

May 2006 Mineral of the Month: Fluorapatite

Fluorapatite is one of the most remarkable, useful, and important of all minerals. As the most abundant phosphate, it has both mineralogical and biological origins and is the material of which bones and teeth are made. And it serves as a gemstone! As the world's primary source of phosphorus and phosphorus compounds, it is the basis of a \$4.2-billion-per-year, worldwide mining industry.

PHYSICAL PROPERTIES

Chemistry: $\text{Ca}_5(\text{PO}_4)_3\text{F}$ Calcium Phosphate Fluoride (Calcium Fluorophosphate), usually containing small amounts of manganese, cerium, and strontium

Class: Phosphates, Chromates, Arsenates, and Vanadates Subclass: Anhydrous Phosphates

Group: Apatite

Crystal System: Hexagonal

Crystal Habits: Usually short-to-long prismatic; sometimes thick tabular to low pyramidal with complex crystal faces; massive, coarse granular to compact, earthy; occasionally globular or reniform with scaly, fibrous, or columnar structure; also forms stalactitic growths and nodular concretions.

Color: Nonessential impurities create a wide range of colors. Usually green, yellow, or yellow-green, but can also be colorless, pink, brown, blue, purple, or violet.

Luster: Vitreous to resinous, sometimes oily

Transparency: Usually transparent to translucent, rarely opaque

Streak: White

Refractive Index: 1.63-1.64

Cleavage: Poor, one direction crosswise.

Fracture: Subconchoidal to uneven; brittle; large crystals often fractured.

Hardness: Mohs 5.0

Specific Gravity: 3.1-3.2

Luminescence: Often fluorescent or phosphorescent

Distinctive Features and Tests: Best field mark is the distinctive, hexagonal cross section. Can be confused with beryl, which is much harder, and tourmaline, which occurs as striated prisms with rounded, triangular cross sections. Some fluorapatite colors are similar to those of the olivine-group mineral forsterite (gem variety peridot) which crystallizes in the orthorhombic system.

Fluorapatite is also difficult to differentiate from the chemically and physically similar minerals chlorapatite and hydroxylapatite. Fluorapatite reacts with hydrochloric acid.

Dana Classification Number: 48.8.1.1

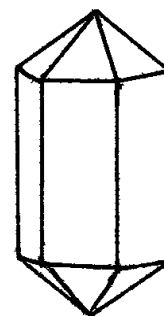


Figure 1.
Fluorapatite

NAME

"Fluorapatite" is properly pronounced flor-APP-a-tite (rhymes with "more appetite"). The word is a combination of "fluor-," referring to the mineral's fluorine anion, and "apatite," the name of its parent mineral group. "Apatite" derives from the Greek *apatē*, meaning "deceit," a reference to its similarity to beryl, olivine, and certain other minerals. The homonym "appetite" comes from the Latin word *appetere*, "to strive after," and has nothing at all to do with apatite, other than having the same pronunciation. Of course, this leads to plays of word, such as having an appetite for apatite.

Early names for apatite include the "davisonite" and "dennisonite" varieties of crandallite (a basic hydrated calcium aluminum phosphate). Other names for fluorapatite are "fluoro-apatite," "fluorine apatite," "apatit," "agustit," and "wilkeite." A green variety is called "asparagus stone," a manganese-rich variety "mangano-fluorapatite," and a strontium-rich variety "saamite" or "strontian-fluorapatite."

May 2006 Mineral of the Month: Fluorapatite

COMPOSITION

Fluorapatite is now the first mineral we have featured three times. In October 1998 we focused on the apatite group when we sent pretty, gemmy light-green fluorapatite crystals in calcite matrix to Club members from Wilberforce, Monmouth Township, Haliburton County, Ontario, Canada, and in May 2003 we highlighted other aspects of this fascinating mineral when we sent large loose crystals from Sludyanka, Lake Baikal Region, Ust'-Orda Buriat Okrug, Transbaikalia, Western-Siberian Region, Russia.

Before discussing fluorapatite, let's first clarify its relationship with apatite and the apatite-group minerals. Apatite was originally assumed to be a distinct mineral species with the chemical formula $\text{Ca}_5(\text{PO}_4)_3(\text{F}, \text{Cl}, \text{OH})$, indicating that it contained the elements calcium (Ca), phosphorus (P), oxygen (O), fluorine (F), chlorine (Cl), and hydrogen (H). Later, mineralogists learned that the amounts of fluorine, chlorine, and the hydroxyl group $[(\text{OH})^{1-}]$ vary so greatly that apatite must be classified as three separate minerals—fluorapatite $[\text{Ca}_5(\text{PO}_4)_3\text{F}]$, chlorapatite $[\text{Ca}_5(\text{PO}_4)_3\text{Cl}]$, and hydroxylapatite $[\text{Ca}_5(\text{PO}_4)_3\text{OH}]$. Casual collectors and dealers often use just the term “apatite” when labeling these three, as do many non-technical guidebooks and mineralogical primers.

Today, the general term “apatite” (not a valid mineral name) refers to the very closely related minerals fluor-, chlor-, and hydroxylapatite, as well as to a Dana group of nine related minerals (see “Mineralogical Classification”). For the purposes of this discussion, “apatite” refers to fluor-, chlor-, and hydroxylapatite. These three minerals form graded, solid-solution series and are easily confused because of their very similar physical properties. The correct identity of apatite depends on the predominance of fluorine, chlorine, or hydroxyl anions and can require laboratory analysis, another reason why some may label specimens simply as “apatite” when unsure of which group member it is.

The ideal molecular weight of fluorapatite, $\text{Ca}_5(\text{PO}_4)_3\text{F}$, is made up of 39.74 percent calcium, 18.43 percent phosphorus, 38.06 percent oxygen, and 3.77 percent fluorine. The actual percentages of fluorine, chlorine, and hydroxyl ions vary considerably within the chemically graded, solid-solution series. Within the fluorapatite molecule, the combined +10 charge of the calcium cation (Ca^{2+}) balances the combined -10 charge of the phosphate $[(\text{PO}_4)^{3-}]$ and fluorine (F^{1-}) anions.

Fluorapatite is one of some 280 members of the Phosphates, Chromates, Arsenates, and Vanadates class of minerals. The basic building blocks of these minerals, the phosphate ion $(\text{PO}_4)^{3-}$, the chromate ion $(\text{CrO}_4)^{3-}$, the arsenate ion $(\text{AsO}_4)^{3-}$, and the vanadate ion $(\text{VO}_4)^{3-}$, all form tetrahedral structures in which four oxygen ions surround the ion of a metal or semi-metal (chromium and vanadium are metals, while phosphorus and arsenic are semi-metals). In phosphates, the phosphorus ion P^{5+} is surrounded by four oxygen ions (O^{2-}). The resulting collective charge of -3 is distributed evenly over the four oxygen ions and enables the phosphate ion to bond with many positively charged metal cations. Within the phosphate anion $(\text{PO}_4)^{3-}$, the phosphorus atom covalently bonds with four oxygen atoms. Three phosphate anions $(\text{PO}_4)^{3-}$ then bond ionically to five calcium cations (Ca^{2+}). The remaining +1 charge is satisfied by addition of a fluorine ion (F^{1-}).

The apatite-group minerals are amenable to anionic substitution by other ions. In the solid-solution series between fluor-, chlor-, and hydroxylapatite, fluorine, chlorine, and hydroxyl ions interchange readily because of their similar electrical charges and ionic sizes. Fluorapatite and hydroxylapatite also form solid-solution series with carbonate ions $(\text{CO}_3)^{3-}$ substituting for phosphate ions $(\text{PO}_4)^{3-}$ to form carbonate-fluorapatite $[\text{Ca}_5(\text{PO}_4, \text{CO}_3)_3\text{F}]$ and carbonate-hydroxylapatite $[\text{Ca}_5(\text{PO}_4, \text{CO}_3)_3\text{OH}]$. In fluorapatite, small amounts of cerium, strontium, and manganese substitute for calcium. (*Continued on page 4.*)

May 2006 Mineral of the Month: Fluorapatite

MINERAL CLASSIFICATION

The Dana mineral classification number of 48.8.1.1 establishes fluorapatite as an anhydrous (non-hydrated) phosphate containing halogen ions (48). Fluorapatite is subclassified (8) by the general formula $(A)_5(XO_4)_3Z_q$, in which A can be a divalent ion of calcium, strontium, sodium, barium, cerium, or lanthanum; X can be a phosphate $(PO_4)^{3-}$ or carbonate $(CO_3)^{2-}$ radical ion (a radical is a group of bonded atoms that acts as an entity in chemical reactions); and Z can be fluorine, chlorine, or hydroxyl ions. The "q" signifies a variable quantity. Finally, fluorapatite is a member of the apatite group (1) as the first (1) of nine members.

Like all minerals, fluorapatite has other mineral-classification numbers. In the Strunz mineral-classification system, fluorapatite is designated VII/B.39.10. In Hey's Mineral Index, fluorapatite's classification number is 22.1.9. The reason for multiple systems is that one system cannot serve all classification purposes.

The first mineral-classification systems were based on practical mineral uses and such physical properties as color, hardness, fusibility, and general morphology. Typical of the systems of the late 1700s is one devised by German mineralogist Abraham Gottlob Werner (1749-1817) that employed seven criteria, including color, crystal form, crystal habit, cleavage, luster, streak, and hardness. But by 1800, chemistry had become the main classification criteria. Later, as knowledge of structural and mathematical crystallography grew, structure became an important classification consideration. But while many prominent mineralogists, chemists, and crystallographers devised their own classification systems, none gained broad acceptance.

Then in 1837, a young, Yale-educated, American researcher named James Dwight Dana (1813-1895) published *System of Mineralogy*. This 580-page classification system, which combined original material with concepts drawn from earlier works, became a widely accepted reference. Dana initially based his *System* on pre-existing botanical and zoological classification systems, but revised it in 1854 to one based on mineral chemistry and to a lesser degree on structure, an approach still used today. In 1892, his son Edward Salisbury Dana (1849-1935) published the sixth edition of Dana's *System of Mineralogy* which went on to become a worldwide, standard reference work on descriptive mineralogy.

When James Dwight Dana first published his *System*, science recognized only 352 mineral species. Within a century, this number had grown to more than 1,500. Using great advances in the chemical and physical sciences, mineralogists began updating the Dana system and devising new systems to classify the rapidly growing number of minerals. One of these, published in 1941 as *Mineralogische Tabellen*, was devised by the German mineralogist Dr. Karl Hugo Strunz (1910-1985). The Strunz mineral-classification system, which is also widely used today, is based on anion groups such as carbonates, sulfates, phosphates, etc., and includes ten major compositional classes.

Meanwhile, mineralogists were continuing to discover more minerals, many with complex chemistries that did not assimilate easily into existing classification systems. This has prompted the need for even newer systems, such as Hey's Mineral Index, published in 1993 by Dr. Andrew M. Clark of the British Museum in London. Hey's Mineral Index, named for the eminent British mineralogist Max H. Hey (1904-1984), recognizes 32 groups based on chemistry and structure and arranged by order of elemental activity.

Today, the Dana (its eighth edition is used in our write-ups) and Strunz systems are the most widely mineral-classification systems. Now, with more than 4,400 minerals and dozens more being recognized each year, mineralogists are continuing to devise new classification systems to serve specialized study and research purposes.

May 2006 Mineral of the Month: Fluorapatite

(From page 2.) The strong, three-dimensional covalent bonds between adjacent phosphate ions within the apatite lattice explain the near-absence of cleavage and the moderate hardness of Mohs 5.0. Apatite is the reference mineral for the 5.0 ranking on the Mohs hardness scale. The Mohs reference minerals include talc (1, softest), gypsum (2), calcite (3), fluorite (4), apatite (5), microcline (6), quartz (7), topaz (8), corundum (9), diamond (10, hardest). These minerals were chosen as Mohs reference species because of their abundance, familiarity, and minimal variation in hardness.

As the most common phosphate, fluorapatite is a minor accessory mineral in many igneous and metamorphic rocks, occurring with magnetite and titanite in plutonic rocks, with muscovite and albite in granite pegmatites, with nepheline in nepheline-syenite pegmatites, and with andradite in hornfels of contact metamorphic rocks. Fluorapatite forms by both mineralogical and biological processes. Biogenic fluorapatite is abundant in a microcrystalline form called collophane (also collophanite), which is common in sedimentary rocks. The greatest concentrations of collophane are in marine sediments deposited by ancient, shallow seas that supported large populations of plankton and other tiny, invertebrate organisms. Their phosphorus-rich remains mixed with sea bottom sediments to eventually lithify into phosphate rock, a variable mixture of cryptocrystalline fluorapatite with lesser amounts of carbonate-fluorapatite, chlorapatite, and hydroxylapatite.

Fluorapatite is often luminescent. Luminescence occurs when minerals absorb electrical, mechanical, or electromagnetic energy which excites electrons, elevating them to higher orbital levels. To return to their normal orbits, these electrons release excess energy as visible light. In fluorescence, this energy is released almost immediately; in phosphorescence, the release is delayed and occurs after the input of incidental energy has ceased. Fluorine is the key to fluorapatite's luminescence. Fluorine has a very high level of chemical activity and its single outer electron readily absorbs, then releases, incident energy.

Fluorapatite is technically an idiochromatic (self-colored) mineral, meaning that its base color—green—is derived from its essential chemical components and its crystal structure. However, fluorapatite also exhibits certain properties of allochromatic (other-colored) minerals. Traces of nonessential minerals, notably rare-earth elements such as cerium, together with subsequent modification of the crystal lattice, can cause fluorapatite to be colorless or to exhibit other colors that mask the basic green. Natural irradiation also influences fluorapatite color.

COLLECTING LOCALITIES

Despite its abundance, fine, large crystals of fluorapatite are uncommon. The type locality at Ehrenfriedersdorf, Saxony, Germany, continues to provide nice specimens. In Brazil in 2004, pegmatite miners discovered fine, two-inch-long, green fluorapatite crystals at the Sapo Mine at Aimorés in Minas Gerais. The nearby Golconda Mine also produces gem-quality, green fluorapatite crystals.

Gem-quality, yellow fluorapatite crystals, called *amarillas*, occur in the iron mines at Cerro de Mercado, Durango, Mexico. Fine crystals also come from Sludyanka, near Lake Baikal, Russia, source of our March 2003 specimens. In northern Pakistan, the Gilgit and Nagar districts yield pink fluorapatite crystals associated with green beryl and muscovite; gem-quality, blue fluorapatite is collected at Inna Nala in the Nagar District. The Lake Boga pegmatite quarry at Pyramid Hill in Victoria, Australia, yields gem-quality, green fluorapatite crystals. Nice specimens are collected at the Kirovskii mine at the Kukisvum apatite deposit on Russia's Kola Peninsula.

Intensely colored, fractured fluorapatite crystals to 12 inches in length occur in marble deposits in Ottawa County, Ontario, Canada, and at Wilberforce, Monmouth Township, Haliburton County, Ontario, Canada,

May 2006 Mineral of the Month: Fluorapatite

where our October 1998 specimens were collected. This month's attractive specimens of dark-green fluorapatite crystals on pinkish white calcite are recovered at the Yates Mine near the small town of Otter Lake in Pontiac County, Ontario, as we will detail later in the write-up. Fluorapatite crystals are also found at the Rapid Creek and Big Fish areas of Canada's Yukon Territory. In the United States, three-inch crystals are associated with actinolite at Pelham, Hampshire County, Massachusetts. The Himalaya Mine in San Diego County, California, has provided many fine, tourmaline-green fluorapatite crystals. In Maine, superb, purple fluorapatite crystals come from Mt. Mica and Mt. Apatite near Auburn in Androscoggin County and from the Emmons and Harvard pegmatites near Greenwood in Oxford County.

JEWELRY & DECORATIVE USES

Despite its attractive colors, excellent cuttability, and a refractive index of 1.63-1.64 (similar to that of peridot and tourmaline), fluorapatite's moderate hardness of Mohs 5.0 limits its use in jewelry. Faceted fluorapatite is mounted in brooches, pendants, and other low-wear types of jewelry. Most fluorapatite used in jewelry is tumbled and drilled for stringing into necklaces and bracelets. The largest fluorapatite gems are cut from bright yellow crystals collected at Durango, Mexico, and sometimes exceed 100 carats in weight, though most weigh less than 20 carats. In the rarer blues and violets, fluorapatite gems usually weigh less than two carats. Maine's granite pegmatites provide most intensely colored violet and purple gems. Fluorapatite gems are often heat-treated to intensify their colors.

Generally, gem apatite colors are associated with specific sources: yellow from Mexico; blue from Sri Lanka; blue-green from Norway; green from Canada, India, Brazil, and Australia; and violet and purple from Germany and Maine. A catseye variety of fluorapatite is found in Brazil and Myanmar (Burma).

As both singular and composite specimens, fluorapatite is highly valued by collectors for display and study purposes. The National Museum of Natural History (Smithsonian Institution) in Washington, D.C., displays a particularly fine specimen—a two-inch, gemmy, intense-purple fluorapatite crystal from the Pulsifer Quarry at Mt. Apatite, Maine.

HISTORY & LORE

Here is the history of the discovery of the element phosphorus, a key component in fluorapatite, taken from our May 1993 write-up: "Phosphorus owns the distinction of being the only element discovered by an alchemist, the group of individuals who, particularly during the thirteenth to the seventeenth centuries, attempted to make gold.

"Like most alchemists, a merchant and physician named Georg Brant in Hamburg, Germany, was convinced that gold, being a yellow metal, could be made from other yellow substances. No success had come to other alchemists after centuries of working with the only other yellow mineral known at the time, sulfur, so Brandt began to look at other yellow substances. He rejected yellow flowers, and finally settled on experimenting with another substance that is sometimes yellowish, urine.

"His exact methods remain secret to this day, but in 1669 he managed to obtain a waxy substance which melted easily, but usually burst into flames in the process, and that glowed in the dark. He had discovered phosphorus! Two other European men, one a chemist and the other an alchemist, made the same discovery at roughly the same time, and in 1670 the Swedish chemist Carl Wilhelm Scheele developed and published a method for extracting phosphorus from bones. Finally, the French chemist Antoine Lauren Lavoisier (1743-1794) proved it to be an element."

May 2006 Mineral of the Month: Fluorapatite

Apatite was first studied and named in 1788 by German mineralogist Abraham Gottlob Werner (1749-1817). Given the limited analytical methods of his era, Werner assumed that "apatite" was a single mineral species. But in 1826, German mineralogist and chemist Gustav Rose (1798-1873) determined that both chlorine and fluorine "varieties" existed. Finally, in 1860, German mineralogist Karl Friedrich Rammelsberg (1813-1899), using new spectrographic- and chemical-analysis methods on specimens from the type locality at Ehrenfriedersdorf, Saxony, Germany, determined that apatite was actually three distinct minerals based upon the predominance of fluorine, chlorine, and hydroxyl anions.

Metaphysicists believe that fluorapatite and other apatite-group minerals enhance insight, learning abilities, and creativity; increase self confidence; and help achieve deeper states of meditation. Apatite-group minerals are also thought to enhance the metaphysical properties of other minerals. Interestingly, although the words "apatite" and "appetite" are not connected in any way, early physicians have for centuries administered finely ground apatite minerals as an appetite suppressant.

Fluorapatite is represented on postage stamps as phosphate rock. Phosphate-rock mining was featured on the 4.50-dirham stamp of Morocco in 1947 and on the 25-cent (Australian cent) stamp of the central-Pacific nation of the Republic of Nauru in 1982. These stamps commemorated the 25th and 100th anniversaries, respectively, of the founding of phosphate-mining industries in these nations.

TECHNOLOGICAL USES

Fluorapatite is by far the most abundant source of phosphorus, the 11th most common element in the Earth's crust. Phosphorus, mainly as fluorapatite, is essential to all plant and animal life and is a vital component of genes, teeth, bones, and muscles. By weight, the human body consists of about one percent phosphorus. The body of a 150-pound adult contains about 1.5 pounds of phosphorus as contained in 4 pounds of fluorapatite. An adult this size requires a dietary intake of more than one gram (1000 milligrams) of phosphorus per day, or nearly a pound of phosphorus per year. Fortunately, phosphorus is so prevalent in foods that phosphorus deficiency is rarely, if ever, a problem.

Fluorapatite, along with lesser amounts of chlorapatite and hydroxylapatite, is the primary component of bones, and especially of teeth, in all vertebrate animals. Of these three minerals, fluorapatite is the hardest and most durable. Fluorides added to drinking water and toothpaste increase the hardness and durability of teeth. Fluorine ions displace the chlorine and hydroxyl ions, thus converting some chlorapatite and hydroxylapatite in the teeth into more decay-resistance fluorapatite.

Microcrystalline fluorapatite is the primary economic component of phosphate rock, the only ore of phosphorus. Phosphate mining is \$4.2-billion-per-year industry. Some 141 million tonnes (metric tons) of phosphate rock are mined worldwide each year from open pits, concentrated, crushed and ground to a powder, then treated with acids to convert the fluoroapatite into a concentrated, hydrated calcium phosphate called "superphosphate." Most superphosphate is used to manufacture nitrogen-phosphorus-potassium (N-P-K) agricultural fertilizers. Superphosphate is also the source of elemental phosphorus and phosphoric acid (H_3PO_4), both feedstocks for manufacturing insecticides, herbicides, matches, pyrotechnics, nutritional supplements, food additives, and a wide array of other products.

Fluorapatite is used as a matrix material for the entombment of zirconium fluoride and other radioactive waste by-products of atomic-fission reactions. Perfect crystals of synthetic fluorapatite serve as laser-rod material. Fluorapatite-impregnated titanium alloys that graft easily onto bone are state-of-the-art hip-replacement materials. Fluorapatite also serves as a coating to promote bone ingrowth into prosthetic implants. In a geo-dating technique called fission-tracking, the study of fluorapatite helps reveal the

May 2006 Mineral of the Month: Fluorapatite

thermal history of sedimentary deposits. Atomic particles emitted by trace amounts of uranium isotopes in fluorapatite have left “tracks” through the crystal lattice. The annealing, or “healing,” rate of these tracks are an indication of past sedimentary burial temperatures.

ABOUT OUR SPECIMENS

As mentioned, our specimens come from the Yates mine, Huddersfield Township, Québec, Canada. This remote locality sits near Lake Huddersfield and the tiny village of Sandy Creek, about 45 miles northwest of Ottawa, Ontario, Canada, near the Ontario/Québec border. Otter Lake (formerly Leslie-Clapham-et-Huddersfield) is the nearest municipality, and is usually found on minerals labels for the site.

This locality is prolific enough and interesting enough to be the subject of an article in the November-December 1981 issue of the *Mineralogical Record*. In this article, the mine is called the Yates Uranium Mine, and its history is traced to the late 1800's, when phlogopite mica and fluorite were first mined there. Mica mining continued on an irregular basis through the 1940's. In the early 1950's, during a uranium boom in Canada (some 200 uranium mines were opened in the Bancroft area alone), prospector J. M. Yates discovered the radioactive minerals thorite $[(Th,U)SiO_4]$ and thorianite $[ThO_2]$ at the mine, solicited investors for the formation of the Yates Uranium Mines Incorporated, and set up a mining camp.



Figure 2. Yates mine, near the town of Otter Lake, Huddersfield Township, Pontiac County, Québec, Canada.

Evidently, a significant source of uranium was never found, so that it would be more accurate to call the site the Yates Prospect than the Yates Mine. By the early 1960's, the site had been abandoned and the mine buildings were slowly being overgrown by local bush. Another uranium boom occurred in 1976, and another mining company took over the site, holding it until 1997, but again no significant sources of radioactive minerals were found. Since then, it has been held as a private claim, and permission must be granted before entering the site. Field trips are occasionally organized through the local mineral clubs.

The MR article reports that the Yates mine sits on a series of skarns, i.e., coarse grained, crystalline rocks rich in calcium silicates, common occurrences in western Québec, intimately associated with the highly folded intrusive rocks of the Canadian Shield. Also called the Precambrian Shield or the Laurentian Plateau, it is an enormous horseshoe-shaped area covering most of central and eastern Canada, a full 50 percent of Canada. This shield is called the backbone of North America, and consists of some of Earth's oldest rock. (See <http://www.worsleyschool.net/socialarts/shield/canadianshield.html> for further fascinating details.)

The Yates mine has been divided by surveyors into four distinct zones: the Camp zone, Belanger zone, Belisle zone, and Matte zone, the latter three named for men involved in the 1950's mining group. Our specimens come from the Matte Zone, where the rock makeup differs from that of the other three zones. The MR article says the skarn on the Matte zone is “composed of large amounts of deep salmon pink calcite, interspersed with in some cases an almost equal volume of deep blue to near black fluorite.

May 2006 Mineral of the Month: Fluorapatite

Imbedded indiscriminately in this mixture are crystals of red (rare) and green apatite and pyroxene (sometimes up to 50 percent of the rock) and lesser amounts of microcline, scapolite, allanite, uranothorite, and uranophane." Some of our specimens had small amounts of the purple, almost black fluorite, as masses of microcrystals. When we examined specimens under ultraviolet light, we found the fluorapatite crystals were inert, but we did notice red fluorescence under shortwave UV light, given off either by small areas of microcline or scapolite in the calcite. Other minerals found in the Matte zone are allanite, diopside, phlogopite, quartz, and the aforementioned thorite and thorianite, which contain the rare element thorium, a slightly radioactive metal that is now considered as an alternative nuclear fuel to uranium. Collectable minerals found in the other zones are molybdenite, titanite, and tremolite.

Green fluorapatite is fairly plentiful here, in crystals of good size, often doubly terminated. The terminations are usually distorted, having a melted-looking appearance, which is typical of fluorapatite from other localities, as well. The crystals prisms are beautifully formed, with sharp edges exhibiting the six-sided hexagonal form illustrated in Figure 1. As part of our lot, we received several large matrix pieces with individual fluorapatite crystals over 6 inches long! We have occasion to see incredibly beautiful, high-quality apatites from a number of worldwide localities in display cases or offered for sale at shows.

Specimens of significant size with sharp crystal forms and gemmy color are quite valuable. With unlimited means, one could make a most impressive display consisting only of fluorapatite, chlorapatite, and hydroxylapatite in an array of colors and forms that would take away the breath of viewers! And this month's specimens would be right at home in such a collection.



Figure 3. Green fluorapatite crystals in salmon pink calcite at Yates Mine.

References: *Dana's New Mineralogy*, Eighth Edition; *Encyclopedia of Minerals*, Second Edition, Roberts, et al, Van Nostrand Reinhold Company; 2004 *Glossary of Mineralogical Species*, J. A. Mandarino and Malcolm E. Back; *Mineralogy*, John Sinkankas, Van Nostrand Reinhold Company; *Gems and Jewelry*, Joel Arem, Geoscience Press; *Gem and Crystal Treasures*, Peter Bancroft, Western Enterprises and Mineralogical Record, 1984; *Gemstone and Mineral Data Book*, John Sinkankas, Geoscience Press; *Gemstones of the World*, Walter Schumann, Sterling Publishing Company; "Apatite and Phosphate Rock," Steve Voynick, *Rock & Gem*, February 2003; "The Geology and Minerals of Cerro de Mercado, Durango, Mexico," Peter Megan and Mark Barton, *Rocks & Minerals*, January-February 1999; "Connoisseur's Choice: Fluorapatite, Inna Nala, Nagar District, Pakistan," Robert B. Cook, *Rocks & Minerals*, March-April 1993; "Phosphate Rock," 2004 *Minerals Yearbook*, United States Geological Survey; "Yukon Phosphates: Mineralogy of the Rapid Creek and Big Fish Areas, Yukon Territory," G.W. Robinson, *The Mineralogical Record*, July-August 1992; "Minerals of the Yates Uranium Mine, Pontiac County, Québec," Duane L. Leavitt, *The Mineralogical Record*, November-December 1981; "Fluorapatite from the Emmons Pegmatite, Oxford County, Maine," W. B. Simmons, A. U. Foster, R. Sprague, T. Wiekiewicz, and B. S. Giller, *Rocks & Minerals*, March-April 2003.