Pencils & Pencil Lead

By Steve Ritter

Most adults probably realize that there isn't any elemental lead in a pencil. But I worried about that when I was a kid after I had the point of a freshly sharpened No. 2 lodged in the palm of my right hand. It's still there, 30 years later.

My cousin Matthew and I used to sit next to each other in the first grade and often shared school supplies. One day I asked to borrow his eraser, and when he turned to hand it to me, he was holding his pencil in the same hand. The wound healed after a few days, but I was left with a visible half-centimeter-long piece of pencil lead in my hand. I'm sure my mother called the doctor to find out about the possibility of lead poisoning, but the doctor probably said not to worry because pencil lead isn't really lead, it's a nontoxic mixture of graphite and clay.

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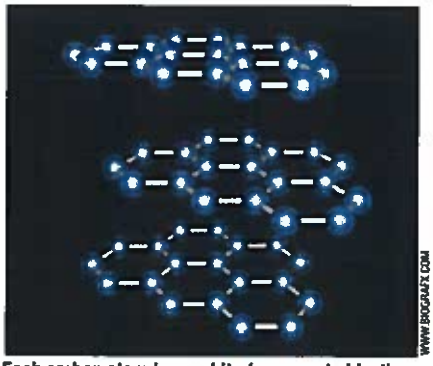
The connection between graphite and lead stems from the days of the Roman Empire (and likely before that), when lead rods were used by scribes to write on papyrus. Both graphite and lead leave a gray mark on paper, although graphite is a bit darker. Graphite didn't come into widespread use for writing until after the 1564 discovery of a very pure graphite deposit in Borrowdale, England. At the time, graphite was thought to be a type of lead and consequently was called black lead or plumbago.



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Each carbon atom in graphite (represented by the blue spheres) is bonded to three other carbon atoms which form hexagonal structures. These hexagonal structures comprise graphite's flat sheets, which are held together by weak intermolecular forces, making it easy for the sheets to slip over one another.

In 1779, Swedish chemist Carl W. Scheele determined that black lead was actually a form of carbon; in 1789, German geologist Abraham G. Werner reportedly gave it the name graphite, after the Greek graphein, meaning "to write." Inks were already widely available and were usually applied to paper with a brush called a peniculus, which is Latin for "little tail," hence the basis for the word "pencil." Charcoal probably was used in ancient times to mark on paper as well.

Graphite from Borrowdale originally was used in chunks called marking stones. Because graphite is softer and more brittle than lead, it requires a holder when carved into pencil-shaped sticks for writing. At first, sticks of Borrowdale graphite were wrapped with string, and the string was slowly unwound as needed as the writing core wore down. Later on, graphite was inserted between two slats tied together or into wooden sticks that were hollowed out by hand to create the first wood-cased pencils.

The Borrowdale deposit was pure enough to use without modification. But lower quality graphite needs help to keep it in a usable form. Various binders mixed with graphite powder have been tried, such as gum, resin, or glue. Sulfur also has been

Top left: A mixture of graphite and clay has been extruded through a thin tube to form long, thin rods that are stored in large pallets.

Bottom center: Machines insert the leads into grooved wooden slats and glue a second grooved slat on top.

Top right: After the glue is allowed to cure individual pencils are cut from the large slats.

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mixed with graphite, which results in writing cores most like pure graphite. In 1795, French chemist and Napoléon courtier Nicolas-Jacques Conté invented a process to mix graphite with clay and water, a process that is still used.

Today, graphite and clay are crushed into a fine powder in a rotating drum containing large rocks. Water is added and the mixture is blended for up to three days. The water is pressed out of the mixture, leaving a gray sludge that is air-dried until it hardens.

The dried sludge is ground into a powder, water is added again, and the mixture is blended to form a soft paste. Carbon black may be added to increase the darkness of the lead. The paste is extruded through a metal tube to form thin rods that are cut into pencil-length pieces—called leads—that are then dried. The leads are heated in an oven to 1,800 °F (about 1,000 °C) or higher to make them smooth and hard. The ratio of graphite to clay can be adjusted to vary the hardness of the lead: the more clay, the harder the lead; the harder the lead, the less graphite comes off onto the paper, making a lighter line.

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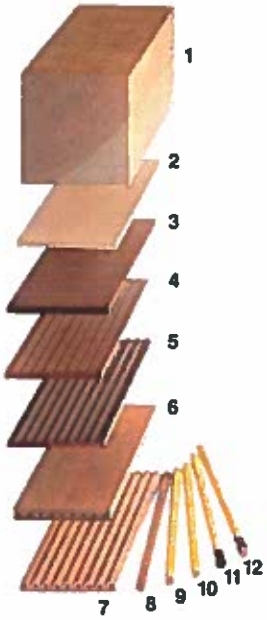

The pencil making process, in brief.

Pencils are made by cutting blocks of wood into slats that are machined to form a groove (two to nine per slat) to place the leads. A second slat is glued onto the first, sandwich fashion, then individual pencils are cut from the sandwich and sanded smooth. The pencils are next painted with five to eight coats of paint, and a recess is cut for the ferrule—the metal ring that holds the eraser. The ferrule and eraser are crimped into place, and a metal stamp is used to press a label onto the pencil.

Various types of wood have been used to make pencils over the years. Red cedar from Kenya and the United States was an early favorite, but today nearly all pencils worldwide are made from incense cedar, a species that grows in California's Sierra Nevada Mountains. The first pencils were unlabeled and unpainted to show the fine grain of the wood used. But by the 1890s, manufacturers started stamping their names on pencils and painting them.

The latter tradition got started when a French merchant-adventurer named Jean-Pierre Alibert discovered very pure graphite along the Russian-Chinese border in the mid-1800s. Alibert later developed a mine and began shipping the graphite to points around the world. Pencils made with high-quality Asian graphite were painted yellow to indicate the source of the graphite. Although there are several domestic and international sources of graphite today, about 75% of the 2.8 billion pencils manufactured annually in the U.S. are still painted yellow.

The hardness of the lead is indicated by a number (1 to 4) stamped on the side of most pencils—the higher the number, the harder the lead. Sometimes there are other markings: H indicates hard, B indicates the blackness of the pencil's mark, and F indicates that the pencil can sharpen to a fine point. Sometimes combinations are used: HB, hard and black; HH, very hard.

Many of the names stamped on pencils are manufacturer's model names or company name, but these generally have historical significance. For example, the Ticonderoga, made by Dixon Ticonderoga Co., is named after the Revolutionary War fort in upstate New York, which is near one of the purest graphite deposits known, 99.9% pure carbon.

Here are some amazing pencil facts: Laid end-to-end, the number of pencils made annually in the U.S. would encircle Earth about 15 times. In 1858, erasers were attached to the ends of pencils for the first time; most pencils in the U.S. have erasers, but those in Europe do not. A pencil lead or a line drawn by a pencil will conduct electricity. Colored pencils are made from chalk, clay, or wax mixed with binders and pigments.

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