in a sandstone or stone mortar and then egg white, linseed oil and juniper gum is mixed with the powder. The mass can be molded to any form. If a large amount of egg white is added to the mixture it dries quickly and if a large amount of gum the rock is harder. Some of these stones can be colored by adding a pigment although if they are made with pitch they are always black.

Bricks are made from earth. They are usually made from whitish marl or red ocher. Luneburg brick is made from an unctuous aluminous earth. Good bricks are made from a pumiceous earth at Sandarlik, Asia Minor, and Calentus and Cartagena, Spain. These will float on water. In olden times bricks were made from earth to which sand, male sand, had been added. No matter what variety of earth is used first it is moistened with water. The bricks are then molded from this mud. They are usually made in spring and fall so they will dry during one uninterrupted period. If they are made in summer, according to Vitruvius, they are usually defective since the sun, when directly overhead, burns so strongly the bricks shrink and soon have the appearance of being dry and yet are moist in-

side. Later, when they finally dry the inside shrinks and breaks the dry outer crust producing numerous cracks and weakening the brick. There are four varieties of bricks, first, those used in walls, second, those used for battlements on the top of walls, third, those spread on the ground, and fourth, those used for roofs. There are three types of bricks used in walls, following the usage of the Greeks who have given names to them. One is called δίδωρον, being two palms (about six inches) wide, whence the name, and twelve inches long. The Greeks call a palm length δῶρον. The second type, twelve inches long and twelve inches wide is called τετράδωρον. The third, fifteen inches in each direction is called πεντάδωρον. The ancient peoples used unbaked bricks but let them stand two years before they were used. According to Vitruvius the people of Utica let their bricks stand for five years so that they would become thoroughly dry. This type can be seen today in certain villages of Bohemia. The Germans use burnt bricks. Care must be taken when burning them. If they are burnt too much they have a glassy appearance and will not take mortar while if they are under-burnt they are fragile and the lime in the mortar will fracture them. Neither is suited for building.

The bricks used for battlements are made in a variety of forms. They may have projections added to them after they are made and they may be shaped into semicircles. The exposed portion of the brick may be given various colors or smeared with litharge to give it a glassy appearance. The bricks used for paving are usually square and three to nine inches on the side although the thick bricks are usually only three inches. The bricks we see paving the roads of the Venetians are thicker and closely fitted in order to reduce the wear by pedestrians. The exposed side of the brick may be colored in order to give a more pleasing appearance. The bricks used to cover the roofs of houses are either tabular like the tongue or concave like a pipe. The younger writers call the former *lingua*, the latter *priscus imbrex*[17] because the rain runs off along these just as along a canal. At one time they made half-bricks for use in walls and today half-bricks of the *lingua* type are made and used for roofing houses. Many famous buildings in Germany, especially in Saxony and Misena, are built of brick. The wall between the city of Leipzig and the monastery of St. Paul is well known. The town of Urbino, Picenum, has a famous brick fortress. This was built by the very renowned and brave Prince Fredrick Maria. Brick walls, as Pliny writes, will last forever if built vertical. Actually they last so well they are used in public buildings and royal homes. The wall of Athens facing Mt. Hymettus was built of brick as well as the temples of Jove and Hercules at Patras although these are surrounded by stone columns and architraves. Other famous buildings are the royal home of Attalus at Tralles, the royal home of Croesus at Sardes which

[17] Ancient hollow tile.

has been made into a hospital, the tomb of Masolus that is preserved today at Halicarnassos. In Italy there are brick walls at Arezzo and Bevagna. So much concerning stones made by the hand of man.

I return to stones formed by nature. There is a petrifying juice found both outside the earth mixed with water and hidden within the earth that turns all things it touches or surrounds into stone. I will mention first the roots, trunk, branches, bark, foliage, flowers and fruit of trees that are turned to stone in fountains and rivers as I have mentioned in Book II of *De Natura Eorum Quae Effluunt Ex Terra.* In Elboganun, near a town that is named for the gliding of the hawk, large fig trees with the bark intact are found in the ground turned into stone with golden pyrite deposited in the cracks. Also near Krakow, Bohemia (a citadel built by Karl the Fourth behind Rakovicius on the road to Swanberg) trees with branches intact are dug up near a river and these have been used by the peasants of Colembrach to make angular whetstones that they have presented to King Ferdinand of Bohemia and his friends. In Misena near the fortified city of Rubenstien, four miles from Chemnitz, in a certain reservoir we see the trunks of many trees that have been changed to stone. Petrified oak wood has been found in an aluminous earth at Hildesheim. In this same district near the citadel of Marienberg there is a hill abounding in petrified tree trunks, the ends of which sometimes project from the hill. These tree trunks are very long and may be found in heaps. There is a black earth in the center of each tree. The trees resemble the marble from Hildesheim that I have mentioned before in that they give off an odor of burnt horn when struck with a piece of iron or another stone. The two stones are of the same material. Actually nature produces certain stones that resemble trees and these must be carefully examined for bark, heart, etc. If these are missing it is evident that they are not petrified trees but only natural stones which resemble them. The trees of Hildesheim are of this origin. We have no way of knowing if the tree trunk that Jovianus Pontanus found on Cape Pausilypus, when a part of the mountain broke away during a storm, was a petrified tree or not. It is not stated whether this was a stone that looked like wood or a piece of petrified wood. The petrified wood found in the aluminous earth of Hildesheim contains mineral ebony. Small quantities of this mineral occur in a similar fashion in hollows in certain other stones. Theophrastus also knew of this occurrence of *ebenum* in rocks. The wood containing the *ebenum* mentioned above is black and without branches or fruit. When polished it has a luster similar to horn, solid and light and with an appearance similar to jet but it is completely different. This *ebenum* is unaffected by fire while jet burns readily and is completely consumed. Branching *ebenum* of this type from Venice was once given me by a friend who thought it to be the black coral called *antipathes* by the Greeks. Pausanias, following a certain Cyprian physician, has written that it represents a root that grew within the earth with neither foliage nor fruit and for that reason is very difficult to find,

being found only in Ethiopia by people who know how to search for it.[18]

There are certain springs and rivers that will petrify gloves, bones and other substances that are thrown into them without changing the original shape. "And bones, dissolving, wasting away with the body often" having been changed into stone have been found recently near a certain river that flows from a mountain falsely named for the pine tree it is supposed to support. They have found bones of animals changed to stone in the aluminous earth of Hildesheim, They have found the petrified bones of some marine monster as well as the teeth of fish in a similar black and unctuous earth near Lunenberg. This earth is used in making bricks. Theophrastus has written, according to Pliny's translation into the Latin, that bones are produced within the earth and bone-like stones are to be found there also. Mutianus has written that mirrors, skin scrapers, clothing and sandals were changed into stone when left in a quarry in Troy. When trees and roots, bones and other objects are changed into stone they become very hard. The stream from a fountain in Parparus makes the earth stone-like when it sinks into it because of a petrifying juice and it is in this same manner that earths along underground channels are made stone-like when they absorb the water flowing along the channel. The stones which have congealed from this petrifying juice alone, either within the earth or outside it, are usually soft and fragile. Such stones hang from caverns and underground passages in those localities I have already mentioned in Book II of *De Natura Eorum Quae Effluunt Ex Terra.* A small rivulet near a small fountain in Cepusius has been changed into a soft white stone in this manner. A similar soft white stone settles from the warm water of underground channels or hangs from the back of the channels in the form of icicles. This stone is called *tofus* because it is porous. The Greeks call it πῶρος. Pliny has named it *pumex.* Stones have been found near the hot springs of Karl the Fourth composed of a large number of units cemented together. The units are as porous as a honey-comb, hemispherical and the size of a pea. They formed from dripping hot water.[19]

Earthen vessels are found within the earth with the neck commonly constricted and the body swollen. They may have one, two or three handles and some have lids. They are dug up in many places but particularly in Ferteslieb, Saxony, near the village of Matthias Schulenberg in a vineyard about two miles from the castle of Sricca. They are also found in Lusatia near the town of Liben, ten miles from Lucca; in Thuringia on Mt. Seberg, a spear's throw from Stein, a citadel of the Vicclebi. The ignorant and uneducated people of Saxony and Lusatia have been persuaded that these vessels have been produced within the earth while the people of Thuringia have been led to believe that the dwarfs who formerly inhabited an excavation on Mt. Seberg used them. Actually they are jars

[18] This must refer to black or dark colored petrified wood and possibly concretions.
[19] Pisolite, a variety of limestone composed of small hemispherical concretions.

that were used by the older Germans who had not been converted to Christianity, to preserve the ashes of their dead. Charcoal and even rings have been found with the ashes in some of the jars that had lids. The jars of Thuringia appear to be much older than those of Lusatia and the latter were probably used within the Christian Era. In addition to these jars, stone vessels have been found near Northusa containing ashes that have been semi-petrified because of the nature of the place where they are found. In Italy stone and earthenware urns have been found as well as glass urns. Caesar Carduinus of Naples has four very beautiful urns that were found in a Neapolitan field.

Enough concerning these things. The last genus of simple natural substances follows.

BOOK VIII

A metal, as I have said, is a natural mineral body that may be liquid, as is quicksilver, or hard although it may melt in a fire as does gold, silver copper, and lead, or become soft as does iron. Metals are found in veins, either pure or mixed with earth and stone. I shall describe the pure metal first and then take up the veins from which each is recovered, i.e., the mixed and compound minerals of that genus. The older writers have held that only gold and true quicksilver are found in veins. Pliny, who has compiled the writings of the Greeks and Latins in his Natural History, denies that silver is ever found pure. He writes that it never occurs naturally in its true form and never has the sparkling brilliancy of gold. However, all the mines of Germany cry out with one voice against this conclusion. Pure silver, copper, iron and bismuth are dug from the earth. The other two genera of "lead" minerals[1] are found almost pure. However, the true, virgin metal created originally within the earth is either simple, such as quicksilver, always, tin and iron, almost always, and silver, commonly, or mixed with another metal, usually gold, copper, lead or bismuth. The oldest writers, Diemachus, Megasthenes, Aristeas, Herodotus and many others, have said that gold is found pure. Whenever I think about their writings the present methods of recovering gold are brought to my mind and I am always led to the conclusion that more gold has been recovered in the metallic form during the ages than has been smelted from earths and stones with which it is commonly mixed. In support of this conclusion I might mention the many famous streams that contain minute pieces of metallic gold, the Ganges of India, Pactolus of Lydia, Hebrus of Thrace, Tagos of Spain, Padus of Italy, and the Elbe of Germany. Additional support is found in all the fabulous stories of the old writers. They tell of the griffins who stole gold, of ants in India that dug up gold, of the golden apples of the Hesperides, of the Golden Fleece, a story beloved by poets. Final support is found in the abundance of small pieces of gold found in Spain associated with larger masses, some of the latter weighing up to ten pounds. According to Pliny the former are called *balux*, the latter *palaca*. An unknown Greek writer is the authority for the statement that masses of gold, probably many of them, had been found in Paeonia weighing one hundred drachma. He mentions two larger masses, one weighing three hundred drachma, another five hundred. Within our own time equally large masses have been brought to Spain from neighboring islands. In the mines of the Lygii, famous because the riffle cloths were once stolen by thieves, they have found one mass of gold weighing more than a pound and several smaller pieces.

[1] In the Latin nomenclature there are three "lead" minerals, *plumbum nigrum*, lead; *plumbum cinereum*, bismuth; *plumbum candidum*, *album*, or *argentarium*, tin.

These large masses of gold may be found free of rock or attached to it. The very tenuous foils of gold that have a sparkling luster are always attached to marble, rock, stones, gems, etc., and may be worn away from these by the force of water (for this reason they are called *ramentum*)[2] and carried away by streams and rivers.

Aurum in its native form is called ἄπυρος by the Greeks, i.e., not recovered by fire while gold that has been heated and separated from the admixed silver is called ἄπεφθος. The latter is also called *obryzus* according to one writer. Gold containing silver is called "argentiferous by the Latins, λευκός, by the Greeks because of its white color. Pure gold is yellow with a distinctive brilliance and a unique and extraordinary natural luster. It melts in a fire and can be cast but the melting has so little effect upon it that it can be separated from all other metals and still lose none of its volume. It is improved and purified by heating it repeatedly for long periods in a broad shallow vessel until it glows with the color of fire. For this reason it has always been regarded as the most precious metal. Since it is acrid other acrid minerals such as salt, soda, vinegar, juice squeezed from unripe grapes, etc. will not dissolve it nor reduce its volume as does the water made from *atramentum sutorium* that separates gold from silver. It contains no impurities such as rust or verdigris. When rubbed on the hands it leaves no filth as do other metals which proves that it is naturally pure. Nothing comes off the pure metal. It will not make a mark of its own or any other color and in this way can be distinguished from all other substances of similar appearance. It will only make a mark when rubbed on a touchstone (*coticula*), a mark that is similar to its color. It is softer than silver and hence if a ring made from white gold or *electrum*[3] is worn day after day on the same finger with a ring made of pure gold the latter will eventually wear away completely. Although gold is soft it is not fragile. It can be hammered so thin that fifty or more foils such as artisans use, approximately four and one-half inches on the side, can be made from about five ounces of gold. This foil is only one-third as thick as that used by pharmacists and painters. Gold can be drawn into thread either with or without silken wool. Sometimes this thread is woven. Gold has about the same weight as lead[4] and neither metal produces any distinctive sound when struck or thrown.

Many objects other than coins are made from gold. I will discuss the latter in *De Precio Metallorum et Monetis*. The former are created as ornaments for man and his temples as well as for other purposes. For ornaments man uses rings, bracelets, brooches, earrings, necklaces, hollow spheres, chains, crowns, and *cicadae*[5] which, since they are worn by the Athenians, are called τεττιγοφόρας. Temples are decorated with golden statues such

[2] Filings or scale.

[3] A silver-gold alloy that may contain up to 20% silver.

[4] Gold is 69% heavier than lead.

[5] A gold insignia made in the form of a cicada and worn in the hair.

as the one of Jupiter made for Cypselus, Tyrant of Corinth; columns, such as the one in the Temple of Hercules in Egypt; lamps, such as those in the Stronghold of Athens that Callimachus built to Minerva; three-legged stands, such as the one placed in the Temple of Delphi by the people of Aegina; stools, such as the one placed in the same temple by Midas, King of Phrygia; tablets, such as the famous one of solid gold in the temple of the Archangel Michael in Luneburg, a tablet two feet long, one foot wide and three-quarters of an inch thick; and finally seals, some of which are set with gems. There is a large and famous goblet in Merseburg given by King Henry. According to Herodotus there were six bowls in the Temple of Delphi that weighed three thousand pounds. These had been placed there by Gyges. Among the gifts of Croesus there were one hundred and seventeen half-bricks of gold. The largest were seventeen and one-half inches long, about nine inches wide and three inches thick. Four were of pure gold, the rest of white gold. The latter weighed one hundred and fifty pounds apiece, the former two hundred pounds. Croesus had a golden lion that weighed one thousand pounds and a large bowl weighing eight hundred and seventy-five pounds. He also has a golden basin and a four and one-half foot statue of a woman. At Thebes in the Temple of Apollo Ismenias there were presents that Croesus had given to Amphiaraus, golden shields, javelins and spears with golden heads.

Man uses golden basins, dishes and goblets. Antoninus Heliogabalus, the most infamous man who ever lived, and Bassa, who amused himself by making fun of the priests of Mars, caught their vomit in golden vessels because they said the metal was unclean. Coffins have been made from this metal, such as the one in Elis made by Trophonius for Augeas. King Antigonus placed the bones of Pyrrhus in a golden urn. Bessus bound Darius Codomanus with golden foot-shackles.[6] Glaucus had golden armor; the Persians, golden swords, sabers, helmets and breastplates. Maximinus the Younger used a gold breastplate and swords. The soldiers of Antiochus, King of Syria, had gold nails in the soles of their sandals. Mention must be made of the famous golden plane tree of Xerxes under which he used to sit and of the golden palanquin of the king of India with pearls hanging all around it. Homer writes that men were accustomed to weave gold through their hair in olden times. The Emperor Gallienus sprinkled bears with gold dust and Heliogabalus sprinkled the portico with it. All of the objects that I have mentioned above were made from either pure gold, gold mixed with variable amounts of silver, or *electrum* which contains a fifth portion of silver.[7] Gold foil is used to cover objects made of silver, brass, iron, wood, and even the pills of physicians. The Romans used it to cover the horns of sacrificial animals while one of the kings of Egypt preserved the body of his daughter in the statue of a cow covered

[6] Darius was later murdered by Bessus.

[7] The *electrum* referred to here is an alloy and not the mineral electrum.

with gold foil. The altar of St. Laurence in Noriberg has the roof of the tower made of brass and covered with foil. Some people spin gold into threads and embroiderers use these in a needle and work them into cloth that they decorate with a variety of colors. Metallic gold is used by chemists to prepare a liquid that they affirm will restore youth when drunk.[8]

I shall now take up silver (*argentum*) which was unknown to the ancient writers as a native metal. One cannot tell from the writings of Albertus whether he knew it as a native metal or not. He writes, "It is found at Freiberg, soft and similar to a tenacious porridge. This is the purest and finest grade of silver with little slag, having been refined by nature."[9] He says nothing about the color of this material. Silver is rarely found in metallic form at Freiberg and although masses and films of argentite do occur there is not enough of this mineral to assure that he refers to it. The latter is commonly soft and has little slag. However, I would not care to argue this point with anyone since much purer silver was obtained from these mines in former times than has ever been obtained since. The Freiberg veins have yielded a great abundance of lead ore rich in silver as well as some pyrite ore but the mines of Misena as well as those of Schneeberg, Annaberg, and Garium have all produced native silver. It occurs in Bohemia in the Joachim and Abertham valleys; sparingly on Mt. Melibocus, Lauterberg; also sparingly in a valley of the Jurassic Mountains of France that takes its name from the charm of Leberthal. In the latter locality, to date, all ore has come from two pits, one named St. Wilhelm, the other named for an oven. Of the many mines of Bohemia and Misena, two are the most important, one at Schneeberg, St. George, is the most famous silver mine that has ever been worked. Silver to the value of two million Rhine gold pieces has been taken from the mine. This is known from the memory of old people who discuss it and many of whom have made note of it. The most accurate figures come from those who kept the account books in which were recorded the quantities of silver smelted. Although the entire vein did not consist of pure silver probably the major part did. The other great mine is at Abertham and is named Laurence and Theodore. In recent years silver to the value of some one hundred and fifty thousand Rhine gold pieces has been taken from this mine, undoubtedly in the form of impure silver. It should be understood that these are unusual mines.[10] There are many other mines at Schneeberg that have been very productive, especially Sonnebirbel, St. Margaret, and St. Andreas. Large masses of silver have been found in some mines. One mass found in the St. George mine of Schneeberg was of such size that Prince Albert of Saxony, that valiant warrior, descended into the mine to have the pleasure of seeing it.

[8] Gold bromide acts as a mild aphrodisiac when taken internally.

[9] This is probably a reference to cerargyrite, native silver chloride.

[10] These were native silver-cobalt ores similar to the rich ore mined in recent years at Cobalt, Ontario.

While he was in the mine the attendants used it as a table and he is reported to have said, "Emperor Fredrick is powerful and rich but today he does not have such a table as this." I have no knowledge of the weight of this mass but it must have weighed several hundred pounds. Another notable mass has been taken recently from the outcrop of a vein of the Stella and Suice mines in the Joachim valley that weighed five hundred and eighty pounds. We see many masses taken from the Theodore mine weighing from fifty-eight to one hundred and sixteen pounds.

Thus in the channels through rocks both large and small masses of native silver are found either free of stones, marbles and rocks or adhering to them, or in very thin sheets enclosed in these rocks. Nature also produces native silver in a variety of shapes, sometimes arborescent, sometimes in branching forms and even in hair-like masses. It is often found in very white ball-like masses consisting entirely of very fine silver threads. We find the silver in this form because it is so stable. I shall speak of silver smelting later.

Silver is next to gold in natural beauty. It is white in color and when polished has an excellent luster although the natural luster is equally pleasing. It melts in a fire and can be cast. When mixed with lead and melted in a large shallow dish the lead is changed, in part, to *molibdaena* and, in part, to litharge (*lithargyron*). Even when copper and other metals are added to this mixture of lead and silver and heated, eventually only pure silver will remain. If heated for too long a time some of the silver is lost and hence gold is a superior metal and is purer. The fact that silver will give a black mark and will soil the hands is additional proof that gold is the purer metal. Acids corrode silver, tint it blue and eventually dissolve it entirely. Some silver is harder than gold but the softer is the best since it is less fragile and spreads under the blows of a hammer to a marked degree although never as much as gold. Like gold it is sometimes drawn into a thread, either with or without wool and can be woven although it is not as heavy. Because of its hardness it gives a sound when struck or thrown to the ground. The same objects are made from silver as from gold but in greater quantities, coins, rings, bracelets, necklaces, earrings, hollow spheres, chains, and crowns. It is used for goblets, basins, dishes, and urns. Silver articles are given to temples by kings, for example, the great silver basin mentioned by Herodotus that Halyattes, King of Lydia, gave to the temple of Delphi when he was convalescing from an illness. Croesus, when the Persians were fighting against him, gave the same temple a silver basin with a capacity of six hundred amphorae,[11] four large silver casks, hand vases and wash basins. Silver statues have been erected to Augustus Ceasar and there are a large number of silver statues in German churches. The arms, helmets, breastplates, and greaves of the Parthi were of silver. When the Carthaginians ran out of iron and

[11] About three thousand four hundred and fifty gallons.

and copper they used gold and silver in their arms. Livy tells of a shield of Barchinus of Asdrubal that weighed one hundred and thirty-eight pounds. The shields of some of the troops of Alexander the Great were made of silver and for that reason the troops were called *argyraspides.* This was in imitation of Emperor Alexander whose troops were also called *argyraspides* and *chrysaspides.* Maximinus Jr. used a silver cuirass and swords. The Turdetani of Spain have large silver casks and cribs, Claudius Caesar used a war chariot of this metal while Nero had many silver sandals and Heliogabalus, book cases, tables, and beds. The army of Antiochus, one of the kings of Syria, had vessels for use in the kitchens. It has been found that the Tectosages[12] used silver millstones. Sometimes the branches used in theaters are made of this metal. Henry the First, of Thuringia, and at the same time Prince of Misena, had a tree of fair size made of silver from the Freiberg mines that have yielded him such an abundance of the metal. The foliage was in part of this metal and these leaves were given to the winners of equestrian contests. The foil is used by physicians to cover pills. Silversmiths, engravers, statuaries, gold-beaters, spinners, embroiderers, and weavers use the metal in their work. But enough concerning silver.

Quicksilver is called ἄργυρος χυτός by Aristotle because it is not solid but liquid and fluid. It is called ὑδράργυρος by Dioscorides, a name derived from the words water and silver since it resembles silver in color although it contains none of this metal and it flows like water. Pliny calls the pure natural mineral *argentum vivum* and the artificial material *hydrargyrum* because it is made from cinnabar. In using different names he believed that he was discussing different things. It is evident to anyone who reads Dioscorides that the Greeks gave each of these the same name. Thus Alexander Aphrodisiensis is correct in calling ἄργυρος χυτός, ὑδράργυρος. Just as the silver that is smelted from veins is not called another name nor differs, except in purity, from the native metal found in mines, the quicksilver obtained from cinnabar is in no way different from the native metal found in mines. The old writers were aware that it was found pure. Pliny writes, "There is a stone in these veins cursed with everlasting fluidity that is called *argentum vivum.*" It is found pure in cavities where the waters that drip from the veins have moistened the cinnabar for it is in this manner that it is collected and turned into quicksilver. It can be observed in the troughs used for washing cinnabar. However, when the quicksilver is dried it goes back to the form of cinnabar. Dry veins do not yield native quicksilver. For this reason it is very rare at Schönbach where the water flows with ease from the wide veins because the mine is on a hill.

Quicksilver is white and liquid by nature. When poured on a flat table it flows in all directions. Unlike other liquids it does not wet the table

[12] A people living near Narbonne, France.

because of the dryness that holds the moisture in check and does not allow it to adhere to the table. It flees from fire with such force that if it is not given an avenue of escape in the lower part of a vessel it will attack the upper part and even adhere to the cover of a closed vessel. Since it contains more air than water, as Aristotle correctly believed, it is not congealed except through the chemist's art. It is friendly to gold. While other metals and objects of great mass and weight float in it, a very small piece of gold sinks. A talent of iron will float in two talents of quicksilver while one seven-thousandth of that amount of gold will sink. Since it draws gold into itself it cleans gold the best, according to Pliny, and removes certain impurities after numerous shakings in earthenware vessels. The impurities are removed when the quicksilver is parted from the gold. It is parted from gold by first pouring it into special skins. It flows through the skin like sweat leaving the gold behind. The quicksilver that has adhered to the gold volatilizes when placed over a hot fire. Quicksilver also adheres readily to the *plumbum* metals, with difficulty to silver, with greater difficulty to copper and with the greatest difficulty to iron. Artisans who gild silver and copper objects first smear them with quicksilver in a manner known only to them after which the objects will hold the gold foil with the greatest tenacity. Artificial cinnabar is made from quicksilver and I shall explain the method in its proper place. The Moors, after drying the quicksilver in the sun, place it in basins that are covered with hides and kept in a cool place. It cannot be stored in just any basin nor in common vases. The proper container must be made of metal, solid rock or glass. It escapes from earthenware and wooden vessels.

This metal offers many uses to the chemist. Physicians use it to cure a mange the Italians call "French mange" and the French call "Spanish mange." Dioscorides writes that it is fatal when drunk since it eats through the vital organs because of its weight. Galen, following Dioscorides, writes in one place that the heat of the body activates it to such a point that it kills by corrosion and in another place considers it among the substances essential to mankind. These are contradictory views since a very small quantity taken into the body attacks it violently. In still another place he writes that no one has actually tested its strength to ascertain if a potion would kill or if it could destroy the body when placed on the outside. Recently a depraved wife gave her husband quicksilver and swallowed some herself but this was ejected from the stomach without any harm. Nevertheless, having committed a crime, she was punished by law. When mixed with other substances so that it does not corrode, when taken internally or rubbed on the skin so that the body heat is able to exert its full force, it attacks the head and causes excessive discharges, part of which flows out through the mouth, part settles in the gums and cheeks and causes them to swell.

When placed in the proper kind of container by a chemist and placed over a fire quicksilver will be carried by the heat to the upper part of the

vessel where it forms a substance they call mercury sublimate. This has corrosive properties equal to quicklime and will even destroy the latter. Enough concerning quicksilver.

The Greeks call copper (*aes*) χαλκός. It is found as a native metal not only in its own veins but also in silver veins. The old writers and even Albertus did not know this although the latter writes that the best and purest is found at Goslar mixed with all kinds of stones such as *marchasita*, his name for pyrite. Actually if it is found mixed with all kinds of stones it is not pure, much less the purest. It is purified by smelting. I do not know if copper is found in masses that equal the size of masses of native silver but small masses occur in different forms, for example, stalactites, small branches, globular masses, etc. Very thin foils are found adhering to stones. Native copper often contains small amounts of silver.

Copper has a characteristic red color. The finest color is found in the metal that has been smelted from veins. However the color varies. Some is the characteristic color such as that smelted at Neusohl in the Carpathian mountains of Hungary; from Cotteberg, Bohemia; from Norway; and from the Harz forest. Some is a dark red as that from the Gairum and Schneeberg mines, Misena. Some from Gairum is whiter and we are wont to call it white copper even when it is also dark red. Pliny mentions white copper but does not say if it was smelted from a vein or tinted with lodestone. A yellowish red copper is produced in smelters that separate silver from copper and this is called yellow or *regulare* copper. In the same smelters a dark yellowish-red copper is produced which is known as *caldarium* copper. The German name for this[13] is derived from *lebes*, a bronze cauldron. I shall say more about each of these later. *Regulare* differs from *caldarium* copper in that the former is easier to forge than cast, the latter easier to cast than forge, in fact it breaks under the hammer. Copper containing zinc has a golden color and is called ὀρείχαλκος. Pliny writes that this is also found in mines and for a long time was regarded as especially beautiful and desirable. Lodestone gives it a white color. Chemists can change the color to silver or gold so that it resembles varieties of these metals. It glows in a fire, melts and can be cast. Copper is not affected by fire when placed in a large shallow vessel, yet when placed in the same vessel with the materials that purify gold and silver it is entirely consumed. It is hard but can be hammered into thin sheets. Pliny writes that when copper is beaten into sheets and tinted with the gall of a bull it resembles gold and since it is used in crowns that are worn by actors it is called *coronarium* copper. When one-sixth ounce of gold is added to an ounce of this copper a thin sheet burns with a flame the clear red color of pyrope garnet. Copper objects such as nails are shattered by the force of cold. Eratosthenes tells of a copper jug which a priest named Stratius placed in the temple of Aesculapius near Panticapaeum and was broken by the

[13] Lebetezkupfer.

cold. When a projecting piece of the metal is struck it makes a sound because it is hard. Copper makes a black mark on wood. When rubbed on a whetstone, Samian earth or similar hard substances it leaves its natural color. When in a solid mass it sinks in water while thin sheets will float. Silver is present in almost all copper although that produced in the Moselle District near Herstein is almost free of silver. Copper often contains imperfections they call *aerugo* especially copper that has been exposed to acid solutions. Pliny is correct when he writes that copper which is rubbed clean draws rust to itself more quickly than that which is neglected and it is recognized that the metal is best preserved in liquid pitch.

Many more things are made from copper than from silver since it is cheaper. Money, tablets upon which public regulations are engraved, goblets, basins, vessels of many kinds used in baths, kitchen utensils and the vats in which malt liquors are cooked are made from copper. It is used in ladles, tanks, ovens, dining couches, gaming boards, pedestal tables, shafts, small table tops, thresholds, doors, folding doors, lamps, candelabra, lamp stands, three-legged stools and statues of deities, animals and men. It is used in statues of horses and other large statues. The shields of the singers of the Salii are made of copper from Mamurius.[14] The heifer of the sculptor Myro was of copper as well as the horse by Domitius and the bull of Phalaris. The hundred gates of Babylon were famous as well as the columns of Hercules in Cadiz that were twelve feet high. The people of Sparta gave Croesus a copper punch bowl with a capacity of seventeen gallons. The manger of Mardonius was of copper as were the horses by Durius and the lioness in Athens. In the center of Athens near the statue of Minerva were copper spheres that were used by athletes to test their strength. The Romans and Greeks erected a great many statues of this metal and the casting of them made many men famous, especially among the Greeks. I shall not discuss these statues since Pliny has mentioned almost all of them. However I shall mention some others. In Taenarum there was a statue of Arion of Methymna together with the dolphin that caught him up and carried him on the sea. In Athens were statues of Harmodius and Aristogiton who tried to protect the Athenians from tyranny. There was a statue of Jupiter in Peribolus and another in Sparta. All of these must have been very old as Pausanias the Laconian believed. Seutonius writes that Caesar Augustus erected a statue to Antonius Musa, a physician, close by the statue of Aesculapius. The ancient peoples often used copper arms, not only the Greeks, Persians and Phoenicians but also the Romans under Servius

[14] The Salii were leapers, a college of priests of Mars, instituted by Numa. Their sacred processions accompanied by singers and dancers carrying shields took place annually in the beginning of March. A shield was believed to have fallen from Heaven during the time of Numa and the safety of the Roman Empire was supposed to depend upon its preservation.

Tullus. Copper scale armor is made, even today, by the Persians. Not only did the ancient peoples use copper arms but also various instruments for cutting such as the ax mentioned by Sextus Pompeius Festus that was used by the priests in Acerra in sacrificial rites.

There are four ancient folding doors in Rome. One very fine door is in the temple of St. Mary, formerly a temple of Jupiter. Another is in the Temple of St. Adria, formerly the temple of Saturn. A third is in the temple of Sts. Cosma and Damian that was formerly sacred to Castor and Pollux. The fourth is in the temple of St. Agnes on the Numentana Way beyond Viminalis. This door was taken from the temple of Bacchus. Recently it has been removed to the church of St. Peter in the Vatican. There are four pillars in the church of St. John Lateran, one of them with only a small capital. Augustus took these from the plunder of Egypt. Because of that Virgil writes, "Pillars rising from copper." There are six old candelabra in the church of St. Agnes that were brought from the temple of Bacchus. Around the bases are birds with human faces and heads of rams and boys collecting grapes. There is a copper equestrian statue of Antoninus in Rome. In Naples there are statues of Scipio, Mutius Scevola, Deianira with the boy Hillus, Hercules, Jupiter throwing lightning, Mercury, and Venus. These were erected by Hadrian Guilielmus. The church of St. John, called the Baptist, in Florence, has three folding doors covered with gold. Some great buildings have copper roofs such as the castle of Prince Perlinus of Brandenburg; temples such as that of St. John in Magdeburg, Saxony, and of St. John in Luneburg and in Cervecius; churches in Annaberg, Misena, Gerlich, Lusatia, and Stukard, Swabia. There are copper towers such as those on the senate building in Schemnitz; the church of St. Thomas in Leipzig, of St. Peter in Freiberg; and on the fortified city of Dresden. There are three towers at Neuenburg, Thuringia, one within the city and two on a church outside. All of these are colored green except those in Schemnitz.

Refined copper is used in medicine. Since it has a certain acridness and, at the same time, is astringent, water in which copper has been washed will reduce the scar from ulcers and leave the flesh soft while ulcers that are not so washed leave the flesh hard.

Plumbum follows. There are three genera, one white (*plumbum candidum*, tin), one gray (*plumbum cinereum*, bismuth), and one black (*plumbum nigrum*, lead). The Greeks call the white κασσίτερος; the black μόλυβδος. Both the Greeks and the Latins did not know of the gray that we call *bisemutum*. Pliny called the white genus *argentarium* because it is similar in appearance to silver and he also used the name *album*. This metal is truly white, so white that when it was compared with the third genus by the Romans the latter appeared to be black. The former can also be distinguished from the latter by its "voice" when the latter is not black but dark gray. The second genus is intermediate in color being blacker than tin and whiter than lead. Hence, if one does not care for the

German name he is at liberty to call it *cinereum*, just as the Romans called the third genus *nigrum*. Although tin may never be found as a metal with its true color the black pebbles from which it is smelted differ from it only in color.[15] Galena (*galena*) is sometimes found with so little stone that it is almost pure lead.[16]

Bismuth is recovered from the ore of a mine at Schneeberg named Bisemutaria. It is common in silver mines. It often escapes the notice of the unskilled miners or anyone who does not look for it carefully. On the other hand a man may think he has been mining argentite when actually he has mined bismuth. Sometimes it contains silver and this material should not be thrown aside. When silver is removed from it the bismuth is entirely consumed in the fire. When not pure it is found in three forms. It may occur in large masses, in small masses with a black luster, and in thin sheets on stones, marbles or rocks. Even though we do not find metallic bismuth the ores from which we recover it come closer to it in color than is the case with the other two metals.[17]

[15] This refers to the tin oxide mineral, cassiterite, that contains seventy-nine per cent tin.

[16] Galena, lead sulphide, contains 86.6% lead.

[17] Agricola makes the following reference to bismuth in *Bermannus*, page 446,–

Bermannus. "Before leaving this place I wish to call your attention to a certain genus that belongs to the metals and which, I believe, was unknown to the Ancients. Our miners call it *bisemutum*.

Naevius. "Then you believe that there are more than the commonly accepted seven genera of metals?

Bermannus. "I am of the opinion that there are more for this metal our miners call *bisemutum* you cannot correctly call either tin or lead since it differs from both and is therefore a third metal. I will not mention the other ways in which it differs from these two since you can see that tin is whiter and lead darker.

Naevius. "We see that it is similar in color to galena.

Ancon. "How then can one distinguish bismuth from galena?

Bermannus. "Easily. When you handle it, it discolors the hands unless it is quite dense. The dense material is not as friable as galena but is sectile. It is somewhat blacker than a genus of silver mineral which we have said is almost the color of lead and hence can be distinguished from these two. It often contains some silver. Wherever it is found it indicates that silver occurs beneath it and for this reason our miners are accustomed to call it the 'roof of silver.' It is commonly roasted and from the richer portions they produce a metal, from the poorer, a pigment that has some value.

Naevius. "Can they make vessels from this metal as they do from the other two?

Bermannus. "They can. They make very fine goblets by adding a certain quantity of bismuth to tin.

Ancon. "Certainly among the Arabs whose alchemists, at different times, were the most diligent of all in imitating the Greeks, I know that no mention was ever made of this metal. For that reason I am convinced that it is to be found in very few places.

Bermannus. "If the alchemists, especially Greek and Arab, have not mentioned it among the six substances they recognized nor among the spirits or inanimate objects, I would not expect to find it mentioned in the writings of the older philosophers or doctors."

Tin is naturally brilliant and polishing makes it even more brilliant. Bismuth is less brilliant and lead, least brilliant of all. Tin is more perfect and more valuable than lead and for that reason chemists use their art to convert lead to tin. Bismuth holds an intermediate position. All three can be cast with ease. Before the metal takes fire it melts. None lasts and maintains its true appearance in a large open vessel but changes in part to litharge, in part to *molybdaena.* Lead is soft and can be hammered with ease and made into sheets. Tin is harder and bismuth the hardest. Tin is tenacious, lead fragile and bismuth the most fragile. Lead gives no sound, bismuth gives a sound while tin creaks. Tin is light, lead heavy, and bismuth intermediate in weight. The vapor of acid produces *cerussa* from both tin and lead by corrosion. That made from tin is called "spanish white" (*album hispanicum*) while that made from lead retains the name *cerussa.*[18] They make a variety of artificial *minium* from lead by burning it and I shall speak about this later. Tin contains less moisture than lead and for that reason they can make objects with ease from lead-tin alloys that can be made only with difficulty from tin-bismuth alloys that contain no lead. Small particles break away from these objects and often leave them with many holes. They make many types of goblets that have pleasing tones, plates, dishes, spheres, vinegar cruets, small drinking cups, salt cellars, various small vessels such as bowls, wash basins, boat-shaped bowls and pots from tin-lead alloys and sometimes from tin-bismuth alloys.[19] Some important buildings, towers and churches are covered with this same material as can be seen in a town called Zuicca in Misena. The bottoms of baths are sometimes covered with it. In the latter case they first spread a layer of sand and cover this with a floor of boards to which the metal sheets are fastened. Those intruments of churches that are called organs are skillfully made from this alloy as well as the candelabra used in some churches.[20]

Goblets are rarely made from lead. It is commonly used for bullets and

[18] Today the name spanish white is usually given to bismuth oxide.

[19] This refers to pewter.

[20] Agricola makes the following reference to tin in *Bermannus,* page 450,—

Bermannus. "We know that lead which the Greeks call μόλυβδος is smelted from galena and pyrite just as tin which the Greeks call κασσίτερος is smelted from small black pebbles containing white streaks. We have never seen nor heard of it being found pure in veins.

Naevius. "What you call *plumbum candidum* (tin) both the learned and ignorant today call *stannum* (an alloy).

Bermannus. "Evidently they have taken the name from the Latin yet it appears to me to be some other material.

Naevius. "You support Pliny's conclusion.

Bermannus. "Also those of others who believe as I do. But we shall say more about these others. The black pebbles from which we smelt tin are found of an exceptional size at Schlackenwald and Irberesdorf, not far from your home, Naevius. I believe that you have seen these mines.

Naevius. "I recall having seen them.

Bermannus. "I have been able to observe how they are found, especially in these two places. . . . They usually occur mixed with other materials, commonly pyrite

water pipes. It is used in making the rectangular tanks in which salt is obtained from salt solutions; soda from soda solutions; alum from aluminous solutions; and *atramentum sutorium* from solutions of *atramentum*. It is used in the lattices in which are set the glass disks to make window panes for transmitting light. Thin sheets are used to roof prominent buildings, churches and towers. Within the year thirty-five buildings in Magdeburg have had lead roofs put on them, the church of St. John being among them. The weight of a solid lead roof on this church would have been too great so alternate strips of lead and copper were used. The towers of the church in the convent of St. Mary were also roofed with lead. When the bottom of a goblet made from tin is coated with molten bismuth it will not change the color of wine.

Of these three metals lead alone is used in medicine. It cools and for that reason mortars and pestles are made from it and if liquids are rubbed in these so that there is a union with the lead solutions are produced that are more cooling. Sheets of lead are advantageously spread beneath the loins of athletes who, because of frequent exercises are harassed by dreams of beautiful women and discharge semen. Having been bound around the testes it drives away such dreams. Burnt lead has mixed properties and cures chronic ulcers. A cooling lotion is made from it. It is most useful in filling ulcers and preventing scars. It can be used to advantage on both hard and cancerous ulcers, sometimes by itself, sometimes mixed with other drugs which prevent scars, for example, the drug made from *cadmia*.[21] Galen is the authority for these statements.

There is a fourth genus in this group that is obtained from stibnite (*stibi*) when smelted.[22] The stibnite is placed in large vessels over a fire and purified and reduced to a metal that has the appearance of bismuth. Dioscorides describes a method to be followed in burning it in order not to produce *plumbum*. This metal is added to bismuth and the letters with which they print books are cast from them after they are melted together.[23,24]

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and a sandy genus of rock. Each mineral can be readily distinguished by eye and sometimes they are seen to be well mixed. The black pebbles are separated from this mixture by drying, crushing, grinding, washing, and again drying. They then smelt the tin. Certainly this metal requires more preparation than any other.

Naevius. "After hearing all this the next time I return to my home I shall study their workings more carefully than I have up to now."

[21] Probably zinc oxide.

[22] It is obvious that Agricola had no knowledge of the Latin name for this metal, *antimonium*, that had been used by alchemists for many years.

[23] Modern type metal is essentially an alloy of lead (80%) and antimony (20%). It is probable that Agricola knew this and bismuth is a text error for lead.

[24] There is the following reference to stibnite in *Bermannus*, page 464,—

Naevius. " . . . Stibnite is not found in metallic mines?

Bermannus. "I do not know that it is found in these silver mines but it is found occasionally in the mines of Persibrana so mixed with silver that it can only be separated by smelting. It is often abundant in separate veins in various places, especially at Fichtelberg in the mountains that are the source of the Moenus, Sala, Egra, and Nabus rivers, and eleven miles from Plana, Bohemia."

I shall now take up iron (*ferrum*). None of the older writers mentions it as being found native. However, on rare occasions, it is mined or found in river sands with its characteristic color. It is not entirely pure as compared with the black pebbles from which tin is obtained since the latter are purer and require less smelting than small masses or fragments of iron. Albertus knew of this for he writes, "Iron is found in watery earth similar to millet seeds and having a large amount of dross."[25] Rough iron is black, polished iron grayish white. When smelted from its ore it liquefies and can be cast. After it has cooled and the slag has been removed it is heated in a fire and softened so it can be hammered into sheets although it cannot be cast. Yet if it is again placed in the proper furnaces it can then be cast.

All iron is hard and because of this produces the clearest tone of all metals. One iron will differ greatly from another. The best is tough, intermediate varieties are moderately tough while inferior varieties are brittle and full of air. The iron from Sweden, Norway, and Noricum is the best. Iron of intermediate quality comes from Lauenstein and Gishubelan, Misena, and Sulcenbach in the mountains of Noricum beyond the Danube. The iron the Greeks call *στόμωμα* and the Romans *acies*, if I am not mis-

[25] Agricola refers to iron in other writings. In *De Ortu et Causis Subterraneorum*, page 79,

"I shall now consider the strength of metals. They all melt because they contain water. Iron contains an exceptional amount and for that reason is more ductile as is indicated by the name of Swedish iron, *osemutum*. Unrefined iron is not so ductile because it contains so much earth and because there has not been a good mixing of the earth and water. However it is soft because the humor no matter how small the quantity, set free by the fire commences to be dissipated."

Page 77,

"A mass of iron weighing fifty pounds fell near Lurgea and because of its hardness could not be broken. A portion of this mass has been sent to the King of Torat. He ordered that swords should be beaten out of it but it could neither be broken nor beaten out. The Arabs say that the German swords, that are the very finest, are made from this kind of iron. Avicenna writes that the Arabs allowed this deception by the merchants themselves. The iron used by the Germans does not fall from the sky but is dug from the earth. But yet Avicenna tells us that both iron and copper fall like rain. He relates that in the Roman annals, mention is made of rains of earth and of stones and we have seen it rain yellow earth several times in the fall. It is not extraordinary for all of this material to be created in the air from time to time for in no other place do we find a more sudden mutation of the elements nor more violent reactions."

De Veteribus et Novis Metallis, page 391,

"Certain metals take their names from countries. . . . Iron, especially the variety *στόμωμα* (steel), is called *chalybs* by many because the Chalybes made the first iron."

Page 412,

"Iron mines are found almost everywhere. Strabo writes that the ore is found on the hills of Britain and Pliny mentions it from northern Spain and all parts of the Pyrenees as well as on the Cantabrian coast where, he says, some of the incredibly high steep mountains are composed entirely of iron."

taken, is made from iron that has been melted several times and thoroughly cleansed of slag. Such iron comes from China, Pathicum, Noricum, Comensis and Spain. In one locality iron changes into steel because of the quality of the ore, as is the case today in Noricum, while in other localities it is changed because of the water in which the iron is quenched as at Como, Italy, and Bilbao and Turassio, Spain. Steel commands a higher price than other varieties of iron because the more often it is cleansed the more volume and weight it loses. Iron contains a defect they call *ferrugo* (scale) and *rubigo* (rust) produced at first through contact with moisture and more quickly through contact with human blood. This defect is produced the quickest by sea water and iron is protected from it by coating it with many substances such as artificial lead oxide, *cerussa*, gypsum, bitumen, and liquid pitch. Unless it has been hardened by hammering it breaks more easily when heated to a red heat.

More things are made from iron than from all other metals. It is used in money; in rings worn by the Spartans; in chains worn by the Spanish women; in large bowls such as those at Delphi that were the work of Glaucus of Chios and placed there by Alyattes, King of Lydia; and in statues such as the one in Laconia, the work of Theodorus Samius. It is used to make nails, door hinges, bolts, keys, lattices, doors, folding doors, spades, staves, small forks, hooks, tridents, three-legged stools, anvils, hammers, wedges, chains, hoes, axes, scythes, baskets, shovels, planes, rakes, ploughshares, pitchforks, dishes, spatulas, platters, spoons, spits, knives, poniards, swords, hatchets, ferrules, weapons, long Macedonian pikes, and various weapons that are known by names derived from their origins, for example, pikes, javelins, murices, corselets, helmets, breastplates, greaves, foot shackles, manacles. So much concerning iron and other simple metals that either occur pure in Nature or are purified by refining.

Now may I speak about the metal alloys that are found native in mines and are also smelted from ores. Nature mixes metals in various proportions. Sometimes a third, fourth, fifth, or even sixth part of one metal will occur in another, more often there is even a smaller quantity. Two, three, four, or five metals may be mixed together. Two metals may be mixed in many ways. Silver is alloyed with gold and gold with silver; gold or silver with copper; silver, copper, or iron with one of the *plumbum* metals; and silver, copper, or one of the *plumbum* metals with iron. Another metal is sometimes mixed with tin or iron but any other metal except silver is rare in bismuth or lead. With the exception of two alloys, all of these lack names. One alloy is called *electrum* (electrum) and is a mixture of one part of silver in four of gold. The other is called *stannum*, an alloy with one part of lead in two parts of silver.

In former times they used *electrum* in making goblets because they would show the presence of poison. Pliny writes that when a poison is placed in one of these goblets a rainbow forms, similar to the rainbow in

the sky, accompanied by a fiery hissing thus giving warning in two ways. There is a goblet of this type in the temple to Minerva in Lindos, a town of Rhodes. Homer writes that Menelaus wore a ring made of *electrum*.

The finest mirrors are made from *stannum*.

In this same fashion, Nature sometimes mixes three metals, for example, gold, silver and copper, and at other times four, silver, copper, tin and bismuth. Having been instructed by Nature we also mix metals in this fashion. Not only does Nature teach us the correct proportions to use in the alloys but we also learn through accidents to imitate Nature. For example, in a fire at Corinth gold, silver and copper were melted together and by good fortune combined in the correct proportions of the three varieties of Corinthian copper. One of these is white and, as Pliny writes, approaches closest to the appearance of silver when that metal is the dominant one. Another is as yellow as gold. The third has the three metals in equal proportions. Art and fraud imitate Nature through mixing metal with metal in various proportions. The Greeks call this correct proportioning κράματος, the Romans *temperatura*. Two, three, or more, simple or complex metals may be mixed together. A simple metal may be mixed with a complex, a complex with a simple, two simple with one complex, two complex with one simple, and many simple with one or two complex metals and vice versa. The proper proportion of these metals varies since sometimes a base metal is mixed with a precious metal and vice versa. One should examine every alloy to determine whether it may be of any use at present or at some future time. It may have neither a present nor future use or it may have a future use and be of no present value or it may have a present use and be of no use in the future. Next one should consider what use each may or may not have. It should be examined to determine if it is a fraudulent or artificial alloy. Finally one should determine what name the Greek or Roman writers have given it or if it lacks a name.

First we shall consider gold that is mixed in various proportions. All these alloys lack names except that with one part of silver to four parts of gold which we call *electrum*. Certain men make a practice of mixing a small quantity of some base metal with a large mass of precious metal, not to make a legitimate alloy but to make a profit. They admit this to be a crime since they do their work in secret. Mention could be made of the fraudulent contractor to whom Hiero of Syracuse gave a contract to make a crown. As he made the crown he substituted silver for some of the gold. This theft was finally detected by Archimedes. On the other hand kings and princes protect the worker who substitutes silver for gold in making coins since they say they have the legal right to make money that is not pure gold. Flavius Vopiscus writes that the Emperor Tacitus, in a speech before the senate, ordered that it be considered a capital crime for anyone to mix copper with silver, silver with gold, or lead with silver, either publicly or privately and offer it for sale as pure metal. This just and good

emperor wished to have every opportunity for fraudulent practice brought under the law. We do not know if it is customary to mix other metals with gold or whether it was customary in the past.

We shall now consider silver. The artisans who coin silver have mixed copper with it at various times and continue to do so today by various methods that I shall discuss in a book I am going to write, *De Precio Metallorum et de Monetis*.[26] Both coin and bar silver usually contain some copper, commonly one and one-half ounces of copper to eight and one-half ounces of silver. Silversmiths make every effort to add as much copper to their silver as the law will permit. The ratio of copper to silver is not universally the same. Some may add more or less copper and chemists sometimes plate copper with silver and sell it as pure silver although this fraud is a capital offense equal to that of the men who coin money and depreciate the silver by adding a large proportion of tin and even iron. The denarius of Antonius was depreciated in this manner according to Pliny.

I shall now consider tin which is more valuable than copper. According to Pliny one part of copper was added to two parts of tin in making an imitation of *stannum*. We do not use this alloy. Today tin smelters usually add one part of lead to nine parts of tin and use this alloy to cast non-malleable articles of different kinds such as small dishes, goblets, plates, platters and spheres.

Two pounds of lead are often added to one hundred pounds of copper. When the copper is finished in the hearth and the carbon is pushed back the upper part will be stiff although the surface is still soft. The copper refiner then seizes the lead with his tongs and pushes it through the surface to the center of the mass so that it will be taken up by the copper. This makes a softer copper and coppersmiths are more willing to work with it than with copper that contains no lead. Some people have added lead to copper, as we learn from Flavius Vopiscus, and made copper coins that were valueless. Antonius mixed iron with copper. Such frauds have been perpetrated by many men. On the other hand, Pliny praises the art of the famous Aristonides who, when he wished to portray the fury of Athaman wishing to destroy his son Clearchus and having destroyed him being overcome with remorse, mixed iron and copper so that the rust of the iron showed through the luster of the copper thus portraying the red blush of shame. Thus a small quantity of a base metal is mixed with a large mass of precious metal in so many ways. From all of these frauds men make money but this is ultimately taken away. On the other hand Aristonides made an alloy from which art has profited.

There is no law to prevent the alloying of a small amount of precious metal with a large amount of base metal. It is no crime to mix a pound of

[26] *De Precio Metallorum et de Monetis* was first published in three books in 1550 at Basel, together with *De Mensuris et Ponderibus*. It treats of the value of money and metals, their weights and impurities.

gold with a hundred pounds of silver, merely a foolish practice that results in a loss of money. A similar practice is to mix a pound of silver with a hundred pounds of tin or copper. There are four alloys belonging to this genus. One contains tin alloyed with copper. Pliny describes this alloy. *Ollaria* is the latest name to be given it, the name being derived from a vase. Three or four pounds of tin are added to one hundred pounds of copper. A second alloy that does not differ greatly from this is called *bombardaria*, a name taken from a new although foreign word since this is a new thing. The name comes from the large ordnance (*bombarda*) made from it. Amazonae, basilisci, lusciniae, quartanea, dragons, serpents, and falconets, both large and small, belong to this class of ordnance. To make this alloy one pound of tin is added to twenty pounds of copper.[27] A third alloy is made by adding a half pound of bismuth to sixteen pounds of tin. This alloy rings and is usually hammered into platters, plates and dishes. The English commonly add more bismuth and make articles from it that closely resemble silver. The fourth alloy is made by adding one part of tin or bismuth to two parts of lead. In olden days this was used to join pipes and was called *stannum tertiarium*. There is another alloy containing equal amounts of two metals, usually tin and lead. In the time of Pliny they called this alloy *stannum argentarium*. Today it is sometimes used in making goblets, dishes, platters, circular vessels and similar objects. In general, these are the five ways in which they alloy two simple metals.

There are three alloys containing three metals, one new and two old. Pliny writes, concerning the old alloys, that one was copper, gold and silver but writes that it had become obsolete because of the casting of more valuable copper. He describes the other in these words, "Until now it has been called *temperatura* and has the form of very delicate copper because a tenth portion of lead and a twentieth portion of tin are added." This alloy can be colored with ease and is then called *graecanica*. The new alloy is made by mixing ten pounds of tin, five pounds of lead and two pounds of bismuth. Some add copper to the lead and bismuth in varying quantities. Tinsmiths hammer this alloy into different objects. I have found no mention of more than three simple metals being mixed together nor one or more mixed metals being alloyed with another mixed metal. However, a simple metal may be alloyed with a mixed metal, for example, tin with *stannum tertiarium*. Pliny writes, "the alloy made from equal parts of *tertiarium* and tin is looked upon with disfavor."

Enough about simple metals and their alloys. In the following book I shall discuss the coloring of these metals, the crude ores, and the artificial metals.

[27] This would be a variety of bronze.

BOOK IX

Nature may tint metals with a color that is foreign to them. The true color of copper is red yet sometimes it occurs yellow. The Greeks call this ὀρείχαλκος. Sometimes copper is white and this is called ψευδάργυρος. The latter has the appearance of silver, the former the appearance of gold. Pliny writes that the yellow copper has a characteristic and pleasing beauty by day. Strabo writes that the white copper was made in Teuthrania near Andera and in Lydia near Mt. Tmolus. Copper can be colored artificially to imitate nature.

Native *cadmia*[1] is added to copper to make brass (*orichalcum*). According to Pliny at one time Livian copper was used chiefly in making brass and later, Marian copper. Brass is made in the following way. Alternate layers of the best broken copper and *cadmia* are placed in a tall crucible. When it is full it is lowered into a furnace in a space that has been hollowed out and is fired as if it were in a covered passage. When entirely melted, the copper is changed into brass with the color of gold. This is the common method. By another method sheets of copper three-quarters of an inch wide are placed in a crucible similar to those used in casting silver but having the outside covered with a clay containing iron scale and the inside covered with the most highly refined honey. The thin sheets of copper are also coated with honey. They then sprinkle over the copper a very fine powder consisting of native calamine, dry dregs of wine that they call tartar (argol) and charcoal in equal amounts. The crucible is covered with an earthenware lid with a hole in it. A rod is thrust through this hole and used to stir the molten copper. The lid is sealed to the crucible with the above mentioned clay. The crucible is then placed in a furnace similar to those used in a mint. When the calamine mixes with the copper it first gives off a red flame, then a flame that is part red, part blue and finally a yellow flame that indicates the mixing is completed. Then the crucible is removed from the furnace.

They make many things from brass but most commonly basins, candelabra, lichnuches, and siphons. These articles are more valuable when made from brass than from copper since they have the same hardness and a more pleasing golden color. Brass, like copper, can be whitened with powdered *gypsum* that occurs in crusts until it has the appearance of silver. Copper so whitened is pleasing and esteemed and for that reason is made into goblets. Copper is also whitened in the following manner.

[1] The literal translation is calamine. This name is given in the United States to the natural hydrous zinc silicate and in England and Europe to the natural zinc carbonate. To eliminate this confusion it has been proposed to use the name calamine for oxide zinc ores in general and call the carbonate smithsonite, the silicate hemimorphite. Under *cadmia* Agricola included not only the natural zinc oxide minerals but also artificial oxides.

Two ounces of artificial white arsenic and an equal amount of *halinitrum* are placed in an earthenware flask and sealed, after which it is placed on a charcoal fire and heated for an hour to allow complete mixing. One-half ounce of this powder, one-half ounce of sublimate of mercury and one-fourth ounce of argol that has been reduced to a powder over a fire are mixed together. Then molten copper is allowed to flow into a silversmith's crucible that has been prepared for it. The rest of the powdered arsenic and *halinitrum* are thrown into the copper and it is stirred rapidly with a rod until purified. When this is completed one part of the second powder is added to four parts of the purified copper and thoroughly mixed. Finally the copper is poured into honey and allowed to cool. This produces white copper.

Iron also can be tinted an alien color. It can be made the color of copper when covered with acid and *alumen* or *atramentum sutorium*. There is nothing extraordinary about this.[2] At Smolensk, a town in the Carpathian mountians in that part of Hungary that was called Dacia at one time, water is taken from a certain pit and poured into canals that are grouped in series of three. Pieces of iron laid along these canals are turned into copper.[3] Very small pieces of iron that are placed at the ends of the canals are eaten by the water in such a fashion as to give the iron a yellowish color. This copper is refined in a furnace. Water similar to that mentioned above also drops from veins filled with minerals that are joined by a natural relationship to *atramentum sutorium* and from which the latter is produced as I have mentioned elsewhere. Old water that has been used to part silver from gold changes iron into copper because it is made from *atramentum sutorium*. Artisans can cover a base metal with a precious metal so that the object made from the base metal becomes beautiful and pleasing. In this manner copper, silver, brass and iron are gold plated and copper and brass silver plated. In the same manner iron is plated with silver and *stannum* and especially with *stannum argentarium* and tin. The methods by which these valuable objects are produced should be mentioned.

Silver is gold plated by three methods. Gold foil may be placed on thin sheets of silver and hammered until the two metals are firmly bonded. Another method is to take a piece of silver about three-quarters of an inch thick and weighing about four ounces and place on it two denarii of gold and then beat the two metals until they are flattened very thin. Objects made from these gold plated sheets are worth more than double the price of the same object made from gold since the gold is not worn away so rapidly through use.[4] These gold plated silver sheets are used to make the gold and silver leaves placed as ornaments on the silk nets worn by women and which sparkle so brilliantly when the head is turned. Oblong and circu-

[2] A method of crude copper plating.

[3] This method of precipitating copper from mine waters is widely used today.

[4] This alloy would correspond, roughly, to seventeen carat gold.

lar leaves three-quarters of an inch wide are made from the thick gold plated sheets. These leaves are fastened to bands and worn around the head by young girls. Thin sheets are not used in the third method of plating silver. Quicksilver is used and although the method was known to Pliny he did not describe it. Today the following method is used. An eighth of an ounce of gold that is quite pure or contains only a very small amount of silver is beaten out into a thin foil three inches long and two inches wide. After the foil is cut into small pieces and placed in a crucible three-quarters of an ounce of quicksilver is added. The mixture is poured into another crucible lined with chalk and then heated over a charcoal fire. It is placed in the fire with a pair of tongs and left until all the gold has been dissolved in the quicksilver and no flash of gold can be observed. When finished the quicksilver is poured into the shell of a marine scallop that has been filled with water. After it has cooled the water is poured off and the quicksilver left in small particles similar to wheat meal and can be picked up with the fingers. This is then spread over the silver object that is to be plated using an iron instrument. Before applying the quicksilver, the silver object is heated in a charcoal fire and quenched in water in which argol and salt have been boiled in order to make it white. After this it is cleaned by brushing with brass wires that have been bound together, although it has already been cleaned by quenching. After the quicksilver has been applied the object is exposed to the fire a second time so that it will take the mixture. During the heating the mixture is spread evenly by brushing it with pig bristles that have been bound together. Eventually the quicksilver is driven off by the heat of the fire and the gold remains. If any part has not received sufficient gold more quicksilver can be added to the area and it is heated and brushed a second time.

Copper and brass can be gold plated in a similar manner. Iron and the steel the Greeks call στόμωμα, as I have said, is first polished and then smeared with wine in which has been boiled one part of argol, one-half part artificial sal ammoniac, one half part verdigris and a little salt. Usually it is brushed with pig bristles that have been dipped in the wine. After drying it is plated with the same mixture of gold and quicksilver, using the same method as that for copper and silver. Enough concerning gold plating.

Copper and brass are silver plated in the following manner. Argol, alum, and salt are first ground to a powder. Then thin silver foil is ground on flint with this powder and the mixture placed in a jar that has been coated with litharge or molten lead. After water is added the article to be plated is placed in the mixture and the jar warmed. After warming for some time the article is removed and brushed with pig bristles to determine if it is plated satisfactorily.

One metal is coated with another metal in the following manner. Copper, brass or iron that is to be coated with silver, *stannum*, *stannum argentarium*, or tin, is first rubbed with vinegar in which artificial sal

ammoniac has been dissolved. It is then placed in molten silver or one of the metals or alloys mentioned above. If left in the molten metal for a short time it becomes covered with it. Copper workers, in order to avoid the expense of making sal ammoniac, cover the inside of copper vases with pitch and pour the molten tin over them until they are covered. Similarly, iron workers add tallow to the molten tin and then, after polishing their object, coat it with the tin without rubbing it with vinegar and sal ammoniac or coating part of it with pitch. Verdigris does not form on brass that has been coated nor rust on iron. The advance of copper and iron rust is checked by the metals with which the objects are coated. This method of coating is not only seemly but very useful since it prevents flaws and gives a more pleasing taste to liquids that are placed in them. Enough concerning these things.

Artificial metallic substances that do not have the appearance and form of metals follow. These are made either within or outside furnaces. They form within the furnaces when ore is smelted or when one metal is separated from another or when copper is melted in a furnace and alloyed with other metals. When metallic ores are smelted in the first furnace many metallic substances are produced, namely, slag, stone, *diphryges*, *cadmia*, *pompholyx*, *spodos*, and *flos aeris*. When one metal is parted from another in the second furnace whose large shallow crucibles for separating the metals are called by our people *foci*[5], litharge, *plumbago*, and *spodos* are the principal materials formed. When copper is alloyed or refined *pompholyx* and *spodos* are produced.

Metallic substances are produced outside of furnaces from metals either mixed with acid and finely powdered, producing verdigris, *caeruleum*, or *cerussa;* or having been set on fire, producing *ochra plumbaria*, or *minium;* or driven to the top of a vessel, producing sublimate of mercury as the chemists call it, or sublimate of *cadmia;* or by a certain special process, producing *cinnabaris*. Finally some metallic substances may be hammered from metals such as scales of copper and iron.

Metallic substances may be produced from other metallic substances either in Nature, such as native minium, or artificially, such as artificial minium, or by both methods, such as *psoricum*.

I shall treat first slag which the Greeks call σκωρία. It is the excrement of metallic ore that has been refined in a furnace. It separates from the molten metal as the latter flows from the furnace into a crucible. The slag of silver, since it is usually drawn out into long threads when it is removed from the crucible with hooks is called ἕλκυσμα by the Greeks. The slag that is formed in smelters where copper is separated from silver acts in this same fashion. Slag forms from ores of gold, silver, copper, tin, lead, and iron but not from ores of quicksilver and bismuth since these ores are not smelted because of the ease with which the metals can be extracted

[5] From the word for hearth.

from them. After the metals have been removed from the latter ores the stone remains having been changed only slightly by the heat of the fire. We do not deny that slag forms from bismuth ore when it is smelted with silver ore. All slag is heavy when it first flows from the furnace because it contains some metal. After the slag is refined, as it usually is, it becomes lighter through loss of the metal. A second and third refining will make it still lighter. Tin slag is the lightest of all, especially after it has been refined for the third time. Slag is usually full of holes as if eaten away and the heavy ones are the most porous. It is usually black although that produced in refineries where silver is separated from copper is variegated and lead slag is light yellow. Some from the lead ore of Goslar is white, the color having come from the argentiferous pyrite in the ore. All have a good luster but only the thin lead slag that is tinted yellow like glass is transparent. All have the power of drying while that from iron is especially strong. When drunk with vinegar it counteracts aconite poison.

Disks of stone, that is, slag, are taken from crucibles either with or without metal in the bottom part. The Germans call this stone by a name of their own[6] just as the Greeks call it λίθος. This stone commonly has a metal or metals mixed with it. The disks are broad at the top, tapering at the bottom and about an inch thick. *Diphryges* is made from these. There are four genera, all obtained from a stony cupriferous material that has been dried, burnt or smelted. The first genus comes from a mud taken from a certain cave in Cyprus. This mud is first dried and then burnt by surrounding it with brush. The name *diphryges* comes from the Greek meaning twice burnt, that is, once by the heat of the sun, once by the heat of fire. Dioscorides writes that it is produced only in Cyprus. Another genus resembles a certain sediment and is the excrement from copper smelting. After the molten copper flows from the furnace into the crucible this remains. It was found by Galen in Cyprus spread on the streets and between buildings used for storing metals. The smelter director said that after the *cadmia* had been taken out the material was valueless and similar to the ash left by burning wood. The third genus is obtained from cupriferous pyrite that artificers place on a hearth and then burn, just as they would lime, until it is completely changed to the color of red ocher. It is then removed from the hearth and preserved. It is also obtained from a cupriferous stone that is first dried in the air and then transferred to pits where it is burned. The *diphryges* forms around the sides and on the bottom. The fourth genus is obtained from stones called *orbes*. If these have resulted from the smelting of pyrite they only need to be dried twice or at the most three times but if they are natural stones they first must be dried in the air, then smelted in a furnace and finally burned five times in another furnace so that the material can be called properly ἑπταφρυγής. Even with all this treatment it still lacks the qualities of true *diphryges*.

[6] Stein.

The best material of the fourth genus has a purplish color while the poorest quality is gray or blackish. The second genus is black, the others reddish. When moistened *diphryges* changes to the color of copper or becomes blue. All genera have a copper taste. They have mixed properties. Some is moderately acrid and astringent and hence is used as a cure for recurrent ulcers. At one time burnt ocher was sold for reddish *diphryges* according to Dioscorides but this fraud can be detected readily by taste since ocher never has a copper taste. *Diphryges* takes up *cadmia* in furnaces by settling, according to Galen. This latter is the portion of the metallic material that pours out from the furnace, as long as the ore is being smelted, through the force of the flame and blast.

Although *cadmia* is produced in furnaces in which gold, silver, and lead ores are smelted the best is produced in copper furnaces from pyrite and native zinc ores. That produced from other kinds of copper ores is never abundant and is not as good as that from pyrite ore that contains some lead and silver. There are four species of *cadmia* but many more names. When the dense part of the charge is poured from the furnace the *cadmia* congeals in a mass on the walls after *diphryges*. If an abundance of material is smelted the crust is thicker than when a small amount is smelted. Crusts of this material form whenever ore is melted in a furnace. When the crusts are thick the furnaces have to be cleaned more often than when they are thin. When these masses resembled crusts the Greeks called them πλακῖτις, when banded ζωνῖτις, and when veined, similar to onyx and hence variable in color, ὀνυχῖτις. When broken *cadmia* is found to have alternate white and gray layers while the surface is usually blue, especially that found in furnaces in which metals have not been refined for some time. In the lower portions of these same furnaces another genera of *cadmia* is obtained from dense material that is earthy and hard. It is called ὀστρακῖτις since it has the appearance of sea-shells. It is more tenaceous, usually black, and found more often in furnaces in which cupriferous pyrite is not smelted. All of these genera are of the dense portions. When a charge is poured a lighter portion is carried upward because of its lightness and settles on the higher parts of the furnace where it congeals in similar forms. These surfaces have the appearance of grapes and for that reason are called βοτρυῖτις. Although it is dense, the lighter material is fragile and the heavier even more so. The color is similar to *spodos*. When broken it is found to be gray inside and usually greenish from copper staining. *Botryites* has even more tenuous portions than the other genera already mentioned. A part of the tenuous portion rests on the iron rods in the top of the furnace and when congealed into a solid mass produces the *cadmia botryites*. Material coming from Alexandria is similar to this and since it is curved everyone recognizes that it has been removed from a rod. The very finest material produced, because of its lightness, is carried to the higher parts of a furnace with the smoke and hence is called καπνῖτις. It is found, as Pliny writes, in the openings of the furnace where

the flame comes out and since it has been completely burnt it has the same lightness as glowing ashes. The foregoing is a description of the *cadmia* produced from copper ores or from pyrite that contains silver and the *plumbum* metals. The *cadmia* found in gold and silver furnaces is usually whiter and lighter since they are cleaned more often.

All *cadmia* produced in furnaces dries and is moderately astringent. If it is washed first it will not cause pain. That obtained from gold, silver, and *plumbum* ores is less efficacious than that from copper ores.

Pompholyx, after *cadmia*, adheres to the upper walls of furnaces and is associated with the latter. It is the ash of either copper or *cadmia fornacum* or both. It forms when copper is smelted from cakes of the roasted ores or when, having been parted from silver, it is refined in a copper furnace. It is here that the ash is carried to the upper part of the furnace where it adheres to the walls and back. It first collects in small balls like drops of water and then swells, whence the name. It grows by addition of other material until it has the appearance of a woolen brush. It forms spontaneously in a furnace. When the copper is smelted from roasted ore the *pompholyx* is sometimes of a copper color and when the copper is refined, of a grayish white color, both being somewhat unctuous. That obtained from the pyrite from Goslar is white.

By exercising care and diligence furnace workers produce *pompholyx* from *cadmia* in three ways. First, by sprinkling *cadmia fornacum* on copper that is being refined. Pure *pompholyx* is produced when alternate layers of copper and native *cadmia* (*cadmia fossilis*) are put in retorts to make brass. The ash of the molten copper is carried up to the hollow in the cover of the retort. If there is no cover on the retort this ash together with the ash of the burning wood is carried upward and adheres to the walls of the furnace producing *spodos*. A third method is to heat furnace *cadmia* with a bellows until it glows. By these methods first quality material is obtained, that is, the whitest and lightest. Today furnace workers produce it by another method and at one time it was produced by two other methods that Dioscorides describes in a manuscript. All three methods produce a white and light material but the one used today produces the whitest.

According to Galen the most tenuous portion of *pompholyx*, after being washed, is the best remedy known to stop the bite of pain. For that reason it is used on malignant ulcers and tumors. It is added to eye salves to stop watering of the eyes and to cure ulcers of the eyes as well as the pustules the Greeks call φλύκταινα (phyctena). It is also used to cure ulcers of the rectum.

Spodos, that some understand to mean ash, does not differ from *pompholyx* in origin since both are ashes that are produced in the same way although they are different genera. *Pompholyx* is white and light, *spodos*, gray and heavy. Some of it adheres to the outside of a furnace while some falls into the lowest part. It is scraped from the walls and swept into

piles. It is not obtained from furnaces in which they smelt copper ores, copper, *cadmia*, or pyrite. It is produced in furnaces in which they smelt gold, silver, and lead ores and here it forms instead of *pompholyx*. In these furnaces the material is gray while that obtained from furnaces in which silver is parted from lead is yellow. Part of the lead is consumed in the fire and carried upward with the smoke and this produces *spodos*.

Dioscorides mentions *plumbaria* from the Cyprian copper smelters. Pliny writes that similar material from gold smelters is very good for the eyes and that the product from silver smelters is called *lauriotis*. This evidently takes its name from Mt. Laurium in Greece where there are silver mines. After the Athenians abandoned these mines the name continued to be used for *spodos* from silver smelters. All *spodos* when cleansed of filth such as carbon, earth, hair, dirt, etc. has the same properties as *pompholyx*. As a rule it is, in part at least, coarser grained or more dense.

Flowers of copper (*flos aeris*), also called ἄνθος χαλκός by the Greeks, consists of small particles of copper that have been loosened from the main mass and have, in general, the appearance of millet. It is produced in two ways, one when the copper has been refined from roasted ore and flows from the hearth along canals into the crucible. It is also obtained when copper that has had the lead and silver removed is melted in the crucible of a single hearth. With either method, after the slag has been removed from the mass of glowing copper the latter is poured into water immediately so that it can be divided into bars. The copper, since it congeals and hardens quickly, spurts out into a flower. These flowers are cut from the bars by a helper with a pair of pinchers and thrown into a basin or trough to quench them. After pouring the water from the basin they are collected. The best of these can be ground easily and when ground have a red color. They have a moderate luster. This material is adulterated with copper filings but the fraud can be detected by biting since the copper filings will spread under pressure. Flowers of copper can be distinguished from the scale the Greeks call λέπος since the former is produced spontaneously from copper bars that are chilled in water while the latter is torn from masses of copper by the blows of a hammer, from nails and then called ἠλῖτις, and from other copper objects. The best material is dense and copper-red. When sprinkled with acid it produces verdigris, the same kind as is now scraped from red copper and at one time was made from Cyprian copper. On the other hand tenuous, crumbling, white or black material is discarded. This is produced from white or black copper. Both flowers of copper and copper scale have the same properties as roasted copper, that is, a certain acridness except that it is astringent. Flowers of copper is more tenuous than either scale or roasted copper and for that reason is mixed with eye remedies to cure irritations and ulcers. When the scale is drunk with honey and water it draws water from the body.

Scale (*squama*) is broken from the hard iron the Greeks call στομωμα,

as I have said, and from iron by blows of a hammer. Although Dioscorides says this scale has the same properties as copper scale, the iron scale is more astringent and that from steel even more so. For this reason the latter is very useful in treating malignant ulcers. Copper scale is more acrid and, therefore, purges and eats away the flesh more than iron scale and is more efficacious in purging the stomach. But this is enough concerning the products of the first furnace and the scale of copper, iron, and steel.

I shall now take up the products of the second furnace, namely foam of silver (*spuma argenti*) and *plumbago*. The Greeks call foam of silver λιθάργυρος, that is, stone of silver. The Greeks regarded it as a natural substance while the Latins believed it occurred in Nature in an impure form. It is more correct to call it foam or stone of lead since it is produced from lead and lead from it and it is not produced from silver nor silver from it. If foam is produced from a mixture of lead and silver when they are being parted we know that it comes from the lead and not from the silver since none of the silver is lost and all of the lead is changed into foam and *plumbago*.

Foam is produced in many ways. First, from *plumbaria arena*,[7] second from galena (*plumbarius lapis*), and third from sheets of lead. All are heated in shallow crucibles until they are completely changed, partly into foam, partly into *plumbago*.[8] A fourth method uses mixtures of lead and silver; a fifth, mixtures of gold and lead; a sixth, using mixtures of gold, silver, and lead. In the last three methods gold, silver, or a gold-silver alloy are left while all the lead is converted into foam or lead oxide. When copper is added to a mixture that contains silver, as is a common practice, it increases the amount of silver in the lead but the copper, together with the lead is converted into foam and *plumbago*.[9]

Foam varies in color. It is either dark yellow or white. The dark yellow variety is called *chrysitis* because it resembles gold while the white variety that resembles silver is called *argyritis*. I realize that Pliny knew of another one. *Chrysitis* is better than *argyritis*. It has been subjected to a hotter fire that has produced the color.[10]

Foam differs in degree of consolidation since it may be either solid or distended. The Greeks call the former *stereotis* since it has congealed in a solid mass, and the latter *pneumenis* when it has congealed in tubular masses. If foam flows down into the lower crucible from the upper and is then left for a long time the mass becomes heavier but if it is taken from the crucible immediately and rolled about in a fine mesh fish-net it will form tubular masses of moderate weight.

[7] Literally, lead sand, probably the fines resulting from hand picking lead ores.

[8] Agricola and other writers include a number of materials under *plumbago*. Here he refers to the lead oxide litharge (yellow) and other oxides.

[9] Actually this practice, in effect, debased the silver.

[10] The white oxide is the basic lead carbonate; the yellow oxide is massicot or litharge.

Foam is produced now, as in former times, in many places. The best is made in Misena and Bohemia. Dioscorides gives preference to that from Greece which was produced at Mt. Laurium and called *lauriotis*. He places the Spanish second and the Puteolian that was made from sheets of lead, third.

Galen believed that foam of silver was moderately drying but obviously it neither warms nor cools. It is moderately cleansing and astringent. Among the ores it has merits of a moderate order and is often mixed with other substances that are either strongly astringent or biting. By itself it is only used for diseases of the thighs. That made from copper and lead, such as is produced in smelters where silver is parted from copper is moderately warming. Although this variety, being of an intermediate composition, tends to be warming *plumbago* is said to be cooling according to the Latins, although the two do not differ in other ways. When produced from copper and lead it is of uniform composition.

The material the Latins call *plumbago* the Greeks call μολίβδαινα, each word having been correctly derived from the words for lead. It is produced from boiling lead when the upper part of the crucible takes up the lead itself in the manner already described. It is not of uniform color. The upper portion approaches the color of foam of silver, the lower portion a gray color and the intermediate portion a mixture of the two. The upper portion is the best, the intermediate, the poorest. Both the intermediate and upper portions have a certain luster and a reddish brown color when pulverized. When boiled in olive oil the color changes to liver-brown. The lower portion with a lead-gray color is impure.

Foam of silver is sometimes melted and colored with pigments and then used by potters to glaze the inside of their jars and by sculptors to glaze the outside of their works. At one time the warming furnaces of the Germans were made in this same manner. They also use the powder for letter sand. Chemists make a powder from the gray portion of *plumbago* and call it *plumbarius cinis*. So much concerning foam of silver and lead.

Aerugo (verdigris), *caeruleum* (blue minerals), and *cerussa* (white lead) are produced by treating metals with acid. The various kinds of verdigris are made from copper. One variety is smooth, another full of holes. One variety is called *santerna* since it is used in soldering gold. The smooth variety is made in many ways. Sometimes strong vinegar is poured into a dolium or similar jar and a copper vessel placed over the top. It is better to use an arched vessel but if none is available a flat bottomed vessel will serve. It should be clean and without holes. After ten days the cover is removed and the verdigris scraped off. It is also made by suspending strips of copper in the dolium above the acid. These are left for ten days before the verdigris is scraped from them. It is sometimes produced by covering masses of copper or copper strips with wine that has gone sour. New wine will not serve. Sometimes copper filings or thin sheets are mixed with gold foil and then sprinkled with vinegar and stirred with a

spatula until the entire mass is converted to verdigris. Pliny writes that some prefer to make it by triturating copper filings and vinegar in a copper mortar. Thus the verdigris used today is made in many ways. This is sometimes called *viride aeris* because of its color.

The porous verdigris is made in the following manner. One-fourth pint of strong white vinegar is poured into a copper mortar, preferably one made from Cyprian copper, and stirred with a copper pestle until it becomes sticky. Then one-half ounce of spheroidal alum and natural salt or the whitest and most compact marine salt is added; if salt is not available use a similar quantity of soda. Then, having been warmed in the sun, the mass is rubbed in the mortar until it turns green and becomes sticky from coagulation. Then, having set into a porous mass, it is laid aside. Material of good color can be made very easily by mixing one part of vinegar with two parts of old urine and using this mixture instead of vinegar. If Cyprian copper is not available the best copper obtainable should be used.

The third variety of artificial verdigris is used by goldsmiths to solder gold, as Dioscorides believed. It is prepared in a mortar of Cyprian copper into which has been poured the urine of a boy. This is stirred around with a pestle made from the same copper. Pliny has described this material under the name *chrysocolla* and mentioned many methods by which it is prepared. It is worth while to consider his descriptions. Goldsmiths have appropriated this material for soldering gold and all others who use it call it by this same name. The best is made from Cyprian copper and the urine of young boys to which soda is added. If it is made in a Cyprian copper mortar and rubbed with a pestle of similar material we call it *santerna*. When soldering argentiferous gold if a little *santerna* is added it makes it brighter. Cupriferous alloys are dulled and soldered with difficulty. They can be soldered however when one part of gold and seven parts of silver are added. Today goldsmiths use a substitute they call borax (*borax*) more often than *chrysocolla*. This is made from soda, as I have said in Book III, and contains no verdigris.

Caeruleum is also produced in different ways although the finest is prepared in the following manner. Three pounds of very strong vinegar is poured into an oak vesssel together with a pound of powdered artificial sal ammoniac. The latter is dissolved and a small staff fastened upright in the center of the vessel. From this staff sheets of silver full of small slits are suspended so that they do not touch the vinegar solution. Before suspending them the slits are first smeared with quicksilver. The vessel is covered with a lid and sealed so that there are no air holes. It is then covered with dung or placed in a trench and covered with earth. After twenty days the vessel is opened and the material that has collected like rust on the silver sheets is scraped off and the vessel is again covered and left for twenty days. This procedure is followed until the silver is entirely eaten away and then new sheets are suspended in the vessel. The material

that has been scraped off is placed to one side in a vessel that has been coated with lead oxide. When enough material is collected the latter vessel is placed over a charcoal fire and the material burned a little. After cooling the material is washed in pure cold water. When it has settled the water is decanted and it is dried in the sun. This is the *caeruleum* that has been so highly esteemed for a long time.[11] Some people, in order to avoid the cost of using sheets of silver, make *caeruleum* from a mixture of three parts of quicksilver, one part of artificial sal ammoniac and two parts of sulphur. The sulphur is pulverized and then melted in a vessel coated with lead oxide. Then the sal ammoniac, also pulverized, is added together with the quicksilver and the mixture stirred with a wooden stick until thoroughly mixed. The mass is then cooled and pulverized. The powder is then placed in a glass vessel that is coated with two inches of chemists mud. An opening is left in the mud and the vessel is set aside to dry. After it is thoroughly dried it is placed on an iron tripod over a charcoal fire with a sheet of iron covering the opening. It is heated slowly and the iron sheet removed from time to time in order to watch the mixture. When it has melted down the opening is closed with mud and the vessel is heated for an hour over a hotter fire. It is then heated over a still hotter fire until it gives off a blue smoke. The *caeruleum* is found in the bottom of the glass.[12]

Just as copper smelters produce *diphryges, cadmia, pompholyx, spodos,* flowers of copper, and copper scale, lead smelters produce *sandyx, cerussa, cerussa plumbaria,* and *ochra plumbaria.* I shall now take up these latter substances. *Cerussa,* that the Greeks call *ψιμίθιον,* is made in the following manner from lead. First twigs are placed in a large earthenware jar and then strong vinegar is poured into it until only about three inches of the twigs project above the acid. A sheet of lead is placed on the twigs. Some do not use twigs but fasten the lead on a piece of wood that suspends it just above the acid. Each sheet of lead weighs a pound. To prevent the escape of the vinegar the jar is covered with an earthen lid and sealed with mud. In summer it is set out in the sun, in winter it is placed over a furnace, oven or bath. The lead sheets are scraped every ten days until entirely eaten away. Sometimes they are only scraped every thirty days. After the sheets are entirely eaten away the pure liquid that covers the *cerussa* is decanted and the glue-like mass that remains in the bottom of the jar is transferred to another vessel and dried in the sun. When dry it is crushed, either in a hand mill or in some other way and sieved. The coarse material that is usually hard and solid is crushed again and again until it passes through the sieve. At one time, according to Dioscorides, the finest *cerussa* came from Rhodes, Corinth, and Lacedaemon; the next best from Puteoli. In our time it is made in all parts of

[11] A silver-lead ammonium acetate.

[12] One would not expect this to produce a blue compound.

Europe. As a remedy it cools and is used as an ointment. Women use it for whitening the skin. If drunk it is fatal.

The *cerussa* called *cerussa cinerea* by some, *plumbarius cinerea* by others, is prepared in the following manner. A new earthenware vessel is placed on a charcoal fire and ground *cerussa* placed in it. It is stirred continuously with a small wooden spoon until it becomes the color of ashes, after which it is removed from the fire.[13]

There is another material that some Greeks call σάνδυκα and Pliny, following them, calls *sandyx*. Other Greeks call it φύκος because it resembles rouge. Vitruvius calls it *sandaraca* since it has the same color as this mineral (realgar). It is prepared in the following manner. A dish is placed on glowing charcoal and filled with crushed *cerussa*. This is stirred with a wooden spoon until the entire mass becomes the color of realgar. Vitruvius writes that men learned how to make this material[14] by accident and that it is superior to the natural mineral found in mines.

The ocher we call *plumbaria* is made from lead. This substance was first discovered by chemists and is prepared in the following manner. Lead is placed in an oblong flask and the latter placed in a chemists furnace. It is heated until the lead becomes the color of ocher. Painters use this as well as *sandyx*.

Tin smelters produce a variety of *cerussa* that is called Spanish White because it is produced by the Spaniards. It is prepared in the following manner. Urine is heated in a flask with an elongated spout, similar to that used in distilling, and tin is added. When the tin is entirely dissolved the urine is decanted. The glutinous mass that remains in the bottom of the flask is dried in the same way as other *cerussa*, then crushed and sieved. This is used by women to whiten the skin.

Quicksilver refineries produce *minium* and an artificial *minium*, each of which is called *cinnabaris* today. Chemists first discovered these substances by accident. When they threw sulphur on quicksilver in an attempt to produce silver or gold they produced this pigment instead. When the quicksilver mines of Betica ceased to produce this pigment *minium* took its place. It is prepared by placing a large shallow dish on a charcoal fire and placing in it one part of ground sulphur. When the sulphur has melted two parts of quicksilver are added and the mixture stirred rapidly and continuously with a wooden spoon until the two are thoroughly mixed and no quicksilver remains. After cooling the mass is pulverized and the powder placed in a flask with rather a long neck. If the flask is of glass it is coated outside with an inch of mud and, if an earthenware flask, the inside is coated with lead or lead oxide. The mouth is then covered and sealed and the vessel placed in a chemists furnace or on an iron tripod over a charcoal fire. It is heated slowly until the sound of the

[13] This would be a mixture of lead oxide and basic lead acetate.

[14] Red oxide of lead. The natural mineral is called minium.

movement of the quicksilver ceases. It is then heated over a very hot fire until it gives off red fumes. It gives off yellow fumes first, then blue and finally red. When the red fumes appear the vessel is removed from the tripod or furnace and after it is cool, broken. Some do not mix the sulphur and quicksilver in a shallow dish first but put them together in the flask and produce the *minium* in a single operation. Some use equal parts of sulphur and quicksilver but this produces a very poor grade of *minium* when compared to that mentioned above. I shall describe vein *minium* that has a scarlet hue and *minium secundarium* in the next book.[15]

I shall now mention the form of quicksilver the chemists call sublimate. This is prepared in the following way. Equal parts of quicksilver and *atramentum sutorium* are ground in a mortar with vinegar until all the quicksilver is taken up. When dry the mixture is placed in an earthenware dish, covered with a similar dish and sealed with mud. After heating for three hours it is removed from the fire and cooled. Both liquid and solid are then removed. The mixture is ground a second time in a mortar, sprinkled with vinegar and heated again. This is repeated until all the quicksilver has been driven to the cover by the heat and congealed.[16] I shall take up the *cadmia* that the chemists call sublimate in the next book.

There are three kinds of *psoricum*. They are all made by mixing either two parts of *chalcitis* with one part of *cadmia fornacum;* two parts of *chalcitis* with one of foam of silver; or equal parts of *chalcitis* and *cadmia*. After mixing the first and second varieties are ground with vinegar which is added a drop at a time. The third variety is ground with wine. Later, when the dog-star Sirius rises and everything is parched with the heat of the sun, each is placed in an earthenware vessel, covered with dung and left for forty days. Afterwards the mixtures are placed in a second vessel and thoroughly dried over a charcoal fire until they turn red. All *psoricum* dries and warms while that made with foam of silver is the weakest. That made with wine does not bite as much as that made with vinegar.[17]

Syricum, which is used by painters, is made by mixing *sinopis*[18] with

[15] At first the mercury sulphide now called cinnabar was called minium. As the alchemists worked with this and other materials it was discovered that an oxide of lead could be produced with a red color almost identical to that of minium. They started adulterating the more valuable mercury sulphide with this artificial lead oxide until eventually this red pigment contained no mercury sulphide and today the name has come to be applied to the adulterant and the original material is now given a new name, cinnabar. The method mentioned above that used a coating of lead oxide on the inside of the flask was one form of adulteration.

[16] This would probably be an impure hydrous basic mercury sulphate.

[17] A mixture of lead oxide and ferric oxide.

[18] The following reference to *terra sinopis* is found in *Bermannus*, page 462, Bermannus. " . . . Now you may mention anything you know concerning *sinopis*. Naevius. "Dioscorides, as you know, chose as *sinopis* ocher that which is dense,

an equal weight of *sandyx*. Since fraud is always with us today we find people crushing bricks into a powder and using this to adulterate *sandyx*.

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heavy, liver-colored, with little gravel, with uniform color and spreading evenly when saturated with water. Material of this same type has been offered to me by Baptista Opizus of Venice, having been brought from Byzantium. However it was not in the form of cakes as Manardus writes, having seen them himself from this same locality. It was in the form of lumps. I have seen cakes in Venice that were brought from this same place, of almost a tawny color and stamped with Turkish letters and for that reason called *terra sigillata*.

BOOK X

Only the natural substances that are called mixtures and combinations remain. I shall discuss the mixtures first. There are six genera, as mentioned in Book I. The first genus includes materials that contain stone and some congealed juice; the second, a metal and an earth; the third, equal parts of stone and metal; the fourth and fifth, also a stone and metal but with either the stone or metal in greater abundance; and sixth, stone, metal and some congealed juice.

The first genus embraces many species. Nature has produced all of them from stone to which she has added salt, soda, or some other congealed juice. Hence there are as many of these species as there are congealed juices. The number of species is not increased in the same fashion by the different species of stone. In order to describe this genus adequately and at the same time briefly, I must describe some of the material and omit the rest. We have certain distinguishing signs and marks that permit us to identify this genus and determine the juice with which the stone has been mixed. For example, when a stone contains a saline or bitter juice or an astringent or acrid juice, if crushed and placed in water it will give the latter the same taste. A stone that contains *halinitrum* will decrepitate in fire as does the Tusculian flint of Italy and the white flint from the Carpathian Mountains of Kremnica. When the hardness of this flint is destroyed by the fire it breaks with a noise as loud as that made by the new variety of cannon the Italians call a *bombarda*. Stone that contains an unctuous juice will burn, those containing sulphur and bitumen burn strongly while those containing realgar or orpiment burn with difficulty. *Lapis sabinus*, *lapis sidicinus*, and *lapis salentinus* from Gnatia contain sulphur and there is an abundance of sulphur in that vicinity. I do not say that you could not find bituminous stone in this same place. The more sulphur a stone contains the lighter the weight, the stronger it burns and the stronger the sulphur odor. On the contrary, the less sulphur a stone contains the heavier the stone, the less it burns and smells of sulphur. Bituminous stones include those found in abundance on the highest parts of the Erineas Mountains; the stone near Bina carried down by the river; *lapis liparaeus;* the stone found on an island near Lipari; and the stone the Greeks call *marithas*. Stones which consist entirely of bitumen, such as jet, differ from these mixed substances in that the former are entirely consumed in fire while only a part of the latter is burned. Actually when the bitumen has been changed into soot the stone that remains resembles pumice, especially that from Lipari. One bituminous stone can be distinguished from another since those containing the most bitumen are lighter, burn more readily and have the strongest odor of bitumen, for example, the stone from the Erineas Mountains. On the

contrary those containing little bitumen are heavy, burn less readily and have only a slight odor of bitumen, for example, the stone from Bina. The latter burn only when placed on live coals and a blast is applied. When the blast is discontinued they cease burning although they can be rekindled again and again. For this reason workmen use this stone for a long time.

Stones that contain a juice useful to painters can be distinguished by their color, for example, those that contain *chrysocolla*, *caeruleum*, *aerugo*, realgar, or orpiment. These stones occur commonly in gold, silver, and copper mines just as stones containing salt, soda, *halinitrum*, alum, *atramentum sutorium*, and related juices occur in distinctive deposits. The latter juices are separated from their mixtures by dissolving them in water; unctuous juices are separated by the heat of fire; and painters separate the juices they wish to use with both fire and water. I shall take up all these things in the, as yet, unwritten book *De Re Metallica*. Since Nature has not given a new form to the majority of these mixtures the older writers correctly called them "stones."

I shall now take up the other genera, discussing them together with the exception of the sixth genus. As many as eight or more species are included under a single genus, in fact as many species as there are metals. All contain either an earth or stone and either gold, silver, quicksilver, copper, tin, lead, bismuth, or iron. Since proper names have not been given to these mixtures it is necessary that I give each one the name of the metal it contains and an additional word to distinguish it from the pure metal, either native or the result of smelting. Thus I use the term *rude aurum* (rude gold[1]), etc., not because I am unaware that Varro has used the same name for gold that had not been cast and stamped but because I cannot find a similar word that is sufficiently distinctive. Thus *rude aurum* etc., are species of these four genera.

Since I am not going to take up the four genera separately I shall mention first the features by which species of one genus may be distinguished from those of another. Thus a silver mineral may be of the second genus of mixtures, or the third, fourth, or fifth, as disclosed by smelting either in ovens or furnaces. If only a small amount of slag is obtained we know the mixture contains earth and not stone as well as silver, and therefore belongs to the second genus. If an equal amount of silver and slag are produced it belongs to the third genus; if more silver than slag, to the fourth; and if more slag than silver, to the fifth. Species of the second and fourth genera contain more metal than slag but can be distinguished from one another since the former contains more metal than the latter. If the silver mineral is soft it belongs to the second genus without question but if it is hard it does not necessarily belong to the

[1] The literal translation of this term would be "rude" or "native." Since this does not convey the intended meaning, the proper translation would be "mineral" or "ore."

fourth since minerals containing an earth and a metal are sometimes as hard as stone. As regards translucency, minerals of the second genus are not translucent since neither earth nor metal is transparent. Thus transparent minerals must belong to the other three genera. The proper one is determined by smelting. Minerals of gold, copper and other metals are classified in the same manner.

Species of these genera are usually classified by color. One genus embraces many species, another few, as I shall explain presently. Since the species of the silver minerals are better known to our miners than those of the other metals I shall consider them first. There are lead-colored, gray, black, white, red, purple, liver-colored, and yellow silver minerals. The lead-colored mineral whose name we derive from *plumbum,* is known to the German miner by a name derived from glass.[2] Actually it lacks the true color of galena and is not transparent as is glass from which the name is seen to have been derived. Sometimes it is the color of galena although darker. The two are similar but anyone acquainted with mineral substances can distinguish one from the other by eye. Nature has produced this mineral from a large amount of silver and a small amount of earth. Galena, composed of lead and stone, sometimes contains silver. The two have distinctive features. Galena can be pulverized with a pestle in a mortar while argentite flattens out. When galena is struck with a hammer or knife or compressed between the teeth it flies apart while argentite spreads under the flow of the hammer, can be cut with a knife and is compressed between the teeth. There is a hard silver mineral belonging to this same species that cannot be distinguished from galena by eye but only by smelting. However, it is readily recognized by experts. Whether a mineral contains a metal and stone, or earth is determined by smelting, as I have said. If it contains stone it is usually a lighter color. Both the hard and soft silver minerals have their characteristic true color inside while on the outside they may be black, yellow, or some alien color. Hammering immediately brings out the true color.

Native silver takes first place, argentite second. Ninety pounds of silver is obtained from one hundred pounds of the purest mineral.[3] From this we know that the pure mineral contains less than a tenth part of earth since some of the silver is burned away and some goes into the slag. This mineral is uncommon at Rhetia, Noricum, and Dacia, and common in Germany although it is not found in all the silver mines. It is most abundant in Misena at Schneeberg, Scheibenberg, Garium, Marienberg, Annaberg; in Bohemia at Abertham in the Joachimstal valley and in nearby mines. Sometimes a portion of a vein is twenty-four to thirty or

[2] Latin, *argentum rude plumbei coloris;* German, glaserze; English, argentite, silver sulphide.

[3] Pure argentite contains 87.1% silver and is often more or less intimately associated with native silver.

more feet long and deep and six, nine, or twelve inches wide and consisting entirely of this mineral. Miners have removed masses of pure argentite weighing one hundred to two hundred pounds from these veins. They found so much in the outcrop of the Abertham mine that our miners have given it the name Divine Gift. This name is very similar to the Greek *θεόδωρος* which is also derived from two words.[4] Sometimes masses of native silver of this same size are found in these veins but they are rare. Masses of similar size have been observed in the Joachimsthal valley where they are mined from pockets in the center of the second vein named the Stella. Often the mineral projects from rocks or stones with the form of an eye. More often it has the form of a bunch of grapes. Sometimes Nature has produced it in rounded or globular forms enclosed in stone. It often resembles twigs or branches. Indeed we see the small statue of a man with an infant in his arms that Nature and not Man has fashioned from argentite. This was found in the famous and richest mine of Schneeberg, the George. Finally, the very thinnest of sheets are often found adhering to the surface of stones.

The red silver mineral (*argentum rude rubrum*), if it is soft, is only slightly inferior, if inferior at all, to argentite, but if hard, contains more silver and possesses an extraordinary beauty that far surpasses it. It is most beautiful when it has a certain bluish tint or when it is transparent like *carbunculus*. There can be no doubt but that this mineral formed from some transparent stony material mixed with the juice of the silver to be. While it has the same color and tarnsparency as *carbunculus* nevertheless the two are quite different. The *carbunculus* is more brilliant, cannot be scratched with a file, and is affected very slowly, if at all, by fire while the ruby silver is less brilliant, soft enough to be scratched with a file and melts in a fire. The form of ruby silver varies as does the form of argentite. Usually it is angular sometimes resembling a cube, sometimes hexagonal like quartz, and sometimes with even more angles like *pangonius*. Very thin sheets are often found coating rocks or stones. The transparent mineral resembles the *carbunculus* while the non-transparent mineral,[5] like ocher, varies greatly in color. Mineral resembling a medium red ocher is common in a mine at Schneeberg that takes its name from Levite. Old men say very definitely that the George mine yielded a much greater quantity of this mineral than any other silver mineral. Ruby silver sometimes contains gold as, for example, that mined in the Carpathian Mountains at Bocchantius and Chemnitz. There is a dark ruby silver mineral (*argentum rude rubrum obscurum*) obtained from the Santa Barbara mine in the Joachimsthal valley which spreads under the

[4] From *θεός*, God, and *δῶς*, gift.

[5] *Argentum rude rubrum*, pyrargyrite; *argentum rude rubrum translucidum* proustite. The former is a silver antimony sulphide, the latter a silver arsenic sulphide. In English the two minerals are collectively known as ruby silver.

blow of a hammer and contains more silver than the transparent ruby silver which breaks into pieces under the blow of a hammer .[6,7]

The white silver mineral (*argentum rude album*) differs from native silver in that the latter spreads under the blow of a hammer as does refined silver. White silver mineral is mined in many places in Bohemia, especially at Cotteberg. I have seen a little taken from the upper part of the Divine Gift mine at Abertham. Gray, black, purple, liver-colored, and yellow natural silver minerals differ from those already mentioned in color but not in composition.[8] They do not have the variety of forms of

[6] This was probably a mixture of argentite or native silver and ruby silver. The dark ruby silver mineral pyrargyrite and the black silver minerals stephanite and polybasite are brittle.

[7] Agricola refers to *argentum rude rubrum* in *Bermannus* on page 445 as follows,—
Bermannus. " . . . I shall take up the red genus first.
Naevius. "It appears to be some genus of *carbunculus*.
Bermannus. "Quite true, but the *carbunculus* is usually a brighter red while this is a softer shade. It occurs in various forms. Sometimes it has a blackish shade, sometimes it is scattered over rocks like sparks, sometimes solid masses adhere to rocks. It may occur in simple masses, either with portions of the mineral projecting upward with pointed ends or the mass may have the appearance of a vein. When it is quadratic it usually has the form of a cube. When hexagonal it resembles diamond, and it may even have more and unequal angles as does the gem iris quartz. Also one can find this mineral sprinkled with a beautiful blue color that gives it great beauty and it appears to me that Nature itself, having been exhausted by such perfect work revived itself with this most beautiful mineral of all. Perhaps such beauty can be obtained by art but only with the greatest effort.
Naevius. "This genus of silver was not known to the Ancients?
Bermannus. "Not that I know of unless Theophrastus refers to this mineral in his book *De Lapidibus*. When discussing gold and silver minerals found in mines he describes one with these words, 'another stone has the color of a live coal.'
Ancon. "How much of its mass is lost when it is smelted?
Bermannus. "Very little as is also true of the lead-colored silver mineral. Hot dry vapors coming up from the depths of the earth color the essence from which Nature produces silver and because of variations in this essence the silver minerals have a variety of colors.
Ancon. "I believe that you are right in believing that Aristotle would not have observed this. Has this mineral any other use than as a source of silver?
Bermannus. "In paintings. A well known color is made from it, a color that is not inferior to cinnabar that was so highly prized by the Ancients and superior to realgar.
Naevius. "Would it be used in medicine by any chance?
Bermannus. "It is probably valueless since no one has experimented with it as yet."

[8] It is difficult to ascertain which silver minerals were included under these various color classes. No doubt there was considerable confusion in the use of these names in the time of Agricola. The principal silver minerals in the mines known to Agricola were native silver, argentite, acanthite, proustite, pyrargyrite, polybasite, stephanite, tetrahedrite, sternbergite, argentopyrite and cerargyrite. It is possible that some silver telluride minerals are included here. The minerals that may have been included in these classes are given below.

the red and lead-colored silver minerals. They are found in the same localities in Misena and Bohemia where the gray and black varieties are the more common, the others rare. Recently the Heavenly Host mine at Annaberg has yielded the gray variety in large quantities. The Schonberg vein in the Joachimsthal valley has produced a large quantity of the purple mineral and a smaller quantity of the yellow mineral. The liver-colored mineral was found in the upper part of the mine at Abertham. Not only are masses of variable size found that have formed from an earth and silver but also gravel and even more often sand that may be cemented with the same minerals. But this is enough concerning the nature of silver minerals.

Copper and gold are mixed with earths to form new species that have alien colors in the same manner as silver. Gold is often red and copper often has a color similar to native argentite.[9] The German miners call it by the same name although it is not as dark. It is found in the mines of Suacium in Noricum and in the mines of Neusohl in the Carpathian Mountains. The other minerals are rarer.[10]

Similar minerals of quicksilver are sometimes scarlet red[11] as the mineral from Schonbach; sometimes liver-colored[12] as the mineral from Idria; and sometimes black[13] as the mineral from Kreucenach. The red mineral resembles sand; the liver-colored mineral, stone; the black, the down of a plant. The red quicksilver mineral is the most common, the liver-colored less so while the black is rare. When the red mineral is massive it is called ἄνθραξ by one Greek writer because it resembles burning charcoal. The material from which *minium* is called is made ἄμμιος by the Greeks which means fine sand, and κιννάβαρι by Theophrastus. Quicksilver is obtained from all of these as I shall explain in the books of *De Re Metallica.*

Minium is prepared in the following manner. Cinnabar, if very pure, is placed in wooden casks and crushed with the ends of iron rods that are operated by a water wheel.[14] The fine material is passed through a screen and then pulverized. That which cannot be pulverized is crushed further

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Argentum rude album (white), in part tetrahedrite; in part amalgam, silver tellurides, etc.

Argentum rude cineraceum (gray), in part cerargyrite; in part tetrahedrite.

Argentum rude jecoris colore (liver-colored), cerargyrite and other silver haloids.

Argentum rude luteum (yellow), in part silver tellurides.

Argentum rude nigrum (black), in part stephanite, polybasite, etc.

Argentum rude purpureum (purple), in part sternbergite.

[9] *Aes rude plumbei coloris*, chalcocite, copper sulphide.

[10] The reference to red gold may refer to finely divided and more or less invisible gold in the outcrops of pyritic veins.

[11] *Argentum vivum rude rubrum*, cinnabar, mercury sulphide.

[12] *Argentum vivum rude jecoris colore*, calomel, mercury chloride.

[13] *Argentum vivum rude nigrum*, metacinnabar, mercury sulphide.

[14] An early type of stamp mill.

under the iron rods. If vein material is mixed with the cinnabar it is first crushed in the above manner and screened. It is then placed in a wooden trough and after water is added the trough is shaken. The vein material, being lighter, moves to the front or upper part of the trough and the mineral, being heavier, moves to the lower part. The vein material is removed and thrown away, the cinnabar collected. If the latter is pure it is screened and the coarse material reground. If impure it is reground and reconcentrated. In refineries where they make *minium* the workers cover their faces with large bladders. I use the words of Pliny, so they will not breath the deadly powder into their lungs. These bladders have openings for the eyes. Formerly, according to Pliny, this ore was brought to Rome from Spain, especially from the very famous town of Guadalcanal in Baetica. Theophrastus writes that this ore was found in Colchis at the foot of inaccessible cliffs from which it would come crashing down. Juba writes that it came from Carmina and Hermogenes mentions it from Ethiopia. Today it is found at Schonbach in Elboganun, Bohemia. The sand found in the Cilbian fields near Ephesus is this same material although Theophrastus believed that it required work to change it to *minium*. Actually any ore of cinnabar requires some work even though it is nothing more than crushing, screening and pulverizing.[15] Today the ore is rarely used since the cinnabar (*cinnabaris*) made from quicksilver has replaced it. If it contains no sulphur it is not as good. According to Pliny *minium* was made from the ore from Guadalcanal in the same manner as it is made today unless it had been smelted with silver. *Minium* was used at one time not only by painters but also by the Romans on feast days to cover the bodies of the winners in various sports to make them look like Jupiter, according to Verrius who copied this from Pliny. During this same period it was placed in the unguent of the victory dinner. A statue of Jupiter painted with *minium* was rented by the Censors. The Ethiopians valued it very highly. Nobles used it as a rouge in order to be a color similar to that of the Gods. But enough concerning *minium*.[16]

The pure black pebbles (cassiterite) from which tin is smelted belong to the mixed minerals. These are rarely white, even less common yellow, and rarest of all, purple. These pebbles are usually dug up mixed with rock and stone but sometimes they are found pure at the junction of veins and veinlets and where persistent, strong veins widen into pockets. These masses of pure mineral may weigh a half-ounce, an ounce, a half-pound or even a pound. Large masses are found at Schlaggenwald and Irberesdorf, another name for the town of Ehrenfriedersdorf.

[15] It is obvious that Agricola applies the name *minium* to powdered cinnabar or cinnabar concentrates.

[16] Agricola discusses *minium* and *cinnabaris* at length in *Bermannus* and it is obvious that he uses the term *argentum vivum rude rubrum* for the cinnabar ore, *minium* for the concentrate or pure cinnabar, and *cinnabaris*, as a rule, for artificial cinnabar.

There are two bismuth minerals among the mixed substances, one black, the other almost gray. It is customary to include here the lead minerals that are yellow, light red, and black as well as the iron minerals that are black or red.

I shall now consider certain species of the fourth genus that have been given specific names, for example, galena, pyrite, *cadmia*, and stibnite. *Plumbago* (galena) takes its name from *plumbum*. The Latins have taken this word from the Greek word μολίβδαινα. Each has taken the name from lead, which it contains and which the Greeks call μόλιβδος. As a rule, it also resembles lead in color. Pliny calls this mineral *galena*. This is either a Spanish word or if from some other tongue its origin is unknown I am sure. Following the Greeks certain writers divide this mixed compound that Pliny calls *galena* into three varieties. The first variety Dioscorides has called μολιβδοειδὴς λίθος and we correctly call it a stone that has the appearance of lead or, as we say, *plumbarius;* the second Dioscorides calls μολίβδιτίδια ἄμμος and we call it *plumbaria arena*. The third Dioscorides calls μολίβδαινας and we call it *plumbago*. The latter was mined near Sebastia which is not far from Corycos, Cilicia. Galen did not mention the stone that has the appearance of a species of lead as a separate variety nor did he mention *plumbaria arena*. However, when he discusses the nature and properties of *plumbago* he writes that he himself had seen *plumbago*, lying along the road between Pergamus and the smelter, having the appearance of a species of stone the same as does the *cadmia* found in the mountains and rivers of Cyprus. Stones and sand are often coated with a color similar to lead.

Plumbago is golden yellow in color.[17] Both the stone and the sand have a brilliant luster and contain lead. The stone and sand are sometimes coated with an alien color, black, blue or brown but within they have their true color that is readily apparent when they are broken with a hammer. As the stone contains more silver it approaches the color of argentite. A certain *plumbarius lapis* has a luster very similar to stibnite but they can be distinguished easily since stibnite is soft and fragile while the former is hard and difficult to crush. The form varies just as does that of argentite. Sometimes only lead is obtained from this variety as well as from the others, for example, that from Villachum, Noricum, and most of the British ores which are silver-free. Sometimes both lead and silver are obtained and those ores are common. The ore from Freiberg, Misena, formerly contained two pounds of silver per hundred pounds of mineral. Some mineral contains only an ounce of silver per hundred pounds as that from the mines of Poland and Suebia. The mineral from Chemnitz in the Carpathian Mountains contains only one-half ounce per hundred pounds. As to the lead content of the mineral, they obtain fifty pounds from one hundred pounds of galena from Pleistadt,

[17] *Plumbago flava* is wulfenite, a lead molybdate.

Bohemia, and from other mineral they obtain from thirty to sixty pounds.[18]

Minium secundarium (red lead oxide) and *spuma argenti* (foam of silver) are made from *plumbarius lapis* (galena). I have discussed the latter in the preceding book. Secondary *minium* is made in the following manner. *Plumbarius lapis* that contains little or no silver or *plumbaria arena* with a color similar to galena is heated in a furnace until red hot. It is then ground to a flour and sieved, the coarse material being reground. This *minium* can be made from galena that contains appreciable amounts of lead and silver. In separating silver the associated metal is lost and during the destruction of the lead the silver collects together so it is not important. *Sandyx* which closely resembles this *minium* is made from *cerussa* that is made from lead. Since there is a good profit in making *minium* it is often adulterated with secondary *minium*, *sandyx*,[19] and *syricum*.[20]

Plumbarius lapis and *plumbaria arena* have the same properties as lead slag. Silver-free galena and *plumbarius lapis* are bright with a lustrous black color. Lead slag that is free of silver and lead, is the same color as the two minerals mentioned above. When this slag is thrown into the same furnace with these minerals it destroys a portion of them.[21]

[18] Galena contains 86.6% lead.

[19] Both *minium secundarium* and *sandyx* were artificial minium.

[20] *Syricum* was a mixture of lead and iron oxides.

[21] Agricola discusses these various materials at length in *Bermannus*, pages 433–436. The following excerpts are significant.

Naevius. " . . . there is still one thing that bothers me.

Bermannus. "What is it? I shall see if it is possible to explain it.

Naevius. "Dioscorides writes that his mineral *molibdaena* found at Sebastia near Corycos is golden-yellow and brilliant yet the mineral you show me has a certain brilliancy but is lead-gray and by no means golden-yellow.

Bermannus. "Of course I could repeat what I have already said about the galena of Pliny that he himself says is called *molibdaena* and my conclusion would in no manner be weakened but, because, up to now you have apparently wished it, I shall say just what I believe and then you are at liberty to agree or disagree with it. This galena that is the color of lead is called by Dioscorides, if I am correct, μολιβδοειδὴς λίθος because it is a species of lead and differs from the native lead mineral *molibdaena* of Dioscorides himself more in color than composition."

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Naevius. "Then what is your conclusion about *plumbarius lapis*? It may be, by chance, a species of lead (*plumbum*) since these have, essentially, the same appearance and color and are, in general, of the same composition. Is it not true that certain people fashion gems today from glass that are so similar to the natural stones that very often they deceive the unwary? Experts can prove that they are not gems but glass through the use of the file and fire.

Bermannus. "That is true and indeed there are many other substances that very often have a deceptive appearance. But it is obvious from the writings of Dioscorides himself that *plumbarius lapis* contains *plumbum* which, he writes, has

Stibi (stibnite) which is called στίμμι by the Greeks has a color somewhat similar to galena but is brighter and whiter. Pliny calls it "the stone of shining white foam" because it is similar in color and brilliancy to *spuma argenti*. The mineral is divided into male and female varieties. Pliny writes that the male stibnite is harsher, rougher, more sandy, lighter in weight, and duller. The female variety is more brilliant, more fragile, and can be cleaved with ease. It is found in the silver mines of Hohenstein, Misena, ten miles from Chemnitz; in Bohemia near the towns of Plana and Perzibram. At one time it was found in Chalcedon, Bithynia, and called *chalcedonius*; also in Italy where it was called *italicus*. At one time stibnite was sold as the native mineral and Dioscorides regarded as the best that which was most brilliant, most easily cleaved, most fragile, and contained the least earth and foreign material. This was the varitey Pliny called female. In former times this was burnt and then shaped into lozenges. In the time of Hippocrates these lozenges were usually cubic and for that reason he called the mineral τετράγωνος. Actually the mineral is not cubic, neither the rounded masses that have not been cleaved nor the cleavages themselves. In our time the refined mineral is sold, not the native stibnite. I shall explain the method of refining it in the book *De Re Metallica*. It is drying and astringent and for that reason is used in eye remedies. It colors black and for that reason women smear it on their eyelids and because of this use some Greeks called it γυναίκιος. Eyes so colored appear to be enlarged and for that reason other Greeks have called it πλατυόφθαλμος.

The name *pyrites* (pyrite) comes from the word for fire which can be produced from it when struck with iron or some hard stone. Aristotle and his student Theophrastus named it πυριμάχος because it is naturally incompatible with fire. When placed in a very hot furnace it melts but when it flows from the furnace into a mold it hardens and congeals again. Before hardening the furnace workers divide the cakes of pyrite into flat circular forms they call "stones." Actually some pyrite is mined that appears to have formed from material that had just been as fluid within the earth as the molten material in a furnace. Although pyrite may contain no gold, silver, copper or lead nevertheless it is a mixed stone, not a pure one, since it consists of a stone and a certain metallic substance characteristic of this form. The metallic substance cannot be worked by hammering although it melts in a fire and can be cast. Pyrite usually contains a metal, that from Reichenstein, Lygius, silver and gold; from Cotteberg, Bohemia, copper and silver; from Goslar, Saxony, lead, tin, copper and silver; and from many places, especially Cuperberg, Bohemia,

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the same properties as lead concentrate and lead slag and is washed in the same fashion as the former. . . . What the Latins call a vein, the Greeks sometimes call an earth, sometimes a stone, as I understand them and thus it appears to me that *plumbarius lapis* is merely another name for a lead vein."

copper. The pyrite from Breitenbrunn, Misena, contains no metal. We can conclude that the older writers who have written of the large amounts of copper that were extracted from pyrite did not know what they were writing about.

One pyrite differs from another not only in the metal or metals it contains but also in color. One may be golden yellow, another silver-white. Each is mentioned frequently in the older writings; each is called *marchasita* by the Moors; each has the appearance of copper; and each is found in copper and silver mines as well as in the lead mine of Goslar. There are two varieties of golden-yellow pyrite. One has the color of pure gold and this the chemists call *marchasita*, the other is silvery gold. There are two varieties of the silver-white pyrite, one almost the color of galena, the other gray. The former is found at Reichenstein, Lygius, and contains silver and gold, the latter is found at this same mine but does not contain these metals.[22]

Pyrite has a variable density and weight. That which is denser and contains more metal is heavier. The hardness varies and some is hard, some soft and some intermediate. Fire is produced with ease from hard pyrite when it is struck with iron or a hard stone and for this reason the Romans, according to Pliny, called it "alive." It is difficult to strike fire from the moderately hard pyrite and the soft material gives no sparks.

The form of pyrite is more variable than that of any other natural mineral.[23] That found in rivers and creeks is rounded or spherical. That found in clay veins is sometimes clyindrical with the appearance of having been polished. At Hanover pyrite that is oblong and hollow like a pipe is found in the ocher that fills joints in the calcareous rocks. Some pyrite is cubic such as that not uncommonly found in rivers and creeks and some resembles eggs. The latter produces *atramentum sutorium* and is related to it. In a mine between Hildesheim and the fortress of Steurenwald and in the moat on the north side of the fortress pyrite is found with the form of shells and grapes. Commonly it occurs resembling masses of branches that are all joined. Masses resembling honeycomb are also found. Sometimes very thin sheets similar to sheets of gold, silver, and copper are found spread on stones and rocks. Sometimes entire veins consist of solid massive pyrite from whence very large masses are obtained *Diphryges* is made from pyrite, as I have said. As a medicament it dries and disperses gatherings and for that reason is used to cure hard and soft tumors.[24]

[22] It would appear that Agricola recognized pyrite (silvery gold), chalcopyrite (pure gold color), marcasite (color of galena), and arsenopyrite (gray) as different varieties and included them under pyrite. The soft pyrite might be chalcopyrite.

[23] In light of present knowledge this would be said of calcite.

[24] Agricola discusses pyrite at greater length in *Bermannus*, page 438.

Bermannus. "Then you will not concede that copper is obtained from pyrite?

Naevius. "Why not? Dioscorides states definitely that this is true.

Ancon. "Serapio writes that copper is smelted from *marchasita*. Perhaps *marchasita* is the same as pyrite. . . .

Cadmia follows, not the artificial product I discussed in the last book nor the natural mineral I discussed in Book V and which contains no metal and is used only to tint brass, but the metallic mineral (*cadmia fossilis metallica*) that Pliny says is a cupriferous stone from which copper is obtained. The older writers say that no other metal can be obtained from it. Actually it contains not only copper but also silver and sometimes the two metals even occur together. Like pyrite it may be free of metals. It is often found in copper mines but is more common in silver mines. It is found at times in veins not associated with other minerals. Galen himself writes that this *cadmia* was found in the mountains and rivers of Cyprus near a mine.

Bermannus. "There is another species of pyrite found in silver mines. Our people smelt copper from it and I believe that it occurs in this vicinity.

Naevius. "Will you please show it to us?

Bermannus. "You see this.

Naevius. "It is similar in appearance to copper. Dioscorides recommends such a mineral as better than all other for use by physicians.

Bermannus. "That is right.

Naevius. "But Pliny writes, 'They call it pyrite because there is so much fire in it.' Is not fire obtained from it?

Bermannus. "It is easy to strike fire from it and I believe, as Pliny, that the Greeks named it thus for this reason although it may have received this name because very often it is the color of fire.

Naevius. "That is possible. . . .

Bermannus. "This second species is almost the color of gold and occurs together with the first in Cyprus, as Pliny has written, and in the mines near Acarnania.

Naevius. "I remember. But I recall that the pyrite he says is similar to copper has distinctive colors and one may be silver-white, the other golden.

Bermannus. "You remember better than I and what he says is true. Copper is obtained from both.

Naevius. "Did you say a little while ago that silver was obtained from pyrite of a silver-white color?

Bermannus. "I did and this is true.

Naevius. "Then it contains both copper and silver?

Bermannus. "Not only silver and copper but sometimes the two together, sometimes silver and lead, sometimes even more metals, sometimes it is sterile and no metal can be obtained from it. You will find that the other species that is golden yellow is similar. Besides these two there is another species that commonly occurs scattered through the golden yellow pyrite.

Naevius. "Tell us about this latter species.

Bermannus. "It is similar in color to galena so that one has difficulty in determining whether it is pyrite or galena and for that reason our miners have another name for this species.

Naevius. "What is it?

Bermannus. "*Kisum.*

Naevius. "That is neither a Greek nor Latin word.

Bermannus. "It is our own word not taken from any other language. Perhaps it is neither pyrite nor galena but a separate genus. It has neither the color nor hardness of pyrite. It is almost the color of galena but has an entirely different composition. Gold and silver are obtained from it. Large qauntities are mined at Reichenstein in Silesia and recently brought to me from there. Even larger quan-

Cadmia is black, yellow brown, or gray. Like the *cadmia* produced in furnaces this mineral occurs in various forms. Some has the appearance of grapes, some occurs in cubes while some forms in crusts. Natural *cadmia* is more potent than that formed in furnaces. Actually it is so corrosive that it will eat the moist hands and feet of a miner. It differs from pyrite both in color and other properties. Pyrite, unless it contains sulphates, is either a golden or silver color, rarely any other, while *cadmia* is black, yellow brown, or gray. The former will cure gatherings while the latter is a deadly poison and will destroy any living substance. It is used to kill grasshoppers, mice and flies.[25]

This *cadmia*, like quicksilver, is placed in a flask and heated until the

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tities are found at Rauris. The latter mineral contains more silver than gold while the former contains only gold or very little silver mixed with the gold. Another species is also gray and is found in quite small grains at Reichenstein. It is mixed with the last species and gold is obtained from it. It is also found at Aldenberg, Silesia, where it has a somewhat different character and both gold and silver are obtained from it. Our miners also call this species *kisum*. (Note, *kisum* is probably arsenopyrite, a sulph-arsenide of iron.)

Naevius. "When we come upon it will you show it to us?

Bermannus. "Certainly. But returning to the pyrite with both a silver and golden color, it is often found in silver mines and more commonly in separate veins that are completely sterile, as I have already mentioned.

Naevius. "What use does it have in metallurgy?

Bermannus. "When it is found in large quantities it is melted into a kind of stone that is widely used in silver smelting. This pyrite is common in rivers and many chemists have collected it, only to be laughed at since it is almost sterile.

Naevius. "Aside from these species Pliny mentions another saying people have another species of pyrite that is very heavy and has a large amount of fire."

[25] This may refer to the cobalt arsenides smaltite, cobaltite and their oxidation products. That it includes cobalt minerals is evident from the following excerpt from *Bermannus*, page 467,

Bermannus. "This genus the miners call *cobaltum*, a name I believe we can now use, the Greeks call *cadmia*. The essences from which pyrite and silver are formed are seen to have congealed into a single body and thus has been created that which the miners call *cobaltum* (cobalt). There are those who believe it to be the same as pyrite since they have almost the same composition and there are others who regard it as a separate genus as do I. Very often it possesses an extraordinary corrosive quality so that it will eat into the hands and feet of workmen unless they take careful precautions against it. We know that pyrite will not do this. There are three species of this mineral which are more easily distinguished by color than by any other property. These are black, gray, and iron-colored. No matter what else they may contain there is usually more silver than in pyrite."

It is possible that the black mineral is asbolan or heterogenite impure mixtures of cobalt and other metals that are found in Hesse, Thuringia, and other German localities. The gray and iron-colored minerals probably refer to several cobalt minerals but particularly to smaltite which has the same crystal form as pyrite and is associated with silver in some German mines.

The derivation of cobalt through kobold, kobelt, etc., is interesting. The alchemists and miners of Saxony derived the name from the Greek root word κόβαλος

mineral is carried to the lid where it forms a black, bluish black, or gray compound which the chemists call sublimate of *cadmia*. This is even more corrosive than the natural mineral.[26] There is a natural relationship between this *cadmia* and *spodos* and *pompholyx* as was noted by Serapio, the Moor. The Greeks did not know it. Each is produced when *cadmia*, pyrite, galena, or similar metallic substances are burnt by subterranean fires or by fires set by miners in underground workings or pits in order to break the hard rocks. Black, bluish black, and gray *spodos* are obtained from *cadmia;* white *pompholyx* and gray *spodos* from pyrite; and yellow and gray *spodos* from galena. The white *pompholyx* obtained from a copper bearing stone will turn green eventually. Black sooty *spodos* is found at Aldenberg, Misena. White fluffy *pompholyx* occurs in the joints of the rocks of almost all quarries at Hildesheim except those in sandy rocks and in the summer it is often seen floating in the air.[27] The gray, dark blue and yellow varieties are found in certain silver mines where the miners break the rock by fire setting. All are tenuous and therefore light while the white *pompholyx* (halotrichite) is the lightest of all. All are strong desiccants. That which is produced from *cadmia* is exceedingly corrosive although it is not especially biting since it is so tenuous.[28] If the Aldenberg mineral falls on a sore or any place where the skin is broken a workman will not feel it particularly although it will eat away the skin until the bone is laid bare. This is enough concerning the four genera of mixed substances that contain a metal and also concerning *spodos* and *pompholyx* found in mines.

I shall now take up the sixth genus, which as I have said, contains a stone, a metal and a congealed juice. Substances placed in this genus are distinguished by the juice they contain. The mixture of a stone and a metal contains either sulphur, bitumen, alum, *atramentum sutorium*, salt, soda, or some other congealed juice. The cupriferous, cleavable rock found in Hesse near Werre Suntel belongs to the first. When burnt it gives off sulphurous moisture. Sulphur and then silver are smelted from a similar blackish rock from Kromen, Bohemia. Sulphur is obtained from pyrite in the Harz forest near Harzgerode and near the Elbe river at Brambach. *Spinus* found in the mines of Thrace belongs to the second species. It is very heavy, as Theophrastus says, and can be recognized readily when held in the hand. Stones that contain a metal are heavy while those that contain bitumen are light and one containing a mixture of the two has an intermediate weight. Having been broken up and heaped

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meaning goblin or some malignant force. The cobalt minerals had the appearance of silver and yet the alchemists and smelters could extract no metal from them, obtaining instead corrosive and poisonous fumes.

[26] This impure sublimate consisting in part of poisonous arsenious oxide was known as Huttenrauch. The natural mineral is arsenolite, arsenic oxide.

[27] This probably refers to alums and other closely related sulphate minerals.

[28] This may refer to goslarite, the hydrous sulphate of zinc.

into a pile it will catch fire readily and burn in the open air. It burns better if it has been rained on or has been sprinkled with water and for this reason we know it contains a metal and bitumen. Bitumen, when placed in a pile, will burn in the open air and a metallic substance burns better after it has been rained on several times. The cleavable stone, similar to *spinus* if not the same, dug up at the foot of Mt. Melibocus or Hosteda, as they now call it, in the Harz forest at Eisleben, Mansfeld, is black, bituminous, cupriferous and having been taken from pits sunk in the sand, is built up into a mound in an open space. The lower part of the mound is then covered with twigs and these in turn covered with the same stone. The twigs are set on fire and these in turn set fire to the stones that cover them and these set fire to other stones and all burn together. The ease with which they burn shows that they contain bitumen combined with sulphur. Small black and pure veins of bitumen occur at times in these same stones and when they burn they give off the same odors as burning bituminous coals. If a moderate rain falls these mounds burn more strongly and become soft more quickly. When the wind takes the smoke from a burning mound and carries it down onto a nearby body of standing water one soon observes a black, dark blue, or purple film that resembles liquid bitumen covering the water. All these things indicate that the stones are bituminous.

A genus of stone found near the Harz forest has crusts of scattered sparkling golden pyrite adhering to it and presenting the appearance of various species of animals such as turbots, pike, perch, and fowl and even salamanders. Numerous effigies have been observed, one of the bearded high priest of Rome with the triple crown upon his head, another of the Blessed Virgin carrying a child in her arms. In Hesse species of fish are found in a bed of this kind. Recently in the Tomashirn mine of Annaberg a bituminous *cadmia* has been mined that will burn when thrown on live coals and give off an odor similar to wood. This burns to an ash and contains a little silver.

The aluminous pyrite found below the highest bituminous coal seam on Mt. Misena about three miles from Zuicca is an example of the third species. This material is cupriferous.

Pale, black, or gray pyrite is an example of the fourth species. This is a sort of parent of *atramentum sutorium* and is related to it. *Atramentum sutorium* is produced from pale pyrite and the material that adheres to it, especially that from Goslar. Silver and lead are smelted from this although only a small quantity is obtained. The black pyrite is found, although rare, in Misena near Zuenicium and in a small wood of Breitenbrunn. In the latter locality the mineral contains the metallic substance characteristic of pure pyrite. This material is not very hard and quite friable. Often it falls apart by itself and melanterite forms as an efflorescence on it especially when the pyrite is kept in a moist place.

Cadmia is also rich in *atramentum*. Like pyrite, when kept in a moist

place it also produces black melanterite which in turn produces a white efflorescence that resembles salt.

Assius lapis that will eat away the flesh, and for that reason is called *sarcophagus*, forms in part from *cadmia* as we know.[29] Pliny writes that a cadaver buried in this material will be completely consumed except the teeth in forty days. *Cadmia* is evidently atramentiferous since it produces a white efflorescence similar to salt. According to Galen *assius lapis* takes its name from Assum where it is found. According to Pliny this is a town of Troy and according to Cornelius Alexander a town of Mysia. Actually it is not found in this single locality, as Pliny writes, but also in the stones of Lycia and in the Orient where the people use it to eat away the flesh of living people who have been tied to stakes. It is also called *asius* because it is found in Asia but this is probably a corruption of the word *assius* from which a letter has been dropped by transcribers either through ignorance or negligence. In medical writings this is called *assius*, *asius*, and *sarcophagus*, names derived from the places where it is found and from its properties. Pliny is in error in placing *sarcophagus* in a class separate from *assius lapis* as I shall explain at greater length elsewhere. It is commonly the color of white pumice or tuff with yellow veins in the lower portion. Since it is incoherent and soft it is light and friable. One variety, found on the surface of stones, resembles very fine flour and will adhere to the teeth. This is called flowers of *assius lapis*. It is, in part white, in part yellowish like pumice and when placed on the tongue is mordacious with a salty taste. Dioscorides calls this *salsugo*. Galen believed that it formed from sea foam that collected on stones and was later dried by the sun and for this reason had qualities of both the sun and the sea. The stone dries, dissipates, and liquefies moist flesh while flowers of *assius lapis* is the more efficacious although it is not so mordacious and is very tenuous. At one time this stone was used to make *carnivorae arcae* (carnivorous burial urns) in which the bodies of the dead were placed and quickly consumed. It was also used to make the vessels into which gouty feet were sometimes placed.

Nature produces the fifth species by congealing a mixture of a stone, a metal, and salt; the sixth from a stone, a metal, and soda. Similar species are made from a stone, a metal, and other congealed juices. I cannot say where these mixtures can be found but I am sure they exist. So much concerning mixed genera and their species. I shall now take up compound genera.

A compound, uniform substance consists of either two, three, or four simple substances, two to six mixed substances or one or more simple and one or more mixed substances. So many natural substances are found in

[29] *Assius lapis* is, in part, quick lime. Agricola has confused the artificial product with various natural minerals with similar appearance and properties but different compositions. Minute quantities of natural quick lime have been reported from Mt. Vesuvius.

these compounds that it is of value to consider them carefully. Otherwise the quality and nature of many things cannot be explained satisfactorily. When two simple substances are compounded they must be two of the following, earth, stone, metal, or congealed juice.

I shall take up first earths to which a congealed juice has been added. If the congealed juice is salt the earth is called saline; if soda, alkali; if alum, aluminous; if *atramentum sutorium*, atramentiferous; if sulphur, sulphurous; if bitumen, bituminous; and if one of the acrid juices such as *chrysocolla*, *aerugo*, *caeruleum*, orpiment, or realgar, similar terms are used.

Melia is one of the aluminous earths or species. It is gray and harsh so that it makes a harsh sound when rubbed between the fingers similar to that of pumice. *Ampelitis cinerea* is a bituminous earth with a white to reddish brown color.

The congealed juices contained in an earth are either visible to the eye or can be seen when the earth is broken apart if they have formed in small masses. On the other hand when an earth has absorbed these liquids in such a manner that they are distributed throughout the mass we recognize the well known ones by color, the rest by taste. Earths containing these are found in places where the same congealed juice is mined or where waters, flowing from the earth, contain them. Saline earths are common in Germany in the mountains near Seburg where there is a salt lake to the north. When the weather is clear those mountains glitter with salt. All the country between Seburg and Salsamund and between Salsamund and Halle is salt.

The Egyptian mud used to treat tumors contains soda. *Halinitrum*, as I have said, occurs in Germany as an efflorescence on the ground near Stassfurt. An aluminous earth, from which they produce alum, is mined near the famous town of Luneburg and near the Elbe at Brambach, Saxony; near Salfeld and Blaa, Voightland; near Radeberg, Misena; and at Schlachic, Bohemia. The earth that occurs in the commonwealth of Parasimus on the Scythian peninsula, according to Pliny, is obviously aluminous since it is used to heal all types of wounds. At Goslar, Saxony, a red earth is found that contains an *atramentum sutorium* essence and closely resembles red ocher. A sulphurous earth is found at the foot of Vulcan, Campania, underlying the plowed fields of Ariccia. The latter earth will burn when placed on a fire. A similar earth is found at Narni together with an aluminous earth that Pliny writes becomes drier with rains. Actually the aluminous earths are not washed away readily by rains as can be observed in certain parts of Hildesheim.

Bituminous earth is found at Halle in the district occupied by the Hermunduri, particularly in a pit to the south and near Satelum, Elboganum. Earths containing acrid juices, *chrysocolla*, *aerugo*, and *caeruleum* are found in gold, silver, and copper mines while earths containing realgar and orpiment are found in characteristic veins.

All these earths have the dual nature of both an earth and the congealed juice contained in them. Nature has given these congealed juices a fiery force. Pure earths dry and cool, saline earths dry and are also moderately astringent and cleansing. Alkali earths are more cleansing; aluminous earths more astringent; atramentiferous earths strongly astringent and also mordacious; sulphurous and bituminous earths discutient; and earths containing the juice that has no name are acrid. *Chrysocolla*, *aerugo caeruleum*, realgar, and orpiment make an earth mordacious. Thus earths possess variable properties depending upon the congealed juice they contain.

There are as many different compound substances as there are species of earths. For example, if any of the congealed juices are added to ocher, red ocher, or another species of earth they will change the nature of the compound substance. Since I have discussed the species of earths in Book II, it will not be necessary to mention them here.

Sometimes the same earth may contain several congealed juices. When the powdered rock from Pozzuolo is used in building walls in the sea it is soon converted into an impregnable stone by the waves, according to Pliny.[30] It contains alum, bitumen, and sulphur and is found on the hills of Pozzuolo in the Baiae district and, according to Vitruvius, in the fields of free towns near Mt. Vesuvius. According to Pliny a similar earth is found in the Cyzicena district where it is quarried in great masses and the earth itself, not a powder, placed in the sea where it is converted into stone. Similar earth is reported to occur near Cassandria. Oropus writes that any earth will be changed to stone if placed in the sea. These earths possess within themselves a quality which changes them into stones although waters may have this same quality as I have mentioned elsewhere. It is necessary that this species of earth be either aluminous, bituminous, or atramentiferous.

I shall now take up the earths that enclose stones and adhere to them. Samian earth sometimes contains *samius lapis* and chalk often contains silicious nodules. Very often small pebbles adhere to lumps of earth. Large masses of earth sometimes contain whole rocks, marbles, and stones, sometimes fragments of these, so it is to be expected that small lumps of earth would contain and surround pebbles of rock, marble, and stone as well as gravel, sand, and even gems. For this reason, when describing a locality we say that the earth or soil contains rocks, marble, or stones, or is full of pebbles or gravel, or it is sandy, or, in some cases, gem-bearing, or full of calcareous nodules. Since there are so many species of stones, gems, marbles, rocks, pebbles, gravel, and sand it is apparent that this genus of compound substances has a very great variety of compositions. For example, if hematite occurs in a mass of earth it will have a very

[30] This is the pozzuolana rock that is used today in the manufacture of hydraulic cement.

different composition from a similar earth that contains geodes or some other stone or an earth that contains a gem such as *smaragdus*, quartz, or any other gem. In the same manner, the presence of marbles, rocks, pebbles, gravel, and sand will vary the composition of an earth. We should consider the great variety of earths that may contain these numerous substances to appreciate the variety of compositions that are possible.

I shall now consider earths that contain metallic particles as well as those to which particles of metal adhere. We call these metallic earths. They vary according to the metal they contain. Those containing gold are called γῆ χρυσῖτις by the Greeks and auriferous earth by the Latins. The Greeks call an earth containing silver ἀργυρῖτις, the Latins, argentiferous earth. When they contain copper or lead the Greeks call them χαλκῖτις and μολιβδῖτις, the Latins, cupriferous and plumbiferous earth. Iron-bearing earth is called σιδηρῖτις by the Greeks and ferruginous earth by the Latins. There are two species of *argentaria* earth and three species of *plumbaria* earth since the former may contain either silver or quicksilver, the latter, lead, tin, or bismuth. The numerous species of earth produced a great many species of this compound substance all of which are recognized by the miner and called by their correct names. So much concerning earths that contain congealed juices, stones, or metals, or to which these adhere. I shall now discuss congealed juices.

Even when a material contains an abundance of a congealed juice, any earth adhering to salt, soda, alum, *atramentrum sutorium*, sulphur, bitumen, the acrid juice that has no name, realgar, orpiment, *chrysocolla*, *aerugo*, or *caeruleum* will change its composition as well as any species of rock, gem, stone, marble, pebble, gravel, sand, or any species of metal. However, natural substances other than earth, pebbles, gravel, and sand rarely adhere to a congealed juice. If the compound substance contains an abundance of stone any species of earth adhering to it will, of course, change the composition. In the same manner any congealed juice adhering to the stone will change the composition and it is in this way that saline, alkali and aluminous stones are produced. Any adhering metal will change the composition. The Greeks call auriferous stones χρυσίτης; argentiferous stones, ἀργυρίτης; cupriferous stones, χαλκίτης; plumbiferous stones, μολιβδίτης; and ferruginous stones, σιδηρίτης. As with the earths, there are three species of plumbiferous stones and two of the argentiferous since among the Greeks the name μολιβδίτης signifies a stone to which lead adheres and ἀργυρίτης a stone to which silver adheres.

Not only do stones have certain natural materials adhering to them but may also have these within themselves as if in a stomach. This enclosed material may be an earth such as the white earth in the geodes found in the marl at Chemnitz; a liquid juice, as the liquid in enhydros; or some other stone, as the *callimus* in some geodes. Such stones are usually spherical or rounded, rarely of any other form. However they differ in other ways. Some may contain stones that have become loose and hence

make a sound when the stone is shaken, for example, the *callimus* in geodes. In some places the stones adhere to the interior of the geode and make no sound when shaken. A stone may contain many stones such as the gems in the round Motschean geodes that are soft, of many species, and adhering to the walls. The Megarian *conchites* stone contains many shells.

Even though a compound substance contains an abundance of metal, any earth, congealed juice, or stone adhering to it will change the composition. So much concerning compound substances that consist of two simple natural substances.

I shall now discuss compound substances containing two mixed substances. Any of the six genera of mixed substances may be combined with any other. There are just as many species of these genera of compound substances as there are different compositions. For example, if the compound contains a species of the first mixed genus, a sulphurous, bituminous, or some other species, the addition of any species of any of the other five genera will change the composition. If the compound substance contains, in abundance, the first genus and species of the second genus are added to it a great variety of compounds are possible, since, in the second genus we have mixed auriferous stones, two species of argentiferous and three species of plumbiferous, cupriferous and ferruginous stones. Each species, as if a genus, embraces many other species. For example, argentiferous stones include the silver minerals that are gray, lead-gray, red, black, white, yellow, liver-colored, and the color of pumice. Any one of these may adhere to a sulphurous stone. Likewise particles of the species of the third to fifth genera may adhere to species of the first genus and produce a great many different compounds. There are as many if not more species in these other genera than in the first genus although they are all known by the same name with the exception of galena, pyrite, *cadmia*, and stibnite that belong to the fifth genus. Finally, if particles of species of the sixth genus are added to species of the first genus they will change the composition. For example, atramentiferous pyrite may combine with an atramentiferous stone. Thus numerous compound substances may be produced by combining species of the second to sixth genera with other species of any of these genera.

I shall now discuss compound substances containing a simple and a mixed substance. First, an earth may contain a particle of one of the species of the first mixed genus or the particle may adhere to it. A sulphurous, bituminous, or some other such stone will change the composition of an earth. The same is true of combinations of the other genera. I shall discuss species of the second genus since these are known by the same names as those of the other genera and also because more metal is recovered from them than from the species of the other genera. Although metal is recovered from the latter species, for the sake of brevity I shall not discuss them. An earth may embrace a mixed auriferous, two species

of argentiferous, three species of plumbiferous, cupriferous, or ferruginous stone. The Greeks are seen to have called these earths containing a mixed substance by the same names as the above mentioned metallic earths. I shall consider these substances briefly and mention only the argentiferous varieties. An earth may contain mixed silver minerals that are either lead-colored, red, white, black, gray, liver-colored, purple, or yellow. I should mention that an earth may contain such mixed substances as galena, pyrite, or *cadmia* of the fourth genus. The combinations may vary since the particles may be the size of walnuts, beans, peas, algaroba seeds, or even so small that no metallic substance is left when the earth is panned. Miners distinguish earths that contain mixed substances by color.

Sometimes particles of species of the sixth genus are contained in an earth or adhere to it. If the earth contains sulphurous or atramentous pyrite, atramentous *cadmia*, or some other species, it will, of course, change the composition. Particles of species of all six mixed genera may adhere to or be enclosed in a congealed juice, stone, or metal. Compounds that contain more mixed than simple substances are different. These include species of the six mixed genera that enclose or have adhering to them particles of earth, congealed juice, stone, or metal.

There remain the compound substances containing three substances. These may be three simple, three mixed, one simple and two mixed, or two simple and one mixed substance. Furthermore, compound substances may contain four, five, and even as many as ten natural substances and these give rise to great numbers of species.

The philosopher takes pleasure in the contemplation of the nature of these compounds while the miner takes pleasure in the profit and use he obtains from the metals he extracts from them.

The names of writers whose works I have used, also writers whose works are not extant. Authors are cited who refer to the subjects concerning which the latter wrote.

Aelius Lampridius
Aelius Spartianus
Aeschylus
Aetius Amidenus
Albertus
Alexander Aphrodisiensis
Alexander Cornelius
Alexander who writes about Lyciaca
D. Ambrosius
Antiphon
Apion Plistonices
Archelaus
Aristeas Procomnesius
Aristophanes
Aristoteles
Asarubas
Averroes
D. Augustinus
Aulus Gellius
Avicenna
Bocchus
C. Pliny Secundus Senior
Cassiodorus
Columella
Cornelius Celsus
Cornelius Nepos
Cornelius Tacitus
Ctesias
Diemachus
Democritus who wrote "De lapidibus"
Demostratus
Diodorus Siculus
Dionysius Afer
Dioscorides
Empedocles Agrigentinus
Eratosthenes
Euripides
Fabius Pictor
Flavius Vopiscus
Galenus Pergamenus
The unknown Greek who wrote "De admirandis auditionibus"
Hermogenes
Herodotus
Hesychius
D. Hieronymus
Hierocles
Hippocrates
Homerus
Horus
Jacchus
Ismenias
Juba
M. Varro
Martialis
Megasthenes
Metrodorus
Mithridates
Mnesias
Mutianus
Nicander
Nicias
Oribasius
Ovidius
Paulus Aegineta
Pausanias
Philemon
Philostratus
Philoxenus
Phocion Grammaticus
Pindarus
Plutarchus
Posidonius
Pselus
Ptolomaeus
Pytheas
Quadrigarius
Satyrus
Seneca
Serapio
Sextus Pompeius Festus
Solinus
Sophocles
Sotacus
Stephanus
Strabo
Sudines
Seutonius
Theognides
Theophrastus
Theomenes
Theopompus
Timaeus
Valerius Maximus
Verrius Flaccus
Virgilius
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Xenophon
Zenothemis
Zoroaster

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