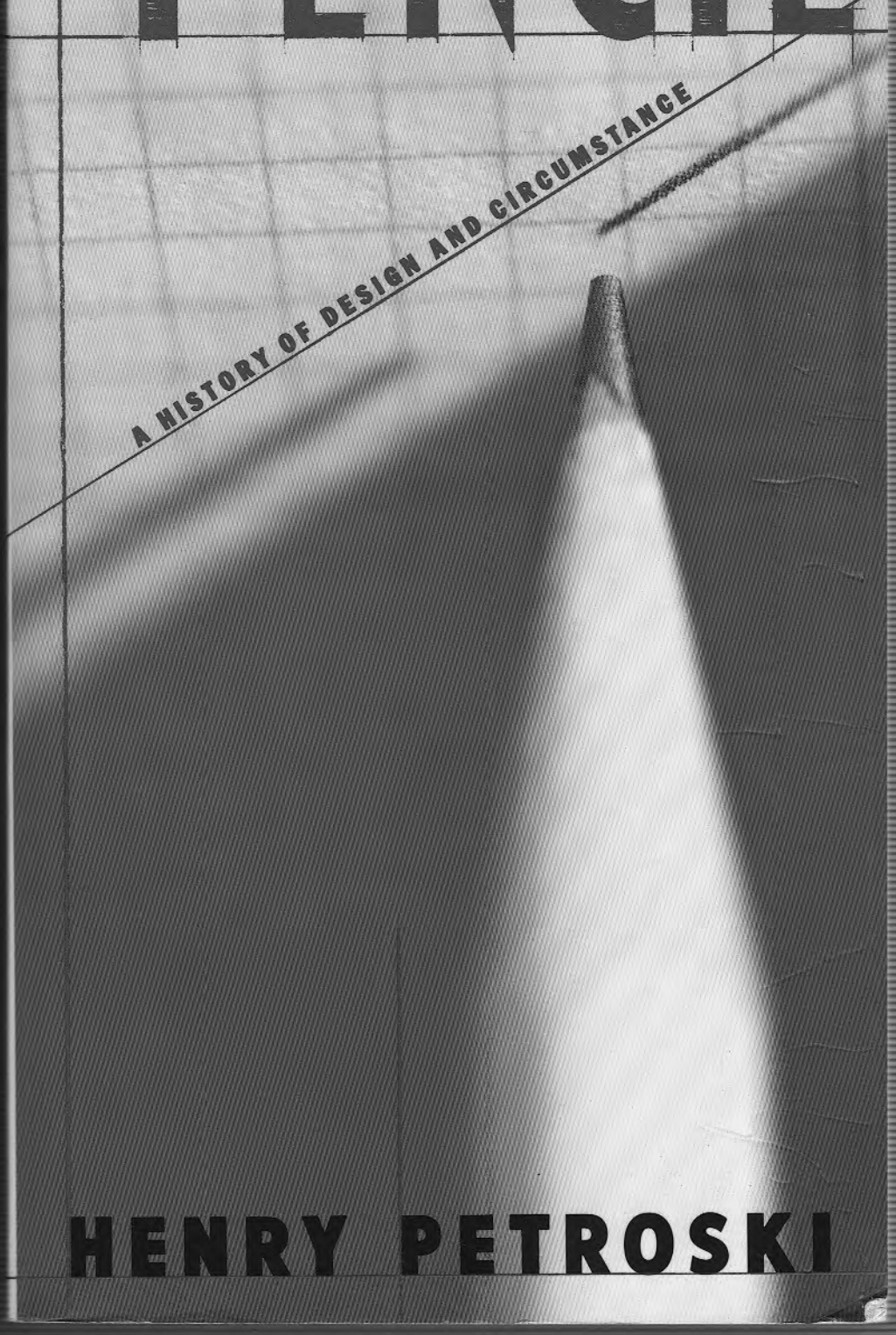
THE PENCIL

A HISTORY OF DESIGN AND CIRCUMSTANCE



HENRY PETROSKI

4/ Noting a New Technology

The modern history of the familiar wood-encased pencil goes back at least four centuries, because a clearly recognizable ancestor of today's pencil is described in a book on fossils written by the German-Swiss physician and naturalist Konrad Gesner and published in Zurich in 1565. Like virtually all scholarly treatises of the time, the book is in Latin, bearing the ponderous title that begins *De Rerum Fossi ium Lapidum et Gemmarum Maxime, Figuris et Similitudinibus Liber,* meaning that this is a book on the shapes and images of fossils, especially those in stone and rock. But unlike most other contemporary treatments of natural history, this book is illustrated. And among the illustrations is one showing not a fossil but what Gesner describes as a new kind of stylus or writing instrument, pictured beside a piece of the mineral from which its marking point was made. Not surprisingly, we know much more about the person who used this first known graphite pencil than we do about the pencil itself, its antecedents, or its artificer.

Konrad Gesner was born in Zurich, Switzerland, in 1516, and his precociousness led his father to send him to school in the household of a relative who grew and collected medicinal herbs. The boy learned to read Greek and Latin, and at the age of twenty-one he prepared a Greek-Latin dictionary. His ability in Greek enabled him to earn enough money to study medicine, and he lectured on Aristotelian physics even after becoming a practicing physician. It was quite natural for Gesner to be as interested in a new kind of writing implement as

Atrij puto, quod aliquos Stimmi Anglicum voca re audio) genere, in mucronem dera ſi, in manubri um ligneum inſerto.

L. Lateres è luto finguntur & coquunt, ad ædificiorum parietes, pauimenta, caminos: item ad furnos, aliosq; vſus.

Lithoſtrota dicuntur loca lapidibus ſtrata: vt apud Varronem pauimenta nobilia lithoſtrota. fiebant autem è cruſtis paruis, marmoreis præcipuè, quibus ſolum pauimẽti incruſtabatur. Vide Agricolam libro 7. de nat. foſſilium.

M. Menſæ fiunt nõ ſolùm è ligno: ſed etiam lapidibus & marmore, ſiue ſolidæ: ſiue marmore aut lapide ſiſili incruſtatæ duntaxat.

Molaris lapidis icon poſita eſt Capite

The first known illustration of a lead pencil, from Konrad Gesner's 1565 book on fossils

he was in fossils, for his curiosity was boundless. He was an omnivorous reader and an equally wide-ranging writer and editor, having about seventy books to his credit, including works that have earned him sobriquets ranging from "father of bibliography" through "German Pliny" to "father of zoology." He was said to have been "born with a pen in his hand," and he seems to have put it down only long enough to take up a pencil to make notes for a new book. Gesner died of the

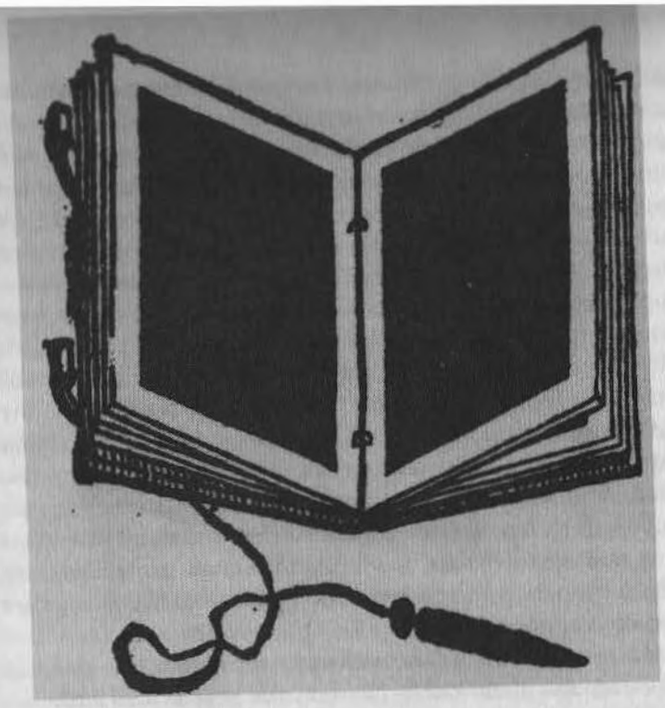
plague in 1565, the year his illustration of the pencil was published.

His other works include a medical tract on the virtues of milk, an account of about 130 languages known in his time, surveys of plant and animal life (heavily illustrated with woodcuts), and a critical bibliography of over 1,800 items, an encyclopedic work in which the recorded knowledge of the world was supposed to be surveyed. Needless to say, works explicitly on engineering were not prominent in Gesner's sixteenth-century bibliography. But for someone whose life must have been so fully occupied with reading and writing, coming across a new and convenient writing instrument must indeed have been as exciting as happening upon a new plant while mountain climbing.

The instrument pictured in Gesner's book looks like a tube of wood with a point of lead inserted in one end and a fancy knob on the other end, where we now expect an eraser. Another of Gesner's illustrations makes it clear that such a knob was used to provide a means of securing a piece of string to a stylus so that it might be tied to a naturalist's field book of tablets, which Gesner referred to as *pugillares,* and the vestiges of such a practice have continued into more recent times. Pencils with knobs and rings on their ends have long been manufactured, including, for example, program pencils for dances or ballot pencils for voting booths. In Victorian times, wooden pencils could be retracted into gold and silver cases to protect the lead as well as their owners' clothes, and the cases invariably had a ring for attaching them to a chain. Workmen and note takers have frequently been known to cut a notch around one end of their pencil, thus making it possible to attach a string and tie the pencil to a desk or clipboard. The modern ball-point pen, which has been described as "no more than an inky pencil," can still be found chained to the counters in post offices and banks.

However, to Gesner it was not the already familiar knob that was really remarkable, but the marking substance inserted in the business end of the tube, thus eliminating the need for any specially prepared surface on which to write or sketch. Gesner says of the object he illustrates only that:

> The stylus shown below is made for writing, from a sort of lead (which I have heard some call English antimony), shaved to a point and inserted in a wooden handle.



Gesner's illustration of a stylus attached to a set of bound wax tablets, also known as a table book

As common as the lead pencil is today, one can still find modern books on sketching and on engineering and architectural drawing that include illustrations of pencils among introductory discussions of equipment. But these books do not show lumps of graphite and only rarely do they describe the origins of the stuff. It must have been the novelty of the use of that substance when Gesner was writing that led him to describe not so much the pencil as its point. And being accustomed to including woodcuts of new species of plants and animals in his books, it was natural for Gesner to include an illustration of the new writing instrument and substance. Exactly what Gesner's illustration shows is somewhat subject to interpretation, but consistent with the idea that it is the material of which the stylus's point is made that is really novel, the lower nondescript object in Gesner's illustration must be a piece of "English antimony."

Although Gesner's stylus appears to be like a modern mechanical pencil, it really is much more primitive than that. The point of "lead" presumably has been sawn or shaved off

the larger piece illustrated and appears to be inserted in a tube that is perhaps in turn inserted into another, larger tube, probably not unlike the way tufts of hair were to make pencil brushes. Alternatively, Gesner's illustration can be interpreted to have some kind of ring compressing what might be a slit tube of wood around the piece of graphite. A small pointed piece of "lead" could easily be held in a tube in either fashion. A properly tapered tube press-fitted into another one and related types of connection to which tightening devices are usually added are in use today. Such devices are used in things as diverse as the telescoping legs of a photographer's tripod, the bit assembly of an electric drill, and, appropriately, the clutch mechanism of a mechanical pencil. The familiar Chinese-finger prison, in which the fingers are trapped when they are pulled apart, is a related device, though one that tightens when it is pulled rather than pushed, and the old penholder, into which the nib is forced and held by friction, is still another variation on the same basic idea.

But whatever the exact mechanism for holding the point in the invention illustrated by Gesner, this represented a considerable improvement over a piece of metallic lead or lead alloy wrapped in paper. Now one could not only produce a darker line but also have a clean, convenient, and comfortable instrument (which could be tied to a traveler's or a rock climber's sketchbook or notebook) in which to hold "leads" of different shapes and sizes, even leads too small to be held in the fingers. This would be an important consideration if the supply of the wonderful new marking substance were to become scarce and expensive and available only in small pieces, as it would from time to time.

In form and function, the marvel that Gesner described is clearly what we today call a lead pencil, and he treated it as a curiosity presumably because, at least to him, it was a new, improved portable writing instrument "from a sort of lead (which . . . some call English antimony)." This stuff would make a good mark on common paper and thus obviate the need for any naturalist to take into the field either *pugillares* in which to scratch with a metal-pointed stylus or a cumbersome and messy pen and inkwell—and the related paraphernalia—with which to record the fossils, flora, and fauna found in all sorts of inconvenient rock formations and other natural settings.

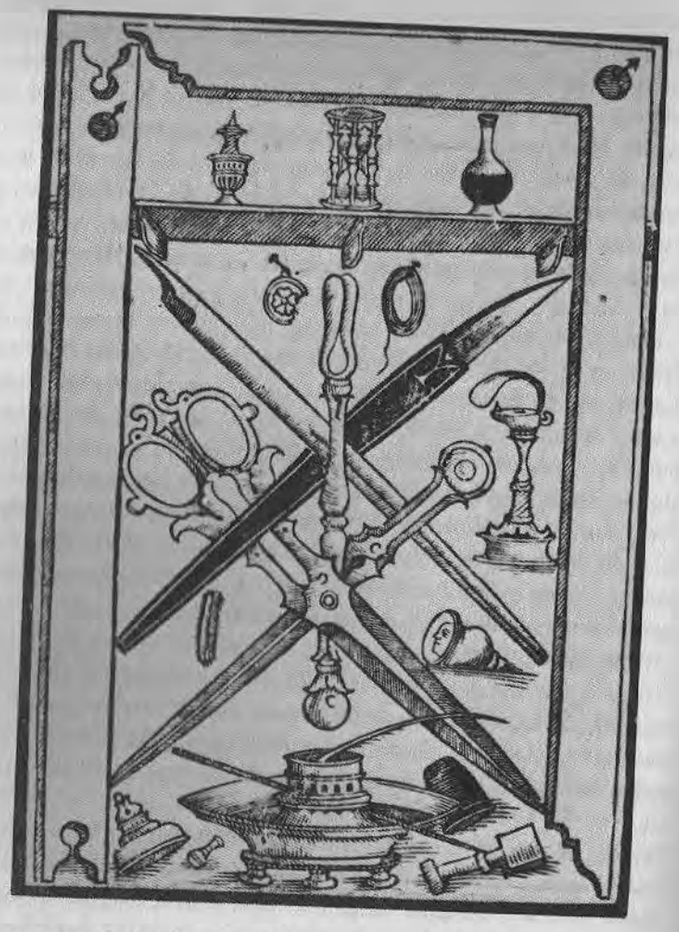
While Gesner's appears to be the first illustration of a modern pencil, it is not the very first reference to one. In 1564, a

year before Gesner's book was published, Johann Mathesius wrote of a then new discovery for writing: "I remember . . . how one used to write with silverpoint . . . and now one writes on paper with a new unrefined mineral." But this unspecific reference falls far short of the thousand words needed to equal Gesner's picture, and so neither it nor its author is remembered the way Gesner's illustration is. And neither Mathesius nor Gesner exactly dates the first appearance of the pencil, for they are only reporting on something already in use.

Gesner's illustration was reprinted, enlarged, in a book published in 1648. This was a posthumous continuation of the encyclopedic *Musaeum Metallicum* of Ulisse Aldrovandi, the sixteenth-century naturalist whose work was a "more complete but less critical compilation than that of Gesner." Aldrovandi, also writing in Latin, did not call the pencil's essential ingredient *"stimmi Anglicanum,"* but rather *"lapis plumbarius,"* or lead stone, but the inclusion of an illustration of the pencil indicates that it could still be considered remarkable—and the names for its marking material still multifarious—in the mid-seventeenth century.

While references to the pencil do document when it already existed, they do not reveal the precise date of its first appearance. But while the absence of references to the pencil does not prove its nonexistence, the silence of certain books can suggest it. For example, a book published in 1540 by the Italian writing master Giovambattista Palatino contains a description and illustration of what he claimed to be "all the tools that a good scribe must have." While a pair of compasses and a metal stylus are included for their use in marking guidelines for the pen, there is not a hint that the author had even dreamed of a piece of graphite, by any name, or a pencil made from it. Thus it may be assumed with some confidence that, at least in Italy in 1540, neither the graphite pencil nor its marking substance was known.

Exactly when and where pencils containing graphite were first made and used appears to be unrecorded, as are so many technological milestones. There are undocumented assertions that place the discovery of the graphite that Gesner refers to as early as about 1500 and as late as 1565, the date of his book. But the scanty evidence generally points to the unearthing of the pencil's marking substance—the "new unrefined mineral" or "English antimony"—as sometime in the early 1560s in Cumberland. However, in his *History of Inventions and Dis-*



A 1540 illustration showing "all the tools that a good scribe must have," but showing no lead pencil

coveries, John Beckmann wrote near the end of the eighteenth century that he was "unacquainted with the time when the pits in Cumberland, which, as is well known, produce the best plumbago, were discovered." The Latin word *plumbago,* which means that which acts like lead, was only one of many names for the curious material, which Beckmann noted was also "called *black lead, kellow* or *killow, wad* or *wadt,* which words properly mean black."

As could be expected to be the case in naming a material whose value lay in its replacing other materials, many other

names, including "black-cowke," "kish," and "crayon noir," were commonly used before the functionally descriptive and scientifically accurate name "graphite," derived from the Greek *graphein,* which means "to write," was suggested by A. G. Werner a full decade after the true chemical nature of the substance was finally determined by K. W. Scheele in 1779. The earliest names for the material, some of which appear in Beckmann's account, ranged from the inexplicable to the obvious. The traditional local name dating from the sixteenth century for the then new material found in the Cumberland hills was "wad" or "wadd," and in dialectal English that word also came to mean a graphite pencil, with the term "wad pencil" being used well into the twentieth century in the vicinity of the plumbago pits. Wadd was also called *nigrica fabrilis,* "for its use in scoring," as late as 1667 because it then still had no universally agreed-upon Latin name. A short communication to the *Philosophical Transactions* for May 1698, entitled "Some Observations Concerning the Substance Commonly Called, Black Lead," which mentions some of the above names, shows that well over a century after its discovery there was still much uncertainty about the nature of graphite:

> The Mineral Substance, called, Black Lead (our common Lead being the true Black Lead, and so called, in Opposition to Tin, which is the White Lead) found only in *Keswick* and *Cumberland,* and there called *Wadt* or Kellow . . . is certainly far from having any thing of Mettal in it, that it has nothing of Fusion, much less Ductility; nor can it be reckoned amongst the Stones, for want of hardness; it remains therefore that it must have Place amongst the Earths, tho' it dissolve not in water . . .

Being uncertain about how to classify graphite, the author of the note concludes, tentatively, with a confusing justification that "the most Proper Name that can be given it, perhaps, may be *Ochra Nigra,* or Black Ochre."

However, since the wadd behaved so much like metallic lead, it eventually came to be more widely called by the Latin term *plumbago.* And, of course, the name black lead was a natural description in English for something that made a much blacker mark than real metallic lead, though the color of the shiny new substance itself was not so unambig ous. The German word adopted for black lead was *Bleiweiss,* which trans-

lates literally as "white lead," and this word stems from an early "misconception of graphite being a shiny white lead-type metal," perhaps akin to tin. Today, of course, "white lead" is used to designate a poisonous paint pigment containing metallic lead carbonate. But by whatever name, the history of discoveries and uses of black lead was of more than academic interest for the "diplomatic science," at least according to Beckmann:

> To ascertain how old the use of black lead is for writing might be of some importance in diplomatics, as the antiquity of manuscripts ruled or written with this substance, or of drawings made with it, could then be determined. What little I know on this subject I shall here communicate, in order that others may be induced to collect more.
>
> I allude here to pencils formed of that mineral called, in common, *plumbago* and *molybdaena*, though a distinction is made between these names by the new mineralogists. The mineral used for black-lead pencils they call *reissbley, plumbago,* or *graphites*. . . . Plumbago . . . contains no lead; and the names *reissbley* and *bleystift* have no other foundation than the lead-coloured traces which it leaves upon paper. These lines are durable, and do not readily fade; but when one chooses, they may be totally rubbed out. Black lead, therefore, can be used with more convenience and speed than any coloured earth, charcoal, or even ink.

While Beckmann's pioneering scholarship may have induced others to collect more, there does not seem to have been very much more to collect. At least, not much more has been collected in the ensuing two centuries. In the early twentieth century debates did arise about the earliest pencil markings on manuscripts, with C. T. Schönemann claiming that lines drawn in black lead appeared on an eleventh- or twelfth-century codex in a German library. This was disputed by C. A. Mitchell, whose pioneering microscopic investigations of the nature of pencil marks turned up none in British museums produced earlier than the seventeenth century, thus defending the dating of the discovery of pure graphite in Cumberland.

Among the most recent histories of the area that became the center of English pencil making and the source of raw material for early pencil factories throughout Europe is Molly Lefebure's book *Cumberland Heritage*. In the introduction she is

blunt about the task of tracing the origins of the principal ingredient of the lead pencil to a fell, or hill, where shepherds once roamed:

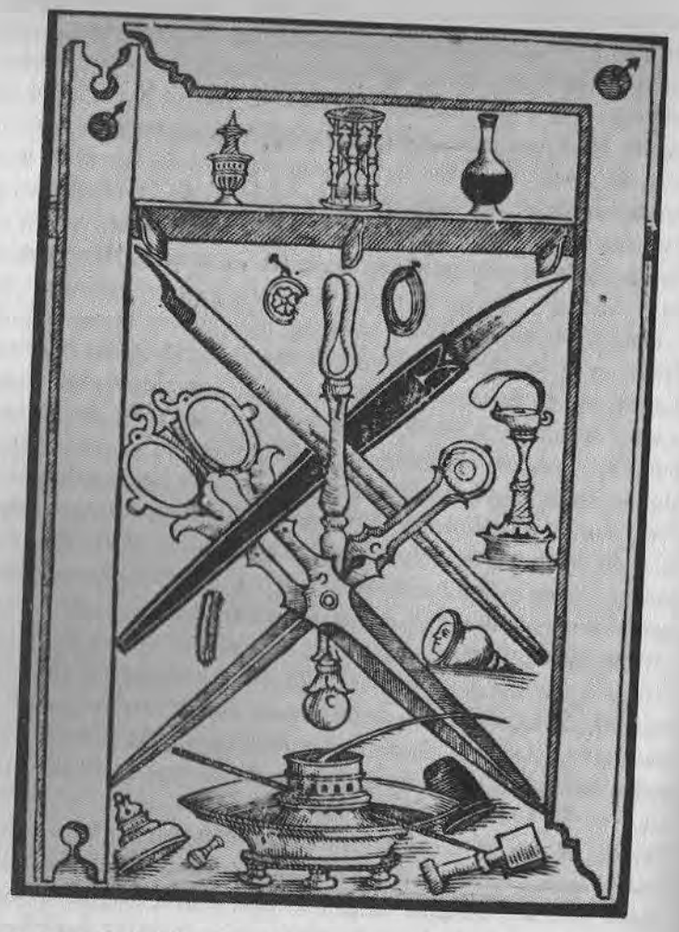
> The recorded history of wadd is patchy and largely unreliable, as is the case, too, with Keswick's famous pencil industry. Seatoller Fell [where the ancient wadd holes are], both literally and figuratively, is mist-distorted: distant rocks, looming through the fog like Peruvian pinnacles, dwindle, when approached, into stones a few feet high; Greenland bears some sheep; wadd, an established commercial commodity for over 300 years, proves amazingly elusive. The quest for its story . . . developed for the author into an almost Alice-like adventure; the nearer she drew to wadd, the further did wadd recede.

In her chapter entitled "In Quest of Wadd," Lefebure writes quite frankly about her frustrating scholarly search for the history of the discovery and the early exploitation of the material:

> Reading up wadd one discovers that most of the authorities are merely repeating the words of a previous writer; thus one digs one's way downwards through a slag-heap of endless (and sometimes erroneous) repetition.
>
> The wadd, according to legend, was discovered originally by shepherds, after a large ash-tree on the fellside (an alternative version of the tale gives it as an oak) had been uprooted by a gale. The date of the discovery is unknown. When first found the substance was simply used by the local people for marking their sheep (continues the legend).

One alternative version of the story of how the first graphite mine was discovered in the Cumberland manor of Borrowdale does not claim the scholarly "reading up" of Lefebure's work but does make a good story that is not quite as tentative. "The Pencil," an essay by Clarence Fleming published in a booklet originally issued in 1936 by the Koh-I-Noor Pencil Company, begins:

> The uprooting of a large oak tree during a storm, led, it is said, to the discovery of the famous graphite mine of Borrowdale, England. This was in 1565, in the time of Queen Elizabeth. A wandering mountaineer, attracted by



A 1540 illustration showing "all the tools that a good scribe must have," but showing no lead pencil

coveries, John Beckmann wrote near the end of the eighteenth century that he was "unacquainted with the time when the pits in Cumberland, which, as is well known, produce the best plumbago, were discovered." The Latin word *plumbago,* which means that which acts like lead, was only one of many names for the curious material, which Beckmann noted was also "called *black lead, kellow* or *killow, wad* or *wadt,* which words properly mean black."

As could be expected to be the case in naming a material whose value lay in its replacing other materials, many other

names, including "black-cowke," "kish," and "crayon noir," were commonly used before the functionally descriptive and scientifically accurate name "graphite," derived from the Greek *graphein,* which means "to write," was suggested by A. G. Werner a full decade after the true chemical nature of the substance was finally determined by K. W. Scheele in 1779. The earliest names for the material, some of which appear in Beckmann's account, ranged from the inexplicable to the obvious. The traditional local name dating from the sixteenth century for the then new material found in the Cumberland hills was "wad" or "wadd," and in dialectal English that word also came to mean a graphite pencil, with the term "wad pencil" being used well into the twentieth century in the vicinity of the plumbago pits. Wadd was also called *nigrica fabrilis,* "for its use in scoring," as late as 1667 because it then still had no universally agreed-upon Latin name. A short communication to the *Philosophical Transactions* for May 1698, entitled "Some Observations Concerning the Substance Commonly Called, Black Lead," which mentions some of the above names, shows that well over a century after its discovery there was still much uncertainty about the nature of graphite:

> The Mineral Substance, called, Black Lead (our common Lead being the true Black Lead, and so called, in Opposition to Tin, which is the White Lead) found only in *Keswick* and *Cumberland,* and there called *Wadt* or Kellow . . . is certainly far from having any thing of Mettal in it, that it has nothing of Fusion, much less Ductility; nor can it be reckoned amongst the Stones, for want of hardness; it remains therefore that it must have Place amongst the Earths, tho' it dissolve not in water . . .

Being uncertain about how to classify graphite, the author of the note concludes, tentatively, with a confusing justification that "the most Proper Name that can be given it, perhaps, may be *Ochra Nigra,* or Black Ochre."

However, since the wadd behaved so much like metallic lead, it eventually came to be more widely called by the Latin term *plumbago.* And, of course, the name black lead was a natural description in English for something that made a much blacker mark than real metallic lead, though the color of the shiny new substance itself was not so unambig ous. The German word adopted for black lead was *Bleiweiss,* which trans-

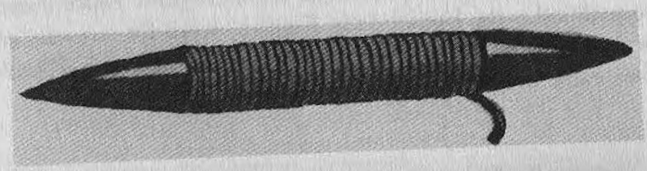
the particles of a strange, black substance clinging to the roots of the fallen tree, soon had the people of the countryside excitedly discussing the mysterious mineral.

The year 1565 is actually, of course, the date of publication of Konrad Gesner's book. Even Lewis Mumford, in the list of inventions appended to his famous *Technics and Civilization*, also dates the introduction of the lead pencil itself as 1565 and appears to credit Gesner with its invention. But this is certainly more than the naturalist claimed for himself, and all that seems certain is that plumbago was available and widely appreciated, especially by naturalists and artists. In 1586, for example, the English antiquary and historian William Camden could write of Borrowdale: "Here also is found abundance of that mineral earth, or hard shining stone, which we call Blacklead, used by painters in drawing their lines and shading."

Queen Elizabeth had encouraged new industries during her reign, and the help of experienced Germans was sought to develop the mining and smelting of various ores in several English counties, including Cumberland. The Germans were involved with mining in Keswick and its environs by the late 1560s, and it is very possible that it was through them that English graphite found its way to the Continent. It may also be a result of their sudden exposure to an abundance of metals in England that the Germans confused the English names for tin, "white lead," and wadd, "black lead," or developed their own reasons for calling graphite *Bleiweiss*, but the true reason, like the true date of the discovery of graphite, may never be known. Flemish traders and Italian artists have also been credited with introducing English graphite to Europe, and in Italy it was known as "Flemish Stone" or "Flanders Stone" because it came to southern Europe via Belgium and the Netherlands. Whatever its route to getting there, graphite was well known throughout Europe by the end of the sixteenth century, and in 1599 the Italian natural historian Ferrante Imperanti wrote of *grafio piombino* that "it is much more convenient for drawing than pen and ink, because the marks made with it appear not only on a white ground, but, in consequence of their brightness, show themselves also on black; because they can be preserved or rubbed out at pleasure; and because one can retrace them with a pen, which drawings made with lead or charcoal will not admit."

As Gesner's reference made clear decades earlier, however, it was not only artists who were interested in using black lead,

and there soon developed various means of holding pieces of it for writing as well as for drawing. Just as metallic lead had been wrapped in paper, so rough pieces of wadd, perhaps straight from the mine, were wrapped in sheepskin, and stylus- or pod-shaped pieces of the raw material were wrapped in paper or string, thus keeping the fingers clean. Rod-shaped pieces of graphite could also be pushed into the end of a hollow twig or reed. A series of short pieces could be inserted into a piece of straw bound around with string, which could be unwound and peeled away as the point wore down in much the way we peel the wrapper off a diminishing pack of mints today. Such natural cases for black lead as vine twigs must not have been uncommon, for even in the present century the term "vine" was still in use for a pencil in parts of Cumberland and County Durham.



A pointed piece of wadd wrapped in string

By the seventeenth century, Borrowdale lead was widely exported. In Germany, where it was regarded as a mixture fused with antimony, it was also known as "bismuth." And with the true chemical understanding of Borrowdale wadd still almost two centuries away, in 1602 Andrea Cesalpino, the Italian physiologist and innovative botanist, wrote of it by still another name, apparently confusing its places of application, where "pointed pencils were made of it for the use of painters and draftsmen," with its place of origin: "I think also that molybdenum is a certain stone shining with black color like lead, so slippery to the touch that it seems to have been polished, which comes off on the hands of anyone who touches it with an ashen stain shining like lead: painters use it in little sticks put into tubes; it comes from Belgium." Cesalpino also noted that some "say they find it in Germany, where they call it bismuth."

By 1610 black lead was sold regularly in the streets of London, for artists and others to fit into their wooden pencil cases, or perhaps for those who did their fieldwork in books in their studies to wrap in paper or string or to insert in twigs. By 1612

not only the blackness of the mark but also its removability were oft-repeated features of Borrowdale lead, and one writer, commenting on making notes in printed books, recommended for those "which you would have faire againe at your pleasure" to "note them with a pensil of black lead; for that you may rub out againe when you will, with the crums of new wheate bred."

The reputation of Borrowdale wadd continued to spread throughout the seventeenth century. Black lead was in great demand everywhere, and as its use grew so did the development of devices for holding it in a clean and convenient way. A holder, called by its French name of *porte-crayon,* had claw-like grips that could be locked in place to hold unrefined pieces of the black lead (or chalk or charcoal, for that matter), and M. C. Escher's haunting *Drawing Hands* are sketching each other with pencils held in metal *porte-crayons*. Since *crayon* unqualified is the French (and English) word for virtually any dry drawing or writing medium, the name *crayons d'Angleterre* came to distinguish black lead from other media.

A wooden *porte-crayon*

As the means to use it became more common and the popularity of the unique product of the Cumberland deposit spread, so did word that the readily stolen and disposed-of commodity was a source of quick money. Wadd was a strategic resource to be protected, and when stockpiles were adequate for England's purposes, the Borrowdale holes would be ordered closed for years at a time, even being flooded to ensure that no wadd could be removed. This precaution was taken because for a period the mine was being worked only six or so weeks every five or six years, for that concentrated effort was sufficient to dig out what graphite was needed. The Borrowdale mine remained closed from 1678, when it was believed to be almost worked out, until 1710, when new lodes were sought. Upon opening the mine it was discovered that pilferers had been at work during that period. Toward the end of the eighteenth century the mine would again be producing poorly, with only about five tons of inferior graphite mined in 1791.

It is not known exactly when the easily concealed wadd began to be smuggled wholesale from the mine, but the practice eventually grew to such proportions that elaborate security and legal steps had to be taken. Military and other uses of graphite, such as for casting "bomb shell, shot and cannon balls," must have been in part responsible for causing a bill to be introduced in the House of Commons entitled "An Act for the more effectual securing Mines of Black Lead from Theft and Robbery," and making it a "felony to break into any mine or wad-hole of wad . . . and steal any." The bill received three readings, was considered by a committee of the whole, and was passed by the House of Lords, to be made law on March 26, 1752, when His Majesty George II, in full regalia on his throne and with the robed Duke of Cumberland at his side, pronounced, "Le Roy le veult."

Appendix A

from "How the Pencil Is Made," by the Koh-I-Noor Pencil Company

The graphite, however pure, is apt to have foreign matter mixed with it, so the first thing to be done is to carefully clean it. The gravitation process is one commonly used. In this, the graphite is mixed with hot water until in a fluid state when it is fed into the first of a number of tubs, usually six, set on steps, the first the highest, the next one step lower, and so on down the line. The fluid is kept in motion by an agitator and pours from the top through a fine mesh sieve to the next tub and so to the last. The sieves grow finer of mesh until that through which the fluid is fed to the last is about 200 meshes to the inch. In each tub, the impurities, which are heavier than the graphite, sink to the bottom so that the material finding its way into the last tub is pure and entirely free from all foreign matter.

The clay, the finest of which for lead pencil purposes is found in Czechoslovakia, is cleaned in the same manner as the graphite. As grit, however minute in size, is fatal to a good lead, and as this thorough washing process insures freedom from it, this extreme care is justified.

The fluid graphite is pumped into a filter press which squeezes the water out, leaving the graphite in large square cakes. The clay is dried in the same manner.

After further drying, the graphite with the addition of clay, which is proportioned according to the degree of lead to be made, is mixed with water and thoroughly milled. The quality of lead to be made determines the time of the grinding. The longer the grinding, the better the lead. It is interesting to note that the average time required to grind Koh-I-Noor lead is approximately two weeks.

The mixture is now ready for forming into leads. It is put into heavy iron cylinders in the bottom of which is a die, usually of sapphire, of the diameter of the lead to be formed. Under great

hydraulic pressure, this mixture is forced through the die, coming out like an endless, round shoestring. This is taken, broken off in correct lengths, and laid out on flat iron plates where it is straightened, dried and cut to pencil lengths. These leads are packed in crucibles and sealed up in a furnace where, in a temperature of more than 2000°F., they are tempered. After a gradual cooling, the leads are "prepared" by immersing in a bath of hot oils and wax. This process has an important effect on the smoothness and general marking ability of the lead. Now with a final drying and cleaning in sawdust, the lead is ready to be put in the wood.

The thoroughly seasoned cedar wood is cut into bolts from which are sawn the "slats" which are worked into pencils. These slats are slightly longer than the length of a pencil, the thickness of a half pencil, and usually the width of six pencils.

The slats are planed and grooved for the leads in one operation. The grooves are deep enough to cover one half the diameter of the lead.

After brushing the grooved slats with glue, the leads are laid in and a similar grooved slat is fitted over the first. A quantity of these are placed in a frame, pressed carefully under hydraulic pressure, locked in the frames, and set away to dry.

The pencils are cut apart in shaping machines by cutters revolving at high speed. Passing through once, half of the pencils' circumference is formed. By turning the block and repeating the operation, the pencils are fully formed. In this state they are known as plain cedar pencils and, while qualified to do the work of finished pencils, there are many operations necessary before they are ready to be offered for sale to the users.

From the shaping machines, the pencils are taken to be sandpapered. A fine paper reduces every slight unevenness of surface, leaving them with a velvet-like feel.

Now the color is applied, usually by varnishing machines. The pencils are fed automatically from a hopper, through a bath of color, then through a disc of felt which smooths the color on and removes the surplus. An endless pin-belt receives the pencils, carries them over a heated compartment, emptying them, dried, into a basket at the other end of the machine. This operation is repeated over and over again until there is a good covering of color. Then the finish coat is applied and the pencils are taken to the sizing machine.

Varnish has accumulated on the ends of the pencils. This is quickly removed in the next operation by two large, rapidly revolving sandpaper-covered drums set opposite each other with a space between, through which moves an endless belt carrying the pencils. The drums turn toward each other, and the sandpaper surface, coming in contact with the ends of the pencil, removes all varnish and at the same time reduces the pencils to exactly the same length.

In America, most people want an eraser on their pencil. As the eraser is usually held by a metal ferrule, there are several operations

necessary to put this on. First, a shoulder is cut or pressed on one end of the pencil, usually by an automatic machine, the ferrule is fitted on, prick-punched, securing it to the wood, and then the rubber plug is inserted, sometimes by an automatic machine and often partly by hand.

Stamping is the next process. This is done by different methods, according to the quality of the pencils. Where pure gold leaf is used, as on the finest Koh-I-Noor goods, the stamping is often done with hand presses. The gold leaf is cut into narrow strips which are applied to the pencil.

The stamping material may also be in the shape of a large roll, automatically fed over the pencil. Sometimes on cheaper goods, bronze powder is used. In any case, the stamping die, which is of steel and heated, generally by electricity, is brought into contact with the pencil under some pressure. The stamping material lies between the pencil and the die and is thus pressed into the painted surface. Any surplus stamping material is then wiped from the pencil, leaving the lettering sharp and clear.

The branded pencils, after a careful inspection and cleaning, are now ready to be boxed.