

## November 2008 Mineral of the Month: Talc

The softest all of minerals, talc is rated at 1.0 on the Mohs scale of mineral hardness. Read on to learn why talc is so soft, its many interesting uses, and the origin and significance of the Mohs scale itself.

### PHYSICAL PROPERTIES

Chemistry:  $\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$  Basic Magnesium Silicate (Magnesium Silicate Hydroxide)

Class: Silicates

Subclass: Phyllosilicates (Sheet Silicates)

Group: Pyrophyllite-Talc

Crystal System: Monoclinic

Crystal Habits: Crystals rare; usually occurs in massive, foliated, granular, fibrous, compact, and waxy forms.

Color: Pale to bright emerald-green; also white, gray, or brown; occasionally silvery.

Luster: Dull vitreous to pearly and greasy

Transparency: Translucent to opaque

Streak: White

Cleavage: Perfect in one direction

Fracture: Uneven to lamellar; thin flakes are flexible.

Hardness: 1.0

Specific Gravity: 2.7-2.8

Luminescence: Often fluorescent

Refractive Index: 1.538-1.575

Distinctive Features and Tests: Best field marks are extreme softness; perfect one-directional cleavage; and greasy or soapy feel. Laboratory tests are often necessary to distinguish talc from pyrophyllite [basic aluminum silicate,  $\text{Al}_2\text{Si}_4\text{O}_{10}(\text{OH})_2$ ]

Dana Classification Number: 71.2.1.3

### NAME

This month's mineral is pronounced as spelled—TALC, with the "a" sounded as in the word "calcium." The English word "talc" is rooted in the Latin *talchus*, which in turn stems from the Arabic *talq*, meaning "pure," a possible allusion to the white color of powdered talc. Widespread occurrence and a long history of use has given talc many alternative names, among them "agalite," "asbestine," "colubrine," "Federweiss," "French chalk," "Gilstein," "kerolite," "lardite," "lavestine," "Lieberstein," "ollite," and "yalck." In European mineralogical literature, talc appears as *talk* (German, Dutch, and Swedish) and *talco* (Spanish and Italian). "Steatite" and "soapstone" are terms for a massive, talc-rich rock that is an ornamental stone and the primary ore of talc.

### COMPOSITION

After more than twelve and a half years of featuring marvelous minerals, common and uncommon, attractive and not-so-attractive, this is the first time we have had access to a large lot of attractive talc. We thought that in order to feature the mineral that holds position one on the Mohs scale of hardness, we would have to send you specimens of an unattractive, off-white or gray color in unappealing masses, as this is how talc is usually found. (Years ago, a mineral store owner once remarked to us how difficult it was for him to sell minerals that all white or all black—that most collectors tend to get stimulated only by colorful minerals—a profound statement that affected the way we buy for our show inventory.) So you can imagine how excited we were when we first laid eyes on these lovely green specimens! We couldn't wait to send them to our members, and made arrangements to pick up a large lot.

## ***November 2008 Mineral of the Month: Talc***

Talc's chemical formula  $\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$  identifies its elemental components as magnesium (Mg), silicon (Si), oxygen (O), and hydrogen (H). The ideal molecular weight of talc is made up of 19.23 percent magnesium, 29.62 percent silicon, 50.62 percent oxygen, and 0.53 percent hydrogen. In the talc molecule, the simple cation, or positively charged ion, consists of three magnesium ions ( $3\text{Mg}^{2+}$ ) with a collective +6 charge. The complex anion, or negatively charged ion, contains two radicals (groups of atoms of different elements that are bound together and act as a single chemical entity). The silicate radical ( $\text{Si}_4\text{O}_{10}$ )<sup>4-</sup> consists of four silicon ions ( $4\text{Si}^{4+}$ ) with a +16 charge and 10 oxygen ions ( $10\text{O}^{2-}$ ) with a -20 charge, which provide the radical with a collective -4 charge. Talc's complex anion also contains two hydroxyl radicals [ $2(\text{OH})^{1-}$ ] with a collective -2 charge. The overall -6 anionic charge balances the overall +6 cationic charge to provide the talc molecule with electrical stability. In talc's chemical name, basic magnesium silicate, the term "basic" indicates the presence of the hydroxyl ions.

Talc is a member of the silicates, which are combinations of oxygen and silicon with one or more metals. The basis of the silicate structure is the silica tetrahedron ( $\text{SiO}_4$ )<sup>4-</sup>, in which four equally spaced oxygen atoms surround a silicon atom. Silicate minerals consist of silica anions bound to metal cations in repeating structural units that are categorized into seven general groups: independent tetrahedral silicates (nesosilicates); double tetrahedral silicates (sorosilicates); framework silicates (tectosilicates); single- and double-chain silicates (inosilicates); ring silicates (cyclosilicates); and sheet silicates (phyllosilicates).

Talc is a phyllosilicate or sheet silicate, a term that aptly describes its crystal structure. The word "phyllosilicate" comes from the Greek *phyllon* or "leaf," which translates roughly as "to leaf apart," a reference to its tendency to flake (separate along cleavage planes) into thin, leaf-like sheets. In the sheet silicates, each silica tetrahedron shares three oxygen ions with adjacent tetrahedra. This arrangement forms very thin, sheet-like structures that extend indefinitely in two directions. Within these flat sheets, the silica tetrahedra are arranged in three-, four-, five-, six-, or eight-membered rings. In the case of talc, the silica rings have six members.

Sheet silicates are subclassified structurally into two-layer and three-layer groups. As a three-layer sheet silicate, talc consists of two outer silica tetrahedral layers with the apices of their tetrahedra pointing toward each other. The charges on these layers are satisfied primarily by positive magnesium ions which occupy the interstitial spaces between the oxygen ions, and by hydroxyl ions that neutralize the residual positive charges. This creates a three-layer unit with the magnesium and hydroxyl-ion layer "sandwiched" between two silica layers. Talc consists of millions of these complex, layered sheets. Because each sheet is neutral, adjacent sheets are not joined by strong bonding, but rather by a very weak, electrostatic attraction called "van der Waals' force." Named for the Dutch physicist Johannes Diderik van der Waals (1837-1923), this is a weak attractive force between neutral atoms and molecules that is generated by the electric polarization induced in adjacent particles and that is similar to a static-electric charge. Other common sheet silicates are apophyllite, chrysotile, and the mica and the chlorite mineral groups.

The talc lattice has three distinct types of atomic bonds: strong covalent bonds within the silica tetrahedra; ionic bonds between the metal cations, hydroxyl anions, and silica sheets; and the weak van der Waals' force that bond the adjacent silica sheets. Van der Waals' force, which is easily broken by minimal physical stress, explains several of talc's most notable properties. As the softest of all minerals, talc is the reference species for the rating of 1.0 on the Mohs hardness scale (see "Friedrich Mohs and the Mohs Scale of Mineral Hardness"). The slight pressure of drawing a fingernail across a talc surface is sufficient to break the van der Waals' force, displace the silica sheets, and create a scratch. Van der Waals' force is present only within a single lattice plane and accounts for talc's perfect, one-directional cleavage. Finally, van der Waals' force explains talc's greasy feel, which is due to the continuous displacement of silica layers under the slightest touch.

## ***November 2008 Mineral of the Month: Talc***

The Dana classification number 71.2.1.3 first identifies talc as a phyllosilicate with a two-dimensional, infinite sheet structure consisting of six-membered rings (71). The subclassification (2) next defines it as a phyllosilicate with three-layered sheets consisting of two silica layers and a middle layer of metal cations and hydroxyl anions. Finally, talc is assigned to the pyrophyllite-talc group (1) as the third (3) of six members. The pyrophyllite-talc group minerals, all of which are basic silicates with similar properties, include:

- 71.2.1.1 Pyrophyllite  $\text{Al}_2\text{Si}_4\text{O}_{10}(\text{OH})_2$
- 71.2.1.2 Ferripyrophyllite  $\text{Fe}_2\text{Si}_4\text{O}_{10}(\text{OH})_2$
- 71.2.1.3 Talc  $\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$
- 71.2.1.4 Willemseite  $(\text{Ni},\text{Mg})_3\text{Si}_4\text{O}_{10}(\text{OH})_2$
- 71.2.1.5 Minnesotaite  $(\text{Fe},\text{Mg})_3\text{Si}_4\text{O}_{10}(\text{OH})_2$
- 71.2.1.6 Brinrobertsite  $(\text{Na},\text{K},\text{Ca})_{0.35}(\text{Al},\text{Fe},\text{Mg})_4(\text{Si},\text{Al})_{80}\text{O}_{20}(\text{OH})_4$

These formulas show the cationic substitution within the pyrophyllite-talc-group minerals. All members form partial solid-solution series and share similar properties and structures. Talc is the most common member, followed by pyrophyllite; the other four members are rare. Pyrophyllite and talc are especially difficult to distinguish in the field.

As a secondary mineral, talc forms primarily through the hydrothermal alteration of basic magnesium-rich rocks and the low-grade metamorphism of silica-rich dolomite rock, that is, rock containing at least 50 percent calcite [calcium carbonate,  $\text{CaCO}_3$ ] and dolomite [calcium magnesium carbonate,  $\text{CaMg}(\text{CO}_3)_2$ ]. Talc often occurs with tremolite [basic calcium magnesium silicate,  $\text{Ca}_2\text{Mg}_5\text{Si}_8\text{O}_{22}(\text{OH})_2$ ] and magnesite [magnesium carbonate,  $\text{MgCO}_3$ ] in the talc schist of regional-metamorphic rocks, and with tremolite in contact-metamorphic rocks. Tremolite and chlorite (a group of greenish clay minerals of varied basic magnesium iron aluminum silicate composition) also alter into, and are frequently intergrown with, talc. Impure talc or “talc rock” (rock containing more than 50 percent talc), is known as “steatite” or “soapstone.”

As an allochromatic (other-colored) mineral, pure talc is colorless or white. Trace amounts of iron impart subtle gray and brown hues. The green colors common in talc are caused by nickel ions substituting for magnesium or the presence of intergrown, partially altered, greenish chlorite minerals.

### ***COLLECTING LOCALITIES***

Our talc specimens were collected at the Argonaut Quarry at Ludlow in Windsor County, Vermont. Other Vermont talc sources include the Granville Talc Quarry at Granville in Addison County, the Waterville Talc Mine at Waterville in Lamoille County, and the Vermont Talc Mine at Windham in Windham County. Numerous talc deposits occur in the highly metamorphosed rock throughout the Appalachian chain. Talc specimens are collected in New Hampshire at the Orford Soapstone quarries at Orford in Grafton County, and at the Frankestown Soapstone Quarry at Frankestown in Hillsborough County; in Massachusetts at the Foliated Talc and Hoosac Talc company mines at Rowe in Franklin County; in New York at the mines of the International Talc Co. at Talcville and the Ontario Talc Co. at Fullerville in St. Lawrence County; and in Pennsylvania at the Manville Talc Mine at Manville in Cumberland County. Moving south, talc is found in Maryland at the Harford Talc and Dublin quarries at Dublin in Harford County; in Virginia at the Blue Ridge Talc Co. mine at Rocky Mount in Franklin County; in North Carolina at numerous quarries throughout the Murphy Marble Belt in Swain and Cherokee counties; in Georgia at the McAfee Soapstone Quarry at Canton in Cherokee County and the Cohutta Mountain quarries at Crandall in Murray County; and in Alabama at the American Talc Co. pits at Winterboro in Talladega County.

## ***November 2008 Mineral of the Month: Talc***

Moving west, talc specimens are collected in Arkansas at the Arkansas Talc Company mine at Little Rock in Saline County; in Texas in the quarries of the Allamoore Talc District in Hudspeth County; in Washington at the Skagit Talc Products Co. quarry at Marblemount in Skagit County; in California at the Palen Mountains Talc Deposit at Fontana in Riverside County; and in Montana at the talc quarries of the Ruby, Greenhorn, and Gravelly ranges of Madison County. Talc is also collected in Canada at the Baker Talc Mine in South Bolton in Brome County, Québec.

In Europe, talc specimens are found in Germany at the Wirsberg quarries in the Münchberg metamorphic complex at Franconia in Bavaria; in France at the huge Trimous Talc Mine at Luzenac in Ariège in Midi-Pyrénées; in Austria at the magnesite quarries at Millstätter Alpe near Radenthein, Carinthia, and at the Zwettl talc deposit at Waldviertel in Lower Austria; in Italy at the Sa Matta, San Francesco, and Su Venosu mines at Orani in Nuoro Province, Sardinia; and in Norway at Overntjern Quarry at the Dypingdal magnesite deposit near Snarum, Buskerud, and the Raudberg talc deposits near Vik in Sogn og Fjordane.

Talc specimens are collected in Japan at the Yaguki Mine at Iwaki in Fukushima Province in the Tohoku Region of Honshu Island; in South Korea at the Choson and Sonman mines at Chung-ju in Chungcheongbukdo; and in China at the Chang-ji talc deposit at Putian, Putian Prefecture, Fujian Province, and the Fanjaipuzi talc deposit at Haicheng in Anshau Prefecture, Liaoning Province. Specimens also come from the Three Springs Talc Mine at Three Springs in Western Australia, Australia; the Wiegel and Cobra talc pits at Gravelotte in the Murchinson Range of Limpopo Province, South Africa; and the Brumado magnesite deposit at Serra dos Eguas, Bahia, Brazil.

### ***JEWELRY AND DECORATIVE USES***

Obviously, as the softest of all minerals and with perfect cleavage in one direction, talc hardly could be cut into gemstones and/or worn in everyday use. However, because soapstone is so easily cut and polished, it has long been a popular carving medium for ornamental objects. Carved soapstone figurines are a traditional art form in many cultures, notably the Aleut and Inuit of subarctic and arctic North America.

### ***HISTORY AND LORE***

Talc was used as a white pigment in the oldest cave paintings of southern France. Archaeologists have recovered talc signature seals from 3,500-year-old Babylonian tombs in what is now Iran, and talc figurines from 3,000-year-old tombs in Egypt and China. By 600 B.C., the Greeks were making bricks from powdered talc, clay, and water. Historians believe it was the marbled look of these white bricks that contributed to the subsequent interest in white marble that marked the Classical Period of Greece. The Greek philosopher and naturalist Theophrastus (ca. 372 - 287 B.C.) referred to talc as “magnetis”—the origin of the modern word “magnesia.”

During Roman times, when talc was known as *talcum* and *talchus*, spheres of silvery talc were set above the doorways and windows of the wealthy, possibly in reverence for the planet Venus. The Roman scholar Pliny the Elder (Gaius Plinius Secundus, A.D. 23-79) wrote of a rock resembling and feeling like fat, presumably talc, that he named *steatitis*, the origin of the word “steatite.” One notable use of talc was to clean the blood from the stone floors of Rome’s gladiatorial arenas.

Talc was used for various cosmetic and hygienic purposes during the Middle Ages. The Frankish king Charlemagne (742-814) kept his hair stiff and glistening with a mixture of egg whites and powdered talc. Catholic priests and upper-class women used talc as an exfoliant to whiten and soften their skin, morticians used it to prepare the skin of the deceased for funeral ceremonies, and physicians prescribed

## ***November 2008 Mineral of the Month: Talc***

talc potions as laxatives and expectorants. In 1546, Agricola (Georg Bauer, 1494-1555), the German scholar and author of the classic mining work *de re Metallica*, recognized talc as a distinct mineral species and formally named it *talck*, the direct root of our modern word, from the old Latin *talchus*.

During the 1700s, solid soapstone or “talc rock” was used as stove tops. Blocks of soapstone were also heated atop stoves and used as bed warmers. New uses for talc emerged in the 1890s, when scientists realized that it was hydrophobic (lacking affinity for water), chemically inert, nonconductive, heat- and acid-resistant, and organophilic (having an affinity for organic compounds). These new uses included laboratory sinks and countertops, electrical switchboards and insulators, lubricants for leather drive-belt systems in factories, and fillers in paints. Perfumed talcum powder, introduced in 1896, quickly gained popularity as a body powder.

Because of the bright white color of its powder, modern metaphysical practitioners believe that talc enhances clarity and purity of thought and brings good fortune. In 1992, the Vermont State Legislature passed Act Number 221 designating talc as Vermont’s official state mineral.

### ***FRIEDRICH MOHS AND THE MOHS SCALE OF MINERAL HARDNESS***

Of all the physical measurements applied to minerals, the most familiar to collectors and amateur mineralogists is the scale of mineral hardness devised by German geologist and mineralogist Friedrich Mohs (1773-1839). The Mohs scale has a special relevance to this month’s mineral because talc, as the softest of all minerals, is the reference species for the Mohs rating of 1.0.

For centuries, scholars and alchemists were puzzled by the broad variations in mineral hardness. Many assumed that hardness was a function of dryness, and that harder minerals simply contained less water. Some believed that the harder gemstones such as diamond [carbon, C] and the corundum [aluminum oxide,  $\text{Al}_2\text{O}_3$ ] gemstones ruby and sapphire developed through eons of slow “drying.” Some medieval alchemists attempted to create hard gemstones by heating softer, brightly colored mineral crystals in efforts to “drive off” their supposed water content.

By the 1600s, European miners realized that mineral hardness was unrelated to water content and routinely scratched specimens to determine relative hardness to help identify different ores. Yet none of this era’s scholars took the logical “next step” of creating a hardness scale. It was not until 1774 that German geologist and mineralogist Abraham Gottlob Werner (1750-1817), head of the Freiburg (Germany) Mining Academy (Technische Universität Bergakademie Freiberg) and author of the first modern textbook on descriptive mineralogy, systematically categorized mineral hardness by assigning minerals to general “hard,” “semi-hard,” “soft,” and “very soft” groups.

The creation of a practical mineral hardness scale was left to Friedrich Mohs. Born in the Harz Mountain region of Germany in 1773, Mohs attended the Freiburg Mining Academy where he studied under Abraham Werner. Mohs worked as a mine foreman, then moved to Graz, Austria, in 1802 to catalogue the mineral collection of a wealthy banker. During this time, Mohs formulated his early ideas about a mineral hardness scale. In 1812, after taking a position as mineralogical curator at the Johanneum Landesmuseum in Graz, he began working seriously on his hardness scale. Finally, in 1820, after Mohs had replaced his old mentor Abraham Werner as professor of mineralogy at the Freiburg Mining Academy, he published his scale of mineral hardness. The Mohs scale, published in German and English, was immediately put to use by mineralogists worldwide.

Mohs based his concept of hardness on resistance to scratching, and he arranged his scale according to observations that certain minerals could scratch some minerals, but not others. The modern scale has 10

## ***November 2008 Mineral of the Month: Talc***

ranks, numbered 1 through 10 (Mohs' original scale included a "0" rating for fluids). Each rank is assigned a mineral of appropriate hardness as a reference species. Mohs chose these specific minerals for two reasons. First, they represented general levels of hardness; second, they were common and readily available to all mineralogists and most mineral collectors. These minerals, according to their Mohs ranking and with familiar materials of comparable hardness, are:

1. Talc [basic magnesium silicate,  $\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$ ], certain soft plastics
2. Gypsum [hydrous calcium sulfate,  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ], fingernail
3. Calcite [calcium carbonate,  $\text{CaCO}_3$ ], bronze coin
4. Fluorite [calcium fluoride,  $\text{CaF}_2$ ], iron nail
5. Apatite (fluorapatite) [calcium fluorophosphate,  $\text{Ca}_5(\text{PO}_4)_3\text{F}$ ], bottle glass
6. Feldspar (orthoclase) [potassium aluminum silicate,  $\text{KAlSi}_3\text{O}_8$ ], penknife blade
7. Quartz [silicon dioxide,  $\text{SiO}_2$ ], steel rasp
8. Topaz [basic aluminum fluorosilicate,  $\text{Al}_2\text{SiO}_4(\text{F},\text{OH})_2$ ], emery paper
9. Corundum [aluminum oxide,  $\text{Al}_2\text{O}_3$ ], knife sharpener
10. Diamond [carbon, C], certain synthetic silicon carbides

The Mohs scale of mineral hardness is not an absolute scale because it lacks orderly arithmetic or geometric progression. As examples, diamond (10) is about 3.5 times harder than corundum (9). Corundum is twice as hard as topaz (8), which in turn is three times harder than quartz (7). At the lower end of the scale, fluorite is only about two or three times as hard as talc (1).

Over the years, many researchers devised new hardness scales. In 1896, Austrian geologist August Rosival (1860-1913) established a cutting-pressure test to measure the absolute hardness of minerals. The Rosival scale, still used today, assigns talc a value of 0.03 and diamond a value of 140,000. In 1925, the British Vickers company devised another absolute scale that incorporates the element of time as well as cutting (scratching) pressure and is used by the International Mineralogical Association today. In 1939, the United States National Bureau of Standards introduced the Knoop mineral hardness scale, an absolute system which ranks talc at 1.0 and diamond at 7,000. All these hardness scales require measurements with laboratory equipment.

Despite its simplicity and shortcomings, the Mohs hardness scale has survived the test of time as a practical, universally accepted system that does not require specialized equipment. The Mohs scale is familiar to all mineral collectors and used by every field geologist to provide an important, immediate clue to mineral identification. Despite its limitations, the Mohs scale should continue to serve both geologists and mineral collectors well into the future. And we are happy to say that we have now featured all ten representative minerals from this scale!

### ***TECHNOLOGICAL USES***

Steatite, the primary ore of talc, is one of the few minerals in which the United States is self-sufficient. Twelve open-pit talc mines currently operate in seven states—Vermont, Virginia, North Carolina, Texas, Indiana, California and Ohio. In 2007, these mines produced 800,000 metric tons of talc. Annual world talc production now amounts to eight million metric tons. The leading producers, in order, are China, the U. S., Korea, India, and Japan. The price of crude (unprocessed) talc is \$32 per metric ton. After mining, crude talc is washed, crushed, purified by flotation or centrifugal separation, and ground to a specific mesh size. The value of processed, powdered talc depends upon purity and mesh size, with top grades worth about \$500 per ton.

Forty percent of the talc supply is used as a filler and whitening agent in paint, paper, plastic, and rubber. Another 33 percent is used to impart whiteness, increase thermal expansion, and resist crazing (surface

## ***November 2008 Mineral of the Month: Talc***

cracking) in ceramics. Talc improves the strength of stoneware ceramics and acts as a flux to enhance the workability of high-temperature glazes. Talc is also used in roofing sealants and as an extender in animal feeds and pharmaceuticals, a texturing agent in processed foods, a lubricant for pulleys and belts, and as a component of Styrofoam™ packing materials. Finely powdered talc serves as a polishing medium for soft plastics, and is compacted in molds and reheated to increase its hardness for use in the manufacturing of electrical insulators. Steatite is the marking “chalk” used by tailors and metalworkers. The softness and whiteness of pure, powdered talc and its ability to hold organic fragrances accounts for its most familiar uses—as the primary ingredient in talcum powder and as the base for many cosmetics. Talcum powders, which consist of finely powdered talc mixed with perfumes and mild antiseptics, are used worldwide as anti-chafing powders to combat skin rashes.

### ***ABOUT OUR SPECIMENS***

As noted, our talc specimens were collected at the Argonaut Quarry at Ludlow in Windsor County, Vermont. Ludlow is located in the rolling, forested hills of south-central Vermont, about 20 miles southeast of the city of Rutland. Ludlow, population 1,400, has an economy based on tourism, outdoor recreation, small farms, and talc mining and milling.

Geologically, Vermont is located in the northern section of the Appalachian Mountains, which extend from Alabama to Newfoundland, Canada. The Appalachians are textbook examples of how metamorphism associated with the crustal deformation that accompanied tectonic mountain-building can create an array of altered rocks. Some 600 million years ago during the early Paleozoic Era, what is now New England was periodically submerged beneath shallow seas that accumulated thick layers of carbonate sediments. During the middle Ordovician Period some 460 million years ago, a change in the motion of tectonic plates set the stage for the Taconic Orogeny—the first Paleozoic mountain-building event in North America that uplifted great blocks of basement rock to form the first phase of the Appalachians. For the next 250 million years, periodic tectonic stresses uplifted different parts of the Appalachians. Some 220 million years ago, the region entered a long period of crustal stability when surface erosion prevailed. By the end of the Mesozoic Era 65 million years ago, the early Appalachians had been eroded almost to a flat plain. Finally, the Appalachian region was uplifted again some 50 million years ago to form the recognizable mountain topography of today. Much more recently, glaciation from the Pleistocene Ice Ages scoured the surface of New England to expose ancient, highly deformed, metamorphosed rocks.

In the early 1700s, Ludlow settlers found talc deposits exposed on the surface. By 1825, soapstone mining had become a small industry. Initially, the quarries produced long blocks of soapstone with square cross sections that were bored hollow and then rounded for use as water pipes. Other soapstone products included fireplace hearths, stoves, foot- and bed-warmers, sinks, and doorsills. Vermont's modern era of talc mining began about 1900, when new industrial and consumer uses spurred demand for the mineral. The mass production of powdered talc began in 1904. By the 1950s, Vermont's twelve large quarries had become a major source of talc. The Ludlow talc deposit, which had been mined sporadically for more than a century, was reopened as the Argonaut Quarry in the 1960s. Subsequent modern, large-scale mining, conducted by drilling, blasting, and mechanical loading and hauling, has since revealed the origin and nature of the Ludlow talc deposit.

The Ludlow talc deposit is part of the Appalachian Orogenic Belt, a trend of highly metamorphosed rock extending from southern Vermont north into the Canadian Province of Québec. Within this belt, talc formed through regional metamorphism of Precambrian peridotite, an ultramafic (magnesium- and iron-rich) igneous rock containing the olivine-group minerals forsterite [magnesium silicate,  $\text{Mg}_2\text{SiO}_4$ ] and fayalite [iron silicate,  $\text{Fe}_2\text{SiO}_4$ ]. Heat and pressure first altered this peridotite into serpentinite, a rock composed largely of the serpentine-group minerals (basic iron magnesium silicates). Eventually, surface

## ***November 2008 Mineral of the Month: Talc***

erosion exposed the metamorphosed serpentinite to atmospheric carbon dioxide (CO<sub>2</sub>) and weak carbonic acid (H<sub>2</sub>CO<sub>3</sub>), which further altered the serpentinite into talc and magnesite [MgCO<sub>3</sub>].

The talc-magnesite mineralization at Ludlow is a complex alteration zone that surrounds a large core of serpentinite rock. The talc zones vary from 3 feet thick and 600 feet long to 450 feet thick and nearly a mile long, and grade between 45 percent and 70 percent pure talc. The main impurities are magnesite, olivine-group minerals, chlorite minerals (a group of basic magnesium iron aluminum silicates), quartz [silicon dioxide, SiO<sub>2</sub>], and muscovite [basic potassium aluminum silicate, KAl<sub>2</sub>AlSi<sub>3</sub>O<sub>10</sub>(OH)<sub>2</sub>]. Also present are small amounts of magnetite [iron (ferric-ferrous) oxide, Fe<sup>2+</sup>Fe<sup>3+</sup>O<sub>4</sub>], chromite [iron chromium oxide, FeCr<sub>2</sub>O<sub>4</sub>], nickel sulfides, and manganese minerals. The pale green color of Ludlow talc is caused by the presence of both chlorite minerals and nickel sulfides.

The Argonaut Quarry, currently Vermont's only remaining active talc mine, is owned by Luzenac America Vermont, a part of the French Luzenac Corporation, the world's largest talc producer. Luzenac in turn is subsidiary of Denver-based Rio Tinto Minerals. In 1999, Luzenac engineers revised the Argonaut mining plan to gain access to the entire ore body in order to extend the life of the mine. Millions of tons of overburden are now being removed and used to backfill and reclaim the nearby, depleted Black Bear talc mine. Forty employees operate the Argonaut mine around the clock on a five-day week; additional employees operate the mill and shipping center. Ore reserves are sufficient for another 15 years of mining at the current rate of production. Our specimens were collected by commercial collectors who are occasionally granted access to the mine dumps by advance arrangement when mining operations are not in progress. Unfortunately, no one involved with the collecting would cooperate with us and by providing us photos of the mine to be used in this write-up.

Looking back at the table of talc's physical properties on page 1, we would apply the term "foliated" as found under "Crystal Habits" to our talc specimens. "Foliated" means having thin, leaflike layers or strata, which is certainly apropos for our pieces. Talc is often fluorescent, but ours are inert, perhaps due to the presence of the chromomorphs--the pretty green color is caused by inclusions of chlorite group minerals (see our December 2005 write-up on clinochlore for more on this mineral group), or by ions of nickel partially substituting for magnesium in the crystal structure. If you were to check the streak of your specimen, you would find it to be white, as mentioned under "Streak." Our specimens also show the pearly luster common to talc, as mentioned under "Luster." And though it is not highlighted under its physical properties, the sense of touch is a way to identify talc. Its characteristic greasy/soapy feel is due to the continuous displacement of silica layers under the slightest touch, as explained in "Composition." Don't touch it too much though, or it may become nothing but a pile of displaced layers! We hope you enjoy this fascinating mineral as much as we have, and that you will share some of this information with others as you show off your collection!

References: *Dana's New Mineralogy*, Eighth Edition; *Encyclopedia of Minerals*, Second Edition, Roberts, et al, Van Nostrand Reinhold Co.; *2004 Fleischer's Glossary of Mineral Species*, Joseph Mandarino and Malcolm Back, The Mineralogical Record Company; *Mineralogy*, John Sinkankas, Van Nostrand Reinhold Co.; *Manual of Mineralogy*, Cornelius Hurlbut and Cornelia Klein, Twenty-first Edition, John Wiley & Sons; *Minerals of the World*, Walter Schumann, Sterling Publishing Co.; *Handbook of Mineralogy: Silica and Silicates*, Vol. 2, J. W. Anthony, et al, Mineral Data Publishing; *Structural Chemistry of Silicates*, F. Liebau, Springer-Verlag Publishing Co.; *The Complete Guide to Rocks & Minerals*, John Farndon, Hermes House, 2006; "Talc: The Softest Mineral," Steve Voynick, *Rock & Gem*, April 2004; "Talc: A Different Kind of Rock," Chloe Young, *Rock & Gem*, February 2007; "Friedrich Mohs and His Hardness Scale," Steve Voynick, *Rock & Gem*, April 1997; "Talc and Pyrophyllite," Robert L. Virta, *2007 Minerals Yearbook*, United States Geological Survey; "Talc and Pyrophyllite," G. P. Tomaino, *Mining Engineering* (Industrial Minerals Review issue), June 2008; *Industrial Minerals of Vermont: 200 Years and Still Going Strong*, Diane Conrad and Diane Vanacek, Vermont Geological Survey, 1992 (updated 2005).