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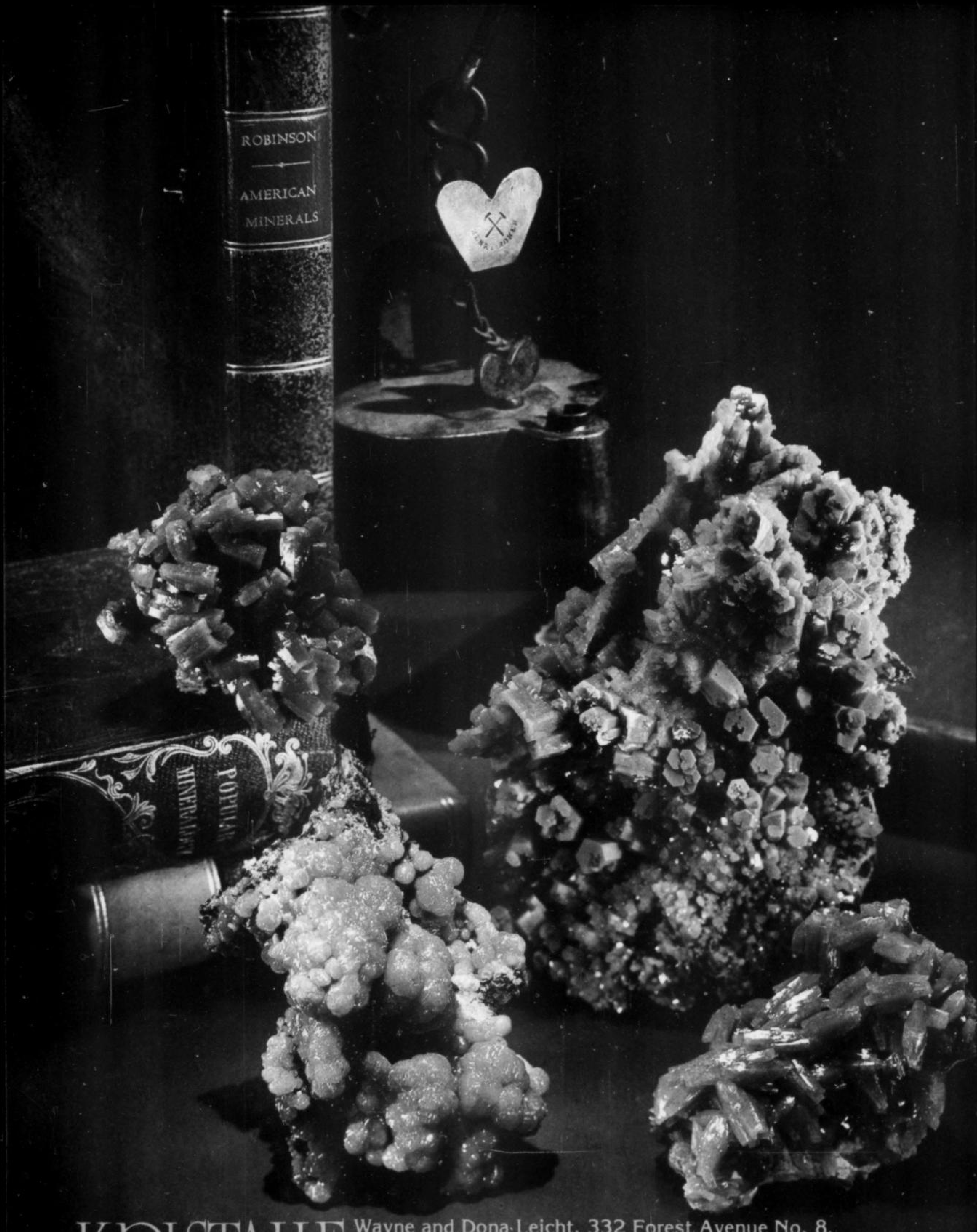
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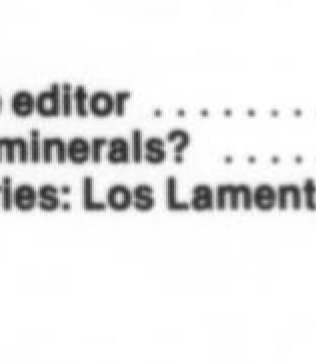

COVER: GROSSULAR from the Jeffrey mine, Asbestos, Quebec. The crystal measures 1 cm. Specimen and photo: Olaf Medenbach. To read more about this locality see the article on the Jeffrey mine in vol. 10 (1979), no. 2, p. 69–80.

notes from the EDITOR

BANCROFT'S BOOK IS COMING!

All good things take time, but readers may nonetheless have been wondering if the long-promised book on famous mineral localities by Peter Bancroft is still in the offing . . . it is! The text and photographs have been completed, and are now undergoing a final edit preparatory to typesetting, layout, color separations and printing.

It has been a long and difficult job for the author, but the final product is unlike anything ever published before. Several years of full-time research and travel, plus the cooperation of a huge number of collectors and curators and many fine photographers, have combined to make a book that few imagined would be possible. In addition to all this, the *Record* has arranged sufficient funding so that no corners need to be cut on size, length, material, photography or overall quality.

Great Gem and Crystal Mines will be about *Record*-size (8½ x 11) and more than 500 pages in length, with hundreds of antique mining photos, recent locality photos, and superb color photos of crystal specimens. (The typed list of figure captions alone is 240 pages, doubled spaced!)

Incidentally, a special leather-bound collector's edition will be produced in very limited numbers, probably containing some extra items of various sorts and a bound-in letter from the author. Price will probably be about $200. Those interested should write *now* to have their names put on the list (send no money at this time).

We can't say yet exactly when the book will be available for delivery, but the project is in its final phase now so it should be relatively soon.

SHOW NOTES

The satellite mineral show in Detroit is at a new location this year: the Holiday Inn in *Troy,* Michigan, on 16 Mile Road (not to be confused with their former location in the Holiday Inn in *Hazel Park,* on 9 Mile Road!).

The Tucson Show is expanding to four days, and will open to the public on Thursday, February 10.

GLOSSARY UPDATES

The first set of additions and corrections to the *Glossary of Mineral Species 1980* was published in the January-February 1981 issue of the *Record;* the second set was published in the January-February 1982 issue. *Glossary* owners may simply xerox those pages and keep them with their *Glossary* for easy reference. However, for the luxury-lovers among you, we have reprinted those additions and corrections as 8-page booklets of the same page-size as the *Glossary,* which may be conveniently stored inside the back cover. Set II is available for 50¢, or Set I and II for 75¢ (in stamps if you like), from the circulation manager.

NOTICES

Died, David D. Eidahl, 26, of a cerebral aneurism in Fallbrook, California, while unloading newly mined tourmaline specimens from the Himalaya mine. Eidahl had been an employee of Pala International since 1974, full-time since 1976, and at the time of his death was director of mineral sales and purchases for Pala International and The Collector shop in Fallbrook. In less than a decade he had built an incredible personal collection of fine miniatures, written for the *Record,* and become known throughout the U.S. and Europe as a knowledgable enthusiast with a highly developed esthetic sense. Though perhaps the youngest of the major mineral dealers worldwide, he nevertheless was instrumental in making additions to some of the world's finest collections, both public and private.

Died, Gertrude (Trudy) Houser, 81, in Cincinnati, Ohio, of a heart attack. Houser was a long-time member of the Cincinnati Mineral Society and a friend to literally thousands of curators, dealers and collectors, young and old. Her modest house was a partial museum containing her collections of over 15,000 fossils and nearly 3000 mineral specimens; an average of 650 guests a year signed her register. A portion of her fossil collection was donated to the Smithsonian Institution in 1977, and the remainder of her fossils and minerals are being donated to the Smithsonian through her daughters, Ronnie Harlan and Erica Stux. (See the personality sketch of Trudy Houser in the September-October 1977 issue of the *Record.*)

Died, Dick Jones, 49, (Dick Jones Mineral Company, Casa Grande Arizona), of leukemia. In the history of Arizona mineral collecting, Jones was unequaled as a dealer specializing in self-collected material. Though largely uneducated, he was highly knowledgable with regard to field occurrences and their geology and mineralogy. An article by Jones on the famous Old Yuma mine near Tucson is scheduled for publication in the next Arizona issue; it will be accompanied by a personality sketch and photo spread covering some of his significant discoveries.

Died, Paul Seel, 78, of bone cancer, Seel was renowned as a micromounter, draftsman, story teller, lecturer, and world traveler. A charter member of the Pennsylvania Mineral Society, he served as President of the American Federation and held many other posts and honors. He could lay claim to having known all of the founders of the *American Mineralogist,* including its first editor, Dr. Edgar T. Wherry. Diamonds were his specialty, and he executed a large number of superbly drafted illustrations showing their various morphological characteristics. A personality sketch of Paul Seel, written by Smithsonian curator Paul Desautels, appeared in vol. 1, no. 1 (Spring, 1970) of the *Mineralogical Record.*

famous mineral localities:

the Les Farges mine

by **A. Brousse**
61 Rue Buffon
75005 Paris, France

In less than a decade the name "Les Farges" has become synonymous, among mineral collectors, with fine pyromorphite because of the abundance, quality and variety of specimens taken from that mine. Unfortunately, the closing of the mine in May of 1981 put an end to a collecting phenomenon of a kind previously long unseen in France.

INTRODUCTION

The Les Farges mine[1] is located in the northwest quadrant of the French Massif Central, in the department of Corrèze, immediately southeast of the small town of Ussel, France. It is about 100 kilometers from Clermont-Ferrand to the northwest, and 400 km from Paris to the North (Fig. 1).

In terms of regional cartography, the Les Farges deposit is located precisely on the boundary of four IGN[2] topographic maps (scale of 1:25,000), two BRGM[3] geological maps (Ussel and Bort-les-Orgues sheets, scale of 1:50,000), and two other BRGM maps (Ussel sheet to the north and Mauriac sheet to the south, scale of 1:80,000).

HISTORY

Evidence of the first known work carried out in the Les Farges area dates to the Gallo-Roman epoch (1st to 5th centuries A.D.). The upper part of the vein, 1200 meters in length, is thought to have been worked to a depth of 12 m. The ore may have been valued less for the lead (galena) than for the silver it contained. It was subsequently not until the first half of the 19th century that some limited work was begun again at this deposit: workings produced include a vertical shaft, a drift and some trenches dug by private prospectors. This period lasted until just prior to World War II. Around 1956 the BRGM became interested in prospecting the deposit. However, the first drilling was not done until about 1963, and four years later prospecting and survey work revealed the value of the deposit. A mining permit for lead, silver and barite was issued to the Corrèze Mining Company on 16 December 1973. Exploitation was not really begun until 1975, and it ended (for good?) on 9 May 1981.

Mining of the deposit, by means of vertical shafts and galleries (including a 250-m shaft, levels at 150 and 250 m, and more than 1000 m of galleries) (Fig. 3) involved two phases and the use of two different techniques. Initially the ore was mined and the waste rock discarded. But the weak condition of the gallery walls and a heavy influx of water caused this technique to be abandoned. Exploitation then continued upward from the second level (250 m), either along upward cuts which were backfilled with waste sand alone, or along downward cuts backfilled with a mixture of waste sand and cement. In 1978 the total exploitable reserves of mine run ore at the Les Farges mine were estimated at 1,766,000 metric tons, distributed as follows:

- **lead** (metal content of 6–8 percent) – 127,000 tons
- **silver** (at 2 kg per ton of concentrate) – 298 tons
- **barite** (at 32.5 percent) – 390,000 tons

The deposit, judging by this assessment, is one of the smallest lead deposits in France.

Pyromorphite specimens of collectible quality have been found at Les Farges more or less since the mine was opened in 1973. The specimens were in high demand among French collectors, and not many pieces found their way into American collections until the exceptional pocket of 1977 was discovered (Sullivan, 1977, 1980).

[1] Pronounced *"Lay Farzh."* The word "Les" simply means "The" in the plural, but is used in French as part of the mine name, so it is not redundant to speak of "*the* Les Farges mine." The name is also sometimes written as "Mine Des Farges," (pronounced *"Meen Day Farzh"*), which is the French word order meaning "Mine of the Farges," and is also correct.

[2] National Geographic Institute

[3] Bureau of Geological and Mining Exploration

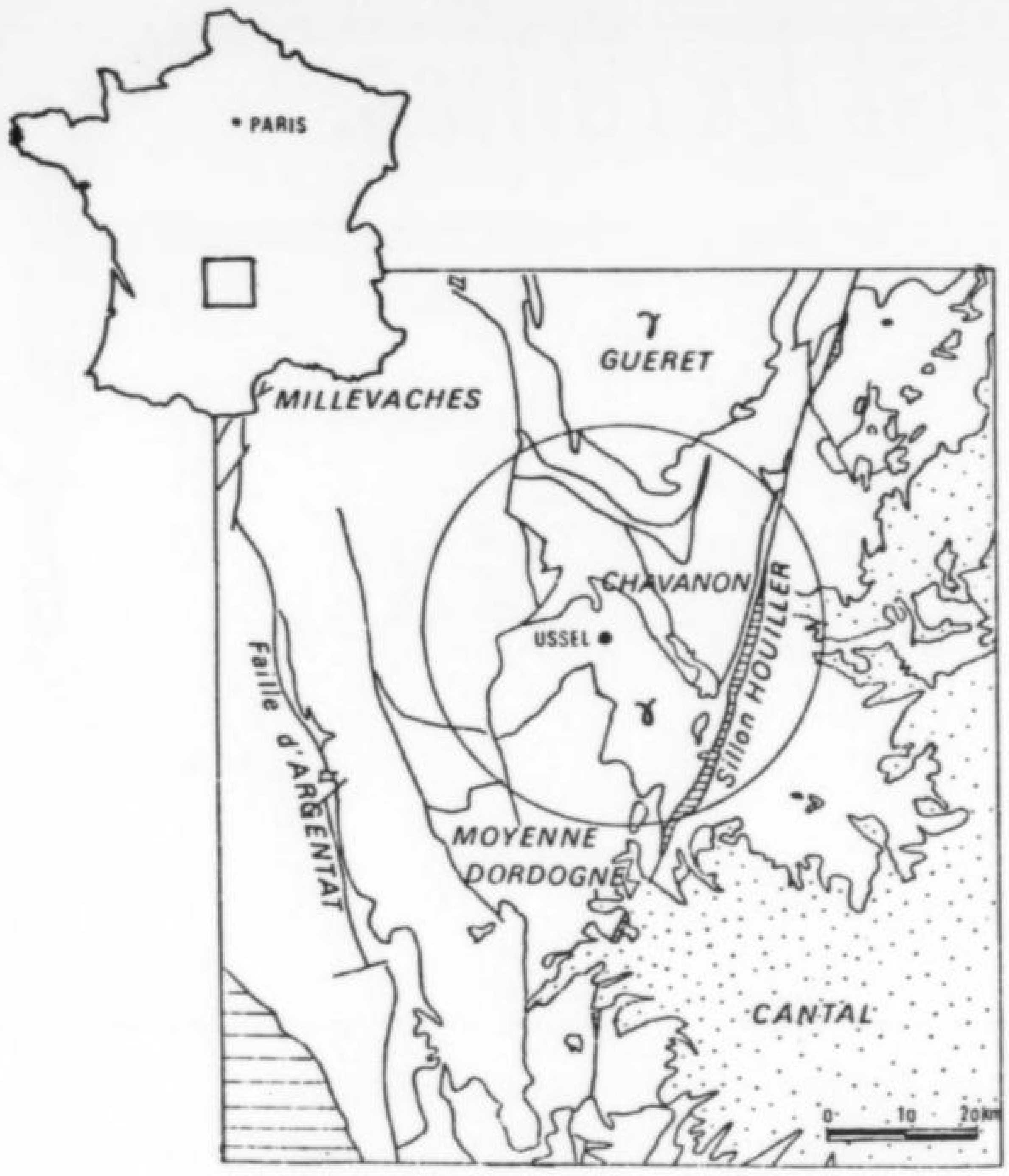

Figure 1. **Location map.**

GEOLOGICAL and MINERALOGICAL SETTING

The geological map of the Ussel sector on a scale of 1:50,000 (reproduced in Fig. 2) shows that the Les Farges deposit comprises a vein which runs substantially north-south, embedded along with other small veins similarly oriented within a granitic mass known as the Ussel granite.

This granite mass is bounded on the northwest by the small so-called Meymac granite, which belongs to the granite series of the Millevaches Plateau located northwest of Ussel.

It is evident that the outcroppings of these two masses form a rough "V," enclosing an area bounded on the west by the Millevaches series and interrupted on the east by a structure called the *Sillon Houiller,* or "coal trench," which in addition cuts the Ussel granite into two sections (Fig. 1).

The Ussel granite, like the adjacent Meymac granite, is a batholith intrusion into two multiply deformed metamorphic series—the Chavanon series to the north, and the Middle Dordogne series to the south. It outcrops over 300 square km. The rock of which it is composed is a homogeneous, gray, medium-grained adamellite which is calc-alkaline and rich in biotite. Pegmatite and aplite veins here are few. This rock is believed to have been formed during pre-Devonian times (395 million years ago).

During the Variscan orogeny in the Carboniferous period (345 to 280 million years ago), the Ussel granite is believed to have undergone the intrusion of the pseudoporphyritic Meymac granite along its northwestern edge, the intrusion within it of a stock of rose granite (Pont Tabourg), and the development of veins of microgranites and lamprophyres (see Fig. 2).

It is possible that the trench fault and later-formed graben of the "coal trench," only 15 kilometers from Ussel, occurred at the end of the Variscan orogeny. The geological picture, moreover, shows a zone divided by great faults lying north-northeast and north-south, dating from the Carboniferous period and serving in the Stephanian epoch as traps for coal deposits, such as the small Lapleau basin southeast of Meymac.

The only later sedimentary (sand) formations known in the region date from the Oligocene epoch, the whole being covered over locally by Pliocene and Quaternary extrusive rocks such as the Bort-les-Orgues phonolite.

The Ussel mining district is a part of a region which is relatively poor in mineral deposits in comparison to the rest of the French Massif Central, although it does contain some important mineral concentrations, such as the Chaillac barite deposit in Indre and the veins of fluorite in Marche. The Ussel region is not, therefore, an "old mining region," although, in addition to Les Farges, three deposits there have been the sites of mining operations since the end of the 19th century. These are:

Meymac (Les Chèzes), where, early as 1874, the mining engineer and mineralogist Adolphe Carnot discovered and extracted bismuth from a deposit of W-Bi-Sn-Mo in which he identified "meymacite" (see Sahama, 1981).

Le Beix, near Bourg-Lastic, in Puy de Dôme, where a vein of fluorite which yielded splendid collectors' pieces of an incomparable blue was exploited from 1906 to 1977.

Saint Pierre-du-Cantal, where an Oligocene deposit of uranium is being exploited.

THE VEIN

The Les Farges mineral-bearing structure extends over 8 km and reaches a depth of at least 400 m. It can be divided into two parts, north and south (Fig. 2).

The northern part consists of a fracture oriented N 20° E, parallel to the Sillon Houiller and to unproductive siliceous veins (hypersilicified tectonic breccia). The only block which has been exploited (650 m long and 250 m high) is located here.

The southern part is consistent with the indicators for the north-south structure but at the outcrop it reveals minor changes in orientation as a result of a virgation phenomenon (Fig. 2).

The exploited portion of the vein has a steep dip of about 80°W. This zone is interrupted and bounded on the south by a strike-slip fault trending S 30° E; the movement of approximately 20 m seems to increase with depth, considering that it affects the vein substantially at the 150-m level.

It is difficult to establish the average thickness of the lode, because it may vary considerably and abruptly (from 10 m to a few cm over a 10-m distance), and the vein splits into multiple veinlets in places.

The deposit consists primarily of two ore shoots separated by a less mineralized zone of 6 meters at the most. The infilling of the vein occurred after a pegmatitic phase and felsic intrusions, but a part of the mineralizing fluid was dispersed throughout the rest of the massif. After this infilling, the structure was broken up by northwest-southeast faults similar to that affecting the 150 m level. The vein itself underwent an extensive reorganization at an undetermined period.

The primary mineral content is principally galena with a small amount of sphalerite, in a matrix which is predominantly baritic between the surface and the 150-meter level, and predominantly quartziferous below. The vein contains very clear vertical zoning (Fig. 7), characterized by the presence of four types of mineralized formations, each occupying a particular position in the lode.

Formation I: This is located in the upper portion and is made up of barite, quartz and banded galena with some sphalerite coatings, as well as a multitude of microscopic silver ore pockets, where the deposits are poorly organized. It is believed that the sphalerite and the quartz were deposited first, and then barite, galena and quartz (Fig. 8).

Formation II: This is situated in the lower part of the structure and is made up exclusively of quartz and galena, the latter occurring in the form of equant, decimetric patches in the quartz. Silver

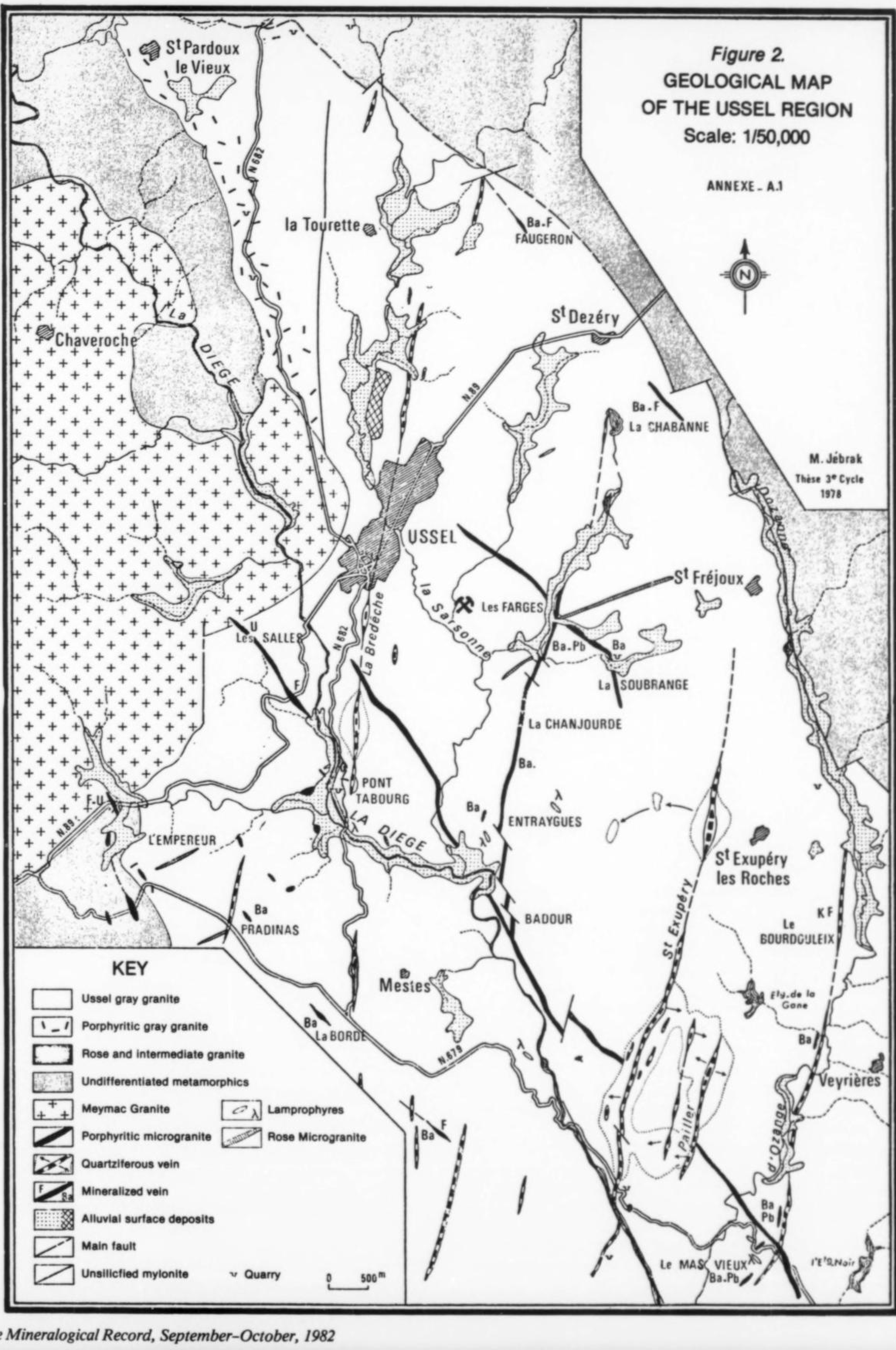

Figure 2.
GEOLOGICAL MAP OF THE USSEL REGION
Scale: 1/50,000

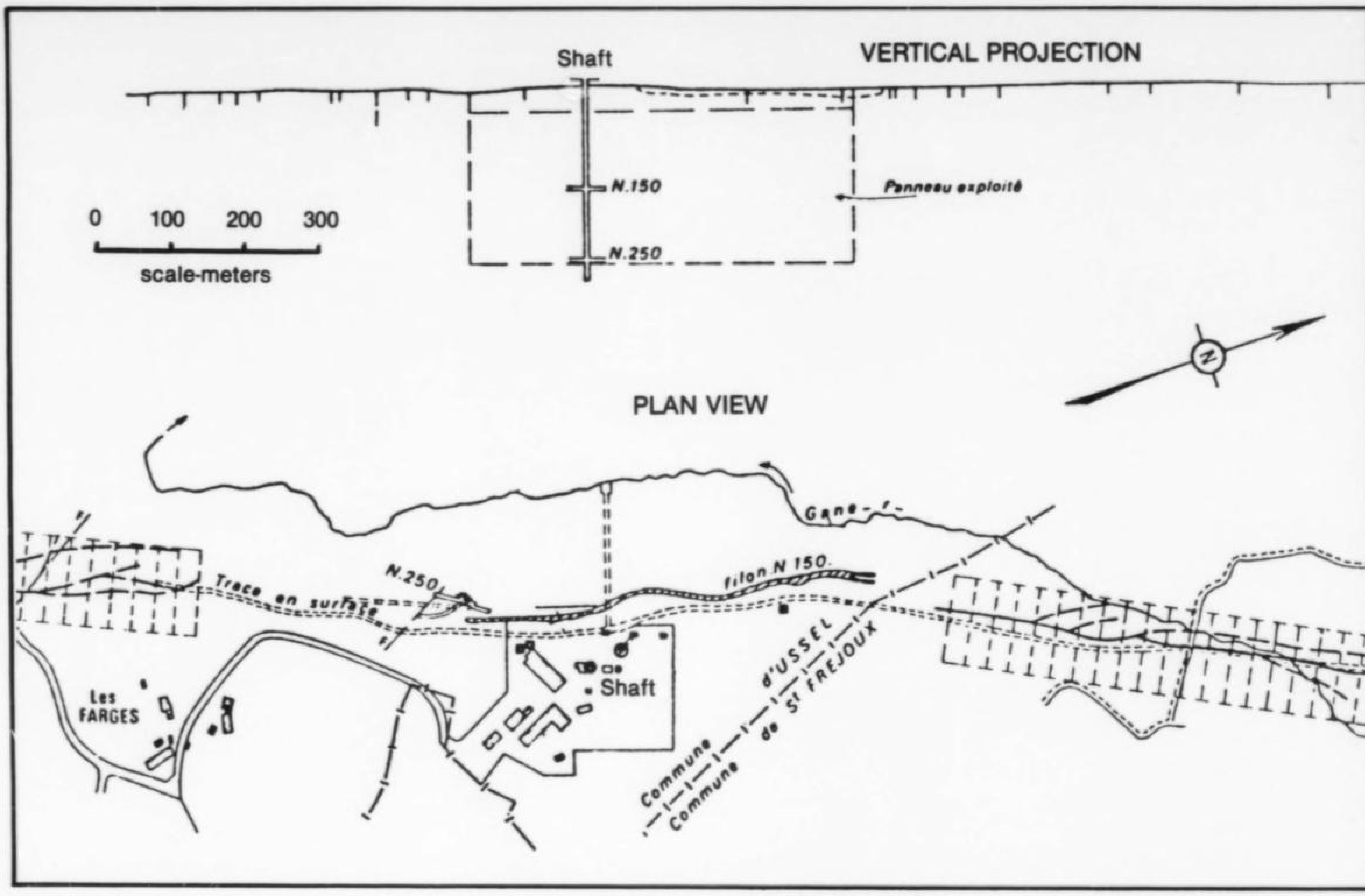

Figure 3. **General plan of the Les Farges mine.**

is present but not in abundance. This formation could be the product of Formation I, due to gradual silicification with a reduction in barite.

Formation III: This "corresponds to a rather different metallogenic episode" (Jebrak, 1978), for it includes only the gangue minerals: quartz, barite and yellow fluorite, in some cases found in a brecciated zone in the lower part of the vein, and sometimes in small satellite veins.

Formation IV: This is made up exclusively of deposits of calcite, found in almost the whole of the Ussel massif.

These four formations are evidence of low-temperature parageneses and reveal an epithermal vein with multiascendant zonality. Structurally the Les Farges vein is a major fault; the emplacement and first reorganizations preceded the mineral formation and probably occurred at the same time as the emplacement of the hypersilicified tectonic breccia veins which lie parallel to it. This fault is believed to have developed lengthwise at first, allowing sulfides to form, then shearing (left lateral), at which time the other minerals formed. Formations I and II, formed by concentrated brine at 130°C, are thought to date from the Permian period. Formation III, with its yellow fluorite of the Liassic epoch, was probably deposited by relatively unsalty waters of the same temperature. Regarding the primary minerals, it should be noted that they have never provided remarkable crystallizations. Fortunately for collectors, supergene alteration developed extensively at Les Farges, giving rise to abundant secondary lead minerals of which pyromorphite is the most important and the most interesting.

THE ALTERATION ZONE and the PYROMORPHITE

Contrary to what one might expect, there is no "iron cap" gossan or any well-defined oxidation zone at Les Farges. The remarkable fact is that the secondary lead minerals have been found at all depths thus far exploited, at 250 m as well as in the "roof" and the "walls" and within the primary mineral zones. They include the following minerals, listed in decreasing order of abundance: pyromorphite [$Pb_5(PO_4)_3Cl$], mimetite [$Pb_5(AsO_4)_3Cl$], cerussite [$PbCO_3$], phosgenite [$Pb_2(CO_3)Cl_2$], wulfenite [$PbMoO_4$], vanadinite [$Pb_5(VO_4)_3Cl$], and descloizite-mottramite [$(Zn,Cu)Pb(VO_4)OH$]. Jebrak (1978) identified four pyromorphite habits at Les Farges:

1. An "amorphous" pyromorphite, dark green or brown, rather abundant, found in concretionary masses several centimeters in thickness on the wall of the vein. These concretions may be stalactitic with a hollow central tube covered with protruberances, or dendritic and reticular, or as greenish coatings on barite.

2. A hexagonal prismatic habit in crystals ranging from dull orange to brown, equant and measuring about 1 x 1 cm. According to Jebrak (1978) "The growth of this form is very special and is characterized by rapid development of the crystal faces $\{10\bar{1}0\}$ at the expense of the center, which appears depressed (cavernous); the face $\{0001\}$ is never formed." Jebrak also associates the genesis of these crystals with a growth model proposed by Grigoriev (1961) for beryls which he described as "trough-like" crystals, the formation of which would be explained by the direction of the movement of the crystallizing solutions (Fig. 9). Jebrak (1978) also suggests "helicoidal" growth with the more rapid development of the faces in contact with the solution. This type of crystal developed mainly, along with that described above, on the skeletal quartz left by the leaching of the primary minerals.

3. Centimetric acicular forms, chestnut-brown in color, may also be similar to Grigoriev's "split growth." They are composite crystals obtained from the juxtaposition of small crystals whose axes are divergent from each other by 5 or 10 degrees. These are bulky, sometimes zoned entities, greener toward the center than on the periphery; they also form millimetric rosettes.

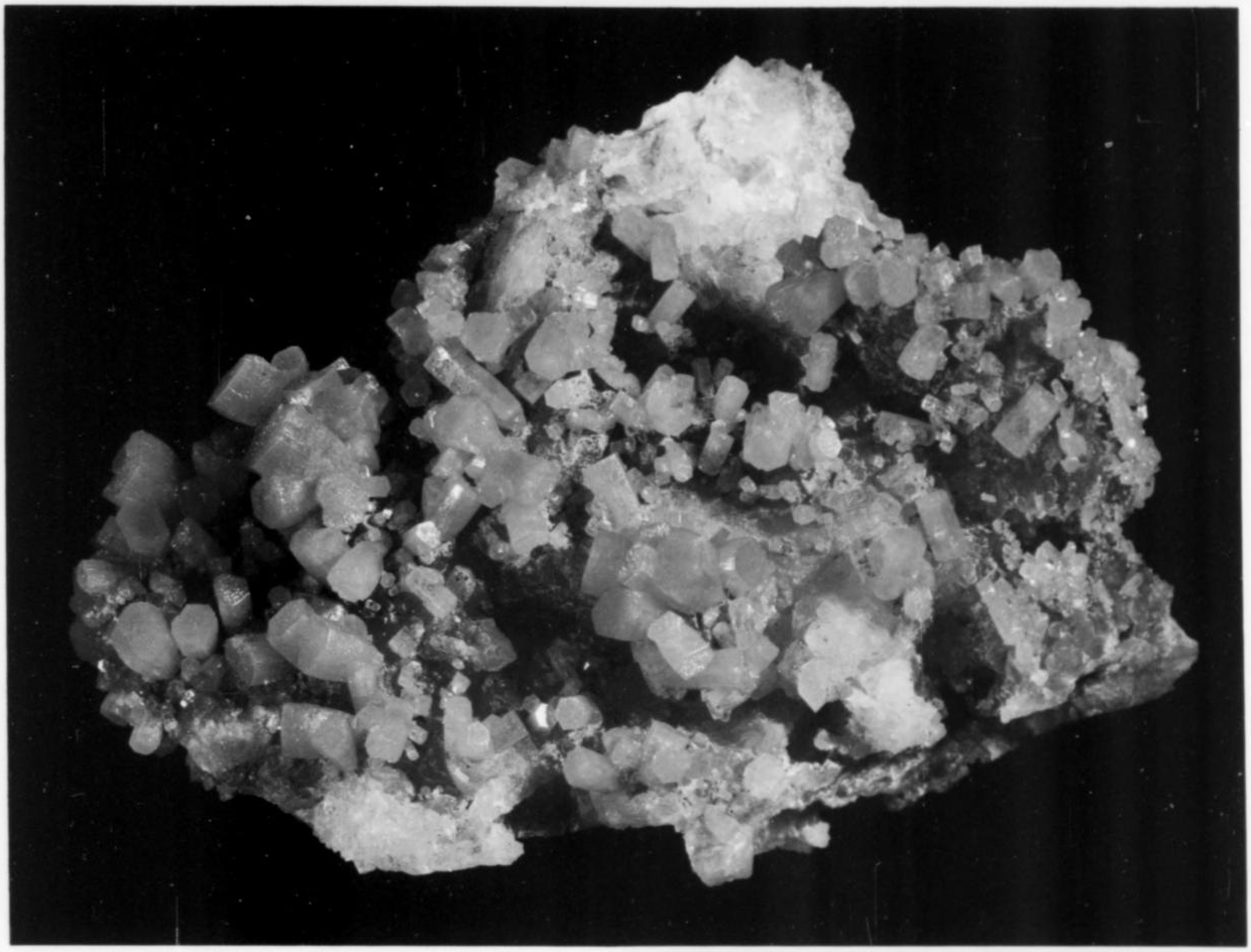

Figure 4. **Pyromorphite on a quartz matrix. Sorbonne specimen; photo by Nelly Bariand.**

Figure 5. **A red wulfebite crystal on yellow pyromorphite. Sorbonne specimen; photo by Nelly Bariand.**

Figure 6. **A brilliant green V-shaped pair of small pyromorphite crystals on yellow-brown pyromorphite. Sorbonne collection; photo by Nelly Bariand.**

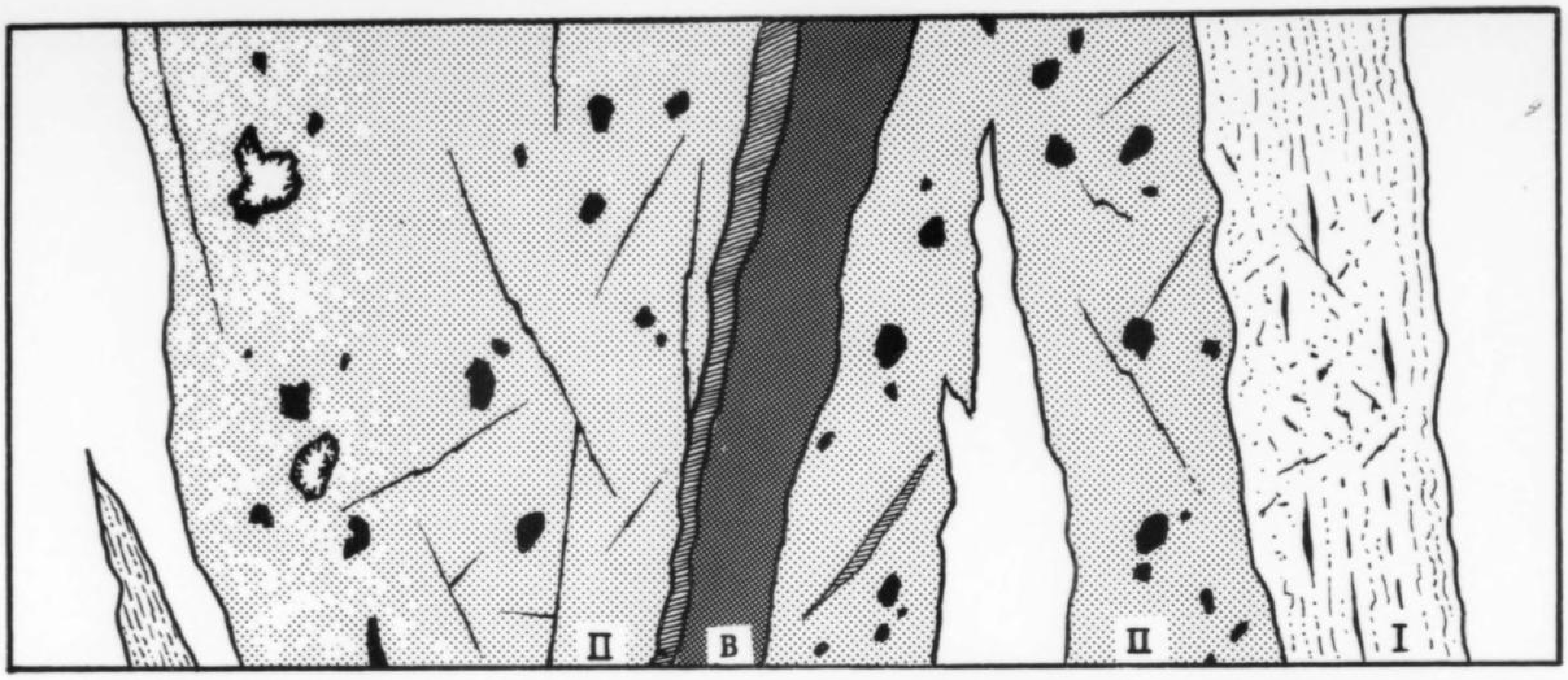

Figure 7. **Vein cross-section showing Formation I (banded galena, barite, quartz), Formation II (galena patches in gray quartz), and a vein of rose-colored barite (B) next to a filled fracture. Note fractures in the rock, and the altered area of Formation II at left (containing pyromorphite). White areas are barite and white fluorite.**

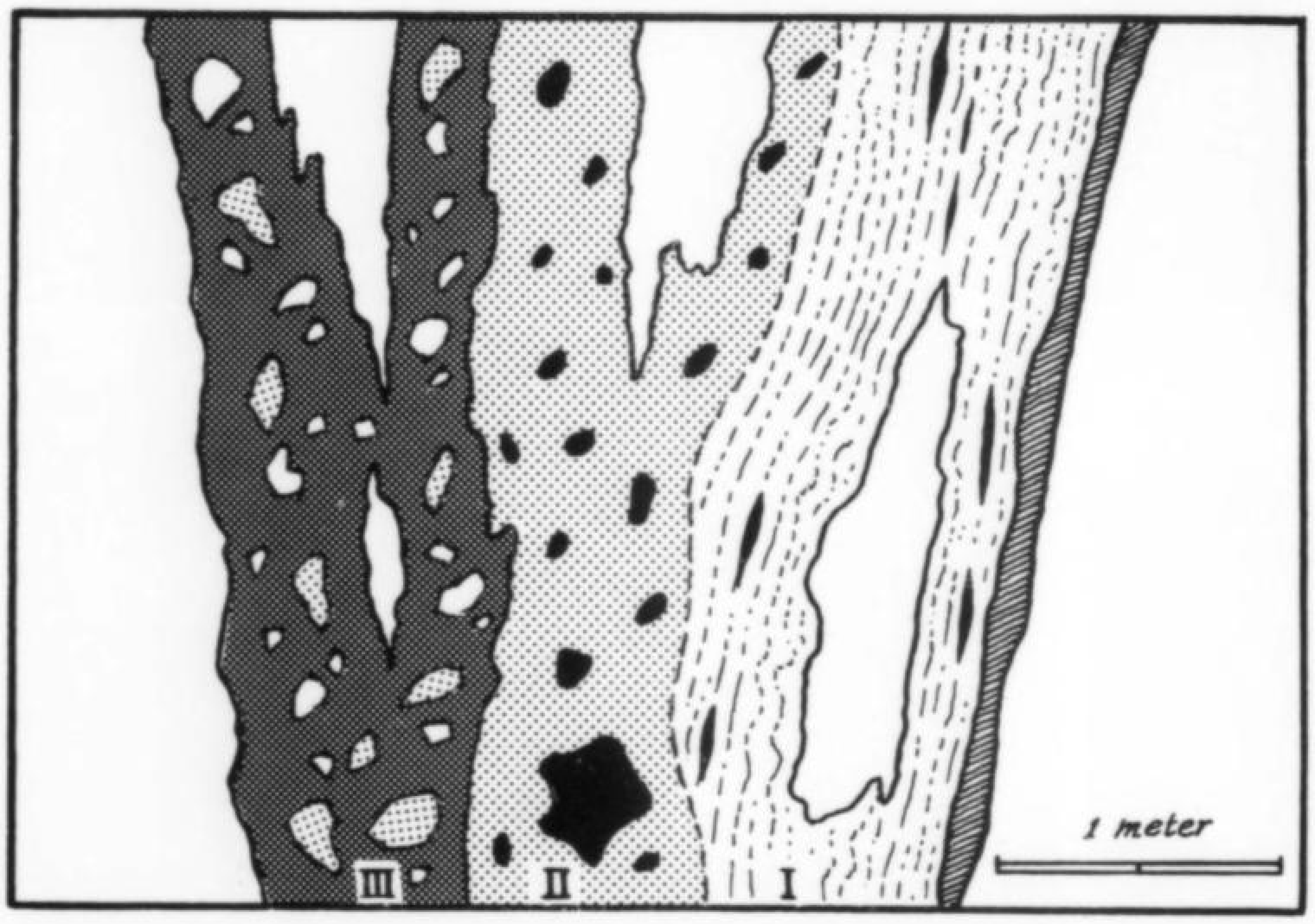

Figure 8. **Vein cross-section showing Formation I (banded galena, barite, quartz), Formation II (galena patches in gray quartz), and Formation III (barite breccia).**

4. A tapered prismatic habit, the most common kind at Les Farges, brown to golden yellow in color or, more rarely, of a magnificent translucent green. The crystals of this type rarely exceed 1 cm, and are found in very attractive sheaves containing several dozen crystals. This is the crystallization habit which has provided the largest specimens taken from the mine (sometimes the crystallized surface is as large as 1 square meter with individual crystals to 2.5 cm). It should in fact be noted that the total weight of the collectors' pieces scattered throughout the world must be estimated in terms of tons. The miners were very familiar with the distribution of the type 4 crystallization: it could be found mainly on the wall of the vein with barite, where brecciated sulfides (Formation III) were lacking, in zones which were unfortunately very often unstable.

The parts of the vein which were richest in pyromorphite measured several tens of meters both in length and height, both in the near-surface area and at a depth of about 200 m!

Quartz crystals of several tenths of a millimeter on certain pyromorphite crystals should also be mentioned. Pyromorphite is not found on galena. These various facts led Jebrak to think that the four types of pyromorphite are related to a primary paragenesis in which only the chemistry differed from the classic paragenesis.

CONCLUSION

The industrially important Les Farges deposit is characterized by a relatively simple geological and metallogenic context. The most interesting aspect of the vein is the occurrence of secondary minerals over such a wide range of depth, especially pyromorphite, the mineralogical qualities of which have made this deposit world famous.

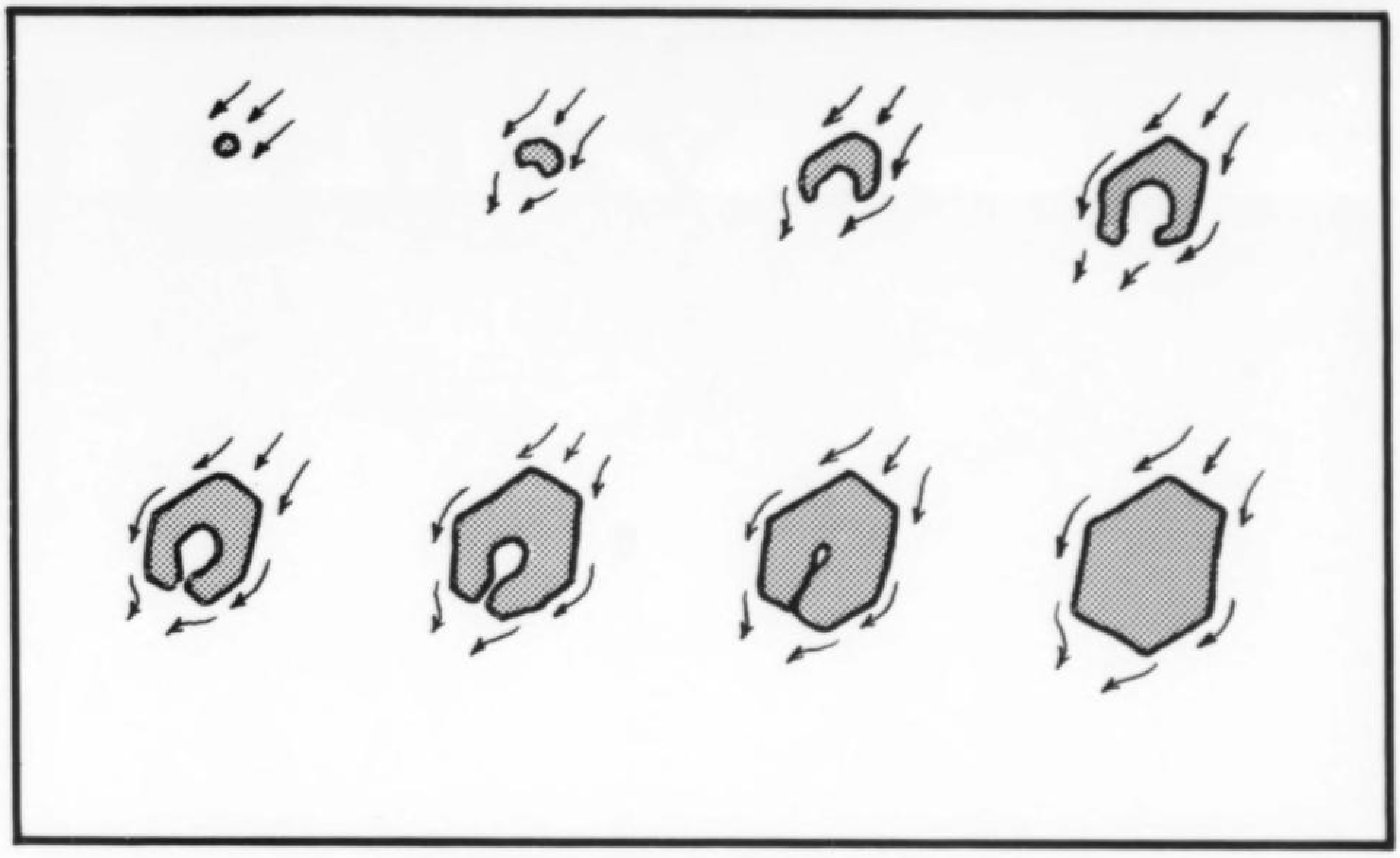

Figure 9. **Stages in the growth of "trough-like" crystals as suggested by Grigoriev (1961). Arrows show the direction of movement of the crystaliizing solution.**

Table 1. **Minerals of the Les Farges mine vein (compiled by Jebrak, 1978).**

Native Elements	
Arsenic	As
Silver	Ag
Sulfides	
Acanthite	AgS_2
Arsenopyrite	$FeAsS_2$
Chalcopyrite	$CuFeS_2$
Covellite	CuS
Digenite	Cu_9S_5
Galena	PbS
Gersdorffite	NiAsS
Marcasite	FeS_2
Pyrite	FeS_2
Pyrrhotite	$Fe_{1-x}S$
Sphalerite	ZnS
Sulfosalts	
Andorite	$PbAgSb_3S_6$
Boulangerite	$Pb_5Sb_4S_{11}$
Bournonite	$PbCuSbS_3$
Dyscrasite	Ag_3Sb
Enargite	Cu_3AsS_4
Famatinite	Cu_3SbS_4
Fizelyite	$Pb_5Ag_2Sb_8S_{18}$
Freibergite	$(Ag,Cu,Fe)_{12}(Sb,As)_4S_{13}$
Freieslebenite	$PbAgSbS_3$
Geocronite	Pb_5SbAsS_8
Pearceite	$Ag_{16}As_2S_{11}$
Proustite	Ag_3AsS_3
Pyrargyrite	Ag_3SbS_3
Semseyite	$Pb_9Sb_8S_{21}$
Tetrahedrite	$(Cu,Fe)_{12}Sb_4S_{13}$
Secondary Lead Minerals	
Cerussite	$PbCO_3$
Descloizite	$PbZn(VO_4)(OH)$
Mimetite	$Pb_5(AsO_4)_3Cl$
Phosgenite	$Pb_2(CO_3)Cl_2$
Pyromorphite	$Pb_5(PO_4)_3Cl$
Vanadinite	$Pb_5(VO_4)_3Cl$
Wulfenite	$PbMoO_4$
Gangue Minerals	
Barite	$BaSO_4$
Calcite	$CaCO_3$
Fluorite	CaF_2
Goethite	FeO(OH)
Magnetite	Fe_3O_4
Quartz	SiO_2

Because of the shutdown, the various levels of the mine are now flooded and extraction of specimens at any depth has become impossible. However, a considerable mass of excavated material remains on the surface, and it is very rich in microminerals.

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Figure 10. **Vary large plate of pyromorphite on quartz, showing a variety of colors and habits. Sorbonne specimen; photo by Nelly Bariand.**

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______ (1980) Letter from Europe. *Mineralogical Record,* **11,** 29.

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Pyromorphite
from the Coeur d'Alene District, Idaho

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For nearly a century the Coeur d'Alene area has been the source of spectacular pyromorphite. Tremendous numbers of high-quality specimens were mined in the late 1800's and early 1900's, though most of this early material has since been lost. A recently discovered bonanza of pyromorphite at the Bunker Hill mine has once again made top-quality specimens widely available.

INTRODUCTION

The Coeur d'Alene region is the most productive portion of the great Coeur d'Alene mineral belt of Idaho and Montana. The mineral belt, which is about 95 miles long, extends from near Coeur d'Alene, Idaho, to near Superior, Montana. The Coeur d'Alene mining district proper is in Shoshone County, Idaho, and has an essentially east-west trend. The western boundary lies a few miles west of Kellogg, Idaho, and the district extends easterly to the Montana state line. The mining district is approximately 15 miles wide by 25 miles long, and is located about 75 miles east of Spokane, Washington.

Coeur d'Alene has long been known for an abundance of spectacular specimens of anglesite, cerussite, silver and pyromorphite collected during the late 1800's and early 1900's. A vast quantity of high-quality specimens were mined, with the majority of these specimens now lost from sight. Perhaps because of the isolation of the mines in the wilds of northern Idaho, few specimens were sent out of the area. Another contributing factor to this disappearance of specimens may have been the general feeling that superb specimens were everywhere and would last forever so that little interest was generated in preserving specimens. Many were thrown into the garbage dump, used as lawn decorations, milled as ore, or generally destroyed by time and poor handling; some were even embedded in concrete bridge abutments as curiosities.

Most of the oxide zone workings in old mines have long since caved and the operating mines have been producing sulfide ores for years. The few oxide zone specimens collected in the past 30 or 40 years have been found in old workings. Most older specimens still extant are in the possession of a few district collectors and miners. An exception is the Bunker Hill mine, one of the few active mines in the district from which a small but steady supply of minerals has been trickling out, almost all of which has been absorbed by the local market.

Pyromorphite is recorded from a large number of mines in the district, and there are undoubtedly additional unrecorded occurrences. Usually pyromorphite occurs by itself in the upper part of the oxide zone of mineral deposits. Rarely does it occur in direct contact with cerussite. Some major finds of pyromorphite, as well as cerussite, anglesite and silver, were made at the Bunker Hill mine from 1979 to 1982.

HISTORY

The first known prospecting in the area took place in 1878 when Thomas Irwin located a gold claim in Gold Run Gulch east of Kellogg. Four years later, extensive gold placers were discovered near the town of Murray, close to the northern boundary of the district. Lead-silver veins had been recognized in several widespread areas of the district by 1884, and mining had started at the Hecla, Tiger-Poorman and Polaris mines (Ransom and Calkins, 1908; Umpleby and Jones, 1923; Fryklund, 1964). Other deposits discovered in 1884 include the Gold Hunter, Morning, and You-Like mines near Mullan, and the Black Bear and Helena-Frisco mines near Gem. In 1885 the Bunker Hill deposit was discovered (see Radford and Crowley, 1981), followed by the Sullivan, Last Chance and Sierra Nevada mines (it is interesting to note that during the early years most of the ore from the Sierra Nevada was cerussite, much of it crystalline). In 1901 the Hercules mine was opened. Judging from the descriptions of Ransome and Calkins (1908), Umpleby and Jones (1923) and Shannon (1926), fantastic mineral specimens were encountered constantly for the first several years of production.

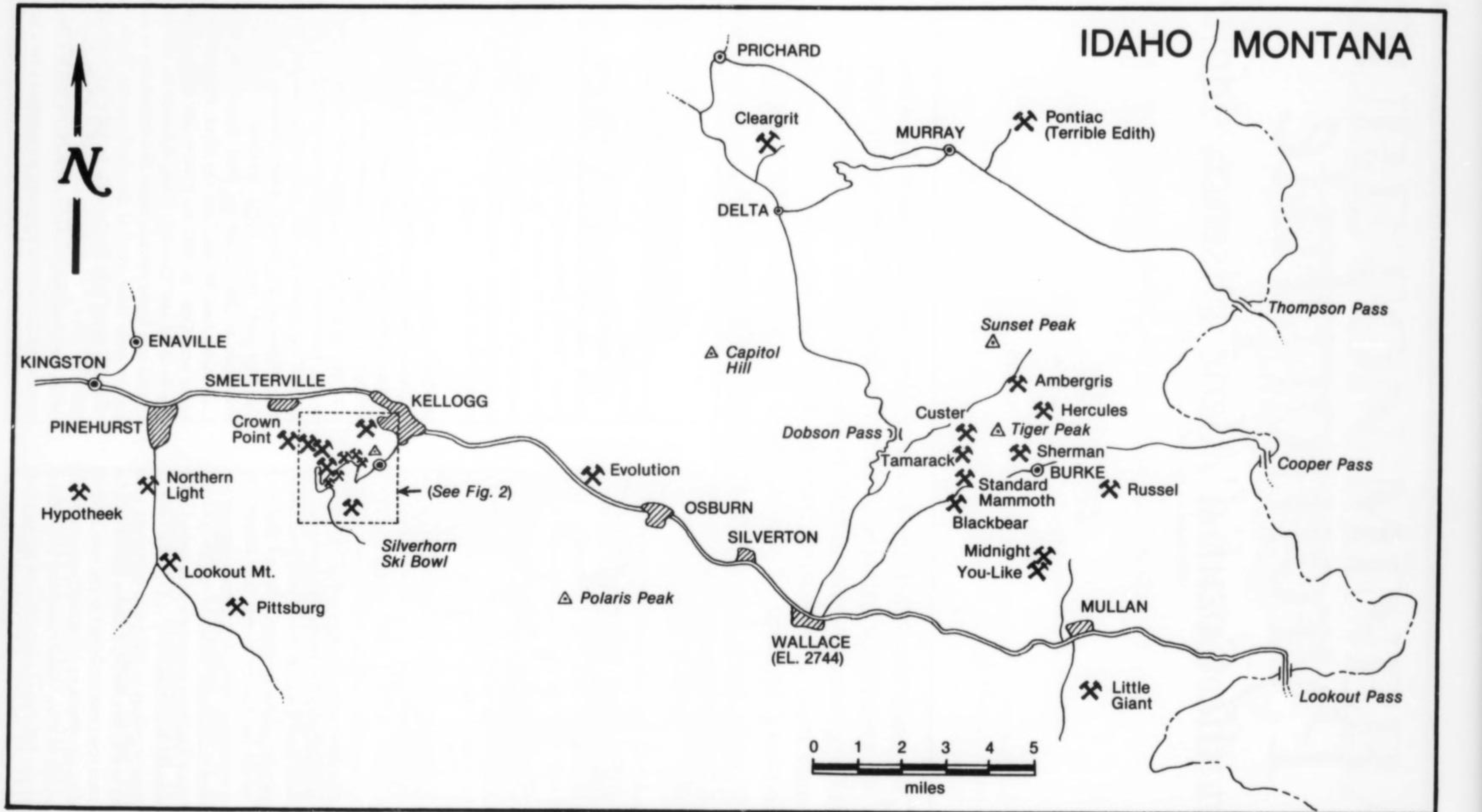


Figure 1. **Pyromorphite localities in the Coeur d'Alene district, Idaho.**

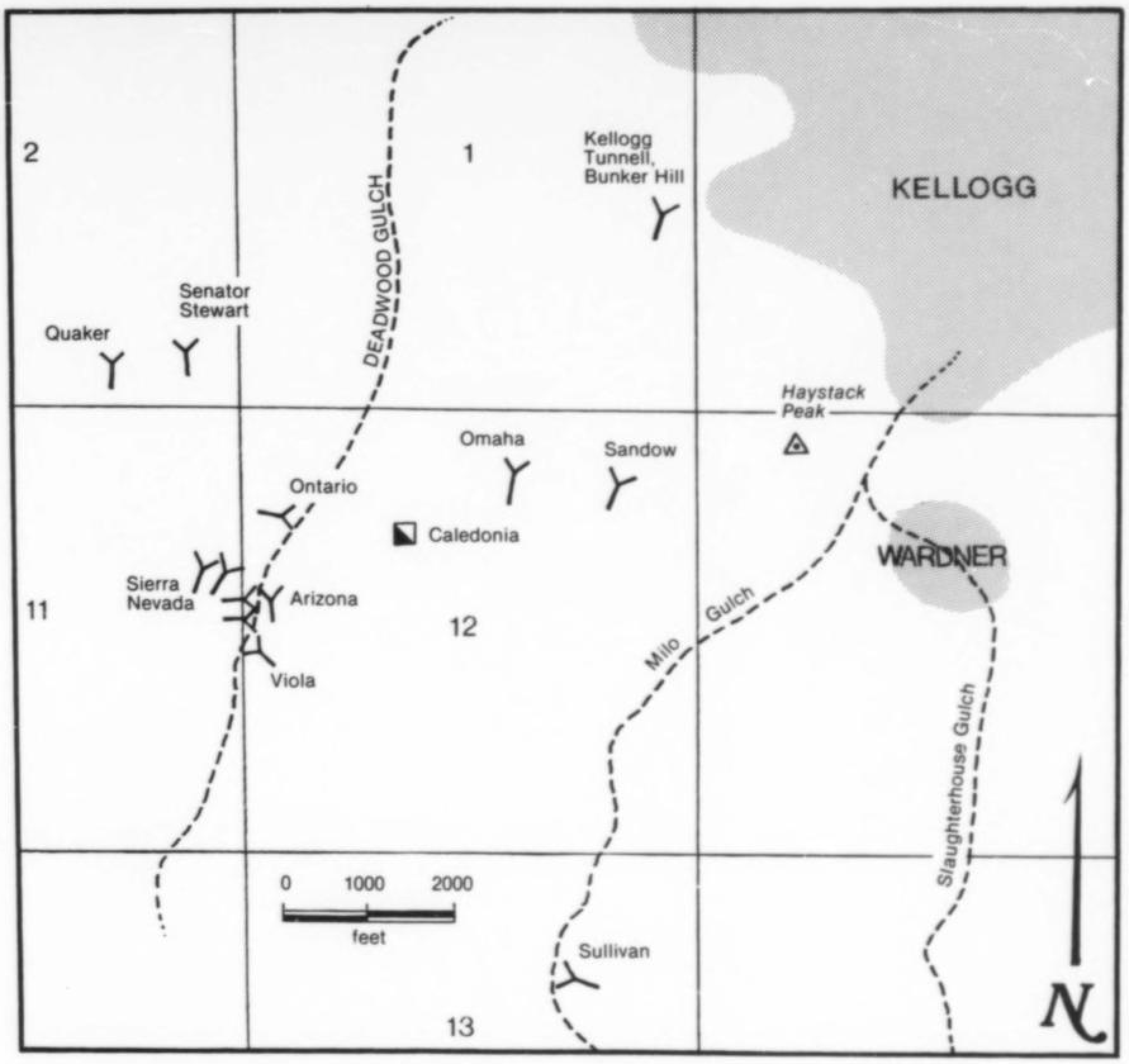


Figure 2. **Major mines in the Kellogg area.**

GEOLOGY

An excellent resumé of the geology of the Coeur d'Alene district is given in Fryklund (1964) and much of the following description is extracted from his report.

The regional country rock consists of the Prichard, Burke, Revett, St. Regis, Wallace and Striped Peak formations of the Precambrian Belt supergroup. These formations are fine-grained quartz-rich rocks that have been regionally metamorphosed to the greenschist facies and now consist of quartzose slate, sericitic phyllite, sericitic quartzite and, in a few areas, schistose quartzite and sericite schist.

Igneous rocks of the area include two monzonite stocks and related monzonite dikes which were probably intruded at the same time as the Idaho batholith, and biotite lamprophyre, diabase and porphyritic hornblende-augite-olivine dikes. The two stocks are part of a line of northeastward-trending intrusions that apparently lie along a major fault. This fault is a likely major control for ore emplacement in the Coeur d'Alene district. The main strike-slip faults—the Osburn, Thompson Pass and Placer Creek faults—have offset mineral belts. Strike-slip movement on the Osburn fault measures about 17 miles.

The major veins are clustered in two groups: one is centered around the towns of Burke and Mullan, north of the Osburn fault; the other lies south of the Osburn fault and centers around Kellogg, but extends eastward almost to Wallace. The productive veins, with two minor exceptions, lie in belts of slight disturbance or shearing, which have been designated as mineral belts. Reconstruction of the major anticline in the district, as it existed before movement on the Osburn, Placer Creek, and Dobson Pass faults, brings the two groups of mineral belts together.

The district ore deposits are primarily replacement veins with simple mineralogy. Six periods of mineralization ranging from Precambrian to Tertiary in age are recognized. The main veins formed in stages, though generally not all stages are represented in any one vein. The silicate stages are the oldest and probably formed at the highest temperatures. During a succeeding carbonate stage, siderite and then ankerite were deposited. In some mines a small amount of barite was deposited, probably after the carbonates; in a few veins barite is a moderately common mineral. Sulfide mineralization followed and some folding and faulting followed the deposition of minerals of particular stages. Sphalerite, tetrahedrite and galena, deposited in that order, are present in almost all the productive veins but in widely varying proportions.

Veins were formed as replacements with occasional open-space filling. Valuable sulfide minerals have directly replaced quartzose rock or pre-existing quartz or siderite bodies. Some ore sulfides have replaced silicates, carbonates and earlier sulfides.

PYROMORPHITE

Pyromorphite has been reported from 23 mines in the district, mostly during the early years of their operations. Sporadic finds have continued up to the present.

The color of pyromorphite from the Coeur d'Alene district is commonly a shade of green or yellow-green. It has also been observed in virtually every other color recorded for pyromorphite: white, gray, silvery gray, tan, brown, flesh-pink, yellow, yellow-orange, orange and red-orange.

Pyromorphite usually occurs as drusy crusts and coatings on oxidized carbonates or manganese oxide-coated fragments. Individual

Figure 3. **The Sullivan mine in 1898, a view of the upper workings looking east across Milo Gulch. Photo courtesy of the Bernard-Stockridge collection, University of Idaho Foundation.**

crystals typically show the prism and basal pinacoids, sometimes with small dipyramid faces also present. Crystals resembling quartz crystals in shape have been noted in the Caledonia workings of the Bunker Hill mine complex. This resemblance is enhanced by the unequal development of alternate "pyramid" faces. This type of distortion is sometimes seen in the recent finds at the Bunker Hill mine. Barrel-shaped crystals forming curved aggregates, sometimes as complete hemispheres, were commonly found. Material of this *campylite* habit was common in the 1980–1981 finds at the Bunker Hill mine. Aggregates in sub-parallel position that taper to a small point have frequently been found. Sometimes the aggregates are like Indian tepees, with individual crystals forming the poles, overlapping and coming to a common point terminated by a ragged pyramid.

Hexagonal crystals with hollow prisms occurred in some of the district mines, particularly the Russel, Sherman and Hercules mines. Some pyromorphite specimens show more than one period of formation. Large crystals may be coated with a younger generation of crystals radiating out from the older crystals like spines on a cactus. It is not uncommon for the younger crystals to have a different crystal habit and/or color from the earlier crystals. Color zoning is also common, with the tips of the crystals usually a lighter shade.

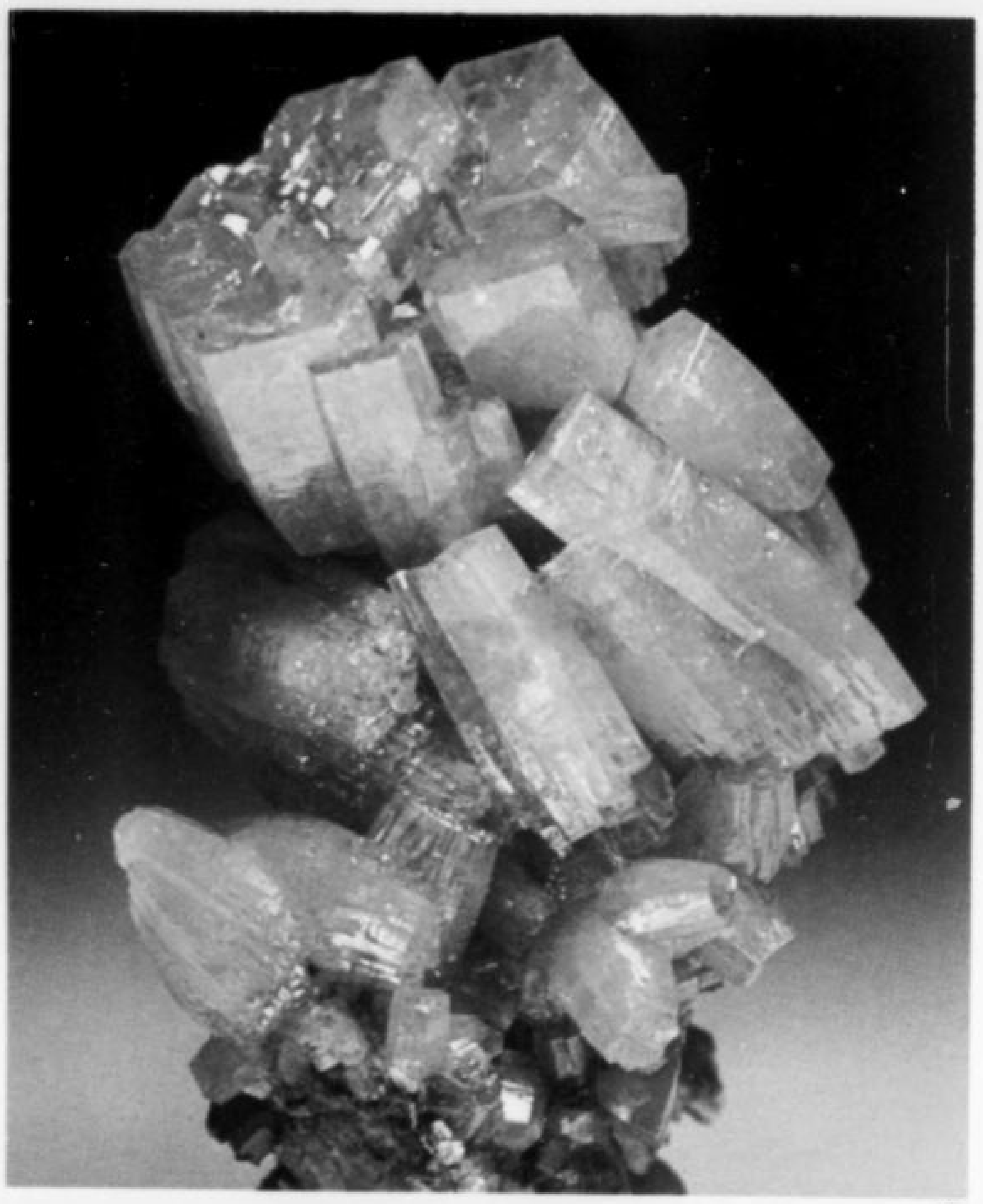
Chemically, pyromorphite and mimetite form a complete solid solution series. Pyromorphite is the phosphate end-member [$Pb_5(PO_4)_3Cl$] and mimetite is the arsenate end-member [$Pb_5(AsO_4)Cl$]. Dunn (1982, this issue) has analyzed recently-found specimens from the Bunker Hill mine, 9 level, and found all to be

Figure 4. **The Bunker Hill mine in 1904, a view of the upper workings (above the 5 level) looking west from Milo Gulch. Photo courtesy of the Bernard-Stockridge collection, University of Idaho Foundation.**

pyromorphite. The bright green crystals proved to be relatively pure end-member pyromorphite, and the yellow, orange and reddish orange crystals proved to be progressively more arsenian. The reddish orange, most arsenic-rich specimens are properly called arsenian pyromorphite. Independent analyses on 9-level specimens in the Bunker Hill Company laboratory confirm these results.

Dunn's (1982) high-quality analyses should clear up the controversy regarding the possibility of some 9-level Bunker Hill specimens being mimetite. It is certainly true that the color, crystal form, and even the *campylite* habit bear a striking similarity to mimetite specimens from other localities. But such physical features are definitely not diagnostic; the similarity is expected in view of the close chemical and crystallographic relationship between the two species.

Collectors and dealers have been using the varietal term *campylite* to describe groups of orange, highly curved, almost botryoidal crystals from the Bunker Hill mine. Even though all such specimens are probably pyromorphite, it is not actually incorrect to continue using the term *campylite;* it is a common misconception that this term applies only to mimetite. But Palache *et al.* (1951) state that: "Crystals of pyromorphite-mimetite distorted into barrel-shaped forms have been distinguished by the name campylite . . . the



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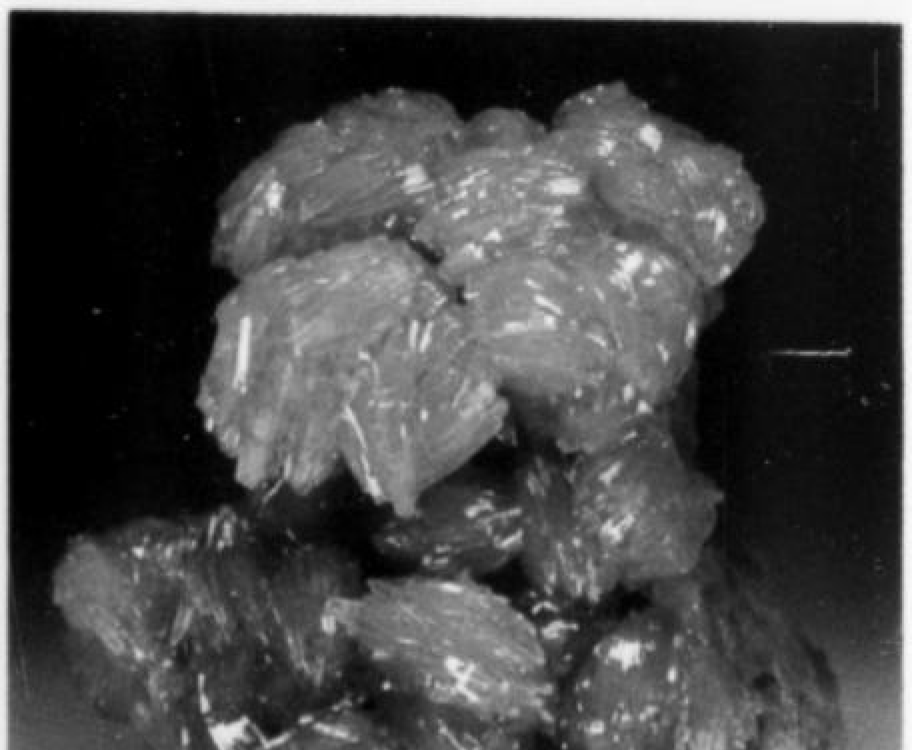

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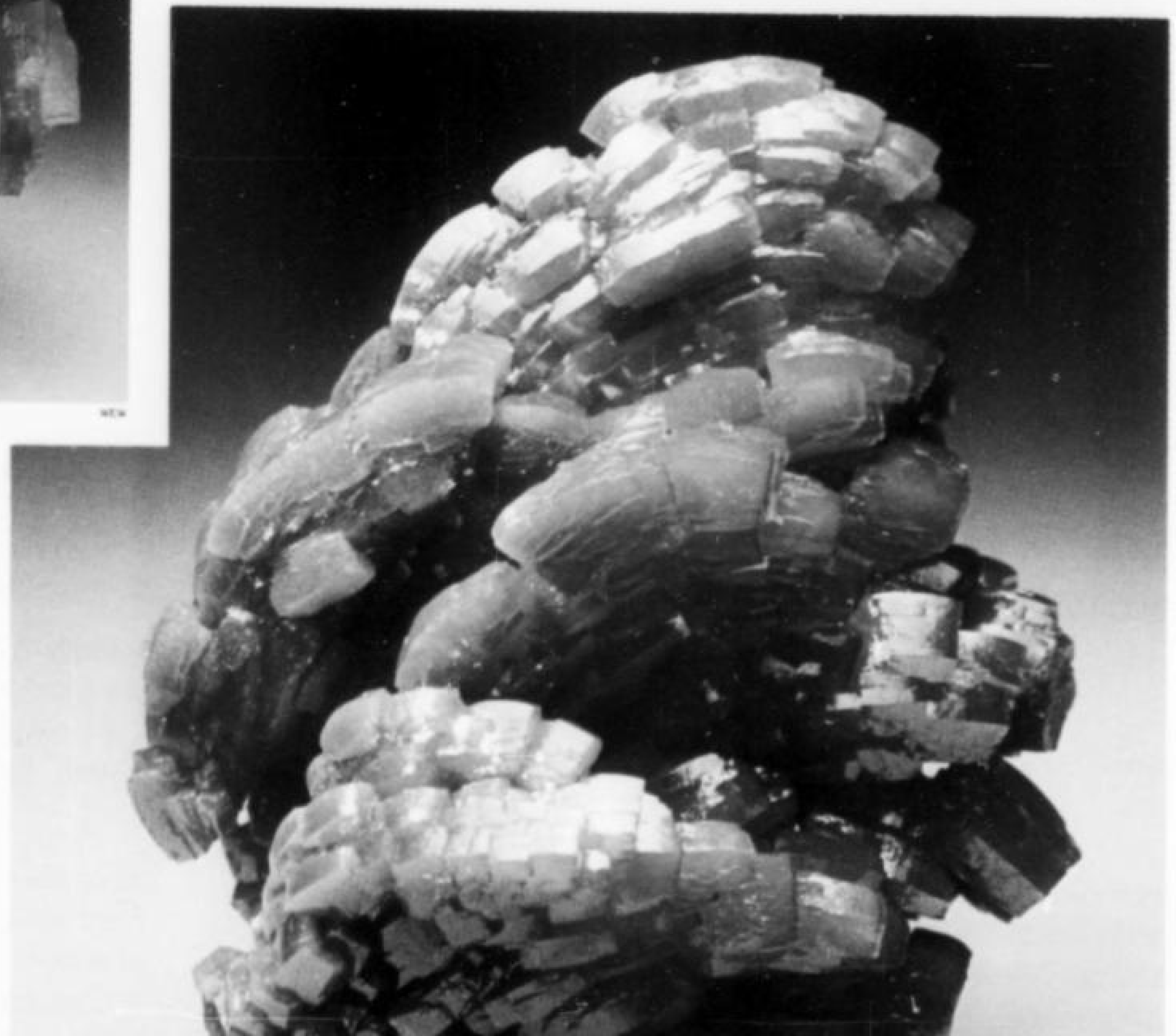

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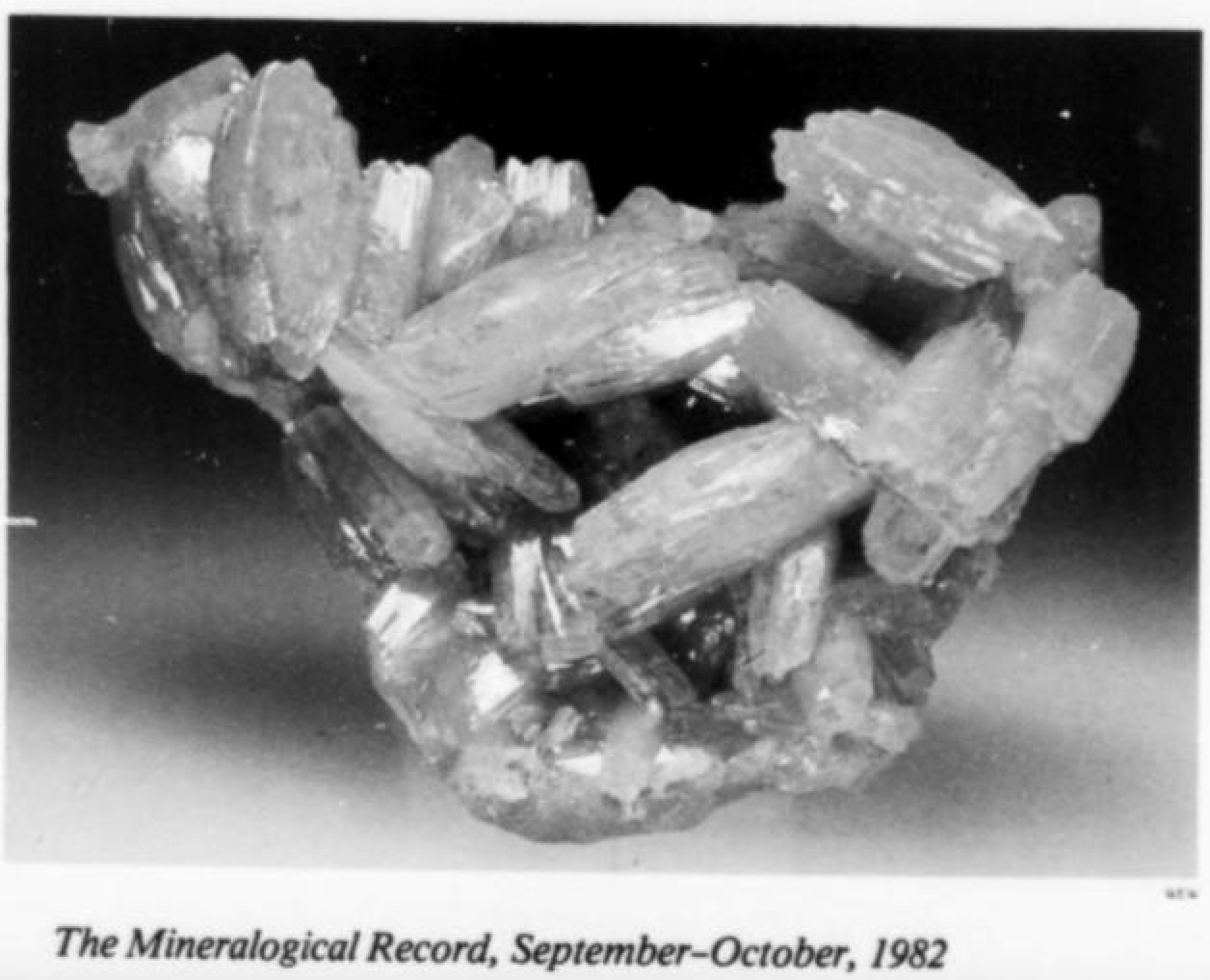

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curved habit is not restricted to material of any particular composition." Nevertheless, use of such antiquated and non-specific varietal names is discouraged by most mineralogists today.

A calcian variety of pyromorphite (10 weight percent Ca; once called *polysphaerite*) has been identified by one of us (NAR) in the Bunker Hill Company laboratory via quantitative spectrographic analysis. The specimens are creamy white to pale tan aggregates with a botryoidal habit, from the Bunker Hill mine.

Mullan Area Mines

In the eastern part of the district, several mines in the Mullan area produced attractive pyromorphite. In the Upper Morning unit area, the You-Like, Midnight and Morning #3 mines have all been noted as good sources. The Midnight mine as late as the mid-1960's produced respectable specimens of pale to light green crystals up to a maximum length of about 3/16 inch on a buff, bleached and weathered matrix. These are mostly simple hexagonal prisms with a vitreous luster and stout habit. The Snowstorm copper mine east of Mullan produced good pyromorphite from one area, but it was not found elsewhere in the workings (Shannon, 1926).

You-Like Mine

Pyromorphite from the You-Like mine is white or gray and occurred with dense, black, botryoidal plattnerite. It was found in hexagonal prismatic crystals up to 3/8 inch long with some stained brown or black by coatings and inclusions of plattnerite. The pyromorphite and plattnerite were found in the uppermost tunnel, 70 feet below the surface. The pyromorphite occurred on wallrock or on the plattnerite nodules (some of which weighed 15 pounds) and formed combined masses of up to 200 pounds. Some pyromorphite was also found scattered through the interior of the plattnerite nodules.

Little Giant Mine

The Little Giant mine, south of Mullan, has produced a large number of specimens. As recently as the mid-1970's good specimens could be procured by anyone daring enough to attempt the steep, narrow, jeep road to the mine. The Little Giant mine adit has an easterly trend into a prominent breccia zone with considerable oxidized siderite. Numerous prospects and mines have been sunk on this vein, but only the Little Giant has produced reasonably attractive pyromorphite specimens. This small mine has pyromorphite crystals and films along the entire adit length of about 300 feet. The crystals are variable in color with gray-green, simple hexagonal prisms up to about 3/16 inch long as the most common type. The crystals form crusts on hard metamorphic rock and coat limonite. Less commonly found were white to silvery gray crystals up to about 3/16 inch in length. These were once abundant in the roof area about half-way back in the adit. Bright yellow-green crystals forming stout hexagonal prisms of about the same size were found on the south side of the adit a little further back. Near the end of the adit on the north side is a zone of white barite which still produces small specimens with translucent, pale lemon-yellow to pale lime-green pyromorphite crystals to 1/8 inch long on the barite. Some jackstraw cerussite has also been recovered from this mine. The Little Giant has been nearly destroyed during the last few years by collectors (?) using explosives. By the summer of 1981 most specimens collected were essentially mediocre in quality or micromount in size.

Burke Area Mines

The region around Burke has produced a large volume of specimens from a number of mines. The Hercules, Sherman, Standard-Mammoth, Ambergris, Blackbear, Russel, Tamarack and Custer mines have all produced good to outstanding specimens. Most of the pyromorphite-bearing zones of these mines are now caved or otherwise inaccessible.

Hercules Mine

The Hercules mine was the source of many very fine specimens, commonly in large slabs and pieces. Some pyromorphite occurred as green crystals both on and in cerussite. This mine produced some of the largest individual crystals found in the district, some singles measuring 1¼ inches long. Some of these crystals are hollow. The last recorded discovery was in 1966, when a pocket of crystals was found. These crystals are mostly green singles from 5/16 to 11/16 inches long by 1/8 to ¼ inch in diameter, with good bright luster. One matrix specimen recovered at a different time measures 3 by 4 inches. It consists of crystallized cerussite with green pyromorphite crystals forming a band of contrasting color across the front. On the 2 or 3 level of the Hercules mine, one vug of pyromorphite that was broken into during mining was called the "grotto." Its floor and ceiling were covered with fine crystallized pyromorphite of a pleasing green color. This "grotto" was reportedly big enough to stand in with considerable room to spare.

Sherman Mine

The Sherman mine is southwest of the Hercules mine, and is located on the south side of Tiger Peak, one of the highest peaks in the district. The pyromorphite-bearing areas were entered via the Sherman 1500 level adit, now caved. The Sherman mine produced a large amount of pyromorphite, mostly from the 1500 level, 1700 level and 1730 raise. Much of this material was a shade of yellowish olive-green to light yellow-green and, rarely, a wax-like greenish yellow color. The crystals from some areas are color-zoned, with the tips of the crystals a much lighter shade of yellow-green. The simple hexagonal prismatic crystal form is dominant. Some groups have barrel-shaped crystals.

Wulfenite in bright, minute, red-orange crystals is a rare accessory mineral on the pyromorphite. Wulfenite crystals are usually

***Figures 5–14. (preceding pages)* Pyromorphite from the 090-23-25 stope, 9 level, Deadwood-Jersey vein of the Bunker Hill mine, all collected during 1981 (see also Fig. 17–19).**

***Figure 5.* Wayne Sorensen specimen; the large crystal is 9/16 inch across.**

***Figure 6.* Roberts Minerals specimen, 1⅞ inches tall.**

***Figure 7.* Harvey Gorden specimen, 1⅞ inches across.**

***Figure 8.* Roberts Minerals specimen, arsenian pyromorphite 1¾ inches tall.**

***Figure 9.* Wayne Sorensen specimen, 2¼ inches tall.**

***Figure 10.* Wayne Sorensen specimen, 2⅜ inches across.**

***Figure 11.* Roberts Minerals specimen, 1⅞ inches across (this is the reverse side of the specimen shown in Fig. 6).**

***Figure 12.* Roberts Minerals specimen, arsenian pyromorphite 1½ inches tall.**

***Figure 13.* Roberts Minerals specimen, 1⅞ inches across.**

***Figure 14.* Harvey Gordon specimen, arsenian pyromorphite 2 inches across.**

Figure 15. **Dark to pale green pyromorphite crystals, many cavernous, from the Sherman mine. The specimen is 2 inches across; J. Crowley photo and specimen.**

1/25 inch or less in size, and randomly scattered atop the pyromorphite clusters.

Many of the pockets encountered in the Sherman mine yielded nice "floater" groups of pyromorphite with no visible attachment points; crystal size is generally less than a half-inch long. These are usually miniature groups, with a few exceptionally nice matrix pieces reaching 6 inches in diameter. Specimens from the walls of the pockets were limited in size by the friable matrix and the skill of the collector in removing them. The matrix of specimens from the Sherman mine is typically red to blackish brown, hard to crumbly limonitic material, sometimes with quartzite or rock fragments. Cohesive groups over 12 inches or so are uncommon. One area near the 1700 level and 1730 raise, was described by one collector as having 50 feet of continuous, vuggy, pyromorphite-bearing ground. This entire area caved in 1973, shortly after a minor rock fall injured two lessee-collectors, requiring their evacuation to a hospital. The Sherman mine is now completely inaccessible.

Russel Tunnel (mine)

South of the Sherman mine on the other side of the canyon, on the north-facing slope between Sawmill Gulch and O'Neill Gulch, is the Russel tunnel or mine. Nothing has been published about this mine, and it is now caved. During the 1960's and early 1970's this mine was worked by a collector-miner for its pyromorphite and its lead-silver ore. The Russel mine produced a moderately large amount of pyromorphite from an unstable fault zone of rusty, oxidized and brecciated quartzite held together by mud, which tends to fall apart when wet.

Russel mine pyromorphite has the typical hexagonal prismatic crystal form with a bright olive-yellow-green color somewhat lighter in color than the material from the Sherman mine. Crystals also tend to be somewhat longer than those attributed to the Sherman, frequently reaching a half inch or more in length, and they are commonly hollow or with cup-shaped terminations.

Specimens from the Russel mine are frequently confused with those from the Sherman mine. The matrix, and the pyromorphite's color, are the best criteria for distinguishing specimens from the two locations. When two specimens are set side by side the difference is discernible but not obvious. No wulfenite has been found on the specimens from the Russel mine. Specimens from the Russel mine are considered to be some of the best from the district and are highly prized by local collectors.

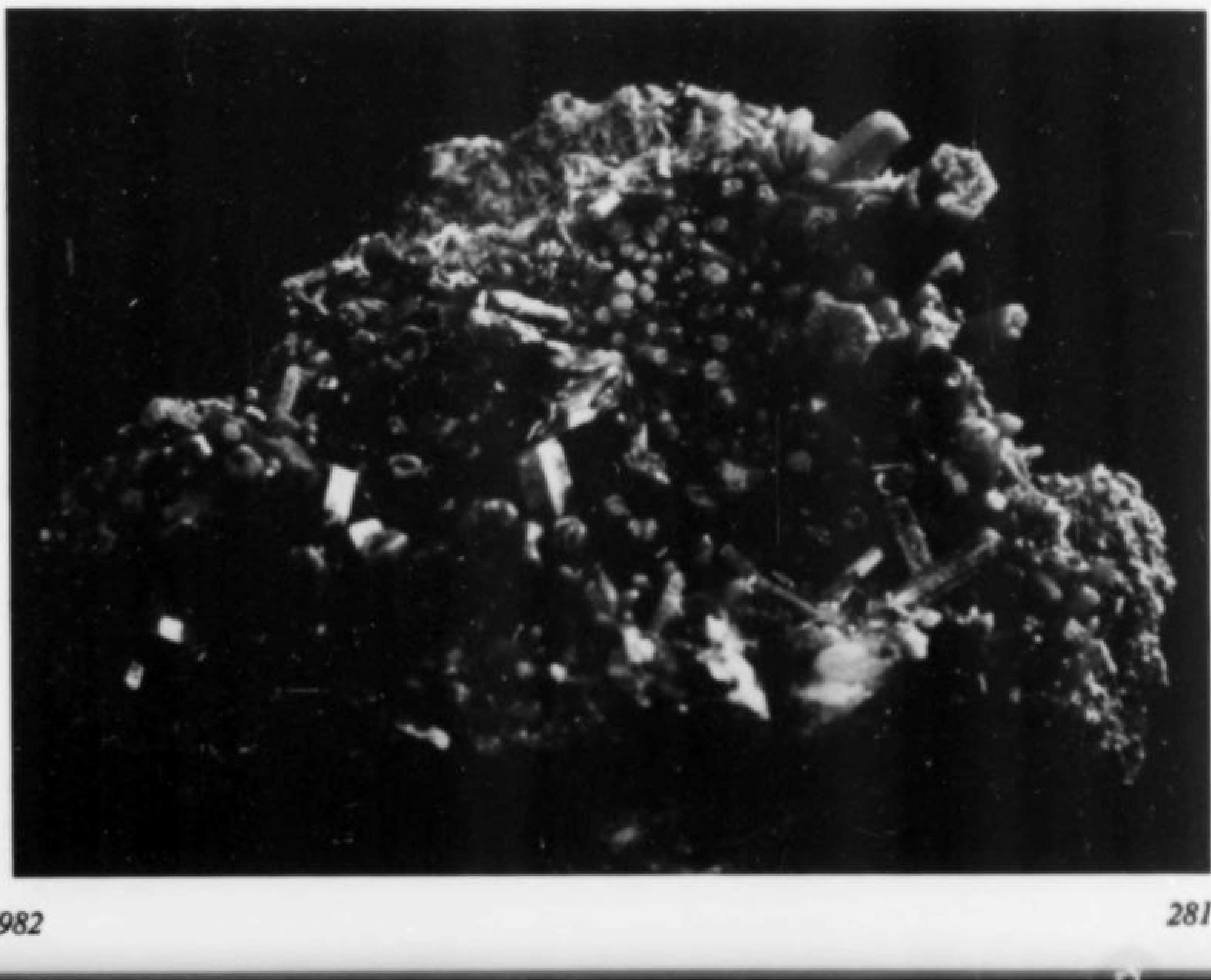
Standard-Mammoth Mine

A short distance west of the Sherman is the Standard-Mammoth mine. In the past it has produced considerable amounts of pyromorphite from the upper workings, principally the uppermost adit and the No. 2 adit (Shannon, 1926). Specimens from the dump, and the dump of the next highest adit, are like those found underground.

Blackbear Mine

The Blackbear mine, now inaccessible, produced much pyromorphite during the early 1900's. Specimens from the upper portion of the Blackbear were described as green, massive to drusy pyromorphite (Shannon, 1926). On the north and west sides of Tiger Peak, pyromorphite was reported to have occurred as quality specimens in several mines including the Custer, Tamarack and Ambergris mines. Specimens from these mines have not been seen for many years and their exact appearance is uncertain.

Figure 16. **Dark green pyromorphite from the Russel tunnel. The group is 3 inches across; J. Crowley specimen and photo.**



Murray Area

Pontiac Mine

One of the mines (actually outside of the main Coeur d'Alene district) that produced some fair pyromorphite is the Pontiac (Terrible Edith) mine near Murray, about 11 miles north-northeast of Wallace. The mine is northeast of Murray about 1.5 miles, near the head of Wasp Gulch. The mine has not been worked nor has it produced specimens for many years.

Some confusion as to the exact occurrence exists, since there are several old workings in the area. Pyromorphite from here is a light, almost frosty green and has a rather delicate appearance. The crystals occur as simple hexagonal prisms forming drusy coatings on a hard, rusty, weathered quartzite. Individual crystals are rarely over a quarter-inch long.

Osburn Area

Evolution Mine

The Evolution mine on the north side of the river between Big Creek and Osburn once produced pyromorphite of small size. The crystals are unusual for the district in that they are flattened, tabular, hexagonal, pale green to colorless crystals. This is the only recorded pyromorphite occurrence between the Burke-Mullan area and the Kellogg area where the Bunker Hill complex is located.

Pine Creek Area

Lookout Mountain and Hypotheek Mines

Two mines in the Pine Creek area southwest of the Bunker Hill complex have also recorded fine pyromorphite specimens: the Lookout Mountain mine and the Hypotheek mine. In 1925 the Lookout Mountain mine was opened on an outcrop above a later haulage drift. The original opening could not be located with certainty in 1980. Specimens from the vein reportedly showed stout prismatic crystals with good green color, up to about a half inch in diameter (Shannon, 1926). Shannon also reported that good specimens were found at the Hypotheek mine in French Gulch south of Kingston. The Hypotheek shaft is currently caved and inaccessible, with a good dirt road leading to the old workings.

Kellogg Area Mines

All of the mines and old workings in the Kellogg-Wardner area that have reported occurrences of pyromorphite are now under the ownership of the Bunker Hill Company. There were dozens of individual mines at the time most of the pyromorphite was being recovered, but it is now very rare to find one with a label bearing the name of an original claim. Most pyromorphite specimens from here are simply labeled "Bunker Hill mine" or, if fairly old, "Bunker Hill and Sullivan mine." The documented occurrences for pyromorphite in this area included the Caledonia, Sierra Nevada, Senator Stewart, Quaker, Bunker Hill, Ontario and Sandow mines.

Caledonia Mine

The occurrences in the Caledonia mine (and the Omaha mine, which merged with the Caledonia) are well documented by Shannon (1917, 1926). The Caledonia mine is not shown on any published maps and the shaft has been caved for many years. Its location is about midway between the Sandow adit and the Ontario adit (see Fig. 2). Large, beautifully crystallized pale-green masses of pyromorphite were found in considerable quantity in the Howard stope about the 300-foot level. These are on limonitic material rather than galena. Shannon (1926) makes special note of the fact that no *green* pyromorphite had ever been found on galena, only beige to brownish pyromorphite.

Lower in the Caledonia mine, on the 900-foot level, a peculiar pinkish pyromorphite occurred coating cracks in the galena and adjacent quartzite. The color ranges from faintly pink to colorless in the smallest crystals, to deep grayish violet on some of the larger ones. The crystals range in length from 1/16 to 3/8 inch, the largest being found in the quartzite wall rock. Those over 1/4 inch long are commonly nearly opaque, with curved prism faces and brush-like terminations. Luster of the smaller crystals is adamantine while the larger opaque crystals are resinous.

Pyromorphite was also noted on mine *timbers* of an abandoned drift on the 200-foot level of the Caledonia (Umpleby and Jones, 1923, p. 63). In the Omaha tunnel, long prismatic colorless crystals were found coating cracks in iron-stained and manganese-stained quartzite. In the Sandow tunnel, where it crossed the Caledonia claim line, a pocket of cup-shaped olive-green crystals was encountered in the roof of the adit. The Caledonia mine was also noted for its fine cerussite, silver and other oxide zone minerals.

Sierra Nevada Mine

The Sierra Nevada mine is a series of adits driven into the hillside on the west side of Deadwood Gulch, almost due west of the Arizona tunnel. The Sierra Nevada orebody was unusual in that the vein was very flat-lying and apparently occupied the nose of an anticline. The deposit was considerably oxidized and noted for very fine cerussite, silver and pyromorphite.

Pyromorphite in good specimens of small yellow-green stout prisms and larger barrel shaped, deep olive-green crystals coating quartzite was obtained in the Clark winze during the Peeples lease operation in 1914, and also in other areas of the flat-lying stopes. The Sierra Nevada mine workings are now caved.

Senator Stewart Mine

The Senator Stewart mine is located above and below the railroad grade, a short distance east of the Quaker adit. When the No. 3 adit located below the railroad grade was being driven to intersect the orebody a small pyromorphite vein was encountered not far from the portal. The pyromorphite was in greenish-yellow masses

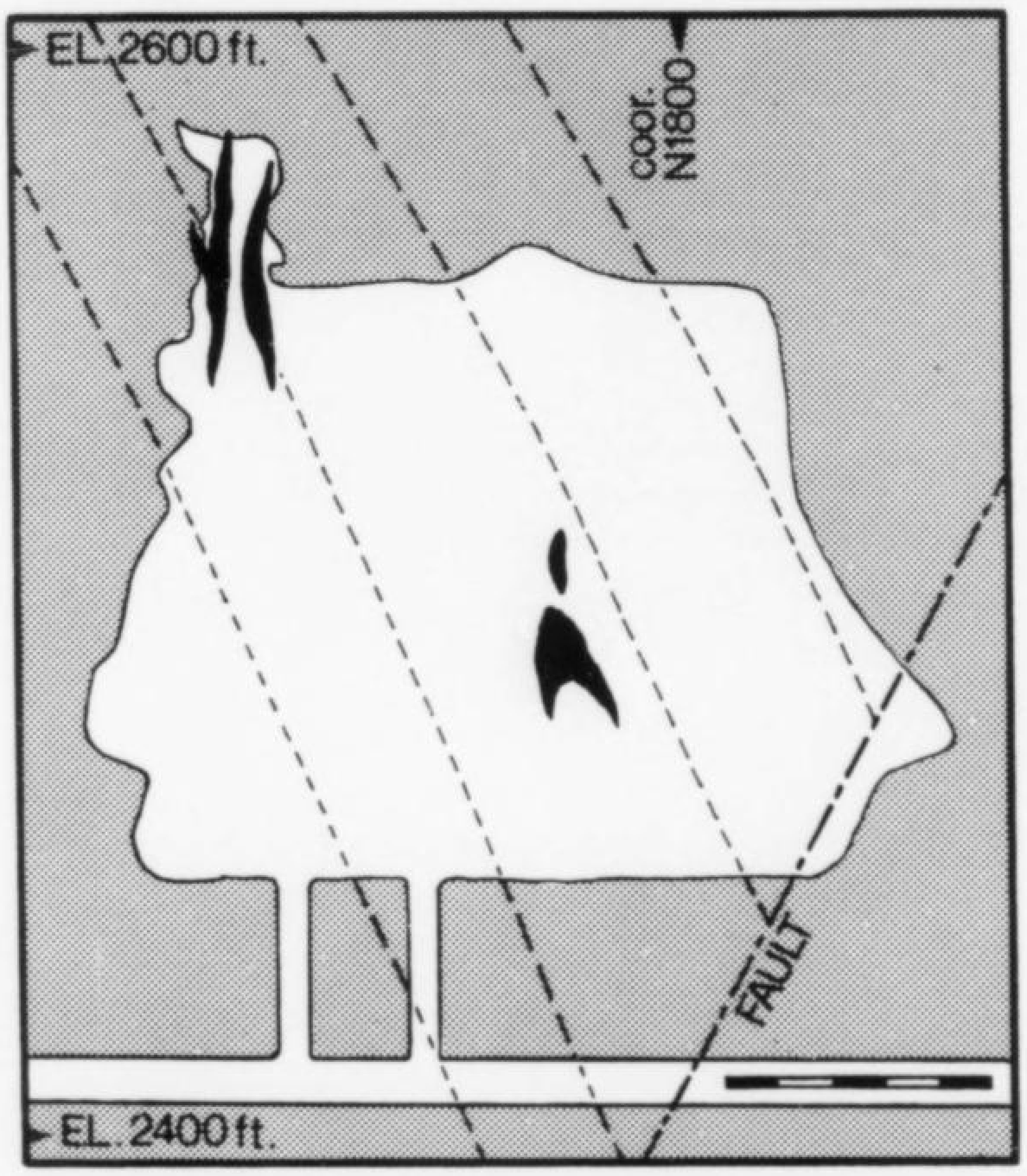


Figure 17. **Pyromorphite pocket locations (shown in black) in stope 090-23-25, 9 level, Deadwood-Jersey vein of the Bunker Hill mine. The four dashed lines show the orientation of quartzite beds in which the pockets are located. This is a vertical longitudinal section looking north, mapped in January, 1982, by N. Radford. Scale bar is 50 feet.**

Figure 18. **A remarkable sight: a view of part of a recently found pocket of superb green pyromorphite in the Bunker Hill mine before the specimens were removed. The largest crystals are about 1 inch in size; the view shows an area measuring about 1½ feet square.**

and small drusy crystals. A short raise was driven on this vein, which subsequently encountered a large area of interlocking, crystalline, vuggy pyromorphite. A small stope was opened into this pyromorphite zone and *30 tons* of pyromorphite were eventually shipped as ore. More was encountered along the adit as seams in the walls. A specimen of cerussite from the Senator Stewart is coated on one side with a thin crust of green pyromorphite crystals.

Quaker Adit

In the Quaker adit above the railroad grade and west of the upper workings of the Senator Stewart mine, and on the same slope, green pyromorphite was found abundantly as crusts of smooth, small, botryoidal coatings and as drusy coatings of crystals.

Bunker Hill Mine

The Bunker Hill mine has long been known for fine pyromorphite. A major discovery made there recently may give some idea of what the "Old Days" were like: in mid-December of 1980, in the Bunker Hill mine, 9 level, Deadwood-Jersey vein area a stope (090-23-25 stope) was being mined that penetrated the first of a

Figure 19. **Another area in the same pyromorphite pocket as shown in Figure 18; crystals near the center measure about 1 inch each. The crystals are a rich, deep green grown on an underlying layer of botryoidal, reddish orange arsenian pyromorphite.**

series of vugs of pyromorphite. These specimens represent the best recovered from the Bunker Hill mine since the 1920's. As find after find occurred, each better than the last, it became apparent that this zone was producing specimens to rival those from the Wheatley mine in Pennsylvania, and easily the best found in the United States in over 50 years.

The first pockets encountered in December were in the Deadwood-Jersey galena vein in quartzite. A series of pockets to 10 by 16 inches were opened in the brecciated quartzite along the vein footwall. Arsenian pyromorphite in botryoidal masses and plates, in yellow, yellow-orange and deep orange shades, was collected on a matrix of brecciated quartzite. Crystalline groups and drusy coatings on matrix were also recovered, as well as some gray to cream, botryoidal calcian pyromorphite. Some pyromorphite crystals are olive-yellow to bright yellow. Individual crystals average a quarter-inch in length, but some specimens are covered with crystals to a half-inch; these are generally long hexagonal prisms commonly terminated by a partial to complete pyramid.

By mid-January of 1981 larger vugs were being found, and the esthetic quality had improved from very nice to exceptional, the color ranging from yellow to a yellowish lime-green. These crystals occur as stout hexagonal prisms terminated by the pinacoid, as barrel-shaped crystals and as more prismatic crystals terminated by a pyramid. Plates to 6 by 10 inches coated with bright, yellowish lime-green crystals and aggregates to an inch long were recovered and many superb smaller pieces with fine half-inch and smaller crystals were also collected. As stoping continued upward, the lime-green crystalline pockets diminished, and the yellow to orange arsenian pyromorphite in the more botryoidal habit was recovered, occasionally with yellow-green crystals implanted on the botryoidal material.

By the end of January, 1981, the pyromorphite zone was seen to be pinching out, and by April it was down to films and crystalline coatings on bedding and fracture planes. It was thought that this might be the end of the pyromorphite finds. During this pyromorphite-deficient period the best cerussite pockets encountered in many years were being uncovered in the nearby 090-23-21 stope. Attractive, bladed crystals to 2 inches long in groups up to a foot across were keeping the miner-collectors occupied. While mining and spare-time collecting for cerussite in the 090-23-21 stope continued, a small series of pyromorphite pockets about 3 feet long by 6 to 8 inches wide and 2 or 3 feet along strike was opened up in this same stope. This find yielded a small number of very fine, light lime-green pyromorphites heavily coating a very friable quartzite and quartzite breccia. One of the largest and the best of these is approximately 3 by 5 inches in size and coated with stout hexagonal crystals up to 5/16 inches long. Many of the specimens that were saved were grabbed by quick miners as the pieces tumbled past them down the ore chute.

On the 1st of June, 1981, the galena vein in the 090-23-25 stope opened up into a rather nice pyromorphite vug. A blast had blown the vug to smithereens, scattering thumbnail and smaller pyromorphite fragments all over the stope. Two days later another small series of vugs was opened. These contained mostly bright yellow-green to lime-green hexagonal prisms on matrix. Individual crystals are somewhat less than a half-inch in length. Again, as mining progressed, the pyromorphite zone dwindled to a thin seam while, simultaneously, more and better cerussite appeared in the adjacent 090-23-21 stope.

Raising continued in the 090-23-25 stope. In early October, 1981, a pyromorphite-lined vug large enough to crawl into was opened up. It yielded the best botryoidal arsenian pyromorphite yet found. Initially brownish in color it rapidly changed color upwards to multi-color yellows and oranges with individual grape-like botryoids frequently an inch across forming exquisite masses to 24 inches by 18 inches . . . bigger ones were too heavy to carry out. Many hundreds of specimens were recovered. Two and a half weeks later the vuggy zone was reopened and another open pocket was discovered. It also was completely lined with yellow, orange, and reddish-orange *campylite* pyromorphite as good or perhaps better than the previous vug. Again, hundreds of specimens were recovered. Pieces 8 by 9 inches were not uncommon, completely covered with up to 1-inch botryoids.

A week later the upper end of this vug was penetrated and a truly astounding series of pockets opened up. These pockets were lined in part with vitreous, bright, yellow-green, orangish yellow-green to yellowish olive crystals. Individual crystals to nearly an inch long are common. Composite crystals made up of side-by-side pyromorphite forming crude hexagonal prisms are up to 2 inches long and an inch in diameter. Several plates up to 14 inches in diameter were found, as well as a multitude of smaller specimens. This series of pockets continued upward, and during the week of November 30 to December 4, 1981, they were again encountered during mining. Crystals this time were slightly smaller and of a slightly darker yellowish lime-green.

Shortly after this find of magnificent crystals, locked steel doors were installed to prevent miners from collecting specimens. The Bunker Hill Company with remarkable foresight began salvaging and collecting these fine specimens. For a period of about a month the company mined and collected pyromorphite from this series of pockets until it became too difficult, without considerable extra expense, to continue to raise even higher in the stope. The specimens mined during this period were dispensed in one large lot to the highest bidder (Roberts Minerals). The Bunker Hill Company and its parent company, Gulf Resources Inc., should be congratulated for their conservation efforts which allowed these fine specimens to be saved and made available to collectors and museums everywhere, instead of sending them to the crusher as so many unenlightened companies have done.

The largest and best specimen mined by the company is a plate some 12 by 12 inches weighing about 50 pounds, of slightly yellowish, lime-green, curved crystals to an inch long. This specimen is to be displayed in the main offices of Gulf Resource and Chemical Corporation in Houston, Texas.

In some cases in this last series of vugs, the pyromorphite crystals were implanted on the orange *campylite* habit pyromorphite which was the dominant type in these pockets. The green crystalline material averaged about 10 percent of the total number of specimens recovered.

Almost completely eclipsed by the Jersey vein finds is a small series of pockets uncovered on the 14 level in the Brown orebody, 140-18-22 stope. This pyromorphite represents the lowest level that oxide zone minerals have been found in the Bunker Hill mine. The crystals are bright, transparent-colorless to silvery or pinkish brown on a vuggy matrix of corroded, very fine-grained massive pyrite, sphalerite and galena. Some are implanted on leached white quartz. These are long hexagonal prisms usually terminated by the pyramid or a partial pyramid truncated by the flat pinacoid. Some specimens have hollow crystals and others demonstrate a second generation of growth by having a coating of smaller crystals sticking out all over the original crystals like short spines on a cactus. Choice esthetic groups with crystals to an inch long have been collected. They are virtually indistinguishable from pyromorphite of similar color from the Ems region in Germany. The number of specimens collected is not great.

CONCLUSIONS

The chances for significant new pyromorphite discoveries in the district are slim unless new near-surface orebodies are discovered and mined.

The recent discoveries of pyromorphite at the Bunker Hill mine, are among the best found anywhere in the world, and probably surpass any ever found in the United States. They give a tantalizing glimpse of what the specimen quality and quantity was like in the district during the heyday of oxide zone mining 75 years ago.

With the closure of the Bunker Hill mine in early 1982 the likelihood of more specimens being produced seems bleak. There is no way of predicting how much pyromorphite remains in the Bunker Hill mine, but it is enjoyable to contemplate that the major finds were made on the 900 level, and it's a long way to the surface!

COLLECTING

Collecting in the district is a challenge. Thick plant growth coupled with heavy rains have caused many old workings to virtually disappear. Most of the old mines have collapsed or are flooded; all are very dangerous. Roads to old mines and prospects, unless maintained, are overgrown and difficult to locate. Many of the small mines and prospects are not located on any maps nor in any existing records. The collecting of specimens is essentially limited to digging through old dumps and investigating old prospects when they can be found. Most of the mines on maintained roads are under claim and posted against trespass.

ACKNOWLEDGMENTS

The authors wish to thank Sid Jones and Art Cooper for allowing us to view and photograph their specimens, and for giving descriptions of various pyromorphite locations. Thanks also to Harvey Gordon, Wayne Sorenson, and Ken and Betty Roberts for allowing their specimens to be photographed. We are particularly grateful to the late William B. Sanborn for his guiding influence.

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On the Chemical Composition of Bunker Hill Pyromorphite

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INTRODUCTION

Through the courtesy of Harvey Gordon, the Smithsonian Institution acquired some specimens from the recent find of pyromorphite in the Bunker Hill mine, Kellogg, Idaho. These specimens were all collected in the 090-23-25 stope, 9 level, of the Deadwood-Jersey vein. Because arsenic was reported in some other samples from this new discovery, it was decided to chemically analyze several samples, representing a range of colors and habits, so as to permit precise characterization of the specimens from this exciting new mineral find (see accompanying article by Crowley and Radford, this issue).

CHEMICAL COMPOSITION

The pyromorphite samples from the Bunker Hill mine were chemically analyzed using an ARL-SEMQ electron microprobe utilizing an operating voltage of 15 kV and a sample current, standardized on brass, of 0.025 μA. The standards used were: PbO (Pb), fluorapatite (P and Ca), synthetic olivenite (As), chlorapatite (Cl), barite (Ba), celestine (Sr and S). The data were corrected using a modified version of the *MAGIC*-4 program of the Geophysical Laboratory. The analyses are presented in Table 1. Barium, strontium and sulfur, which might substitute in pyromorphite-mimetite, were sought but not found. The samples were not analyzed for fluorine, but the obtained chlorine content is in good agreement with the theoretical value, suggesting that fluorine, if present at all, must be very minor. Vanadium was not analyzed for either; however, the close agreement of the analyses with theoretical pyromorphite composition indicates that vanadium substitution, even in the reddish crystals, is absent or extremely minor.

Examination of the data indicates that all of the studied Bunker Hill mine samples, which vary considerably in color (from green to dark red-orange), are pyromorphite. Arsenic substitution is limited to approximately 6 weight percent, which indicates that the analyzed crystals vary from essentially pure pyromorphite (analysis 1) to material containing approximately 25 percent of the mimetite end-member (analysis 5). Analysis 1 is of bright yellow-green euhedral crystals; 2 is of light yellow-brown, grainy-lustered, subhedral crystals; and analyses 3, 4 and 5 are of botryoidal orange to reddish-orange masses with very high luster.

The analyses indicate a direct correlation between specimen color and arsenic content. The bright yellowish green crystals of analysis 1, which are visually identical to those figured earlier in the *Mineralogical Record* (Wilson, 1982), are essentially end-member pyromorphite, having no detectable arsenic and only a trace of calcium. With increasing arsenic content (analyses 3, 4, 5) the samples have brown to orange coloration, the bright reddish orange having the highest arsenic content and properly named an arsenian pyromorphite. Analyses 2 and 4 were performed on the same specimen; analysis 2 is of light brown material which is overlain by reddish orange material of analysis 4. The calcium content of all studied specimens is negligible. Thus, none of these are the variety *polysphaerite*. They are all pyromorphite; the green is essentially pure material, and the reddish orange is arsenian. Calculation of a chemical formula for the most arsenic-rich specimen (analysis 5), on the basis of $\Sigma(As + P) = 3$ atoms, with (OH) added for charge balance, yields:

$(Pb_{5.01}Ca_{0.09})_{\Sigma 5.10}[(PO_4)_{2.30}(AsO_4)_{0.70}]_{\Sigma 3.00}(Cl_{1.05}(OH)_{0.15})$.

NOTE

Because chemical analyses of pyromorphite-mimetite are exceptionally time-consuming, the author does not wish at this time to examine additional pyromorphite-mimetite samples from Idaho.

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Table 1. **Microprobe analyses of Bunker Hill pyromorphite.**

NMNH #	CaO	PbO	As_2O_5	P_2O_5	Cl	less O=Cl	Total	Color	#
Theory*		82.28		15.69	2.61	0.58	100.00		
–	0.1	82.6	0.0	15.5	2.7	0.6	100.3	Green	1.
149435	0.3	82.5	0.0	15.5	2.7	0.6	100.4	Yellow-brown	2.
149309	0.4	81.2	3.3	12.5	2.7	0.6	99.5	Orange	3.
149435	0.4	80.8	4.7	12.9	2.7	0.6	100.9	Reddish orange	4.
–	0.4	80.9	5.8	11.8	2.7	0.6	101.0	Reddish orange	5.

Accuracy of data: ±4 percent of the amount present.
*Theoretical composition for pyromorphite, $Pb_5(PO_4)_3Cl$.

Ferroaxinite

from New Melones Lake, Calaveras County, California, a remarkable new locality

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In the fall of 1981, very fine ferroaxinite specimens were collected from a new locality in the Sierra Nevada foothills. This occurrence is in the spillway adjacent to New Melones Lake near Copperopolis in Calaveras County. Since its discovery, this locality has produced some of the finest ferroaxinite specimens ever found in North America.

INTRODUCTION

This paper summarizes data from our initial examination of this interesting locality and its mineral assemblages.

Ferroaxinite is one of several members of the axinite group of minerals with the general formula (Lumpkin and Ribbe, 1979):

$$[(Mn,Fe^{+2},Mg)(Ca,Mn)_2(Al,Fe^{+3})_2]_2(OH)_2(B_2Si_8O_{30})$$

These minerals are found as accessory phases in skarns, pegmatites and certain metamorphic rocks, where their presence records unusually high boron concentrations. Axinite has been reported from a number of other localities in California – perhaps the best known being from near Coarse Gold in Madera County (Murdoch and Webb, 1966). At the New Melones Lake spillway area, ferroaxinite was first noticed in the early 1970's by engineers during dam construction, when it was observed during overburden removal. There are no known published reports of ferroaxinite or other minerals from this particular area by other investigators. The locality has remained dormant since the completion of the dam. Access to the site is restricted because the area comprises part of the New Melones Dam installations which are under the jurisdiction of the U.S. Bureau of Reclamation.

GEOLOGICAL SETTING

REGIONAL GEOLOGY

The spillway (Figs. 1, 2) of New Melones Lake has been excavated in rocks of the western Sierra Nevada metamorphic belt (Clark, 1964). This belt forms part of the western limb of a northwest-trending faulted synclinorium (a broad regional syncline on which are superimposed minor folds), the axial part of which is occupied by the granitic rocks of the Sierra Nevada batholith. Rocks in this belt consist of alternating metamorphosed volcanic and sedimentary units which are considered to be part of an early Mesozoic island-arc system and the underlying oceanic crust (Bateman and Clark, 1974; Schweikert and Cowan, 1975; Schweikert, 1978). In the New Melones Lake area the rocks have been divided into three major units by Schweikert (1978): a basement of melange and serpentinite matrix melanges, an overlying island-arc volcanic unit (Penon Blanco Volcanics of Clarke, 1964), and finally an upper unit of slate and graywacke designated as the Mariposa formation. According to Morgan and Stern (1977), the melange and lower parts of the volcanic succession have been faulted into the overlying Upper Jurassic Mariposa formation sediments.

LOCAL GEOLOGY

Although the regional geologic fabric trends northwest, the rocks exposed in the spillway (Fig. 1) show contacts oriented from west to west-northwest. The main lithologic units are massive grey-green gabbros with abundant diabase dikes, fine-grained and in some places vesicular basalts, and volcanics including both tuff and pillow lavas, all of which have been altered to greenstones. These are considered to be part of the Penon Blanco volcanics (Clark, 1964). Meta-argillites, melange rocks and serpentinites comprise a minor part of the stratigraphic section. All of these rocks have undergone greenschist facies metamorphism and locally show pervasive alteration to fine-grained albite-epidote-quartz assemblages.

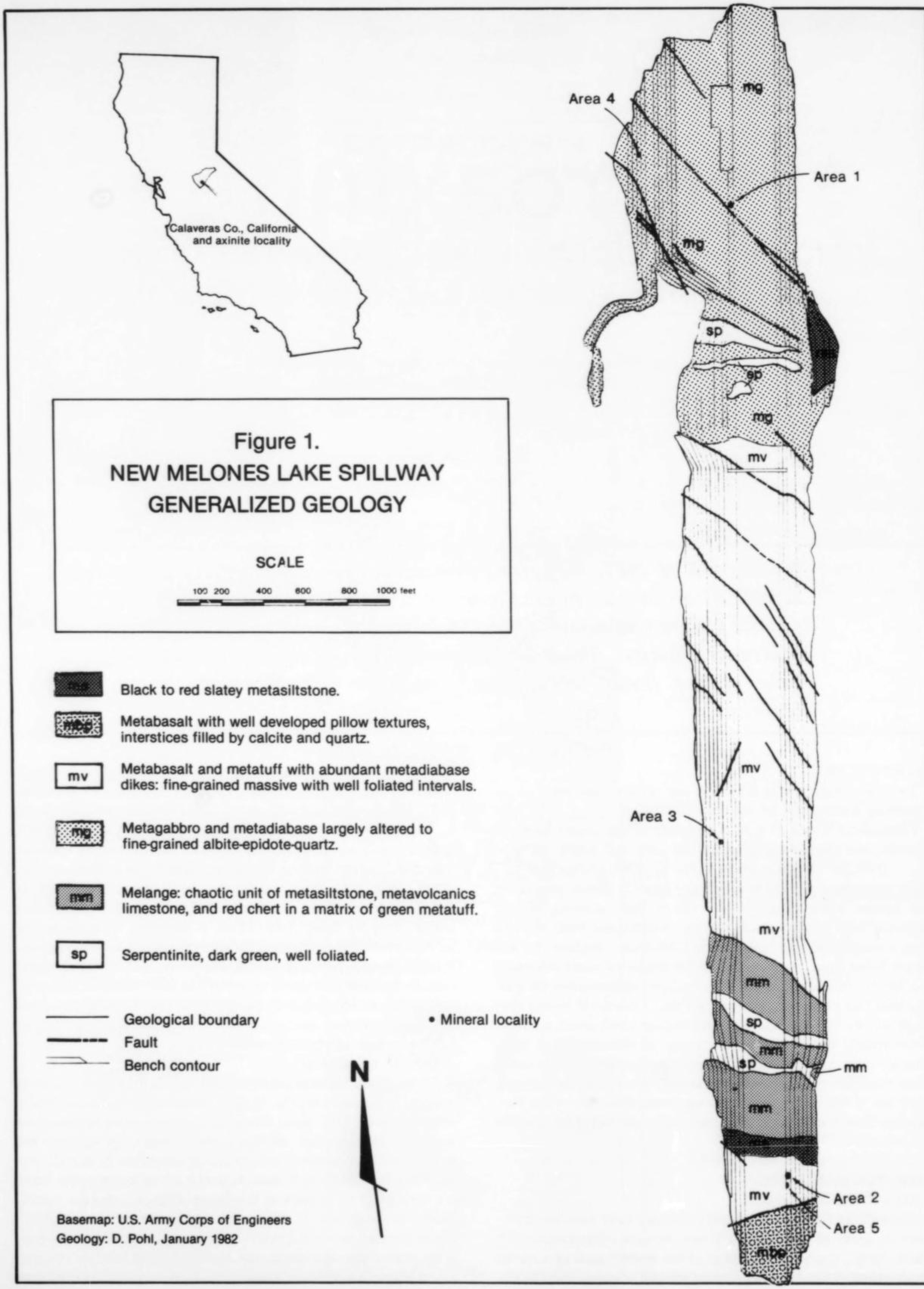


Figure 1.
NEW MELONES LAKE SPILLWAY
GENERALIZED GEOLOGY

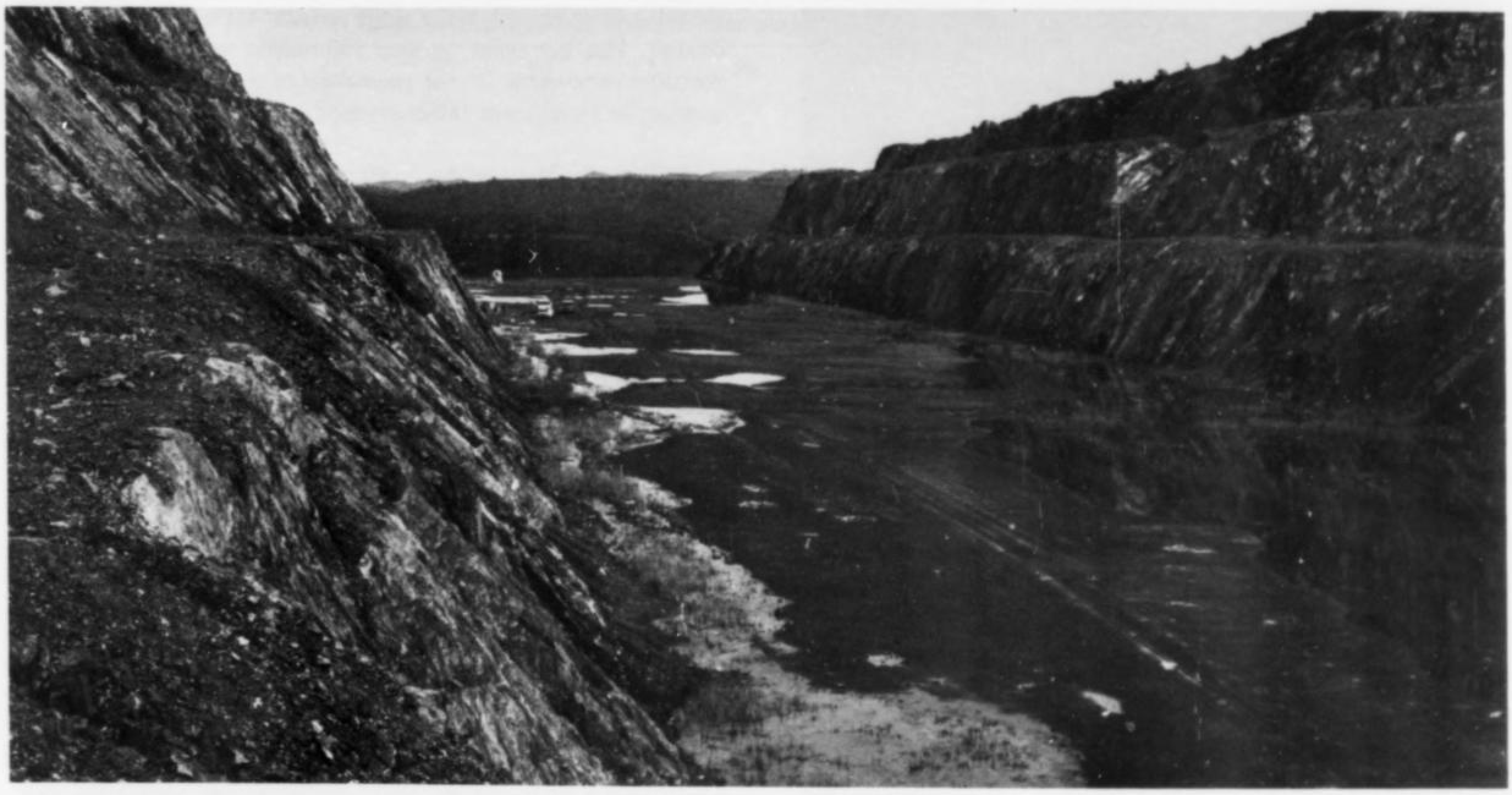


Figure 2. **Spillway of New Melones Lake looking north from area 3. Benches are approximately 40 feet high.**

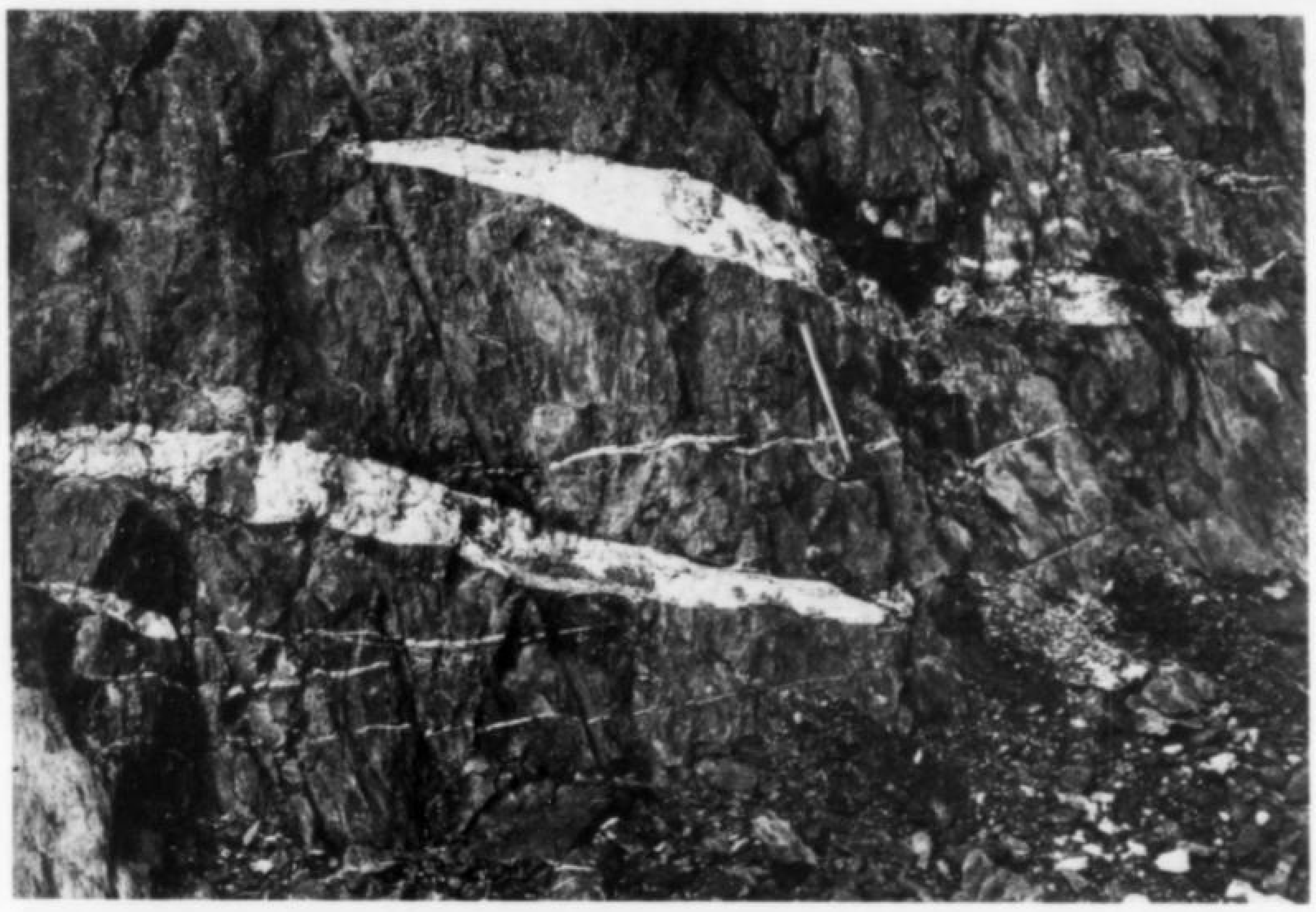


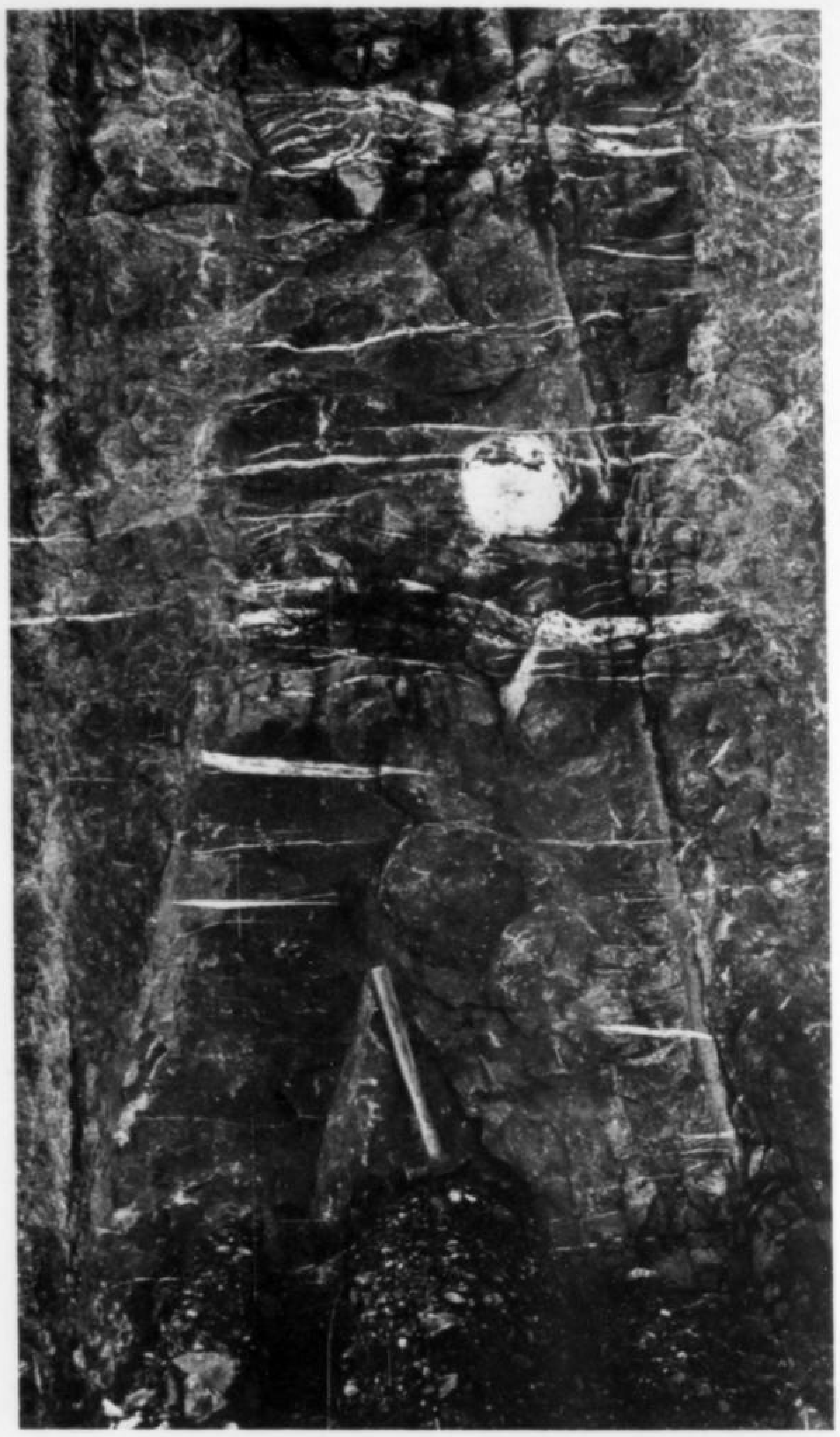
Figure 3. **Numerous, *en echelon* (both left and right lateral), tension gash veins with cores of purple brown ferroaxinite from area 3. One vein with excavated hole yielded euhedral ferroaxinite crystals associated with attractive quartz, albite and actinolite crystals.**

In spite of the extensive alteration, deformation and faulting of the rocks, many original igneous and sedimentary features have been preserved. A shear foliation or schistosity is developed in the rocks only locally in the vicinity of major faults.

Rocks in the spillway are cut by many northwest-trending faults and shear zones which dip either steeply to the northeast or more gently to the southwest. Extension fractures or tension gashes are abundant in the metagabbro and metabasalt units in the spillway walls (Fig. 3), but are absent in the less competent metasediments and serpentinite. These gash veins generally occur as subhorizontal, *en echelon,* left-lateral groups dipping gently to the west. Some of these veins form ladder-like sets (Fig. 4); these are confined to basic dikes which intrude the metagabbro and metavolcanics. The length of the gash veins varies from 10 centimeters to 10 meters with a thickness of 2–30 cm. In plan view they are lens shaped. In some cases individual veins are stacked so closely as to coalesce, as in areas 1 and 2 (Fig. 1), with resultant thicknesses up to 1 m. Most veins are undeformed and not offset by later events, and consequently record one of the last tectonic episodes in the area. It is in these gash veins that the ferroaxinite and other minerals of interest occur in the spillway (Fig. 5). Ferroaxinite is confined to veins, in contrast to the other minerals which also occur disseminated in the wall-rock.

In general, most of the veins are completely filled with massive ferroaxinite and only rarely will an open cavity be encountered. To date only five major veins which contain central cavities with free-growing ferroaxinite and associated minerals have been found. These locations, numbered as areas 1 to 5, are shown on Figure 1. Mineralogical data presented in this paper were collected from an examination of specimens collected at these localities.

In summary, the rocks found in the New Melones Lake area consist of a structurally complex assortment of ancient oceanic crust, melanges and sheets of ultramafic rocks that evidently were deformed prior to the formation of the island arc (Schweikert, 1978). This entire assemblage has undergone additional tectonic shuffling during the Late Jurassic, both prior to and during the



Nevadan Orogeny, when the entire terrane was strongly folded and cleaved. This last event, around 150 million years ago, was most probably responsible for the generation of the gash veins and their spectacular ferroaxinite mineralization.

MINERALOGY

Ferroaxinite

Although a large number of tension veins exposed in the spillway walls contain massive, coarsely-crystalline ferroaxinite, to date only a few of them have produced well-formed euhedral crystals. Locations of the major veins with crystal-lined pockets are shown on Figure 1. Ferroaxinite displays slightly differing color, morphology and paragenesis, depending on the location of the vein.

Eighty-six X-ray diffraction peak positions from 5° to 90° 2θ corrected with an internal aluminum metal standard were used to determine the unit-cell parameters for a piece of glassy ferroaxinite from area 2. The following unit cell parameters compare favorably with data reported by Lumpkin and Ribbe (1979).

a = 8.959(2) Å
b = 9.207(3) Å
c = 7.155(2) Å

α = 102.02(2)°
β = 98.05(2)°
γ = 88.04(2)°

V = 571.60(2) Å^3

Electron microprobe analyses carried out on representative crystals from areas 1, 2 and 3 (Table 1) show that all axinites analyzed are typical ferroaxinites (Lumpkin and Ribbe, 1979). Crystals from the 3 areas display distinct compositional signatures (Fig. 12). Significant compositional variability exists within each area as well as within individual crystals. Although not all crystals exhibit simple compositional zoning, a generally similar core-to-rim zoning trend can be distinguished in many crystals from areas 2 and 3 and possibly also from area 1. This trend is evident as a decrease in Mg and Fe and an increase in Mn from core to rim.

The morphology of the crystals is typical of axinite, the crystals being thin and tabular with a wedge-like habit. Both single crystals and complex groups have been found. Figure 6, taken from Gold-

Figure 4. **System of quartz and ferroaxinite ladder-like veins in basic dike on the third bench on west side of the spillway.**

Figure 5. **Pocket of purple-brown ferroaxinite exposed in a vein at area 1. Thin dark blades are ferroaxinite crystals covered by palygorskite "mud."**

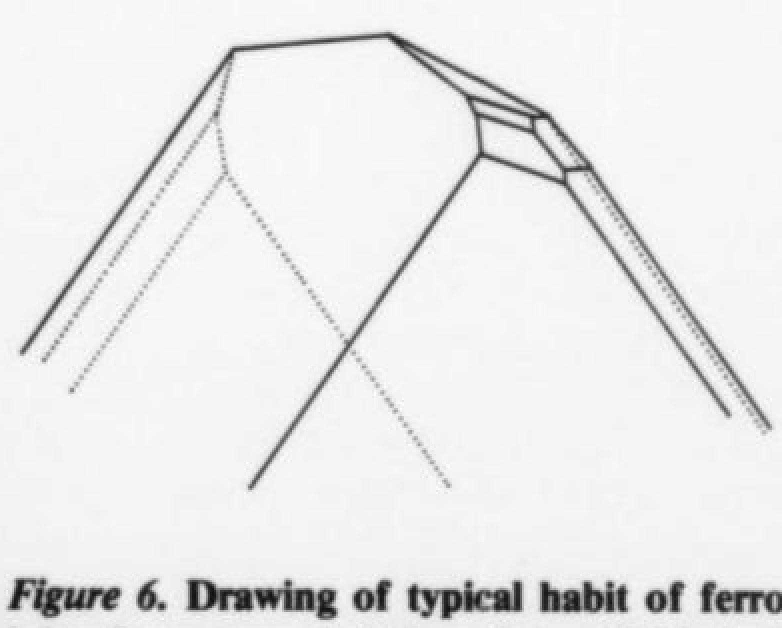


Figure 6. **Drawing of typical habit of ferroaxinite from area 1 (taken from Goldschmidt, 1913).**

Table 1. **Microprobe analyses of ferroaxinites and associated vein minerals.**

Analysis:	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13
Mineral:	Ax.	Ax.	Ax.	Ax.	Ax.	Ax.	Ax.	Ax.	Ax.	Ab	Act.	Chl.	Epid.
Area:	1	1	1	2	2	2	3	3	3	2	1	5	1
SiO_2 (wt. %)	43.14	43.09	42.74	42.65	43.28	42.90	42.79	43.20	42.24	68.50	56.63[c]	26.46	38.01
Al_2O_3	17.75	17.94	17.95	17.70	17.85	17.31	17.83	17.65	17.94	19.71	2.27[c]	17.90	23.98
Fe_2O_3[a]	–	–	–	–	–	–	–	–	–	–	–	–	12.95
FeO[a]	7.33	8.40	7.57	9.56	8.64	8.27	8.03	7.30	6.93	–	10.50[c]	29.45	–
MnO	0.62	0.67	1.53	0.97	0.88	2.18	2.66	3.16	3.84	–	0.20[c]	0.23	0.02
MgO	2.98	2.50	2.14	1.57	2.12	1.31	1.30	1.33	1.11	–	16.06[c]	14.72	0.02
CaO	19.88	19.78	19.52	19.63	19.59	19.46	19.54	19.49	19.39	0.10	11.86[c]	0.21	22.71
Na_2O	–	–	–	–	–	–	–	–	–	11.49	0.20[c]	–	–
K_2O	–	–	–	–	–	–	–	–	–	0.04	0.16[c]	–	–
(B_2O_3)[b]	(6.26)	(6.23)	(6.22)	(6.19)	(6.22)	(6.18)	(6.18)	(6.18)	(6.17)	–	–	–	–
(H_2O)[b]	(1.62)	(1.61)	(1.61)	(1.60)	(1.61)	(1.60)	(1.60)	(1.60)	(1.60)	–	(2.12)[c]	(11.03)[d]	(1.90)
Total	99.58	100.22	99.28	99.87	100.19	99.21	99.93	99.91	99.21	99.83	100.00[c]	100.00	99.59

[a] All Fe calculated as Fe_2O_3 for epidote and FeO for axinite, actinolite and chlorite.
[b] B_2O_3 and H_2O contents interpolated from pure end-member compositions unless otherwise noted.
[c] Analysis of porous fibrous aggregate normalized to 100 percent.
[d] H_2O calculated by difference.

Microprobe analyses were performed using a three-spectrometer ARL EMX-SM microprobe operated at 15kV and 100nA. The data were reduced using the MAGIC IV computer program by John Colby.

schmidt (1913), illustrates a commonly-observed habit for this locality. While its crystal habit is not unusual, the size, color, luster and general quality of this ferroaxinite are exceptional. Individual crystals can range up to 8 cm in longest dimension (Fig. 7) and parallel-growth aggregates up to 12 cm. Crystal groups to 20 cm, which consist of one or two large, 5 to 8-cm individuals among the more typical 3 to 4-cm crystals, have been found.

While much of the ferroaxinite is cloudy or opaque, thin fragments, small crystals and even many of the large ones are transparent and gemmy, particularly at their tips. This cloudiness is due in part to crazing but commonly is caused by numerous tiny inclusions of actinolite and epidote. Such inclusions are most common near the base of the ferroaxinite crystals where the earlier-formed actinolite and epidote have been overgrown.

All the ferroaxinite from the spillway is violet or clove brown. Crystals from areas 1, 2, and 4 exhibit strong selective absorption as they are rotated in front of a light source; their color changes from pale violet-brown to deep reddish-violet. This color change is much less noticeable for the higher manganese ferroaxinites from area 3. Thus, there appears to be a relationship between color characteristics and chemical composition. The strongly-absorbing magenta-violet crystals from area 1 have the lowest average Mn and the highest Mg content of the analyzed ferroaxinites; the weakly-absorbing clove-brown crystals from area 3 show the highest Mn content.

Veins from area 1 have produced both the most spectacular and largest number of ferroaxinite crystals to date. This ferroaxinite generally occurs as fans and rosettes of crystals, boxworks of bladed crystals, or single, parallel-growth crystals implanted on either massive granular ferroaxinite or a matrix of small epidote, actinolite and albite crystals (Figs. 8, 13). Occasionally, small groups, single crystals and fragments occur as floaters in gel-like palygorskite. The last appear to have been detached from nearby larger aggregates. The broken surfaces have since been rehealed. The bulk of the ferroaxinite occurs on the vein floors but rosettes to 10 cm in diameter consisting of 1 to 2-cm crystals are sporadically developed on plates of actinolite and albite on the roof of the veins.

While many of the crystals have razor-sharp edges, some show small serrations which upon close-examination are found to be multiple terminations or possibly growth hillocks. Loose crystals and fragments commonly have a later generation of ferroaxinite forming steplike surfaces on earlier fractures. Area 1 is also notable for a second generation of small (3–15 mm), clear, floater crystals occurring within a breccia interstitial to and covering larger ferroaxinite crystals on the floor of the veins. The breccia consists of a poorly-cemented aggregate of granular wall rock and broken crystals of epidote and albite. The ferroaxinite from area 1 is very lustrous and deeply colored, and forms crystals up to 10 cm across, though 2–3 cm is more typical. A few exceptional groups up to 20 cm across have been recovered.

Ferroaxinite from area 2 typically occurs as very large crystals (up to 10 cm). It is generally cloudy, very fractured and paler in color relative to the material from area 1. In area 2 the crystals occur associated with quartz, albite, and calcite. The calcite crystals apparently grew as early, large plates which interfered with the later development of ferroaxinite, albite and quartz. The evidence for this relationship can be clearly seen after the intergrown calcite has been removed by dilute acid. Large planar areas, delineating what was obviously once a single calcite crystal, terminate many of the now-exposed silicate minerals. Relict calcite cleavages are evident as reticulated etch lines on these truncated crystals.

The mineral association of area 3 is similar to that of the classic Isère and le Bourg d'Oisans localities in France (La Croix, 1893–1895), with lustrous, light-brown, 1 to 3-cm crystals intergrown with clear quartz, albite, actinolite and chlorite. In parts of the pocket, chlorite is included within and coats ferroaxinite and quartz giving both a green, frosted appearance. Several crystals of ferroaxinite from this area exceed 5 cm on edge, but these are most unusual.

Ferroaxinite from area 4 has the deepest color, a dark brownish-purple, but the vein and pockets were generally very small and only a few 2-cm single crystals and small groups were recovered. A few small pockets from scattered veins throughout the spillway have produced a handful of mediocre quality crystals and groups.

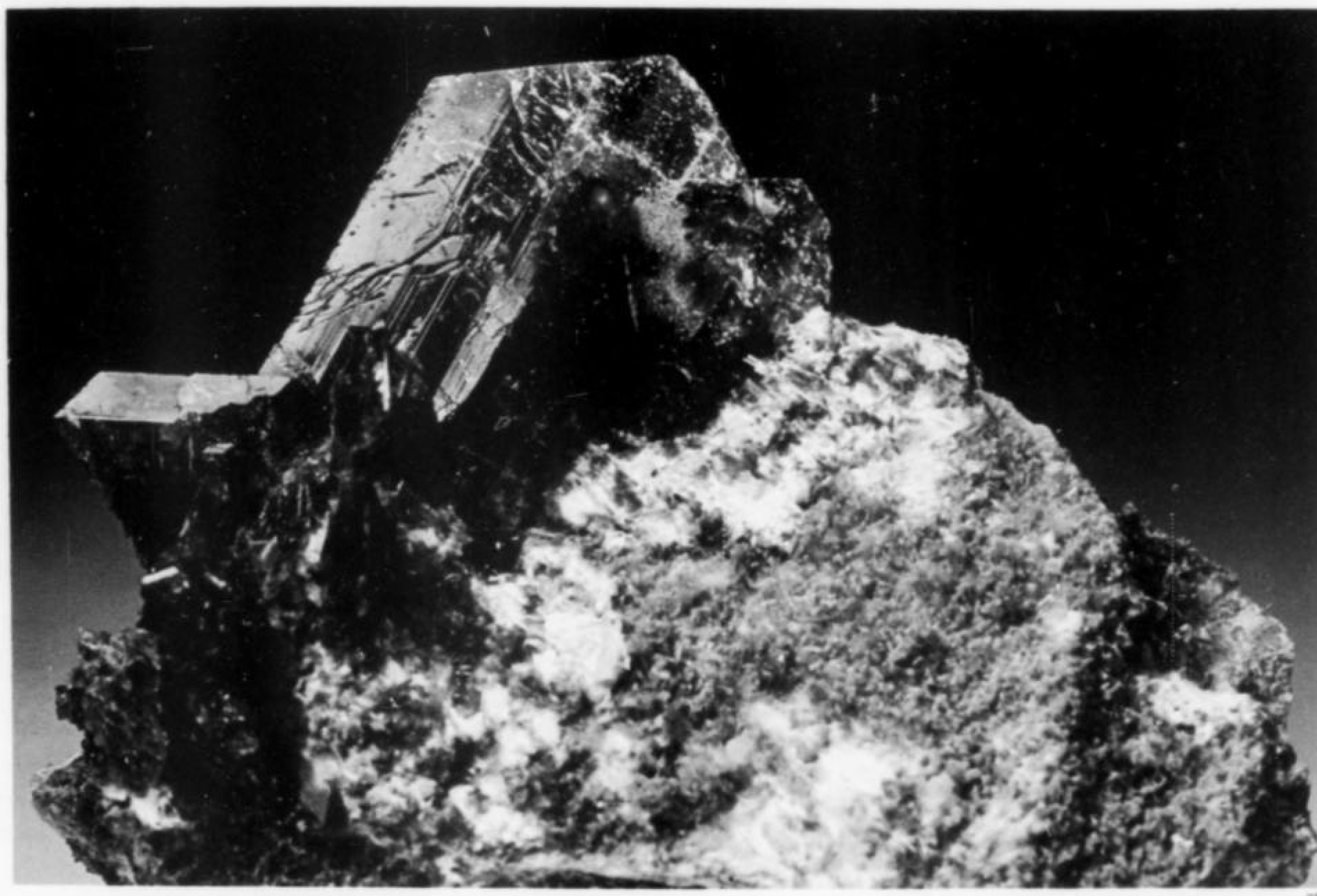
Associated Minerals

Actinolite

Actinolite commonly occurs as white to very pale-green flexible fibers in areas 1 and 3 as well as in many of the other smaller veins. In area 1, fibrous crystals to 1 cm cover areas up to 60 x 30 cm and occur with albite to form attractive plates. Actinolite has also been found in one vein south of area 3 as flexible, long-fibered (up to 15 cm) parallel aggregates. For the analyzed specimens, Mg/(Mg +

Figure 7. **Large clove-brown ferroaxinite with quartz, albite and actinolite crystals from area 3. Crystal measures 6.8 cm; collected by D. Pohl.**

Figure 8. **Gemmy group of ferroaxinite crystals on a crust of small actinolite and epidote crystals. Largest crystal is 4 cm on edge. Collected by R. Guillemette.**



Fe^{+2}) = 0.73 to 0.83, placing them in the 0.50 to 0.89 actinolite range defined in the amphibole classification of Leake (1978).

Albite

Albite is found in all major open cavities discovered to date. It occurs as translucent white to water-clear, euhedral, striated, twinned crystals ranging from microscopic to almost 2 cm in diameter. Figure 14 shows microcrystals that have nucleated on fibers of actinolite. Chlorite phantoms are sometimes seen within specimens from areas 3 and 5. Microprobe analyses show that the albites contain less than one percent of anorthite and orthoclase components.

Calcite

Calcite most commonly occurs as colorless, translucent to transparent very coarsely-crystalline anhedral vein fillings. In areas 2 and 5 it is also found as large, thin, platy crystals forming a boxwork among other minerals in the cavities. Several paper-thin hexagonal plates up to 3 cm across have been found as floaters in granular chlorite. Small, well-defined, blocky crystals are sometimes found growing on platy calcite and directly on ferroaxinite from areas 1 and 2. Late joints and fault surfaces are commonly coated by calcite, but this form of mineralization is of minor significance.

Chalcopyrite

Chalcopyrite has been found only at a small unreferenced vein area across the spillway from area 1. The crystals occur as crude polyhedra up to 6 mm in diameter within chlorite, and as thin veinlets in the vein core and in the surrounding rock.

Chlorite

Chlorite occurs as thick, loose, clay-like fillings within the open vein cavities of areas 3 and 5, as well as in many minor veins throughout the spillway. It typically forms attractive phantoms within quartz and albite. Chlorite inclusions within, and coatings of chlorite on quartz and ferroaxinite give these crystals a dark grey-green corroded appearance. Under the microscope the crystals appear as vermiform pseudohexagonal euhedra (Fig. 15).

Epidote

Epidote has been found as small euhedral crystals (Fig. 16) in areas 1, 3 and 4 and in many smaller open cavities, and as granular and fibrous masses filling veins. The crystals rarely exceed 10 mm in length, form parallel groups and crusts, and display the typical olive-green color. In area 3, however, the crystals are pale yellow. Microprobe analysis (Table 1) showed the latter to contain only a few weight percent less Fe than some of the bright olive-green crystals from area 1.

Palygorskite

This fibrous clay-like mineral has only been found in area 1. It occurs as pale brown to orange gel-like or fibrous cavity fillings which completely envelop most of the central crystals in this area. It presents formidable problems in exposing and cleaning the enclosed minerals because of the inability of ultrasonic cleaning methods to dislodge it.

Pyrite

Small (less than 1 cm) cubes of pyrite have been found only in area 2, as an early-formed vein and wall-rock phase. It also occurs as disseminated crystals in the wall rocks of the spillway.

Quartz

Quartz has been found in all major veins except those of area 1. It generally occurs as colorless, translucent to transparent crystals up to 10 cm or more in length, though the average is 2-5 cm (Fig. 17). Some of the crystals have patches and phantom inclusions of chlorite and more rarely ferroaxinite, albite, epidote and actinolite.

Smectite

A pale greyish yellow smectite-group mineral – most probably montmorillonite – fills interstices between ferroaxinite and albite crystals in area 2. It also occurs as a coating between calcite plates and possibly as inclusions in calcite.

PARAGENESIS

Each of the major vein pockets from areas 1 to 5 have somewhat different mineral assemblages and the paragenesis of each pocket is shown in Figure 18. The absence of particular minerals from pocket to pocket is especially striking. There are also small but significant chemical differences between the pockets as shown by variations in ferroaxinite color and composition, differences in clay mineralogy, and the color of epidote.

Two types of mineral zoning can be recognized in the veins: **1.** A concentric oldest-to-youngest zonation of epidote-quartz-ferroaxinite-albite-calcite is observed in the massive veins. Although all of these phases are not always present, the succession appears to be consistent throughout the spillway vein systems. **2.** An additional footwall to hangingwall zonation is common in areas

Figure 9. **Ferroaxinite crystal group measuring 6.3 cm.**

Figure 10. **Gemmy crystals of ferroaxinite; the left crystal is 3.5 cm wide; the right crystal is 4.6 cm wide.**

Figure 11. **A transparent, gemmy ferroaxinite crystal on matrix of actinolite and albite. Crystal is 3.5 cm across at the base. Collected by R. Guillemette.**

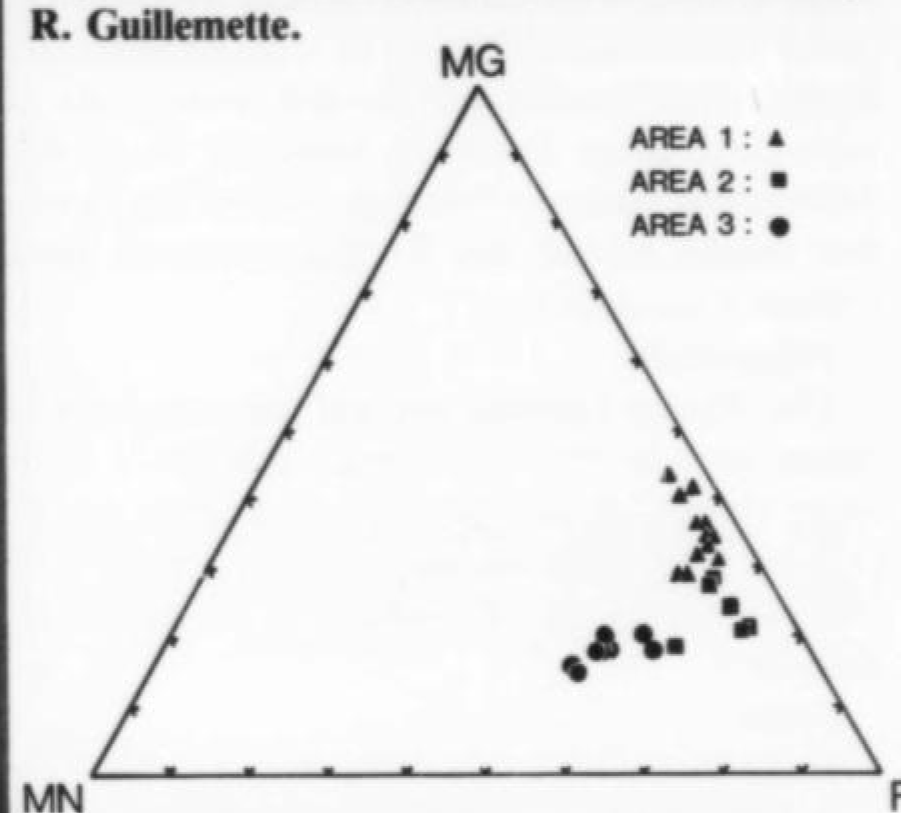


Figure 12. **Triangular diagram showing the Mn-Fe-Mg contents (normalized to (Mn + Fe + Mg) = 1.00) of ferroaxinites from areas 1, 2 and 3. The figure shows that all are ferroaxinites and that compositions of crystals from each area appear to be distinct from one another.**

Figure 13. **Group of ferroaxinite crystals from area 1. Specimen is 4 cm across; largest crystal, 3.5 cm. Collected by R. Guillemette.**

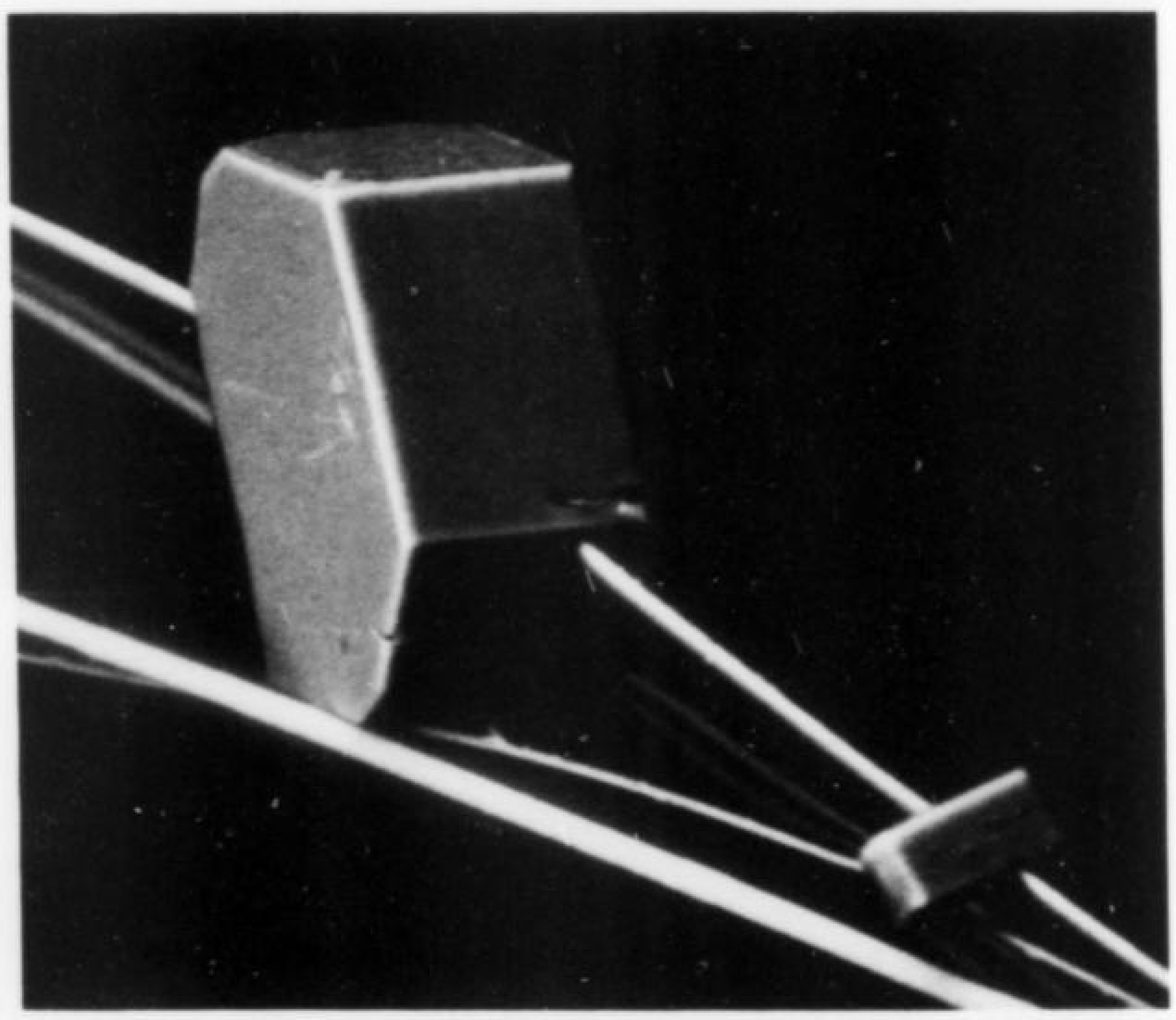


Figure 14. **SEM photograph of simple albite crystals nucleated on actinolite fibers. Large crystal is approximately 100 microns in diameter. Collected by G. Dunning.**

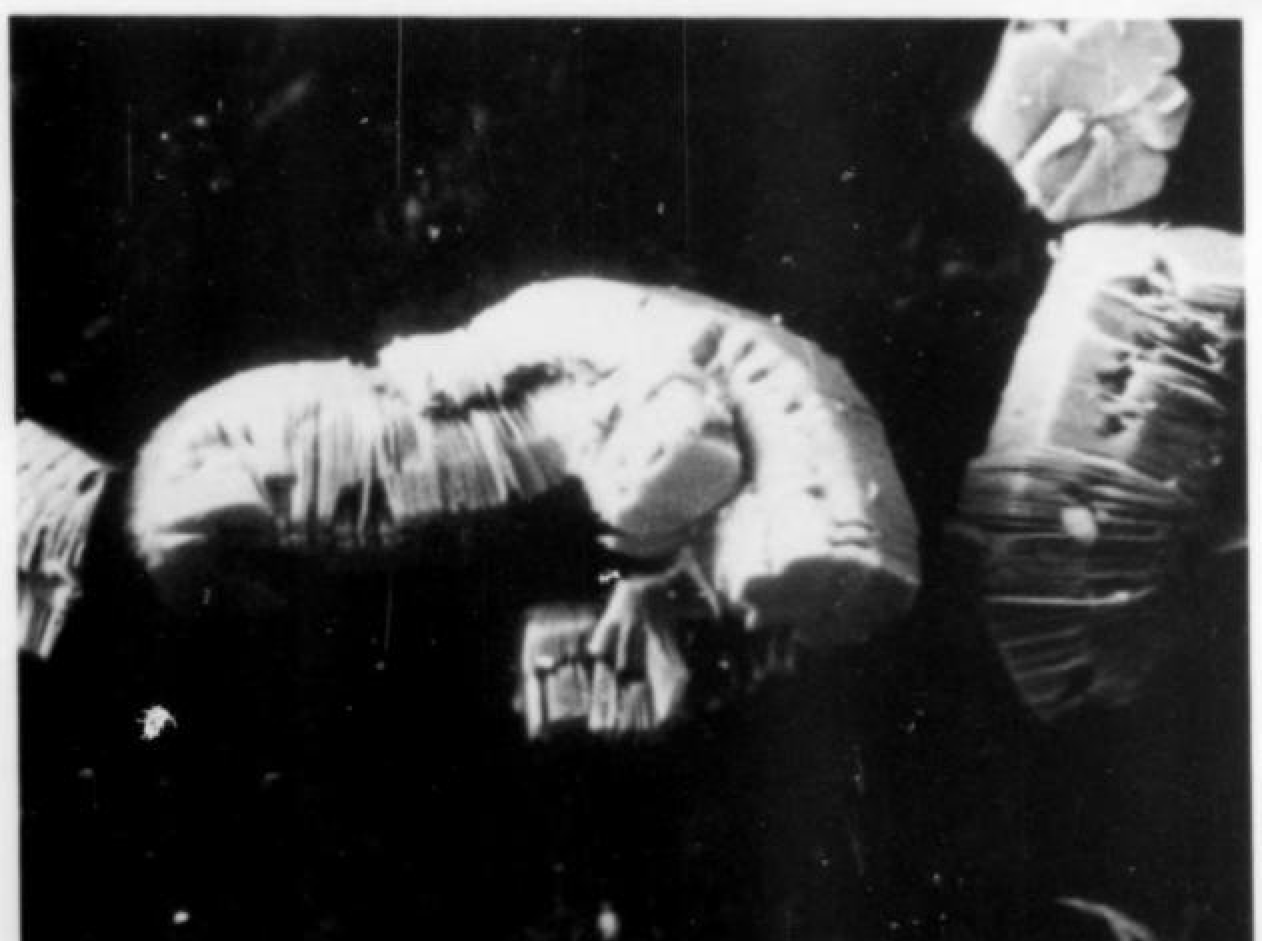


Figure 15. **SEM (scanning electron microscope) photograph of vermiform, stacked platelets of pseudohexagonal chlorite. Scale bar is 100 microns. Collected by G. Dunning.**

where the massive veins open up into cavities. In these instances, epidote followed by ferroaxinite generally occurs at the base of the cavity whereas quartz, actinolite and albite are present at the top. The central cavity commonly contains calcite and one of several clay-like minerals.

Pockets from area 1 show the simplest paragenesis with relatively minor overlap in the mineral succession. The only perturbation appears to be a generation of late ferroaxinite occurring with fragments of albite, epidote and country rock which sometimes fills

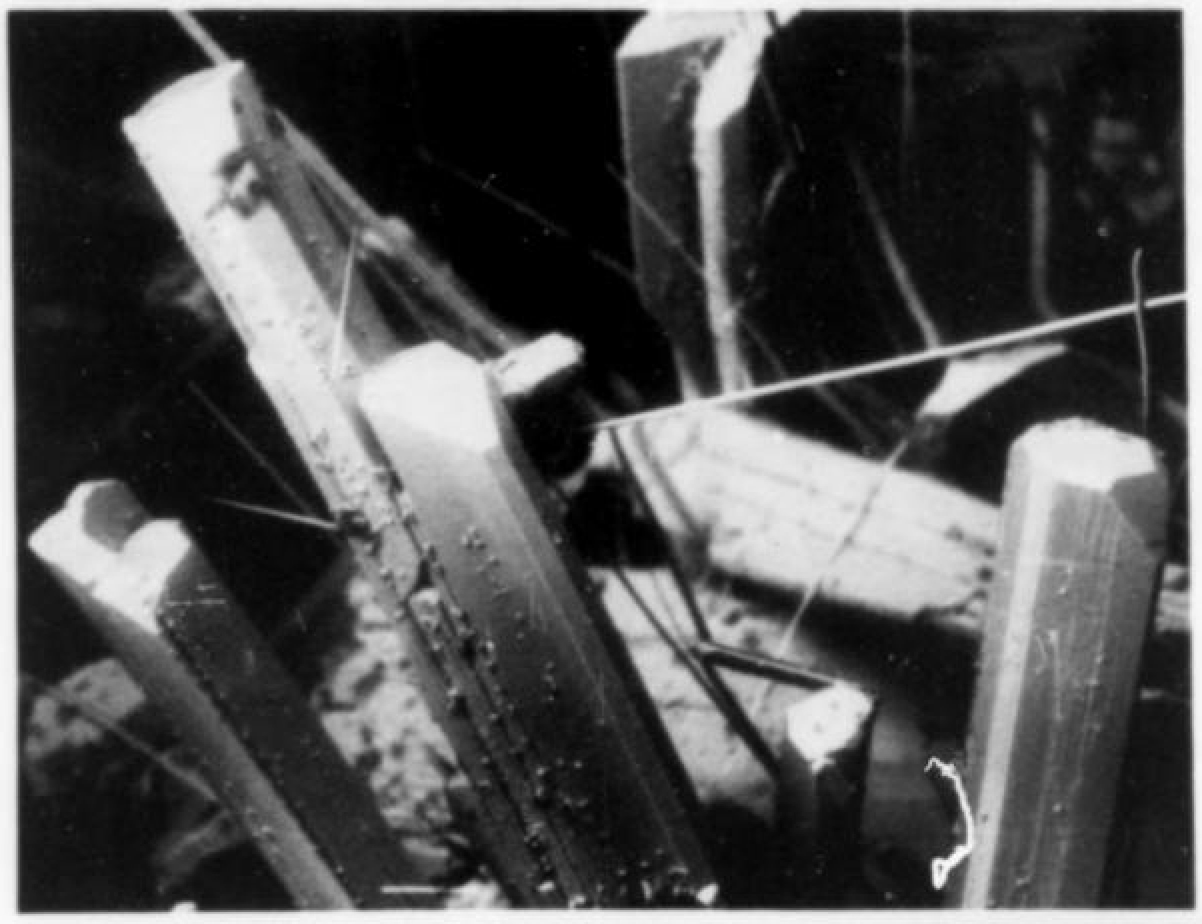


Figure 16. **SEM photograph of epidote crystals with fibrous actinolite. Crystals are up to 0.5 mm long.**

the interstices between the large early-formed ferroaxinite crystals. These crystals are probably coeval with the generation of ferroaxinite which heals fracture surfaces of earlier-formed crystals.

The mineral assemblage of area 4 is also very simple but differs in that quartz is present and palygorskite and calcite are absent. The floor of this cavity consists of epidote overgrown by deep purple-brown ferroaxinite. Only quartz and albite occur on the roof; both postdate the ferroaxinite.

Area 3 paragenesis is again a fairly simple succession except that there appears to be mutual overlap among all phases other than epidote and pyrite. Quartz in this vein pocket encloses all phases except calcite, but in turn may also have ferroaxinite, albite and chlorite implanted on it. Many of the quartz crystals show multiple chlorite phantom terminations.

In area 2 the veins are much thicker and have a lamellar cyclic structure. Of the assemblage shown in Figure 18, ferroaxinite, albite, quartz and calcite show mutually transgressive relationships.

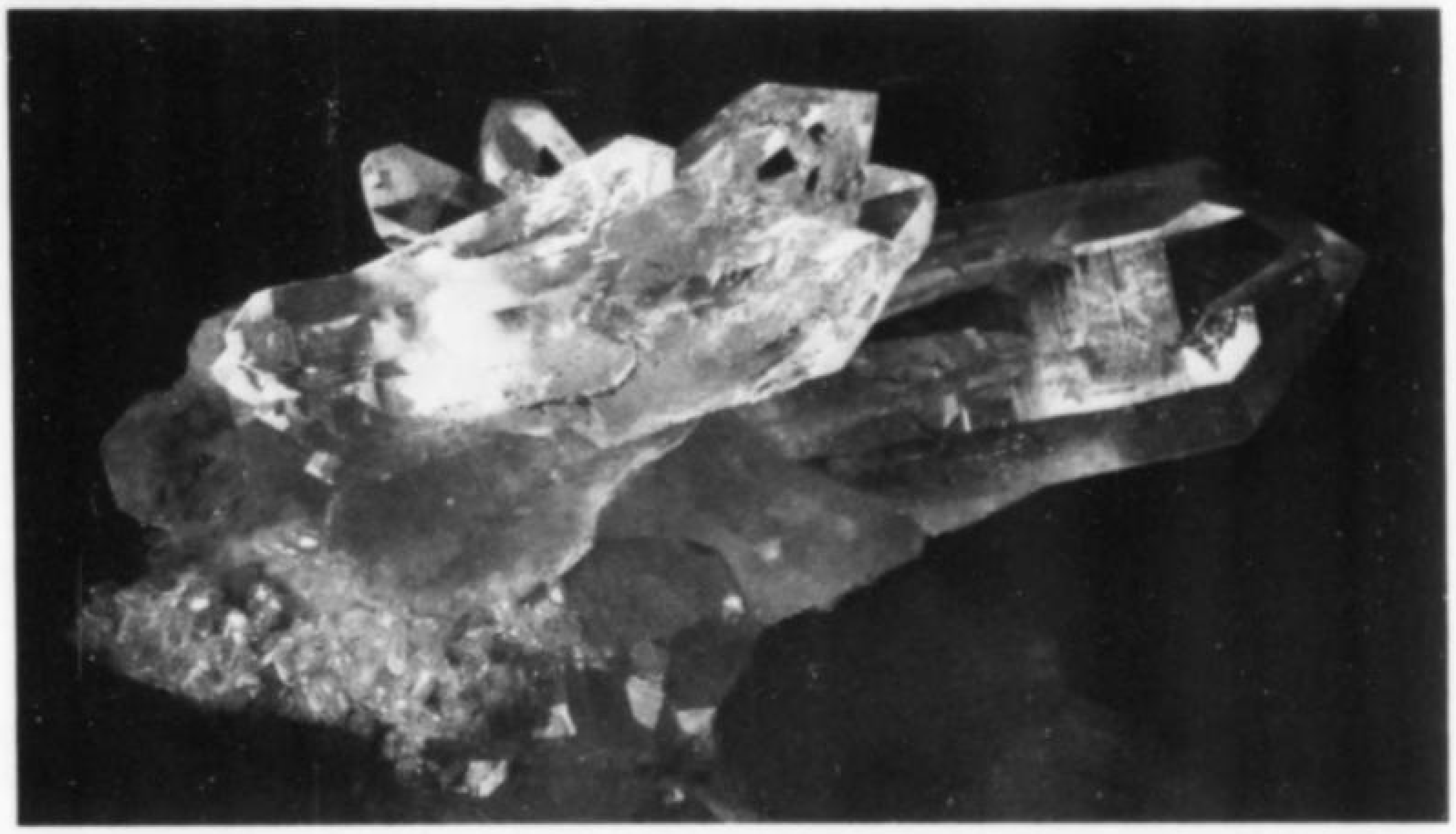


Figure 17. **Clear to milky quartz crystals from area 2. Largest crystal is 6 cm long. Collected by R. Guillemette.**

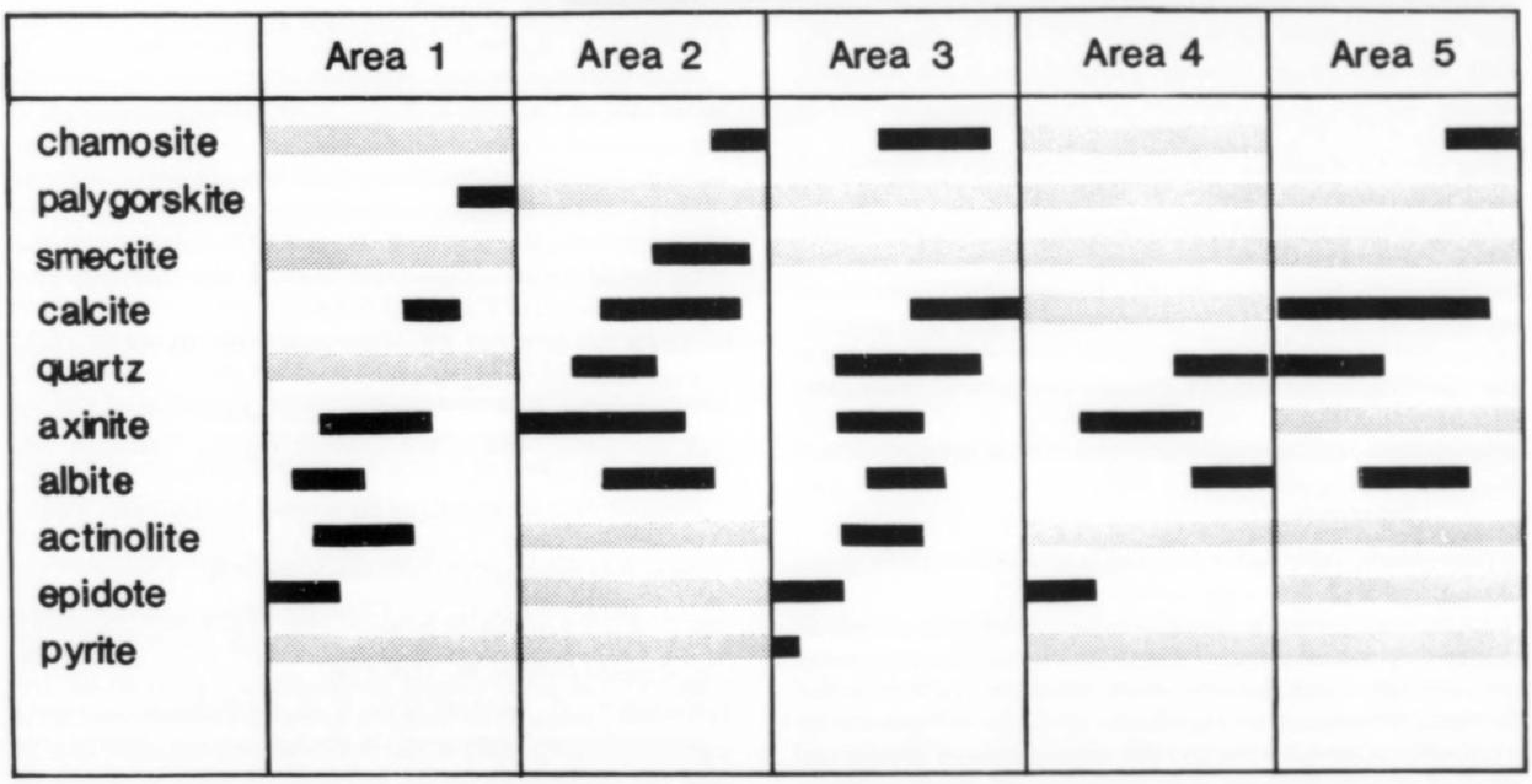


Figure 18. **Paragenesis diagram of minerals from veins in areas 1 to 5. Earliest to latest time succession is from left to right. Phases absent are shown by the stipple pattern.**

Epidote is absent and ferroaxinite occurs directly on the vein walls or on a crust of albite. Ferroaxinite, albite and quartz all show planar interference features indicating that their growth was impaired by platy calcite. Albite both precedes and postdates ferroaxinite.

The sheet structure and repetition of the mineral assemblages in the veins of area 2, as well as the mutual growth interference of the phases, indicate that some of the minerals, especially calcite, grew rapidly and almost simultaneously, possibly in response to repeated rupturing and sealing of the vein system. A pressure drop during rupturing has been shown to favor rapid and simultaneous deposition of the minerals with slower growth resuming after sealing of the cavity and reestablishment of more stable conditions. Such a process appears to have occurred many times during the history of this vein set.

DISCUSSION

The veins and mineral assemblages of the New Melones Lake spillway are typical "alpine kluft" occurrences (Parker, 1954; Weibel, 1966), and as such the constituents of the veins are thought to have been derived from the surrounding country-rock (Weibel, 1966). Because of their relative abundance, the more common components SiO_2, FeO, MgO, CaO, Al_2O_3, and Na_2O can easily be derived from the host rock. However, the origin of the boron within the veins is more enigmatic.

Thompson and Melson (1970) have shown that basaltic and ultramafic rocks become enriched in boron after reaction with seawater at low temperature. This boron apparently can be released to a fluid phase during hydrothermal alteration at higher temperatures. Boron retention in serpentinite is also enhanced by high solution pH (Walter Dibble, personal communication, 1982), a condition that can often occur as a result of olivine alteration to serpentinite. The geochemical behavior of boron is thus in accord with the tectonic setting of the New Melones region in which oceanic crust containing basalts, olivine-rich ultramafic rocks and island arc-derived sediments and volcanics were accreted to North America during the Late Jurassic and underwent serpentinization and greenschist-facies metamorphism during or just prior to the Late Jurassic Nevadan Orogeny. Temperatures at this time were around 300–450° C as evidenced by the metapmorphic mineral assemblages (Turner, 1968). The tension gashes and their accompanying minerals apparently were formed in response to folding and faulting during this last event.

Since the veins are discontinuous and "rootless" structures whose filling material was derived from the surrounding country rock, the mineralogical differences among the various pockets are attributed to variations in the local host-rock geochemistry and physical parameters of vein formation. It may be of interest to note that a high Ca/Na ratio and high pH favor the formation of ferroaxinite over schorl, which is a common accessory mineral in some greenschist facies rocks. This can be seen from the following reaction:

$$\underset{\text{ferroaxinite}}{3Ca_2FeAl_2BSi_4O_{15}OH} + Na^+ + 6H_2O =$$

$$\underset{\text{schorl}}{NaFe_3Al_6(BO_3)_3Si_6O_{18}(OH)_4} + \underset{\text{quartz}}{6SiO_2} + 6Ca^{+2} + 11OH^-$$

If albite, quartz and a calcium-bearing mineral, e.g. epidote or calcite, are present in the rock, then a high hydroxide concentration (i.e., high pH) in solution will drive the above reaction to favor the formation of ferroaxinite. The reaction of olivine and pyroxene in ultramafic rocks with water to form serpentine could provide the required alkaline fluid for such a reaction. In this context the association of axinite with ultramafic and mafic rocks at le Bourg d'Oisans and Isère, France (La Croix, 1893–1895), and Santa Rosa, Brazil (Cassedane *et al.*, 1977), may be significant.

The ferroaxinites recovered from the New Melones Lake area are among the finest ever found in North America. The best specimens certainly rival, if not surpass, those from the classic localities in France, Japan and Brazil.

ACKNOWLEDGMENTS

We wish to thank the U.S. Bureau of Reclamation for permission to collect samples and the personnel of the New Melones Lake Headquarters, in particular Keith Davis, Bill Suehowicz, Jean Flowers and Larry Vojkufka, for their generous cooperation without which this study would not have been possible. The U.S. Army Corps of Engineers provided valuable information and assistance through their Sacramento district office. Here we would like to express our appreciation to Justin Moses, Dan Boyd, Robert Treat and Steve Roe. Walter Dibble has been invaluable for his geochemical insights and constructive criticism. A representative collection of samples from this area is housed in the mineral collection of the Geology Department of Stanford University and is available for further research.

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the discovery of Powellite at nasik, india

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The basalt quarries on the eastern flank of Pandulena Hill near Nasik, India, have produced large and uniquely beautiful crystals of powellite. Perhaps a score of truly great specimens have been found since 1974.

HISTORY

In 1972 I made a trip to India with the explicit intention of entering the mineral business as a dealer. At that time there were just four or five established mineral dealers in Bombay, Nasik and Poona. Beyond acquiring specimens from them, I also obtained specimens by visiting a number of quarries in the vicinity of these cities. The workers at the quarries had begun to realize that the *gaar* (crystals of zeolites and associated minerals) they sporadically encountered during quarrying operations had some value but they had no appreciation or concern for the esthetic quality of specimens. Exquisitely crystallized specimens were treated equally with massive hunks. They were simply dumped together, usually in a gunny sack, to await the occasional collector or dealer's agent who would carry away a selection for a small sum by today's standards. Nowadays the best quarries are zealously monitored by dealers' agents or by the owners themselves. The operators and workers have become increasingly sophisticated. Great care and skill are exercised in extracting and preserving specimens, which is one reason why the selection and variety of Indian minerals continues to improve.

In the early seventies I was able to purchase significant specimens at the quarries; that hasn't been possible in the past three years. Almost all of the fine pieces now go to a plethora of dealers in the main cities. New dealers seem to spring up almost every year, particularly in Bombay. Almost as many fade from sight after a year or two. Except for the recently started *Rupalee Gems,* the lion's share of the best specimens are still to be found with the early comers: *B. H. Kela* in Nasik, the *Makki brothers* in Poona, *Hussein Tyebjee* and *Burjor F. Mehta* in Bombay. It was Burjor Mehta, in fact, who started the export of mineral specimes from India when he sold a batch of zeolites to the American dealer Ronald Romanella in 1963.

A group of specimens purchased from a quarry worker in 1972 contained material from obviously different localities, though I lacked the experience to know which specimens came from where. One specimen (Fig.1), slightly larger than miniature, carried prominent pseudocubic crystals of apophyllite, colored pink by inclusions of iron oxide. Perched alongside were what appeared to be octahedrons, in parallel growth, of a transparent, honey-colored mineral with a faint greenish cast. It had subadamantine luster and displayed angled striations on all the prominent faces. It was not a zeolite. I guessed it might be datolite in a peculiar crystal form; if so, it was a rare find since datolite had not been reported from the Deccan traps of India.

Upon returning to Cambridge, Massachusetts, I submitted the unknown mineral to Cornelius Hurlbut and Clifford Frondel at Harvard and they positively identified it as powellite, calcium molybdate. It was thought to be far and away the finest and most unusual specimen of powellite known. (Since then several people have called attention to a larger, excellent, dark single crystal of powellite from the Michigan copper deposits, on display at the Seaman Mineralogical Museum in Houghton, Michigan, but at the time few knew of it.)

At the Tucson Show in 1973 the Indian powellite specimen stirred intense interest. Some could not believe the geochemically incomprehensible association of powellite with apophyllite even though Pough (1960) had once reported powellite crystals from a basalt quarry in Panama. Powellite in match-head-size crystals is well known from hydrothermal metallic and contact metamorphic deposits, and rarely from the Lake Superior copper deposits (Koenig and Hubbard, 1893). But powellite in clear crystals up to 1.7 cm associated with apophyllite was something unique. The first day it was shown at the Desert Inn the specimen was purchased for $1500 by David Wilber, from whom it soon passed to Edward Swoboda, and recently to P. D. Sams. The piece was on display in the Swoboda collection at the Stanford Geological Sciences library for several years.

Figure 1. **This is the original specimen which started the search for the powellite locality in 1972. It measures 6.5 cm across. Pyramidal, striated, pale greenish honey-colored crystals of powellite (upper right) are in parallel growth on pink apophyllite. Perkins Sams specimen.**

Immediately following the 1973 Tucson Show a swarm of eager treasure hunters, I among them, descended on India in hope of finding the source. Indian dealers were bombarded with questions about powellite but none knew what it looked like, let alone where it occurred; colored photos of the original specimen were of no help. I did not turn to any of the local dealers for cooperation, deciding instead to locate the deposit myself. I bought a second-hand jeep (no small undertaking in India) and with the assistance and company of Toby Marotta set out to examine, if necessary, each and every accessible quarry in the state of Maharashtra. It proved to be a disastrous enterprise. I had never known India to be hotter: mosquitos were at a peak, and cholera raged in some areas, adding to our misery. The jeep was the worst lemon imaginable; every system broke down in turn before we abandoned the monster after less than two months. I was broke, sick and exhausted to the core. Although we hadn't seen a particle of powellite, I had examined scores of quarries and had gained considerable knowledge about distinctive varieties of zeolites, their associated minerals and their specific occurrences in Maharashtra. I felt certain that the apophyllite on the original powellite specimen was from somewhere around Nasik. Henceforth, I decided to spend no more than a few convenient days during each trip to India, slowly and comfortably investigating the area near Nasik.

On one such pleasant reconnaissance in April of 1974 I stopped at a well-known quarry for a picnic lunch with Liz Van Horn, who shared my enthusiasm for minerals and travel. With a sandwich in one hand, I chatted in Hindi with a knot of workers as I casually examined the working face of the quarry. A cylindrical cavity, lined with unexciting pink stilbite, had near the back a half-centimeter crystal that I supposed was calcite. I almost swooned when, in the open, it was instantly recognizable as powellite. "We've found it," I announced to Liz in English, suppressing my excitement. We finished our lunch, bid *adieu* to the workers and returned to our modest quarters in Nasik. We had a secret to keep.

Today the area around the quarry is a growing industrial development but in 1974 there was no habitation nearby except for a cluster of workers' huts safely out of sight of our target. Around 11 pm that night we drove to near the quarry and carefully pulled the car off the road, concealing it as well as possible behind some brush.

In pitch blackness, using our flashlights sparingly, we scrambled up the slope to the quarry. Our ultraviolet lamps immediately revealed the brilliant yellow fluorescence of powellite in tiny fragments scattered on the ground and on the working face. Almost all the powellite *in situ* occurred as irregular grains completely enclosed in stilbite or intergrown with laumontite crystals. Powellite was most common in an irregular vein of massive stilbite, more than a meter wide in places, containing a few open spaces in which we discovered two excellent euhedral powellite crystals. With mounting apprehension that someone would surely come to investigate the deafeningly loud hammering from the quarry at midnight, we worked feverishly for an hour until we had extracted both specimens. Having thoroughly searched the quarry for more powellite crystals and finding none, we picked our way down the hill. I was relieved that no one had seen us . . . or so I thought that night. (Months later, when I was supervising operations at this very quarry under a subcontract, one of the workers, during a friendly tall tale session, related one about the time he heard hammering during the dead of night and found this strange sahib and memsahib banging away at the rocks in the darkness. He had been . . . fortunately for us . . . as fearful of revealing himself as we would have been had he done so.)

Carrying the two powellite specimens in my hands we arrived at the car with a feeling of triumph. Immediately half a dozen flashlight beams blazed at us and a voice barked an order to halt. A band of men advanced directly. When they were almost upon us we saw their uniforms. The leader, an Inspector of Police, demanded to know who we were and what we were doing here in the sticks at

Figure 2. **Pandulena Hill (West), near Nasik, where the powellite occurrences were finally found. This view is from the northeast; quarries visible are (left to right) #3, #4, #5 (Aurora quarry) and #6. (See Fig. 3).**

this outrageous hour. They had been lying in wait for us, having spotted my car obviously in a situation of attempted concealment in this forsaken spot, with the engine still warm. Highly suspicious.

In India there is rarely reason to fear that one will be mistreated or brutalized by the police. On the other hand there is every reason to fear that on the flimsiest excuse one may be helplessly drawn into a tangle of bureaucratic procedures that defy rational resolution, gobble up days or weeks, and sap one's spirit. I regarded the two of us, revealed by the flashlights, carrying ultraviolet lamps, hammers, chisels and rocks, one of us a foreign woman; we were a ludicrous spectacle.

I answered the inspector in authentic Indian English that I was a geologist, that we had come to examine rocks at the quarry. "At this time of night?", he bristled. "Yes," I said, "some rocks are best examined in the night," raising the two specimens in my hands to reinforce my point. He was not eager to accept my explanation but all the evidence fit, and 15 more minutes of grilling failed to shake my story. Finally, annoyed that his stakeout had yielded only a couple of dotty strangers, he drove off with a warning to confine my geological investigations to daylight hours. The secret of our powellite discovery would probably remain intact unless one of the Indian dealers happened to hear of this incident; Nasik is a small town for gossip.

During the following months, with the aid of my cousins, I reached a contract with the quarry lessee, an extremely decent person, the late Mr. Aurora. During October and November of 1974 I directed blasting operations so as to rapidly explore the major zeolite zones in the Aurora quarry. Only by such an on-the-spot investigation could I gain a realistic idea of the frequency of occurrence of powellite specimens. Many tons of almost entirely worthless massive zeolites were extracted during a six-week period. All this material was examined both in daylight and under ultraviolet light. Powellite was spotty in occurrence but ubiquitous, comprising less than a hundredth of a percent of the zeolitic mass. Only six modest but saleable specimens were collected. Even though these might sell for handsome prices the financial return could not possibly justify the cost of operation. Besides, I had discovered powellite in a number of the adjacent quarries. Clearly I had to abandon thoughts of working the locality myself and depend instead on a collecting strategy.

Everyone in the Indian mineral specimen business surmised correctly that I was hot on the trail of powellite, so my frequent motorcycle excursions to the many quarries and dam excavations around Nasik were followed with great interest. My obvious activity at the Aurora quarry was ignored, amazingly, as a red herring because that quarry was extremely well known and had operated continuously for many years. Two years later, B. H. Kela showed me a specimen form the Aurora quarry and asked me to identify it. It was powellite; the cat was finally out of the bag.

OCCURRENCE OF POWELLITE

The Aurora quarry (#5) is one of several quarries on Pandulena Hill, 8 km southwest of Nasik city on the main Bombay-Nasik highway (Fig. 2, 3). Actually there are two neighboring hills, twins, both called Pandulena. The one to the east of the highway has elaborately carved cave temples of archeological interest. The one to the west of the road has been Nasik's major source of quarry rock for the past decade or two. It stands about 200 meters above the level of the surroundings and is composed of horizontal superposed basaltic layers giving it a stratified appearance typical of hills in a trap rock region. All the quarries are located along the thickest single stratum, about 30 m thick and about 120 m below the peak.

A remarkable aspect of the Pandulena quarries is the different minerals or associations that can be seen in adjacent cavities. For example, I have observed cavities within a 3-meter circle of one

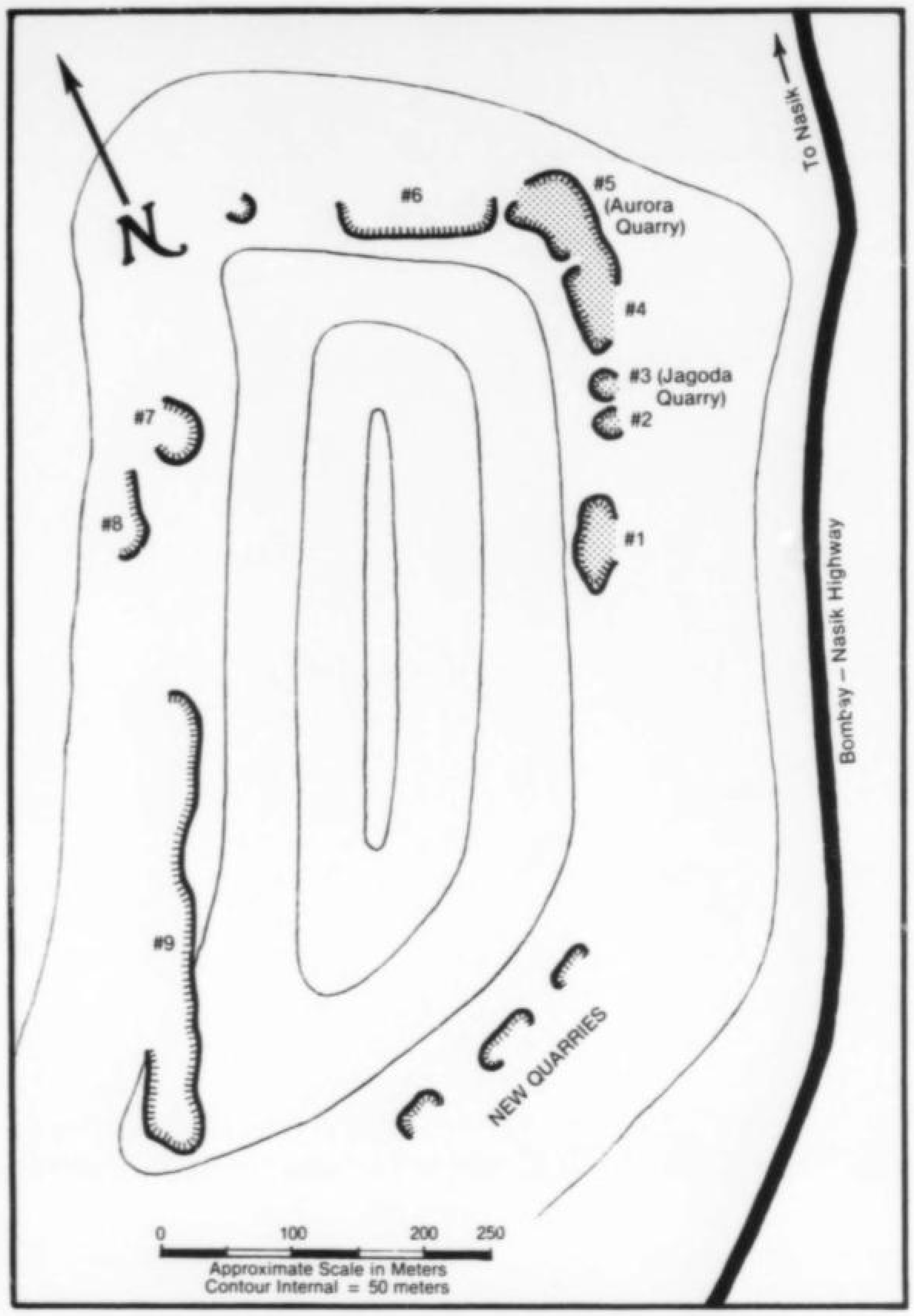


Figure 3. **Sketch map of Pandulena Hill (West) showing the various quarries and those that have produced powellite (stippled).**

another containing, respectively, clear apophyllite with stilbite, stilbite with laumontite, heulandite, and amethyst. Another noteworthy observation is that a number of quarries, all located on the same basaltic member, produce many distinctive forms and associations of zeolitic minerals; the locations where specimens were found can often be pinpointed on the basis of habit and associations alone. For example, clear apophyllite on smoky gray stalactitic quartz was encountered exclusively in quarries #7 and #8 (Fig. 3).

Powellite was identified in all the quarries (#1, #2, #3, #4 and #5) on the eastern flank of Pandulena hill. It has two distinct modes of occurrence differing in association (apophyllite is absent in one) and emplacement (replacement versus open cavity filling). Both modes were observed in proximity to one another in all except quarry #3 (Jagoda quarry).

Mode 1

In this mode, alluded to earlier, powellite occurs in scattered grains and crystals with massive pink stilbite and abundant laumontite in thick veins, networks, *en echelon* fracture fillings and replacement breccias (Figs. 4 and 5). The breccias provide clear evidence of wholesale replacement of the original basalt by stilbite. Black residual islands of basalt in zeolite and the wallrock adjacent to the zeolite veins are completely altered, the mafic minerals having altered to chlorite.

Laumontite occurs as meshed crystals up to 8 cm long perched on stilbite sheaves or occupying interstices. It therefore represents a later stage of deposition than the stilbite. Powellite grains exist within stilbite masses and in intimate intergrowth with laumontite crystals; therefore, powellite crystallization must have occurred more or less continuously during the period of hydrothermal alteration and deposition.

Figure 4. **Liz Van Horn is shown here at the site of the first discovery of powellite in place, the Aurora quarry. A network of stilbite-laumontite veins penetrates the altered basalt of the quarry.**

Figure 5. Replacement breccia containing massive stilbite-laumontite surrounding dark residual islands of chloritized basalt; Aurora quarry.

Figure 6. Transparent, pale golden powellite crystal group 2.5 cm (1 inch) across perched on pink stilbite. R. Kothavala specimen; photo by Liz Van Horn.

The origin of the sodium and calcium contained in the sometimes enormous stilbite masses is worth pondering. Either they were derived from some external source or they were provided by the breakdown of plagioclase in the original basalt. I observed no field evidence to support the former hypothesis. Neither the underlying nor overlying basalt strata show evidence of channelways or conduit systems. Furthermore, to the degree that any broad trend was observable in the stilbite veins and replacement breccias, it appears to be a horizontal north-south trend extending through quarries #1, #2, #4 and #5. An external source for the sodium and calcium (and molybdenum) would have to be a lateral one.

Powellite occurring in Mode 1 is generally paler than in Mode 2. It varies from colorless through rich golden yellow. Rarely it is pale green. Beautiful specimen crystals up to 5 cm have been found but they are almost always flawed by intergrowth with laumontite. Even with the best of care the laumontite tends to dehydrate and expand, cracking the powellite crystals and gradually crumbling the specimen. In the rare examples where laumonite is absent, the clear tetragonal dipyramidal crystals of powellite make attractive specimens (Fig. 6). One of the finest, attached to pink stilbite crystals, is in the British Museum (Fig. 7).

Mode 2

In the second mode powellite occurs with apophyllite, pink stilbite, calcite or quartz in discrete vugs or open vein-like cavities. Laumontite is minor. Many vugs appear unconnected to channelways and the adjacent basalt is apparently unaltered. Apophyllite, stilbite and, less commonly, quartz or calcite are the vug minerals in immediate contact with the basalt wallrock, deposited in pre-existing open cavities such as original gas bubbles trapped in cooling lava. Powellite is found in contact with basalt wallrock, completely enclosed in apophyllite or stilbite, and in euhedral crystals on the open surfaces of these minerals, indicating once again that all the vug minerals, including powellite, were deposited contemporaneously. Powellite occurring in Mode 2 varies in color from pale yellow through amber to brown. Specimens can be exceedingly esthetic (Figs. 8 and 9). Although the color is generally darker than in Mode 1, powellite in Mode 2 is commonly more transparent. The largest single crystal I have observed is pale transparent yellow with pyramidal edges 3 cm long. It was on display at the Harvard Museum in 1978 and 1979 and now resides in the Smithsonian collection.

Apophyllite occurs in blocky crystals that are commonly 5 cm across, but giants go to 15 cm and more. White or colorless crystals are the most common. Pink crystals like the apophyllite on the original discovery (Sams specimen) are rare. Some colorless crystals contain an interior yellow or brown halo; when transparent, such crystals are very attractive. Quarry #9, where no powellite was

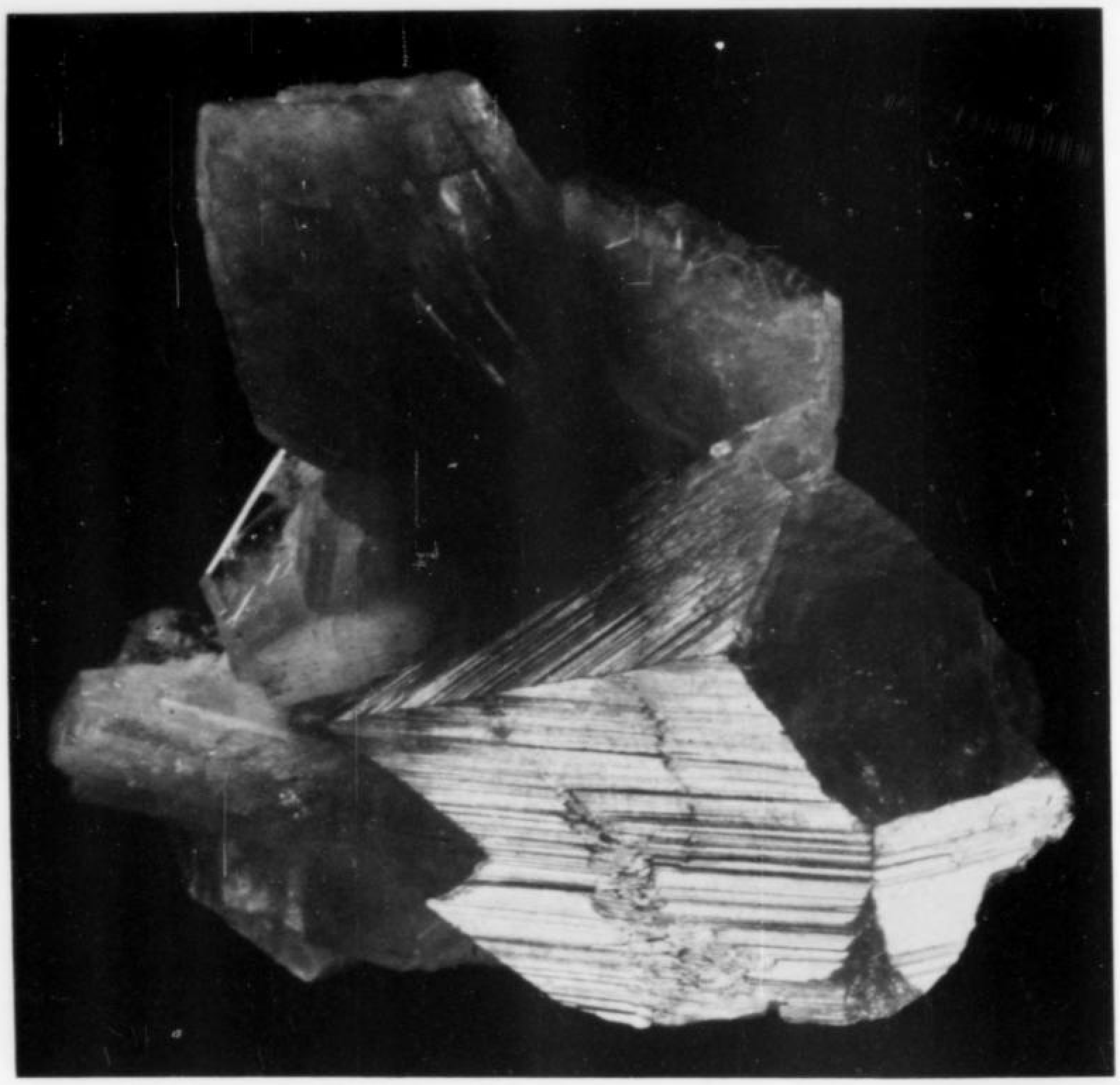
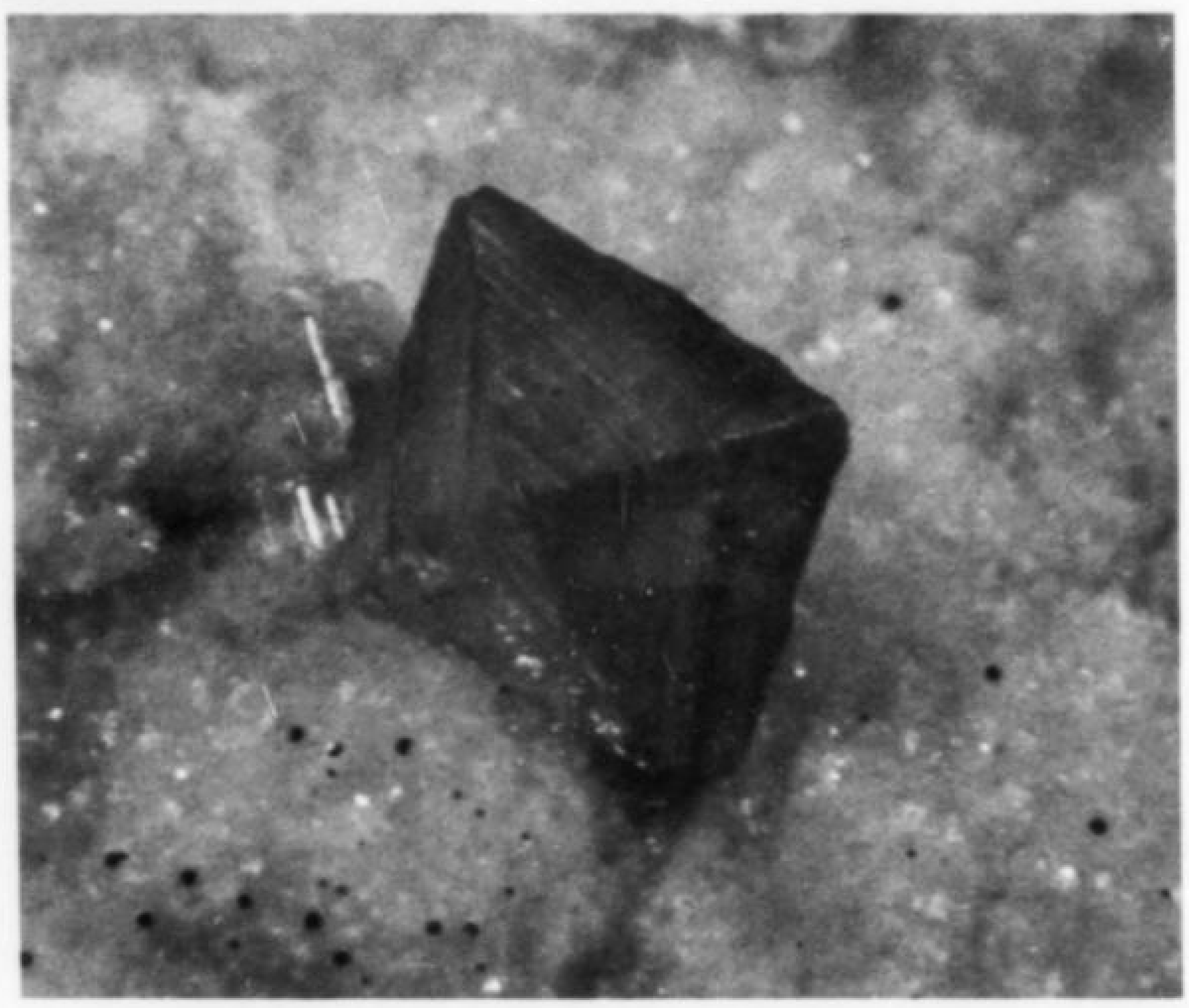


Figure 7. **Sheaves of pink stilbite on a crystal of golden yellow powellite. The specimen measures 2.5 x 3.5 cm. British Museum specimen #BM1981,173; photo by Philip Crabb.**

Figure 8. **A transparent, 1-cm dipyramid of pale yellow powellite on drusy quartz. The black specks are tiny spherules of chlorite. R. Kothavala specimen; photo by Liz Van Horn.**



detected, yields pleasing green crystals of apophyllite but these are never as fine as the brilliant green specimens that have appeared from another locality near Nasik in the past couple of years.

Stilbite occurs in pink to buff sheaves and bows as large as 20 cm across.

Other Modes

Quarry #4 exposes large (up to 2 meters across) irregular bodies of massive radiating scolecite containing powellite but I have not yet seen any euhedral crystals or even modest specimens from this occurrence.

There is one remarkable specimen of colorless euhedral powellite on crystallized stalactitic quartz, but its specific origin is unknown.

Even though heulandite is an abundant and ubiquitous mineral in the quarries at Pandulena, I have encountered only one specimen with both powellite and heulandite. In zones where powellite, heulandite and stilbite occur in proximity, the powellite is in contact with stilbite, not heulandite. The latter lines the cavity margins and probably represents the earliest stage of deposition.

ORIGIN OF POWELLITE

Examination, using an ultraviolet light, of a long abandoned quarry on Pandulena Hill's eastern twin revealed no powellite. This quarry is situated on the same basalt member as the active quarries across the highway and less than a kilometer away. Nor was any powellite detected at quarries #6, #7, #8 and #9 on the western flank of Pandulena Hill. The occurrence of powellite appears confined to a linear zone including quarries #1, #2, #3, #4 and #5 on the eastern flank of Pandulena Hill. Large replacement bodies of massive pink stilbite were seen in four of these five quarries (quarry #3 was the exception) suggesting a genetic link with the powellite.

All the basalt strata in the region lie perfectly horizontal with no sign of any structural disturbance, yet in one small elongated zone of one of these strata are zeolitic deposits uniquely enriched in molybdenum. If the molybdenum was derived from the basalt itself by local hydrothermal alteration, as the weight of field evidence suggests, then the content of molybdenum in the basalt at Pandulena must be exceptionally high. This bears investigation. I have no hypothesis to explain the linear localization of the elaborate north-south trending conduit system responsible for dissolution of basalt and replacement by massive stilbite bodies accompanied by powellite. I have seen no other location in Maharashtra with similar enormous bodies of zeolites.

CONCLUSION

The powellite specimens from Pandulena Hill are unique, not even vaguely resembling those of any other locality. Good specimens appear sporadically. Some years have gone by during which almost no specimen-grade material was found. Occasional years have produced truly great specimens of which I have counted no more than a score since 1974.

Very few gemmy powellite crystals have been faceted, the largest being less than 3 carats. Larger stones labeled powellite, from other

Figure 9. **A magnificent cluster of pinkish brownish yellow powellite 4.2 cm tall, on colorless apophyllite and pink stilbite from Pandulena Hill. R. Kothavala specimen; photo by Liz Van Horn.**

localities, are almost surely scheelite with a significant molybdenun content.

My observations at Pandulena Hill were made during a 6-week stay in Nasik in 1974 and many visits in the following years, the last in December 1981. Since most of the quarries are actively worked, all the observations and hypotheses presented here must be regarded as subject to modification in the light of new exposures and field evidence.

ACKNOWLEDGMENTS

I am deeply indebted to my cousins, Nawshir and Roshan Khurody, for the enthusiasm and effort they lent me from the beginning. B. H. Kela has provided me with regular opportunities to examine a wide variety of powellite specimens and to enlighten myself from his unsurpassed knowledge of zeolite deposits in the Nasik area. I owe thanks to others who contributed to the discovery of this powellite deposit: Cornelius Hurlbut, Clifford Frondel and David Cook for identifying the original specimen; Toby Marotta and Liz Van Horn for sharing the thrills and trauma of the hunt. I am grateful to Professor Hurlbut for patiently working with me toward this publication, to Jean Peterman Kemp for information on powellite from Michigan, and to Peter G. Embrey for pictures and critical comments on this article prior to publication.

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Powellite from Nasik, India

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INTRODUCTION

In 1972 Rustam Kothavala brought to Harvard University a number of handsome specimens of zeolites and related minerals he had recently acquired in India. On one specimen were crystals of a submetallic, honey-colored mineral quite foreign to the association. Determinations of specific gravity and refractive indices proved the mineral to be powellite, $CaMoO_4$. On subsequent trips to India Dr. Kothavala returned with more powellite, some of which he made available for this study.

CRYSTALLOGRAPHY

Thirteen specimens of powellite ranging in maximum dimension from 5 to 25 mm were available for study. Of these, eight were crystals suitable for measurement with the optical goniometer. Seven crystals presented a similar appearance with a pseudo-octahedral habit. This habit results from the dominance of a single form, the tetragonal dipyramid *h* {123} (Fig. 1a). The only other form always present is *p* {011} which on one crystal predominates (Fig. 1b).

On only one crystal, that with {011}dominant, were small faces of other forms detected. These forms are *c* {011}, *e* {112}, *S* {211} and {106}, a form previously unreported. All the faces of *h* {123} are striated parallel to their intersections with {011} and thus give poor signals. However, many of the faces of {011} are of excellent quality and using their angular measurements a morphological axial ratio of $a{:}c$ = 1:2.179 was obtained.

A diffractometer analysis of colorless powellite using an internal quartz standard gave the 5 strongest peaks: 4.76 (25), 3.11 (100), 2.86 (20), 1.929 (25) and 1.589 (18) Å. The peaks were indexed using data of the National Bureau of Standards; the unit cell dimensions were determined as a = 5.23, c = 11.44Å.

PHYSICAL PROPERTIES

The powellite is nonuniform in color with a variation from brown through yellow to colorless. Some crystals are uniformly straw-yellow and some are completely colorless, but in others there is a sharp dividing line between brown or yellow and colorless. In all crystals showing a color difference the darker portions appear to have formed early and the colorless portions represent the final crystallization. In both shortwave and longwave ultraviolet light the brown and yellow materials fluoresce a golden yellow; the colorless crystals fluoresce a creamy white.

The specific gravity varies with the color, being least in colorless crystals and greatest in the darkest material. The specific gravities determined on the Berman balance are: brown 4.278, and colorless 4.258. The latter is in excellent agreement with the calculated density of 4.255.

The optical properties of colorless crystals determined by the immersion method with sodium light are: optically (+), ω = 1.974, ϵ = 1.985, both ± 0.002. Within the limits of error the indices of refraction of the dark powellite are the same as those of the colorless crystals. It is interesting to note the close agreement of the refractive indices of the powellite here described with those determined by Zambonini (1923) on synthetic $CaMoO_4$. His measurements are ω = 1.974, ϵ = 1.984.

CHEMISTRY

Electron microprobe analyses of colorless and yellow-brown powellite were made by David Walker of Harvard University. The analyses showed marginally detectable amounts of Fe, Cr and Mn (0.0x percent level) and variable amounts of W. The tungsten is concentrated in the yellow-brown material and reaches levels as high as 2.3 percent WO_3. The averages of 5 analyses of each type are as follows:

	Colorless	Yellow-brown
CaO	27.90	27.11
MoO_3	71.05	70.69
WO_3	0.02	1.32
Total	98.97	99.12

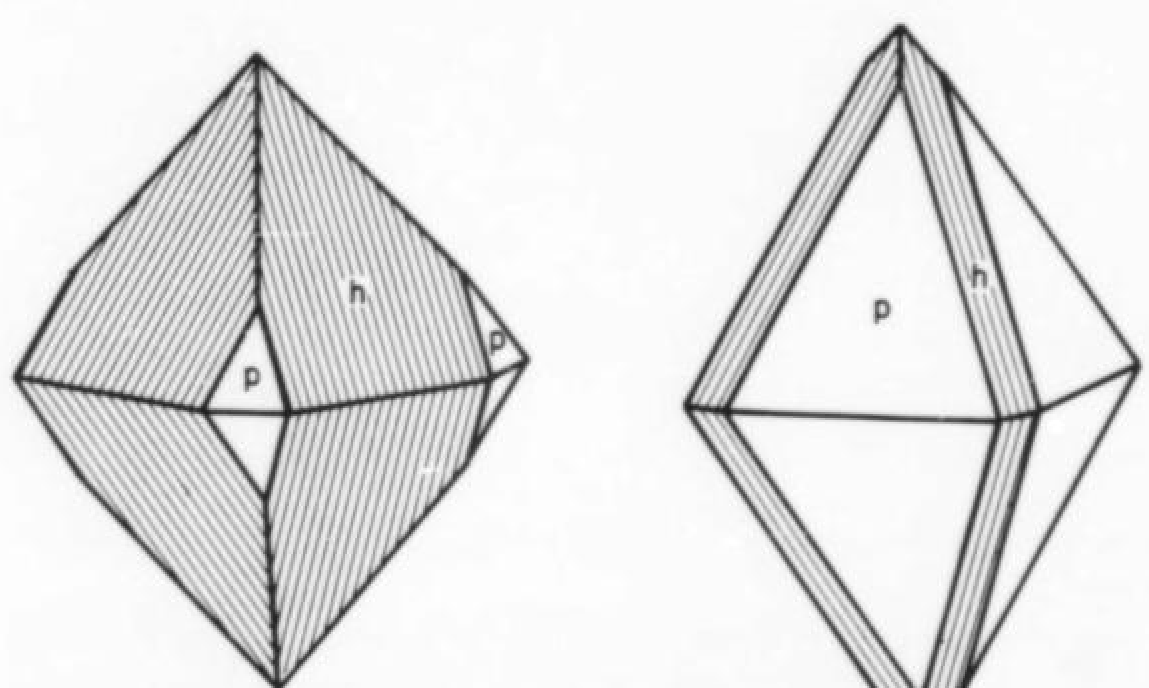

Figure 1. **Crystal drawings of powellite. (a) Typical habit with faces of *h* {123} striated. (b) Less common habit with *p* {011} the major form.**

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the Morphology of a Large Powellite Crystal from Nasik, India

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Nearly all of the powellite crystals that we have seen from Nasik, India, have been bounded by striated surfaces, with good cleanly-reflecting faces small or absent. Crystals without good faces are usually considered unsuitable for optical goniometry, and are measured with a contact goniometer or not at all. The large incomplete bipyramid (2½ x 2½ x 3½ cm; BM 1981, 173), referred to and figured by Kothavala (1982, this issue), presented a problem when being described for cataloging: not only were there no smooth faces, but the contact goniometer measurements gave no indication of what the striated faces might be – apart from the fact that they could not all belong to the same form.

We decided to make measurements on a Goldschmidt two-circle optical goniometer, despite the large size of the crystal. Computation would have been very tiresome by traditional procedures, so the results were processed by an unconventional method. A program written for an HP-85 desktop microcomputer (Embrey, in prep.) enables measurements to be made on a randomly-oriented crystal, and to be presented on a graphical projection in any desired orientation on a computer screen or external plotter. This method has the advantage of allowing a crystal to be mounted on the goniometer arcs in any position that best enables the faces to be measured without associated minerals getting in the way, and avoids the constraints of conventional procedures for adjustment of the arcs.

Two directions of striation have been reported for powellite. The less common one, on a single crystal from Michigan, is parallel to the zone-family ‹ 311 › (Palache, 1937; Palache *et al.*, 1951). Much more common is that parallel to the ‹ 111 › zones, on many crystals from Tonopah, Nevada (Pough, 1937) and from Nasik, India (Hurlbut, 1982, this issue). The striae have curved surfaces, which give rise to "trains of reflections" or elongated streaks of light when viewed through the goniometer telescope. Pough found such streaks running from the position of face *e*{112} to that of *p*{011}, about 40°, but on Nasik crystals their extent is usually 30° or less, ending at the *p*{011} position. Rudimentary faces on the curved striae give rise to poor, often confused signals discernible against the background streak. Powellite is remarkable for the variety of reported forms lying in the ‹ 111 › zones between {112} and {011} – {5.6.11}, {235}, {4.7.11}, {123}, and {156}. Any form {hkl} in the zones must have |h| + |k| = |l|. It is this complexity, with many closely similar angles, which causes difficulty, and only on the best of crystals can some of these forms be indexed with confidence.

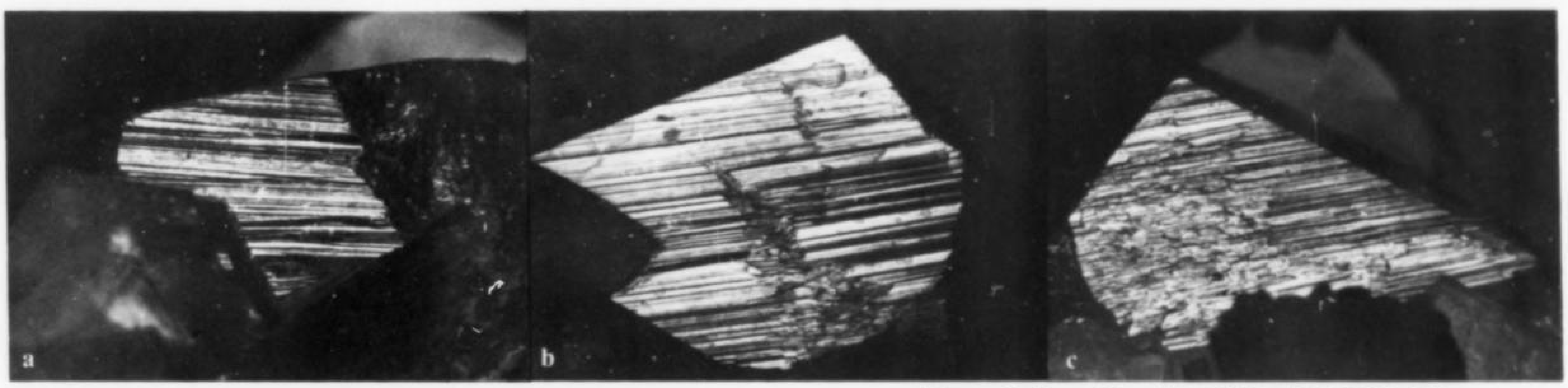

Figure 1. **Powellite with stilbite, BM 1981, 173, showing striations on (a) ($\bar{1}\bar{1}.4.\bar{1}\bar{5}$), (b) ($12\bar{3}$), and (c) ($\bar{4}1\bar{5}$); (a) and (c) are bounding "planes," and not true faces in the crystallographic sense.**

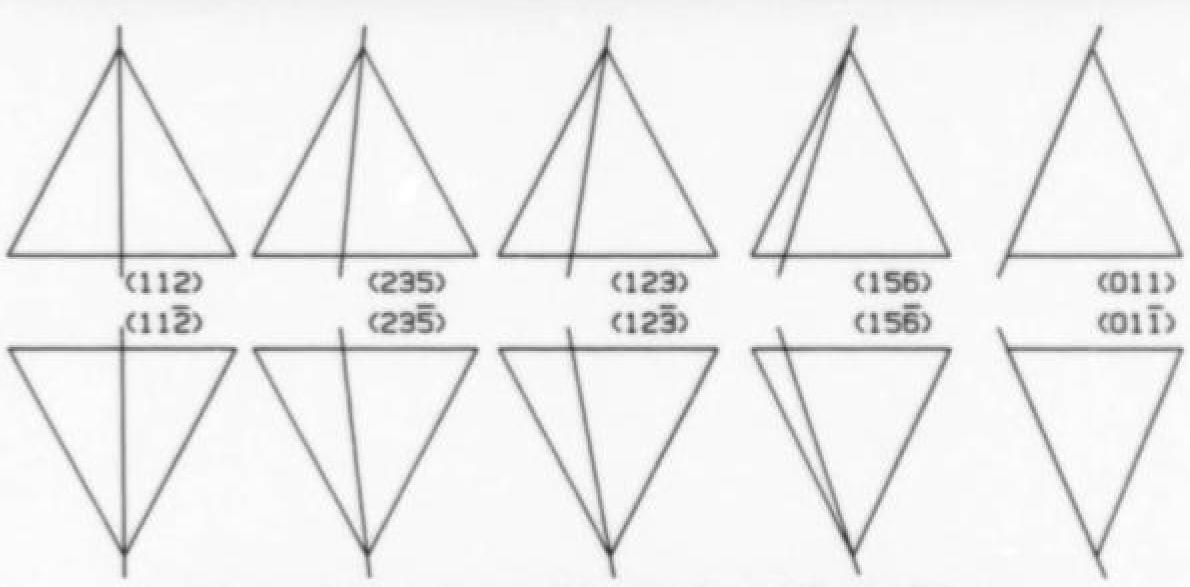

Figure 2. **Drawings of "upper" and "lower" faces of various bipyramidal forms of powellite, with an additional line showing the striation direction (see text).**

On our large crystal, measurements were made at arbitrary intervals of 2-3° along the streaks, noting the positions of fairly distinct signals, and from these were calculated the positions of the zones in projection. In the absence of good faces, the zone positions were used to fix the orientation of the crystal and so to index the few, more distinct signals from the streaks and the striated planes themselves. For the latter, small squares of coverslip glass were at-

(continued on pg. 313)

tached to the planes by dabs of petroleum jelly so as to lie touching the tops of the striae; the clear signals from the glass thus gave an averaged estimate of the direction of the planes.

The results are too approximate to give an accurate axial ratio for this powellite, but are nonetheless interesting. The best reflections from the striae were nearly all of the form {4.7.11}, but there was one example of {156}; {4.7.11} was also the most common reflecting form on three other crystals measured, all on a single matrix specimen kindly lent to us by Rustam Kothavala. Reflections from a fractured surface of the large crystal showed the cleavages {112} and {011}, the latter at the end of a train of reflections. One would not expect a fracture surface to show trains similar to those on a growth surface, unless growth (or solution) took place after fracturing.

Three of the four striated bounding planes are shown in Figure 1; 1(b) is the largest, and the only one to lie unequivocally in a reported position ($12\bar{3}$); Hurlbut (above) has also found {123} as the dominant form. The smallest plane (not figured here, but clearly visible in Kothavala's Fig. 6 lies centrally below 1(b), and is between (123) and (4.7.11). Neither of the remaining planes may be given indices of a reported form: if they were to be indexed, 1(a) would be ($\overline{11}.4.\overline{15}$) and 1(c) would be ($\bar{4}1\bar{5}$), but it must be emphasized that we do not regard these as new forms for powellite since there is no reflection from them other than that given by the coverslips. The planes bounding a crystal do not necessarily correspond to actual faces that may be observed on close inspection (e.g. Gait, 1978).

Powellite belongs to symmetry class $4/m$, and so lacks the "vertical" symmetry planes of the holohedral class. This reduced symmetry is not apparent unless faces are present which belong to forms {hkl}, with $h \neq k$. If it were not for the characteristic striations on these faces, it would be necessary for other forms to be present in order to identify the symmetry by inspection. There are two possible, and equally permissible, orientations for an {hkl} bipyramid, say {123}: it is only convention, established by earlier workers on powellite, which determines that the crystal has its *c*-axis in one direction (leading to {123}), and not turned the other way up (leading to {213}).

Figure 2 shows the directions of the striae on upper and lower triangular faces of various bipyramidal forms, in conventional orientation. The striae bisect the angle at the apex for {112}; for all other bipyramids they run obliquely on the faces, from bottom left to top right on "upper" faces and in a mirror-image sense on "lower" faces. If the face is a triangle (i.e., not intersected by a face of a different bipyramid), a line through the apex and parallel to the striae will cut the base of the triangle in the ratio h:k. It is thus possible, by inspection alone, to determine whether a given crystal is the "correct way up" or "upside down"—in the conventional sense—on the matrix. Of the few crystals we have seen, a majority are upside down; it would be interesting to learn whether this is generally true.

ACKNOWLEDGMENT
We thank our colleague Phil Crabb for the photographs.

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What's New in Minerals?

WASHINGTON, D.C. SHOW 1982

The annual *International Gem, Mineral and Jewelry Show* in Washington, D.C., has been increasingly a lapidary-oriented show; in recent years it has assumed an oriental flavor due to the many Far Eastern lapidary dealers taking part. However, a number of prominent mineral dealers also attend, so the show is worth a visit.

This year a significant new mineral find made its debut at the International Show: remarkably fine erythrite from a mine near Bou Azzer, Morocco, brought in by Herb Obodda. The specimens, perhaps a dozen or more from thumbnail to small cabinet size, were found not in the originally productive mine at Bou Azzer (now closed) but in another mine some distance away which exploits the same vein (this according to Victor Yount). Specimens from the earlier occurrence are commonly erythrite-lined vugs in blocks of matrix; some of the crystals are partially coated or dusted with a dull, buff-colored, clay-like material, while other crystals are bright and lustrous. The newly found specimens are very different: they consist of granular, irregular lumps of skutterudite almost completely covered by brilliant, lustrous, richly colored and well formed crystals commonly 1/16 to nearly ½ inch in size. These pieces must have been found as virtual "floaters," considering their all-around crystal coverage. The corroded grains of skutterudite protrude here and there, some as frosty little pyritohedrons to 1/16 inch. A few of the smaller specimens seem to have very nearly complete coverage by erythrite, vaguely resembling azurite "roses." Tony Jones, Curt Van Scriver, and Fossilien Mineralien Galerie (Frankfurt, West Germany) obtained more than a hundred specimens from the same pocket, some with doubly terminated crystals to nearly 1½ inches.

To review the Idaho pyromorphite situation: the big strike at the Bunker Hill mine last year resolved itself into two large lots. The first lot was marketed by Harvey Gordon (*Sierra Nevada Minerals*) at the 1982 Tucson Show. The second lot was retained until recently by the Bunker Hill Company, and is now being marketed by *Roberts Minerals*. The two lots are *not* alike, but rather they complement each other. The first lot was heavy in bright green pyromorphite crystals (including many fine miniatures and small to large cabinet pieces with large crystals), and also in botryoidal or campylite-habit, orange-red arsenian pyromorphite. The second lot, now available, contains many excellent thumbnails of the green crystals and fewer large pieces; it also contains a large variety of intermediately colored pyromorphite including some pure yellow crystal groups, some better crystallized reddish orange material, and more multicolored specimens. The arsenian material (yellow to reddish) generally underlies the larger, purer, greener crystals, although there seem to be exceptions. For more details, see the two articles on Idaho pyromorphite in this issue (and the Roberts' ad).

Bob Sullivan made available some fine purple adamite specimens, most around miniature size, from the recent discovery at the Ojuela mine near Mapimi, Mexico, reported here earlier. Also included were some groups of yellow adamite crystals of such peculiar habit that they had been held back until now for verification as adamite. The crystals are actually parallel growths about an inch long, doubly terminated, pale yellow and thickest in the middle, tapering in steps toward the terminations. Perched near the middle of each is a small parallel overgrowth crystal of pale purple adamite, the whole being lustrous, partially transparent and on matrix. Only a few such specimens were found.

Mineral Kingdom offered a selection of newly found material from the famous Tsumeb mine in Namibia (Southwest Africa). It was good to see that this classic locality still has some mileage left in it, though it is nevertheless in its last years as a specimen producer. There is little hope that it will ever again yield up the huge *quantities* of specimens that characterized two earlier periods in its glorious history. New examples at the Zweibels' booth included cabinet and miniature specimens of attractive pink smithsonite in half-inch, rounded crystals; cabinet and smaller green smithsonites in sharp, semi-transparent rhombohedrons; and cabinet specimens of dioptase in solid-cover layers of ¼-inch crystals from the 31st level.

Also new at the Zweibels' booth were several superb, terminated crystals of crocoite from Tasmania. The brilliant red crystals measure 3 to 5 inches long and about ¼ inch in diameter. They are very smooth and lustrous, with internal phantoms parallel to the termination face, all collected in October of 1981.

The Touissit(e) mine in Morocco continues to yield fine specimens and spelling confusion. According to Victor Yount, maps and the local post office spell the name "Touissite" with an "e" at the end; but signs posted at the village and at the mine spell it without the "e." This type of problem is common when a language using non-roman characters is transcribed (e.g. Russian, Chinese, Arabic, Korean, etc.). In this case, both spellings should probably be considered correct.

There is no confusion about specimen quality though: it continues to be superb. Newly found anglesite crystals are large (to about 2 inches), flawlessly gemmy and bright yellow; or larger (3 to 6 inches) and frosty white. Recently found azurite crystals are 1 to 3 inches in size and of excellent quality, some actually a stunning transparent blue when held up to a bright light. Wulfenite in frosty yellow crystals is improving in quality, and cerussite crystals of spectacular form, brownish color and flawless transparency are still being found. In fact, a large V-twin in Vic's case is one of the best yet found. In addition to the above species, descloizite crystals have turned up for the first time at the Touissite mine.

Pegmatite gem minerals continue to arrive from Afghanistan despite the problems in that troubled country. Herb Obodda had a huge pink and green tourmaline crystal (about 5 x 6 inches or so), among other fine specimens. And Shams Rind of *Gem Materials Inc.* (P.O. Box 4761, Hialeah, FL 33014) offered a fine selection of small to large single crystals. Included in Rind's stock were quantities of gem-grade yellow beryl, pinkish brown topaz and blue topaz which yielded plenty of fine single specimen crystals after a brief search. Crystals on matrix could also be found, especially among the large (to 5 inches) blue aquamarine crystals on white feldspar crystals.

All in all it was a very satisfactory show, especially for visitors with an additional interest in carved ivory, Chinese cloisonné, netsuke or snuff bottles. Visitors to Washington could also drop by the Smithsonian to view their spectacular exhibit of gold specimens.

W.E.W.

Los Lamentos, Mexico–1949

A note from the editor . . .

One thing mineral collectors always enjoy is a good tale. In fact, collecting stories (which are usually a minor part of a larger article or memoir) have been among the most popular aspects of the *Mineralogical Record* over the years. So why not indulge, once in a while, in a good story for its own sake?

The one presented here was taken from an article in an early issue of *Rocks & Minerals* magazine, entitled "A visit to Los Lamentos, Mexico" by Louis W. Vance (vol. 24, no. 11–12, November–December 1949). It was brought to our attention by Art Smith of Houston, and permission to reprint it was graciously granted by *R&M* editor Marie Huizing. (For a more comprehensive treatment of the locality, readers are referred to the article in the September–October 1980 issue of the *Record.*)

Readers are invited to nominate other such narratives from old literature which we might reprint. And, of course, a first-person account of a reader's own experience would certainly be considered as well.

Earl Calvert and I busied ourselves preparing for the long-planned visit to the Ahumada mine at Los Lamentos. This mine is justly celebrated for the spectacular wulfenite it has produced. A large share of this material now found in collections was collected by Earl Calvert and Wendell Stewart, who have made several trips there.

We spent a day and a half getting the car out of storage and serviced, repacking and checking our equipment. The offices of the company controlling the mine were visited where we discovered the mine was not working and only a caretaker was there. We were given a letter to the caretaker which authorized our collecting.

Driving to Villa Ahumada we looked up Senor Gomez, a friend and guide of Earl's on former trips, who was to be our guide also. He was away working and his daughter, a cute kid of about 10, guided us to him. After arranging to get started at 5 p.m., we took his daughter home. We drove slowly down the main street of the town and she sat up very straight, obviously thrilled to death. I suppose that ride of a few blocks gave her something to boast about for quite a while.

At 5 o'clock we picked up Gomez and after loading 10 gallons of water and getting a couple of sticks of dynamite, just in case, we headed east toward Sierra de Los Lamentos, 50 miles away. The ungraded dirt road was crossed by numerous deep, narrow gullies which made the going slow. We dipped into these with brakes set, bumped slowly across and climbed out in low gear. Other portions of the road were not bad.

We presented our letter to the caretaker about 8:30 p.m. and were assigned quarters in an adobe building where we tossed our sleeping bags on the cement floor, set up the stove and prepared dinner. Our room, about 12x14 feet, had been an office when the mine was operating. It contained a desk, 3 chairs and a large iron safe. Spindles on the wall still held reports, invoices, etc. This is about the only habitable building in what once was quite a settlement. Wood is so very scarce in this part of the country that none is allowed to go to waste and upon abandonment of the town the roof beams were removed. Left unprotected, the adobe walls soon disintegrate.

Earl tells that upon an earlier visit when the mine was going full blast the village of Los Lamentos was a little oasis in the desert. Water from the mine was used to irrigate corn fields and gardens. Now all is desolation, the buildings in ruins and the fields now taken over by sage and other desert growth.

Sierra de Los Lamentos is a range of limestone mountains rising for 2000 feet above the plain. The limestone is characterized by an extensive system of connecting caverns. At certain times the wind blowing through these caves produces a low moaning sound which rises and falls much like the lamentations of a church congregation, hence the name – The Lamentors.

The limestone was so fissured that it was more than a joke when it was said that early miners prospected with a cigaret. The miner lighted a cigaret and watched for the fissure into which the smoke disappeared. A shot or two along this crack often opened into another large cavern where, perhaps, ore worth many thousands of dollars would be found. Due to the fissures the air circulation in the mine is very good. At the 800 level more than 3000 feet from the portal we found the air fresh and good and but little warmer than on the surface. The ore is oxidized to considerable depth. An early visitor tells of seeing 40 carloads of finely crystallized wulfenite on the way to the smelter. All of this was from below the 800 level, now under water.

We were up bright and early and with our guide, Gomez, and the caretaker, Gregorio, entered the mine. The way led through a horizontal tunnel for 1500 feet to a point where it intersected an inclined tunnel and then down this incline for 3000 feet. The incline dips at first at 14 degrees for a few hundred feet and then at 22 degrees the balance of the way. At regular intervals ore chutes from the caverns above were encountered. At about 600 level we left the incline and followed a steep trail over waste rock through old, partially filled stopes to the 800 level, just above the water. We made headquarters in an immense stope which could have accommodated a large building with room to spare.

There was wulfenite everywhere but not very good. Either the crystals were small or badly stained by the red iron oxide so plentiful here. While prospecting around, Gomez came to me and with the most innocent expression proffered a specimen of very ordinary wulfenite, asking, "Is this good?" I looked it over carefully and hesitated to tell him it was not very good. Finally I took it and upon turning it over I found that the other side was a superb specimen. My expression sent him into gales of laughter. I later found that he is one of the very few Mexican miners who know what constitutes a specimen. He is intelligent and good humored and always alert to anything that will produce a laugh. He is a good worker and while not a large man, is tremendously strong.

Gomez soon located some good wulfenite in a narrow fissure in a solid, compact limestone. We succeeded in getting a few specimens but found the going tough with our hand tools. Making little headway here we prospected around and found a small stope which contained lots of wulfenite but all coated thickly with drusy brown vanadinite. It was all over the place – it was impossible to move without walking on it. We collected a few of the better specimens as it is not very spectacular. (Having seen what is here we are getting choosey.) Some of it is quite interesting, however, the wulfenite having been leached until it is paperthin, leaving the vanadinite coating as a cast showing the original size of the wulfenite. Some think that the vanadinite received at least a part of its lead from leaching the wulfenite.

Time to go to the surface arrived all too soon and about 3 p.m., with our bags full, we started out. Climbing up the trail through the old stopes was strenuous and by the time we reached the incline we were perspiring freely and I was puffing like a locomotive, so we rested a few minutes. There was a strong draft of cool air moving down the incline as we started out briskly. After a bit I was forced to slow down and long before reaching the surface I was counting my steps and stopping for a few seconds at the end of each 25 to let my lungs catch up. That is by far the longest five-eighths of a mile I have ever walked. Try walking up a 22 degree slope with a bag full of lead minerals on your back after a hard day's work and you'll see what I mean. It's like walking up stairs without any stairs. The miners didn't seem to mind but went steadily along. They say that they regularly climbed out in 20 minutes carrying a full load. It took us an hour.

Upon arrival below ground the second day we sent the Mexicans to blast in the hope that we could open up the seam of good wulfenite so we could get at it. In the meantime Earl and I prowled around, occasionally finding a specimen that seemed worthwhile. Shortly the blast was heard and after waiting a short time for the air to clear we went to take a look. It was a very sad sight. The shot had opened up the fissure all right but it also had shaken nearly all the crystals off the rock. Careful search salvaged a few specimens and hundreds of broken crystals were scattered about. These were cubes of a beautiful orange-yellow color measuring from three-fourths to a full inch on an edge.

While we were eating lunch Earl questioned Gomez as to where they had worked on a former visit. Gomez replied, "Right here." So Earl got up and started working between an immense rock and the wall. I went over to help him but as there was not room for the two of us I moved around the rock in order to give him the benefit of my light. Earl was lying on his stomach, head down at a steep angle working at a crack in the rock at the base of the wall. His position was quite uncomfortable as the loose rock he was lying on had sharp edges which gouged unmercifully. After prying several slabs of rock off without seeing any indications he was becoming discouraged. I happened to move my light a bit and the beam fell upon a narrow crack. As Earl worked it opened up a little and I could see good crystals there. I kept encouraging him and finally, being unable to see what I saw, he said: "How about you coming in and giving it a try?" So he backed out and I crawled in.

I had worked perhaps 5 minutes when I moved a big slab, and what a sight was there. I let out a whoop, shouting: "Earl, we have hit the jackpot." He crawled in beside me, took a look, and said: "I believe you are right, but what are you leaving this here for?" Whereupon he reached in and picked up a superb specimen about 10x10 inches and thickly coated with large wulfenite of good color.

We sat looking into a cavity a yard wide by a yard high and almost as deep. Everything we could see was thickly coated by large yellow wulfenite crystals. This cavity was apparently part of an ancient solution channel which had become filled with rubble and then wulfenite had crystallized over everything. It was just a matter of reaching in and picking up good specimens with a minimum of work. Occasionally we had to pry a little where wulfenite had cemented two pieces together. We soon had all we could hope to carry so knocked off and rested prior to the killing climb to the surface.

While Earl and I were working here, Gregorio had disappeared for a while. He returned with four large specimens of excellently crystallized descloizite. We were so enamored of the beautiful wulfenite that we gave anything less spectacular scant attention. In looking back I wish we had taken a few minutes to investigate because the descloizite was very good.

The climb to the surface was even worse than before due to our heavier loads and we reached our quarters practically exhausted.

Our third day was spent working the same pocket until we were warned to either quit or do some timbering, so we had to quit. We did find another small seam nearby where we found some pyramidal wulfenite. The smaller crystals are needle-sharp but as they increase in size they become more blunt until the larger ones are the usual cubic type. The cubes look like pieces of caramel candy sitting on the rock.

As this was our last day and we had far more than we could carry we sorted the specimens carefully, taking only the very best. So about 3 p.m. we started out. (I have not yet found any way to keep a Mexican miner below ground after 3 o'clock, their usual quitting time.)

We had very big loads and the going was slow climbing over the big boulders in the stope fill. As I did not want to risk a broken ankle at this stage, I refused to jump lightly off the big rocks. I sat down and slid cautiously off until I had a firm footing. This gave Gregorio, who was behind me, a lot of fun. Each time I did this I could hear him laughing heartily. That was all right with me.

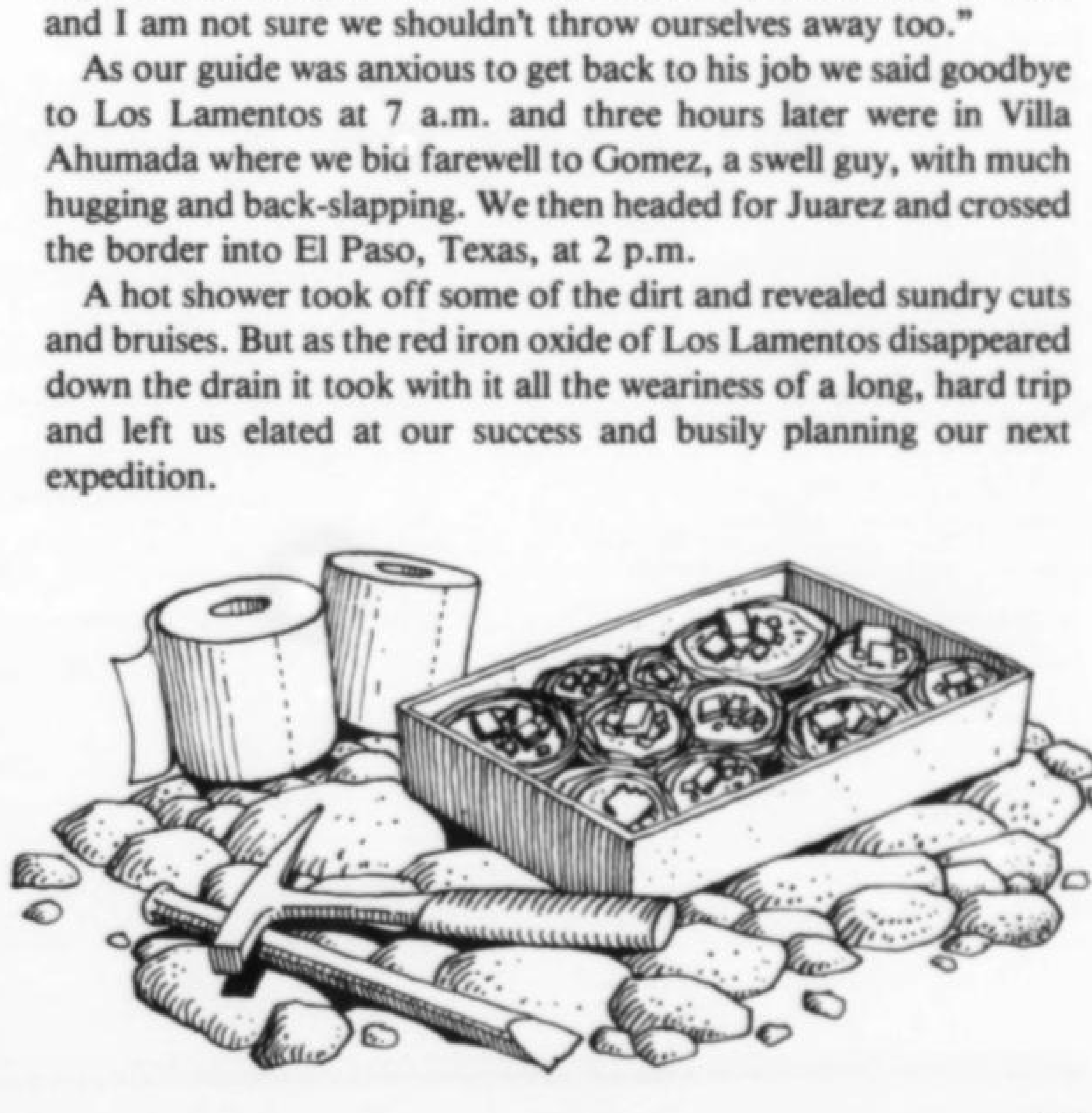
Upon reaching the incline we had a short rest and then started the long climb. It was much worse than before, in fact I staggered rather than walked. The Mexicans went right along and were soon out of sight. After what seemed years of wearily placing one foot before the other we saw their lights way off in the upper distance. They had been out and shed their loads and were coming back to help us. When they relieved us of our bags we were only about half way up the incline.

We finally made it and spent the rest of the afternoon sitting in the bright sunshine packing our specimens. As we looked at each other we burst out laughing. We were a sight. Referring to my diary I find the following:

"We leave early in the morning and I hope will be able to get a bath soon. The three days in the mine have coated us from head to foot with the red iron oxide. I am red headed for the first time in my life. Our clothes are stained and torn and I am using a piece of rope in lieu of suspenders. We will throw away the clothes we wore and I am not sure we shouldn't throw ourselves away too."

As our guide was anxious to get back to his job we said goodbye to Los Lamentos at 7 a.m. and three hours later were in Villa Ahumada where we bid farewell to Gomez, a swell guy, with much hugging and back-slapping. We then headed for Juarez and crossed the border into El Paso, Texas, at 2 p.m.

A hot shower took off some of the dirt and revealed sundry cuts and bruises. But as the red iron oxide of Los Lamentos disappeared down the drain it took with it all the weariness of a long, hard trip and left us elated at our success and busily planning our next expedition.



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