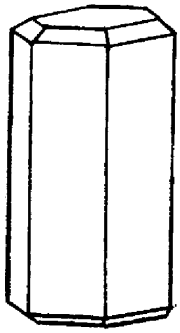
July 2002 Mineral of the Month: Pyromorphite

"The early miners did not value the oxidized ores which occurred there in large quantities, but during the 19th century hundreds of tons of 'colored lead ores' were raised; some of the finest pyromorphite specimens in the world were included in the material saved from the crusher."
– Michael Cooper and Chris Stanley, Pyromorphite Group Minerals from the Caldbeck Fells, Cumbria, England, *The Mineralogical Record*, March-April 1991

PHYSICAL PROPERTIES

Chemistry: $Pb_5(PO_4)_3Cl$ Lead Chlorophosphate (may contain small amounts of arsenic)
Class: Phosphate, Arsenates, and Vanadates Group: Apatite
Dana's: Anhydrous Phosphates, Arsenates, and Vanadates Containing Hydrogen or Halogen
Crystal System: Hexagonal
Crystal Habits: Usually prismatic, often in rounded, stubby, barrel-shaped form; sometimes with cavernous or pitted basal terminations, especially when crystals are hollow prisms; rarely shows pyramid truncations; commonly clustered in arcuate, subparallel aggregates which taper to a point; also incrusting, reniform, disseminated, globular, fibrous, earthy, and granular



Color: Usually dark green to yellow-green; also orange, brown, yellow, orange-yellow, gray, and white
Luster: Resinous to adamantine
Transparency: Translucent to transparent
Streak: White
Refractive Index: 2.05
Cleavage: None
Fracture: Subchoncoidal, uneven
Hardness: 3.5--4.0
Specific Gravity: 6.5--7.1
Luminescence: Sometimes fluoresces weak pink, yellow, and other colors under SW and LW UV light
Distinctive Features and Tests: Pyromorphite is very heavy for a translucent mineral. Its unusually high index of refraction--2.05--is typical of translucent or transparent lead-containing minerals. It is soluble in nitric acid. Pyromorphite's most distinctive visual characteristic is its unique crystal habit of "stacked," barrel-shaped crystals that branch in a manner similar to that of certain branching cactus species
Dana Classification Number: 41.8.4.1

NAME

Pyromorphite was first described by Swedish chemist Johann Gottschalk Wallerius (1709-1785) in 1748, but was not formally named until 1813. The name derives from the Greek words *pyr*, meaning "fire," and *morphe*, or "form," in reference to the manner in which a melted globule assumes a crystalline shape upon cooling. Pyromorphite is also known as "green lead ore." Its correct pronunciation is pie-row-MORF-ite.

COMPOSITION

Pyromorphite is the third member of the apatite mineral group to be featured in our Club, after fluorapatite in October 1998 and vanadinite in November 2001. Because pyromorphite and apatite $[Ca_5(PO_4)_3(Fl,Cl,OH)]$ have the same basic molecular structures, the crystals of these two minerals have similar shapes, as seen in the drawing above.

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APATITE GROUP MINERALS

Hexagonal, or monoclinic, pseudohexagonal arsenates, phosphates, and vanadates of general formula $A_5(XO_4)_3(F,CL,CH)$; A = Ba, Ca, Ce, K, Na, Pb, Sr, Y; X = As^{5+}, P^{5+}, Si^{5+}, V^{5+}; (CO_3) may partially replace (PO_4)

Mineral	Formula	Notes
Alforsite	$Ba_5(PO_4)_3Cl$	Strongly fluorescent in electron beam, not UV
Belovite-(Ce)	$Sr_3Na(Ce,La)(PO_4)_3(F,OH)$	Discovered at Lovozero Massif, Kola Peninsula, Russia
Belovite-(La)	$Sr_3Na(La,Ce)(PO_4)_3(F,OH)$	
Carbonate-fluorapatite	$Ca_5(PO_4,CO_3)_3F$	Carbonate radical may substitute for phosphate radical or fluorine; this is the formula for most biologic apatite found in bones and teeth
Carbonate-hydroxylapatite	$Ca_5(PO_4,CO_3)_3(OH)$	Synthetic only
Chlorapatite	$Ca_5(PO_4)_3Cl$	Contains chlorine, very rare; has been found in meteorites
Clinomimetite	$Pb_5(AsO_4)_3Cl$	Monoclinic polymorph of mimetite, but strongly pseudohexagonal
Fermorite	$(Ca,Sr)_5(AsO_4,PO_4)_3(OH)$	
Fluorapatite	$Ca_5(PO_4)_3F$	Contains fluorine; the most common in this group
Hedyphane	$Pb_3Ca_2(AsO_4)_3Cl$	Weak light yellow fluorescence in UV
Hydroxylapatite	$Ca_5(PO_4)_3(OH)$	Contains hydroxyl, also common
Johnbauminite	$Ca_5(AsO_4)_3(OH)$	Fluorescent pink-orange in SWUV only
Mimetite	$Pb_5(AsO_4)_3Cl$	Dimorphous with clinomimetite
Morelandite	$(Ba,Ca,Pb)_5(AsO_4,PO_4)_3Cl$	
Pyromorphite	$Pb_5(PO_4)_3Cl$	Forms a complete series with mimetite
Strontium-apatite	$(Sr,Ca)_5(PO_4)_3(OH,F)$	
Svabite	$Ca_5(AsO_4)_3F$	Fluoresces red-orange in LWUV
Turneaureite	$Ca_5[(As,P)O_4]_3Cl$	Fluoresces bright orange in SWUV, sometimes phosphorescent
Vanadinite	$Pb_5(VO_4)Cl$	

Britholite-(Ce), Britholite-(Y), Fluorbritholite-(Ce), Chlorellestadite, Fluorellestadite, Hydroylellestadite, and Mattheddleite are silicates that are isostructural with members of the Apatite group; so is the sulfate Cesanite

Pyromorphite forms a solid-solution chemical series with mimetite [$Pb_5(AsO_4)_3Cl$] and at least a partial series with vanadinite [$Pb_5(VO_4)_3Cl$.] Interestingly, this solid-solution series is a bit different from most other series in which the substitution takes place between metallic cations, such as calcium for

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magnesium. Instead, in the pyromorphite-mimetite-vanadinite series, substitution takes place between the anions, which include the phosphate (PO_4), arsenate (AsO_4), and vanadate (VO_4) radicals. To make the graded chemical composition of the series even more complex, small amounts of calcium (Ca), copper (Cu), and zinc (Zn) often substitute for a portion of the cationic lead.

As seen in its chemical symbol $Pb_5(PO_4)_3Cl$, pyromorphite consists of the element lead (Pb) which, with its ionic +2 charge, is drawn to the combined -3 charge of the phosphate radical (PO_4) and the -1 charge of the chlorine (Cl) ion. In terms of atomic weight, each molecule of pyromorphite consists of 82.2 percent PbO, 15.7 percent P_2O_5, and 2.6 percent Cl.

Pyromorphite is usually green; vanadinite, red-orange; and mimetite, yellow. But the complex, graded substitutions that characterize this solid-solution series create a broad range of colors which can make identification difficult. Yellow pyromorphite and green mimetite, which are not uncommon, are especially difficult to distinguish. Nevertheless, color remains the best general means of distinguishing between pyromorphite, mimetite, and vanadinite. In the case of ambiguous coloration, tests are needed. However, it is helpful to remember that mimetite rarely forms cavernous, hexagonal crystals, and that pyromorphite, regardless of color, retains its unique habit of stacked, barrel-shaped crystals.

COLLECTING LOCALITIES

Pyromorphite is a secondary mineral that forms in the alteration, or oxidized, zones of hydrothermal lead sulfide (PbS) deposits, often in association with anglesite ($PbSO_4$), cerussite ($PbCO_3$), barite ($BaSO_4$), galena (PbS), wulfenite ($PbMO_4$), smithsonite ($ZnCO_3$), and vanadinite [$Pb_5(VO_4)_3Cl$]. These colorful minerals often form when the primary lead mineral (galena in most cases) is attacked by circulating groundwater and carbon dioxide in the presence of phosphorous and chlorine. Although generally rare, pyromorphite may be locally abundant in environments that favor its formation. Pyromorphite pseudomorphs after galena and cerussite are common.

In northern Idaho's Coeur d'Alene Mining District, the oxidized zones of the upper ore bodies of dozens of district mines once provided many well-developed pyromorphite crystals. Today, these oxidized ores have been virtually mined out, with the exception of some remaining pockets at the Bunker Hill Mine. During the past few decades, the occasional reopening of the Bunker Hill's 9 Level has yielded world-class pyromorphite crystals measuring up to one inch in length. Colors include various shades of green and most notably a spectacular and rare orange. A major find in 1981 at the Bunker Hill Mine yielded some of the largest orange pyromorphites ever found.

The Wheatley lead-zinc mines near Phoenixville, Pennsylvania, are another source of fine green pyromorphites. In 1999, collectors found a 50-pound, pyromorphite-encrusted boulder in mine dumps at the Loudville Mine in Hampton County, Massachusetts.

At Moyie, British Columbia, the Society Girl lead-silver mine has long yielded world-class pyromorphite crystals from its extensive oxidized zone. Pyromorphite has been collected in both massive form and as well-developed crystals as long as one inch, often in beautiful clusters on a cerussite matrix. The pyromorphites occur as yellow-green to green prismatic crystals in their characteristic barrel shape. Because these crystals and crystal aggregates were only loosely attached to their matrix, they tended to fall free as they were trammed to the smelter. During the early 1900s, Society Girl miners collected thousands of these superb floaters.

Germany has many fine sources of pyromorphite, among them Bad Ems in the Rheinland and

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Johanngeorgenstadt, Saxony. Fine specimens have also come from Caldbeck Fells, in Cumberland, England, where crystals are found that are lime-green at one termination and a yellowish-green at the other; Leadhills, Scotland; Les Farges, France; Kadwe (Broken Hill), Zambia; Beresovsk, Russia; and Broken Hill, New South Wales, Australia. At some of these localities, including Caldbeck Fells, Broken Hill, and Leadville, Colorado, pyromorphite was so plentiful that much of it was used as lead ore, as mentioned in our opening quote. Fortunately, miners preserved some pieces that now grace collections the world over. Because of its bright color and wonderful crystal habits, pyromorphite is much sought after by collectors. Some collectors make this "fire form" mineral the core of their collections, attempting to add spectacular specimens from all these mines and many others to their collections. No doubt these were extremely excited when the new find was made in China a few years ago, as we will see.

JEWELRY & DECORATIVE USES

Pyromorphite has two outstanding gem qualities. First, its color often resembles the attractive lime green of fine peridot. Second, its relatively high index of refraction of 2.05, typical of translucent and transparent lead-containing minerals, assures considerable brilliance and sparkle. However, pyromorphite's brittleness makes faceting extremely difficult, and its Mohs 3.5--4.0 softness does not stand up to even moderate jewelry wear. Pyromorphite has only rarely been fashioned into collector's gems.

HISTORY & LORE

According to current metaphysical teaching, pyromorphite is a stone for "Victory," and wearing a small cluster of pyromorphite crystals is believed to freshen one's attitude and increase personal power by attracting material assets and energy.

TECHNOLOGICAL USES

As indicated by its synonym "green lead ore," pyromorphite was once an important ore of lead. Because it occurs only in shallow, oxidized ore zones, most major mine-site deposits of pyromorphite were exhausted long ago, usually before miners even drove underground workings into the lower-lying sulfide ores.

ABOUT OUR SPECIMENS

One of the most exciting developments in the mineral world in the last decade or so is the virtual flood of new mineral finds coming from China, including the new mineral hubeite on inesite we featured last August in the Club. The pyromorphite find ranks near the top of the list. The new pieces started showing up at shows in 1999, with first mention made in the November-December 1999 *Mineralogical Record*. By Tucson 2000, pieces were springing up in dealer stocks, at the very high prices one might expect to pay for an exceptional new find of a colorful mineral, but all that was known regarding the locality was that it was coming from an old lead mine in Jiangxi Province, which proved not to be correct.

By the time of the East Coast Gem & Mineral Show in August 2000, more was known about the locality, as expressed so well by new editor Tom Moore in the January-February 2001 *Mineralogical Record*: "Somehow there is an energy, and up-and-comingness, about this material such that one senses that future specimens may well compete with French, German and Idaho pyromorphites at their most authoritative. The mystery, so far, of these Chinese specimens concerns, you guessed it, the locality. What with the problems of transliteration from Chinese characters added to the usual problems of error,

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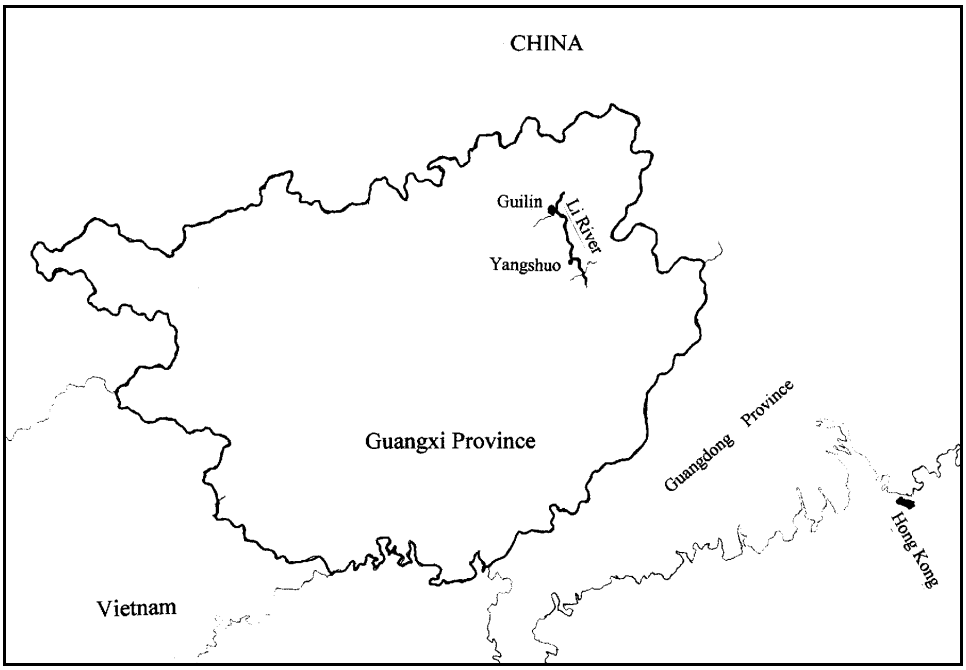
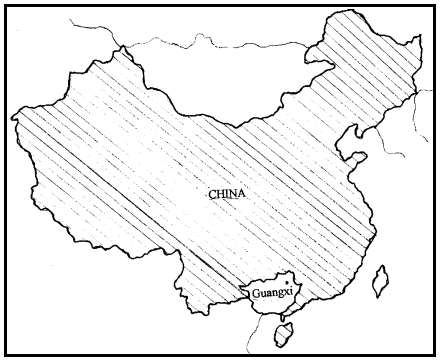
vagueness, paranoid disinformation-giving, and other ills that flesh is heir to along the supply pipeline, confusion about the locality is not surprising." Locality names such as Gulin, Yangshu, and Baise were being offered, but at least all agreed they were from Guangxi Province, China. (The two most outstanding things about new Chinese finds are of course the finds themselves, and the fact that in most cases the prices are affordable for all collectors, except for the best, biggest, and brightest of each new find; the two negatives are the poor handling by the Chinese miners, collectors and dealers that result in damage to much of the new material, and the fact that often these folks do not want to divulge where they have made a new find, for fear of others collecting all the choice material there.)

By the Denver Show of 2000, evidently a consensus had been made as to the locality, as again reported by Tom Moore: "A mountain near the town of Yangshuo, near the city of Guilin, in the province of Guangxi, contains an old lead mine now being worked for ore and specimens, with two main adits coming in from opposite sides of the mountain; the mine is called the Daoping." Our source gives the mine name as Tang Ping, probably due to a difference in translation.



Guangxi Province, as you can see from the maps, is located in southern China, along the Gulf of Tonkin. It is more properly known as Guangxi Zhuang Autonomous Region, so designated by the Chinese government to reflect it large minority population and to allow it greater political representation. This region of almost 45 million people, with its capital at Nanning, is among China's poorest. Much of Guangxi's surface rock is limestone that has been attacked by circulating groundwater containing weak carbonic acid. Over the ages, sinkholes, gorges, domes, towers, and caves with underground rivers have been etched out from the limestone, a process accelerated in humid climates such as in Guangxi. The technical name for this type of topography is **karst landscape**, named from a limestone region in Yugoslavia. Guilin has become a tourist center, where travelers, poets, and painters have long been inspired by the stark beauty of the karst



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formations. Cave tours are available around Guilin, and a tour boat brings viewers down the Li river from Guilin to Yangshuo, pausing to admire the natural sculptures.
Yangshuo, an ancient city built during the Jin Dynasty (265-420 AD) is also known for its exceptional views. Tangerines, oranges, pomelos, chestnuts, and kumquats grown in the neighboring fertile land can be bought from vendors along its main street. Let's go for a visit, perhaps we can also visit the lead mine and get its correct name!

Karst formations outside Yangshuo, Guangxi Province, China

No doubt the most enjoyable part of the write-up for us is examining closely a number of the wonderful specimens we receive for the Club each month! (And of course it can be frustrating trying to find the right words to convey the beauty and intricacy of the crystal colors and forms.) But with our trusty 10x loupe we were able to really enjoy the perfection of the hexagonal crystals, many with complete, sharp, flat terminations. A number also had the barrel form that pyromorphite is known for, being slightly thicker in the center than on the ends. The glorious grass-green color is absolutely exceptional, as well. Many of our specimens were different from those we have seen at shows, in that they had a number of small crystals spread out all over the white quartz matrix they formed on, whereas most of what we have seen at shows are sprays of tightly-packed crystals on brown, iron-stained quartz matrix. As are pyromorphite crystals from most localities, the individual crystals are quite small. We noticed only a very weak greenish-tan fluorescence in shortwave UV light.

When and where will the next great pyromorphite find be made?

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